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Influence of biochemical constituents and epicuticular wax content in different types of cabbage with life stages of diamondback moth

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Abstract
An attempt was made to find out the influence of biochemical constituents and epicuticular wax content in different types of cabbage with life stages of *P. xylostella*. Diamondback moth, *Plutella xylostella* is the serious and cosmopolitan pest for crops and vegetables especially cabbage all over the world. The investigation on comparative biology of diamondback moth on cabbage was carried out at Department of Entomology, Sardarkrushinagar Dantiwada Agricultural University, during 2018-19. The study covered comparative biology of diamondback moth on chinese, purple and green cabbage. The Maximum length and breadth was recorded on green cabbage 0.49 ± 0.05 and 0.25 ± 0.02 mm while it was minimum on chinese (0.46 ± 0.04 and 0.24 ± 0.02 mm). Maximum hatching per cent was observed on chinese cabbage (93.22%) while, it was minimum on purple cabbage (86.10%). Total life duration of diamondback moth varied from 24 to 42 days on three different cabbage hosts. The duration of male and female was recorded maximum on purple cabbage 32.62 ± 0.39 and 35.0 ± 0.57 days, followed by chinese cabbage 28.03 ± 0.34 and 29.04 ± 0.18 days. The total duration observed on green cabbage was 26.70 ± 0.10 and 28.52 ± 0.3 days for male and female. The per-oviposition period of female were 1.35 ± 0.12, 1.45 ± 0.16, 1.60 ± 0.31 days on green, chinese and purple cabbage, respectively. The oviposition period was 2.67 ± 0.42 days with maximum on purple cabbage followed by chinese cabbage and green cabbage with an average of 2.52 ± 0.37 and 2.30 ± 0.62 days. The post oviposition period was 2.47 ± 0.18, 3.02 ± 0.52 and 3.86 ± 0.20 days on green, chinese and purple. The highest fecundity of 45.62 ± 0.52 eggs per female was observed on green cabbage followed by 40.12 ± 0.52 eggs on chinese cabbage and 26.50 ± 0.37 eggs on purple cabbage. The study clearly indicated that the biochemical constituents and epicuticular wax content greatly influenced on the life cycle of *P. xylostella*. Among the cabbage types *P. xylostella* took maximum duration to complete the life cycle on purple cabbage, whereas minimum time in green cabbage. For chinese cabbage total life period was in between the purple and green cabbage.

Keywords: Biology, diamondback moth, cabbage, larva

Introduction
Vegetables play an important role in the balanced diet of human beings by providing not only energy-rich food, but also supplying vitamins and minerals. Comparatively, vegetables are one of the cheapest sources of natural nutritive foods. Among the vegetables, cabbage (*Brassica oleracea* var. *capitata* Linnaeus) is one of the most important winter vegetable grown on five continents and in more than 90 countries throughout the world. It is a leafy vegetable belong to the family: Brassicaceae (formerly Cruciferae) sometime also referred to as Cole crops, is very closely related to kale, broccoli, cauliflower *etc.* cabbage is a unique source of several types of phytonutrients, with antioxidant activity due to high content of phenol, polyphenol and anthocyanin. Being rich in glucosinolates and isothiocynates, it also has anticancer properties (Mezencev, 2002 and Mehta and John, 2002) [14, 13]. The productivity of cabbage is very low compared to other countries and losses in the yield have been reported to the extent of 57 to 97 per cent due to insect pests alone (Prasad, 1963) [19]. More than 37 insect pests have been reported attacking on cabbage right from the vegetative phase to harvest of the crop (Sachan and Gangwar, 1980) [22]. Among them, diamondback moth (*Plutella xylostella* Linnaeus), Cabbage butterfly (*Pieris brassicae* Linnaeus), Cabbage aphid (*Brevicoryne brassicae* Linnaeus), Cabbage borer (*Hellula undalis* Fabricius), Leaf eating caterpillar (*Spodoptera litura* Fabricius), Cabbage head borer [*Helicoverpa armigera* (Hubner) Hardwick], Painted bug (*Bagrada hilaris* Kirkaldy), Flea beetle (*Phyllotreta cruciferae* Goeze), Mustard sawfly (*Athalia lugens proxima* Klug.) are most serious causing economical damage (Prasad, 1963; Sachan and Srivastava, 1972 and Rao and Lal, 2005) [19, 23, 21].

