Pest Management in Horticultural Ecosystems
Vol. 24, No.2 pp 126-132 (2018)

Farmscaping methods to enhance *coccinellids* and suppress aphid, *Lipaphis erysimi* (Kaltenbach) population in cabbage ecosystem

G. THAIYALNAYAGI[1], N. MUTHUKRISHNAN[2], Y.S. JOHNSON THANGARAJ EDWAD, R. UMARANI[3] and T. ARUMUGAM[4]

[1, 2] Department of Agricultural Entomology, TNAU, Coimbatore-3, Tamil Nadu
[3]Department of Seed Science and Technology, TNAU, Coimbatore-3, Tamil Nadu
[4] Department of vegetable crops, TNAU, Coimbatore-3, Tamil Nadu

***E-mail**:divya.thaiyal@gmail.com

ABSTRACT: Present studies were conducted to enhance coccinellid population to suppress aphids in cabbage ecosystem using farmscaping methods. In this studies cabbage was border cropped with Cowpea, Onion, Lab Lab, Tomato, Coriander and French bean separately during 2017 and 2018 to enhance activity of predatory coccinellids. Cabbage + cowpea border cropping system significantly influenced coccinellids on cabbage 3.26/plant along with highest pest defender ratio (PDR) of 1: 0.8, occurrence ratio (OR) of coccinellids (3.57), attract minimum number of *Lipaphis erysimi* (3.52/inch^2/leaf), preference ratio (PR) of *Lipaphis erysimi*(0.81) and maximum BC ratio (1: 1.75). Followed by cabbage with French bean, Lab lab and tomato border cropping systems also effected for higher population of coccinellids; higher PDR and OR of coccinellids; and minimum *Lipaphis erysimi* and PR; Order of preference of coccinellids towards leaves and flowers was cowpea, French bean, tomato, lab lab, onion and coriander by olfactometer studies.

Keywords: Border crops, cabbage, coccinellids, farmscaping, *Lipaphis erysimi*

INTRODUCTION

Cabbage (*Brassica oleracea* L. var. *capitata*) is the most popular winter vegetables grown throughout India. It is used as salad, boiled vegetable and dehydrated vegetable as well as in cooked curries and pickles. It is also rich in minerals and vitamins A, B1, B2 and C. In India the area under cabbage cultivation is around 395 thousand hectare with 8807 thousand MT production and average yield of 22.0 thaosand MT/ha during 2016-17 (Agricoop, 2017). Indian cabbage ecosystem in general is a rich source of biodiversity of beneficial arthropods and insect pests. The major pests of cabbage on Naraseeuram region are diamondback moth, *Plutella xylostella* (L); cutworm, *Spodoptera litura,* Cabbage looper, *Trichoplusi ani* and aphids. Among the insect pests, aphids alone cause 9-96 per cent reduction in yield (Singh and Sharma, 2012). These aphids are widely distributed throughout the world on all *Brassica* crops (Yue and liu, 2000). The aphids, due to their sucking propensities devitalise the plant tissues leading to yield reduction and their presence reduce the quality of cabbage heads (Bhagat *et al*., 2018). Kennedy, 1958 stated that the apex leaves, as sites of protein synthesis, and the oldest leaves which were going leaf proteolysis, were frequently preferred sites for aphid attack because of high soluble nitrogen levels. This hypothesis has been supported by observations on the distribution of the green peach aphid (GPA), *Myzus persicae* (Sulzer), and the cabbage aphid, *Brevicoryne brassicae* (L.), on a variety of host plants. Plant produced many volatile compounds which guide them towards their host (Kumar *et al*., 2017). Prevailing pest-control strategy has been the utilization of insecticides. But pest population has developed high levels of resistance, and insecticides showed toxicity to non-target parasitoids and predators of cabbage ecosystem.

Farmscaping is a holistic (whole-farm) ecological approach to pest management particularly for insects. Define “deliberate use of specific plants and landscaping techniques to attract and conserve beneficials”. It refers to the arrangement of plants used for economic purposes (cash crops) and insectary plants used for food and habitat for beneficial insects. The use of farmscaping to increase beneficial organism habitat must be understood and practiced within the context of overall farm management goals (Dufour, 2000). Therefore, this study aims at knowing the significances of cabbage and non crucifer flowering crop diversities in the conservation biological control.

