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Madhu TN
a) Scientist, Division of Entomology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India
b) Scientist, ICAR-Central Institute for Cotton Research, Nagpur, Maharashtra, India

Shah VK
Scientist, ICAR-Central Institute for Cotton Research, Nagpur, Maharashtra, India

Prabhulinga T
Scientist, ICAR-Central Institute for Cotton Research, Nagpur, Maharashtra, India

Chakravarthy AK
a) Scientist, Division of Entomology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India
b) ICAR- Indian Institute of Horticultural Research, Hesaraghatta, Bengaluru, Karnataka, India

Ashok Kumar CT
Scientist, Division of Entomology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India

Correspondence
Madhu TN
a) Scientist, Division of Entomology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India
b) Scientist, ICAR-Central Institute for Cotton Research, Nagpur, Maharashtra, India

Optimization of pheromone trap densities and impact of insecticides on pheromone catches for mass trapping *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in chickpea

Madhu TN, Shah VK, Prabhulinga T, Chakravarthy AK and Ashok Kumar CT

Abstract

Chickpea pod borer, *Helicoverpa armigera* is an economically important insect pest. The trials were performed at four locations using with 10, 20, 30 and 40 sex pheromone funnel traps/acre during 2012-13 and 2013-14. The moth catches were higher in the locations with a trap density of 20/acre (12.93±4.05 and 13.82±5.0) and least percent pod infestation at such locations compared to other treatments. Peak activity of moths was recorded in the third standard meteorological week. Four insecticides, i.e., indoxacarb, chlorantraniliprole, novaluron and quinalphos were evaluated to determine their efficacy with pheromone traps. Among the treatments, fields treated with chlorantraniliprole and positioned 20 pheromone traps recorded least moth catches (0.15 to 0.25/trap) as well as percent pod infestation, followed by indoxacarb and novaluron. The present study observed that 20 traps/acre was the optimum trap density required to ensure maximum catches and integration of chlorantraniliprole+20 pheromone traps/acre proved considerably effective against *H. armigera.*

Keywords: pheromone trap, mass trapping, *Helicoverpa armigera*, insecticides, chickpea

1. Introduction

Chickpea (*Cicer arietinum* L.) is an important food legume grown in around 12 million hectares and consumed in large quantities in regions ranging from South East Asia to India, Middle-East and Mediterranean countries as a source of protein. India is the largest producer of chickpea with an area of 8.32 million hectare and production of 9.1 million tons [2].

The pod borer, *Helicoverpa armigera* (Hubner) is a dreaded pest of chickpea, with a wide range of host plants including cotton, corn, peanuts, pigeon pea, sorghum and others [39]. *H. armigera* inflicts heavy loss on chickpea from the stage of a seedling up to its maturity, but the maximum damage is caused during pod formation [22, 11]. The yield losses due to *H. armigera* vary from about 10% to 60% under normal conditions, while under favorable weather conditions about 50% to 100% loss was recorded [18, 34, 35, 27, 26]. In general, indiscriminate use of insecticides on major invasive pests, notably, lepidopteran insects induces resistance development and results in secondary outbreak. Further, the repeated use of broad-spectrum insecticides disturbs the predator and parasitoid population [1]. Overuse of insecticides results in the problem of pesticide resistance and although some insecticides provide specific control, they still turn out to be harmful for beneficial arthropods [28, 7, 25]. Adoption of bio-rational approaches, such as the use of pheromones is a better alternative to insecticides. At present, the farmers are employing eco-friendly pest management practices and use of sex pheromones is one among those.

Sex pheromones play a vital role in insect courtship and can be used to decrease the reproductive success rate of the target pest [35] and their impact on lepidopterans has been extensively studied [17]. Besides, using sex pheromones for pest management also addresses the concerns of bio-safety [21]. Unlike monitoring and mating disruption, mass trapping technique results in a sustainable control of target pest apart from being cost effective. Mass trapping technique has been successfully used to control several major pests of different crops, such as the Brinjal shoot and fruit borer (*Leucinodes orbonalis)*, Bark beetles (*Ips duplicatu*) and American palm weevils (*Rhynchophorus palmarum*) [8, 9, 10. 23, 31]. Additionally, mass trapping method is a cost effective tool to suppress the pest population [15].