Diamondback moth has its origin in southwest of Europe (Sarfraz *et al*., 2006) [24] and is a serious pest of brassica crops both in tropical and temperate climatic region (Wang *et al*., 2008) [30]. The diamondback moth *P. xylostella* (Lepidoptera: Plutellidae) was first recorded on cruciferous vegetable in 1914 (Fletcher, 1920) [6]. Now, the pest has been noticed all over India, infesting plants belong to Brassicaceae.

In India, Krishnamoorty (2004) [11] reported a 52 per cent yield loss on cabbage due to DBM, while cabbage aphid play a prominent role in reducing yield ranging from 50 to 80 per cent (Khan and Munir, 1986 and Ellis and Singh, 1993) [10, 5].

Material and Methods

The investigation on comparative biology of diamondback moth on cabbage was carried out at Department of Entomology, Sardarkrushinagar Dantiwada Agricultural University, during 2018-19. The study covered comparative biology of diamondback moth on different types of cabbage. The diamondback moth larvae were reared individually under laboratory conditions on chinese, purple and green cabbage leaves in transparent Petri dish. Fresh leaves of respective host plants were provided as food material daily in the morning until pupation and emerged adults were collected. The sex of adults was determined on the basis of colour pattern and external morphological characters. Five pairs of newly emerged male and female of diamondback moth adults were transferred into a rectangular glass jar (20 cm height × 12 cm length × 10 cm breadth). Fresh leaves of chinese, purple and green cabbage were provided for oviposition. The open end of glass jar was covered with a piece of muslin cloth and secured tight in position with the help of rubber band. Five per cent honey solution was provided as food for moths. The eggs laid by diamondback moth reared on different cultivars where further used to study the comparative biology on green, purple and chinese cabbage under laboratory condition.

Twenty eggs laid on each cultivar were examined under microscope to study their colour, shape and size. The length and breadth of the eggs were measured with the help of occular and stage micrometer. To study the incubation period and hatching per cent of eggs, twenty freshly laid eggs were kept on tender leaves of each cabbage type *i.e.* green, purple and chinese cabbage in a Petri dish, repeated by three times and observed under microscope daily in the morning and evening till it hatched. The eggs were considered hatched when tiny larva emerge out from the egg. Duration and number of eggs hatched was recorded and from the data incubation period and hatching per cent was computed. To determine the number and duration of different larval instars on different cultivars and total larval period, newly emerged ten larvae (first instar) were transferred separately in Petri dish (15 cm diameter × 1.5 cm height) with the help of fine camel hair brush repeated by three times and tender and uninfested fresh cabbage leaves, were kept inside the Petri dish as a food. The leaves of each cultivar in each Petri dish were changed daily in the morning. To determine the number of larval instars, the Petri dish were observed daily to confirm the moulting. All rearing requirements were provided to newly hatched larvae. The total larval period was calculated from the date of hatching of eggs to date of formation of pre-pupa. Each larval instar was studied for their colour, shape and size. Observations on number of instars, duration of each instar and total larval period were recorded separately, on each cabbage type under study. Measurement of first instar was taken under microscope with the help of stage and ocular micrometer, while, the length and breadths of the remaining instars were measured with millimeter scale. The total larval period was calculated from the date of hatching of egg to pre-pupal stage. This procedure was followed for all the three cultivars. If a fully grown larva stop feeding, contracted in size and become sluggish in movement was considered as pre-pupal stage. The pre-pupal stage was observed critically under the microscope for its colour, shape and size in all the three cultivars. The size of pre-pupa was measured using millimeter scale. The pre-pupal period was recorded individually from inactive stage to complete pupal formation. The pupa obtained from all the three types of cabbage was studied for its colour, shape, size and duration carefully. The length and breadth of pupa was measured by using ocular and stage micrometer. The pupal period was computed from the date of formation of pupa to the date of adult emergence. The diamondback moth adults emerged from each cultivar were paired and transferred to a glass chimney for oviposition. They were provided with five per cent honey solution as food and fresh leaves of different cultivars of cabbage for oviposition. The leaves were replaced daily for counting the eggs. The pre-oviposition, oviposition and post-oviposition period were computed using the date of emergence, date of first oviposition to date of last oviposition and date of death of the moth in respective hosts. To determine the fecundity, eggs laid by single female were collected daily in the morning and counted till the death of the female. The length and breadth were measured directly with the help of a standard scale.

