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Assessing the impact of varietal resistance and planting dates on pest spectrum in chickpea

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Abstract: The cotton bollworm *Helicoverpa armigera* [Hübner (1808)] is one of the most widely spread pest which limits the chickpea production, while the beet armyworm, *Spodoptera exigua* (Hübner, 1808) has emerged as a serious pest in recent years, in southern India and parasitic wasp *Campoletis chlorideae* Uchida, 1968 is an important larval parasitoid which naturally manages both pests under field condition. Insecticides adoption leads to development of resistance in pod borer. In view of climate change scenario, the focus of the present studies was the identification of climate resilient cultivars of chickpea for pod borers and the results reveled, that there were significant variations in the level of eggs and larval population among the genotypes. Across seasons, the crop sown in October recorded the maximum number of eggs. 'ICC 3137' had the highest number of *H. armigera* eggs (11.6) across seasons. 'JG 11', (6.3) in 2012 and' ICCV 10' (3.6) in 2013 recorded the lowest number of *H. armigera* eggs. During 2014-15, the maximum(80.7) *H. armigera* larval incidence was observed in October sown crop and the lowest (21.1) in January crop. The number of *S. exigua* larvae were substantially higher in the December crop. For all seasons, the highest number of *C. chlorideae* were found in October crop. Across seasons, multiple regression analysis for both pest had a strong interaction with weather patterns.

Key words: chickpea; pod borer; *Helicoverpa armigera*; *Spodoptera exigua*; *Campoletis chlorideae*

Ocenjevanje vpliva odpornosti sorte in datumov setve na pojav škodljivcev na čičeriki

Izvleček: Južna plodovrtka (Helicoverpa armigera [Hübner (1808)]) je škodljivec, ki že dolgo najbolj omejuje pridelek čičerike, medtem, ko sovka Spodoptera exigua (Hübner [1808]) postaja pomemben škpodljivec v južni Indiji v zadnjih letih. Parazitska osica Campole-tis chlorideae Uchida 1968 je pomemben parazitoid gosenic obeh vrst za uravnavanje njunih populacij v poljskih razmerah, pred--vsem zato, ker uporaba insekticidov vodi k odpornosti škodljivcev. Glede na scenarij bodočih podnebnih sprememb je prepozna-vanje odpornih sort čičerike na škodljivca zelo pomembno in je predmet te raziskave. Ugotovljene so bile značilne razlike v številu jajčec in gosenic med genotipi. Glede na rastno dobo je imel posevek, sejan oktobra, največ jajčec, z največjim številom (11,6) na genotipu ICC 3137. Genotip JG 11 (6,3) v letu 2012 in ICCV 10 (3,6) v letu 2013 sta imela najmanjše število jajčec južne plodovrtke. V obdobju 2014-15 je bilo največ gosenic (80,7) pri oktobrski setvi in najmanjše (21,1) pri setvi januarja. Gosenic vrste S. exigua je bilo znatno več pri setvi v decembru. V vseh obdobjih opazovanja je bilo največje število parazitoidov C. chlori--deae pri setvi v oktobru. V vseh preučevanih obdobjih je analiza multiple regresije za oba škodljivca pokazala močan vpliv vre-mena.

Ključne besede: čičerka; plodovrtka; *Helicoverpa armigera; Spodoptera exigua; Campoletis chlorideae*

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1 INTRODUCTION

The increasing human population and food demands are placing unprecedented pressure on agriculture and natural resources. Safeguarding crop productivity by protecting crops from damage by insect pests, pathogens and weeds is a major pre-requisite to ensure food and nutritional security and conserve the natural resources (Bohinc et al.,. 2019). Chickpea (*Cicer arietinum* L.) is one of the most important grain legume crops in Asia and parts of East and North America, Mediterranean Europe, Australia, Canada and USA (Kelly et al., 2000). Chickpea is the most predominant crop in India, accounting for 40 % share of the total pulse production, followed by pigeon pea *Cajanus cajan* (L.) Millsp. (18-20 %), mungbean, *Vigna radiata* (L.) Wilczek (11 %), urdbean, *Vigna mungo* (L.) Hepper (10-12 %), lentils, *Lens culinaris* Medik. (8-9 %) and other legumes (20 %) (Anonymous, 2011, Jaba et al., 2021). Currently chickpea is grown around the globe on over 17.81 million hectares with a production of 17.19 million tonnes of which Asia accounts for 77 % of the total world production (FAOSTAT, 2018). In India, the area under chickpea production during 2017-18 was about 10.6 million ha with a production of 11.1 million tonnes (Anonymous, 2018). There is a steady decline in the area, production, and productivity of chickpea (Babu et al., 2018). More than 200 species of insects live and feed on chickpea. Most of the pests have a sporadic or restricted distribution or are seldom present at high densities to cause economic losses. On the other hand, some of them can be devastating to these crops. The cotton bollworm (*Helicoverpa armigera* [Hübner, 1808] is one of the most dominant insect pests in agriculture, accounting for half of the total insecticides usage in India for protection of crops. The beet armyworm (*Spodoptera exigua* (Hübner, 1808)) is an emerging serious pest of chickpea, especially in southern India. The young larvae of *S. exigua* initially feed gregariously on chickpea foliage. As the larvae mature, they become solitary and continue to eat, producing large, irregular holes on the foliage (Ahmed et al., 1990; Sharma et al., 2007). Being leaf feeder, the beet armyworm consumes much more chickpea tissues than the cotton bollworm, *H. armigera*, but it has not been reported as being serious pest on pods. In view of their economic importance in agriculture, strategies for integrated management of these pests have been suggested (Lal et al., 1986; Pimbert, 1990; Wightman et al., 1995). However, development of an effective management programme depends much on the reliable estimate of field population densities which can be achieved through developing suitable sampling plans based on the distribution pattern of the pest within a field (Southwood, 1978; Taylor, 1984). The pod borer could be managed to some extent naturally under field conditions by larval parasitoid *Campoletis chlorideae* Uchida, 1957 (Hymenoptera: Ichneumonidae) in chickpea ecosystem. It causes up to 78 % parasitisation of early instars under natural conditions (Agnihotri et al., 2011). However, activity of the parasitoid occurs only during November to March, coinciding with the vegetative stage of the crop and winter season.

