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Characterization of four *Brassica* crops for development of diamondback moth *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae)

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ABSTRACT

Development of *Plutella xylostella* was studied on cauliflower, cabbage, broccoli and radish in protected field condition under nylon net cage for two consecutive years. Result revealed that *P. xylostella* preferred to lay maximum eggs on cauliflower followed by cabbage, broccoli and radish. Fecundity was more at beginning but declined gradually with advancing of female age. The highest unhatched eggs were recorded on radish and minimum on cauliflower. Larval mortality was least when *P. xylostella* reared on cauliflower and maximum on radish. Mortality survival ratio for immature stages was highest on radish and lowest on cauliflower. The immature stages of *P. xylostella* were over within 27.45 days on cauliflower and 30.62 days on radish. Thermal constants significantly differed among the host plants during both the years of study. Maximum degree-days 66.66 and 125.00 was required for development of *P. xylostella* on cauliflower and minimum 37.03 and 58.82 on radish during both the cropping seasons, respectively. However, *P. xylostella* required maximum degree days to complete the development of immature stages on broccoli 473.03 and 394.95 degree-days in both cropping years.

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INTRODUCTION

Relation of insect pest and host is an important aspect to study the feeding behaviour, fecundity and longevity of life stages. This is an important mechanism by which a plant can be limiting the damage caused by an insect pest and it is an important component of integrated pest management. Among many herbivore insects, oviposition on newer leaves of a particular host tends to be preferred over oviposition on older leaves (Klemola *et al.*, 2003) which was less suitable for larval development and survival than younger leaves (Rodrigues and Pires-Moreira,1999). Host potential to use against diamondback moth has been studied by several DBM researchers.

Monks and Kelly (2003) investigated that the role of learning and host deprivation in host acceptance by adult *P. xylostella* in which responsiveness to host was a function of the recent counter rate with host specific stimuli and the oviposition reflex was regulated by non-specific causes as eggs load. Oogenesis of *P. xylostella* was higher with an unsuitable host, *Barbarea vulgaris* than with the suitable host (cabbage) (Badenes-Perez *et al.,* 2006). Adult *P. xylostella* are attracted to volatiles emanating from their host plants (Palaniswamy *et al.*, 1986 and Pivnick *et al.*, 1990). Three green leaf volatiles have been found in the extract of cabbage and attracted mated females for oviposition (Reddy and Guerrero, 2000). Allyl isothiosynates, the hydrolysis products of mainly aliphatic glucosinolates were found as feeding attractants for DBM and also stimulated enhanced oviposition (Renwick, 2002).*Plutella xylostella* is one of the most important insect pest of cruciferous crops of the family Brassicaceae such as cauliflower, cabbage, broccoli and radish (Dosdall *et al.*, 2011and Kianpour *et al.,* 2014). India is the largest producer of vegetables in the world after China with an annual production of 101.43 million tonnes from 6.76 million ha of land (Rai and Pandey, 2007). Cabbage and cauliflower are most preferred winter vegetables and their total share in country's vegetable production is 6.1 and 4.4 per cent, respectively. India occupies first position in the production of cauliflower and third in cabbage. The four *Brassica* crop, particularly cauliflower, (*B. oleracea* var. *botrytis*), cabbage (*B. oleracea*), broccoli (*B. oleracea*) and radish (*Raphanus sativus*) are important vegetable crops grown throughout India. The population of the pest remain exit during cropping season, specially July to April in Aligarh and substantially losses the production and outbreak occurred in 2006 caused hundred per cent crop loss and farmers were no choice except plough their crop without any harvest (Ahmad *et al*., 2009). In Guangdong province of China, outbreak of DBM recorded due to climate change or failure of management (Li *et al.,* 2012). The effort has been made to find out the alternative best suitable *Brassica* crop that may be useful tools in intercropping/trap cropping management for diversion of DBM from the sole crop growing as commercial crop.

MATERIAL AND METHODS

Cultivation of *Brassica* crop :

Development of *P. xylostella* was studied on cauliflower, cabbage, broccoli and radish under protected field condition (no-choice test) for two consecutive years 2004 and 2005. Seeds of cauliflower (*B. oleracea botrytis* var. Pusa Snowball), cabbage (*B. oleracea* var. Golden Acre), broccoli (*B. oleracea italica* var. Green Globe) and radish (*R. sativus* var. Pusa Desi) were sown in September of 2004 and 2005 in earthen pots, with application of Farm Yard Manure in a ratio of 3:1 and were kept under protected condition to avoid other insect infestation.