2. Materials and Methods
2.1 Pheromone source
The rubber dispensers in funnel traps baited with 2 mg of ((Z)-11-hexadecenal (Z11-16: Ald) and (Z)-9-hexadecenal (Z9-16: Ald)) used as a pheromone source. The sample was obtained from the Pest Control (India) Ltd. Bombay, Division of Biocontrol Research Laboratories, Bengaluru which is manufactured and marketed as Helilure™

2.2 Experimental site
Field experiments were conducted during the period from 2012 to 2015 in the farm lands of Chikka Madurae, Kodipalya, Agrahara, Byatha, Hanabe and Neralaghatta villages (13º5' latitude and 77º35' longitude; and an altitude of 930 meters from mean sea level (MSL)) situated in the eastern dry zone of Karnataka, India. The chickpea growing fields were adopted by Bio-Control Research Laboratory (BCRL), Sreeramanahalli, Bengaluru, India. The experiments were conducted in the isolated chickpea fields to neutralize the overlapping of sensory receptivity and orientation of male *Helicoverpa* moths. None of these experimental fields were imposed with plant protection activities or chemicals other than the test insecticides used for the study.

2.3 Optimization of trap density
In order to optimize the trap density per unit area of cultivated chickpea crop, funnel shaped pheromone traps were evaluated by positioning different densities during 2012-13 and 2013-14 at five isolated fields of one acre each with 10, 20, 30 and 40 traps ranging. Further, 10 traps without having pheromone lures were placed in control fields. The chickpea crop was sown in October first week, pheromone traps baited with lure were positioned after 30 days of sowing and maintained at height of 0.4 meter above the crop canopy. All the traps were positioned randomly at an equidistance covering an acre and changed the lures regularly once in 20 days. We have taken the precaution to maintain at least 2 km distance between the experimental fields to avoid overlapping and movement of the borer population from one field to another. Each location was considered as one replication and trap catches were recorded at weekly intervals. Statistical analysis was performed using randomised complete block design (RCBD) after the data on moth catches were subjected to square root transformation ($\sqrt{(X+0.5)}$).

2.4 Combinatorial analysis of sex pheromone traps and insecticide
On the basis of the performance of pheromone traps in 2012-13, their efficacy in combination with different routinely used pesticides was evaluated. Four insecticides of different chemical groups, namely, indoxacarb (0.05%), chlorantraniliprole (0.03%), novaluron (0.1%) and quinalphos (0.2%) was selected for the trial based on the feedback from the chickpea growers through questionnaire method and sprayed only at the flowering stage. Chemical treatments were imposed along with the standardized 20 traps per acre at four locations and pheromone traps without imposing chemical treatment were maintained as a control. The observation on moth catches and defoliation at early stage was recorded weekly, while the percent pod infestation was recorded during the reproductive stage from 50 randomly selected plants in each field. The data was subjected to square root transformation ($\sqrt{}$ (X+0.5) before analysis followed by one-way ANOVA [37].

3. Results
3.1 Traps density and moth catches
Maximum number of adult males of *H. armigera* were found in fields with 20 traps per acre during 2012-13 (12.93±4.05) and 2013-14 (13.82±5.0) which was statistically significant over 10 and 40 traps. Maximum moth catches were also reported from fields with 30 traps per acre (5.80±1.08 and 5.51±1.28) but it was lower than 20 traps. Fair volume of moth catches was also reported from fields with 10 and 40 traps per acre (5.18±1.36 and 5.2±1.40; 3.16±0.43 and 2.70±0.49) respectively (Fig. 1 and 2).

3.2 Population trends
As per the field observations, *H. armigera* started appearing from the 49th meteorological standard week which continued up to sixth standard week. The pest population began to build up gradually from the second standard week and reached its peak in the third standard week in all the treatments. Furthermore, more abundant catches were consistently recorded at trap densities of 20 per acre in the third week of January (61.5±2.92 and 75.6±3.35) in the two consecutive years of the study.

