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Restricting lepidopteran herbivory through trap cropping and bird perches in Egyptian clover (*Trifolium alexandrinum* L.)

Ravinder Kumar^{1*}  and Harpreet Kaur Cheema²

Abstract

The Egyptian clover L. is a winter season leguminous forage that supports a great diversity of insect pest populations in the Northern Indian Plains. In the context of evolving non-chemical approach for pest control, different trap crops viz. marigold, *Tagetes erecta*; chickpea, *Cicer arietinum* L.; and sunflower, *Helianthus annuus*, were planted as border rows around the clover plots to trap lepidopteran larvae. The push and pull strategy was further augmented by the help of neem seed kernel extract (NSKE) 3% spray on the main crop. Services of insectivorous birds were utilized through T-shaped bird perches for feeding on lepidopteran larvae. The lowest larval population of *Helicoverpa armigera* (2.29 individuals/m row length) was recorded in the plots with the trap crops such as marigold and bird perches, and those that received neem insecticidal sprays which indicated the decrease of larval population due to the repellent action of neem gave (75.8%) a reduction in larval population than the sole cropped plots, followed by chickpea (2.58 larvae; 72.8%) reduction in larval population and sunflower (3.53 larvae; 63%). Sunflower recorded the highest number of *H. armigera* population, at flowering stage of berseem which depicted the suitability of sunflower for the attractiveness of low number of the larvae (2.75 larvae/m row length) on berseem. The plots with berseem as a sole crop without any control measure exhibited significantly high *H. armigera* larvae (12.95 larvae per meter row length). The fecundity of pod borer on different trap crops revealed the highest fecundity population (7.25 larvae) of *Helicoverpa* on either chickpea or sunflower as trap crops. During the vegetative phase of berseem and the flowering stage of marigold and sunflower, these were recorded as favorable hosts. The highest green fodder yield (GFY; 1115 q/ha) was recorded in plots sown with marigold as the trap crop and with bird perches and in plots that received NSKE sprays as compared to sole cropped plots (700 q/ha). The data on seed yield also revealed superiority of berseem plots with sunflower, as a trap crop, and also a high parasitization by parasitoids.

Keywords: Egyptian clover, Trap crop, Bird perches, Lepidopteran pests, Neem insecticide

Background

The Egyptian clover (berseem), *Trifolium alexandrinum* L., a nitrogen-fixing, multi-cut forage crop, is cultivated around 2 million hectares in entire India, spanning the north west zone, the hill zone, and part of the central and eastern zone of the country. A broad spectrum of lepidopteran and other species of insect pests hampers crop establishment, impairs forage quality, and reduces green fodder and seed yield (Saxena et al. 2002). Insect pests such as the American bollworm (*Helicoverpa armigera* Hub.), beet armyworm

(*Spodoptera exigua* Hub.), Bihar hairy caterpillar (*Spilosoma oblique* Walk.), hairy caterpillars (*Euproctis virguncola* and *E. lunata*), green semi-looper (*Plusia nigrisigna* Wlk.), *Thysanoplusia orichalcea* Fab.), cowpea aphid (*Aphis craccivora* Koch.), and leaf miner (*Phytomyza* sp.) are reported to cause damage to berseem during their different growth stages (Shah et al. 2010). The use of pesticides in forage crops has certain constraints, such as low feasibility due to high cost/benefit ratio, residue accumulation in the food chain through milk and milk products, and even direct toxicity to livestock (Koli and Bhardwaj 2018). Due to the lipophilic nature of pesticides, they easily get accumulated in milk and other fat-rich substances finding its way through animal-derived products (John et al. 2001). Considering these high-

* Correspondence: drravinderchandel@pau.edu

¹Department of Vegetable Science, Punjab Agricultural University, Ludhiana, India

Full list of author information is available at the end of the article

risk factors, eco-friendly pest management methods are being continuously worked to reduce pesticide usage and improve habitat diversification (Poveda et al. 2008).