MATERIALS AND METHODS

Field experiments were conducted in farmer’s holdings at Viraliur village, Thondamuthur block, Coimbatore district, Tamil Nadu during 2016 - 2017 and 2017 – 20178. Experiments were laid in Randomized Block Design (RBD) with 7 X 7 m^{2}plot size. Cabbage seeds were sown on protray in nursery. After 30 days of sowing seedlings were transplanted as main crop with a spacing of 45X 30 cm. Cowpea (PKM 1), Onion (CO (on) 5),Lab Lab (Arkavijay),Tomato (CO 3), Coriander (CS. 2) and French bean (Arka Anoop) were raised as border crops around cabbage separately (five rows of cabbage and two rows of border crops).

Effect of cabbage and non crucifer border crops to enhance entomophages for pest suppression

All border crops were sown at the season of transplanting of cabbage. Typical agronomic practices like compost application and manual weeding were done according to the prescribed yield creation practices of Tamil Nadu Agricultural University (Anonymous, 2017). No chemical pesticides were connected all through the season. *In- situ* observations on the population of grubs and adults of various species of coccinellids (number/plant) and population of nymphs and adults of *Lipaphis erysimi* (number/inch^2) on cabbage and border crops from 10 randomly selectedplants from every replication were made. Standard taxonomic keys (Poorani, 2002) were utilized for the identification of coccinellid species saw amid the examination.

Observations were taken during early morning hours at seven days interval from 15 days after transplanting (DAT) to 75 DAT. Based on the observations, Occurrence ratio (OR) of coccinellids, preference ratio (PR) of aphids and Pest defender ratio (PDR) were estimated by using the formulae as used by (Muthukrishnan *et al*., 2014). (PDR = Population of natural enemies on cabbage or border crops / population of *Lipaphis erysimi* on cabbage or border crops; OR = Population of natural enemies on border crops / population of natural enemies on cabbage; PR = Population of pests on border crops / Population of pests on cabbage). Cost benefit ratio was estimated by the formula of cost of produce / cost of cultivation + Cost of plant protection (Akila *et al*., 1994).

Behavioral bioassay of predators for host plant volatiles using Olfactometer

Eight arms Olfactometer studies were conducted. About ten gram of healthy plant leaves of individual border crop were kept in individual arm and firmly closed with a lid. The inlet of the Olfactometer on the top center place was connected to an aquarium pump (220-240volt Ac) to release the pressure. Out of the eight arms, leaf samples were kept in six arms and two arms were treated a scontrol. The medical air was passed from aquarium pump atthe rate of 4 lit/min into the Olfactometer. Twenty numbers of coccinellids (male and female) were released to the Olfactometer through a central hole which also served as odour exit hole. Observations were made on number of predators settled on each arms at 5, 10, 15 and 20 MAR. (Minutes After Release) for their host preference. Similar methodology was followed for the flower samples of all theborder crops.

Statistical analysis

The experiments were replicated four times. The data from field experiments and Olfactometer experiments were scrutinized by RBD and CRBD analysis of variance (ANOVA) respectively after getting transformed into $\sqrt{x+0.5}$ using AGRES (Akila and Sundara Babu, 1994). Pooled RBD ANOVA was done using IRRI STAR statistical package. Critical difference values were calculated at five per cent probability level and treatments mean values were compared using Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

RESULT

Population of coccinellids on cabbage and border crops

Through first and second season the observed coccinellid species were; *Coccinella septempunctata, Menochilus sexmaculatu s*and *Coccinella transversalis.* Experiments observations on the population of coccinellids on cabbage at 15, 30, 45, 60 and 75 DAT are given in Table1.

First season mean population of coccinellids ranged from 2.13 to 3.26 per plant due to various border crops. Cowpea border crop was significantly superior in increasing the coccinellids to 3.26 per plant. French bean and Lab lab border crops were the next best and achieved population of 3.01 and 2.86 per plant respectively. These 3 border crops were significantly influenced for the maximum population of coccinellids on cabbage. Tomato, coriander and onion also influence for the higher population of coccinellids 2.75, 2.63 and 2.43 per plant respectively on cabbage. However the minimum population of coccinellids were observed on cabbage alone plot (2.13 per plant). During second season cabbage with the border crops of cowpea, French bean, lab lab, Tomato and onion recorded maximum population of coccinellids (2.40, 2.35, 2.31, 2.15 and 2.15 per plant respectively) when compared to cabbage alone (1.08 per plant). This was followed by coriander which contributes 1.89 per plant.

