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Effect of induced meteorological changes due to staggered planting on pest incidence in chickpea

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ABSTRACT

Pest incidence in chickpea was studied across sowing dates to understand the effect of climatic factors on pest incidence on five genotypes of chickpea. The egg laying by the pod borer, *Helicoverpa armigera* decreased across sowing dates from October to December, with a slight increase in oviposition was observed in the January sown crops. ICC 3137 was most preferred for egg laying (9.5 eggs/5 plants), followed by KAK 2 (6.8 eggs/5 plants). The incidence of *H. armigera* decreased with a delay in time of sowing (60.0 larvae/ 5plants in the October sown crop to 21.9 larvae/5plants in the December sown crop). However, a slight increase was observed in the January sown crop (34.8 larvae/5plants). The highest incidence of *H. armigera* larvae was recorded on ICC 3137 (55.1 larvae/5plants), and the lowest on ICCV 10 (29.9 larvae/5plants).The numbers of H. armigera larvae were negatively correlated with open pan evaporation, temperature (both maximum and minimum), wind velocity and solar radiation in all the chickpea genotypes, except in ICCV 10. However, oviposition by beet armyworm, Spodoptera exigua was positively correlated with open pan evaporation, temperature (both maximum and minimum), and solar radiation in ICC 3137 and ICCV 10. The abundance ofS. exigua larvae was significantly and positively correlated with rainfall, open pan evaporation, temperature (both maximum and minimum), wind velocity and solar radiation, except in ICCV 10, which showed a non-significant negative correlation. The pod borer damage was significantly and positively correlated with rainfall, open pan evaporation, temperature (both maximum and minimum), wind velocity and solar radiation, suggesting the global warming will lead to an increase in pest incidence in chickpea. The numbers of *H. armigera* larval parasitoid, *Campoletis chlorideae* cocoons were significantly and negatively correlated with rainfall, open pan evaporation, temperature (both maximum and minimum), wind velocity and solar radiation, indicating that increase in temperature will decrease the efficacy of natural enemies. Grain yield decreased with an increase in rainfall, open pan evapouration, temperature (both maximum and minimum), wind velocity and solar radiation, but was positively correlated with relative humidity. The present studies suggested that global warming will decrease the incidence of *H. armigera*, but with result in an increase in the incidence of *S. exigua*. Increase in temperature will also decrease the extent of parasitization of *H. armigera*, which will result in a significant decrease in crop yields. Therefore, there is a need to develop strategies to mitigate the effects of climate change on crop production and food security.

Keywords: Chickpea, Climate change, *Helicoverpa armigera*, Pest incidence, *Spodoptera exigua*

Chickpea (*Cicer arietinum* L.) also known as Bengal gram or gram, is the second most important food legume in Asia, North Africa, and Mexico. Recently, it has also become an important grain legume crop in North USA, Canada, and Australia. It is grown on 13.5 million hectares worldwide, with an average production of 8.8 million tonnes. India is the largest producer of chickpea in the world sharing 71.0 and 67.2% of the total area (9.6 mha) and production (8.8mt), respectively(FAOSTAT, 2013).Several biotic and abiotic constraints limit the production and productivity of chickpea, of insect pests are a major constraint to increase the production and productivity of chickpea (Sharma 2005 and Yadav *et al*. 2006; Sharma et al. 2011). Losses due to insect pest damage are likely to increase as a result of changes in cropping patterns,and global warming.

The pod borer, *Helicoverpa armigera* (Hubner), is one of the most important constraints in chickpea production (Sharma, 2005). Its populationpeaks generally correspond to the fullbloom and pod formation stage of the crop in the post rainy season. Temperature, relative humidity (Yadava and Lal 1988, Yadava *et al*. 1991), rainfall (Tripathi and Sharma 1985), predators (Thakur *et al*. 1995, Gunathilagaraj 1996) andparasitoids (Bhatnagar 1980, Srinivas & Jayaraj 1989, Thakur *et al*. 1995) affect the incidence and population densities of *H. armigera* on chickpea. Information onpest incidence under field conditions across sowing dates can be used to assess the effect of different climatic variables on pest incidence and grain yield. Therefore, we studied the effect of climatic factors on pest incidence and grain yield on five genotypes of chickpea.