The indiscriminate use of chemical insecticides to control these insect pests leads to resistance in insect, secondary pest outbreaks, threat to their natural enemies and residual effect on environment. To overcome above threats some workers have advocated adopting the agronomical practices like altering the date of sowing, which might be a possible resort to protect chickpea crop from this pest (Summerfield, 1990; Singh et al., 2002). Several researchers have studied the effect of different dates of sowing and the seasonal abundance of cotton bollworm with the corresponding yield of chickpea in different parts of India. It is learnt from the past studies that the sowing date has a 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 harbored less pest population corresponding to high yield than the late sown crops (Chaudhary and Sachan, 1995; Ambulkar et al., 2011; Prasad et al., 2012). Limited work was carried out on this subject and the information available at present is very scanty. Therefore, the present study was carried out to evaluate the effect of different dates of sowing and weather parameters on the incidence of *H. armigera, S. exigua* and *C. chlorideae* populations in chickpea under field conditions.

2 MATERIALS AND METHODS

The experiments were conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana, India (latitude 17°27'N, longitude 78°28'E, and altitude 545 m above mean sea level), during the post-rainy seasons of 2012-15 (October to January). The test entries were planted in deep black soils (Vertisols) during the post rainy/ *Rabi* season at monthly intervals.

We monitored the incidence of legume pod borer/ cotton bollworm, *H. armigera,* beet armyworm, *S. exigua* and parasitic wasp, *C. chlorideae* on five chickpea genotypes (ICCL 86111 and ICCV 10 – resistant, and JG 11 and KAK 2 – commercial checks, and ICC 3137 – susceptible check) sown at monthly intervals between October to January during *Rabi* season for three years. These genotypes were categorized as resistant and sus-

Helicoverpa armigera eggs

Helicoverpa armigera larva

Spodoptera exigua eggs

Spodoptera exigua larvae

Cocoon of larval parasitoid, *Campoletis chlorideae*

Plate 1: Insect pests complex in chickpea ecosystem @Source: ICRISAT

ceptible based on the number of *H. armigera* larvae, eggs, leaf damage rating and the number of *C. chlorideae* cocoons (Shankar et al., 2014). In each sowing window, 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. 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 after 15 days of seedling emergence. Basal fertilizer (N : P : K : = 100 : 60 : 40) was applied in rows before sowing. Top dressing with urea (80 kg ha^{-1}) was done at one month after crop emergence. Intercultural/weeding operations were carried out as and when needed. There was no insecticide application in the experimental plot.

The observations were recorded at 15 days after germination (DAG) for each sowing, on number of eggs/ egg masses of *H. armigera* and *S. exigua* respectively, larvae of both pests and larval parasitoid *C. chlorideae* cocoons on five randomly selected plants at fortnightly intervals (Plate 1). Weather data during the experimental period was obtained from the agro meteorology station at ICRISAT farm. The correlation analysis of the weather parameters viz., maximum, and minimum temperature, morning and evening relative humidity and rainfall with the eggs and larval population of *H. armigera*, *S. exigua* and *C. chlorideae* cocoons across sowings was carried out using GenStat 14th edition. The data on insect population (eggs and larvae) was analyzed using square root transformation (√ x+0.5) in RBD as described by Panse & Shukhatme (1985), while yield data were recorded from the all plots after harvest and converted to grain yield (kg ha^{-1}).

3 RESULTS

3.1 OVIPOSITION PREFERENCE OF *H. ARMIGERA* FEMALES ON DIFFERENT GENOTYPES OF CHICKPEA ACROSS SOWINGS

There were huge contrasts in the numbers of *H. armigera* eggs across various dates of planting as over the seasons as appeared in Table 1. The egg laying diminished with planting dates till December (26.3–2.7 in 2012-13; 17.0–1.0 in 2013-14; 36.33–2.33 in 2014-2015 and 26.5–3.8 across three seasons), with a slight increase in January (8.0 in 2012 13; 7.3 in 2013-2014; 6.3 in 2014-2015 and 6.2 across three seasons). Higher numbers of eggs were recorded in 2012-13 contrasted with 2013-14 and 2014-15. Most noteworthy numbers of eggs were seen in the crop sown in October, across seasons.

There were no significant differences in number of *H. armigera* eggs during 2012-13 in all the chickpea genotypes, yet critical significant differences were observed in 2013-14 and 2014-15. Among the genotypes tested, 'ICC 3137' had the maximum number of eggs (11.63) across all seasons followed by '8.03' in 'KAK 2'. The lowest number of eggs were recorded on 'JG 11 (6.3)' in 2012-13, 'ICCV 10 (3.6)' in 2013-14 and 5.66 on 'ICCV 10' and 'ICCL 86111' during 2014-15. Across seasons, 'ICC 3137' was generally favored for egg laying (11.64) followed by 'KAK 2 (8.03)', 'ICCV 10' and 'JG 11 (5.8 and 6.0)' were relatively non-preferred for egg laying.

