Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2015; 3 (1): 144-148

Received: 16-01-2015
Accepted: 26-01-2015

Bashir Ahmad
Department of Plant Protection, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan.

Ahmad-Ur-Rahman Saljoqi
Department of Plant Protection, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan.

Muhammad Saeed
Department of Agriculture, The University of Haripur, Pakistan

Farman Ullah
Department of Plant Protection, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan.

Imtiaz Ali Khan
Department of Entomology, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan.

Correspondence:
Bashir Ahmad
Department of Plant Protection, The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan.

Population dynamics of *Plutella xylostella* (L.) in cauliflower and its correlation with weather parameters at Peshawar, Pakistan

Bashir Ahmad, Ahmad-Ur-Rahman Saljoqi, Muhammad Saeed, Farman Ullah and Imtiaz Ali Khan

Abstract
Studies were carried out from June to November, during 2012 and 2013 at Peshawar, Pakistan to determine the population dynamics of *Plutella xylostella* (Lepidoptera: Plutellidae) in Cauliflower, *Brassica oleracea* L. var. botrytis and its correlation with weather parameters. The highest mean population of larvae and pupae (4.75±2.14 and 6.7±1.71) per plant was recorded in September whereas the lowest (0.2±0.41 and 0.4±0.71) was recorded in July, 2012 and 2013 respectively. A negatively non-significant correlation (r = -0.31 and -0.18) was recorded with maximum temperatures, whereas with minimum temperature, the association (r = 0.02 and 0.06) was positively non-significant. Percent Relative Humidity showed a positively significant ($p \leq 0.05$) relationship (r =0.79 and 0.67) with population dynamics whereas a negative correlation ((r = -0.98 and -0.46) was recorded with total rainfall but was statistically significant in 2012 and non-significant in 2013. Multiple regression models showed 90-98% (R^2) interaction between the population of *P. xylostella* and weather parameters.

Keywords: Weather parameters; Population dynamics; *Plutella xylostella* (L.); *Brassica oleracea* (L.) var botrytis

1. Introduction
Cauliflower, *Brassica oleracea* L. var. botrytis belongs to the famous *Brassica oleracea* family. It is one of the main sources of livelihood for farmers in Pakistan, especially who grow vegetables in their farms instead of other seasonal crops. Growth and cultivation of this kind of vegetable is strongly dependent on various factors. A considerable reduction in production has been observed due to several biotic and abiotic factors around the world and among those limiting factors, insect pests such as *Plutella xylostella* (normally called diamondback moth), aphids, cabbage worms, cabbage white butterfly, *Pieris rapae,* caterpillars, *Helicoverpa armigera, H. punctigera* and flea beetles are mainly responsible [1].

Plutella xylostella is one of the major and oligophagous pests, mainly responsible for low production [2, 3]. All cruciferous vegetables including cauliflower, cabbage, broccoli, brussels sprouts, chinese cabbage, collard, kale, kohlrabi, mustard, radish, turnip are attacked by this pest. The free mustard oil present in the cruciferous crops is a key element of attraction for *P. xylostella* [4]. *P. xylostella* has now been reported and documented from at least one hundred and twenty eight countries or territories of the world and is believed to be the most universally distributed of all lepidopterous insect pests [3]. Shelton [5] reported that currently this insect pest is present all over the world wherever the crucifers exist.
The importance of climatic factors in the population dynamics of *P. xylostella* has been emphasized by plethora authors [6, 7]. Biology and development of *P. xylostella* are highly dependent on temperature and humidity [8]. Ansari *et al.* [9] reported that temperature is a vital factor for the development of *P. xylostella*. Life table and population studies showed that besides host plants, rainfall, temperature, humidity and natural enemies greatly influence the survival and reproduction of *P. xylostella* [10, 11]. Heavy rain is also one of the important factors affecting DBM's abundance [12, 13].
It is a key pest of cruciferous vegetables in Pakistan [14] whereas Abro *et al.* [15] stated that *P. xylostella* is the most serious pest of all crucifers in Southern Sindh (province), Pakistan. Worldwide, *P. xylostella* contributed for over seventy percent (70%) of destruction in crucifers [16] whereas Verkerk and Wright [17] reported that *P. xylostella* caused 90% crop losses. Abro *et al.* [18] reported that *P. xylostella* has become a serious pest in South Asia region and if left

untreated the pest may cause up to 100% losses in Pakistan. Verkerk and Wright [17] reported more than 90 % crop loss by *P. xylostella*. It is believed and reported that *P. xylostella* inflicts loss of more than one billion US $ per year around the globe [19, 20].