MATERIALS AND METHODS

Five chickpea genotypes (2 resistant ICCL 86111 and ICCV 10, 2 commercial cultivars JG 11 and KAK 2 and 1 susceptible genotype ICC 3137) were sown across four planting dates between October-January at monthly intervals during 2012-14 post rainy seasons under field conditions. The experiment was laid out in randomized complete block design with three replications for each genotype, in a plot of four rows 2 m long (with a spacing of 60 cm between the rows and 10 cm between plants with in a row). Data were recorded on numbers of insects/plant. at fortnightly intervals in each planting. Data were also recorded on leaf feeding (leaf damage rating on a 1 to 9 scale (1=<10% leaf area damaged, and 9=> 80% leaf area damaged) (Sharma *et al*. 2005). The incidence/abundance of different insect pests was correlated with the climatic factors (average temperature, open pan evaporation, rainfall, sunshine hours, solar radiation, wind velocity, and relative humidity during the observation period). The crop was raised under normal agronomic practices, and there was no insecticide application in the experimental plots. Weather data during the experimental period was obtained from the agro meteorology station at the ICRISAT farm. Data on rainfall, temperature, relative humidity, open pan evaporation, sunshine hours, solar radiation and wind velocity during the experimental period was correlated with lead damage, and egg and larval density (Incidence) during the experimental period.

RESULTS AND DISCUSSION

Oviposition by H. armigera females on different genotypes of chickpea: There were significant differences in the numbers of *H. armigera* eggs across different dates of sowing in both the seasons, as well as across the seasons. The egg laying by the *H. armigera* females decreased as the sowing dates advanced from October to December (19.9–5.2 eggs/5 plants in 2012/13; 9.2–3.7 eggs/5 plants in 2013/14 and 13.9–4.3 eggs/5 plants across the seasons), but a slight increase in oviposition was recorded in the January sown crop (5.9 eggs/5 plants in 2012 –13, 4.3 eggs/ 5 plants in 2013 – 2014, and 5.1 eggs/5 plants across the seasons). More number of eggs were recorded in 2012 –13 than in 2013 –14. Highest numbers of eggs were observed in the crop sown in October in both the seasons.

There were significant differences in oviposition on different genotypes across sowing dates, and the interaction effects were nonsignificant. Among the genotypes tested, ICC 3137 had the highest number of eggs across the seasons (11.3 eggs/5 plants, in 2012 - 13; 7.7 eggs/ 5 plants in 2013 - 14 and 9.5 eggs/5 plants across the seasons), while theoviposition was recorded on JG 11 (6.3 eggs/ 5 plants) in 2012-13, and on ICCV 10 and ICCL 86111 (3.5 eggs/5plants) in 2013-14. Across seasons, ICC 3137 was most preferred for egg laying (9.5 eggs/5plants), followed by KAK 2 (6.8 eggs/5plants). ICCV 10 and JG 11 (5.9 eggs/5 plants) were relatively non-preferred for egg laying. (Fig 1).

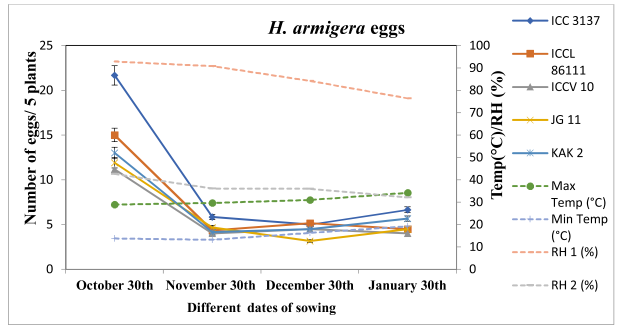

Fig 1. Oviposition by *H. armigerafemales* on different genotypes of chickpea in relation to temperature and RH under natural infestation in the field.

Variation in density of H. armigera larvae on different genotypes of chickpea across sowings:The incidence of *H. armigera* larvae was highest in the crop sown in October (80.7 larvae/5plants), and lowest in the December sown crop (20.1 larvae/5plants) in 2012 – 13. In the 2013 – 14 cropping season, the incidence of *H. armigera* was quite high in the crop sown in November (40.7 larvae/5plants), October (39.3 larvae/5plants) and January (38.3 larvae/ 5plants), but lowin the December sown crop (23.8 larvae/ 5plants). Across seasons, the incidence of *H. armigera* declined as the sowing date was advanced from October (60.0 larvae/5plants) to December (21.9 larvae/5plants), but increased in the January sown crop (34.8 larvae/5plants).