Trap cropping is essentially a method of concentrating a pest population into a manageable area by providing the pest with an area of a preferred host crop and, when strategically planned and managed, can be utilized at different times throughout the year to help manage a range of pests (Hokkanen 1991; Zehnder et al. 2007; Shelton and Perez 2009). For enhancement of trap cropping effectiveness, ensure that the attractive phenological stage for pest oviposition starts earlier and lasts longer in the trap crop than in the main crop (Rhino et al. 2014). Sandhu and Arora (2014) observed that marigold was the most effective trap crop for *H. armigera* fecundity, recording maximum numbers of eggs and larvae with similar support for coriander as preferred host over tomato crop. Kumar et al. (2017) reported the lowest incidence of *H. armigera* was when chickpea was intercropped with linseed at the ratio of 2:2 followed by chickpea + mustard at 2:2. The equivalent yield of chickpea was highest when intercropped with coriander at 2:2 ratio, followed by chickpea + coriander (2:1) and chickpea + lentil at 2:2 ratio.

Ecosystem services provided by insectivorous birds are also a significant component as natural regulators of harmful insects, and their mobility allows them to respond numerically to pest population increase (Woods 1974). Though India is bestowed with a rich heritage of avian diversity, the beneficial role of insectivorous birds in the insect pest management has not received much recognition beyond faunastic documentation. Robinsons and Holmes (1982) reported that vegetation structure, plant species composition, prey abundance, and distribution significantly affected the foraging height selection of insectivorous bird species. In chickpea, birds like myna, sparrow, babbler, black drongo, cattle egret, etc. feed on borer larvae and cause significant reduction in pod damage with resultant high yield (Parasharya et al. 2002; Gopali et al. 2009). Mehta et al. (2010) conducted studies for management of *H. armigera* in tomato fields using neem biopesticide and T-shaped bird perches reported 9 bird species fed on *H. armigera* larvae in tomato crop. *Pycnonotus cafer* and *Acridotheres tristis* used the T-shaped perches more frequently than other species. In plots where T-shaped perches were installed, the larval survival was less than in the netted and control plots. Gregory and Sieving (2005) reported predatory birds like black drongo, house sparrows, blue jays, cattle egret, rosy pastor, and mynah have been commonly recorded as predators on large numbers of *H. armigera* and lepidopteran insect species on vegetables, if the sunflower is grown as a crop to attract a large number of insectivorous birds.

For testing the hypothesis, we (1) tested the potential of different trap crops and synchronized the susceptible

stage of berseem clover with that of trap crop as a source to divert the lepidopteran herbivore, (2) studied the role of bird perches, and (3) evaluated the biopesticide along with trap crop to enhance control potential.

Materials and methods

The study was carried out at the Forage Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana (latitude 30.91098 and longitude 75.8012), in the winter seasons of years 2015–2016 and 2016–2017. The berseem variety (BL 42) (multi-cut forage with large number of side tillers per unit area) was sown by a hand-driven rake (row of tines fitted on iron plate) with a row-row spacing of 30 cm. All the cultural practices were applied as per standard recommendation, except use of chemical pesticides. Concept of trap crop selection included winter (marigold and chickpea)/summer season (sunflower) crops, grown as the outer 2 outer rows around the periphery of plots that measured 5 × 8 m². The treatments were arranged in a randomized block design, with 3 replications/treatment. Among treatments, an isolation distance of 10 m planted with other forage crops viz. oats, *Avena sativa*, which are known to be not commonly infested with a high population of lepidopteran pests under N-Indian conditions.

Trap crop planting

Planting of trap crops was planned to match the susceptible growth stage of the main crop in order to shift the pests' load. Two trap crops viz. marigold *Tagetes erecta* (Punjab Sugandh variety having flowers with multi whorl ray florets-mw) and chickpea *Cicer arietinum* L. (PBG 7 variety having tall, semi-erect plants, lush green foliage, and long duration crop) were planted after sowing of berseem in early October. Another trap crop, comprising the sunflower, *Helianthus annuus* (hybrid PSH 1962: medium tall hybrid with bold seeds), was planted in allotted plots at a 30-cm P-P spacing around the periphery at the end of January to coincide with the flowering of trap crop as well as the main crop. The effect of trap crops was further accentuated by a neem insecticidal spray (Neem Baan at 3%) as feeding deterrent/repellent to attract maximum population of lepidopteran pest on trap crops. Numbers of eggs and larvae of *H. armigera*, *Spilosoma oblique* (Walk.), and *Spodoptera exigua* (Hub.) were recorded simultaneously from 1-m row length in the main crop (Egyptian clover) area as well as per plant population for trap crop. The mean data was compared to plots having a sole crop of berseem without any border row and also against plots receiving no spray of neem insecticide within the trap crop plotted area. In addition, beneficial services of natural enemy arthropods viz. parasitoids and predators were also confirmed by collecting the parasitized eggs or larvae from the tested field at fortnightly intervals. The

