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# Effect of different Sowing Windows on Major Insect Pests and Host Plant Resistance to Pod Borer, *Helicoverpa armigera* in Pigeonpea (*Cajanus cajan* (L.) Millsp.)

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**The idea was conceived by JJ and SV. JJ, SV, SG and SPM generated data. SPM analysed and guided for trait analysis. JJ and SV drafted sections of the manuscript and prepared tables and figures. JJ, SV and SPM made a critical revision of the manuscript.**

**Key words**
**Short duration, Pigeonpea, *Clavigralla tomentosicollis, Helicoverpa armigera*, planting dates**

## ABSTRACT

Effect of sowing dates, climatic variables on major insect pests population, and host plant resistance with special reference to pod borer *Helicoverpa armigera* (Hubner) in pigeon pea (*Cajanus cajan* (L.) ecosystem was studied on two cultivars namely, ICPL 87 and ICPL 88039. The insect pest population on two cultivars differed significantly across sowing dates. ICPL 87 was most vulnerable to insect pests as it suffered more damage by the pod borer *H. armigera*, pod sucking bugs (*Clavigralla tomentosicollis* Stal.) than ICPL 88039. The maximum leaf/pod feeding insect population was recorded on first sowing and then gradually decline for the rest of the plantings. Maximum *H. armigera* egg population exhibited 21.10 on ICPL 87 in first sowing and at least 1.23 on ICPL 88039 in sixth sowing. Web forming insect pests *Maruca virata* (3.95) and leaf webber (4.66) weremaximum recorded on ICPL 88039 in second and first planting respectively. The leaf feeding beetle was recorded highest 6.29(ICPL 87) in the third planting. Amid two cultivars maximum insect-pests population was recorded on ICPL 87 when compared to ICPL 88039 except web forming insect *Maruca* and leaf webber due to its indeterminate genotypic character of ICPL 88039. Between the two genotypes, the sucking pests more preferred to ICPL 87 when compared ICPL 88039. Maximum jassids were recorded 12.76 and 8.38 (ICPL 87) in fourth sowing and third sowing respectively. It was observed that highest spider population recorded 2.23(ICPL 88039) in first and second sowing. Ladybird beetle *Coccinella transvasalis* population recorded a maximum 8.52 (ICPL 87). The leaf webber (r= 0.449**) and pod bug (r= 0.421**) showed a highly significant positive correlation with maximum temperature and *H. armigera* larvae population exhibited highly significant positive correlation with minimum temperature (r= 0.491**) and morning relative humidity (r= 0.528**). Solar radiation also exhibited and showed a significant positive correlation with leaf webber (r= 533**).



## INTRODUCTION

In India, the area grown under pigeonpea crop is 4.65 mha with an annual production of 3.02 mt leading to productivity of 650 kg/ ha (Anonymous, 2015). Pigeonpea is grown throughout the country, except in the hilly regions where winter temperature is very low. It is an important pulse crop in the semi-arid tropics and sub-tropical farming systems, providing high- quality vegetable protein, animal feed, and firewood (Mittal and Ujagir, 2005; Jaba et al., 2014; Ambidi et al., 2022). The major pigeonpea growing states are Maharashtra, Uttar Pradesh, Karnataka, Gujarat, Telangana, and Andhra Pradesh that altogether accounting for more than 87 % area and 83 % of the production (Anonymous, 2000). The major constraint in the production of pigeon pea is the damage caused by insect pests with avoidable losses extending up to 78% in India (Lateef and Reed, 1983). Legume pod borer, *Helicoverpa armigera* (Hubner) is one of the most important pests of field crops, including pigeon pea, and crop failures due to pod borer damage are quite common (Sharma, 2001). The effective control of insect pest numbers by using chemical insecticides are used injudiciously which result in development of resistance in insect, secondary pest outbreaks, the threat to their natural enemies and residual effect on environment. Currently the effect of

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climate change has influence on the patterns and new threats of insect pests under field conditions. To overcome these threats some workers have been advocated about agronomical practices like altering the date of sowing which might be a possible resort to escape pigeon pea crop from this pest (Summerfield *et al*., 1991; Singh *et al*., 2002). Several researchers have studied the effect of different dates of sowing and the seasonal abundance of gram pod borer with the corresponding yield of pigeon pea in different parts of India. It is learnt from the past studies that the date of sowing has great impact on the incidence of the pest which may be attributed to the difference in weather conditions (Deka *et al*., 1989; Yadava *et al*., 1991; Cumming and Jenkins, 2011). Early planted crops harboured lowest pest population with corresponding increase in the yield than the late -planted crops (Chaudhary and Sachan, 1995; Ambulkar *et al*., 2011; Prasad *et al*., 2012).