There were significant differences in numbers of *H. armigera* larvae across genotypes in both the seasons, but the interaction effects were nonsignificant. Highest number of *H. armigera* larvae were recorded on ICC 3137 (51.9 larvae/5plants), followed by KAK 2 (46.6 larvae/ 5plants) and ICCL 86111 (41.8 larvae/5plants). The lowest incidence of *H. armigera* larvae was recorded in ICCV 10 (28.2 larvae/5plants), followed by JG 11 (38.3 larvae/5plants). In 2013 – 14 post rainy seasons, the *H. armigera* larval density was significantly higher on ICC 3137 (58.3 larvae/ 5plants) and KAK 2 (37.9 larvae/5plants) than on ICCV 10 (31.7 larvae/5plants), JG 11 (30.1 larvae/5plants and ICCL 86111 (24.7 larvae/5plants). Across seasons, highest incidence was recorded on ICC 3137 (55.1 larvae/5plants), and the lowest on ICCV 10 (29.9 larvae/5plants). The larval

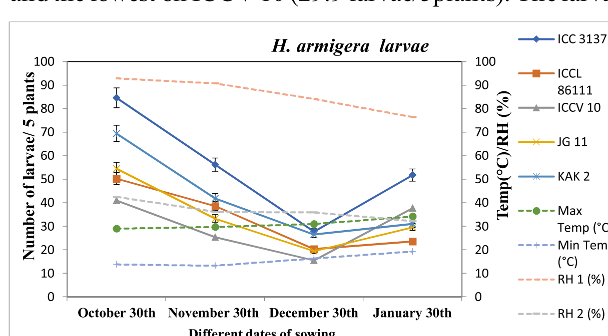

Fig 2. Abundance of *H.armigera* larvae on different genotypes of chickpea in relation to temperature and RH under natural infestation in the field.

density decreased from October to December, but a slight increase was observed in the crop sown in January. Across seasons, lowest larval density was recorded on ICCV 10 (15.5 larvae/5plants) in the December sown crop, and highest on ICC 3137 (84.6 larvae/5plants) in the October sown crop (Fig 2).

Oviposition by beet armyworm, S. exigua on different genotypes of chickpea*:*There were no significant differences in the numbers of *S. exigua* egg masses across the sowings in the 2012-13 cropping season. No egg masses were observed in the October sown crop in 2012-13. Highest egg laying was recorded in the January sown crop (0.4 egg masses/5 plants). The number of egg masses differed significantly across sowing dates in the 2013-14cropping season. In 2013-14, significantly highest numbersof egg masses were recorded in the December sown crop (1.3 egg masses/5 plants), but the differences in egg laying were nonsignificant in the crops sown in October, November and January. Similar trend was observed across seasons. The highest numbers of egg masses were recorded in the December sown crop (0.7 egg masses/5 plants), and greater egg laying was recorded in 2013-14 than in 2012-13 cropping season.

No egg laying was observed on ICCL 86111, while a fewer egg masses were recorded on ICCV 10 (0.3 egg masses/5plants) in the January sown crop, and in JG 11 in the November and January sown crops. The number of egg masses deposited on different genotypes differed significantly during the 2013-14 cropping season, and highest number of egg masses (1.7 egg masses/5plants) were recorded on KAK2, while no eggs were recorded in ICCV 10. Across seasons, highest number of *S. exigua* egg masses (1.0 egg masses/5 plants) were recorded on KAK 2, followed by ICC 3137 (0.4 egg masses/5 plants) and ICCL 86111 (0.4 egg masses/5 plants). The interaction effects were non–significant across the seasons. No egg masses were recorded in the October sown crop in both the seasons, except on KAK 2 in the 2013–14 cropping season (Fig 3).

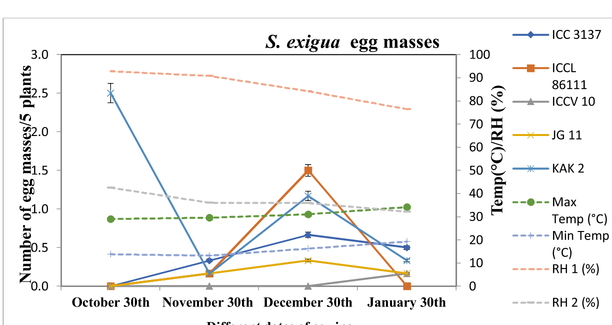

Fig 3. Oviposition by *S. exiguafemales* on different genotypes of chickpea in relation to temperature and RH under natural infestation in the field.

