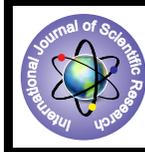


Crucifer Habitat Engineering And Activities Of Diamondback Moth, *Plutella Xylostella* (L.) And It's Natural Enemies



Agriculture

KEYWORDS : Parasitization, Diamondback moth, Non-cruciferous intercrops, *Cotesia plutellae*

G. Thanavendan

Ph.D. Research Scholar; Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, India

J. S. Kennedy

Professor of Agricultural Entomology, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, India

ABSTRACT

*The objective of this study was to determine the effect of engineering the crucifer ecosystem with different intercropping systems on diamondback moth infestations and its parasitoid activity. studies were conducted on cauliflower and cabbage with five different intercropping system in minimizing the incidence of major insect pests. Cauliflower and cabbage were intercropped with crucifer and non-crucifer host plants such as radish (*Raphanus sativus hortensis* L.), marigold (*Tagetes erecta* L.), onion (*Allium cepa* L.) tomato (*Lycopersicon esculentum* L.), coriander (*Coriandrum sativum* L.) and sole crops of cauliflower and cabbage are recorded overall mean incidence of diamondback moth on five plants per plot as 5.00, 4.50, 4.42, 5.67 and 3.19 next to the farmer practices (1.31) and neem oil (3.21) and in cabbage 3.16, 3.64, 1.98, 1.94 and 1.85 next to the farmer practices (1.06) and neem oil (1.71) respectively. *Cotesia plutellae* incidence was highest when cauliflower and cabbage was intercropped with coriander (5.54 and 2.83), followed by neem oil and marigold (2.42 and 1.29). The results showed that cauliflower and cabbage, when intercropped with coriander harboured significantly less DBM larvae, when compared to other intercrops. All intercropping systems with non-crucifer plants significantly support parasitoid and reduced larvae of diamondback moth incidence than the sole crop of cabbage and cauliflower.*

INTRODUCTION

Upon days increasingly involves intensive agricultural practices based on machinery and pesticides, allowing cultivation of vast areas dominated by single crop (monoculture systems) environments. In this context, the term polyculture applies to intercropping and mixed cropping for support of natural enemies (Andow, 1991). Intercropping can be defined as the production or growing of two or more crops simultaneously in the same piece of land (Ofori and Stern, 1987). It is a simple and inexpensive strategy and has been recognized as a potentially benefited technology for increased crop production (Awal *et al.*, 2006).

The most serious pest of crucifer crops worldwide, the diamondback moth, *Plutella xylostella* (L.) was thought to be restricted to the family cruciferous (Talekar and Shelton, 1993). The increasing concern on agricultural sustainability favours the maintenance of the intercropping systems, due to an positive effect on soil conservation and improvement of soil fertility (Jarenyama *et al.*, 2000), more stable yields of intercropping systems using natural resources more effectively (Horwith, 1985). The targets of biodiversity conservation and food production have taken a new perspective since the Millennium Ecosystem Assessment in 2005 (Perrings *et al.*, 2011, Ferreira *et al.* 2012; Melo *et al.*, 2013).

The objective of this study was to describe the insect communities, classified into two functional groups, herbivores and natural enemies, when a plot of intercropping system was introduced into a vegetable production farm to enhance local plant diversity. The scientific questions that oriented our study were: (1) Do less-disturbed habitats such as intercropping systems, favor the establishment of insect communities with higher species diversity and abundance evenness compared with non host crops? (2) Do intercropping system play a role in structuring insect communities, within the functional groups of herbivores and natural enemies, in vegetable production plots? (3) Is the balance in the abundance of herbivores and natural enemies throughout the year? We expected that by answering these questions we could understand the role of intercropping systems in structuring insect communities, with consequences for the abundance of herbivores and natural enemies that contribute to the intercropping ecosystem management and favorable biological control as an ecosystem service reported by Souza *et al.* (2014).