3.2 POPULATION OF *H. ARMIGERA LARVAE* ON DIFFERENT GENOTYPES OF CHICKPEA ACROSS SOWINGS

Significant differences were observed in *H. armigera* larval incidence across sowing dates across seasons (Table 2). It was highest in October sown crop (80.7) while lowest in the December sown crop (20.1) during 2012-13. During 2013-14, the incidence of *H. armigera* was higher in the crop sown during November (40.7) and it was maximum in October sown crop (56.86). But lower incidence of *H. armigera* larvae was recorded in January sown crop (21.1) during 2014-15. Across seasons, the occurrence of *H. armigera* declined from October (58.9) to December (22.4) and increased (38.0) in the January sown crop.

There were significant differences in the incidence of *H. armigera* larvae in all genotypes across all seasons. The highest number of *H. armigera* larvae were recorded on 'ICC 3137' (55.2) which was on par with 'KAK 2' (39.9). The lowest number of *H. armigera* larvae were recorded on 'ICCV 10' (28.2) followed by 'ICCL 86111' (29.5).

3.3 EGG LAYING BY *S. EXIGUA* ON DIFFERENT GENOTYPES OF CHICKPEA ACROSS SOWING DATES

There were no significant differences in the number of *S. exigua* egg masses across sowings in 2012-13 cropping season (Table 3). No egg masses were seen in the October sown crop across all the seasons except in 'KAK 2' during 2013-14 (5.0). The highest egg laying was recorded in December sown crop during 2013-14 (3.00) and 2014-15 (1.33) on 'ICCL 86111'. The number of egg

Table 1: Evaluation of different chickpea genotypes for resistance to *H. armigera* egg laying at different sowing dates

	Helicoverpa armigera eggs (2012-2013)					*Helicoverpa armigera* eggs (2013-2014)					*Helicoverpa armigera* eggs (2014-15)					*Helicoverpa armigera* eggs (Pooled)				
Genotype	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean
ICC 3137	26.3	7.0	5.7	6.0	11.3	17.0	4.7	4.3	7.3	8.3	36.33	15.0	4.66	5.3	15.33	26.57	8.9	4.88	6.2	11.63
	(10.0)	(5.6)	(5.3)	(5.9)	(6.7)	(8.1)	(5.1)	(5.3)	(5.8)	(6.1)	(5.97)	(3.63)	(2.27)	(2.41)	(3.97)	(7.93)	(4.77)	(4.2)	(4.70)	(5.42)
ICCL 86111	22.7	6.0	3.3	8.0	10.0	7.3	2.7	7.0	1.0	4.5	8.97	8.0	2.33	3.33	5.66	12.9	5.56	4.21	4.1	6.71
	(8.4)	(5.5)	(4.8)	(6.2)	(6.2)	(5.4)	(4.6)	(5.3)	(3.9)	(4.8)	(2.47)	(2.25)	(1.68)	(1.95)	(2.48)	(5.42)	(4.11)	(3.9)	(4.01)	(4.3)
ICCV 10	16.0	4.7	8.0	4.3	8.3	6.3	3.3	1.0	3.7	3.6	9.0	4.0	3.33	6.3	5.66	10.43	4.0	4.11	4.76	5.8
	(7.8)	(5.0)	(5.7)	(5.0)	(5.9)	(5.7)	(4.9)	(3.8)	(4.8)	(4.8)	(2.77)	(1.54)	(1.95)	(2.61)	(2.48)	(5.42)	(3.81)	(3.8)	(3.617)	(4.16)
JG 11	14.0	3.7	2.7	5.0	6.3	9.8	5.7	3.7	4.0	5.8	9.33	6.66	5.0	2.66	5.91	11.04	5.35	3.8	3.88	6.0
	(7.2)	(4.8)	(4.6)	(5.1)	(5.4)	(6.1)	(5.5)	(5.0)	(4.7)	(5.3)	(2.63)	(2.18)	(2.34)	(1.77)	(2.53)	(5.31)	(4.16)	(3.98)	(3.857)	(24.3)
KAK 2	20.7	5.0	6.3	6.0	9.5	5.3	3.3	2.7	5.3	4.2	23.46	11.33	2.33	4.66	10.45	16.48	6.25	3.80	5.32	8.03
	(8.7)	(4.9)	(5.4)	(6.3)	(6.4)	(5.3)	(5.0)	(4.7)	(5.2)	(5.0)	(4.72)	(3.11	(1.68)	(2.27)	(3.30)	(6.24)	(4.33)	(3.92)	(4.59)	(4.77)
Mean	19.9	5.3	5.2	5.9	9.1	9.2	3.9	3.7	4.3	5.3	17.41	8.98	3.53	4.46	8.60	15.48	6.07	7.64	7.64	4.61
	(8.4)	(5.2)	(5.2)	(5.7)	(6.1)	(6.1)	(5.0)	(4.8)	(4.9)	(5.2)	(4.23)	(3.07)	(2.0)	(2.22)	(3.01)	(15.4)	(4.24)	(4.15)	(4.15)	(7.64)
	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)
Genotype (G)	0.169	1.71	0.37	NS		0.02	3.3	0.29	0.83		<.001	10.13	0.063	0.181		<.001	6.15	0.2041	0.5843	
Sowing (S)	<.001	22.3	0.33	0.95	21	0.002	5.71	0.26	0.74	19.2	<.001	40.77	0.057	0.162	17.4	<.001	28.49	0.1826	0.5226	15.3
G x S	0.852	0.57	0.74	NS		0.34	1.17	0.58	NS		<.001	4.32	0.126	0.362		0.341	1.17	0.4082	1.1687	

Table 2: Evaluation of different chickpea genotypes for resistance to *H. armigera* larvae at different sowing dates