Rearing method of *P. xylostella* :

Five potted host plants were kept under the nylon cage (1 x 1 x 1 m) and five pairs of newly emerged adults obtained from the stock culture were released in the cage. The host plants were removed from the cage after 24 h and the experiment was replicated 10 times. Larval, pre-pupal, pupal and adult, longevity and mortality were recorded to calculate different parameters of life stages. Number of eggs was counted daily till the death of adults and observations were also made on hatching of eggs in order to obtain fertility.

Statistical analysis :

The development of *P. xylostella* was analyzed by using Sigma Plot-Version 10. Finally, the data was analyzed statistically by application of correlation and further subjected to test of significance by Duccan's multiple range test. Maximum and minimum temperatures were also recorded from November to December of 2004 and same in 2005.

Estimation of degree days and linear regression model :

Rate of development is defined as the reciprocal of time required for completion of a life stage *i.e.* 1/d (d=days of development of one stage).

Linear regression equation was adopted to express the relationship between the temperature (T) and rate of development (D)

$$D=a+bT \quad \ldots(1)$$

where,

D = Development rate

a and b are constants which were determined by least square method

T = Temperature

Lower thermal threshold (T_{min}) was calculated by

putting D=0 in equation (1) which gives

$$T_{min} = - a/b \quad \text{.....(2)}$$

Thermal constant was calculated by :

$$K = 1/b \quad \text{.....(3)}$$

K = Thermal constant expressed in degree-days (DD)

b = Regression slope

The thermal units required to complete development were calculated by using the formula of (Arnold, 1960):

$$DD = (T_1 - T_{min}).D \quad \text{.....(4)}$$

where,

DD = Degree day,

D = Mean development time,

T_1 = Rearing temperature

T_{min} = Minimum threshold temperature

RESULTS AND DISCUSSION

All four host plants was significantly ($P<0.05$) affected the development of *P. xylostella*. The fecundity of *P. xylostella* significantly ($P < 0.05$) affected by host plants and also discriminated by females for the oviposition in the present study. *Plutella xylostella* preferred cauliflower by ovipositing highest number of eggs (*i.e.* 190.02 ± 2.11) followed by cabbage (*i.e.* 164.86 ± 2.07) and least on radish (*i.e.* 83.56 ± 1.89) in 2004; although there was an increase in egg deposition in the experiments conducted during *Rabi* season of 2005 (Table 1). The female preferred to lay more eggs on cauliflower (241.26 ± 3.86) followed by broccoli. Regression analysis for eggs on host plants yielded 0.858 and 0.154 values of R^2 in both cropping seasons, respectively. Fecundity (m_x) was considerably affected by age of female and host plants and was greatest in the beginning of age for all host plants means maximum number of eggs deposited by a female one day after emergence and then declines gradually with advancing age. The results revealed that *Brassica* host plants significantly affected the developmental stages of *P. xylostella*. A significant ($P < 0.05$) difference was obtained in the incubation period of eggs on cauliflower and radish in 2004, while no marked difference was found in 2005. Value of R^2 was 0.947 and value of correlation was negatively non-significant. Development of immature stage from egg to pupa was not significantly varied on cauliflower and cabbage but significantly differed ($P < 0.05$) on broccoli and radish in 2004 and 2005, respectively (Table 2). In 2004, development of immature stage was 27.45 ± 2.95 days on cauliflower and prolonged to 30.62 ± 4.11 days on radish. However, in 2005, 24.15 ± 3.90 days were on cauliflower and prolonged upto 28.95 ± 4.65 days on radish. Field temperature was negatively affected the development of immature stages of *P. xylostella*. Longevity was shortest 7.50 ± 0.59 days on radish and 12.45 ± 0.81 days on cauliflower and significantly ($P<0.05$) varies among the host plants in 2004 and 2005. Field temperature substantially enhanced the longevity in 2004; however negatively ($P<0.01$) affected in 2005. Values of R^2 were quite low; while RSS was high on *Brassica* hosts grown in field condition of 2004 and 2005 (Table 3) showing that prevailing field temperature substantially affected the hatching of eggs. Thermal constants (K) significantly varied among the host plants (Table 3). The result showed that thermal constants are significantly varied among the host plants during the two cropping seasons. Thermal requirement was highest on cauliflower followed by cabbage and the