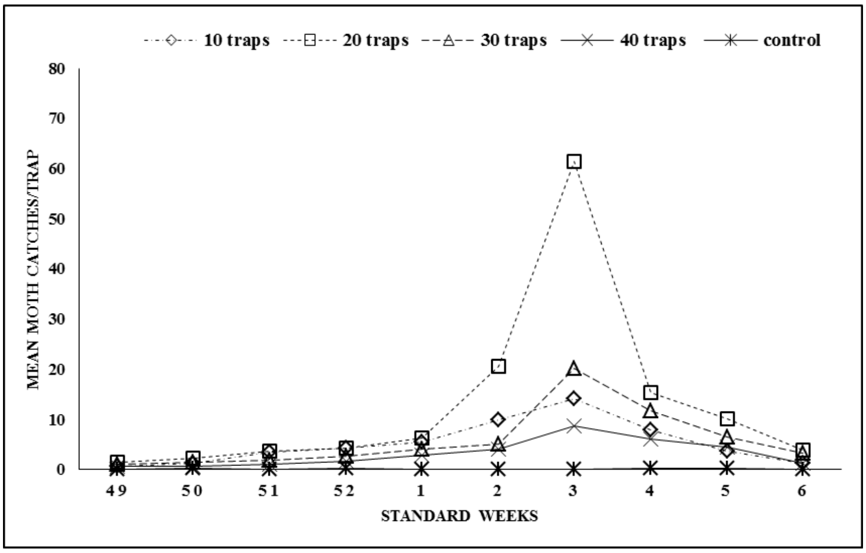

Fig 1: Mean male moth catches of *H. armigera* at different trap densities in experimental chickpea fields in 2012-13.

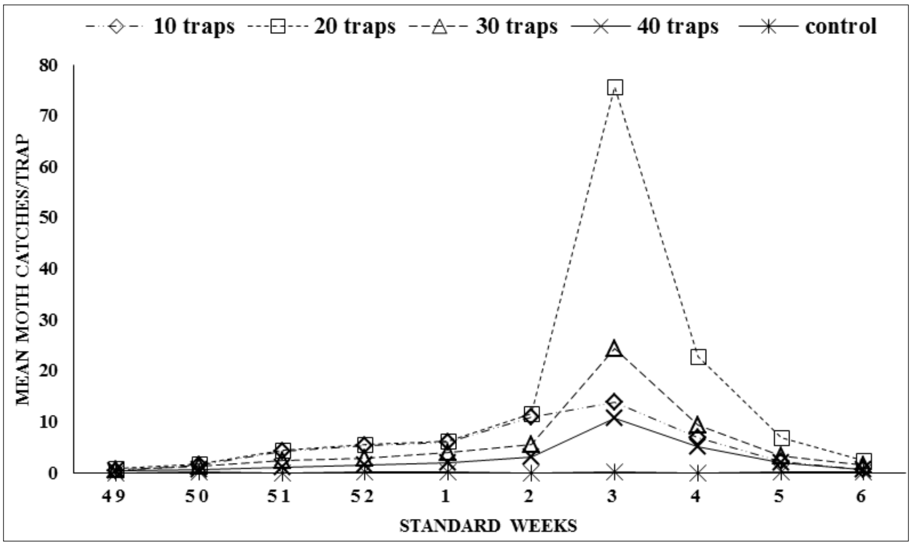

Fig 2: Mean male moth catches of *H. armigera* at different trap densities in experimental chickpea fields in 2013-14.

3.3 Sex pheromone traps and insecticide

Among the treatments, the chickpea fields with chlorantraniliprole + 20 traps per acre recorded lesser moth catches varying from 0.15 to 0.25 per trap (Table 1) with least pod infestation followed by fields with indoxacarb, novaluron and quinalphos (Table 2). Similarly, the evidence showed that the fields treated with Chlorantraniliprole alone also recorded the lowest pod infestation (5.80±0.36) which was significant over other insecticides (Fig. 3).