Season wise pooled mean population of coccinellids ranged from 1.61 to 2.83 per plant and significantly maximum due to cowpea (2.83/plant with 34.58 % increase over control) and French bean (2.68/plant with 29.01 % increase) border crops. Lab lab and Tomato were the next best border crops that influenced for the higher population of coccinellids (2.59 and 2.45 per plant with 25.38% and 22.51% increase respectively). Onion and coriander border crops resulted in coccinellid population of 2.28 (19.67 % increase) and 2.26 (18.98% increase) per plant. However, non-border crop resulted in 1.61 coccinellids per plant only on cabbage.

In the first season experiment, mean population of coccinellids on various border crops ranged from 0.00 to 7.55 per plant. Maximum coccinellids were observed on cowpea (7.55/plant) and French bean (6.79/plant). These to crops were significantly influence more number of coccinellids populations. Lab lab, and tomato border crops registered next higher coccinellids population 5.90 and 5.86 per plant respectively. In first season no coccinellids were recorded on coriander and onion border crops. Similar trend of population of coccinellids on border crops (4.68, 4.21, 4.07, 3.49, 1.09 and 0.00 / plant on cowpea, French bean, lab lab, Tomato, coriander and onion respectively) was observed in the second season experiment. Pooled season mean population of coccinellids on border crops ranged from 0 to 6.11 per plant. The order of preference of coccinellids was cowpea (6.11/plant), French bean (5.50/plant), lab lab, (4.99/plant), tomato (4.68/plant), coriander (0.55/plant) and onion (0.00/plant). Occurrence ratio of coccinellids was maximum due to cowpea (3.54) and French been (3.18). This was followed by lab lab (2.76) and tomato (2.75). However, both coriander and onion registered no number of occurrence ratio.

Table 1. Effect of cabbage – non crucifer border cropping systems on population of coccinellids

Treatment	Mean population of coccinellids predators (No./plant) on cabbage						
	Cabbage				Border crops		
	Season I *	Season II *	Pooled mean	Percent increase	Season I *	Season II *	Pooled mean
Cabbage + Cowpea	3.26[a]	2.40[a]	2.83[a]	34.58	7.55[a]	4.68[a]	6.11[a]
Cabbage + Onion	2.42[d]	2.15[a]	2.28[b]	19.67	0.00[b]	0.00[c]	0.00[b]
Cabbage + Lab Lab	2.86[bc]	2.31[a]	2.59[ab]	25.38	5.90[a]	4.07[a]	4.99[a]
Cabbage + Tomato	2.75[bcd]	2.15[a]	2.45[ab]	22.51	5.86[a]	3.49[a]	4.68[a]
Cabbage + Coriander	2.63[cd]	1.89[a]	2.26[b]	18.98	0.00[b]	1.09[b]	0.55[b]
Cabbage + French bean	3.01[ab]	2.35[a]	2.68[ab]	29.01	6.79[a]	4.21[a]	5.50[a]
Cabbage	2.13[e]	1.08[b]	1.61[c]	-	-	-	-
SED	0.05	0.11	0.06	-	0.33	0.20	0.32
CD (0.05%)	0.11	0.23	0.12	-	0.68	0.41	0.71

* Each value is the mean of 15, 30, 45, 60 and 75 DAT.

In a column, means followed by common letter (s) is / are not significantly different by DMRT at P=0.05 %.

Population of aphids on cabbage and border crops

Population of aphids on cabbage and border crops at 15, 30, 45, 60 and 75 DAT during first and second year experiments are given Table 2. In first season experiment, mean Population varied from 2.99 to 6.06 per inch^2 / leaf/ plant on cabbage. There was significant variation on the population due to border cropping systems. Cowpea, lab lab and French bean border crops most significantly influenced for the minimum population of aphids on cabbage (2.99, 3.14 and 3.30 / per inch^2 / leaf/ plant respectively). Tomato, coriander and onion border crops also influenced for the lower population of aphids on cabbage (3.57, 4.08 and 4.19 / per inch^2 / leaf/ plant respectively). However, maximum population (6.06 / per inch^2 / leaf/ plant) was observed when cabbage was grown alone. During the second season experiment, mean population ranged from 4.04 to 7.76 per inch^2 / leaf/ plant. Cabbage when border cropped with cowpea, French bean and lab lab registered for the minimum population (4.04, 4.56 and 4.84/ per inch^2 / leaf/ plant) when compared to cabbage alone (7.07 / per inch^2 / leaf/ plant). This was followed by tomato, coriander and onion which contributed for the population of 5.09, 5.28 and 5.60 per inch^2 / leaf/ plant.