Materials and methods

Experimental design

The experimental design was a randomized complete block design with three replications. Each plot size was 5.0 × 8.0m. Cauliflower and cabbage spacing was 45 cm × 30 cm in both sole cropping and intercropping. Two experiments were conducted during December 2014 to June 2015 of cauliflower and cabbage growing each at Vadavalli and Pooluvapatti in Coimbatore district. Crops were raised with TNAU recommended package of practices and transplanting was done on 25th December 2014 in cauliflower and on 26th February 2015 in cabbage. Cabbage and cauliflower were systematically assigned to the treatment ratios were randomly assigned to the plots. Approximately 6-week old seedlings were transplanted in cabbage, *B. oleracea* var. *capitata* cultivar quisor, and cauliflower *B. oleracea* var. *botrytis* cultivar kimaya and cultivar were obtained from a commercial producer Green Gold Nursery, Thondamuthur, Coimbatore.

Data collection and analysis

All observations were made from centre rows after border rows were discarded to avoid edge effects. Visual count of the diamondback moth (larvae and pupae) was carried out on weekly basis of cabbage and cauliflower experiment in five randomly selected plants in each sub plot. Different plants were surveyed on each week of counting and repeated selection of some plants was performed there after (Andow *et al.*, 1986).

All the data were subject to analysis of variance (ANOVA) for three replications in randomized block design by using AGRSS software. The least significant difference (LSD) was calculated in the treatments were compared by means at $p = 0.05$.

Results and Discussion

Diamondback moth, *P. xylostella*

In both experiments, the plots of cabbage and cauliflower under sown with different intercropping treatments were associated with similar rates of infestation occur at an early stages. Comparison of infestation levels among the intercrops revealed that those with radish had significantly higher larvae and pupae than other treatments. In the cauliflower (Table 1) and cabbage (Table 3) experiment recorded less number of immature diamondback moth in all non host plants except radish. Coriander (10:1) tomato (10:1) and onion (2:1) ratio showed significantly reduced the populations of DBM each of the treatments of both the crops.

On the other hand, the neem oil sprayed plots had the lowest larval populations which however did not differ significantly ($P>0.05$) from the onion and coriander intercrop. Sivapragasam *et al.* (1982) stated that intercropping of tomatoes with cabbage at 1:4 ratio significantly reduced DBM infestation by 36%. Similarly, confirm the mean number of larvae that occurred on tomato intercropped with cauliflower (5.67/plots) was significantly fewer than on the pure crop (6.13/plot) with present results. Talekar *et al.* (1986) also reported that a similar result when cabbage was intercropped with other plant species. It would appear that all the test plants were less attractive to DBM when compared with sole unsprayed crop plots, with tomato intercropped plots being the least preferred by DBM larvae.

Uma Shankar *et al.* (2005) ; Hasheela *et al.* (2010) stated that cauliflower and cabbage when intercropped with coriander harboured significantly less diamondback moth larvae when compared to tomato intercrop treatment and does not support the feeding and development of DBM. The control plot (5.84) attracted the highest number of DBM to lay eggs on cabbages which resulted in higher mean number of larvae per five plants and damage level as compared with tomato (1.85) and other treatments. Broad *et al.* (2008) indicated that the success of crop diversification strategies through cropping systems such as border crops depends on the relative ability of the target herbivore to locate its host plant and the scale of diversity rather than diversity itself. The DBM will reduce both the quality and quantity of the cabbage yields, hence impacting on the farmer income. Therefore, Indian mustard and coriander, which performed better, should be promoted for the management of DBM infestation on cabbage fields. Their adoption is expected to lower usage of pesticides in farmer fields, increase productivity and income of cabbage farmers.

Braconid larval parasitoid, *C. plutellae*

Cotesia is a large group of primary parasitoids of Lepidoptera and recorded about 1500-2000 species worldwide (Rattan *et al.*, 2006). Many countries have developed and implemented a bio-control based IPM approach that has proved successful (Lohr *et al.*, 2007). However, larval endoparasitoids belonging to the genera *Diadegma* and *Cotesia* are the main and most effective species in the management of diamondback moth (Fitton and Walter,1992) has also been shown to contribute significantly to DBM control (Kirk *et al.*, 2004).

The study has confirmed the presence of *C. plutellae* in both cauliflower (Table 2) and cabbage (Table 4) plots. It has reaffirmed the positive numerical responsiveness of the parasitoid of the

DBM populations as was earlier reported by Alam, (1992). *C. plutellae* also appeared not to discriminate between monocrop and intercropped plots. These finding are in agreement with Talekar and Yang, (1993). The higher parasitism levels recorded should however, be viewed with caution in both the crops. But, in controversy of the other hand, the mean parasitism by *C. plutellae* was maximum on tomato intercropped cauliflower (29.61%), nearly 50% higher than that on the pure crop (Kalyanasundaram, 1995).