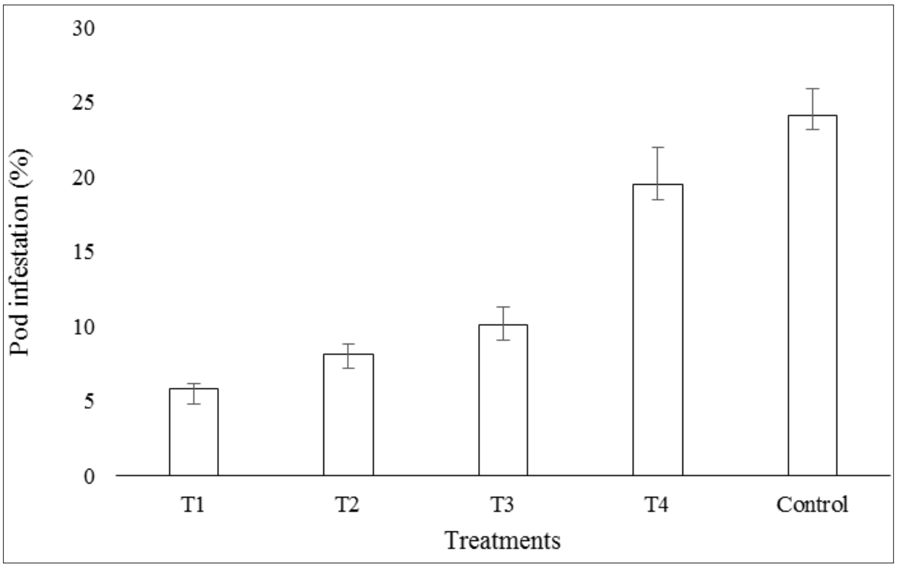

Fig 3: Influence of insecticides on pod infestation of chickpea pod borer: T1- Chlorantraniliprole, T_2-Indaxocarb, T_3- Novaluran, T_4-Quinalphos and Control

3.4 Crop yield

Among the different trap densities evaluated, higher crop yield was recorded in the fields deployed with 20 traps per acre (13.52±1.0 q/ha) as against the control (7.35±0.68 q/ha). The fields treated with chlorantraniliprole in combination with 20 traps per care recorded the maximum yield of 18.61±0.42 quintals/ha.

Table 1: Influence of insecticides and pheromone traps on moth catches of chickpea pod borer

Location/ Treatment	I					II					III					IV				
	Pre-spray	**7th Day**	**14th Day**	**21st Day**	**28th Day**	**Pre-spray**	**7th Day**	**14th Day**	**21st Day**	**28th Day**	**Pre-spray**	**7th Day**	**14th Day**	**21st Day**	**28th Day**	**Pre-spray**	**7th Day**	**14th Day**	**21st Day**	**28th Day**
Chlorantraniliprole + 20 Traps	0.95 (1.13)^{a}	0.30 (0.86)^{a}	0.21 (0.81)^{a}	0.20 (0.81)^{a}	0.25 (0.84)^{a}	1.30 (1.24)^{a}	0.40 (0.91)^{a}	0.25 (0.84)^{a}	0.35 (0.89)^{a}	0.15 (0.78)^{a}	1.45 (1.35)^{a}	0.40 (0.91)^{a}	0.25 (0.84)^{a}	0.35 (0.89)^{a}	0.20 (0.81)^{a}	0.60 (0.99)^{a}	0.25 (0.84)^{a}	0.20 (0.81)^{a}	0.30 (0.86)^{a}	0.15 (0.78)^{a}
Indoxacarb + 20 Traps	1.15 (1.20)^{a}	0.45 (0.93)^{b}	0.40 (0.91)^{a}	0.40 (0.91)^{a}	0.50 (0.96)^{bc}	1.15 (1.23)^{a}	0.60 (1.01)^{a}	0.45 (0.94)^{ab}	0.50 (0.97)^{ab}	0.35 (0.89)^{ab}	1.30 (1.28)^{a}	0.65 (1.02)^{ab}	0.50 (0.96)^{a}	0.70 (1.05)^{ab}	0.45 (0.94)^{ab}	0.65 (1.01)^{a}	0.40 (0.91)^{a}	0.30 (0.86)^{a}	0.45 (0.93)^{a}	0.25 (0.84)^{ab}
Novaluron + 20 Traps	1.05 (1.16)^{a}	0.55 (0.98)^{b}	0.50 (0.97)^{a}	0.60 (1.00)^{ab}	0.75 (1.07)^{cd}	1.35 (1.31)^{a}	0.75 (1.07)^{a}	0.60 (1.00)^{ab}	0.55 (0.98)^{ab}	0.40 (0.91)^{ab}	1.40 (1.32)^{a}	0.80 (1.09)^{ab}	0.55 (0.99)^{a}	0.80 (1.11)^{ab}	0.60 (1.02)^{bc}	0.55 (0.98)^{a}	0.40 (0.91)^{a}	0.35 (0.89)^{b}	0.50 (0.96)^{a}	0.40 (0.91)^{abc}
Quinalphos + 20 Traps	1.10 (1.20)^{a}	0.70 (1.05)^{c}	1.10 (1.22)^{b}	1.05 (1.18)^{bc}	1.20 (1.25)^{d}	1.10 (1.22)^{a}	0.80 (1.10)^{a}	0.70 (1.66)^{b}	0.85 (1.14)^{b}	0.65 (1.04)^{b}	1.35 (1.29)^{a}	0.95 (1.16)^{b}	1.05 (1.21)^{b}	1.20 (1.26)^{b}	0.95 (1.16)^{c}	0.75 (1.07)^{a}	0.60 (1.01)^{ab}	0.65 (1.04)^{bc}	0.70 (1.05)^{ab}	0.55 (0.98)^{bc}
Control (20 Traps)	1.00 (1.13)^{a}	1.30 (1.27)^{d}	1.25 (1.27)^{b}	1.40 (1.33)^{c}	1.60 (1.41)^{e}	1.40 (1.33)^{a}	1.65 (1.43)^{b}	1.90 (1.52)^{c}	2.05 (1.58)^{c}	1.50 (1.35)^{c}	1.35 (1.29)^{a}	1.60 (1.39)^{c}	1.85 (1.49)^{c}	2.05 (1.54)^{c}	1.65 (1.41)^{d}	0.80 (1.06)^{a}	0.85 (1.11)^{b}	1.05 (1.21)^{c}	1.10 (1.20)^{b}	0.75 (1.06)^{a}
F-test	NS	*	*	*	*	NS	*	*	*	*	NS	*	*	*	*	NS	*	*	*	*
SEm ±	0.10	0.08	0.06	0.07	0.07	0.08	0.07	0.06	0.05	0.07	0.09	0.08	0.07	0.08	0.07	0.08	0.06	0.05	0.07	0.06
CD @ P=0.05	-	0.21	0.18	0.20	0.20	-	0.19	0.18	0.16	0.18	-	0.22	0.19	0.22	0.19	-	0.18	0.16	0.20	0.17

