Survival and development of *Helicoverpa armigera* on artificial diet impregnated with lyophilized leaf and pod powder of different chickpea genotypes

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ABSTRACT

Host plant resistance is one of the components for minimizing the damage by the noctuid pod borer, *Helicoverpa armigera* in chickpea. However, due to variations in *H. armigera* infestations in space and time, it becomes difficult to evaluate the test material in under natural infestation. Therefore, we evaluated the diet impregnation assay to evaluate chickpea genotypes for resistance to *H. armigera*. Ten-day old larvae weighed highest on the standard diet, followed by those reared on diets with leaf powder of the susceptible checks, ICC 4918 and ICCC 37. Larval weights were significantly lower in larvae reared on the leaves/pods of ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 as compared to those reared on the susceptible check, ICC 12426. The larvae reared on artificial diet impregnated with lyophilized leaf and/or pod powder of ICC 12475, ICC 12476, ICCV 2, and ICC 12479 also weighed significantly lower than those fed on diets with ICC 12426, and ICC 3137. Of these, larval period was prolonged on fresh leaves/pos of ICC 506, and in diets with pod powder of ICC 3137, ICC 12479, ICCV 2, and ICC 506. Comparatively lower pupal weights were recorded in larvae reared on fresh leaves/pods and on artificial diets with leaf and pod powder of ICC 12476, ICC 12477, ICC 12478, and ICC 506 as compared to those on ICCC7 37; while larval survival, pupation, and adult emergence were lower on the fresh leaves/pod and on artificial diets with leaf and pod powder of ICC 12476, ICC 12477, ICC 12478, and ICC 506 as compared to the insects reared on the susceptible checks, ICC 37 and ICC 4918. Larval survival and development were also adversely affected on the F1 hybrids based on these genotypes as compared the susceptible check, ICCC 37. There was a significant reduction in fecundity of insects reared on the fresh leaves/pods and on artificial diets with leaf and pod powder of ICC 12476, ICC 12477, ICC 12478, ICC 12479, and ICC 506 as compared to the insects reared on ICCV 2, ICC 4918, and ICCC 37. The results indicated that the antibiosis to *H. armigera* in chickpea is expressed in terms of slower development, and reduced survival and fecundity. Survival and development of *H. armigera* of fresh leaves/pods and on diets with lyophilized leaf and pod powder of different chickpea genotypes were highly correlated suggesting that diet impregnation assay can be used to assess antibiosis component if resistance to *H. armigera* in chickpea.

Key words: *Helicoverpa armigera*, chickpea, biology, resistance, artificial diet.

INTRODUCTION

The noctuid *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is the most important pest on a wide variety of crops such as cotton, pigeonpea, chickpea, tomato, fruits, and vegetable crops (Sharma, 2001). It is widely distributed in Asia, Africa, Oceania and the Europe (IIE, 1993). Its significance as a pest is based on the peculiarities of its biology such as high mobility, polyphagy, high reproductive rate, and diapause (Fitt, 1989). Its preference for flowering/fruiting parts of high-value crops confers a high socio-economic cost to its depredations under subsistence farming in the tropics and subtropics. Monetary losses result from the direct reduction in crop yield and the cost of monitoring and control, particularly the cost of insecticides. The extent of losses in chickpea has been estimated at over $328 million in the semi-arid tropics (ICRISAT, 1992). Total losses due to *H. armigera* in cotton, legumes, vegetables, and fruits may exceed US$2 billion in the semi-arid tropics, and the cost of insecticides used to control *H. armigera* may be over $500 million annually (Sharma, 2001).

Chickpea germplasm accessions with resistance to *H. armigera* have been identified by several workers (Lateef 1985; Chhabra et al. 1990; Lateef and Sachan 1990; Singh and Yadav 1999ab, Das and Kataria 1999). However, the genotypic responses have been found to be quite variable across seasons and locations (Sharma et al. 2003). There are large differences in the flowering times of different chickpea genotypes (35 to >90 days), whereas *H. armigera* infestation varies over space and time. The *H. armigera* infestations in chickpea are either too high and cause a complete damage to the crop or too low to result in significant differences among the test genotypes. The onset of infestation also varies over seasons and locations, resulting in differential crop response to damage by *H. armigera*. Because of variation in insect pressure and onset of insect infestation, it is difficult to get reliable results under natural infestation.