observations were recorded in vivo for emergence of parasitoid, and percent larval parasitization was calculated. Yield data (green fodder yield and seed yield) was recorded per plot and converted to equivalent yield on an area of hectare after suitable transformation.

Bird perches

The avian diversity in berseem ecosystem for their predatory services as identified through the documentation of Salim and Dillon (1983) was studied through T-shaped bird perches. It consisted of a vertical wooden stick of 1-m length with a horizontal 60-cm stick affixed at the top, secured tightly with nylon rope to provide solid platform for alighting avian predators. The T-shaped bird perch was fixed at a height of 80 cm above the ground in all experimental plots. In the observation on diversity of predatory birds (Salim and Dillon 1983), foraging activity was recorded across all the plots twice a week, coinciding with appearance of pest in the crop. The reduction percentages of larval population due to treatment affect (trap crop, bird perch, and neem spray) was calculated on the basis of the plots compared to sole crop without any border rows.

Statistical analysis

The experimental data was subjected to statistical procedure, using analysis of variance for randomized block design, and treatment means were separated by least significant difference test (Gomez and Gomez 1984). ANOVA was used to account the potential effects of treatments over time, using statistical software CPCS-I (Cheema and Singh 1991). Data were log transformed [$\lg(N+1)$] or square-root transformed ($N+0.5$) when necessary to meet normality assumptions.

Results and discussion

Data on the effect of integrated strategies for pest management in Egyptian clover showed significant effects on

population density of lepidopteran caterpillars in comparison to the sole cropped plots.

H. armigera population

As shown in Table 1, larval population recorded during the vegetative stage of berseem started appearing during March (3.22–7.48 larvae/m row length) across all the treatments, and its population tends to decline in April over the two seasons of study (Table 1). The berseem plots with border row of marigold, chickpea, and sunflower as trap crops with additional neem seed kernel extract (NSKE) sprays harbored larval numbers comparatively lower than the plots with same trap crop without spray of biopesticide. Statistically significant differences were recorded than the plots with berseem as sole crop. The lowest larval population of *H. armigera* (overall pooled mean value 2.29 larvae/m row length) was recorded in plots with border rows of marigold along with bird perches and foliar NSKE sprays indicating the shift of *Helicoverpa* caterpillars due to repellent action of neem, providing (75.8%) reduction in larval population than in marigold only (4.06 and 57.35% reduction). Chickpea as a trap crop also recorded non-significant difference in larval counts (2.58 larvae with NSKE spray and 5.03 without spray (72.8 and 47.16% reduction in larval population, respectively)). Similarly, sunflower recorded 3.53 and 5.18 larvae for spray and non-sprayed with NSKE, respectively. The berseem plots that received NSKE sprays, at 5-day intervals during the observation period, recorded 4.37 larvae of pod borer being statistically on-line with plots sown with trap crops and bird perches alone. However, among all treatments, significantly, the highest larval population (9.52 larvae) was recorded in plots with berseem as a sole crop receiving no pest control intervention.