Average of four replications/treatment/week at four locations; Figures within the Parentheses are √x+0.5 transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT;* Significant at 5%; NS= Non-Significant

Table 2: Influence of insecticides and pheromone traps on percent infestation of chickpea pod borer

Location/Treatment	I					II					III					IV				
	Pre-spray	**7th Day**	**14th Day**	**21st Day**	**28th Day**	**Pre-spray**	**7th Day**	**14th Day**	**21st Day**	**28th Day**	**Pre-spray**	**7th Day**	**14th Day**	**21st Day**	**28th Day**	**Pre-spray**	**7th Day**	**14th Day**	**21st Day**	**28th Day**
Chlorantraniliprole + 20 Traps	8.90 (17.22)^{a}	7.50 (15.83)^{a}	5.23 (13.02)^{a}	4.40 (11.11)^{a}	3.80 (11.03)^{a}	9.87 (18.14)^{a}	6.73 (14.89)^{a}	5.30 (13.07)^{a}	4.50 (12.14)^{a}	3.87 (11.24)^{a}	9.27 (17.56)^{a}	6.50 (14.65)^{a}	5.37 (13.28)^{a}	4.53 (12.19)^{a}	3.83 (11.20)^{a}	7.70 (16.01)^{a}	5.17 (12.97)^{a}	4.03 (11.37)^{a}	3.20 (10.18)^{a}	2.87 (9.63)^{a}
Indoxacarb + 20 Traps	8.87 (17.21)^{a}	7.63 (15.96)^{a}	5.67 (13.61)^{ab}	4.80 (12.44)^{a}	4.13 (11.53)^{a}	9.70 (17.85)^{a}	7.07 (15.26)^{a}	6.00 (14.00)^{ab}	5.17 (13.01)^{ab}	4.83 (12.60)^{b}	8.97 (17.31)^{a}	7.40 (15.67)^{ab}	6.47 (14.56)^{b}	5.97 (13.95)^{b}	4.83 (12.43)^{b}	7.57 (15.80)^{a}	6.03 (13.99)^{ab}	5.20 (12.89)^{b}	4.17 (11.40)^{b}	3.63 (10.64)^{ab}
Novaluron + 20 Traps	9.03 (17.39)^{a}	7.90 (16.26)^{a}	6.30 (14.37)^{b}	5.63 (13.58)^{b}	4.87 (12.65)^{b}	9.37 (17.63)^{a}	7.17 (15.43)^{a}	6.47 (14.64)^{b}	5.53 (13.51)^{b}	5.30 (13.20)^{b}	9.07 (17.42)^{a}	7.53 (15.81)^{b}	6.73 (14.88)^{b}	6.33 (14.38)^{b}	5.86 (13.87)^{b}	7.63 (15.96)^{a}	6.20 (14.22)^{b}	5.63 (13.58)^{b}	4.00 (11.41)^{b}	3.70 (11.00)^{b}
Quinalphos + 20 Traps	8.97 (17.27)^{a}	8.10 (16.45)^{a}	7.73 (16.02)^{c}	8.03 (16.37)^{c}	8.37 (16.71)^{c}	9.33 (17.71)^{a}	8.40 (16.77)^{b}	8.07 (16.39)^{c}	8.20 (16.51)^{v}	8.47 (16.82)^{c}	9.10 (17.42)^{a}	8.20 (16.53)^{bc}	8.47 (16.83)^{c}	8.80 (17.17)^{c}	9.23 (17.61)^{c}	7.73 (16.07)^{a}	6.83 (15.04)^{c}	7.20 (15.47)^{c}	7.40 (15.71)^{c}	6.60 (14.67)^{c}
Control (20 Traps)	9.27 (17.50)^{a}	10.07 (18.30)^{b}	10.77 (19.03)^{d}	11.63 (19.82)^{d}	12.10 (20.24)^{d}	10.70 (18.33)^{a}	10.53 (18.82)^{c}	11.20 (19.46)^{d}	11.60 (19.83)^{d}	12.20 (20.37)^{d}	9.23 (17.53)^{a}	10.03 (18.35)^{c}	10.77 (19.08)^{d}	10.07 (18.43)^{d}	10.36 (18.71)^{d}	8.03 (16.38)^{a}	8.40 (16.76)^{d}	8.77 (17.11)^{d}	9.00 (17.34)^{d}	7.97 (16.23)^{d}
F-test	NS	*	*	*	*	NS	*	*	*	*	NS	*	*	*	*	NS	*	*	*	*
SEm ±	0.43	0.35	0.42	0.40	0.37	0.50	0.37	0.40	0.34	0.32	0.42	0.37	0.37	0.37	0.36	0.34	0.41	0.41	0.38	0.41
CD @ P=0.05	-	0.97	1.16	1.12	1.05	-	1.04	1.10	0.96	0.88	-	1.04	1.03	1.03	1.00	-	1.14	1.15	1.07	1.14

Average of four replications/treatment/week at four locations; Figures within the Parentheses are Arc sin transformed values; In a column means followed by same letter(s) are not significantly different as per DMRT; * Significant at 5%; NS= Non-Significant.

4. Discussion