Intercropping is one way of introducing more biodiversity into agro ecosystems and results from intercropping studies indicate that increased crop diversity may increase the number of ecosystem services provided. Intercropping has been an important production practice in many parts of the world and it continues to be an important farming practice in developing countries (Clawson, 1985). Despite its potential and multiple advantages, mainstream agronomic research has largely focused on monocrop systems, with little interest in ecological interactions between species in intercropping systems (Malezieux *et al.*, 2009).

Conclusions

The present study indicated that on intercropped plots fewer larvae and pupae of the diamondback moth were noted compared with monoculture. It can be concluded that intercropping of coriander and onion in 10:1 and 2:1 row ratios were found to be better for profitable production in both the crops. Whenever the activity of bio-control agents is not sufficient, insecticide applications often may necessary to avoid economic crop loss. Intercropping can result in an increase in the productivity of vegetables per unit area, and improve net income. The results of the present study indicate that cauliflower and cabbage intercropped with other vegetables like non cruciferous vegetables would be a remunerative cropping system which produced higher yields and economic returns when compared to a monocrop. From the results of this research, it is recommended that smallholder, resource-poor farms to use their family labour and inputs more efficiently. It is worthy to investigate that the yield of intercrops can be raised without affecting the yield of the main crop.

Acknowledgements

We are very grateful to Department of Agricultural Entomology, Tamil Nadu agricultural University and University Grants Commission (UGC) for generous financial and legal support (Project Number: 56379/2013) and to Chairman of the advisory committee for valuable comments on the manuscript.

Table 1 Mean larval and pupal populations of diamondback moth, *Plutella xylostella* (L.) recorded in cauliflower based cropping systems at Coimbatore from December, 2014 to March, 2015.

WAT/ Treatments	5	6	7	8	9	10	11	12	Overall mean
T ₁ Farmer's practices ^s	4.33 (2.08)	1.50 (1.22)a	0.83 (0.91)a	0.83 (0.91)a	1.33 (1.15)a	0.67 (0.82)a	0.67 (0.82)	0.33 (0.58)	1.31 (1.15)a
T ₂ Cauliflower + Neem oil	3.33 (1.83)	4.67 (2.16)b	3.67 (1.91)bc	2.67 (1.63)a	3.00 (1.73)a	2.67 (1.63)b	2.33 (1.53)	1.67 (1.29)	3.21 (1.79)b
T ₃ Cauliflower + Radish	4.67 (2.16)	4.00 (2.00)b	5.00 (2.24)bc	7.00 (2.65)c	9.67 (3.11)e	4.00 (2.00)b	5.00 (2.24)	4.67 (2.16)	5.00 (2.24)c
T ₄ Cauliflower + Marigold	5.00 (2.24)	4.33 (2.08)b	5.33 (2.31)bc	3.67 (1.91)b	5.67 (2.38)cd	4.67 (2.16)b	2.67 (1.63)	1.67 (1.29)	4.50 (2.12)bc
T ₅ Cauliflower + Onion	4.33 (2.08)	6.33 (2.52)c	6.00 (2.65)c	5.00 (2.24)bc	4.00 (2.00)bc	3.00 (1.73)b	3.00 (1.73)	2.67 (1.63)	4.42 (2.10)c
T ₆ Cauliflower + Tomato	6.00 (2.45)	7.00 (2.65)d	7.67 (2.77)c	5.00 (2.24)bc	4.33 (2.08)d	3.00 (1.73)b	3.33 (1.83)	2.33 (1.53)	5.67 (2.38)c
T ₇ Cauliflower + Coriander	4.67 (2.16)	3.67 (1.91)a	1.67 (1.29)ab	2.67 (1.63)a	2.33 (1.53)ab	4.33 (2.08)b	3.56 (1.89)	2.67 (1.63)	3.19 (1.79)b