Results and Discussion

Freshly laid eggs by the female reared on all the three types of cabbage were pale with yellowish in colour which changed to dark or grey black, day before hatching. The eggs were oval in shape. Patel (2002) [16]. However, the length and breadth of eggs varied on these varieties under study. Maximum length and breadth of 0.49 ± 0.05 and 0.25 ± 0.02 mm was recorded on the green cabbage whereas, it was minimum (0.46 ± 0.04 and 0.24 ± 0.02 mm) on chinese cabbage. The length and breadth of eggs were 0.47 ± 0.04 and 0.22 ± 0.02 mm, respectively, when reared on purple cabbage. Maximum hatching per cent was observed on chinese cabbage (93.22%) while, it was minimum on purple cabbage (86.10%). Green cabbage registered 90.43 per cent hatching of eggs under laboratory condition. Patil and Pokharkar (1999) [17] observed 80.19 to 93.33 hatching per cent on cabbage, while it was 95.67 to 96.33 per cent on cabbage under Gujarat condition (Patel, 2002) [16].

The newly emerged first instar larvae were sluggish in nature which becomes active after 1 to 3 hours. Larvae were dull whitish in colour with brown head in all the three types of cabbage. The first instar larval duration ranged from 1 to 3 days, on purple cabbage with a maximum average duration of 2.07 ± 0.71 days, followed by chinese cabbage (1.50 ± 0.47 days) and the lowest larval period of 1.46 ± 0.40 days on green cabbage. Measurement of first instar larvae revealed that the green cabbage, recorded highest length and breadth of (0.82 ± 0.08 and 0.17 ± 0.02 mm) followed by chinese cabbage (0.80 ± 0.09 and 0.16 ± 0.02 mm) and lowest on purple cabbage (0.75 ± 0.07 and 0.18 ± 0.09 mm) (Table 2). Sharma *et al*. (1999) observed first instar larval period of 2 to 3 days at Palanpur (Himachal Pradesh). Patel (2002) [16] recorded that freshly emerged larvae of DBM were creamy white in colour with dark head. Dhaduk (2007) [4] observed

first larval duration of 2.50 ± 0.5 days. Raghuwanshi *et al.* (2010) [20], Gangurde and Wankhede (2010) reported first instar larval period as 2.75 and 2.50 days, respectively. Tarivia (2011) described the first instar larva of *P. xylostella* as white in colour with a larval duration of 2.50 ± 0.52 days at Junagadh. Meena and Singh (2012) observed the length and breadth of first instar larva was 1.33 to 1.47 and 0.15 to 0.24 mm with larval duration of 1.80 days. The duration of first instar larva and its size observed in the present study is in agreement with earlier reports.

The second instar larva was light yellowish in colour with brown head. No significant variation in colour was observed while rearing of the larvae on different types of hosts. The length and breadth of second instar larvae varied among different types of cabbage and maximum body size of 1.21 ± 0.08 and 0.27 ± 0.02 mm was recorded on green cabbage and it was minimum on purple cabbage (1.18 ± 0.08 and 0.24 ± 0.03 mm). The length and breadth of second instar was 1.20 ± 0.10 and 0.25 ± 0.01 mm respectively on chinese cabbage. The results indicated that second instar larval period was 2 to 4 days. A variation in second instar larval period was observed, when reared on different types of cabbage and the second instar larval duration was 2.76 ± 0.37, 2.90 ± 0.28 and 3.60 ± 0.18 days on green, chinese and purple cabbage, respectively. Sharma *et al.* (1999) recorded the second instar duration from 1 to 1.5 days. Dhaduk (2007) [4] observed 1.20 ± 0.25 days at Junagadh Das and Chaudhary (2007).

Gangurde and Wankhede (2010) observed 3.10 and 2.20 days for second instar larva. Tarivia (2011) reported that the second instar larva was yellowish green in colour. The duration of second instar was 2.70 days. Meena and Singh (2012) noticed the colour of the second instar larva as light yellowish with brown head and larval duration was 2.70 days with the length and breadth of 2.59 and 0.28 mm, respectively.