This study revealed the probable solution for the management of *H. armigera* infestation by deploying sex pheromone traps for mass trapping and demonstrated the influence of insecticides on trap catches. We observed that the fields deployed with lower trap density, i.e., 10 traps per acre attracted fewer moth catches and it may could be owing to less competition between the traps for mass trapping. Which is similar with study stated, lower number of traps would be highly beneficial for pest monitoring rather than mass collection and weak trap competition could occur when the distance between the traps increases [4]. In parallel to our study, positioning the 10 pheromone traps per hectare can only help to monitor pest build up in order to take timely pest control measures as a part of integrated pest management [30]. Higher trap densities, i.e., 30 and 40 traps per acre also failed to attract the males of *H. armigera,* yet maximum moth catches were recorded from fields with 30 traps per acre and insignificant moth catches were recorded from those with 40 traps. This could be due to the 'high pheromone concentration' in the fields, i.e., an increase in the number of pheromone traps per unit area could reduce the ability of the male adults to recognize the point of release, thereby considerably affecting the mating disruption instead of mass collection. The inference is similar in one of the study, moth collection will be hampered if pheromone concentration exceeds the upper threshold level which would make it difficult for the male moths to distinguish between odour sources [24, 5]. We observed appreciable trap interactions in the fields deployed with 20 traps per acre which also attracted adult males of *H. armigera* significantly in all the four locations. In contradictory to our study, many researchers have reported different trap densities for the mass collection of *H. armigera* in chickpea fields which may be on account of the influence of geographical variations and weather factors on pest population. Some studies were reported that 40 traps per hectare was the optimum trap density for the mass collection of chickpea pod borer [29, 13], whereas 20 traps per hectare also impact on suppression of the pod borer population effectively [36]. Further, standardization of sex pheromone traps has been found effective against several major pests and 20 traps per hectare have been found to result in maximum moth catches of pink boll worm in cotton and yellow stem borer in rice [10, 6]. However, 20 to 40 traps per hectare resulted in maximum moth catches of potato tuber moth, *Phthorimaea operculella* (Zeller)) and 40 traps per hectare was found effective in managing the sweet potato weevil, *Cylas formicarius* (Fabricius) at many locations [16, 19]. Spatial interaction between the traps proved crucial for the effective management of *H. armigera* in the chickpea ecosystem. Hence, this study reports 20 traps per acre was the optimum density to attract the maximum *H. armigera* moths.

