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Efficacy of integrated pest management strategies against gram pod borer, [*H. armigera* (Hübner)] under chickpea (*Cicer arietinum* L.) agro-ecosystem

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Abstract
The present experiments were laid out at farmer's field in Lalganj Block of District Mirzapur, Uttar Pradesh to find out the efficiency of eco-friendly Integrated Pest Management (IPM) strategies against gram pod borer, *Helicoverpa armigera* (Hübner) in chickpea agro-ecosystem during *Rabi* season of 2013-14 and 2014-15. Among all the IPM modules, Module-2 (M_2) was found superior over all the modules. Results revealed that the minimum per cent pod damage was observed in M_2 (10.1 and 9.9% during *Rabi* 2014 and *Rabi* 2015, respectively). Maximum per cent pod damage was recorded in Module-8 (M_8) (24.8% during 2014 and 26.0% during 2015). The effect of these IPM modules was also observed on the yield attributes. Highest grain yield of 2289, 2317 kg/ha was recorded, respectively in M_2 followed by M_5 with 2106, 2182 kg/ha during *Rabi* 2014 and *Rabi* 2015, respectively. Thus the highest pooled Benefit-Cost Ratio was also recorded in M_2 (5.78:1) and M_6 (5.32:1) of *Rabi* 2014 and *Rabi* 2015, respectively.

Keywords: benefit-cost ratio, chickpea, *H. armigera*, IPM modules, per cent pod damage

Introduction

Chickpea commonly known as 'gram' is an important pulse crop of India and known as king of pulses that grows as a seed of a plant named *Cicer arietinum* L. in the Leguminosae family. Its seeds are eaten as green vegetable, fried, roasted; as snack food and grind to obtain flour and dhal. It also plays an important role in maintaining soil fertility, particularly in dry, rainfed areas (Sudhir *et al*., 2015). Chickpea is the world's third most important food legume. Chickpea production has increased during the past 30 years from 6.5 million tons (1978-1980 average) to 9.6 million tons (2007-09) because of increase in grain yields from 630 to 850 kg/ha during this period (Yogeeswarudu and Venkata, 2014) [19]. India ranks first in the production and consumption of chickpea (*Cicer arietinum* L.) in the world (Parmar *et al.*, 2015) [10]. Per capita production and availability of pulses in the country has witnessed sharp decline. Per capita net pulse availability has declined from around 60 grams per day in the 1950s to 40 grams in the 1980s and further to around 35 grams per day in 2000s, but it has increased from 35 grams per day to 47.2 grams per day in 2015, according to Directorate of Economics and Statistics.

Chickpea is attacked by 57 insect species but *Helicoverpa armigera* is a key pest that causes heavy economic loss throughout the country. Due to its polyphagous nature, the pest has attained a national status and is causing devastating damage (Sachan and Katti, 1994) [12]. One larvae of *H. armigera* is capable of damaging 30-40 per cent pods in its life time. Estimates indicate that 8 larvae reared on 10 plants (in 1m row) caused up to 39 per cent yield loss (Sharma *et al.*, 2006). *Helicoverpa armigera* is responsible for causing sometimes as high as 90 to 95 per cent damage in chickpea (Ali *et al*., 2010) [4].

Control of *H. armigera* is still based on common method that is chemical control, but some problems like; insecticidal resistance and environmental pollution has been created. To overcome these problems, it has resulted in the utilization of integrated pest management (IPM) modules to manage insect population below the economic injury level (EIL). Keeping these points in view, the present investigations were carried out to estimate the per cent pod damage, yield and Benefit-Cost Ratio.

Investigations on IPM were undertaken in 900 m^2/ module area with eight modules as detailed in Table 1.

Materials and Methods

The field investigations were conducted during *Rabi* seasons of 2013-2014 and 2014-2015 at farmer's field in Lalganj block of District Mirzapur (UP) by following the normal agronomic practices. Six integrated pest management (IPM) modules were evaluated along with farmer's practice and untreated control. Chickpea cv. Pusa-362 was grown in approximately 900 m^2 (30×30m) plot size for each module under Randomized Block Design (RBD) with 3 replications. Sowing was done in November 2013 and in November 2014. The row to row and plant to plant spacing was maintained as 40×10 cm, respectively, and harvested in March 2014 and in March 2015. Applications of various treatments of different modules are presented in Table 1.