In order to quickly screen varieties of pigeonpea against pod borer *H. armigera* leaf/flower/pod can be used under laboratory condition (Sharma *et al*., 2005). Hence, the present study was carried out to know the effect of different dates of sowing of pigeon pea varieties on the insect pests incidence under field conditions, and to study damage potential of *H. armigera* using detached leaf, flower, and pod assay techniques under lab conditions.

## MATERIALS AND METHODS

The experiments were conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana State, India, during the post-rainy season of 2015-16 under field conditions. The test genotypes were evaluated for resistance to *H. armigera* using detached leaf assay under laboratory conditions (Sharma *et al*., 2005).

### *Evaluation of pigeonpea genotypes for resistance to insect pests for different plantings under field conditions*

Two pigeon pea genotypes, ICPL 88039 (moderate resistance) and ICPL 87 (susceptible check) were sown at fortnightly intervals across six plantings between June to August under the rainy season. The experiment was laid out in randomized block design (RBD) with three replications for each genotype, in a plot of four rows with a spacing of 30 cm between rows and 10 cm between plants within a row, respectively. The plots were separated by an alley of 1 m. The seeds were sown with a 4-cone planter at a depth of 5 cm below the soil surface at optimum soil moisture conditions. The seedlings were thinned to a spacing of 30 cm between the plants within a row at one month after seedling emergence. Basal fertilizer (N: P: K:100: 60: 40) was applied in rows before sowing. Topdressing with urea (@ 80 kg $ha^{-1}$) was given one month after crop emergence. Interculture/weeding operations were carried out as and when needed. There was no insecticide application in the experimental plot. Observations on incidence were recorded at fortnightly intervals, starting at 30 days after sowing (DAS) until crop harvesting across six plantings. Five randomly selected plants in each entry with three replications were tagged for recording the observations. Larvae of spotted pod borer and leaf webber were observed on leaves, flower buds, and pods. Similarly, the larva of gram pod borer was counted on pods of all the tagged plants. The mean number of larvae/beetle/bugs per five plants was calculated. Besides these, pods of five randomly selected plants were harvested across the field during Kharif 2015-16 to ascertain the pod damage. The weather parameters were recorded fortnightly from ICRISAT agro meteorology observatory station in order to co-relate insect pests population with weather parameters.

### H. armigera *culture*

The larvae of *H. armigera* used in the bioassays were maintained in the laboratory at ICRISAT, Patancheru, Telangana State, India. The *H. armigera* larvae were reared on chickpea-based artificial diet (Armes *et al*., 1992) at 27 ± 2°C. The neonates were reared for 5 days in groups of 200 to 250 in 200 ml plastic cups having a 2 to 3 mm layer of artificial diet on the bottom and sides of the cup. Thereafter, the larvae were transferred individually to six cell-well plates (each cell-well measured 3.5 cm in diameter and 2 cm in depth) to avoid cannibalism. Each cell-well had a sufficient amount of the artificial diet (7 ml) to support larval development until pupation. The pupae were removed from cell-wells, sterilized with 2% sodium hypochlorite solution (with 4% available chlorine), and kept in groups of 50 in plastic jars containing moistened vermiculite. Upon emergence, 10 pairs of adults were released in an oviposition cage (30 x 30 x 30 cm). Adults were provided with 10% sucrose or honey solution on a cotton swab for feeding. Liners having a rough surface were provided as a substrate for egg laying. The liners were removed daily, and the eggs were sterilized in a 2% sodium hypochlorite solution. The liners were then dried and placed inside the plastic cups. After 4 days, the liners were removed. Freshly emerged neonate larvae were used for bioassays using detached leaf assay and diet impregnation assay (Sharma *et al*., 2005).