Population of beet armyworm, S. exigua larvae on different chickpea genotypes*:* In the 2012-13 cropping season, the numbers of *S. exigua* larvae were highest in the crop sown in January (16.1 larvae/5plants), followed by the December (11.6 larvae/5plants), November (10.1 larvae/ 5plants) and October (4.7 larvae/5plants) sown crops. During the 2013-14 cropping season, the numbers of *S. exigua* larvae were significantly higher in the crop sown inJanuary (15.5larvae/5plants), followed by the December sown crop (11.6 larvae/5plants). Significantly lower larval population was recorded in the November (1.3 larvae/ 5plants) and October (2.0 larvae/5plants) sown crops. Across the seasons, the *S. exigua* incidence was significantly greater in the January sown crop (15.8 larvae/ 5plants) than in the crops sown in October, November and December. The January sown crop was most affected by *S. exigua* larvae in both the cropping seasons, as the crop grew and matured during the warm months of February to May. The larval incidence was comparatively greater in the 2013-14 than in 2012-13 cropping season.

There were no significant differences in the numbers of *S. exigua* larvae on different genotypes in the 2012-13 cropping season. KAK 2 had the maximum numbers of *S. exigua* larvae (15.6 larvae/5plants), followed by ICCL 86111 (11.6 larvae/5plants), JG 11 (9.3 larvae/5plants) and ICC 3137 (8.8 larvae/5plants). Less *S. exigua* larval numbers were recorded on ICCV 10 (7.8 larvae/5plants). During the 2013-14 cropping season, there were no significant differences among the genotypes tested. However, the highest numbers of *S. exigua* larvae were observed on JG 11 (12.1 larvae/5plants), followed by ICC 3137 and ICCL 86111 (5.1 larvae/5plants). Across seasons, the highest numbers of *S. exigua* larvae were recorded on KAK 2 (12.9larvae/5plants) and lowest on ICC 3137 (7.0 larvae/5plants).The interaction effects between the genotypes and sowing dates were not significant. The lowest (2.5 larvae/5plants) incidence was recorded in ICCV 10 in the November sown crop, and highest in KAK 2 in the January sown crop (27.2 larvae/ 5plants). Highest numbers of egg masses were also recorded on KAK 2-Kabuli type genotype, suggesting that it is highly susceptible to *S. exigua.* KAK 2 was found to be highly susceptible to *S. exigua,* while ICC 3137 was highly susceptible to *H. armigera*. ICCV 10 was relatively resistant to both *H. armigera* and *S. exigua.* The *S. exigua* incidence

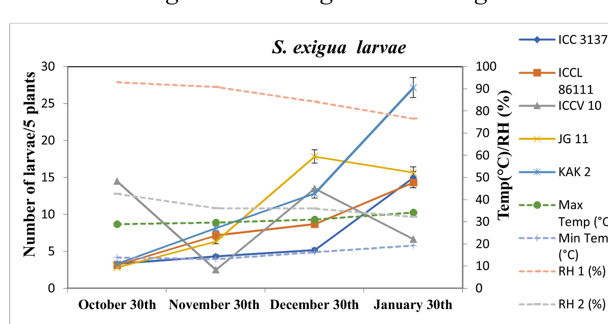

Fig 4. Abundance of *S. exigua* larvae on different genotypes of chickpea in relation to temperature and RH under natural infestation in the field.

was observed mostly in the early stages of the crop, irrespective of the planting dates (Fig. 4).

***Variation in parasitization of H. armigera by the larval parasitoid Campoletis chlorideae*:** During the 2012-13 cropping season, greater numbers of cocoons of *C. chlorideae* were observed in the December sown crop (3.4 cocoons/5plants), followed by the October sown crop (2.4 cocoons/5plants). Lowest parasitization (0.1 cocoons/ 5plants) were recorded in the January sown crop. In the 2013 – 14cropping season, maximum parasatization (5.7 cocoons/5plants) was recorded in the October sown crop, and the lowest (0.4 cocoons/5plants) in the January sown crop. Across seasons, highest (4.0 cocoons/5plants) activity of the parasitoid was recorded in the October sown crop, andthe lowest (0.2 cocoons/5plants) in the January sown crop, suggesting that the parasitoid is mostly active during the cooler part of the winter season. There were no significant differences in the numbers of *C. chlorideae* cocoons on different genotypes in both the seasons. However, highest numbers of cocoons were recorded on ICC 3137 (2.6 cocoons/5plants), and the lowest on KAK 2 and JG 11 (2.0 cocoons/5plants). The interaction effects were not significant (Fig. 5).