T ₈ Cauliflower alone	6.33 (2.52)	6.67 (2.58)c	5.67 (2.38)c	6.67 (2.58)c	6.00 (2.45)cd	5.00 (2.24)b	3.67 (1.91)	4.67 (2.16)	4.96 (2.23)c
SEd	0.25	0.45	0.49	1.26	0.98	0.40	1.35	0.65	0.16
CD (0.05)	NS	0.96	1.06	2.70	2.12	0.86	NS	NS	0.32
C.V. %	20.00	25.83	32.18	34.92	24.28	30.08	61.92	54.63	16.39

§ - Cauliflower alone with prophylactic application of insecticides and Fungicide at weekly interval
WAT - Weeks after transplanting

Means in the column followed by the same letter are not significantly different (P>0.05) by LSD
NS- F value is not significant at the given probability level (P = 0.05)
The figures in parentheses are transformed as $\sqrt{x + 0.5}$.

Table 2 Mean pupal population of *Cotesia plutellae* Kurdjmov recorded in different cropping system of cauliflower (Kimaya) at Coimbatore from December, 2014 to March, 2015.

WAT/ Treatments	5	6	7	8	9	10	11	12	Overall mean
T ₁ Farmer's practices ^s	1.67 (1.29)	1.33 (1.15)	1.00 (1.00)	0.87 (0.93)b	1.00 (1.00)c	0.33 (0.58)d	0.50 (0.71)b	0.50 (0.71)c	0.90 (0.95)d
T ₂ Cauliflower + Neem oil	3.33 (1.83)	4.33 (2.08)	3.67 (1.91)	2.67 (1.63)ab	3.00 (1.73)ab	1.00 (1.00)cd	0.67 (0.82)b	0.67 (0.82)c	2.42 (1.55)bc
T ₃ Cauliflower + Radish	2.33 (1.53)	3.00 (1.73)	4.33 (2.08)	3.33 (1.83)ab	1.00 (1.00)cd	2.33 (1.53)bc	1.00 (1.00)b	0.33 (0.58)c	2.21 (1.49)c
T ₄ Cauliflower + Marigold	3.00 (1.73)	3.33 (1.83)	1.67 (1.29)	2.67 (1.63)b	1.67 (1.29)bcd	1.00 (1.00)cd	0.67 (0.82)b	1.00 (1.00)bc	1.88 (1.37)c
T ₅ Cauliflower + Onion	2.33 (1.53)	1.67 (1.29)	2.00 (1.41)	1.00 (1.00)b	0.33 (0.58)cd	0.33 (0.58)cd	0.33 (0.58)c	0.33 (0.58)c	1.04 (1.02)d
T ₆ Cauliflower + Tomato	2.67 (1.63)	2.33 (1.53)	1.67 (1.29)	5.00 (2.24)a	1.67 (1.29)abc	2.00 (1.41)cd	1.33 (1.15)b	1.67 (1.29)bc	2.29 (1.51)bc
T ₇ Cauliflower + Coriander	3.67 (1.91)	3.67 (1.91)	4.67 (2.16)	4.33 (2.08)a	5.00 (2.24)a	4.00 (2.00)ab	10.00 (3.16)a	8.00 (2.83)a	5.54 (2.35)a
T ₈ Cauliflower alone	4.67 (2.16)	3.00 (1.73)	4.00 (2.00)	3.67 (1.91)ab	2.67 (1.63)a	3.67 (1.92)a	1.33 (1.15)b	3.00 (1.73)b	3.25 (1.80)b
SEd	0.45	0.53	0.40	0.37	0.30	0.24	0.25	0.26	0.18
CD (0.05)	NS	NS	NS	0.79	0.65	0.53	0.54	0.56	0.35
C.V. %	30.79	37.09	29.03	27.14	24.42	22.71	25.89	24.91	24.07

§ - Cauliflower alone with prophylactic application of insecticides and Fungicide at weekly interval
WAT - Weeks after transplanting

Means in the column followed by the same letter are not significantly different (P>0.05) by LSD
NS- F value is not significant at the given probability level (P = 0.05)
The figures in parentheses are transformed as $\sqrt{x + 0.5}$.

Table 3 Mean larval and pupal populations of diamondback moth, *Plutella xylostella* (L.) recorded in cabbage based cropping systems at Coimbatore from February to June, 2015.