Plutella xylostella is a key and destructive pest of cauliflower and other cruciferous around the world, but still little attention has been paid to forecast its population dynamics [21]. Forecasting population dynamics of *P. xylostella* is not easy as many factors influence its abundance and fluctuation [22, 23]. To develop a proper planning for the management of this pest, prediction of the population abundance, its proper timing of occurrence and level (pest pressure) is highly important [24].

The latest knowledge of incidence pattern of the *P. xylostella* on cauliflower, *B. oleracea* crop in relation with the weather parameter is therefore, a prerequisite for implementation of an effective and successful management tactics against this insect. The present research was consequently conducted to observe and monitor the population dynamics of *P. xylostella* on cauliflower and determine the effects of maximum and minimum temperature, percent relative humidly and rainfall on population trend.

2. Materials and Methods

2.1. Study Area and Parameters

To study the population dynamics of *Plutella xylostella* (L.) in cauliflower, the experimental procedures of Mohammed [25] and Kfir [26] with some modification were used. The population dynamics of *P. xylostella* was examined in Peshawar district of Khyber Pakhtunkhwa in the cropping seasons from June to November during the years 2012 and 2013. The population density and fluctuation was correlated with the weather parameters including mean maximum and minimum temperature, percent relative humidity and total rainfall.

For documentation of population dynamics, standard agronomic practices, including normal weeding, irrigation practices, fertilization and sanitation etc. except plant protection measures were followed as per recommended package of practices in the cauliflowers fields. Experiments were laid down in randomized complete block design (RCBD) having experimental unit size of 3.5 meter in width and 3.5 meter in length within the experimental field selected within commercial fields transplanted with 23 days old 'Shumaila' (Syngenta Company) seedlings. Each experimental unit consisting of forty (40) cauliflower plants, having five (5) rows and every row was consisted of eight (8) plants. Plant to plant distance of cauliflower was about 43 cm and row to row distance was 66 cm. For studying population dynamics of *P. xylostella,* each experimental unit was replicated four times under the same experimental conditions.

Five infested plants were randomly selected from each replication and were thoroughly inspected fortnightly and the number of *P. xylostella* larvae and pupae were counted but not removed. The experiment was continued until harvest in both years. Population of *P. xylostella* was determined as the mean number of larvae and pupae per cauliflower plant. Observations were recorded for each plant and the mean maximum and minimum temperature, relative humidity and rainfall were recorded. Data regarding maximum and minimum temperature, relative humidity and rainfall were taken from Meteorological department, Peshawar, Khyber Pakhtunkhwa and were correlated with the population dynamics of *P. xylostella*.

2.2. Statistical Analysis

The data was subjected to correlation (Pearson) analysis and linear multiple regression by using Statistical Software Statistix 8.1 [27].

3. Results and Discussion

3.1. Population dynamics of *Plutella xylostella* (L.) during 2012 and 2013

The mean population of *P. xylostella* significantly varied in different months from July to November in both years. Pest appeared in the first week after transplanting the 23 days old cauliflower seedlings to the research field in July. These findings were in conformity with the reports of Hasanshahi [28] who reported that *P. xylostella* population appears at the beginning of the cauliflower season and shortly after transplantation of the seedlings in the field. Patra *et al*. [29] reported that *P. xylostella* attacked the crop about one month after transplanting in the field. Mohammed *et al*. [25] accounted that there is a gradual increase in the population density of *P. xylostella* after transplantation. It was found that *P. xylostella* was available in the field from July to November (cropping season) with a mean temperature range of 37 ºC (max.) in July to 7 ºC (mini.) in November, thus indicating that it can survive in a wide range of temperatures. These findings are confirmed by Liu *et al*. [30] who stated that *P. xylostella* remains active throughout the year in China at daily minimum temperature in January below 2 ºC to daily maximum temperature in July rises above 35 ºC. CAB International [31] also reported that *P. xylostella* is distributed in wide range of temperature from the tropics to cool regions all over the world.