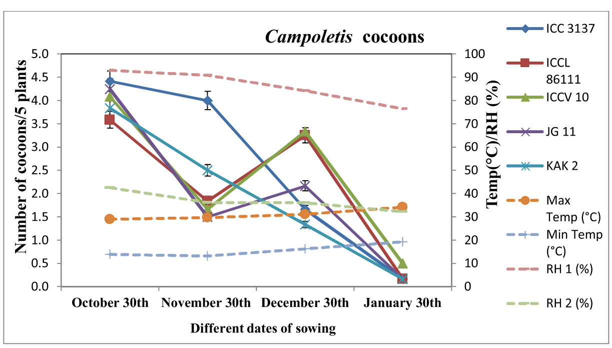

Fig 5. Numbers of *C. chloridaeacocoons* on different genotypes of chickpea in relation to temperature and RH under natural conditions in the field.

Influence of climatic conditions on pest incidence in chickpea Pod borer, *H. Armigera*: Leaf and pod damage by*H. armigera* was significantly and positively correlated with rainfall, open pan evaporation, temperature (both maximum and minimum), wind velocity and solar radiation, except in ICC 3137. In ICC 3137, leaf damage was significantly and positively correlated with rainfall, but negatively correlated with the sunshine hours. There was a significant and negative association between leaf damage and relative humidity (morning and evening), except in ICC 3137. Sunshine hours were positively correlated with leaf damage in ICCL 86111 (Table 6).

The numbers of *H. armigera* eggs exhibited a significant and negative correlation with most of the climatic factors viz., evaporation, temperature (both maximum and minimum), wind velocity, solar radiation and sunshine hours in all the chickpea genotypes. Relative humidity (both morning and evening) showed a significant and positive correlation, while rainfall had a non-significant but negative association with oviposition by *H. armigera* (Table 1).The numbers of *H. armigera* larvae were negatively correlated with open pan evaporation, temperature (both maximum and minimum), wind velocity and solar radiation in all the chickpea genotypes, except in ICCV 10, which is relatively resistant to *H. armigera*. Larval density on all the genotypes, except on ICCV 10 showed a significant and positive correlation with relative humidity, but a non - significant association with rainfall and sunshine hours (Table 2).

Beet armyworm, *S. Exigua*: Oviposition by *S. exigua* and rainfall were positively correlated in ICCV 10; while a significant and positive correlation was observed with open pan evaporation, temperature (both maximum and minimum), and solar radiation in ICC 3137 and ICCV 10. Maximum temperature and oviposition were also negatively associated on KAK 2, which is highly susceptible to *S.*

Table 1. Association between climatic factors and oviposition by *H. armigera* females on different genotypes of chickpea

Genotype	Rain (mm)	Open pan evaporation (mm)	Temperature (°C)		Relative Humidity (%)		Wind velocity	Solar radiation (mj/m^2)	Sunshine hours
			Maximum	Minimum	Morning	Evening			
ICC 3137	-0.19	-0.59**	-0.52**	-0.39*	0.57**	0.87**	-0.73**	-0.50**	-0.52**
ICCL 86111	-0.26	-0.62**	-0.57**	-0.42*	0.60**	0.91**	-0.71**	-0.55**	-0.61**
ICCV 10	-0.28	-0.63**	-0.58**	-0.43*	0.61**	0.92**	-0.72**	-0.56**	-0.60**
JG 11	-0.21	-0.62**	-0.55**	-0.44*	0.61**	0.87**	-0.78**	-0.53**	-0.42*
KAK 2	-0.10	-0.50**	-0.44**	-0.30	0.49**	0.83**	-0.65*	-0.41*	-0.57**

*, ** Significant at P $\leq$ 0.05 and 0.01, respectively.