WAT/ Treatments	5	6	7	8	9	10	11	12	Overall mean
T ₁ Farmer's practices ^s	2.00 (1.41)a	1.25 (1.12)a	0.88 (0.94)a	1.00 (1.00)a	1.33 (1.15)b	1.00 (1.00)a	0.67 (0.82)a	0.33 (0.57)a	1.06 (1.03)d
T ₂ Cabbage + Neem oil	2.00 (1.41)a	2.48 (1.57)b	1.67 (1.29)b	1.33 (1.15)ab	1.67 (1.29)c	1.84 (1.36)bc	1.67 (1.29)c	1.00 (1.00)c	1.71 (1.31)c
T ₃ Cabbage + Radish	2.78 (1.67)bc	3.00 (1.73)c	2.84 (1.69)d	3.33 (1.82)e	3.67 (1.92)f	3.33 (1.82)d	3.00 (1.73)d	3.33 (1.82)d	3.16 (1.78)b
T ₄ Cabbage + Marigold	4.00 (2.00)e	3.48 (1.87)d	4.00 (2.00)d	4.33 (2.08)d	4.00 (2.00)e	3.67 (1.92)c	3.00 (1.73)e	2.67 (1.63)d	3.64 (1.91)b
T ₅ Cabbage + Onion	2.70 (1.64)b	2.33 (1.53)d	2.00 (1.41)d	1.95 (1.40)c	1.17 (1.08)a	2.47 (1.57)d	1.35 (1.16)c	1.86 (1.36)e	1.98 (1.41)c
T ₆ Cabbage + Tomato	3.42 (1.85)d	3.00 (1.73)d	2.84 (1.69)d	1.22 (1.10)b	1.67 (1.29)d	1.00 (1.00)b	1.33 (1.15)c	1.00 (1.00)f	1.94 (1.39)c
T ₇ Cabbage + Coriander	3.00 (1.73)bc	2.68 (1.64)b	2.42 (1.56)c	2.14 (1.46)c	2.00 (1.41)ef	0.75 (0.87)a	0.97 (0.98)b	0.83 (0.91)b	1.85 (1.36)c
T ₈ Cabbage alone	4.00 (2.00)e	6.33 (2.52)e	5.33 (2.31)e	6.00 (2.45)f	5.67 (2.38)g	6.33 (2.52)e	5.85 (2.42)f	6.67 (2.58)f	5.84 (2.42)a
S.Ed	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.10
CD (0.05)	0.15	0.06	0.07	0.07	0.06	0.07	0.07	0.05	0.20
C.V. %	5.19	2.17	2.63	2.96	2.49	3.11	3.07	2.39	12.94

§ - Cabbage alone with prophylactic application of insecticides and Fungicide at weekly interval
WAT - Weeks after transplanting

Means in the column followed by the same letter are not significantly different (P>0.05) by LSD
 NS- F value is not significant at the given probability level (P = 0.05)
 The figures in parentheses are transformed as sqrt. x + 0.5.

Table 4 Mean pupal population of *Cotesia plutellae* Kurdjmov recorded in different cropping system of cabbage (Quisor) at Coimbatore from February to June, 2015.