Furthermore, *H. armigera* population observed at the flowering stage of berseem (Table 2) depicted sunflower as a suitable crop for attracting the maximum number of larvae with lower population (larvae/m row length) on berseem crop (4.0) and 2.75 with additional spray of

Table 1 Larval population of *H. armigera* in different treatment combinations in berseem during vegetative growth stage

Treatments	<i>H. armigera</i> population/m row length in Egyptian clover					Pooled mean	Reduction (%)
	1st week March	2nd week March	3rd week March	4th week March	1st week April		
T ₁ : marigold + bird perches	5.29 (2.50)	5.15 (2.47)	4.00 (2.23)	3.23 (2.05)	2.63 (1.90)	4.06 (2.03)	57.35
T ₂ : marigold + bird perches + NSKE	3.22 (2.05)	2.33 (1.82)	2.10 (1.76)	1.90 (1.70)	1.90 (1.69)	2.29 (1.80)	75.8
T ₃ : chickpea + bird perches	6.20 (2.68)	5.51 (2.55)	5.0 (2.44)	4.66 (2.37)	3.80 (2.19)	5.03 (2.44)	47.16
T ₄ : chickpea + bird perches + NSKE	3.78 (2.18)	3.23 (2.05)	2.96 (1.99)	2.33 (1.82)	1.96 (1.72)	2.58 (1.95)	72.8
T ₅ : sunflower + bird perches	6.16 (2.67)	5.85 (2.61)	5.40 (2.50)	4.56 (2.35)	3.96 (2.22)	5.18 (2.47)	45.6
T ₆ : sunflower + bird perches NSKE	4.71 (2.39)	4.33 (2.30)	3.60 (2.14)	2.83 (1.95)	2.20 (1.78)	3.53 (2.11)	63.0
T ₇ : NSKE at 3%	6.31 (2.70)	5.86 (2.61)	5.20 (2.48)	4.36 (2.31)	4.50 (2.34)	4.37 (2.48)	54.0
T ₈ : sole crop	7.48 (2.91)	7.46 (2.90)	8.50 (3.0)	10.66 (3.41)	13.66 (3.82)	9.52 (3.20)	–
CD ($p=0.05$)	0.13	0.13	0.15	0.20	0.25	0.56	

Figures in parenthesis are $\sqrt{n+1}$ transformed value

Table 2 Larval population of *H. armigera* in different treatment combinations in berseem during flowering stage

Treatments	<i>H. armigera</i> population/m row length in Egyptian clover					Pooled mean	Percent reduction
	1st week March	2nd week March	3rd week March	4th week March	1st week April		
T ₁	7.0 (2.82)	10.25 (3.34)	6.5 (2.73)	4.0 (2.23)	3.0 (1.97)	6.15 (2.63)	52.50
T ₂	4.5 (2.33)	5.5 (2.54)	5.5 (2.54)	2.75 (1.91)	1.75 (1.64)	4.0 (2.20)	69.11
T ₃	9.75 (3.27)	12 (3.6)	9.25 (3.19)	6.0 (2.41)	3.25 (2.05)	8.05 (2.96)	38.0
T ₄	5.0 (2.44)	8.0 (2.99)	7.25 (2.86)	4.75 (2.49)	2.75 (1.92)	5.55 (2.53)	57.14
T ₅	4.75 (2.39)	6.0 (2.64)	5.75 (2.58)	3.0 (2.43)	1.5 (1.57)	4.2 (2.24)	67
T ₆	3.0 (1.99)	3.5 (2.10)	5.0 (2.44)	1.5 (1.99)	0.75 (1.28)	2.75 (1.89)	78
T ₇	4.0 (2.23)	6.75 (2.78)	7.25 (2.86)	3.5 (1.72)	2.75 (1.91)	4.85 (2.39)	62.5
T ₈	13 (3.73)	16.75 (4.20)	18.25 (4.38)	12.75 (3.70)	4.0 (2.86)	12.95 (3.65)	–
CD ($p = 0.05$)	0.32	0.31	0.29	0.38	0.36	0.30	

Figures in parenthesis are $\sqrt{n+1}$ transformed value

NSKE (5%). It also showed a maximum percentage of reduction percentage (78%) in the larval population, followed by marigold (69.11%). Berseem plots planted with chickpea as the trap crop alone recorded 8.05 pod borer larvae/m row length opposed to 5.55 larvae in case of NSKE spray providing 38.0 and 57.14% larval reductions, respectively. The plots with berseem, as a sole crop without any control measure, exhibited significantly high *H. armigera* larvae (12.9/m row length).