The population trends of *H. armigera* have been recorded in two consecutive years. The moth catches appeared from the 49th standard week, (first week of December), but the population density was negligible up to the first week of January 2013 and 2014. Further, the maximum number of moth catches were found in the third standard week in all the treatment modules. Among them, the fields deployed with 20 traps per acre recorded the highest catches of adult males of *H. armigera* in both the years and the volume was comparatively higher in 2013-14. During the present experimental period we observed that, 20 traps per acre continued to lure the chickpea pod borer and copious number of male moths get attracted in third standard week. *H. armigera* moths were first trapped in the second fortnight of December with an average of 2.55 moths per trap and two peaks were observed in their appearance, i.e., in the first fortnight of January and second fortnight of March [32], which was not similar to our finding. A study reported that rapid increase in the pheromone trap catches from February to March with a rise in temperature [3]. Furthermore, the moth catches were positively correlated (r=0.77 and r=0.63) with maximum and minimum temperatures and negatively correlated (r= -0.79) with relative humidity [38].

In this paper, we also incorporated the objective to study the effect of insecticides and pheromone traps for the management of *H. armigera*. While the pheromone traps can only capture adult males and insecticides can control the hidden larvae. Therefore, optimized trap densities of 20 traps/acre were positioned in the insecticide trial fields based on the observations made during 2012-13 and 2013-14. Moth catches were higher in all the treatments initially, but decreased progressively after application of the insecticides. Among the treatments, the fields sprayed with chlorantraniliprole + 20 traps per acre recorded exiguous number of moth catches with minimal infestation followed by those fields treated with indoxacarb and novaluron. Indoxacarb treated fields with 20 pheromone traps also functioned satisfactorily in terms of moth catches but the catches were a little higher compared to the fields treated with chlorantraniliprole. However, we did not get any literatures in this context of experiment to support our study.

Meantime, other trials were also carried out in the similar framework by applying insecticides over chickpea crop without integration of pheromone traps. Results revealed that, significant lower pest infestation was found in the fields treated with chlorantraniliprole among other insecticides. Similarly, other studies were also supported our study and reported that chlorantraniliprole and spinosad were found more effective for the control of *H. armigera* in groundnut ecosystem [12]. After testing the maximum mortality of gram pod borer with different intervals, it was observed that coragen and profenofos treated fields recorded highest mortality compared to fields sprayed with other insecticides such as sannate and emamectin [14]. Whereas, novaluron and clothianidin could not show any notable gain over cost [20]. However, there was no significant difference with regard to the number of moths trapped and percent infestation in fields treated with quinalphos + 20 traps per acre and control. The use of specific insecticides in combination with optimum number of pheromone traps results in good economic yield by keeping the larval and adult pest population under check. The impact of insecticide alone on chickpea pod borer was very much higher in chlorantraniliprole treated fields among other treatments; however, the level of infestation was a little higher than fields treated with chlorantroniliprole+20 traps per acre. This could be attributed to the fact that although the insecticide successfully controlled the larval population but the immature that survived will continued to propagate their population on becoming adults.

5. Conclusion

The extrapolation of our data suggests that, the chickpea fields deployed with 20 traps per acre was highly effective on *H. armigera* and attracted maximum moth catches compared to other trap densities. Incorporation of single spray of chlorantraniliprole at flowering stage along with positioning the 20 traps per acre had a significant impact on the immature as well as adult stages of chickpea pod borer.

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