	Helicoverpa armigera larvae (2012-2013)					*Helicoverpa armigera* larvae (2013-2014)					*Helicoverpa armigera* larvae (2014-15)					*Helicoverpa armigera* larvae (Pooled)				
Genotype	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean
ICC 3137	113.2	43.0	22.0	29.3	51.9	56.0	69.3	33.7	74.3	58.3	94.66	57	34.33	36.0	55.5	87.95	56.43	30.01	46.53	55.23
	(23.3)	(13.9)	(9.2)	(11.6)	(14.5)	(15.6)	(17.8)	(11.6)	(16.9)	(15.5)	(11.46)	(8.65)	(5.90)	(6.04)	(7.48)	(16.79)	(13.45)	(8.9)	(9.7)	(12.21)
ICCL 86111	69.7	46.7	22.3	28.3	41.8	31.0	30.7	18.3	18.7	24.7	46.66	31.66	26.33	15.33	30.0	49.12	36.33	22.31	20.78	32.14
	(18.3)	(14.4)	(9.4)	(11.2)	(13.3)	(12.1)	(12.1)	(8.7)	(8.1)	(10.2)	(7.35)	(6.07)	(5.18)	(3.97)	(5.52)	(12.58)	(10.86)	(7.76)	(7.76)	(9.74)
ICCV 10	49.7	21.0	11.7	31.0	28.2	32.3	29.7	20.0	44.7	31.7	31.33	23.33	23.66	20.66	24.75	37.77	24.68	18.75	32.12	28.26
	(15.3)	(9.9)	(7.0)	(12.1)	(11.1)	(12.2)	(12.2)	(8.6)	(13.2)	(11.5)	(6.17)	(5.19)	(4.91)	(4.60)	(5.02)	(11.22)	(9.1)	(6.84)	(9.97)	(9.28)
JG 11	74.3	34.3	21.7	23.0	38.3	34.7	32.3	17.2	36.3	30.1	49.33	31.66	16.0	20.33	29.33	52.77	32.75	18.3	26.54	32.59
	(18.4)	(12.3)	(9.5)	(10.4)	(12.7)	(13.2)	(12.5)	(8.6)	(12)	(11.6)	(7.90)	(6.19)	(4.06)	(4.56)	(5.46)	(13.17)	(10.33)	(7.39)	(8.99)	(9.97)
KAK 2	96.7	42.0	23.3	24.3	46.6	42.3	41.7	29.8	37.7	37.9	62.33	49.66	16.33	13.3	35.41	67.11	44.45	8.0	25.0	39.93
	(20.8)	(13.9)	(9.4)	(10.5)	(13.6)	(14.4)	(13.7)	(10.5)	(12.3)	(12.7)	(9.07)	(8.00)	(4.10)	(3.71)	(5.99)	(14.76)	(11.87)	(23.14)	(8.84)	(10.8)
Mean	80.7	37.4	20.1	27.2	41.3	39.3	40.7	23.8	38.3	36.5	56.86	38.66	23.33	21.1	35.0	58.95	39.0	22.0	30.2	38.0
	(19.2)	(12.9)	(8.9)	(11.1)	(13)	(13.5)	(13.7)	(9.6)	(12.5)	(12.3)	(7.57)	(6.25)	(4.88)	(4.65)	(5.95)	(13.7)	(11.12)	(7.77)	(9.04)	(10.41)
	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)
Genotype (G)	<.001	7.03	0.49	1.39		<.001	20.95	0.43	1.24		0.002	4.98	0.149	0.427		0.004	4.55	0.543	1.555	
Sowing (S)	<.001	104.9	0.43	1.24	12.9	<.001	23.41	0.39	1.11	12.2	<.001	27.8	0.133	0.382	20.9	<.001	28.44	0.486	1.391	18.1
G x S	0.012	2.62	0.97	NS		0.071	1.87	0.87	NS		0.309	1.21	0.298	0.854		0.541	0.92	1.086	3.11	

Table 3: Evaluation of different chickpea genotypes for resistance to *Spodoptera exigua* egg laying at different sowing dates

	Spodoptera exigua eggs (2012-2013)					*Spodoptera exigua* eggs (2013-2014)					*Spodoptera exigua* eggs (2014-15)					*Spodoptera exigua* eggs (Pooled)				
Genotype	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean
ICC 3137	0.0	0.7	0.3	0.7	0.42	0.0	0.0	1.0	0.3	0.32	0.0	0.0	0.0	0.0	0.0	0.0	0.23	0.33	0.56	0.28
	(0.71)	(1.09)	(0.89)	(1.09)	(0.95)	(0.71)	(0.71)	(1.22)	(0.89)	(0.88)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.83)	(.94)	(0.89)	(0.84)
ICCL 86111	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.0	0.0	0.82	0.0	0.0	1.33	0.0	0.33	0.0	0.1	1.44	0.0	0.38
	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.89)	(1.87)	(0.71)	(1.04)	(0.71)	(0.71)	(1.35)	(0.71)	(0.91)	(0.71)	(0.77)	(1.31)	(0.71)	(0.87)
ICCV 10	0.0	0.0	0.0	0.3	0.075	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.33	0.0	0.08	0.0	0.0	0.11	0.1	0.053
	(0.71)	(0.71)	(0.71)	(0.89)	(0.60)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.91)	(0.71)	(0.76)	(0.71)	(0.71)	(.77)	(.77)	(0.74)
JG 11	0.0	0.3	0.0	0.3	0.15	0.0	0.0	0.7	0.0	0.19	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.18
	(0.71)	(0.89)	(0.71)	(0.89)	(0.80)	(0.71)	(0.71)	(1.09)	(0.71)	(0.80)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.77)	(0.83	(.77)	(0.77)
KAK 2	0.0	0.3	0.7	0.7	0.42	5.0	0.0	1.7	0.0	1.78	0.0	0.0	0.66	0.0	0.16	1.66	0.0	1.04	0.23	0.73
	(0.71)	(0.89)	(1.09)	(1.09)	(0.94)	(4.2)	(0.71)	(1.48)	(0.71)	(1.85)	(0.71)	(0.71)	(1.08)	(0.71)	(0.81)	(1.87)	(0.71)	(1.21)	(0.83)	(1.17)
Mean	0.0	0.26	0.12	0.42	0.0	1.0	1.06	1.29	0.06	0.84	0.0	0.0	0.46	0.0	0.11	0.33	0.08	0.63	0.2	0.13
	(0.71)	(0.85)	(0.82)	(0.93)	(0.82)	(1.40)	(0.60)	(1.27)	(0.74)	(1.00)	(0.71)	(0.71)	(0.98)	(0.71)	(0.78)	(0.94)	(0.77)	(1.04)	(0.79)	(0.88)
	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)
Genotype (G)	0.151	1.79	0.07	0.2		0.09	2.17	0.09	0.27		0.876	0.3	0.013	0.036		0.185	1.64	0.0457	0.1308	
Sowing (S)	0.176	1.74	0.06	0.18	6.6	0.002	5.83	0.08	0.24	8.7	0.018	3.79	0.011	0.032	6.1	<.001	8.83	0.0409	0.117	5.9
G x S	0.952	0.41	0.14	0.4		0.305	1.22	0.19	0.53		0.986	0.3	0.025	0.072		0.163	1.51	0.0914	0.2616	