Fecundity of the pod borer on different trap crops of the berseem during vegetative and flowering phase showed maximum eggs of *Helicoverpa* egg count (7.25 eggs/plant) on either chickpea or sunflower as trap crops and received additional NSKE spray. Marigold, as a trap crop, recorded a comparatively lower fecundity (6.0 larvae) though statistically at par with other two crops receiving NSKE repellent spray. The egg counts on different trap crops and bird perches without neem spray were in the range of 3.75–5.25 eggs during the observation period. Furthermore, *H. armigera* fecundity during flowering stage of berseem was recorded to be high on marigold and sunflower (13.25 and 13 eggs/plant) and (10.0 eggs) in the case of marigold as a trap crop with

bird perches and received neem spray. The numbers of eggs laid per plant in other treatments ranged from 3.25 to 7.50 eggs (Table 3).

Other lepidopteran pests

The larval population of other lepidopteran pests, viz. hairy caterpillar *S. oblique*, appeared only on the main crop ranging from 0.5 to 2.25 larvae/m row length of berseem crop (Table 3) being statistically at par irrespective of plots with different trap crops. In the case of *S. exigua*, the larval population was recorded to be the highest (6.75 larvae/m row length of berseem) with sunflower as a trap crop. Other plots showed a range of 0.25–3.5 larvae across different treatments with a sole trap crop or neem-sprayed plots.

Green fodder yield

Forage yield as GFY and seed yield showed significant differences across different treatment combinations than to the berseem as a sole crop. The highest GFY (1115 q/ha) was recorded in plots sown with marigold as a trap crop, with bird perches and receiving NSKE sprays. It was significantly superior to all other treatments under consideration. GFY across other treatment plots varied in range of 1002–

Table 3 Per plant egg and larval counts of *H. armigera* and other lepidopteran larvae on trap crop (per plant) in relation to berseem growth stages

Treatments	No. of eggs of <i>H. armigera</i>		Larval population of <i>H. armigera</i>		Larval population	
	Vegetative stage	Flowering stage	Vegetative stage	Flowering stage	<i>Spilosoma oblique</i>	<i>Spodoptera exigua</i>
T ₁ : marigold + bird perches	3.75 (2.16)	10 (2.32)	1.5 (1.53)	5.25 (2.49)	1.5	1.0 (1.39)
T ₂ : marigold + bird perches + NSKE	6.0 (2.63)	13.25 (3.77)	3.0 (1.99)	6.5 (2.73)	2.25	0.25 (1.10)
T ₃ : chickpea + bird perches	5.25 (2.49)	3.25 (2.03)	3.75 (2.17)	3.5 (2.11)	2.0	3.0 (1.95)
T ₄ : chickpea + bird perches + NSKE	7.25 (2.86)	4.5 (2.32)	5.0 (2.44)	2.75 (1.91)	0.5	1.5 (1.57)
T ₅ : sunflower + bird perches	4.75 (2.39)	7.5 (2.91)	1.25 (1.47)	8.0 (2.99)	2.5	6.75 (2.74)
T ₆ : sunflower + bird perches NSKE	7.25 (2.87)	13 (3.73)	1.5 (1.53)	10 (3.30)	1.0	3.5 (2.1)
CD ($p = 0.05$)	0.34	0.37	0.27	0.32	NS	0.54

Figures in parenthesis are $\sqrt{n+1}$ transformed value

1075 q/ha than the control (700 q/ha). On the contrary, the data of seed yield revealed the superiority of berseem plots with sunflower as a trap crop + bird perches + NSKE sprays, recording highest seed yield (4.62 q/ha). In other treatments, the range of seed yield was recorded to be (2.67–4.12 q/ha) higher than that (2.20) obtained in the case of berseem plots as a sole crop.