### *Screening of pigeonpea genotypes for resistance to* H. armigera *using detached leaf and pod assay*

The pigeon pea plants grown in the field were bioassay for resistance to *H. armigera* under controlled conditions in the laboratory [27±20°C, 65-75% RH, and photoperiod of 12:12 h. (L: D)] using detached leaf assay (Sharma *et al*., 2005). The terminal branches of pigeon pea (three to four fully expanded leaves) were placed into plastic cups (4.5 x 11.5 cm diameter) in solidified agar-agar (3%). The solidified agar-agar served as a substratum for holding the pigeon pea branches. The terminal branches were cut with scissors and immediately placed in a slanting manner into the agar-agar medium. Care was taken so that the pigeon pea branches did not touch the inner walls of the cup. Ten neonates of *H. armigera* larvae were released on the pigeon pea leaves or flowers in each cup, while for pod bioassay three third instar larvae were released and then covered with a lid to keep the pigeon pea terminals in a turgid condition. The experiment was conducted in a completely randomized design, and there were five replications for each genotype. The experiments were terminated when >80% of the leaf area or flower area or pod area was consumed in the susceptible genotype or when there were maximum differences between the resistant and susceptible genotypes (generally at 5 days after releasing the larvae on the leaves or flowers and 3 days in case of pods). The plants were scored for leaf, flower and pod feeding visually on a 1 - 9 scale (1 = <10%, and 9 = >80% leaf area consumed). Data were also recorded on larval survival, and weights of the larvae 4 h after terminating the experiment.

*Statistical analysis*

Data were subjected to analysis of variance by using GENSTAT 14.0. The significance of the difference between the treatments was measured by F-test, whereas the treatment means were compared using the least significant difference (LSD) at P 0.05 and simple coefficient of correlation analysis was performed using the same software to study the effect of weather parameters for influencing in insect pest population under unprotected conditions.

## RESULTS AND DISCUSSION

*Effect of different sowing dates of pigeonpea genotypes on resistance to major insect pests under field conditions*

*Leaf and pod feeding insects*

The results of the effect of sowing dates and major abiotic parameters on leaf and pod feeding insect pests population on two genotypes ICPL 88039 and ICPL 87 revealed that the maximum insect population was recorded on first sowing and then gradually declined for the rest of sowing (Fig. 1A and 1B). There was a significant difference in the number of insect pest populations across plantings and on two cultivars. The maximum *H. armigera* egg population exhibited 21.10 on ICPL 87 in first sowing and at least 1.23 on ICPL 88039 in sixth sowing. The *H. armigera* larval population maximum of 10.57 and minimum of 0.61 (ICPL 88039) were observed in the first and sixth planting, respectively. It was observed that the web forming insect pests *Maruca* and leaf webber recorded on ICPL 88039 in maximum on second (3.95) and first (4.66) planting, respectively. The leaf feeding beetle was recorded highest 6.29 (ICPL 87) in the third planting. Among two cultivars, maximum insect population was recorded on ICPL 87 when compared to ICPL 88039 except web forming insect *Maruca* and leaf webber due to the indeterminate genotypic character of ICPL 88039, it produces two to three new flushes during the crop period, so it influences in build up for web forming insects. The evening humidity influence a major key factor for the population build-up of *H. armigera* population. It was observed that *H. armigera* population decline gradually as the relative humidity and intermittent rainfall decline from first sowing to sixth sowing. The pigeon pea is photo insensitive crop, which indirectly influence the plant growth. It results in a gradual decline in the insect population at end of the sixth plating.

The findings of the present investigation are in close conformity with the work of earlier scientists who showed significant damage ($p<0.05$) to the seeds of the cultivars especially that of ICPL 87 by *H. armigera.* This finding agreed with the earlier work of Lateef and Reed (1980) in India who reported that the damage caused by *H. armigera* to the seeds of short and medium duration cultivars was high in particularly to those of the determinate habit. This could be related to the cluster pod habit of the improved cultivars which helps to conceal the larvae of *H. armigera* from their prey and harsh weather. Sharma and Franzamann (2000) found that the incidence of *M. vitrata* on pigeon pea was bimodal where early infestation starts from September reaching its first peak during middle October and second peak during December. The incidence of *M. vitrata* increased with the initiation of flowering, having the highest population at a full podding stage of pigeon pea (Imosanen and Singh, 2005) and larval population/ plant gradually increased from the third week of November (47$^{th}$ standard week) and reached peak level (12.6 larvae/ plant) at the third week of December (51$^{st}$ standard week), which coincides with the peak flowering stage of the crop. The pest remained active up to the last week of January. The maximum, minimum and mean temperatures and, relative humidity recorded at morning, evening and mean were found to be highly correlated with that of larval population of *M. obtusa, M. testulalis* and borer complex, while *H. armigera* remained unaffected Kumar *et al*., 2003). Sreekanth *et al*. (2015) confounded that a highly significant correlation was obtained between *M. vitrata* and minimum temperature, mean temperature, and wind speed with correlation coefficient (r) being -0.759, -0.815 and -0.838, respectively. A moderately