masses differed significantly across sowing dates in all cropping seasons. Comparative pattern was observed across seasons, and the highest numbers of egg masses were recorded in December sown crop (0.63). Comparatively higher number of egg masses were recorded in 2013- 14 than in 2012-13 and 2014-15.

There were no significant differences in egg laying across genotypes in 2012-13. The least number of egg masses were seen on 'KAK 2' (0.7) followed by 'ICCL 86111' (0.38) across seasons. The number of egg masses deposited on different genotypes differed during 2013-14 cropping season. The highest numbers of egg masses (1.7) were recorded on 'KAK 2', while no egg masses were recorded on 'ICCV 10'. Across seasons, the highest number of *S. exigua* egg masses (0.73) were recorded on 'KAK 2', followed by 'ICCL 86111' (0.38) and 'ICC 3137' (0.28). The interaction effects were critical over the seasons. No egg masses were recorded in the October sown crop in all the crop growing seasons, besides 0.80 on 'KAK 2' during 2013-14.

3.4 POPULATION OF *S. EXIGUA* LARVAE ON DIFFERENT CHICKPEA GENOTYPES ACROSS SOWINGS

There were significant differences in *S. exigua* larval incidence across sowing dates. The number of *S. exigua* larvae were highest in the crop sown during January (16.1; 15.5), followed by the December (11.6) during 2012-13 and 2013-14 respectively. But during 2014-15, the number of *S. exigua* larvae were significantly higher in the crop sown during December (15.8), followed by November (9.46). Across the seasons, *S. exigua* larval incidence was significantly higher in December sown crop (12.9), than the crop sown in October, November and January. However, minimum *S. exigua* larvae were recorded in January sown crop of 2014-15 due to the drought conditions. The December sown crop was most affected by *S. exigua* larvae in all the cropping seasons (2012-2015). The larval incidence was comparatively higher in 2012-13 than in 2013-14 and 2014-15 (Table 4).

3.5 VARIATION IN PARASITIZATION OF *H. ARMIGERA* BY THE LARVAL PARASITOID *C. CHLORIDEAE*

Significant differences were observed in the number of *C. chlorideae* cocoons in different sowing dates across seasons (Table 5). During 2012-13 cropping season, higher number of cocoons were recorded in the December sown crop (3.4), followed by October sown crop (2.4) while in other crop growing seasons maximum number of cocoons were recorded during October 2013-14 and November 2014-15. There were no significant differences in the number of *C. chlorideae* cocoons on different genotypes in all the seasons. However, the highest number of cocoons were recorded on 'ICC 3137' (2.5) and lowest on 'KAK 2' (1.6) and 'JG 11' (1.7).

3.6 INFLUENCE OF CLIMATIC CONDITIONS ON PEST INCIDENCE IN CHICKPEA ACROSS SOWING PATTERNS

In the October sown crop (Table 6), the maximum temperature exhibited a negative correlation with *H. armigera* larval population. The *S. exigua* egg masses were decidedly corresponded with RH, while other weather parameters were non-significant with the insect pest population in all the crop growing seasons. In the November sown crop (Table 7), only *H. armigera* larval population showed a significant positive correlation with minimum temperature and RH. While in December sown crop (Table 8) the *H. armigera* eggs population was significantly positively correlated with maximum temperature and negatively correlated RH. While significant negative correlation was observed between the *S. exigua* larvae and minimum temperature. In the case of January sown crop (Table 9), the *H. armigera* larval population was essentially decidedly associated with most extreme and least temperature, and contrarily related with RH across seasons.

Multiple regression analysis of the *H. armigera, S. exigua* eggs and larval population showed a significant interaction with weather parameters during all cropping seasons (Table 10). The coefficients of multiple determinations (R^2) were 0.795, 0.844, 0.793 for *H. armigera* eggs, *S. exigua* egg masses and *S. exigua* larval populations respectively, during October sown crop. Whereas, in November sown crops the R^2 for *H. armigera* larvae was 0.821. The R^2 for *H. armigera* eggs and *S. exigua* larvae were 0.979 and 0.866 respectively during December sown crop. In January sown crop, the R^2 value for *H. armigera* larvae was 0.866.