The mean minimum population of *P. xylostella* in the form of larvae and pupae (0.2±0.41 and 0.4±0.71) per plant was recorded on 15th of July whereas the highest population (4.75±2.14, 6.7±1.71) per plant was collected on September, 28 during the year 2012 and 2013 respectively (Table 1). This trend of highest population continued from August to the mid of October whereas a decline was noticed from mid-October till harvesting of the crop. These findings are in conformity with Hasanshahi *et al*. [32] who reported that on the 10th of September, the highest quantity of 1st and 3rd instar larvae were documented in all cultivars of cauliflower whereas the lowest number was observed in the beginning of the cauliflower cropping season. He also reported the highest density of larvae (6.68 ± 3.36) and pupae (4.92 ± 2.25) per plant on a cauliflower variety in Tehran, Iran. Mohammed *et al.* [25] described that the population density of *P. xylostella* ranged from 0 to 9.28 moth larvae and pupae per plant. Ahmad and Ansari [33] reported that the population of the *P. xylostella* showed flare up in the month of August and September and then gradually declined. Our finding was in conformity with Venkateswarlu *et al*. [34] who reported that peak incidence of *P. xylostella,* was observed during 1st week of September. Nagarkatti and Jayanth [35] revealed that the highest larval population of *P. xylostella* was recorded in July-September.

Table 1: Population dynamics of *P. xylostella* (L.) on Cauliflower at District Peshawar during 2012 and 2013

Date	2012					2013				
	Number of *P. xylostella* (Mean ±SE)	T. Max (^{0}C)	T. Min (^{0}C)	RH (%) (0300Z	RF (mm)	Number of *P. xylostella* (Mean ±SE)	T. Max (^{0}C)	T. Min (^{0}C)	RH (%) (0300Z)	RF (mm)
15 Jul	0.2±0.41	39.99	26.7	67	1100	0.4±0.71	38	26.5	70	1122
30 Jul	0.9±0.65	38.15	26.5	60	980	1.75±0.63	36.2	25.7	84	1002
14 Aug	2.15±0.85	37.5	26	59	870	2.75±1.11	35.9	25.6	84	943
29 Aug	3.75±1.89	35.9	25.8	81	459	4.45±1.80	34.5	25.4	86	704
13 Sep	4.4±1.58	33.8	23.6	86	410	5.5±1.26	32.2	23.2	83	234
28 Sep	4.75±2.14	31.2	20.8	84	331	6.7±1.71	31	20.5	84	200
13 Oct	3.05±1.55	30	17.6	82	540	4.1±1.50	30	17.4	85	375
28 Oct	2±1.08	29.4	13.6	81	760	2.2±1.68	28.3	13.2	80	95
12 Nov	1.2±1.47	27.6	11.2	62	1010	1.55±0.95	25.5	10.8	70	110

3.2. Correlation Matrix of *P. xylostella* Population with weather parameters during 2012 and 2013

The correlation matrix of *P. xylostella* population with the weather parameters revealed that mean maximum temperature exhibited statistically non-signification ($p>0.05$) and negative correlations ($r = -0.31$ and -0.18) in 2012 and 2013 respectively, whereas the relationship with mean minimum temperature was also statistically non-significant ($p>0.05$) but positive ($r = 0.02$ and 0.06). The Percent Relative Humidity (RH) with $r = 0.79$ exhibited positive, highly significant ($p \leq 0.01$) relationship in the year 2012 with *P. xylostella* population, but the interaction was significant ($p \leq 0.05$) and positive in the year 2013 having $r = 0.67$. Similarly, there was a negative and highly significant ($p \leq 0.01$) interaction ($r = -0.98$) between the population dynamics of *P. xylostella* with the total rainfall during the year 2012 whereas there was a non-significant ($p>0.05$) but negative correlation ($r = -0.46$) in the year 2013 between the *P. xylostella* population and total rainfall (Table 2).

These results are in conformity with the finding of Sow *et al*. [36] who studied that there was a negative correlation between temperature and *P. xylostella* populations and high temperatures did not increase the pest populations. Patra *et al*. [29] accounted that hot conditions favored the multiplication of *P. xylostella* while cold ones in November-February limited its population dynamics. According to Shelton [5] hot and dry conditions are known to be conducive for *P. xylostella.* Hemchandra and Singh [37] reported that lower relative humidity, higher temperature and lower total rainfall, seem to favor *P. xylostella* population builds up. Venkateswarlu *et al*. [34] reported that among different climatic tools, maximum and minimum temperature had a significant positive correlation whereas percent relative humidity showed significant negative correlation with *P. xylostella* population.