Table 1 : Fecundity (m_x) of *Plutella xylostella* on *Brassica* hosts

Host plant	2004		2005	
	Egg±SE	% Hatching	Egg±SE	% Hatching
Cauliflower	190.02±2.11d	94.00	241.26±3.86c	95.00
Cabbage	164.86±2.07c	91.00	196.24±3.81b	91.00
Broccoli	156.20±1.45b	89.00	226.5±11.28d	86.00
Radish	83.56±1.89a	86.00	124.50±2.33a	84.00
LSD P= 0.05	1.09		13.98	
F	154.13		6.25	
d.f.	6, 11		6,11	
R^2	0.858		0.154	

Values not followed by same letter are significantly different (P=0.05) by DMRT SE=Standard error

least on radish in both years of study with a base temperature of 6.05°C. More degree days required for completing the development of immature stage on radish than other host plants and least heat was required on cauliflower in both years of study on *P. xylostella*. Maximum heat accumulated for development of *P. xylostella* on cauliflower during both experimental seasons and minimum on radish although, thermal constant differed in both year of study.

Developmental period of *P. xylostella* from egg to pupal stage (Immature stage) was found shortest on cauliflower and prolonged on radish in the present study and similar observation was also reported by Sant *et al.* (1982) that DBM completed larval and pupal

Table 2 : Effect of *Brassica* hosts on development of *Plutella xylostella*

Host plant	Egg±SE	I instar±SE	II instar±SE	III instar±SE	IV instar±SE	Pre-pupa ±SE	Pupa±SE	Immature stage±SE	Adult±SE	Total±SE
2004-2005								(Egg to pupa)		
Cauliflower	4.65±0.49a	5.25±0.62a	3.75±0.43a	3.85±0.23a	4.05±0.84a	1.00±0.00a	4.90±0.35a	27.45±2.95a	12.45±0.81c	39.90±3.76b
Cabbage	4.75±0.43a	5.35±0.89a	4.30±0.46b	3.95±0.35a	4.15±0.81b	1.00±0.00a	4.50±0.61a	28.00±3.55a	12.50±0.87c	40.50±4.42b
Broccoli	5.25±.75b	5.75±0.35a	4.55±0.52b	4.45±0.40a	4.50±0.72c	1.00±0.00a	5.50±0.66a	29.25±3.40b	10.75±0.40b	40.00±3.80b
Radish	5.52±0.71b	5.80±0.20a	4.75±0.64b	.50±0.84a	4.50±0.81c	1.00±0.00a	4.55±0.92a	30.62±4.11c	7.50±0.59a	38.12±4.7a
LSD P= 0.05	0.57	1.02	0.47	1.01	0.05	0.54	0.97	1.05	1.22	1.61
df	3, 11	3,11	3,11	3,11	3,11	3,11	3,11	3,11	3,11	3,11
F	35.07	17.19	66.13	13.47	97.47	9.41	25.14	150.66	15.36	320.00
R^2	0.947	0.906	0.939	0.890	0.875	1.000	0.000	0.969	0.834	0.192
r	-0.413	-0.48	-0.766	-0.459	-509	NC	0.135	-0.442	0.247	-0.177
2005-2006										
Cauliflower	3.80±0.40a	3.50±0.55a	3.75±0.76a	4.10±0.66a	3.75±0.64a	1.00±0.14a	4.25±0.75a	24.15±3.90	11.45±1.04d	35.60±4.94a
Cabbage	3.55±0.69a	3.75±0.35a	3.90±0.79a	3.95±0.89a	4.05±0.84a	1.00±0.20a	4.15±0.78a	24.35±4.54	10.50±1.15c	34.85±5.69a
Broccoli	4.59±0.92a	4.65±0.47b	4.75±0.75b	4.95±0.49a	4.75±0.81b	1.00±0.43a	4.80±0.84b	29.49±4.71	9.84±0.72b	39.33±5.43b
Radish	4.25±0.75a	4.75±0.46b	4.55±0.40b	4.50±0.66a	5.05±0.84b	1.00±0.50a	4.85±0.95b	28.95±4.65	8.50±0.66a	37.45±5.22a
LSD P= 0.05	0.59	0.31	0.55	0.44	0.40	0.53	0.31	1.12	0.83	1.33
d.f.	3, 11	3, 11	3, 11	3, 14	3, 15	3, 16	3, 17	3,7	3, 18	3, 19
F	46.15	110.22	65.46	122.08	159.24	13.45	336.1	513.25	55.98	712.96
R^2	0.609	0.966	0.895	0.646	0.97	1	0.756	0.771	0.999	0.612
r	0.462	-0.777	0.214	0.778	-0.821	NC	0.865	-0.775	-0.990**	-0.814