There is a need to identify genotypes with different mechanisms (genes) of resistance to develop chickpea cultivars with stable resistance to *H. armigera* (Sharma et al., 2005). Resistance genes from diverse sources need to be combined to increase the levels (gene pyramiding), and diversify the bases of resistance to this pest. To achieve this objective, there is a need to quantify the contribution of different mechanisms of resistance, and to identify genotypes with different resistance mechanisms. However, this is quite difficult under natural infestation because of staggered flowering of different genotypes, and the difficulty in locating eggs and small larvae on the plant. Also, a proportion of the larvae are lost because of parasitism and predation, and cannibalism amongst the large grown up larvae. As a result, it becomes difficult to obtain a precise estimate of antibiosis component of resistance to *H. armigera* in chickpea genotypes under natural infestation. Therefore, the present studies were undertaken to assess the usefulness of diet impregnation assay to evaluate chickpea genotypes for antibiosis component of resistance to *H. armigera* in chickpea.

MATERIALS AND METHODS

Test material. Nine chickpea genotypes (eight desi and one kabuli type) based on their reaction to *H. armigera* earlier (Lateef, 1985; Sharma et al., 2005) were selected for these studies. Amongst these, ICC 12475 (ICC 506), ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 (ICC 12968) had different levels of resistance to *H. armigera,* while ICCC 37 (ICC 12426), ICC 3137, and ICC 4918 were used as susceptible checks. These lines are mated in all possible combinations, and the F_1 hybrids were also studied for their reaction to *H. armigera*.

Plants. The chickpea genotypes were raised on a sterilized mixture of black soil (Vertisols), sand, and farmyard manure (2: 1: 1). The soil was filled into the medium sized pots (30 cm in diameter and 30 cm in depth). The seeds were sown 5 cm below the soil surface and watered as and when required. Ten seeds were sown in each pot, and 5 plants with uniform growth were retained at 10 days after seedling emergence. The plants were fertilized with diammonium phosphate (DAP) at 20 g per pot at 15 days after seedling emergence. The plants were raised in the greenhouse, which was cooled by desert coolers (27 ± 5^{o}C and 65 -90% RH). Survival and development of *H. armigera* was studied on chickpea leaves (10 cm long terminal branches) for the first 7 days, and later on pods. Chickpea terminals at 30 days after seedling emergence were collected from the pots, and placed in an icebox. The leaves were freeze-dried, powdered in a Willey mill, and used for diet impregnation assay.

Survival and development of *Helicoverpa armigera* on leaves and pods of chickpea genotypes

To study the survival and development of *H. armigera* on different chickpea genotypes, the neonate larvae were fed on the leaves of nine chickpea genotypes grown in the greenhouse for seven days. Afterwards, the larvae were held individually in plastic jars (11 cm diameter and 15 cm height) and placed on chickpea branches with pods to simulate feeding under natural conditions. Larval weights were recorded on 10th day after release of the larvae. The food was changed everyday. The experiment was conducted in a completely randomized design, and there were five replications. Each replication had 10 larvae. Data were also recorded on larval and pupal periods, pupation and adult emergence, larval and pupal survival, and fecundity.

Survival and development of *H. armigera* on artificial diets impregnated with lyophilized leaf and pod powder of different chickpea genotypes

To study the antibiosis component of resistance, 20 g of freeze dried powder of leaves and pods of 81 chickpea entries (72 hybrids + 9 parents) was impregnated into the artificial diet used for rearing *H. armigera* under laboratory conditions (Armes et al., 1992). For this purpose, branches with tender green leaves and pods with developing seeds were collected from the plants grown under pesticide-free conditions in the field. The leaves and pods were freeze-dried in a lyophiliser, and then powdered in a blender into fine powder (<80 mesh). The lyophilized leaf and pod powders were mixed with the artificial diet (20 g in 250 ml diet), and 7 ml diet was poured into each cell well in a 6-cell plate. The neonate larvae were released into the cell wells individually. There were three replications for each genotype, and each replication had 10 larvae. Data was recorded on larval and pupal weights, larval and pupal duration, pupation and adult emergence, sex ratio, oviposition, viability of eggs, and adult longevity.