Leu and Lee [12], Talekar and Lee [13] reported that profound rain is one of the essential detrimental factors affecting the abundance of *P. xylostella*. Our results demonstrated that rainfall had a highly significant interaction with infestation in terms of population index, which are in close conformity with the studies of Sow *et al*. [36] who reported that during the dry season the population of larvae and pupae of *P. xylostella* were higher than the rainy season. Talekar and Ying Lin [38] reported that *P. xylostella* is a surface feeder and spent entire life on plant surface therefore, during rainy season it does not create a grave threat to crops because of the drowning and physical removal of the larvae and pupae from the plant surface.

Table 2: Correlation Matrix of *P. xylostella* and weather parameters in District Peshawar during crop season 2012 and 2013

Weather Parameters	Correlation coefficient for *P. xylostella* population	
	2012	2013
Mean Max temp (^{0}C)	-0.31^{NS}	-0.18^{NS}
Mean Min Temp (^{0}C)	0.02^{NS}	0.06^{NS}
Mean R.H (%)	0.79**	0.67^{*}
Total Rainfall (mm)	-0.98**	-0.46^{NS}

NS: Non Significant
*Significant 0.05 level of probability
**Highly Significant at 0.01 level of probability

3.3 Multiple Regression equation for *P. xylostella* in Peshawar during 2012 and 2013

Multiple regression equation for the population dynamics of *P. xylostella* showed that during 2012, there was 98.06% (R^2) interaction between the population of *P. xylostella* and the weather parameters (maximum and minimum temperatures, percent relative humidity and total rainfall) whereas in the year 2013 the relationship of *P. xylostella* population was (R^2) 90.96% (Table 3). There was a variation of 90-98% (R^2) recorded between the weather parameters and the population of *P. xylostella* during 2012 and 2013 which can be used by cauliflower grower's communities and other researchers for developing a sound programme to counter the attack of *P. xylostella*. These results are confirmed by Talekar *et al.* [39] who reported that rainfall has negative and unfavorable correlation with the population of *P. xylostella* and due to its vulnerability to rainfall it is not a serious pest during rainy season. They also confirmed that artificial rainfall in terms of irrigation can reduce the infestation of this insect at dusk significantly. Harcourt [40] stated that climatic conditions, including higher temperature and decreased rainfall were cited as major factors which regulate the population dynamics of *P. xylostella*. Patra *et al.* [30] reported a positive correlation in case of maximum temperature with the population density of *P.*

xylostella whereas a negative association was recorded with the mean relative humidity and rainfall.

Table 3: Multiple Regression equation for *P. xylostella* in District Peshawar during 2012 and 2013.

Year	Multiple Regression equation	R^2 Value
2012	Y1= 8.84+0.22X1-0.17X2-0.05X3-0.008X4	98.06 %
2013	Y2= I.80-0.49X1+0.58X2+0.09X3-0.004X4	90.96%

Where
Y1 and Y2= Population of *P. xylostella*
X1= Temperature Maximum
X2= Temperature Minimum
X3= Percent Relative Humidity
X4= Total Rainfall

4. Conclusion

It is concluded that attack of *P. xylostella* commenced during the first week after transplantation of cauliflower seedlings and the highest infestation was recorded from August to September. The correlation between population of *P. xylostella* and temperature (maximum and minimum) was found a statistically non-significant. Similarly, the interaction between percent relative humidity and larval and pupal population of *P. xylostella* was statistically significant, whereas this interaction of the population dynamics with total rainfall was negative and highly significant. 90-98% (R^2) association of the *P. xylostella* population with the weather parameters was recorded in 2012 and 2013. These finding can be used by the farmers for developing a sound programme to counter the attack of *P. xylostella* in cauliflower crop to minimize losses.

5. Acknowledgement

This research manuscript is a part of the PhD thesis of the 1st author submitted to The University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan and the authors would like to acknowledge the support of the Government of Pakistan, Meteorological Department, Regional Meteorological Center, Peshawar and Higher Education Commission of Pakistan for their support.