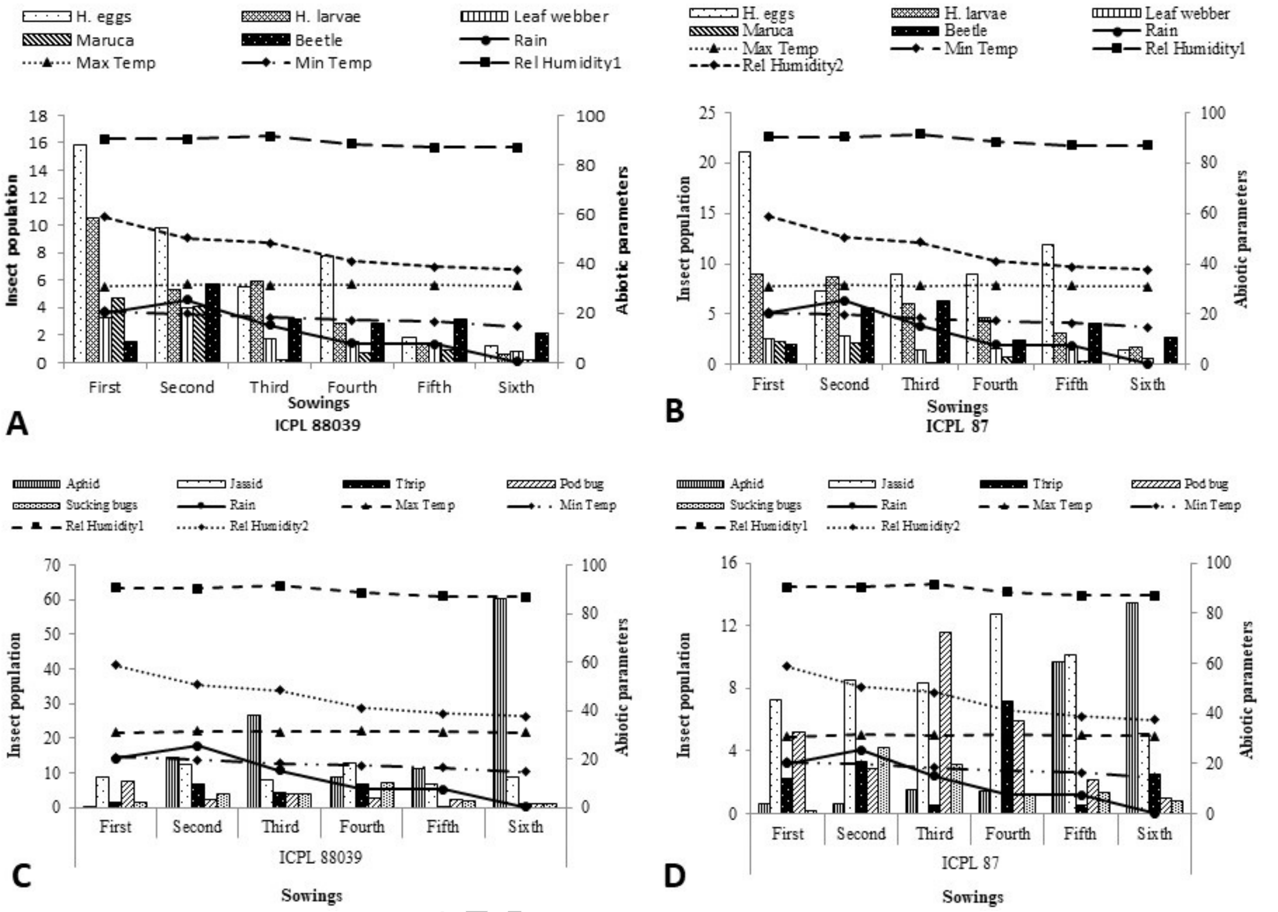


Fig. 1. Effect of different plantings on the population of leaf feeding (A, B) and sap sucking insects on ICPL 88039 and ICPL 87.

significant correlation was obtained between *M. vitrata* and sunshine hours and evening relative humidity (RH-II) with correlation coefficients (r) being 0.656 and -0.609, respectively.