Freshly emerged third instar larvae was light green in colour and it was longer than that of second instar with a blunted appearance on both anterior and posterior ends. The data clearly indicated that, those reared on green cabbage registered maximum length and breadth (3.52 ± 0.32 and 0.34 ± 0.05 mm) followed by chinese cabbage (3.48 ± 0.30 and 0.32 ± 0.03 mm) and purple cabbage (3.39 ± 0.32 and 0.28 ± 0.02 mm). The third instar larval duration ranged from 2 to 5 days on different types of cabbage with a minimum duration of 3.20 ± 0.32 days on green cabbage followed by 3.53 ± 0.26 days on chinese cabbage with a maximum duration of 4.60 ± 0.19 days on purple cabbage. Sharma *et al.* (1999) reported that the third instar larva lasts 1 to 2 days on cabbage, whereas, the duration was 3.22 days on cabbage with length and breadth of 3.46 mm and 3.48 mm by (Patel, 2002) [16] and Dhaduk (2007) [4] observed that the third instar lasted 1.84 ± 0.34 days, whereas, it was 3.0 days on cabbage at Pundibari (West Bengal). Das and Chaudhary (2007), Dhaduk (2007) [4] observed third instar larval duration of 1.84 ± 0.34 and 3.0 days, respectively. They also observed that the third instar larva was light yellowish in colour with brown head and the duration lasted 1.64 ± 0.50 days. Meena and Singh (2012) noticed that third instar larvae were longer than second instar with light brown head having a larval duration of 2.70 days. They observed the length and breadth of third instar 4.29 and 0.38 mm, respectively. The third instar larval duration in the present investigation ranged from 2 to 5 days, which is somewhat longer period compared to earlier reports. This may be due to the fact that in purple cabbage the development is a little slow. The larval duration observed in green cabbage collaborate with the observation made by earlier workers.

There is no difference in colour and shape of the fourth instar larvae when reared on different types of cabbage. The newly emerged fourth instar larva was pale green in colour with spindle shape *i.e.* tapering both anterior and posterior end and wider in middle portion. There was a difference in size of the fourth instar larvae on different types of cabbage as the length and breadth was maximum on green cabbage (5.72 ± 0.12 and 0.70 ± 0.16 mm) followed by chinese cabbage (5.47 ± 0.27 and 0.13 mm) and purple cabbage (5.20 ± 0.20 and 0.46 ± 0.03 mm). The fourth instar larval period varied from 3 to 6 days among the different types of cabbage and average longest period was observed on purple cabbage (5.80 ± 0.12 days) followed by chinese cabbage (4.50 ± 0.6 days) and green cabbage (4.20 ± 0.18 days). The fourth instar larval duration reported by earlier workers were very short *i.e.* 2 to 3 days, whereas, in the present study the fourth instar larval duration was more than 5 days. The life cycle of an organism is influenced by the rearing conditions and also attributed to different types of hosts in which *P. xylostella* was reared. Patel (2002) [16] recorded 2.22 days as fourth larval period with a length of 5.45 mm and breadth of 5.53 mm on cabbage. Dhaduk (2007) [4] also observed similar larval duration of 2.04 ± 0.24 days. Das and Chaudhari (2007) recorded 3.50 days for fourth instar, whereas, Raghuwanshi *et al.* (2010) [20] reported 2.30 days as fourth larval duration. Tarivia (2011) described the colour of the fourth instar larva as green to dark green with light brown head and observed a larval duration of 2.71 ± 0.47 days. Meena and Singh (2012) reported that full grown fourth instar larvae were yellowish green in colour and remain outside the mines and mostly found on lower side of the leaves with duration of 2.80 days with 5.06 mm length and 0.53 mm, breadth. In the present investigation we have not observed such a behavior of fourth instar larvae.

A perusal of the data given in Table 3 revealed that the total larval period was shortest (11.32 ± 0.42 days) on green cabbage, whereas it was maximum on chinese cabbage (12.8 ± 0.67 days). The larval duration of purple cabbage was 14.50 ± 0.30 days. Kunderia *et al.* (1994) reported that the total larval period of diamondback moth was 6.8 to 24.7 days, Devi and Raj (1995) also reported a total larval period of 5 to 7 days on cauliflower in the month of April to May, whereas, Chauhan *et al.* (1997) reported 11.0 days on cabbage. The difference on larval duration may be due to the chemical constituents present in different types of cabbage under study. However, the total larval period observed by Chauhan *et al.* (1997) confirm the present observation.