Statistical Analysis

The data were subjected to analysis of variance to test the significance of differences among the genotypes. The significance of differences between the genotypes was measured by F test at P = 0.05, whereas the treatment means were compared using the least significant difference (LSD) at P = 0.05. Correlation coefficients between larval survival and development on fresh leaves/pods and on artificial diet impregnated with lyophilized leaf and pod powder were computed to assess the relevance of diet impregnation assay to assess antibiosis component of resistance to *H. armigera* in chickpea.

RESULTS

Larval and pupal weights

Weights of the 10-day-old larvae reared on leaves of different chickpea genotypes differed significantly, and ranged from 298.1 mg on ICC 12475 to 396.3 mg on ICC 4918 (Table 1). Larval weights were significantly lower in larvae released on the leaves/pods of ICC 12476, ICC 12477, and ICCV 2 as compared to those reared on the susceptible check, ICC 12426 (382.9 mg). Pupal weights were lower (274.2 to 292.3 mg) in insects reared on ICC 12476, ICC 12478, and ICC 506EB as compared to the insects reared on ICC 3137 (324.5 mg) and ICC 4918 (323.9 mg).

Weights of the larvae reared on artificial diet impregnated with lyophilized leaf powder were highest on the standard artificial diet (445.8 mg per larva), followed by the larvae reared on diets having the leaf powder of ICC 4918 (417.5 mg) and ICC 12426 (415.6 mg) (Table 2). Larval weight was lowest in larvae reared on artificial diets with leaf powder of the resistant check, ICC 12475, followed by ICC 12478 and ICC 12477. Larvae fed on artificial diet impregnated with lyophilized pod powder of ICC 12475 (253.3 mg), ICC 12476 (285.4 mg) and ICC 12479 (288.3 mg) weighed significantly lower than those fed on standard artificial diet (468.8 mg per larva), ICC 12426 (443.8 mg), and ICC 3137 (424.1 mg) (Table 3). The pupal weights were lower on artificial diets with leaf powder of ICC 12476, ICC 12477, ICCV 2, and ICC 506EB as compared to those on ICCC 37. The highest pupal weights were recorded on diet with pod powder of ICC 12426 (351.4 mg), followed by standard artificial diet (342.1 mg), and ICC 4918 (327.9 mg). The lowest pupal weights were recorded on diet with pod powder of ICC 12475 (244.1 mg), ICC 12478 (245.7 mg), and ICC 12476 (249.5 mg).

Larval and pupal periods

Larval period was prolonged when the larvae were reared on the fresh leaves/pods of ICC 12475 (17.8 days) as compared to those reared on ICCC 37 (15.5 days) (Table 1). Pupal period was longer on ICC 12477 (11.8 days), ICC 12476 (11.8 days), and ICC 12475 (11.7 days) as compared to the insects reared on the susceptible check, ICC 12426 (8.8 days). When the larvae reared on artificial diet with lyophilized leaf powder, larval period ranged from 14.9 (ICCC 37) to 17.0 days (ICCV 2), and was also prolonged on ICC 12478 and ICC 12475 (17.4 days); while in diets with pod powder, the larval period was longer (17.6 to 18.3 days) on ICC 506EB, ICCV 2, and ICC 12479 as compared to that on ICC 37 (15.4 days) (Table 3). The pupal period ranged between 9.0 days on ICCC 37 to 11.4 days in diets with leaf powder of ICC 12475 and 11.6 days on ICC 12479. Duration of the pupal period of the insects reared on diets with lyophilized pod powder was longer (10.5 to 12.03 days) on ICCC 506EB, ICC 12479, ICC 12476, and ICC 12478 as compared to that on ICCC 37 (9.2 days).

Larval survival, pupation, and adult emergence

Larval survival on 10th day after release of the larvae was lowest on resistant check, ICC 12475 (66%) and highest on the susceptible checks, ICC 12426 and ICC 3137 (88%). More than 80% larval survival was recorded on ICC 3137, ICCV 2, ICC 4918, and ICC 12426 as compared to 66% survival on the resistant check, ICC 12475. Pupation was lowest in insects reared on ICC 12475 (64%), followed by those reared on ICC 12476 (66%), and ICC 12477 (70%). Adult emergence was 60 to 62% on ICC 12476, ICC 12477, ICC 12478, ICC 12479, and ICC 12475 (Table 1).