4 DISCUSSION

In the chickpea ecosystem, the insect pest range varies with different plantings on different genotypes. In the current study the maximum number of *H. armigera* eggs, larvae, and *C. chlorideae* cocoons were recorded in 2012-13, owing to good meteorological scenarios, such as rain followed by optimum temperature, which result-

Table 4: Evaluation of different chickpea genotypes for resistance to *Spodoptera exigua* larvae at different sowing dates

	Spodoptera exigua larvae (2012-2013)					*Spodoptera exigua* larvae (2013-2014)					*Spodoptera exigua* larvae (2014-15)					*Spodoptera exigua* larvae (Pooled)				
Genotype	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean
	3.7	8.3	7.7	15.7	8.8	3.0	0.3	2.7	14.3	5.1	6.66	5.0	17.33	1.0	7.5	4.43	4.53	9.24	10.33	7.14
ICC 3137	(5.0)	(5.5)	(5.7)	(7.7)	(5.9)	(4.3)	(3.7)	(4.6)	(6.4)	(4.8)	(2.02)	(1.65)	(4.22)	(1.22)	(2.82)	(5.11)	(3.773)	(3.62)	(4.84)	(4.33)
ICCL 86111	6.3	13.3	6.3	20.3	11.6	0.0	1.0	11.0	8.3	5.1	4.66	11.66	19.33	0.33	9.0	3.65	8.65	12.21	15.97	10.1
	(5.9)	(7.1)	(5.6)	(7.9)	(6.6)	(3.5)	(3.9)	(5.8)	(5.7)	(4.7)	(1.80)	(2.17)	(4.45)	(0.91)	(3.08)	(4.84)	(3.73)	(4.39)	(5.28)	(4.56)
ICCV 10	4.0	2.7	16.7	7.7	7.8	25.0	2.3	10.3	5.7	10.8	2.66	13.6	10.6	0.0	6.75	10.53	6.2	12.53	4.47	8.44
	(5.2)	(4.6)	(6.9)	(6.10	(5.7)	(5.3)	(4.5)	(5.9)	(5.2)	(5.2)	(1.35)	(2.35)	(3.34)	(0.71)	(2.69)	(4.00)	(3.95)	(3.82)	(5.38)	(4.28)
JG 11	4.7 (5.4)	12.7 (6.6)	8.0 (6.1)	11.7 (7.1)	9.3 (6.3)	1.0 (3.7)	0.0 (3.5)	27.7 (7.6)	19.7 (8.4)	12.1 (5.8)	5.33 (1.89)	5.0 (1.59)	16.6 (4.14)	0.0 (0.71)	6.75 (2.69)	3.67 (5.40)	8.9 (3.66)	17.43 (3.89)	10.47 (5.95)	9.37 (4.73)
KAK 2	4.7 (5.4)	13.3 (6.7)	19.3 (7.7)	25.0 (9.5)	15.6 (7.3)	1.0 (3.8)	3.0 (4.6)	6.3 (4.9)	29.3 (9.7)	10.2 (5.8)	4.33 (1.71)	12.0 (2.33)	15.0 (3.93)	0.0 (0.71)	7.83 (2.88)	3.34 (6.64)	9.43 (3.637)	13.53 (4.54)	18.1 (5.51)	11.1 (5.08)
Mean	4.7 (5.4)	10.1 (6.1)	11.6 (6.4)	16.1 (7.7)	10.6 (6.4)	2.0 (4.1)	1.3 (4.1)	11.6 (5.7)	15.5 (7.1)	8.6 (5.3)	4.73 (2.28)	9.46 (3.15)	15.8 (4.03)	0.26 (0.87)	7.56 (2.84)	5.13 (3.75)	6.94 (4.05)	12.99 (5.3)	11.86 (5.19)	9.24 (4.59)
	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)
Genotype (G)	0.112	2.01	0.44	NS		0.469	0.91	0.54	NS		0.202	1.57	0.05	0.143		0.58	0.72	0.38	1.087	
Sowing (S)	0.002	5.79	0.39	1.13	23.9	<.001	9.06	0.48	1.38	35.5	<.001	44.65	0.045	0.128	15.6	0.002	5.79	0.34	0.972	28.6
G x S	0.633	0.82	0.88	NS		0.263	1.29	1.08	NS		0.018	2.43	0.1	0.287		0.913	0.48	0.759	2.174	

Table 5: Evaluation of different chickpea genotypes for resistance to *Campoletis* cocoon at different sowing dates