*Sap feeders*

In context to sucking pests, the pest population gradually increased with sowing dates and the maximum population was recorded on the sixth sowing/planting. Among the two genotypes, the sucking pests more preferred ICPL 87 when compared to ICPL 88039. There was a significant difference between in the number of insect pest populations in the two cultivars across plantings. Among two cultivars, the maximum Aphid *A. craccivora* population recorded 60.29 on ICPL 88039 in sixth sowing and a minimum 0.33 on ICPL 88039 in first sowing. In ICPL 87 there was a minimal population of *A. craccivora* across sowing dates except at sixth sowing where the population rose to 13.43 (Fig. 1C and 1D). Another important sap -feeding insect in pigeon pea was jassids, the mean across the population was at par with both cultivars but the maximum was 12.76 and 8.38 (ICPL 87) in fourth sowing and third sowing respectively. The thrips population was also at par within each cultivar. The highest pod bug population was recorded in third planting (11.57) in ICPL 87, and the highest sucking bug population was observed at 6.95(ICPL 88039).

It was observed that the sucking insect pest's population decline gradually as the relative humidity and intermittent rainfall decline from first sowing to sixth sowing. Among two cultivars maximum sap feeding insect population was recorded on ICPL 88039 except pod bug. Due to the indeterminate genotypic character of ICPL 88039, it produces two to three new flushes during the crop period, so it influences for maximum population build dup sap feeders. As the relative humidity gradually declines from first to sixth sowing, it indirectly influences in decreasing of the population of sap feeders. The results were in conformation with earlier results and the damage to the seeds of the cultivars was significant (p<0.05) by *Clavigralla* spp., confirming the findings of Odak *et al*. (1978) who reported that pod sucking bugs caused deformation and shrivelling of grains resulting in substantial losses to pigeon pea. Damaged seeds are dark and shrivelled. They do not germinate and are not acceptable for human consumption (Materu, 1970). The crops planted in August had the highest seed damage while the least percentage seed damage was obtained from crops planted in June. Kyamanywa *et al*. (2001) reported that in pigeon pea late sowing increases damage by pod suckers. The significant planting date differences observed in this study could be related to the variation in weather conditions existing during the three planting periods which might have influenced the level of damage.

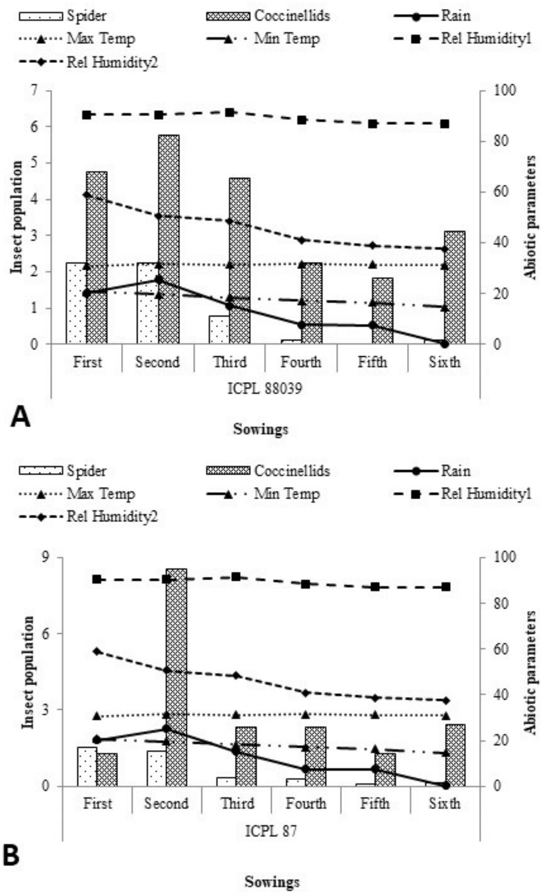


Fig. 2. Effect of different plantings on the population natural enemies on ICPL 88039 and ICPL 87.

*Natural enemies*

There was a significant difference between the natural enemies' population between sowing dates but among the two cultivars the population was at par with each other. It was observed that the highest spider population recorded was 2.23 (ICPL 88039) in the first and second sowing. Coccinellids population recorded a maximum of 8.52 (ICPL 87) (Fig. 2).

The relative humidity was the key factor gaining up the population of natural enemies in both cultivars. The present findings are in agreement with Borah and Dutta (2003) who reported predatory spiders of *H. armigera* in pigeon pea ecosystem included *Oxyopes ratnae* Tikader, *Oxyopes shweta* Tikader, *Neoscona* sp. and *Plexippus paykullii* Tikader and Biswas which appeared from flowering until maturity and at senescence. Kumar and Nath (2003) reported that ladybird beetle, mirid bug, praying mantis, dragonfly, green lacewings, and spiders were noticed on pigeon pea varieties in Western Rajasthan.