Table 1: Details of IPM modules

S. No.	Treatment imposed	Symbol
Module: 1	Pheromone traps @ 20 ha^{-1}; Profenophos 50 EC @ 2 lt. ha^{-1}; *Bt*. kurstaki @ 1.0 Kg ha^{-1}; Indoxacarb 14.5 SC @ 400 ml ha^{-1}	M_1
Module: 2	Pheromone traps @ 20 ha^{-1}; Profenophos 50 EC @ 2 lt. ha^{-1}; Ha NPV @ 500 LE ha^{-1}; Indoxacarb 14.5 SC @ 400 ml ha^{-1}	M_2
Module: 3	Pheromone traps @ 20 ha^{-1}; Profenophos 50 EC @ 2 lt. ha^{-1}; Azadirachtin 5%; Indoxacarb 14.5 SC @ 400 ml ha^{-1}	M_3
Module: 4	Pheromone traps @ 20 ha^{-1}; Profenophos 50 EC @ 2 lt. ha^{-1}; Azadirachtin 5%; Spinosad 45 SC @ 170 ml ha^{-1}	M_4
Module: 5	Pheromone traps @ 20 ha^{-1}; Profenophos 50 EC @ 2 lt. ha^{-1}; Indoxacarb 14.5 SC @ 400 ml ha^{-1}; Spinosad 45 SC @ 170 ml ha^{-1}	M_5
Module: 6	Pheromone traps @ 20 ha^{-1}; Azadirachtin 5%; HaNPV @ 500 LE ha^{-1}; Bt. kurstaki @ 1.0 Kg ha^{-1}	M_6
Module: 7	Farmers practice of the region (Cypermethrin 25 EC @ 1.25 lt. ha^{-1} + Indoxacarb 14.5 SC @ 400 ml ha^{-1} + Cypermethrin 25 EC @ 1.25 lt. ha^{-1})	M_7
Module: 8	Untreated Control (A control module with no inputs either chemical or non chemical was also kept for the purpose of comparison between the test modules.	M_8

Pheromone traps @ 20 ha^{-1} were installed at 1m above the crop canopy at the end of November. The pheromone traps were monitored once in a week. The larval count was started after the pheromone trap catches exceeded 4 moths/ trap. 5-6 moths per pheromone trap per day for 3-4 days during post winter months was used as a warning signal for close monitoring of eggs and larval population (Ahmad and Chandel, 2004) [2]. Each Pheromone lure was replaced with a new lure after an exposure of 28 days.

For estimation of per cent pod damage, after 80 per cent maturity of the crop pod samples were drawn from 150 randomly selected plants from each module, leaving the border area from each side. Both healthy and damaged pods were plucked from all the 150 plants and pooled together. Three hundred pods were picked up randomly from the pooled pods and data was recorded on per cent pod damage by gram pod borer.

For estimating the grain yield, all the plants from the area of 10m × 10m from 3 places in each module were harvested. The grain yields obtained were converted into kg ha^{-1} and subjected to standard statistical analysis (Singh *et al*., 2009) [14].

The benefit-cost ratio was calculated by the total cost of IPM modules (pheromone traps, insecticides, labour and cost of spraying) and net returns obtained from each module. The benefit value was calculated on the basis of the increased yield over control with supporting price of gram during both the years.

$$\text{Benefit} - \text{Cost Ratio} = \frac{\text{Net return (₹ ha}^{-1}\text{)}}{\text{Cost of IPM module (₹ha}^{-1}\text{)}}$$

The per cent values were transformed to their angular arc sine values and are presented in parenthesis. Necessary statistical analysis was carried out as per the procedure given for the Randomized Block Design (Gomej and Gomej, 1984) [6].

Results and Discussion

Per cent pod damage

The evaluation of different IPM modules during both the years of investigation, on the pod damage of chickpea crop showed that all the modules found significantly superior over the untreated control and presented in Table 2.

During the year 2013-14, among all the modules evaluated, M_2 containing sequential spray of Profenophos 50 EC @ 2 lt. ha^{-1}, Ha NPV @ 500 LE ha^{-1} and Indoxacarb 14.5 SC @ 400 ml ha^{-1} received the lowest pod borer damage (10.1%) followed by M_6 containing the sequential spray of Azadirachtin 5%, HaNPV @ 500 LE ha^{-1} and *Bt. kurstaki* @ 1.0 kg ha^{-1} showing 11.9 per cent pod damage. The module M_8 (untreated control) in the present investigations gave the highest per cent pod damage (24.8%).