Larval survival was 70 to 75% on artificial diets with leaf powder of ICC 12476, ICC 12477, ICC 12479 and ICC 506EB compared to 91.7% survival on ICCC 37 and 98.0% on standard artificial diet (Table 2). Pupation (63.3 to 71.7%) and adult emergence (63.3 to 70%) were lower on ICC 12476, ICC 12477, and ICC 12478 as compared to that on ICC 37 (89 % pupation and 87% adult emergence). In diets with pod powder, larval survival was lower on ICC 12476, ICC 12478 and ICC 506EB as compared to that on ICC 37 (93.3%) (Table 3). Pupation and adult emergence were lower in insects reared on diets with pod powder of ICC 12476, ICC 12478, and ICC 506 as compared to that on ICC 37.

Larval survival and development on diets with lead powder of F_1 hybrids

Larvae reared on diets with leaf powder of the hybrids based on ICC 12475 had the lowest weights (318.9 mg), followed by the larvae reared on the hybrids based on ICC 12479 and ICC 3137 (319.9 mg) (Table 4). The larvae weighed 345.6 mg on the hybrids based on the susceptible check, ICC 12426) and 468.9 mg on standard artificial diet. Pupal weights were 279.5 to 294.1 mg in hybrids based on ICC 12475, ICC 12478, ICC 3137, and ICC 4918 compared to 345.6 mg on the susceptible check, ICC 37 and the hybrids based on it (333.5 mg). Larval period in diets impregnated with lyophilized leaf powder of F_1 hybrids did not vary much, and ranged from 15.5 days in hybrids based on ICC 12476 to 16 days in hybrids based on ICC 12479 and ICC 3137. The pupal period ranged from 9.7 days in hybrids based on IC 12476 to 10.1 in hybrids based on ICC 12477 and ICC 12478 as compared to 11.93 days on ICC 506EB and 0.02 days on ICCC 37, and the differences were not large, although they were significant. Larval survival ranged from 74 to 80% in diets with leaf powder of F_1 hybrids compared to 70% in diets with leaf powder on ICC 506 and 93.3% in diets with that of ICCC

37. Pupation ranged from 61 to 76% on F_1 hybrids compared to 63.3% on ICC 506 and 90% on ICCC 37; while adult emergence was 56 to 73% on F_1 hybrids and 63.3% in ICC 506 and 88% on ICCC 37.

Fecundity, sex ratio, and longevity of adults

Reduced fecundity (785 to 907 eggs female^{-1}) was observed in insects reared on the leaves/pods of ICC 12476, ICC 12477, ICC 12478, ICC 12479, and ICC 12475 as compared to that on the susceptible check, ICC 12476 (1291.2 eggs female^{-1}) (Table 5). Egg viability was lower in insects reared on ICC 12476, ICC 12479, and ICC 12475 as compared to the insects reared on ICC 12426. Highest and lowest longevity of adults was recorded on resistant and susceptible checks, ICC 12475 and ICC 12426, respectively. Female fecundity was lower (675 to 855 eggs female^{-1} in diets with leaf powder and 632.8 to 860.5 eggs female^{-1}in diets with pod powder) in insects reared on artificial diet with leaf/pod powder of ICC 12476, ICC 12477, ICC 12479, and ICC 506 as compared to the insects reared on diets with the leaf powder of ICCC 37 (1150 eggs female^{-1} with leaf powder and 1241.2 eggs female^{-1}with pod powder). Egg viability ranged from 62 to 88.5% in diets with leaf or pod powder, but the differences were non-significant. Similarly, the there no significant differences in the longevity of adults reared on diets with leaf/pod powder of different genotypes.

Association between development parameters of *Helicoverpa armigera* on leaves/pods and diet impregnation assay

Larval (r = 0.67 – 0.82) and pupal (r = 0.31 – 0.63) periods were significantly correlated in insects reared on fresh leaves/pod and on diets impregnated with leaf and pod powder of different genotypes (Table 6). Similarly, larval survival, pupation, and adult emergence on fresh leaves/pod and on diets with leaf and pod powder of different genotypes were also positively correlated (r = 0.85 – 0.95). Larval and pupal weights (r = 0.63 – 0.88), sex ratio (r = 0.47 – 0.76), fecundity and egg viability (r = 0.92 – 0.96), and adult longevity (r = 0.76 – 0.890 were also correlated significantly. Except for pupal period and sex ratio in diets with pod powder and on fresh leaves/pods, the rest of the correlation coefficients were significant and positive. The results suggested that diet impregnation assay can be used to assess antibiosis component if resistance to *H. armigera* in chickpea.