*Expression of resistance to* H. armigera *in pigeonpea across different sowing dates with detached leaf and pod assay*

*Detached leaf assay*

There were significant differences in leaf feeding between the genotypes ($Fp < 0.005$, LSD=0.425) and sowing dates ($Fp < 0.001$, LSD =0.735), whereas the interaction effects were highly significant ($Fp < 0.001$, LSD=1.039). Mean leaf damage rating across sowing dates levels varied from 4.85 to 7.59 (Fig. 3). The mean damage rating between genotypes tested across six plantings was observed when infested with 10 neonates per branch (DR = 5.78 in ICPL 87 and 6.39 in ICPL 84060) larvae per trifoliate. The leaf damage rating was lower (DR 3.67) on ICPL 87 in the second planting and the highest (DR 8.39) in ICPL 88039. Both genotypes suffered damage at par with each other. There were substantial differences in % larval survival between the genotypes ($Fp < 0.037$, LSD=4.77) and sowing dates ($Fp < 0.001$, LSD =8.27), whereas the interaction effects were non- significant. The differences in larval survival between the genotypes were highly significant, among six planting lowest mean survival of 15% in the second planting and highest survival was observed 72.67 % in fifth planting. Among the two genotypes tested, the lowest mean larval survival across plantings was observed in 33.86 % (ICPL 87) and the highest 44.88 % (ICPL 88039) but the lower mean larval weight gain of 0.68mg in second planting and highest 158.4 mg during first planting. The larval weight was significantly variations across plantings. Among genotypes, mean weight gain in larvae was 29.09 and 31.48 mg respectively for ICPL 87 and ICPL 88039 across plantings. Hence, our results showed that the *H. armigera* larvae more prefer leaf feeding, weight gain, and larval survival on ICPL 88039 than ICPL 87.

As we know the screening for resistance to *H.*

*armigera* under natural conditions is a long-term process because of variations in insect population in space and time. As a result, it is difficult to identify stable sources of resistance under natural infestation (Sharma *et al.*, 1997). Therefore, the development and standardization of techniques for rapid screen for resistance to insect pests is the key for an effective insect resistance breeding program and marker-assisted selection of plants with resistance to insects. Genotypic reactions to feeding by *H. armigera* is diverse; therefore, careful consideration should be given to using the insect density that results in maximum differences between the resistant and susceptible genotypes. The detached leaf assay not only gives an idea of the relative feeding by the larvae on different genotypes but also provides useful information on the antibiosis component of resistance in terms of larval weight. Larval weights were significantly lower in the larvae fed on the leaves of ICPL 87 (although this genotype is most susceptible to pod borer at the podding stage under field conditions) compared with those fed on the leaves of ICPL 332, which is resistant to *H. armigera* at the podding stage (Lateef and Sachan, 1990). Some of these differences maybe because of the differences in relative susceptibility of leaves and pods of different genotypes, and the oviposition non -preference as an additional component of resistance under field conditions. Thus, the detached leaf assay did not seem to be a proper test to screen for resistance to *H. armigera* in pigeon pea. Thomas *et al*. (1966) compared the reactions of attached versus excised leaves of alfalfa for resistance to spotted alfalfa aphid, *Therioaphis maculata* (Buckton). They reported that nymphal survival was greater on excised leaves than on intact leaves, but the differences in survival varied across genotypes. The results suggested that excised leaves tended to underestimate the resistance levels of the plant population tested. Similar observation also has been reported by Hackerrot and Harvey (1959). The relationship between insect reaction to the excised leaves and the field performance of a genotype depends on insect-host plant relationships, plant part preferred by the insect, and induced resistance. In addition, the relative susceptibility of the test genotypes in the field and the detached leaf assay will be influenced by the relative importance of non-preference for oviposition and feeding, antibiosis, and tolerance. Therefore, care should be exercised to see that the results of excised leaf assays are not different than those under felid conditions. However, where the non-preference for feeding and antibiosis are important components of resistance, this technique can be used effectively for rapid and large-scale screening of germplasm, breeding material, and mapping populations under uniform insect pressure.