Table 2. Association between climatic factors and abundance of *H. armigera* larvae on different genotypes of chickpea

Genotype	Rain (mm)	Open pan evaporation (mm)	Temperature (°C)		Relative Humidity (%)		Wind velocity	Solar radiation (mj/m^2)	Sunshine hours
			Maximum	Minimum	Morning	Evening			
ICC 3137	-0.11	-0.56**	-0.45*	-0.44*	0.56**	0.69*	-0.80**	-0.44*	-0.05
ICCL 86111	-0.50	-0.84**	-0.76**	-0.76**	0.84**	0.84**	-0.97**	-0.76**	-0.01
ICCV 10	0.44	-0.02	0.11	0.11	0.02	0.28	-0.35	0.11	-0.05
JG 11	-0.20	-0.63**	-0.54**	-0.49**	0.63**	0.79**	-0.84**	-0.52**	-0.19
KAK 2	-0.37	-0.76**	-0.68*	-0.62**	0.75**	0.89**	-0.90**	-0.67**	-0.26

*, ** Significant at P $\leq$ 0.05 and 0.01, respectively.

Table 3. Association between climatic factors and oviposition by *S. exigua* females on different genotypes of chickpea

Genotype	Rain (mm)	Open pan evaporation (mm)	Temperature (°C)		Relative Humidity (%)		Wind velocity	Solar radiation (mj/m²)	Sunshine hours
			Maximum	Minimum	Morning	Evening			
ICC 3137	0.31	0.71**	0.62**	0.60**	-0.71**	-0.81**	0.90**	0.61**	0.09
ICCL 86111	-0.28	0.12	-0.02	0.09	-0.13	-0.13	0.45*	-0.01	-0.42*
ICCV 10	0.98**	0.87**	0.93**	0.88**	-0.87**	-0.70**	0.64**	0.93**	0.21
JG 11	0.02	0.48**	0.36*	0.36*	-0.47**	-0.62**	0.74**	0.35	0.02
KAK 2	-0.30	-0.54**	-0.54**	-0.33	0.52**	0.88**	-0.53**	-0.51**	-0.83**

*, ** Significant at P ≤ 0.05 and 0.01, respectively.

Table 4. Association between climatic factors and density of *S. exigua* larvae on different genotypes of chickpea

Genotype	Rain (mm)	Open pan evaporation (mm)	Temperature (°C)		Relative Humidity (%)		Wind velocity	Solar radiation (mj/m²)	Sunshine hours
			Maximum	Minimum	Morning	Evening			
ICC 3137	0.97**	0.93**	0.97**	0.91**	-0.92**	-0.78**	0.74**	0.97**	0.22
ICCL 86111	0.84**	0.97**	0.97**	0.89**	-0.96**	-0.95**	0.89**	0.96**	0.32
ICCV 10	-0.12	-0.19	-0.24	0.01	0.16	0.58**	-0.08	-0.20	-0.99**
JG 11	0.52**	0.84**	0.76**	0.79**	-0.84**	-0.77**	0.98**	0.76**	-0.13
KAK 2	0.92**	0.99**	1.00	0.95**	-0.98**	-0.89**	0.87**	0.99**	0.21

*, ** Significant at P ≤ 0.05 and 0.01, respectively.

Table 5. Association between climatic factors and abundance of *C. chlorideae* cocoons on different genotypes of chickpea

Genotype	Rain (mm)	Open pan evaporation (mm)	Temperature (°C)		Relative Humidity (%)		Wind velocity	Solar radiation (mj/m²)	Sunshine hours
			Maximum	Minimum	Morning	Evening			
ICC 3137	-0.84**	-0.99**	-0.96**	-0.97**	0.99**	0.83**	-0.97**	-0.96**	0.04
ICCL 86111	-0.77**	-0.74**	-0.81**	-0.64**	0.73**	0.83**	-0.54**	-0.79**	-0.65**
ICCV 10	-0.66**	-0.70**	-0.75**	-0.56**	0.68**	0.87**	-0.53**	-0.73**	-0.75**
JG 11	-0.63**	-0.81**	-0.82**	-0.66**	0.80**	0.98**	-0.75**	-0.80**	-0.63**
KAK 2	-0.76**	-0.97**	-0.94**	-0.89**	0.97**	0.95**	-0.97**	-0.93**	-0.20

*, ** Significant at P ≤ 0.05 and 0.01, respectively.