The present study related to the system of trap cropping and other bio-intensive methods in berseem resulted in statistical difference among treatments for egg and larval count of *H. armigera* on traps as well as the main crop. The repellent action of NSKE spray at 3% was evident in all plots irrespective to the trap crop with shift of larval population from berseem to a trap crop. These studies are in conformity to the results of Shah et al. (2010) who evaluated various combinations of botanicals for the management of pests/diseases in berseem (*Trifolium alexandrinum* L.) mixed with mustard (*Brassica compestris* (Linn.) Watt.) fodder production. It showed various combinations of botanicals and seed coating with neem seed kernel powder and neem seed kernel extract provided maximum protection (68.22% reduction in the root rot intensity in berseem and a reduction of 70.28% in aphid population in mustard). Consequently, an increase of 33.61% occurred in green forage yield over the untreated plots. Basha et al. (2017) observed chickpea intercropped with mustard in the north-east plains zone, and chickpea intercropped with safflower or linseed in the peninsular zone of India was highly attractive to chickpea pod borer than in sole crops. Wheat, coriander, safflower, and sunflower intercropped with chickpea considerably decreased pod borer damage to reach 5–6% as compared to 16% pod damage in a sole crop. The highest reduction percentage (75.8%) was recorded in the case of marigold as a trap crop and chickpea, attributed to being the highly preferred host plants for *H. armigera*. Studies of Hussain and Bilal (2007) on tomato for *H. armigera* control showed that proportion of larvae counted on a trap row increased with increasing rate while on the main crop decreased with decreasing rate at 65 and 80 days after

transplanting. All the treatment combinations recorded the lowest fruit damage and larval population on tomato but trapped high larvae on marigold. Moreover, 3:1 (tomato: marigold) combination resulted in 81.0–88.89% larval reduction than sole crop and was significantly superior to other treatments. In a study with 4 trap crop species to control *Crociodolomia pavonana* (Lepidoptera: Crambidae), Smyth et al. (2003) stated that the periods of highest preference of *C. pavonana* for all the tested plants were ephemeral and that trap crops would have to be planted sequentially in order to be present throughout a period of the highest cabbage susceptibility.

From the present study, it is evident that plots with sunflower as a trap crop had less preference during the vegetative growth phase of Egyptian clover than other trap crops with comparatively low number of flower buds and their small size during the period of March–April as that of chickpea and marigold. Furthermore, as the growth of berseem progresses towards flowering/seed formation phase coinciding with bud/flower initiation of sunflower crop, it attracted the maximum number of larvae on sunflower as trap crop with the highest percent reduction (78%) of larval population on berseem than in marigold (69.11%) with small size of flower buds at that period, followed by chickpea (57.14%) approaching the maturity/harvesting phase. Even berseem plots with sunflower as a trap crop without NSKE spray showed 67% less number of *H. armigera* larvae in comparison to sole cropped plots.

The fecundity of *H. armigera* on different trap crops recorded during vegetative and flowering stages of berseem showed the trend of highest number of eggs per plant on chickpea and marigold as preferred host plants for oviposition (Table 3). As number of larvae on trap crops, chickpea was a favorable host (5.0 larvae/plant) for *Helicoverpa* with synchronous leafy stage of trap as well as the main crop. However, at the flowering stage of berseem, the larval population of pod borer (8.0–10.0 larvae/plant) tended to shift towards sunflower as a trap crop with co-existence of flower heads of both traps as well as main crop which was

Table 4 Green fodder and seed yield in different treatment combinations

Treatments	Green fodder yield (q/ha)	Percent increase in yield (GFY)	Seed yield (q/ha)	Per cent increase in yield (seed)
T ₁	1049	33.26	3.85	42.0
T ₂	1115	37.21	4.12	46.0
T ₃	1002	30.1	2.67	21.0
T ₄	1075	34.88	4.0	45.0
T ₅	950	26.31	4.12	46.0
T ₆	1057	33.77	4.62	52.0
T ₇	1015	31.03	3.77	41.0
T ₈	700	–	2.20	–
CD ($p = 0.05$)	25.8	–	16.4	–

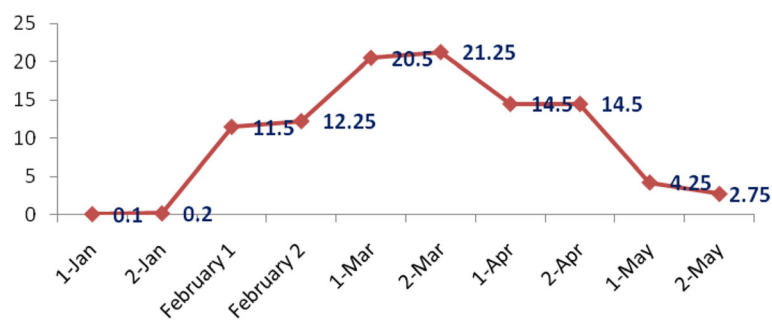
Table 5 Record of insectivorous birds and their activity