Genotype	*Campoletis* cocoons (2012-2013)					*Campoletis* cocoons (2013-2014)					*Campoletis* cocoons (2014-15)					*Campoletis* cocoons (Pooled)				
	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean	30th Oct	30th Nov	30th Dec	30th Jan	Mean
ICC 3137	1.3	0.3	3.3	0.0	1.22	7.5	7.7	0.0	0.3	3.87	1.66	5.33	0.33	2.33	2.41	3.48	4.44	1.21	0.87	2.50
	(1.34)	(0.89)	(5.0)	(0.71)	(1.98)	(5.5)	(6.4)	(0.71)	(0.89)	(3.37)	(1.07)	(1.94)	(0.91)	(1.68)	(1.70)	(2.63)	(3.07)	(2.0)	(1.09)	(2.25)
ICCL 86111	1.7	0.0	4.0	0.0	1.42	5.5	3.7	2.5	0.3	3.0	0.66	5.33	0.33	1.33	1.91	2.62	3.01	2.27	0.54	2.11
	(1.48)	(0.71)	(5.0)	(0.71)	(1.97)	(4.9)	(5.1)	(4.2)	(0.89)	(3.78)	(0.83)	(1.99)	(0.91)	(1.35)	(1.54)	(2.40)	(2.6)	(3.37)	(0.98)	(2.33)
ICCV 10	3.7	0.3	6.7	0.3	2.75	4.5	3.0	0.0	0.7	2.06	2.66	4.0	0.33	0.66	1.91	3.62	2.43	2.34	0.44	2.22
	(5.0)	(0.89)	(5.8)	(0.89)	(3.12)	(4.7)	(4.8)	(0.71)	(0.89)	(2.07)	(1.34)	(1.59)	(0.91)	(1.08)	(1.55)	(3.68)	(2.42)	(3.4)	(0.95)	(2.61)
JG 11	2.7	0.0	2.3	0.0	1.25	5.8	3.0	2.0	0.3	2.77	2.0	2.0	0.33	1.66	1.5	3.5	1.66	1.54	0.21	1.76
	(4.7)	(0.71)	(4.4)	(0.71)	(2.63)	(5)	(4.8)	(4.1)	(0.89)	(3.06)	(1.18)	(1.18)	(0.91)	(1.47)	(1.41)	(3.62)	(2.23)	(3.13)	(1.02)	(2.50)
KAK 2	2.7	1.0	0.77	0.0	1.11	5.0	4.0	2.0	0.3	2.82	1.0	2.33	0.33	0.0	0.91	2.9	2.44	1.01	0.21	1.64
	(4.6)	(1.22)	(0.89)	(0.71)	(1.83)	(5.5)	(5.3)	(3.8)	(0.89)	(3.42)	(0.93)	(1.27)	(0.91)	(0.71)	(1.19)	(3.67)	(2.59)	(1.86)	(0.77)	(2.22)
Mean	2.42	0.32	3.41	0.06	1.54	5.7	4.3	1.3	0.4	2.92	1.6	3.8	0.33	1.2	1.73	3.22	2.79	1.67	0.45	2.04
	(3.42)	(0.88)	(4.21)	(0.74)	(2.30)	(5.1)	(5.3)	(3.8)	(3.7)	(3.10)	(1.44)	(2.07)	(0.91)	(1.30)	(1.49)	(3.20)	(2.58)	(2.79)	(0.96)	(2.28)
	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)	Fp	Vr	SE ±	LSD (P 0.05)	CV (%)
Genotype (G)	0.279	1.32	0.21	0.6		0.36	1.12	0.2	0.57		0.155	1.77	0.035	0.1		0.885	0.29	0.1961	0.5614	
Sowing (S)	<.001	10.36	0.19	0.54	17.4	<.001	20.58	0.18	0.51	15.5	<.001	15.48	0.031	0.09	14.1	0.024	3.52	0.1754	0.5021	20.7
G x S	0.611	0.84	0.42	1.2		0.398	1.09	0.4	1.15		0.319	1.2	0.07	0.201		0.984	0.31	0.3922	1.1228	

Table 6: Correlation between pest incidence and different weather parameters during 2013-2015 in chickpea in October sown crop

	Rain (mm)	Temperature (°C) Maximum	Temperature (°C) Minimum	Relative Humidity morning (%)	Relative Humidity evening (%)
H. armigera eggs	-0.098	0.409	-0.419	0.309	-0.343
H. armigera larvae	-0.609	-0.892*	-0.462	-0.632	-0.168
S. exigua egg mass	0.847	0.386	0.577	0.919**	0.613
S. exigua larvae	0.720	0.570	0.561	0.891*	0.488
Campoletis cocoon	0.307	0.718	-0.073	0.415	-0.188

*, ** Significant at $p \leq 0.05$ and 0.01

Table 7: Correlation between pest incidence and different weather parameters during 2013-2015 in chickpea in November sown crop

	Rain (mm)	Temperature (°C) Maximum	Temperature (°C) Minimum	Relative Humidity morning (%)	Relative Humidity evening (%)
H. armigera eggs	-0.335	-0.218	-0.821	0.644	0.178
H. armigera larvae	0.327	0.698	0.82	-0.905*	-0.609
S. exigua egg mass	-0.578	-0.725	0.2	0.203	0.619
S. exigua larvae	-0.455	-0.08	-0.755	0.505	0.097
Campoletis cocoon	0.708	0.516	0.68	-0.619	-0.606

*, ** Significant at $p \leq 0.05$ and 0.01

Table 8: Correlation between pest incidence and different weather parameters during 2013-2015 in chickpea in December sown crop

	Rain (mm)	Temperature (°C) Maximum	Temperature (°C) Minimum	Relative Humidity morning (%)	Relative Humidity evening (%)
H. armigera eggs	0.818	0.881*	0.956**	-0.921**	-0.427
H. armigera larvae	0.445	0.722	0.683	-0.846	-0.805
S. exigua egg mass	-0.52	-0.419	-0.6221	0.425	-0.113
S. exigua larvae	-0.8	-0.805	-0.916*	0.813	0.237
Campoletis cocoon	-0.45	-0.077	-0.163	-0.117	-0.72

*, ** Significant at $p \leq 0.05$ and 0.01

Table 9: Correlation between pest incidence and different weather parameters during 2013-2015 in chickpea in January sown crop

	Rain (mm)	Temperature (°C) Maximum	Temperature (°C) Minimum	Relative Humidity morning (%)	Relative Humidity evening (%)
H. armigera eggs	-0.291	0.594	0.453	-0.55	-0.318
H. armigera larvae	0.538	0.975**	0.99**	-0.994**	-0.325
S. exigua egg mass	0.233	-0.117	0.04	-0.077	0.565
S. exigua larvae	-0.381	-0.275	-0.255	0.143	0.37
Campoletis cocoon	-0.015	0.301	0.338	-0.44	0.17

*, ** Significant at $p \leq 0.05$ and 0.01

Table 10: Regression between weather parameters and insect pest population in chickpea across seasons