Discussion

There are considerable differences in numbers of *H. armigera* larvae on different genotypes under field conditions (Lateef, 1985; Lateef and Sachaan, 1990). Antibiosis is expressed in terms of larval mortality, decreased larval and pupal weights, prolonged larval and pupal development, failure to pupate, and reduced fecundity, and egg viability (Yoshida *et al*., 1995). Srivastava and Srivastava (1990) assessed the antibiosis in terms of larval survival, larval and pupal weights, and adult longevity and fecundity, while Sharma and Yadav (2000) used life table analysis to assess antibiosis component of resistance to *H. armigera*. Larvae of *H. armigera* reared on leaves or pods of ICCV 7 weighed significantly lower than those reared on ICCC 37, while the pupal weights were lower in larvae reared on ICC 506 and ICCV 7 than those reared on ICCC 37 (Cowgill and Lateef, 1996).

In the present studies, larval and pupal weights and larval survival were greater in larvae reared on lyophilized leaf and pod powder compared to those reared on intact leaves/pods. This may be because of more nutrients available in the artificial diet as compared to the plant material *per se*. Ten-day old larvae weighed highest on the standard diet, followed by those reared on diets with leaf powder of the susceptible checks, ICC 4918 and ICCC 37. Larval weights were significantly lower in larvae reared on the leaves/pods of ICC 12476, ICC 12477, ICC 12478, ICC 12479 and ICCV 2 as compared to those reared on the susceptible check, ICC 12426. The larvae reared on artificial diet impregnated with lyophilized leaf and/or pod powder of ICC 12475, ICC 12476, ICCV 2, and ICC 12479 also weighed significantly lower than those fed on diets with ICC 12426, and ICC 3137. Of these, larval period was prolonged on fresh leaves/pos of ICC 506, and in diets with pod powder of ICC 3137, ICC 12479, ICCV 2, and ICC 506. Comparatively lower pupal weights were recorded in larvae reared on fresh leaves/pods and on artificial diets with leaf and pod powder of ICC 12476, ICC 12477, ICC 12478, and ICC 506; while larval survival, pupation, and adult emergence were lower on the fresh leaves/pod and on artificial diets with leaf and pod powder of ICC 12476, ICC 12477, ICC 12478, and ICC 506 as compared to the insects reared on the susceptible checks, ICC 37 and ICC 4918. Larval survival and development were also adversely affected on the F1 hybrids based on these genotypes as compared the susceptible check, ICCC 37. There was a significant reduction in fecundity of insects reared on the fresh leaves/pods and on artificial diets with leaf and pod powder of ICC 12476, ICC 12477, ICC 12478, ICC 12479, and ICC 506 as compared to the insects reared on ICCV 2, ICC 4918, and ICCC 37. The results indicated that the antibiosis to *H. armigera* in chickpea is expressed in terms of slower development, and reduced survival and fecundity.

Survival and development of *H. armigera* of fresh leaves/pods and on diets with lyophilized leaf and pod powder of different chickpea genotypes were highly correlated, except (pupal period in diets with pod powder), suggesting that diet impregnation assay can be used to assess antibiosis component if resistance to *H. armigera* in chickpea. Growth inhibitor and/or antifeedant substances in chickpea leaves/pods might contribute to antibiosis to *H. armigera* in chickpea (Yoshida and Shanower, 2000). Slower larval growth, which results in prolonged development, may also increase the probability of predation, parasitism, and infection by pathogens, resulting in reduced population of the pest on the crop.