*Detached pod assay*

The pod damage rating was non-significant between the genotypes and across sowing dates but it showed interaction effects were highly significant ($Fp < 0.01$, LSD=3.49). The podding stage is most preferred for *H. armigera*, there were significant and non-significant differences in pod damage ratings among two genotypes against *H. armigera* across plantings. The overall mean damage rating across six plantings was 7.27; 7.72 for ICPL 87 ICPL 88039, respectively (Fig. 4). The minimum (5.83) and maximum (7.97) pod damage rating was recorded on the third planting and fourth planting on ICPL 87. The mean weight gain % was at par with between genotypes across the planting and showed highly significant across sowing dates ($Fp < 0.01$, LSD=2.49) and interaction effect ($Fp < 0.01$, LSD=3.53). The lowest weight gain % was recorded at 2.82 % (ICPL 88039) in the fourth planting and maximum weight gain (%) was recorded at 16.82% (ICPL 87) in the sixth planting.

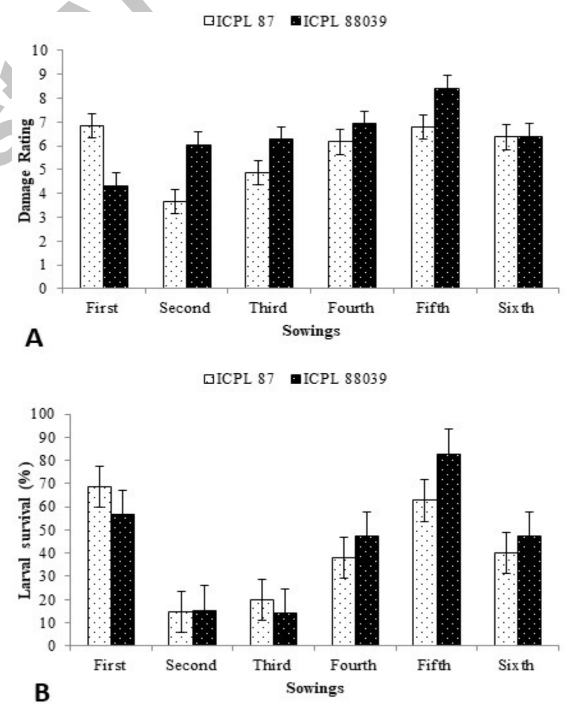


Fig. 3. Effect of different plantings on the damage ratings and larval survival percentage of *H. armigera* in detach leaf assay.

It is concluded that the *H. armigera* larvae were preferred more for podding stage and weight gain was more when compared to the leaf and flower stage. Percentage of damage to bolls/pods is the most common parameter used for determining genotypic resistance or susceptibility to *H. armigera* under field conditions (Sharma *et al*., 2003).

However, this criterion often leads to variable results due to variations in insect population and the stage at which the crop is infested. In addition, the damage to foliage, flowers, and small pods, which are devoured by the larvae, is not reflected in the percentage of pod damage. At times, the pods or bolls sampled for recording insect damage may be from the second flush, which might have escaped insect damage. To overcome these problems, the test material can be evaluated for resistance to the target insect by using the detached flower/pod assay under uniform insect pressure at pod developmental stages.

*Effect of abiotic factor on incidence of insect pests population on pigeonpea*

To understand the relationship between weather parameters prevailed during cropping seasons and the number of larvae per five plants, the correlation was worked out and presented in Table I. Correlation co-efficient values worked out between insect pests of pigeon pea and weather parameters revealed that leaf webber (r= 0.449**) and pod bug (r= 0.421**) showed a highly significant positive correlation with maximum temperature and *H. armigera* larvae population exhibited a highly significant positive correlation with minimum temperature (r= 0.491**) and morning relative humidity (r= 0.528**). Solar radiation also exhibited and showed a significant positive correlation with leaf webber (r= 533**).

All the other factors had no significant correlation with insect pests population on pigeon pea across plantings (Table I). Earlier, Falerio *et al.* (1986) stated that the jassid population had no significant correlation with any environmental factors, except rainfall. Gupta and Desh (2002) reported a positive correlation between *H. armigera* population with maximum temperature, relative humidity and rainfall in chickpea. Yadav *et al.* (2006)