Season	Insect-pests	Regression equation	R^2 Value
October	*H. armigera* eggs	Y = 309.36 - 2.19 (Rain) -10.24 (Max.Temp) -8.94 (Min.temp)- 6.70 (RH1) + 2.70 (RH2)	0.7959
	S. exigua egg mass	Y =-7.98 + 0.080 (Rain)+ 0.0 (Max.Temp) + 0.15 (Min.temp) + 0.0875 (RH1) + 0.011 (RH2)	0.844
	S. exigua larvae	Y =-59.33 + 0.577 (Rain) + 0.0 (Max.Temp) + 1.26 (Min.temp) + 0.65 (RH1) -0.28 (RH2)	0.793
November	*H. armigera* larvae	Y = 99.06 + 6.04 (Rain) + 0.0 (Max.Temp) + 0.22 (Min.temp)- 1.05 (RH1) + 1.09 (RH2)	0.821
December	*H. armigera* eggs	Y = 19.46 + 0.80 (Rain) -0.39 (Max.Temp) + 0.27 (Min.temp)- 0.12 (RH1) -0.361 (RH2)	0.979
	S. exigua larvae	Y = 6.86 + 8.81(Rain) +0.628 (Max.Temp) -1.50 (Min.temp)+ 1.38 (RH1) -6.02 (RH2)	0.866
January	*H. armigera* larvae	Y = 6.86 + 8.81(Rain) +0.628 (Max.Temp)-1.50 (Min.temp)+ 1.38 (RH1) -6.02 (RH2)	0.866

ed in increased pod borer activity under field conditions. There were considerable differences in *H. armigera* larval incidence across the test genotypes in the early plantings, while the differences were less noticeable in the late plantings. Though the number of *H. armigera* and *S. exigua* larvae decreased as planting dates progressed, the extent of *H. armigera* damage increased across all cropping seasons. The current studies are in corroboration with Shankar et al., (2014) who reported that the number of *S. exigua* and *H. armigera* larvae were maximum in October planting compared to late planting. The present studies additionally link with the work of Shah & Shahzad (2005) who observed that the oviposition by *H. armigera* was low from December to Mid- February due to cold conditions, whereas Ali et al., (2003) reported that the numbers of eggs laid by *H. armigera* differed considerably across sowings and genotypes of cotton. Similarly, Ali et al., (2009) ascertained that there were no significant variations in larval population and damage across genotypes and different sowing dates. Hossain et al., (2008) found that the *H. armigera* larval population was high in early sown crops (October 15th to November 1st) and delayed sowings (November 1st to 30th) resulted in lower population of *H. armigera*. Accessions ICC 506EB, ICC 12476, ICC 12477, ICC 12478 and ICC 12479 showed oviposition non-preference and suffered low leaf damage (Narayanamma et al., 2007).

The cocoons of the parasitoid *C. chlorideae* also attenuated with the planting dates, that ultimately resulted in an enormous decrease in biological control of *H. armigera* larvae. The inflated temperature across the planting dates, resulted in increased damage by *H. armigera* and also a reduction in the dry matter and grain yield. The current findings were consistent with Pavani et al., 2019, who reported the highest levels of parasitoid activity in the October planted crop, and lowest in the January planted crop. The parasitoid was more active at temperatures ranging from 15 to 28 degrees Celsius (Jaba & Agnihotri 2018; Jaba et al., 2016). The parasatization came down after January (5th SW) in chickpea sole crop and there was negative correlation ascertained with minimum temperature and morning RH. In case of intercropping system, the result elucidated that a significant positive correlation was observed with evening RH and rainfall in consecutive years.

The results of the correlation analysis in the present study are in corroboration with earlier reports by Patnaik & Senapati (1996), who observed a negative correlation between mean temperature ranges and larval incidence. However, a positive association was observed between *H. armigera* and *S. exigua* larvae, and similar results were earlier reported by Sharma (2012). The positive correlation has also been reported earlier between *H. armigera* larval incidence and the maximum and the minimum temperatures by (Sharma et al., 2005; Shah and Shahzad, 2005; Upadhyay et al., 1989; Pandey 2012). Ugale et al., (2011) reported that moth emergence was negatively correlated with the maximum (r = -0.62) and minimum temperatures (r = -0.75), but there was no association with relative humidity. Prasad et al., (1989); Jaba & Agnihotri, 2015 confounded that minimum temperature and rainfall exerted a negative influence on pheromone trap catches of *H. armigera*. The population of *H. armigera* and *S. exigua* larvae was negatively correlated with relative humidity across the genotypes.

5 CONCLUSION

The present studies were carried out to identify climate resilient cultivars and best sowing window with least pest incidence under climate change scenarios. Our results, concluded that the egg laying by *H. armigera* diminished across sowing dates until December, while a small increase was recorded in the January sown crop. In the early plantings there were significant differences among the genotypes, but such differences were less apparent in the late plantings. 'ICC 3137' was most preferred for egg laying, followed by 'KAK 2', The genotypes 'ICCV 10' and 'JG 11' were relatively not preferred for egg laying. There were no significant differences in egg laying by *S. exigua* in the crops sown in October, November, and January. The highest numbers of *S. exigua* egg masses were recorded on 'KAK 2', followed by 'ICC 3137' in the December sown crop. The *S. exigua* larval incidence was greater in the January sown crop than in the crops sown in October, November, and December. Though the number of *H. armigera* larvae decreased with the planting dates, the extent of damage by *H. armigera* increased across the planting dates across seasons. The cocoons of the parasitoid *C. chlorideae* decreased with the planting dates, which ultimately resulted in decreased biological control of *H. armigera*. As the temperature exaggerated across the planting dates, there was an increase in damage by *H. armigera* under field conditions.

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7 CONFLICTING INTEREST

The authors declare no conflict of interest.

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