6. References

1. Nyambo BT, Pekke A. Brassica Pest Management. In Proc. of the Brassica planning workshop: East and South Africa Region. Lilongwe, Malawi, May 15-18, 1995.
2. Talekar NS, Shelton AM. Biology, ecology, and management of the diamondback moth. Annual Review of Entomology 1993; 38:275-301.
3. Sarfraz M, Dosdall LM, Keddie BA. Diamondback moth-host plant interactions: implications for pest management. Crop Protection 2006; 25:625-639.
4. Gupta PD, Thorsteinson AJ. Food plant relationship of the diamondback moth, *Plutella maculipennis* (Curt). I. Gustation and olfaction in relation to botanical specificity of the larva. Entomologia experimentalis et applicata 1960; 3:241-250.
5. Shelton AM. Regional outbreaks of diamondback moth due to movement of contaminated plants and favorable climatic conditions. Proceedings of the IV International workshop on Management of Diamondback Moth and other Crucifer Pests, Melbourne, Victoria, Australia, November 26-29, 2001, 96-101.
6. Cohen AC. Water and temperature relations of two Hemipteran members of a predator-prey complex. Environmental Entomology 1982; 11(3):715-719.
7. Vickers RA, Furlong MJ, White A, Pell JK. Initiation of fungal epizootics in Diamondback moth populations within a large field cage: proof of concept of auto-dissemination. Entomologia experimentalis et applicata 2004; 111:1-17.
8. Guo S, Qin Y. Effects of temperature and humidity on emergence dynamics of *Plutella xylostella* (Lepidoptera: Plutellidae). Journal of Economic Entomology 2010; 103(6):2028-2033.
9. Ansari MS, Ahmad T, Ali H. Effect of Indian mustard on feeding, larval survival and development of *Plutella xylostella* at constant temperatures. Entomological Research 2010; 40:182-188.
10. Wakisaka S, Tsukuda R, Nakasuji F. Effects of Natural Enemies, Rainfall, Temperature and Host Plants on Survival and Reproduction of the Diamondback Moth and Other Crucifer Pests. In: "Diamondback Moth and Other Crucifer Pests", Proceedings of the Second International Workshop" 1992, 16-36.
11. Haseeb M, Kobori Y, Amano H, Nemoto H. Population Density of *Plutella xylostella* (Lepidoptera: Plutellidae) and its Parasitoid *Cotesia plutellae* (Hymenoptera: Braconidae) on two varieties of cabbage in an urban Environment. Applied Entomology and Zoology 2001; 36:353-360.
12. Leu FM, Lee HS. Observation of the life history of diamondback moth, *P. xylostella* (L.) in whole year. Journal of Agriculture Research, China 1984; 33:424-430.
13. Talekar NS, Lee ST. Seasonality of insect pests of Chinese cabbage and common cabbage in Taiwan. Plant Protection Bulletin 1985; 27:47-52.
14. Ghouri ASR. Insect pests of Pakistan. FAO, Plant Protection Commission South Asia and Pacific Region Technical Report 1960; 8:31.
15. Abro GH, Soomro RA, Syed TS. Biology and behavior of diamondback moth, *Plutella xylostella* (L.). Pakistan Journal of Zoology 1992; 24:7-10.
16. You MS, Wei H. The research of diamondback moth. China Agriculture Press. China 2007.
17. Verkerk RHJ, Wright DJ. Multi tropic interactions and management of the diamondback moth: a review. Bulletin of Entomological Research 1996; 86:205-216.
18. Abro GH, Jayo AL, Syed TS. Ecology of Diamondback moth, *Plutella xylostella* (L.) in Pakistan. Host Plant Preference, Pakistan Journal of Zoology 1994; 26(1):35-38.
19. Food and Agriculture Organization (FAO) of the United Nations. FAO annual Report 1992; 46:1-281.
20. Grzywacz D, Rossbach A, Rauf A, Russel DA, Srinivasan R, Shelton AM. Current control methods for diamondback moth and other brassica insect pests and the prospects for improved management with lepidopteran resistant BT vegetable brassicas in Asia and Africa. Crop Protection 2010; 29:68-79.
21. Zalucki MP, Furlong MJ. Predicting outbreaks of a migratory pest: an analysis of DBM distribution and abundance revisited pp. 8-14. In Srinivasan R, Shelton AM, Collins HL. Management of the Diamondback Moth and other Crucifer Insect Pests, Proceedings of the Sixth International Workshop, AVRDCD. The World Vegetable Center, Shanhua, Taiwan 2011.