WAT/ Treatments	5	6	7	8	9	10	11	12	Overall mean
T ₁ Farmer's practices ^s	0.58 (0.76)b	0.68 (0.82)c	0.33 (0.57)c	0.50 (0.71)c	0.33 (0.57)e	1.50 (1.22)d	0.67 (0.82)e	0.50 (0.71)g	0.57 (0.76)c
T ₂ Cabbage + Neem oil	1.00 (1.00)b	0.67 (0.82)c	1.33 (1.15)b	0.50 (0.71)c	1.00 (1.00)c	2.67 (1.63)b	1.00 (1.00)d	0.67 (0.82)f	1.11 (1.05)b
T ₃ Cabbage + Radish	0.33 (0.57)d	0.67 (0.82)c	1.33 (1.15)b	0.50 (0.71)c	0.67 (0.82)d	0.67 (0.82)e	1.00 (1.00)d	1.33 (1.15)d	0.81 (0.90)b
T ₄ Cabbage + Marigold	1.33 (1.15)a	1.45 (1.20)b	1.67 (1.29)a	0.50 (0.71)c	0.67 (0.82)d	1.00 (1.00)d	2.00 (1.41)b	1.67 (1.29)c	1.29 (1.13)b
T ₅ Cabbage + Onion	1.67 (1.29)e	0.33 (0.57)d	0.67 (0.82)b	0.83 (0.91)b	1.33 (1.15)b	2.00 (1.41)c	1.67 (1.29)c	1.00 (1.00)e	1.19 (1.09)b
T ₆ Cabbage + Tomato	1.00 (1.00)c	1.33 (1.15)b	1.00 (1.00)b	0.50 (0.71)c	0.33 (0.57)e	1.00 (1.00)d	2.00 (1.41)b	1.67 (1.29)c	1.10 (1.05)b
T ₇ Cabbage + Coriander	1.33 (1.15)a	2.33 (1.53)a	1.00 (1.00)b	1.30 (1.14)a	4.67 (2.16)a	4.00 (2.00)a	3.67 (1.92)a	4.33 (2.08)a	2.83 (1.68)a
T ₈ Cabbage alone	1.00 (1.00)b	0.33 (0.57)d	1.47 (1.21)a	0.50 (0.71)c	0.67 (0.82)d	2.00 (1.41)c	1.67 (1.29)c	2.33 (1.53)b	1.25 (1.12)b
S.Ed	0.04	0.02	0.02	0.15	0.02	0.02	0.09	0.02	0.13
CD (0.05)	0.10	0.05	0.04	0.32	0.05	0.05	0.20	0.04	0.26
C.V. %	3.81	3.53	2.11	18.84	3.34	2.38	5.35	2.38	23.88

\$ - Cabbage alone with prophylactic application of insecticides and Fungicide at weekly interval
 WAT - Weeks after transplanting

Means in the column followed by the same letter are not significantly different (P>0.05) by LSD
 NS- F value is not significant at the given probability level (P = 0.05)
 The figures in parentheses are transformed as sqrt. x + 0.5.