Similarly, this trend of pod damage was observed during the year 2014-15 in M_2 (9.9%) and in M_6 (10.7%). Generally, all the modules were found significantly superior in reducing the per cent pod damage by *H. armigera* as compared to untreated M_8 (control). This may be due to the fact that the larval population was highest in untreated M_8 and lowest in M_2 during both the years of experimentation. The control plot in the present studies showed highest pod damage with 24.8 per cent and 26.0 per cent in both the years of experimentation.

Ahmad *et al.*, (1999) [1] evaluated the two application of HaNPV either alone or HaNPV followed by insecticide resulted in effective control of *H. armigera* infesting chickpea. Mean pod damage in treated plots ranged from 4.2 to 6.7 per cent as compared to 10.9 per cent in control, which is in partial agreement with the results of our investigation.

The findings of the present study agreed with the findings of Suganthy and Kumar (2000) [17]. Vikram *et al.*, (2000) [18] who evaluated different IPM modules comprising insecticides and bio-pesticides found superior to untreated control in protection and production. Singh *et al.*, (2009) [14] reported that all the IPM modules were significantly superior in reducing the pod damage by *H. armigera* as compared to untreated control.

Singh *et al.*, (2014) [13] found that Indoxacarb 14.5 SC @ 60 g a.i. ha-1 was effective in controlling *H. armigera*, which ultimately resulted in higher grain yield and more return, based on B-C ratio.

Ahmad *et al.*, (2014) [3] reported that the pods damage due to *H. armigera* was as high as 38.5, 33.2 and 58.8 per cent during first, second and third year of experimentation, respectively in the untreated plots. The yield of chick pea was found to be negatively correlated in relation to the pod damage.

Grain yield

Chickpea yield is decreasing day by day due to many biotic and abiotic factors among which the major factor is direct damage caused by larvae of *H. armigera* (Hübner). Perusal of Table 2 revealed that the highest grain yield 2289 kg ha^{-1} was obtained from module, M_2 and lowest grain yield 1293 kg ha^{-1} was obtained from M_8 (untreated control), during *Rabi* 2013-14. Similar trend was also observed during *Rabi* 2014-15, where highest grain yield 2317 kg ha^{-1} was obtained from M_2 and lowest grain yield 1205 kg ha^{-1} was obtained from M_8 (untreated control). This may be due to the fact that the lowest larval population was observed from M_2 and highest larval population was observed from M_8 (untreated control) in both the years of investigation. The more larval population resulted greater damage to the pods of the crop and provided the lower yield in M_8 (untreated control). Similarly, the low larval population resulted less damage to the pods and provided the greater yield in M_2. However, all the IPM modules tested provide significantly higher grain yield including M_7 (farmer's practice) over M_8 - untreated control (Table 2).

Present findings are in conformity with the results of Singh *et al.*, (2009) [14]. They reported that the yield of chickpea grain was higher as compared to untreated control. Hossain *et al.*, (2010) [7] reported that out of seven modules studied, module 5 consisting of sequential first spray with Helicoverpa nuclear polyhedrosis viruses (HNPV) @ 500 LE/ha and second spray after seven days interval with Cypermethrin @ 1 ml/ litre gave the best protection with the lowest pod borer damage (4.6%) and provided the highest yield (2096 kg ha^{-1}), whereas the lowest yield (1764 kg ha^{-1}) was recorded in untreated control.

Singh *et al.*, (2014) [13] found that all the treatments were effective in controlling *H. armigera.* Indoxacarb 14.5 SC @ 60 g a.i. ha-[1] was most effective treatment for *Helicoverpa* management as this resulted higher grain yield.

Ahmad *et al.*, (2014) [2] found that the egg count as well as larval mortality was significantly decreased over control with all the insecticides tested after the treatment. Pod damage due to *H. armigera* was as high as 38.5, 33.2 and 58.8 per cent during first, second and third year, respectively in the untreated plots. The maximum yield was obtained from the plot treated with neem oil and NPV. All the insecticides proved to be effective in increasing the yield of chick pea over control.