22. Schellhorn NA, Pierce S, Bianchi FJJA, Williams D, Zalucki MP. Designing landscapes for multipleoutcomes in broad-acre environments. Australian Journal of Experimental Agriculture 2008; 48:1549-1559.
23. Muthuthantri S, Maelzer DA, Zalucki MP, Clarke AR. The seasonal phenology of *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae) in Queensland. Australian Journal of Entomology 2010; 49:221-233.
24. Maelzer DA, Zalucki MP, Laughlin R. Analysis of historic light trap data for *Helicoverpa punctigera*: forecasting the size of pest population. Bulletin of Entomological Research 1996; 86:547-557.
25. Mohammed K, Randall FR, Griffin P, Carner G, Gorsuch, CS. Diamondback Moth (Lepidoptera: Plutellidae) Population Density and Parasitism by *Diadegma insulare* on Collard in South Carolina. Journal of Agriculture and Urban Entomology 2004; 21(3):164-170.
26. Kfir R. The diamondback moth with special reference to its parasitoids in South Africa, The Management of Diamondback Moth and other Crucifer Pests: Proceedings of the Third International Workshop (ed. by Sivapragasam, A, Loke WH, Hussan AK, Lim GS). Malaysian Agricultural Research Institute, Kuala Lumpur, Malaysia 1997, 54-60.
27. Bowden J, Morris MG. The influence of moon light on catches of insects in light traps in Africa. Part III. The effective radius of nursery vapor light trap and the analysis of the trap catch using effective radius. Bulletin of Entomological Research 1995; 65(2):303-348.
28. Hasanshahi G, Abbasipour H, Askarianzadeh A, Karimiand J, Jahan F. Seasonal population fluctuations of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) on different cauliflower cultivars. Archives of Phytopathology and Plant Protection 2013; 46(10):1136-1149.
29. Patra S, Dhote VW, Alam SKF, Das BC, Chatterjee ML, Samanta A. Population dynamics of major insect pests and their natural enemies on cabbage under new alluvial zone of West Bengal Journal of Plant Protection Science 2013; 5(1):42-49.
30. Liu S, Wang X, Guo S, He J, Shi Z. Seasonal abundance of the parasitoid complex associated with the diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae) in Hangzhou, China. Bulletin of Entomological Research 2000; 90(3):221-231.
31. CAB International. Crop protection compendium, global module (CD-ROM), 2nd ed. CAB, Wallingford, UK 2000.
32. Hasanshahi GH, Jahan F, Askarianzadeh A, Abbasipour H, Karimi J. Efficacy of insecticides in cauliflower fields of the south of Tehran and they effects on environment. National Conference of Environment and Plant Production 2012; 3:177-181.
33. Ahmad T, Ansari MS. Studies on seasonal abundance of diamondback moth, *Plutella xylostella* (L.) on cauliflower crop. Journal of Plant Protection Research 2010; 50:3.
34. Venkateswarlu V, Sharma RK, Chander S, Singh SD. Population dynamics of major insect pests and their natural enemies in cabbage. Annals of Plant Protection Sciences 2011; 19:272-77.
35. Nagarkatti S. Jayanth KP. Population dynamics of major insect pests of cabbage and of their natural enemies in Bangalore district (India). In: Proceedings of the International Conference on Plant Protection in the Tropics. 1-4 March, Kuala Lumpur, Malaysia. 1982, 325-347.
36. Sow G, Diarra K, Arvanitakis L, Bordat D. The relationship between the diamondback moth, climatic factors, cabbage crops and natural enemies in a tropical area. Folia Horticulturae 2013; 25(1):3-12.
37. Hemchandra O, Singh TK. Population dynamics of DBM, *Plutella xylostella* (L.) on cabbage agro-ecosystem in Manipur. Indian Journal of Entomology 2007; 69:154-61.
38. Talekar NS, Ying Lin M. Training Manual on IPM of Diamondback Moth, AVRDC, Shanhua, Taiwan 1998.
39. Talekar NS, Lee ST, Huang. Intercropping and modification of irrigation method for the control of diamondback moth. In Diamondback Moth Management. Proceedings of the First International Workshop 1986, 145-55.
40. Harcourt DG. Population dynamics of the diamondback moth in Southern Ontario. In: "Management of Diamondback Moth and other Crucifer Pests: Proceedings of International Workshop" (N.S. Talekar, ed.). Tainan, Taiwan, 11–15 March, 1986, 3-15.