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Table 1. Survival and development of *Helicoverpa armigera* on leaves and pods of nine chickpea genotypes (ICRISAT, Patancheru, 2003-05 post-rainy season)

Genotype	Larval weight on10th day (mg)	Larval period (days)	Pupal period (days)	Pupal weight (mg)	Larval survival on 10th day (%)	Pupation (%)	Adult emergence (%)
ICC 3137	361.8	16.4	10.6	324.5	88.0	84.0	84.0
ICC 12476	320.5	16.2	11.8	274.2	76.0	66.0	60.0
ICC 12477	340.8	16.4	11.8	302.6	74.0	70.0	60.0
ICC 12478	367.5	16.5	11.0	292.3	78.0	74.0	62.0
ICC 12479	359.8	16.5	11.1	317.8	78.0	72.0	60.0
ICCV 2	329.7	16.5	12.0	300.0	84.0	76.0	70.0
ICC 4918	396.3	15.5	10.9	323.9	86.0	84.0	84.0
Controls							
ICC 12475 (R)	298.1	17.8	11.7	286.2	66.0	64.0	62.0
ICC 12426 (S)	382.9	15.5	8.8	316.6	88.0	86.0	86.0
Mean	350.8	16.4	11.1	304.2	79.8	75.1	69.8
Fp	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
SE ±	0.01	0.10	0.10	0.01	0.91	0.03	0.04
LSD (P 0.05)	29.00	0.27	0.27	16.00	9.40	11.20	13.10

R = Resistant check. S = Susceptible check.

Table 2 : Survival and development of *Helicoverpa armigera* on artificial diet impregnated with lyophilised leaf powder of nine chickpea genotypes (ICRISAT, Patancheru, 2004-05 post-rainy season)

Genotype	Larval weight on 10th day (mg)	Larval period (days)	Pupal period (days)	Pupal weight (mg)	Larval survival on 10th day (%)	Pupation (%)	Adult emergence (%)
ICC 3137	383.8	16.2	9.3	329.0	87.0	83.3	80.0
ICC 12476	321.8	16.2	10.4	298.9	75.0	71.7	66.6
ICC 12477	366.9	16.2	10.0	300.2	75.0	66.6	66.6
ICC 12478	355.6	16.5	10.8	297.3	76.6	71.0	70.0
ICC 12479	375.8	16.7	11.6	342.5	75.0	73.3	71.7
ICCV 2	378.7	17.0	10.7	317.0	80.0	76.6	76.6
ICC 4918	417.5	16.3	10.5	355.7	89.0	86.6	86.6
Controls							
ICC 12475 (R)	307.2	17.4	11.4	311.2	70.0	63.3	63.3
ICC 12426 (S)	415.6	16.0	9.0	342.7	91.7	89.0	87.0
Artificial diet	445.8	14.9	8.9	365.8	98.0	97.0	95.0
Mean	376.9	16.3	10.3	326.0	81.7	77.8	76.3
Fp	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
SE ±	0.01	0.09	0.09	0.01	0.05	1.51	0.03
LSD (P 0.05)	24.55	0.31	0.26	14.00	12.00	9.10	6.80

R = Resistant check. S = Susceptible check.

Table 3. Survival and development of *Helicoverpa armigera* on artificial diet impregnated with lyophilised pod powder of nine chickpea genotypes (ICRISAT, Patancheru, 2003-05, post-rainy season)

Genotype	Larval weight on 10th day (mg)	Larval period (days)	Pupal period (days)	Pupal weight (mg)	Larval survival on 10th day (%)	Pupation (%)	Adult emergence (%)
ICC 3137	424.1	16.6	8.5	315.8	86.6	80.0	70.0
ICC 12476	285.4	15.6	10.5	249.5	76.6	70.0	60.0
ICC 12477	359.1	16.2	8.9	262.4	80.0	73.3	63.3
ICC 12478	334.9	16.5	10.7	245.7	76.6	70.0	60.0
ICC 12479	288.3	17.6	11.6	233.8	80.0	76.6	66.6
ICCV 2	420.2	17.6	9.5	274.7	83.3	80.0	66.6
ICC 4918	413.9	16.9	9.3	327.9	90.0	86.6	80.0
Controls							
ICC 12475 (R)	253.3	18.3	12.0	244.1	76.0	63.3	60.0
ICC 12426 (S)	443.8	15.4	9.2	351.4	93.3	86.6	83.3
Artificial diet	468.8	14.8	8.8	342.1	100.0	100.0	100.0
Mean	369.2	16.6	9.9	284.7	84.2	78.6	71.0
Fp	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
SE ±	2.22	0.15	0.15	2.24	3.14	2.65	0.98
LSD (P 0.05)	31.60	0.35	0.26	41.80	12.20	14.30	9.10

R = Resistant check. S = Susceptible check.