Per cent yield increase over control

During 1st year of the investigation, it varied from 22.1 per cent in M_7 to 77.0 per cent in M_2 followed by 62.9 per cent in M_5, 58.4 per cent in M_6, 55.1 per cent in M_1, 43.9 per cent in M_4 and 39.7 per cent in M_3. During 2nd year of the investigation, same trend was observed ranging from 25.3 per cent in M_7 to 92.2 per cent in M_2 followed by 81.1 per cent in M_5, 66.1 per cent in M_6, 64.1 per cent in M_1, 55.7 per cent in M_4 and 48.5 per cent in M_3. Result revealed that the highest yield was recorded in M_2 followed by M_5, M_6, M_1, M_4, M_3 and M_7 in both the years of investigation in 2013-14 and 2014-15.

Benefit: Cost Ratio

In the present investigation, the data on cost of protection, total return, realization over control and benefit-cost ratio with respect to different IPM modules are presented in Table 3. In the year 2013-14, total cost of protection involved in different IPM modules varied from ₹4570 in M_6 to ₹7870 in M_5 and total return was obtained minimum of ₹48980 in M_7 and maximum ₹70959 in M_2. Further, realization over control was minimum ₹8897 in M_7 and maximum ₹30876 in M_2 followed by ₹25203 in M_5, ₹23405 in M_6, ₹22103 in M_1, ₹17608 in M_4 and ₹15903 in M_3. Despite lower yield, better benefit-cost ratio (BCR) was calculated in M_6 (5.12) as compared to M_5 (3.20). Highest benefit-cost ratio was obtained from M_2 (5.40) and lowest was in M_7-farmer practice of the region (1.71).

In the year 2014-15, BCR improved in most of the IPM modules and highest BCR was recorded in M_2 (6.17) due to lower cost of protection compared than M_4 and M_5. The BCR in order of merit in different IPM modules was 6.17 in M_2, 5.53 in M_6, 4.41 in M_1, 3.94 in M_5, 3.58 in M_3, 3.05 in M_4 and 1.86 in M_7-farmer's practice of the field (Table 4).

The present findings are in conformity with the earlier findings of Suganthy and Kumar (2000) [17]; Singh and Kumar (2012) and Kumar *et al.*, (2013) [8]. Thus, integrated management using low doses of insecticides were found to be better options as reported by Nagmani *et al.*, (2013) [9] and Kumar *et al.*, (2014).

The data over two years (2013-14 and 2014-2015) experimentations are presented in Table 5. The data revealed highest benefit-cost ratio in module, M_2 (5.78) followed by M_6 (5.32), M_1 (4.18), M_3 (3.32), M_5 (3.09), M_4 (2.78), respectively. The lowest benefit-coast ratio was obtained from M_7-farmer's practice as 1.78.

The present findings are more or less close to Sabir *et al.*, (2008) [11] they reported the benefit-cost ratio of 4.27 in IPM conditions over non-IPM one. Bhosle *et al.*, (2009) [5] recorded the benefit-coast ratio for IPM and non-IPM condition was 1.52 and 1.01, respectively.

Therefore, on the basis of the above results regarding to evaluation of different treatments of IPM modules with untreated control, it can be concluded that the M_2 (Pheromone traps @ 20 ha^{-1} + Profenophos 50 EC @ 2 lt. ha^{-1} + Ha NPV @ 500 LE ha^{-1} + Indoxacarb 14.5 SC @ 400 mL ha^{-1}) is the best module as it recorded lowest male moth, lowest larval population, lowest pod damage, highest grain yield and highest Benefit-Cost ratio. The next best module was M_6 and M_5 in consideration of environmental safety and effective management of *H. armigera* with reasonable cost.

These studies clearly revealed the efficacy of various IPM components individually or in integrated approach in the management of pod borer, *H. armigera* in chickpea. Now based on the resources available and the level of management required, the farmers could adopt various management strategies without having deleterious effects on the ecosystem as well as the products.