Table 6. Association between climatic factors and *H. armigera* damage on different genotypes of chickpea

Genotype	Rain (mm)	Open pan evaporation (mm)	Temperature (°C)		Relative Humidity (%)		Wind velocity	Solar radiation (mj/m²)	Sunshine hours
			Maximum	Minimum	Morning	Evening			
ICC 3137	0.50**	0.15	0.20	0.37	-0.17	0.34	-0.04	0.23	-0.67**
ICCL 86111	0.76**	0.91**	0.92**	0.80**	-0.91**	-0.98**	0.84**	0.90**	0.47**
ICCV 10	0.91**	0.99**	1.00**	0.95**	-0.99**	-0.89**	0.89**	0.99**	0.19
JG 11	0.90**	1.00**	1.00**	0.97**	-1.00**	-0.88**	0.91**	1.00**	0.13
KAK 2	0.92**	1.00**	1.00**	0.98**	-1.00**	-0.85**	0.91**	1.00**	0.08

*, ** Significant at ≤ 0.05 and 0.01, respectively.

exigua. Numbers of *S. exigua* egg masses and relative humidity (both morning and evening) were significantly and negatively correlated, except in ICCL 86111. Wind velocity was positively correlated with oviposition by *S. exigua*,except in KAK 2, where a significant and negative correlation was observed (Table 3).The abundance of *S. exigua* larvae was significantly and positively correlated with rainfall, open pan evaporation, temperature (both maximum and minimum), wind velocity and solar radiation, except in ICCV 10, which showed a non-significant negative correlation. The abundance of *S. exigua* larvae on ICC 3137, ICCL 86111, JG 11 and KAK 2 was significantly and negatively correlated with relative humidity (morning and evening), but positively correlated with the minimum relative humidity in ICCV 10 (Table 4).

***Effect of climatic factors on activity and abundance of the larval parasitoid, C. Chlorideae*:** The numbers of *C. chlorideae* cocoonswere significantly negatively correlatedwith rainfall, open pan evaporation, temperature (both maximum and minimum), wind velocity and solar radiation, but positively correlated with morning and evening relative humidity across genotypes. However, asignificant and negative association was observed with sunshine hours in ICCL 86111, ICCV 10 and JG 11 (Table 5).

Effect of climatic factors on grain yield across sowing dates: Grain yield was significantly and negatively correlated with rainfall, open pan evaporation, temperature (both maximum and minimum), wind velocity and solar radiation, but positively correlated with morning and evening relative humidity (Table 7).

Table 7. Association between climatic factors and yield on different genotypes of chickpea

Genotype	Rain (mm)	Open pan evaporation (mm)	Temperature (°C)		Relative Humidity (%)		Wind velocity	Solar radiation (mj/m^2)	Sunshine hours
			Maximum	Minimum	Morning	Evening			
ICC 3137	-0.63**	-0.90**	-0.86**	-0.77**	0.89**	0.99**	-0.92**	-0.85**	-0.38
ICCL 86111	-0.66**	-0.92**	-0.88**	-0.80**	0.91**	0.98**	-0.94**	-0.87**	-0.33
ICCV 10	-0.66**	-0.93**	-0.88**	-0.84**	0.93**	0.95**	-0.98**	-0.88**	-0.20
JG 11	-0.67**	-0.94**	-0.89**	-0.84**	0.93**	0.95**	-0.97**	-0.89**	-0.22
KAK 2	-0.75**	-0.97**	-0.93**	-0.89**	0.96**	0.95**	-0.97**	-0.93**	-0.20

*, ** Significant at P≤ 0.05 and 0.01, respectively.

In the early sown crop, which developed and matured during the cooler part of the postrainy season, there were significant differences in genotypic susceptibility to pod borer damage, but the differences between the genotypes were less apparent in *H. armigera* larvae in the late sown crops. Though the numbers of *H. armigera* larvae decreased with the planting dates, the extent of damage by *H. armigera* increased across the planting dates in both cropping seasons, which could be ascribed to warmer conditions during crop development and maturity. Parasitization of *H. armigera* larvae by *C. chlorideae* also decreased with the planting dates, resulting in in a decreased in biological control of *H. armigera* larvae, and increased crop damage. Damage by *H. armigera*increased with an increase in temperature as a result of reduction in the dry matter and grain yield.