Season wise pooled mean population of aphids ranged from 3.52 to 6.91 per inch^2 / leaf/ plant and significantly minimum due to cowpea (3.52/ per inch^2 / leaf/ plant with 49.14 % decrease over control), French bean (3.93/ per inch^2 / leaf/ plant 43.18 % decrease) and lab lab (3.99 / per inch^2 / leaf/ plant with 42.24% decrease) border crops. Tomato and coriander were the next best border crops that influenced for the lower population of aphids (4.33 and 4.68/ per inch^2 / leaf/ plant with 37.32 % and 32.33 % decrease respectively). Onion border crop resulted in population of 4.90 (29.14 % decrease) per inch^2 / leaf/ plant. However, non-border cropped cabbage resulted in 6.91 aphids per inch^2 / leaf/ plant.

In the first season experiment, mean population of aphids on various border crops ranged from 0 to 3.18 per inch^2 / leaf/ plant. Maximum aphids were observed on cowpea (3.18 / inch^2 / leaf/ plant) and French bean (2.95 / inch^2 / leaf/ plant). Lab lab and Tomato was the next best border crop that influenced for attract more population of aphids (2.75 and 2.44 per inch^2 / leaf/ plant). No aphids population was registered in coriander and onion border crops.

Similar trend of population of aphids on border crops (7.88, 6.48, 5.96, 5.39, 0.00 and 0.00/ inch^2 / leaf/ plant on cowpea, French bean, lab lab, Tomato, coriander and onion respectively) was observed in the second season experiment. Pooled season mean population of aphids on border crops ranged from 0 to 5.53 per terminal shoot. The order of preference for maximum population of aphids was cowpea (5.53/ inch^2 / leaf/ plant), French bean (4.71/ inch^2 / leaf/ plant), lab lab (4.36/ inch^2 / leaf/ plant), tomato (3.92 / inch^2 / leaf/ plant).

Table 2. Effect of cabbage – non crucifer border cropping systems on population of Aphids

Treatment	Mean population of aphids / inch ^{2} / leaf/ plant on cabbage						
	Cabbage			Border crops			
	Season I *	Season II *	Pooled mean	Percent decrease	Season I *	Season II *	Pooled mean
Cabbage + Cowpea	2.99^a	4.04^a	3.52^e	49.31	3.18^a	7.88^a	5.53^a
Cabbage + Onion	4.19^c	5.60^d	4.90^b	69.14	0.00^b	0.00^c	0.00^d
Cabbage + Lab Lab	3.14^{ab}	4.84^{bc}	3.99^{cde}	51.85	2.75^a	5.96^b	4.36^{bc}
Cabbage + Tomato	3.57^{bc}	5.09^{bcd}	4.33^{bcd}	58.94	2.44^a	5.39^b	3.92^c
Cabbage + Coriander	4.08^c	5.28^{cd}	4.68^{bc}	67.26	0.00^b	0.00^c	0.00^d
Cabbage + French bean	3.30^{ab}	4.56^{ab}	3.93^{de}	54.39	2.95^a	6.48^{ab}	4.71^b
Cabbage	6.06^d	7.76^e	6.91^a	-	-	-	-
SED	0.07	0.07	0.08	-	0.16	0.14	0.06
CD (0.05%)	0.16	0.15	0.17	-	0.33	0.30	0.15

* Each value is the mean of 15, 30, 45, 60 and 75 DAT.

In a column, means followed by common letter (s) is / are not significantly different by DMRT at P=0.05 %.

Pest defender ratio, occurrence ratio, preference ratio and cost benefit ratios in cabbage and non crucifer border cropping system.

The aphids preference ratio was maximum due to cowpea (0.81) and French bean (0.69). This was followed by lab lab (0.63) and tomato (0.57). No aphids population was registered in coriander and onion border crops. Pest defender ratio (PDR) ranged from 1:0.23 and 1:0.81 due to various border crops. Cabbage + cowpea border cropping system influenced for maximum PDR. French bean and lab lab contributed for higher PDR of 1: 0.68 and 1: 0.65 respectively. PDR of 1: 0.57, 1: 0.48 and 1: 0.47 were resulted in due to tomato, coriander and onion. Cabbage alone however accounted for the minimum PDR of 1: 0.23. Benefit cost ratio (BCR) was maximum (1:1.73) due to cabbage + cowpea border cropping system. This was followed by higher BCR of 1:1.58 and 1: 1.46 due to c French bean and Lab lab. Tomato, coriander and onion however, resulted in BCR of 1:1.33, 1: 1.26 and 1: 1.13) when compared to cabbage which contributed 1: 0.23 (Table 3)