The fully grown fourth instar larva, stop its feeding, contract its size and appendages and become quiescent. This is pre-pupal stage. This pre-pupal stage recorded 1 to 2 days in all types of cabbage. The length and breadth of pre-pupa was maximum (5.21 ± 0.52 mm and 1.13 ± 0.32 mm) on green cabbage and it was minimum on purple cabbage (5.05 ± 0.5 mm and 1.16 ± 0.02 mm). The pre-pupa lasted for 1.65 ± 0.47 days on purple cabbage, 1.32 ± 0.60 days on green cabbage and 1.20 ± 0.36 days on chinese cabbage. Patel (2002) [16] recorded a pre-pupal stage of *P. xylostella*, for 1 to 2 days, while its length and breadth was 5.26 and 1.15 mm, respectively. Dhaduk (2007) [4] also reported a pre-pupal period of 1 to 2 days with an average of 1.54 ± 0.49 days. Similar observation were also recorded by Gangurde and Wankhede (2010), Tarivia (2011) and Meena and Singh (2012), which is in fully agreement with present findings.

The newly formed pupa was light yellowish in colour, which later turned to light brown in colour. The pupa of diamondback moth form silken cocoon which was closed at both ends. The pupa was obtect and rounded narrowly at both ends. The data presented in Table 4 clearly indicate that the size of the pupa was maximum on green cabbage (4.97 ± 0.55 and 1.12 ± 0.08 mm), whereas it was minimum on purple cabbage (4.60 ± 0.42 and 1.03 ± 0.10 mm). The pupal duration varied from 3.0 to 6.0 days on all cabbage types (Table 5). The minimum pupal duration of 5.70 ± 0.32 days was observed on purple cabbage, followed by chinese cabbage (4.92 ± 0.10 days) and green cabbage (4.20 ± 0.62 days).

The result obtained in the present investigation was more or less similar with observation made by Sharma *et al.* (1999) who recorded a pupal period of 3 to 5 days on cabbage. Patel (2002) [16] observed that the pupa of DBM form silken cocoon which was open at both the ends. However, we noticed that cocoon was closed at both ends. The length and breadth of pupa were 5.26 and 1.15 mm, respectively. Gangurde and Wankhede (2010), Raghuwanshi *et al*. (2010) [20] noticed a pupal period 5.87 days. Tarivia (2011) observed a pupal period of 4 to 6 days and Harika *et al*. (2019) reported 3 to 5 days. The present findings on pupal period is in agreement with the observation made by earlier workers.

The adult male is a small, slender and greyish brown in colour and in resting stage one or more light coloured diamond shape clearly observed. The male typically dark in colour. The size of male is smaller than female. No difference in colour of the adult was observed when reared on different types of cabbage. The longevity of male varied from 5.0 to 9.0 days and average longevity of male was 8.32 ± 0.20 days on purple cabbage, 7.80 ± 0.37 days on green cabbage and 7.50 ± 0.32 days on chinese cabbage. The body length of male was 6.73 ± 0.41 mm when reared on green cabbage, 6.68 ± 0.40 mm on purple cabbage and 6.62 ± 0.42 mm on chinese cabbage.

The female moth is typically lighter in colour as compared to male. The size of the female was more as compared to male. When the female moth is in resting position, wings turn upward slightly. The body length of female was 7.34 ± 0.22 mm when reared on green cabbage, 7.32 ± 0.02 mm on chinese cabbage and 7.29 ± 0.17 mm on purple cabbage. The longevity of female varied from 5.0 to 14.0 days. An average longevity of female was 12.10 ± 0.31 days on purple cabbage, 9.13 ± 0.16 days on green cabbage and 8.33 ± 0.87 days on chinese cabbage. Sharma *et al*. (1999) reported male and female longevity of 6 to 9 and 14 to 20 days, respectively. Patel (2002) [16] observed an adult longevity of 6.80 days and 7.20 days on cabbage and cauliflower, respectively. Das and Chaudhry (2007) reported an adult period of 9 to 10 days on cabbage. Tarivia (2011) observed that adult moth was small, slender and brownish grey in colour. The female moth was typically lighter and marking were less distinct than male moth. The longevity of male and female moth varied from 6 to 9 days and 11 to 14 days. The present findings are in agreement with observation made by earlier workers.