Table 4. Survival and development of *Helicoverpa armigera* on artificial diet impregnated with lyophilised leaf powder of chickpea hybrids (72 hybrids) based on nine parents (ICRISAT, Patancheru, 2004-05 post-rainy season)

Genotype	Larval weight on 10th day (mg)	Larval period (days)	Pupal period (days)	Pupal weight (mg)	Larval survival on 10th day (%)	Pupation (%)	Adult emergence (%)
F_1s based on ICC 12475	318.9	15.8	9.8	279.5	75.0	61.3	56.3
F_1s based on ICC 12476	394.3	15.5	9.7	317.9	76.3	71.3	63.8
F_1s based on ICC 12477	369.4	15.8	10.1	317.7	73.8	66.3	61.3
F_1s based on ICC 12478	353.8	15.9	10.1	294.1	76.3	71.3	65.0
F_1s based on ICC 12479	319.8	16.0	9.4	300.4	73.8	66.3	61.3
F_1s based on ICC 3137	319.9	16.0	10.1	287.1	76.3	71.3	61.3
F_1s based on ICC 4918	329.0	15.9	9.8	285.4	77.5	75.0	67.5
F_1s based on ICCC 37	333.5	15.9	9.9	305.6	80.0	76.3	72.5
F_1s based on ICCV 2	326.2	15.8	9.9	318.0	73.8	68.8	65.0
Controls							
ICC12475 (R)	356.6	16.8	11.9	338.6	70.0	63.3	63.3
ICC12426 (S)	434.6	15.5	9.0	345.6	93.3	90.0	88.0
Artificial diet	468.9	15.1	8.9	351.5	98.0	98.0	96.0
Fp	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SE ±	0.03	0.23	0.30	0.01	0.51	0.06	0.81
LSD (P 0.05)	42.00	0.65	0.82	39.00	13.00	16.00	11.10

R = Resistant check. S = Susceptible check.

Table 5. Sex ratio, fecundity, egg viability, longevity, and growth indices of *Helicoverpa armigera* on nine chickpea genotypes (ICRISAT, Patancheru, 2003-05 post rainy season)

Genotype	Sex ratio	No. of eggs laid female^{-1}	Egg viability (%)	Adult longevity (days)		Growth index	Adult index	Oviposition index	Pupal index
				Male	Female				
ICC 3137	1: 0.9	1066.5	78.5	10.0	12.0	5.13	0.83	0.83	1.02
ICC 12476	1: 0.8	839.5	72.5	9.5	11.5	4.06	0.79	0.65	0.87
ICC 12477	1: 0.9	882.9	76.0	10.5	11.5	4.26	0.88	0.68	0.96
ICC 12478	1: 0.9	907.1	80.0	9.5	12.0	4.47	0.79	0.70	0.92
ICC 12479	1 : 1.1	901.3	75.5	10.0	12.5	4.37	0.83	0.70	1.00
ICCV 2	1: 1.1	1170.1	82.5	11.0	13.0	4.60	0.92	0.91	0.95
ICC 4918	1: 1.2	1270.7	84.0	11.5	12.5	5.44	0.96	0.98	1.02
Controls									
ICC 12475 (R)	1: 1.1	785	69.0	9.0	10.5	3.61	0.75	0.46	0.90
ICC 12426 (S)	1: 1.1	1291.2	85.0	12.0	13.5	5.54	1.00	1.00	1.00
Mean	-	1012.7	-	-	-	-	-	-	-
Fp	-	<0.001	-	-	-	-	-	-	-
SE ±	-	12.84	-	-	-	-	-	-	-
LSD (P 0.05)	NS	20.80	NS	NS	NS	NS	NS	NS	NS

R = Resistant check. S = Susceptible check.

Table 6. Sex ratio, fecundity, egg viability, longevity and growth indices of *Helicoverpa armigera* on artificial diet impregnated with lyophilised leaf powder of nine chickpea genotypes (ICRISAT, Patancheru, 2003-05 post-rainy season).