Table 2: Per cent pod damage by *H. armigera* and yield in different IPM modules

Module	*Rabi* season (2013-14)		*Rabi* season (2014-15)	
	Per cent pod damage	Chickpea grain yield (kg ha^{-1})	Per cent pod damage	Chickpea grain yield (kg ha^{-1})
M_1	14.1(22.06)^{bc}	2006^{cde}	14.4(22.34)^{b}	1978^{c}
M_2	10.1(18.54)^{a}	2289^{f}	9.9(18.33)^{a}	2317^{d}
M_3	17.0(24.35)^{cd}	1806^{bc}	16.9(24.27)^{bc}	1790^{b}
M_4	18.4(25.43)^{d}	1861^{bcd}	19.0(25.84)^{cd}	1876^{bc}
M_5	12.8(20.94)^{ab}	2106^{ef}	14.1(21.23)^{b}	2182^{d}
M_6	11.9(20.17)^{ab}	2048de	10.7(19.06)^{a}	2001^{c}
M_7	20.2(26.72)^{d}	1580^{ab}	21.2(27.43)^{d}	1510^{a}
M_8 (UC)	24.8(29.85)^{e}	1293^{a}	26.0(30.66)^{e}	1205^{a}
SE(m)	0.78	6.61	0.91	5.39
C.D. @ 5%	2.40	20.24	2.78	16.50

UC= untreated control, In a column, treatment means having the same letter are not significantly different by DMRT at 5% level; Figures in parentheses are arc sine transformed value

Table 3: Details of economics and Benefit: Cost ratio in different IPM modules for chickpea during *Rabi* season 2013-14

Module	Cost of IPM (₹ ha^{-1})	Average yield (kg ha^{-1})	Total return (₹ ha^{-1})	Realization over control (₹ ha^{-1})	B: C Ratio (BCR)
M_1	5570	2006^{cde}	62186	22103	3.97:1
M_2	5720	2289^{f}	70959	30876	5.40:1
M_3	5190	1806^{bc}	55986	15903	3.06:1
M_4	6990	1861^{bcd}	57691	17608	2.52:1
M_5	7870	2106^{ef}	65286	25203	3.20:1
M_6	4570	2048de	63488	23405	5.12:1
M_7	5210	1580^{ab}	48980	8897	1.71:1
M_8	750	1293^{a}	40083	-	-

UC= untreated control, BCR= Benefit-Cost Ratio; Minimum Support Price of gram as on 2013-14 = ₹31.0/ kg; In a column, treatment means having the same letter are not significantly different by DMRT at 5% level

Table 4: Details of economics and Benefit: Cost ratio in different IPM modules for chickpea during *Rabi* season 2014-15

Module	Cost of IPM (₹ ha^{-1})	Average yield (kg ha^{-1})	Total return (₹ ha^{-1})	Realization over control (₹ ha^{-1})	B: C Ratio (BCR)
M_1	5570	1978^{c}	62802	24543	4.41:1
M_2	5720	2317^{d}	73565	35306	6.17:1
M_3	5190	1790^{b}	56833	18574	3.58:1
M_4	6990	1876^{bc}	59563	21304	3.05:1
M_5	7870	2182^{d}	69279	31020	3.94:1
M_6	4570	2001^{c}	63532	25273	5.53:1
M_7	5210	1510^{a}	47943	9684	1.86:1
M_8	750	1205^{a}	38259	-	-

UC= untreated control, BCR= Benefit Cost Ratio; Minimum Support Price of gram as on 2014-15 = ₹ 31.75/kg; In a column, treatment means having the same letter are not significantly different by DMRT at 5% level

Table 5: Details of economics and pooled Benefit: Cost ratio of IPM modules in chickpea during *Rabi* 2013-14 and 2014-15

Module	Cost of IPM (₹ ha^{-1})	Average yield (kg ha^{-1})	Total return (₹ ha^{-1})	Realization over control (₹ ha^{-1})	B: C Ratio (BCR)
M_1	5570	1992	62494	23306	4.18:1
M_2	5720	2303	72262	33074	5.78:1
M_3	5190	1798	56410	17222	3.32:1
M_4	6990	1868.5	58627	19439	2.78:1
M_5	7870	2144	67283	28095	3.09:1
M_6	4570	2024.5	63510	24322	5.32:1
M_7	5210	1545	48662	9274	1.78:1
M_8	750	1249	39188	-	-

UC= untreated control, BCR= Benefit Cost Ratio; Minimum Support Price of gram as on 2013-14 = ₹ 31.0/kg and as on 2014-15 = ₹ 31.75/kg

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