Total life duration of diamondback moth varied from 24 to 42 days on three different cabbage hosts (Table 7). The duration of male and female was recorded maximum on purple cabbage 32.62 ± 0.39 and 35.0 ± 0.57 days, followed by chinese cabbage 28.03 ± 0.34 and 29.04 ± 0.18 days. The total duration observed on green cabbage was 26.70 ± 0.10 and 28.52 ± 0.3 days for male and female, respectively. Abro *et al*. (1992) reported a total development period of 11.93 to 21.2 days for diamondback moth. Miyasono *et al*. (1992) reported a life cycle of 27 to 33 days, whereas, Grillo-Ravelo *et al*. (1994) reported 20 to 28 days. Sontakke *et al*. (2010) observed that total development period of 20.2 days on cabbage. The present finding are in agreement with earlier observation reported by many workers.

The per-oviposition period of female ranged from 1 to 2 days under laboratory condition, with an average of 1.35 ± 0.12, 1.45 ± 0.16, 1.60 ± 0.31 days on green, chinese and purple cabbage, respectively. Thus the green cabbage recorded the shortest pre-oviposition period as compared to other. Patel (2002) [16] observed a pre-oviposition period of 1 to 2 days and similar observation was also noticed by Sharma *et al*. (1999), Das and Chaudhari (2007) and Dhaduk (2007) [4], which supported the present findings.

The data in Table 8 on oviposition period revealed that the female laid eggs for 1 to 3 days. The average oviposition period was 2.67 ± 0.42 days with maximum on purple cabbage followed by chinese cabbage and green cabbage with an average of 2.52 ± 0.37 and 2.30 ± 0.62 days, respectively. The present results are also in conformity with earlier finding by Patel (2002) [16], Tarivia (2011) and Sontakke *et al*. (2016), who were reported similar observations.

The post oviposition period was also observed in the life cycle of *P. xylostella* and it ranged from 2 to 5 days on green, chinese and purple cabbage with a mean of 2.47 ± 0.18, 3.02 ± 0.52 and 3.86 ± 0.20 days, respectively. Similar results were also recorded by Dhaduk (2007) [4] Tarivia (2011) reported a post-oviposition period 4.20 days at Junagadh (Gujarat), which is in agreement with present observation.

The egg laying capacity of female was varied when reared on three test cabbages. The highest fecundity of 45.62 ± 0.52 eggs per female was observed on green cabbage followed by 40.12 ± 0.52 eggs on chinese cabbage and 26.50 ± 0.37 eggs on purple cabbage, respectively.

Patel (2002) [16] reported that the female of diamondback moth laid 2 to 8 eggs in a batch Dhaduk (2007) [4] reported the fecundity of diamondback moth as 34 to 70 eggs on cabbage, which supported the present findings.

An attempt was made to find out the influence of biochemical constituents and epicuticular wax content in different types of cabbage with life stages of *P. xylostella*. The data clearly indicated that the biochemical constituents and epicuticular wax content greatly influenced on the life cycle of *P. xylostella*. Among the cabbage types *P. xylostella* took maximum duration to complete the life cycle on purple cabbage, whereas minimum time in green cabbage. For chinese cabbage total life period was in between the purple and green cabbage. This has been true for all other life stages *viz.,* larval period, pupal period and adult period for both male and female. It is also interested to note that incubation period was shortest in case of green cabbage (3.06 days) with highest fecundity (45.62 eggs/ female). If, we observe the biochemical component and epicuticular wax among these cabbage types, it is very obvious that, green cabbage which is having least amount of epicuticular wax (0.00210 µg/cm^2), high amount of total soluble sugar (376.1 µg/500 µl), low quantity of and tannin (0.42 µg/ 500 g) supported the *P. xylostella* larvae to complete its life cycle quickly with highest fecundity. The reverse, is the case with purple cabbage, wherein, the amount of epicuticular wax was high (0.00741 µg/cm^2), total soluble sugar was low (210.8 µg/500 µl) and phenol and tannin content was comparatively high where, the life cycle of *P. xylostella* was prolonged with a

lowest fecundity of 26.50 eggs/female. All the parameters were in between on chinese cabbage and the life parameters were also correspondingly between these two cabbage types.