Common name	Scientific name	In field (per hour)	Alighted on perch
Cattle egret	<i>Bubulcus ibis</i>	3.4	–
Common myna	<i>Acridotheres tristis</i>	6.2	0.8
House crow	<i>Corvus splendens</i>	5.0	0.4
Red-wattled lapwing	<i>Vanellus indicus</i>	0.4	–
Black drongo	<i>Dicrurus macrocercus</i>	2.6	1.6
Eurasian collared-dove	<i>Streptopelia decaocto</i>	1.8	0.8
Green bee eater	<i>Merops orientalis</i>	1.2	0.8

further exaggerated with repellent NSKE sprays on berseem. These findings are corroborated by the studies on oviposition efficiency of *H. armigera* on trap crops of marigold and coriander by Sandhu and Arora (2014) proving that marigold was the most effective trap crop for *H. armigera*, as the maximum numbers of eggs and larvae were recorded. The highest oviposition percentage of 79.4 ± 2.82 was recorded on marigold. The two coriander cultivars, Punjab Sugandh and local with 61.5 ± 3.58 and $58.2 \pm 5.08\%$, respectively, were also preferred, albeit to a lesser extent, over the tomato plants for oviposition. In the present experiment, apart from eggs and larval populations, other lepidopteran pests viz. Bihar hairy caterpillar *S. obliqua* were also recorded as regular visitors on berseem without apparent host specificity (Table 3). However, in case of beet army worm *S. exigua*, a significantly high number of larvae were recorded in berseem plots sown with sunflower as a border crop being preferred host than the other trap crops.

The GFY (q/ha) as across from different treatment combinations (Table 4) recorded the highest green fodder yield (1115q/ha) produced from plots with chickpea as border row, harboring lowest number (2.29 larvae) than other trap crops with 26.31–34.88%, a high yield irrespective of receiving NSKE sprays or not. On the contrary, seed production was the maximum in plots sown with sunflower as border row with 52% higher seed yield than other sole crops. In other treatments, there was 21–46% increase in seed yield. The highest

seed yield in sunflower may be attributed to large attractive yellow-colored flower heads attracting a maximum number of pollinators and natural enemies and also benefitting berseem clovers in pollination too. Shown in Table 5 are the recorded 7 species of insectivorous birds visiting berseem fields at varying durations. The maximum visit in berseem fields was recorded for *A. tristis* (6.2 times/h), and the least visited was by *Vanellus indicus* (0.4 visits/h). The use of bird perches as substrates for predation activity was recorded to be the maximum in case of black drongo and thus served an important strategy as a part of bio-intensive management of insect pests in berseem clover. Rao et al. (1998) reported the beneficial role of birds to significantly reduce the larval population of *Spodoptera* and *Helicoverpa* in groundnut crop. Golage et al. (2011) evaluated different eco-friendly IPM modules for management of Lucerne, *Medicago sativa* pests. Among the IPM modules tested against *S. litura*, IPM II (*Bt* 0.1% + bird perches) was found significantly superior over other IPM modules at 7 days after treatment. Whereas, IPM I (trap crop + *S. litura* NPV + bird perches) and IPM III (*SINPV* + bird perches) proved to be equally effective against *S. litura* and production of green forage yield. IPM II (*Bt* 0.1% + bird perches) and IPM I (trap crop + *HaNPV* + bird perches) showed less than 1 larva of *H. armigera*/m² after 7 days on average of 2 scheduled treatments. IPM II recorded the highest seed yield (4.05 q ha⁻¹) of Lucerne, followed by IPM I and IPM III.