Genotype	Sex ratio	No. of eggs laid $female^{-1}$	Egg viability (%)	Longevity (days)		Growth index	Adult index	Oviposition index	Pupal index
				Male	Female				
ICC 3137	1: 0.9	1025.0	80.5	10.5	12.0	4.96	0.95	0.89	0.96
ICC 12476	1: 1.3	730.7	76.5	9.5	12.1	4.49	0.86	0.64	0.85
ICC 12477	1: 0.9	839.8	78.5	10.5	11.5	4.11	0.95	0.73	0.80
ICC 12478	1: 0.9	899.7	80.0	10.0	12.0	4.24	0.91	0.78	0.87
ICC 12479	1: 1.1	854.5	77.5	10.0	12.5	4.47	0.91	0.74	0.98
ICCV 2	1: 1.1	975.7	82.5	11.0	13.0	4.70	1.00	0.85	0.97
ICC 4918	1: 1.2	1015.0	84.0	10.0	12.5	5.48	0.91	0.88	1.02
Controls									
ICC 12475 (R)	1: 1.3	675.0	65.0	9.0	10.5	3.77	0.82	0.59	0.98
ICC 12426 (S)	1: 1.1	1150.0	86.5	11.0	12.5	5.81	1.00	1.00	1.00
Artificial diet	1: 0.9	1220.0	91.5	11.5	12.0	6.50	1.05	1.06	1.02
Mean	-	938.5	-	-	-	-	-	-	-
Fp	-	<0.001	-	-	-	-	-	-	-
SE ±	-	11.08	-	-	-	-	-	-	-
LSD (P 0.05)	NS	18.91	NS	NS	NS	NS	NS	NS	NS

R = Resistant check. S = Susceptible check.

Table 7. Sex ratio, fecundity, egg viability, longevity and groth indices of H. armigera on artificial diet impregnated with lyophilised pod powder of nine chikpea genotypes (ICRISAT, Patancheru, 2003-05 post-rainy season).

Genotype	Sex ratio	No. of eggs laid $female^{-1}$	Egg viability (%)	Longevity (days)		Growth index	Adult index	Oviposition index	Pupal index
				Male	Female				
ICC 3137	1: 0.9	1092.9	82.5	9.5	11.5	4.82	0.92	0.88	0.90
ICC 12476	1: 1.3	672.5	75.6	10.5	12.0	4.49	0.96	0.54	0.71
ICC 12477	1: 1.1	860.5	78.5	11.0	11.2	4.52	0.90	0.69	0.75
ICC 12478	1: 0.9	901.6	81.8	9.5	12.0	4.24	0.96	0.73	0.70
ICC 12479	1: 1.1	842.0	76.3	10.0	12.5	4.35	1.00	0.68	0.67
ICCV 2	1: 1.1	1051.5	82.5	10.5	12.8	4.55	1.02	0.85	0.78
ICC 4918	1: 0.8	1198.1	84.0	11.5	12.5	5.12	1.00	0.97	0.93
Controls									
ICC 12475 (R)	1: 1.2	632.8	62.0	8.5	11.0	3.46	0.88	0.44	0.69
ICC 12426 (S)	1: 0.9	1241.2	88.5	11.5	12.5	5.62	1.04	1.00	1.00
Artificial diet	0.0	1290.2	90.5	11.5	12.0	6.76	0.96	1.04	0.97
Mean	-	978.3	-	-	-	-	-	-	
Fp	-	< 0.001	-	-	-	-	-	-	-
SE ±	-	6.31	-	-	-	-	-	-	-
LSD (P 0.05)	NS	12.4	NS	NS	NS	NS	NS	NS	NS

R = Resistant check. S = Susceptible check.

Table 8. Association between larval survival and development on fresh leaves/pod and on artificial diet impregnated with lyophilized leaf and pod power of nine chickpea genotypes (ICRISAT, Patancheru, 2003-05 post-rainy season).

Survival/development parameter	Artificial diet with leaf powder	Artificial diet with pod powder
Larval weight 10th day	0.88**	0.64*
Larval period (days)	0.82**	0.67*
Pupal period (days)	0.63*	0.31
Pupal weight (mg)	0.83**	0.63*
Larval survival 10th day (%)	0.92**	0.85**
Pupation (%)	0.95**	0.91**
Adult emergence (%)	0.93**	0.88**
Number of eggs laid $female^{-1}$	0.91**	0.96**
Viability of eggs (%)	0.93**	0.92**
Adult longevity (male)	0.76**	0.86**
Adult longevity (female)	0.89**	0.86**

*, ** = Correlation coefficients significant at P 0.05 and 0.01, respectively.