The effect of epicuticular wax on growth and development of *P. xylostella* is well documented in recent years (Stoner, 1997; Ulmer *et al*., 2001; Agrawal and Kurashige, 2003 and Poelman *et al*., 2008). Eigenbrode and Shelton (1990) established non acceptance behaviour *P. xylostella* larvae on cabbage, due to the presence of leaf waxes. The larval growth was adversely affected by presence of tannin in the diet (Fenny, 1968 and Berenbaum, 1978). Increased stadium duration and decreased relative growth due to tannin was also reported by Lindroth *et al.* (1986) [33] and Panzuto *et al*. (2002) [34]. The present findings are in agreement with earlier reports.

Table 1: Size, incubation period and hatching per cent of eggs of *P. xylostella* on different types of cabbage

Cabbage types	Parameters									
	Measurement						Incubation period (days)			Hatching per cent
	Length (mm)			Breadth (mm)						
	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	
Green cabbage	0.40	0.52	0.49 ± 0.05	0.20	0.26	0.25 ± 0.02	1.0	4.0	3.06 ± 0.60	90.43
Purple cabbage	0.41	0.49	0.47 ± 0.04	0.19	0.24	0.22 ± 0.02	2.0	5.0	4.70 ± 0.10	86.10
Chinese cabbage	0.41	0.50	0.46 ± 0.04	0.20	0.25	0.24 ± 0.02	1.0	4.0	3.50 ± 0.04	93.22

Table 2: Bionomics of various larval instars of *P. xylostella* reared on different cabbage type

Larval instars	Parameters	Measurement (mm)								
		Green cabbage			Purple cabbage			Chinese cabbage		
		Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.
1st instar	Length	0.70	0.95	0.82 ± 0.08	0.65	0.85	0.75 ± 0.07	0.70	0.93	0.80 ± 0.09
	Breadth	0.14	0.20	0.17 ± 0.02	0.16	0.19	0.18 ± 0.09	0.14	0.22	0.16 ± 0.02
2nd instar	Length	1.10	1.34	1.21 ± 0.08	1.0	1.30	1.18 ± 0.08	1.05	1.35	1.20 ± 0.10
	Breadth	0.14	0.20	0.27 ± 0.02	0.20	0.29	0.24 ± 0.03	0.23	0.27	0.25 ± 0.01
3rd instar	Length	3.0	3.99	3.52 ± 0.32	2.9	3.7	3.39 ±0.32	3.1	3.9	3.48 ± 0.30
	Breadth	0.30	0.39	0.34 ± 0.05	0.25	0.32	0.28 ± 0.02	0.30	0.35	0.32 ± 0.03
4th instar	Length	5.10	5.27	5.72 ± 0.12	4.90	5.50	5.20 ± 0.20	3.1	3.9	5.47 ± 0.27
	Breadth	0.50	0.98	0.70 ± 0.16	0.47	0.82	0.46 ± 0.03	0.31	0.35	0.63 ± 0.13

Table 3: Duration of various larval instars of *P. xylostella* on different types of cabbage

Larval instars	Period (days)								
	Green cabbage			Purple cabbage			Chinese cabbage		
	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.
1st instar	1.0	2.0	1.46 ± 0.40	1.0	3.0	2.07 ± 0.71	1.0	2.0	1.50 ± 0.47
2nd instar	2.0	3.0	2.76 ± 0.57	2.0	4.0	3.60 ± 0.18	2.0	3.0	2.90 ± 0.28
3rd instar	2.0	4.0	3.20 ± 0.32	3.0	5.0	4.60 ± 0.19	2.0	4.0	3.52 ± 0.26
4th instar	3.0	5.0	4.20 ± 0.18	3.0	6.0	5.80 ± 0.12	3.0	5.0	4.50 ± 0.36
Total larval period	8.0	14.0	11.32 ± 0.42	9.0	18.0	14.50 ± 0.30	8.0	14.0	12.82 ± 0.67