**Fig. 1** Egg parasitization by *Trichogramma chilonis* recorded on eggs of *H. armigera* in berseem/trap cropping during 2017

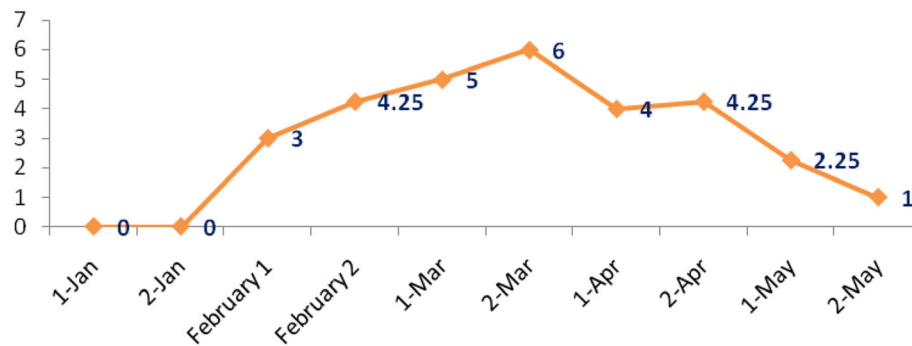


Fig. 2 Parasitization by *Campoletis chlorideae* recorded on larvae of *H. armigera* in berseem/trap cropping during 2017

The population of natural enemies, as recorded in the present study, commenced with appearance of *Trichogramma chilonis*, the egg parasitoid of *H. armigera* with a parasitization observed during January (Fig. 1), thereby increasing to 11.5% in the first fortnight of February and reached a peak of 21.25% during first fortnight of April and thereby started declining to 2.75% in May. In addition, field-collected parasitized larvae showed emergence of the larval parasitoid *Campoletis chlorideae* Uchida (Hymenoptera:Ichneumonidae) feeding on pod borer. The pattern of appearance of this parasitoid showed a peak of 6.0% parasitization in April (Fig. 2). The presence of bio-control agents in berseem was confirmed by Mari and Leghari (2015) supporting that berseem holds a high conservatory potential for control of soft bodied insect pests due to harboring a large number of predators and parasitoids, i.e., coccinellids, syrphids, chrysopids larvae, carabids, and spiders in addition to hymenopteran parasitoids. Based on the field data of predators in the present study, it is advisable that berseem crop should be grown in strips near cash crops as a part of IPM strategy to conserve natural enemy population. This practice would certainly be a step towards exploitation of natural enemies against many insect pests. El Hussein et al. (2018) reported the diversity of important bio-control agents in Egyptian clover, *T. alexandrinum*, the principal forage crop in Egypt, and reported 35 species of predators and parasitoids. According to the above information, it seems that clover fields are very good habitats for numerous biological control agents that distribute safely in these fields far from any chemical control applications.

Conclusion

Trap cropping can be a valuable contribution for agro-ecological management of targeted pests where insecticide usage has its own limitations. The present study contributed to defining this strategy for the Egyptian clover system, thus providing a way to improve the use of some trap crops, marigold and chickpea, as border rows during the vegetative growth stage and sunflower during

seed formation. Furthermore, the push-pull effect was evident from pests' larval counts on trap crops in comparison to the main crop with high outputs in the form of GFY and seed yield in plots with marigold and sunflower as trap crop. The natural enemy population was also considerable with *Trichogramma chilonis* and *Campoletis chlorideae* observed in egg and larval stages of pod borer, respectively. The pattern of appearance of the natural enemies signifies the beneficial effect of trap cropping system in attracting natural enemies for enhanced pest control services.

Abbreviations

ANOVA: Analysis of variance; GFY: Green fodder yield; NSKE: Neem seed kernel extract; PBG: Punjab gram; P-P: Plant-plant; PSH: Punjab sunflower hybrid

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Authors' contributions

RK contributed to the conceptualization of idea and planning of treatment combination, trial layout in the field, sowing of crop, and data recording. HKC contributed to the support in conduct of research trial and data recording. Both authors read and approved the final manuscript.

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Availability of data and materials

The available data is included in the present manuscript.

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Not applicable

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Author details

¹Department of Vegetable Science, Punjab Agricultural University, Ludhiana, India. ²Forage and Millets Section, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, India.

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