Shankar *et al.* (2014) reported that numbers of *S. exigua* and *H. armigera* larvaewere maximum on ICC 3137 at the vegetative, flowering and podding stages in both the seasons, while ICCL 86111 harboured the lowest numbers of *H. armigera* and *S. exigua* larvae. More *H. armigera*moths were trapped during March to April (Mahapatra *et al.*2007), and November sown crops suffered less pod damage than that sown in December(Prasad *et al.* (1989; Begum *et al.* 1992). Delayed sowing of chickpea is risky under rainfed conditions due to inadequate stored soil moisture, and increased risk of damage by *H. armigera.*(Prasad and Singh 1997). Oviposition by *H. armigera* was low in the crop sown between December to Mid- February due to cold conditionsin Pakistan (Shah and Shahzad, 2005), whereas Ali *et al*. (2009) observed that the numbers of eggs laid by *H. armigera* differed significantly across sowings on different genotypes of cotton, but there were no significant differences in larval density and damage across genotypes and sowing dates.

The *H. armigera* larval population was high in early sown crops (October 15th to November 1st) than in and delayed sowings (November 1st to 30th) (Anwar *et al.*,1994). The genotypic response to damage by *H. amigera* vary across seasons and locations (Sharma *et al*. 2003). The genotypes (ICC 506EB, ICC 12476, ICC 12477, ICC 12478 and ICC 12479) that are not preferred for oviposition also suffer low leaf damage by *H. armigera*(Narayanamma *et al.* 2007).The abundance of *H. armigera* decreased with an increase in temperature, but plant damage increased with a rise in temperature.Thismay be due to better plant growth in early sowings than in the late sown crops due to inadequate soil moisture and dry weather conditions, whichretarded the plant growth, with less pod setting, and consequently resulting in poor grain yield. The vegetative growth and the dry matter production decreased with an increase in temperature due to water stress.The numbers of *C. chlorideae* cocoons decreased with an increase in temperature. Higher temperatures resulted in reduced efficacy of control agents of*H. armigera,* which may also have contributed to increase in plant damage. Patnaik and Senapati (1996) observed a negative correlation between mean temperature range and larval incidence of *H. armigera*. A positive association was observed between *H. armigera* and *S. exigua* larvae, and similar results were earlier reported by Sharma (2012b). Positive correlation has earlier been observed between *H. armigera* larval incidence and the maximum and the minimum temperatures (Sharma *et al.* 2005. Shah and Shahzad, 2005. Upadhyay *et al.*1989; Pandey 2012). Ugale *et al*. (2011) reported that moth emergence was negatively correlatedwith the maximum (r =-0.62) and minimum temperature (r =-0.75), but there was no association with relative humidity.Minimum temperature and rainfall exerted a negative influence on pheromone trap catches of *H. armigera* (Prasad *et al.* (1989)The population of *H. armigera* and *S. exigua* larvae was negatively correlated with relative humidity across genotypes. However, a significant and negative correlation has earlier been reported between *H. armigera* larval density and maximum relative humidity (Sharma *et al*. 2005, Upadhyay *et al*. 1989, Pandey 2012 and Shah and Shahzad, 2005). Densities of eggs and of different larval instars of *H. armigera* were significantly and negatively correlated with the maximum relative humidity, but not with the minimum relative humidity.Extremes of temperature, humidity and other weather factors (e.g., wind and hailstorm) might result in mortality of eggs, larvae and pupae of most of insect species (Pearson, 1958 and Qayyum and Zalucki, 1987). Pest outbreaks are more likely to occur with stressed plants as a result of weakening of plants' defensive system, and thus, increasing the level of susceptibility to insect pests. Global warming will lead to earlier infestation by *H. armigera* in North India (Sharma, 2010a), resulting in increased crop loss. Climate change may also alter the interactions between the insect pests and their host plants (Sharma, 2014)). Relationships between insect pests and their natural enemies will change as a result of global warming, resulting in both increases and decreases in the status of individual pest species. Changes in temperature will also alter the timing of diurnal activity patterns of different groups of insects and changes in inter specific interactions could also alter the effectiveness of natural enemies for pest management (Hill and Dymock, 1989).

Global warming and climate change will influence survival, development and population dynamics of *H. armigera*, and this will have a major bearing on extent of crop losses, and timing of diferent components of pest management to minimize the losses due to this pest. Future studies should focus on simultaneously testing the effects of multiple environmental factors on insect-plant interactions, to gain a realistic perspective ofhow global climatic changes may impact the production of secondary chemicals and its potential implications for co evolutionary associations between the interacting plant and insect species.

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