Table 4: Measurements of pre-pupal and pupal stages of *P. xylostella* on different cabbage types

Life stages	Parameters	Measurement (mm)								
		Green cabbage			Purple cabbage			Chinese cabbage		
		Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.
Pre-pupa	Length	4.60	6.10	5.21± 0.52	4.52	5.90	5.05 ± 0.57	4.65	6.30	5.10 ± 0.72
	Breadth	1.10	1.29	1.13 ± 0.32	1.10	1.21	1.16 ± 0.02	1.11	1.30	1.20 ± 0.09
Pupa	Length	4.30	5.80	4.97 ± 0.55	4.20	5.72	4.60 ± 0.42	4.40	5.10	4.82 ± 0.40
	Breadth	1.00	1.20	1.12 ± 0.08	0.92	1.20	1.03 ± 0.10	1.0	1.27	1.15 ± 0.03

Table 5: Duration of Pre-pupal and Pupal stages of *P. xylostella* on different cabbage types

Life stages	Duration (Days)								
	Green cabbage			Purple cabbage			Chinese cabbage		
	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.
Pre-pupa	1.0	2.0	1.20 ± 0.36	1.0	2.0	1.65 ± 0.47	1.0	2.0	1.32 ± 0.60
Pupa	3.0	6.0	4.20 ± 0.62	4.0	6.0	5.70 ± 0.32	3.0	6.0	4.92 ± 0.10

Table 6: Measurements of adult male and female of *P. xylostella* on different cabbage types

Life stages	Parameters	Measurement (mm)								
		Green cabbage			Purple cabbage			Chinese cabbage		
		Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.
Male	Length	6.00	7.10	6.73 ± 0.41	6.0	7.15	6.68 ± 0.40	6.10	7.20	6.62 ± 0.42
Female	Length	7.0	7.7	7.34 ± 0.22	7.10	7.55	7.29 ± 0.17	7.0	7.68	7.32 ± 0.02

Table 7: Duration of adult male and female and total life cycle of *P. xylostella* on different types of cabbage

Life stages	Duration (Days)/Total life cycle								
	Green cabbage			Purple cabbage			Chinese cabbage		
	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.
Male	5.00	9.00	7.80 ± 0.37	5.00	9.00	8.32 ± 0.20	5.0	8.0	7.50 ± 0.32
Female	5.00	11.0	9.13 ± 0.16	6.0	14.0	12.10 ± 0.37	5.0	11.0	8.33 ± 0.87
Male	24	36	26.70 ± 0.10	25	39	32.62 ± 0.39	23	37	28.03 ± 0.34
Female	25	38	28.52 ± 0.31	27	42	35.0 ± 0.57	24	38	29.04 ± 0.18

Table 8: Pre-oviposition, oviposition, post-oviposition periods of *P. xylostella* on different types of cabbage

Period	Duration (Days)								
	Green cabbage			Purple cabbage			Chinese cabbage		
	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.
Pre-oviposition	1.0	2.0	1.35 ± 0.12	1.0	2.0	1.60 ± 0.31	1.0	2.0	1.45 ± 0.20
Oviposition	2.0	3.0	2.30 ± 0.62	1.0	2.0	2.67 ± 0.30	2.0	3.0	2.52 ± 0.37
Post-oviposition	2.0	4.0	2.47 ± 0.18	2.0	5.0	3.86 ± 0.20	2.0	4.0	3.02 ± 0.52

Table 9: Fecundity of *P. xylostella on* different types of cabbage

Cabbage types	Fecundity (Number of eggs/female)		
	Min.	Max.	Mean ± S.D.
Green cabbage	25.0	61.0	45.62 ± 0.67
Purple cabbage	20.0	50.0	26.50 ± 0.37
Chinese cabbage	30.0	70.0	40.12 ± 0.52

Table 10: Effect of epicuticular wax and biochemical parameters on life stages of *P. xylostella* on different cabbage types

Cabbage types	Epi-cuticular wax content (µg cm^2)	Total soluble sugar (µg/500 µl)	Phenol (µg/500 µl)	Tannin (µg/500 g)
Green cabbage	0.00210	376.1	80.2	0.42
Purple cabbage	0.00741	210.8	230.6	0.70
Chinese cabbage	0.00365	225.8	201.4	0.46

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