Values not followed by same letter are significantly different (P=0.05) by DMRT,
* and ** indicate significance of value at P=0.01 and 0.05, respectively SE=Standard error, NC=Not correlated, NCD=Not

Table 3 : Estimates of linear regression equation of development of *Plutella xylostella*

Host plant	a	b	d.f.	R^2	RSS	K
2004-2005						
Cauliflower	0.230	0.015	6, 8	0.017	0.562	66.667
Cabbage	0.220	0.018	6, 8	0.024	0.561	55.556
Broccoli	0.203	0.020	6, 8	0.029	0.575	50.000
Radish	0.173	0.027	6, 8	0.053	0.544	37.037
2005-2006						
Cauliflower	0.291	0.008	6, 8	0.006	0.535	125.000
Cabbage	0.287	0.009	6, 8	0.006	0.533	111.111
Broccoli	0.235	0.015	6, 8	0.017	0.556	66.667
Radish	0.222	0.017	6, 8	0.022	0.554	58.824

development in the shortest time on cauliflower, cabbage and radish as compared to mustard and radish. It was further confirmed by Reddy *et al.* (2004) that shortest larval development time on cauliflower, cabbage and radish compared with turnip and mustard. While larvae consumed less foliage and required more time to complete development on kohlrabi and kale than other crops. Reports of Wakisaka *et al*. (1991) showed that development rate was varied when *P. xylostella* reared on Brassicacea plants, including wild hosts and shortest period (15.2 days) on broccoli and 16.8 days on cabbage. Development time of *P. xylostella* was longer when reared on wild host plants than on cultivated varieties. Hamilton *et al.* (2005) compared the development time of larvae of *P. xylostella* reared on two cultivars, savoy king and green coronet cabbage and reported that larvae developed more rapidly on green coronet than savoy king. Syed and Abro (2003) found shortest and longest development period of larvae of *P. xylostella* on cauliflower and radish, respectively. Moreover, *P. xylostella* attacks on the *Brassica* crops and showed a marked preference for cauliflower and cabbage because they possessed fleshy succulent leaves that provides both olfactory and gustatory stimuli. Idris and Grafius (1996) showed that DBM reared on cultivated *Brassica* cultivars, *B. oleracea* var. *capitata* and *B. oleracea* var. *acephala* that had a shorter larval development time than the wild crucifers due to suitability of the crop. Development period of larvae was shorter on cabbage than the larvae reared on kale (Kahuthia *et al.*, 2008). In the present study, thermal requirements or degree days vary from year to year and at different stages of life of *P. xylostella*. Thermal constants for each stage of life of *P. xylostella* were determined by regression model for both years of study. The required degree day for development of *P. xylostella* was calculated which showed that for the development of egg to emergence of adult varies in both cropping seasons (Fig. 1). When *P. xylostella* reared on radish more degree days were required to complete the development of immature stages as compared to other host plants. 418.5 and 331.13 degree days were required for development on cauliflower during 2004 and 2005, respectively. It was also found that degree days requirement was more in 2004 in comparison to 2005 and the same was in the averaging method. While, Golizadeh *et al.* (2007) estimated lower thermal threshold and thermal constant

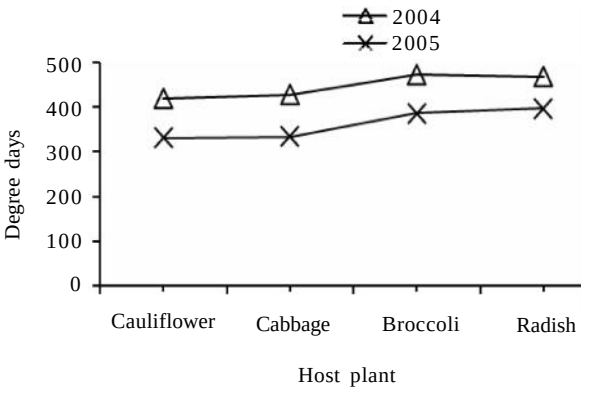

Fig. 1 : Degree days (DD) for development of *Plutella xylostella* at different host

from linear model and showed that at 7.06°C, 263.74 *DD* and 7.84°C, 261.68 DD on cauliflower and cabbage, respectively. They also found that development time was shorter on cauliflower than on cabbage. Thermal constant for development of immature stage was estimated to be 268.2 degree days with a base temperature of 7.2°C on cabbage (Liu *et al.,* 2002).

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