Table 3. Effect of cabbage and non crucifer border cropping systems on pest defender ratio, occurrence ratio, preference ratio and cost benefit ratio

Treatment	Pest Defender ratio on		Occurrence ratio of predators	Preference ratio of pest	Benefit cost ratio
	Cabbage	Border crop			
Cabbage + Cowpea	1:0.81	1:1.11	3.54	0.81	1:1.73
Cabbage + Onion	1:0.47	1:0.00	0.00	0.00	1:1.13
Cabbage + Lab Lab	1:0.65	1:1.14	2.76	0.63	1:1.46
Cabbage + Tomato	1:0.57	1:1.19	2.75	0.57	1:1.33
Cabbage + Coriander	1:0.48	1:0.00	0.00	0.00	1:1.26
Cabbage + French bean	1:0.68	1:1.17	3.18	0.69	1:1.58
Cabbage	1:0.23	-	-	-	1:1.09

Response of coccinellids towards leaf and flower samples by olfactometer

Coccinellids population attracted towards leaf and flower samples of pulse crops at 5, 10, 15 and 20 minutes after release (MAR) in olfactometer are given in Table4. There was significant difference in the attraction of coccinellids in olfactometer arms due to leaf and flower samples of border crops. The order of preference of leaves for the coccinellids was cowpea (2.42 beetles and 12.08% attraction), French bean (1.67 beetles and 8.33% attraction), tomato (1.33 beetles and 6.67% attraction), lab lab (1.25 beetles and 6.25% attraction), onion (1.08 beetles and 5.42% attraction), coriander (1.00 beetles and 5.00% attraction) and cabbage (0.75 beetles and 3.75% attraction). The order of preference of flowers for the coccinellids was cowpea (3.00 beetles and 15.00% attraction), lab lab (2.75 beetles and 13.75% attraction), French bean (2.25 beetles and 11.25% attraction), tomato (2.17 beetles and 10.83% attraction), coriander (1.33 beetles and 6.67% attraction) and onion (1.08 beetles and 5.42% attraction).

Table 4. Behavioral response of coccinellids towards leaf and flower samples of cabbage and border crops by olfactometer

Treatment	No. attracted towards leaves at MAR						No. attracted towards flowers at MAR					
	5	10	15	20	Mean	Percent attraction	5	10	15	20	Mean	Percent attraction
Cowpea	1.00^{b}	2.00^{a}	2.67^{a}	4.00^{a}	2.42^{a}	12.08	2.00^{a}	2.67^{a}	3.33^{a}	4.00^{a}	3.00^{a}	15.00
Onion	0.33^{d}	1.00^{d}	2.00^{b}	1.00^{e}	1.08^{de}	05.42	0.00^{e}	1.00^{d}	2.33^{cd}	1.00^{c}	1.08^{c}	05.42
Lab Lab	1.33^{a}	1.00^{d}	2.00^{b}	0.67^{f}	1.25^{cd}	06.25	1.67^{b}	2.33^{a}	3.00^{ab}	4.00^{a}	2.75^{a}	13.75
Tomato	1.00^{b}	0.67^{e}	1.67^{c}	2.00^{c}	1.33^{c}	06.67	1.33^{c}	2.00^{b}	2.33^{cd}	3.00^{b}	2.17^{b}	10.83
Coriander	0.00^{e}	1.67^{b}	0.67^{e}	1.67^{d}	1.00^{e}	05.00	1.00^{d}	1.67^{c}	2.00d	0.6d	1.33c	06.67
French bean	0.67^{c}	1.33^{c}	1.67^{c}	3.00^{b}	1.67^{b}	08.33	1.00^{d}	1.67^{c}	2.67^{bc}	3.67^{a}	2.25^{b}	11.25
Cabbage	0.00^{e}	0.33^{f}	1.00^{d}	1.67^{d}	0.75^{f}	03.75	-	-	-	-	-	-
SEd	0.04	0.05	0.05	0.05	0.04	-	0.05	0.05	0.06	0.06	0.05	-
CD (0.05%)	0.09	0.11	0.12	0.11	0.09	-	0.10	0.11	0.14	0.13	0.12	-

* Each value is the mean of three replication

In a column, means followed by common letter (s) is / are not significantly different by DMRT at P=0.05 %.