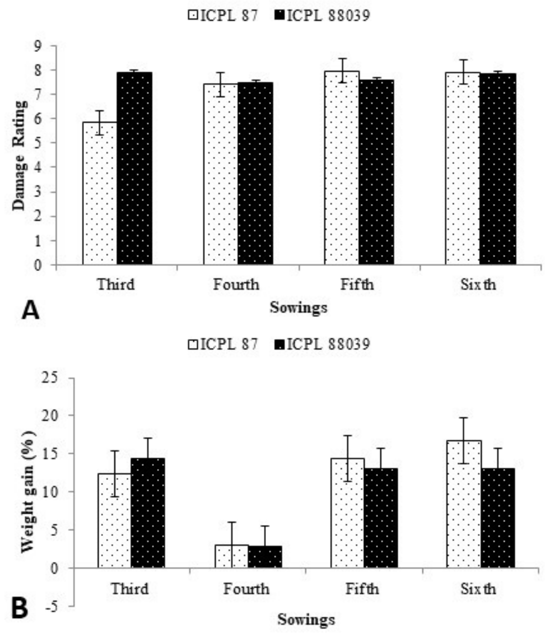


Fig. 4. Effect of different plantings on pod damage rating and % weight gain of *H. armigera* in pod assay.



**Table I. Correlation coefficient (r) between pigeonpea pod borer and prevailing weather parameters during crop growing seasons.**

| Pests | Rain (mm) | Evaporation (mm) | Max T | Min T | RH 1 | RH 2 | WV(kmph) | Solar (mj/m2) |
|---|---|---|---|---|---|---|---|---|
| H. eggs | -0.057 | 0.128 | 0.183 | 0.038 | 0.528** | -0.098 | -0.272 | 0.274 |
| H. larvae | -0.173 | 0.009 | 0.228 | 0.491** | 0.135 | -0.107 | -0.176 | 0.234 |
| Leaf webber | 0.071 | 0.139 | 0.449** | 0.320 | 0.103 | 0.010 | -0.504 | 0.533** |
| Maruca | 0.059 | 0.108 | 0.172 | 0.156 | 0.100 | 0.071 | -0.102 | 0.296 |
| Beetle | 0.306* | 0.206 | 0.258 | 0.265 | 0.045 | 0.050 | -0.365 | 0.306* |
| Aphid | -0.155 | -0.110 | 0.263 | -0.086 | 0.164 | -0.189 | 0.103 | -0.222 |
| Jassid | -0.178 | -0.036 | 0.082 | 0.036 | 0.198 | -0.120 | -0.096 | 0.056 |
| Thrip | -0.055 | 0.095 | 0.041 | -0.097 | -0.132 | -0.216 | -0.093 | 0.080 |
| Pod bug | -0.165 | 0.081 | 0.421** | -0.039 | 0.198 | -0.244 | 0.109 | 0.041 |
| Sucking bugs | -0.157 | -0.030 | 0.122 | -0.010 | 0.044 | -0.155 | -0.003 | 0.023 |
| Spider | 0.191 | -0.011 | 0.259 | 0.219 | 0.075 | 0.046 | -0.294 | 0.230 |
| Coccinellids | -0.146 | -0.149 | 0.206 | -0.045 | 0.188 | -0.133 | 0.045 | -0.162 |
| Leaf minor | 0.020 | 0.154 | 0.241 | 0.354* | 0.097 | 0.199 | -306.0 | 0.368* |
| Blister beetle | 0.189 | -0.051 | 0.123 | 0.237 | 0.063 | 0.171 | -0.072 | 0.164 |
| Mealybug | -0.042 | -0.060 | 0.085 | 0.121 | 0.169 | 0.038 | -0.125 | 0.059 |

concluded that maximum temperature, average temperature, morning relative humidity, evening relative humidity, average relative humidity and wind velocity showed a non-significant negative correlation with *H. armigera* population whereas sunshine hours showed a non-significant positive correlation. reported that *H. armigera* exhibited negative correlation with relative humidity, while maximum temperature and sunshine hours showed a significant positive correlation with pest population, whereas the other factors did not show any correlation (Patel, 1997; Kumar *et al*., 2003).

## CONCLUSIONS

Host plant resistance and different planting dates have great potentials as management strategies for major insects' pests of pigeon pea under Semi-Arid Tropical region, the control of *Helicoverpa, M. vitrata* and other sap sucking insect pests in pigeonpea production and could provide suitable alternatives for pest control on field crops of small scale and low-input agriculture as commonly practiced in SAT countries without degrading the environment. Proper planting time in association with resistance varieties could offer effective control measures of pigeonpea pod borer complex and sap feeding insects with optimum grain yield. Further, the tolerant variety can be utilized in breeding programs and test the cultivars at varied environment conditions across regions to know the performance against major insect pests, and it can be included as a component of the IPM package for the management of pod borer complex of pigeon pea.


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*Statement of conflict of interest*

The authors have declared no conflict of interest.




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