REFERENCE

[1]Alam, M.M.1992. Diamondback moth and its natural enemies in Jamaica and some other Caribbean Islands.pp. 233-243. In Talekar, N.S. (ed.) Diamondback moth and other crucifer Pests: Proceedings of the Second International Workshop, Tainan, Taiwan, Asian Vegetable Research and Development Center, Shanhua, Taiwan. [2]Andow, D.A. 1991. Vegetational diversity and arthropod population response. Annual Review of Entomology. 36: 561-586. [3]Andow, D.A., Nicholson A.G., Wien H.C., Willson H.R.1986. Insect populations on cabbage grown with living mulches. Environmental Entomology. 15: 293-299. [4]Awal, M.A. Koshi H, Ikeda T. 2006. Radiation interception and use by maize/peanut intercrop canopy. Agric. Forest. Met. 139: 74-83. [5]Broad, S.T., Schellhorn, N.A., Lissou, S.N., and Mendham, N.J. 2008. Host location and oviposition of lepidopteran herbivores in diversified broccoli cropping systems. Agriculture Forest Entomology. 10: 157-165. [6]Clawson, D.L. 1985. Harvest security and intraspecific diversity in traditional tropical agriculture. Econ. Bot. 39: 56-67. [7]Ferreira, J., Pardini, R. Metzger, J.P. Fonseca, C.R. Pompeu, P.S. Sparovek, G. and Louzada, J. 2012. Towards environmentally sustainable agriculture in Brazil: challenges and opportunities for applied ecological research. J. Appl. Ecol. 49: 535-554. [8]Fitton, M.G. and Walter, A.K. 1992. Hymenopterous parasitoids associated with diamondback moth: the taxonomic dilemma. pp. 225-232. In: Talekar, N.S. (ed.) Diamondback moth and other crucifer pest: Proceeding of the Second International Workshop, Tainan, Taiwan. [9]Hasheela, B.S.E., J.H. Nderitu and F.M. Olubayo. 2010. Evaluation of border crops against infestation and damage of cabbage by diamondback moth, (*Plutella xylostella*) Tunisian Journal of Plant Protection 5: 99-105. [10]Horwith, B., 1985. A role for intercropping in modern agriculture. Bioscience. 35: 5. [11] Jarenyama, P., Hesterman, O.B., Waddington, S.R., Harwood, R.R., 2000. Relay- intercropping of sunnhemp and cowpea into a smallholder maize system in Zimbabwe. Agron. J. 92: 239-244. [12]Kalyanasundaram, M. 1995. Bioecology and management of diamondback moth, *Plutella xylostella* (Linnaeus) on cauliflower . Ph.D thesis, TNAU, Coimbatore. p.138. [13]Kirk, A. A., Mercadier, G., Bordat, D., Delvare, G., Pichon, A., Arvanitakis, L., Goudegnon, A.E. and Rincon C. 2004. Variability in *Plutella* and its natural enemies: implications for biological control. pp. 71-77 In: Endersby, N.M. and Ridland, P.M. (eds). The management of diamondback moth and other crucifer pests. Proceedings of the Fourth International Workshop, 26-29 November 2001. Melbourne, Australia: Department of Natural Resources and Environment. [14]Lohr, B., Gathu, R., Kariuki, C., Obiero, J. and Gichini. 2007. Impact of an exotic parasitoid on *Plutella xylostella* (Lepidoptera: Plutellidae) populations dynamics, damage and indigenous natural enemies in Kenya. Bull. Entomol. Res. 97: 337-350 [15] Malezieux, E., Crozat Y, Dupraz C, Laurans M, Makowski D, Ozier-Lafontaine H, Rapidel B, de Tourdonnet S, Valantin-Morison M. 2009. Mixing plant species in cropping systems: concepts, tools and models. A Review. Agron. Sustain. Dev. 29: 43-62. [16]Melo, E.P.L., Arroyo-Rodriguez V, Fahrig L, Martinez-Ramos M, Tabarelli M. 2013. On the hope for biodiversity friendly tropical landscapes. Trends in Ecological Evolution: doi:10. 1016/ j.tree. 2013.01.001. [17]Ofori, F and Stern, W.R. 1987. Cereal-legume intercropping systems. Adv. Agronomy. 4: 41-90. [18]Perrings, C., Naeem S, Ahrestani F, Bunker DE, Burkhill P,Canziani G, Elmquist T, Fuhrman J, Jaksic F, Kawabata Z, Kinzig A, Mace GM, Mooney H, Prieur Richard AH, Tschirhart J, Weisser W2011. Ecosystem services, targets, and indicators for the conservation and sustainable use of biodiversity. Front. Ecol. Environ. 9: 512-520. [19]Rattan, R.S., Reineke, A., Hadapad, A., Gupta, P.R. and Zebitz, C.P.W. 2006. Molecular phylogeny of *Cotesia* species (Hymenoptera: Braconidae) inferred from a 16S gene. Current Science. 91: 1460-1461. [20]Russell, A.E. 2002. Relationship between crop-species diversity and soil characteristics in south West Indian Agroecosystems. Agr. Ecosyst. Environ. 92: 235-249. [21] Sivapragasam, A., Tee, S.P and Ruwaida, M. 1982. Effects of intercropping cabbage with tomato on the incidence of *Plutella xylostella* (L.). MAPPS Newsletter. 6: 6-7. [22]Souza, S.H.E., P.H.B. Togni, C.S.S. Pires and E.R. Sujii. 2014. The role of integrating agroforestry and vegetable planting in structuring communities of herbivorous insects and their natural enemies in the Neotropical region. Agroforest Syst: DOI 10.1007/s10457-013-9666-1. [23]Talekar, N.S. and A.M. Shelton. 1993. Biology, ecology, and management of the diamondback moth. Ann. Rev. Entomol. 38:275-301. [24]Talekar, N.S. and Yang, J.C. 1993. Influence of crucifer cropping system on the parasitism of *Plutella xylostella* (Lepidoptera: Yponomeutidae) by *Coteia plutellae* (Hymenoptera: Braconidae) and *Diadegma semiclausum* (Hymenoptera:Ichneumonidae) Entomophaga 38: 541 -556. [25]Talekar, N.S, Lee S.T and Huang, S.W. 1986. Intercropping and modification of irrigation methods for control of diamondback moth. In: Talekar, N.S. and Griggs T.D. (eds.) diamondback moth management. Proceedings of the First International Workshop, 11-15 March-1985, Taiwan, Asian Vegetable Research and Development Centre, Shauhua, Taiwan pp. 145-151. [26]Umashankar, U.K, Bar and S.V.S, Raju. 2005. Impact of intercropping in cauliflower on Diamondback Moth, *Plutella xylostella* (L.). Indian J. Plant Protection 33:43-47.