DISCUSSION

In the present study non crucifer flowering crops can be used as attractant plants to encourage coccinellids such as *C. sexmaculata*, *Coccinella septempunctata* and *Brumoides suturalis* in and around cabbage (AESA, 2014). Accordingly, six non crucifer crops (flower crops) were raised around cabbage. Among them, cabbage + cowpea, cabbage + French bean and cabbage + lab lab resulted in maximum population of coccinellids and minimum occurrence of aphids. Diversified ecosystems in the form of border crops might have provided continuous availability of resources like proteins, vitamins and minerals to the coccinellids. The results substantiate the observations of Rekha *et al*., 2009 that *C. transversali s*and *B. suturalis* were the dominant taxa in both rice and cowpea ecosystem. Similarly, Chandrasekar *et al*., 2016 also observed highest number of *C. septempunctata* on rice when border cropped with cowpea. According to them, other diversified cropping systems such as rice + sunflower, rice + okra, rice + gingelly, rice + tomato and rice + brinjal also influenced higher population of coccinellids on rice. Lokesh *et al*., 2017 also reported more number of coccinellids on pulse when border cropped with cowpea and French bean. These findings are in corroboration with the resource abundance hypothesis of ecological engineering concept that plants, which offer more resources, have the potential to support more species and greater abundances of insect predators (Hunter and Wilmer, 1989). In the present study, increased availability of grubs and adults of coccinellids due to cowpea, French bean and lab lab border crops might be reason for the fewer occurrences of aphids on cabbage. It was attributed that aphids infesting cowpea might have provided highly preferred prey to coccinellids for their survival and multiplication. Similar results were obtained in rice + cowpea border cropping system which registered maximum population coccinellids and rove beetle on rice and border crops and minimum population of planthoppers and leafhoppers on rice (Chandrasekar *et al*., 2016). Okra + cowpea border cropping system registered a maximum population of dragonflies, damselflies, wasps, predatory pentatomid bugs and coccinellids on okra and border crops, and reduced the population of *Bemisia tabaci* and *Helicoverpa armigera* on okra. This border cropping system also had the highest population of ichneumonid and braconid wasps and tachinid flies on okra and trap crops. These conditions resulted in higher occurrence ratio of natural enemies, higher pest defender ratio, higher yield and cost benefit ratio (Deepika, 2016). The findings are also in line with (Bharathi and Muthukirshnan, 2014) who found that cotton + okra, cotton + brinjal and cotton + tomato trap cropping systems, and cotton intercropped with cowpea, green gram and black gram situations registered a lower population of *P. solenopsis*on cotton, trap crops and intercrops. Preference ratio was less for okra, brinjal, and tomato trap crops and high for sunflower; and less for cowpea, green gram and black gram and high for ground nut intercrops. These trap and inter cropping systems also registered the highest population of coccinellids, chrysopids and spiders on cotton and trap and intercrops as they had higher occurrence ratio, higher yield and cost benefit ratio.

Attraction of coccinellids towards cowpea plants may be due to extra floral nectars present in stipules and inflorescence stalk (Pemberton and Vandenberg, 1993) and flower shape and flower colour (Vattala *et al.,* 2006 , Nicolson and Thornburg, 2007). Provision of substitute foods may be more effective during some phases of the life-cycle than others (Crum *et al*. 1998). Finally, for the incorporation of physical refugia in the field, questions centre on the usefulness of diverse habitats and the ability of natural enemies to commute between the refugium and the pest habitat.

CONCLUSION

This study concluded that cowpea, French bean and lab lab as border crops in cabbage fields could be a better choice for conserving the coccinellids fauna, which is used for the natural suppression of cabbage aphids. In this farmscaping system can be well fitted into integrated pest management in cabbage ecosystem as environmentally safe and cost effective strategy in small farmer's holdings.

ACKNOWLEDGEMENT

Authors are also thankful to Mr. K. Kulandhaivel (progressive pulse farmer), Viraliur, Thondamuthur Union, Coimbatore District, Tamil Nadu for providing facilities for the conduct of experiments and Dean (SPGS), Professor and Head and faculty members of Tamil Nadu Agricultural University,Coimbatore for granting permission to publish the results.

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MS Received 8 September 2018
MS Accepted 16 October 2018