

**Elmas Sırtlı Güve, *Plutella xylostella*'nın (Linnaeus, 1758) (Lepidoptera: Plutellidae) Farklı Lahanagiller Familyasına Ait Bitkilerdeki Yaş-Evre, İki Cinsiyetli Yaşam Tablosu &**

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**Öz**

Elmas sırtlı güve, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), Brassicaceous bitkilerinin dünya çapında önemli bir zararlıdır. Yaş-evre ve iki cinsiyetli yaşam parametrelerinin belirlenmesi, daha etkili kontrol stratejileri geliştirmek için önemlidir. Bununla birlikte, *P. xylostella*'nın gelişimi için en uygun konukçunun belirlenmesi de kritiktir. Bu çalışmanın amacı, farklı konukçularda biyolojik özelliklerinin incelenerek en uygun konukçuyu belirlemek ve yaş-evre ve iki-cinsiyetli yaşam parametrelerini ortaya çıkarmaktır. GGE Biplot analizleri, biyolojik özellikler ve farklı konukçular kullanılarak oluşturulmuştur. Two-Sex MSChart programı, yaş-evre ve iki-cinsiyetli yaşam tablosu parametreleri için kullanılmıştır. GGE Biplot analizlerinde, *P. xylostella* için en uygun konukçu karnabahar olarak belirlenmiştir. GRR ve R0 karnabaharda daha yüksek (106,25±27,56 ve 96,88±25,59 nesil/birey) kanolada (22,93±10,18 ve 15,76±6,79 nesil/birey) daha düşüktür.  $\lambda$  değeri ve r, kara lahanada (1.27±0.02 ve 0.24±0.02 gün) daha yüksek iken, beyaz lahanada (1.13±0.01 ve 0.12±0.01 gün) ve kanolada (1.13±0.03 ve 0.12±0.02 gün) azalmıştır. En yüksek günlük yumurta bırakma (mx) karnabaharda (18.47 adet) ve en düşük kara lahanadadır (3.05 adet). Sunulan sonuçlar, Brassicaceous bitkilerindeki popülasyon yoğunluğunun ve zararının tahmin edilmesi ve yeni mücadele stratejilerinin geliştirilmesinde yararlı olacaktır.

**Anahtar kelimeler:** *Plutella xylostella*, Elmas sırtlı güve, Two sex life table, GGE Biplot, biyoloji

**Age-Stage, Two-Sex Life Table of The Diamondback Moth, *Plutella xylostella* (Linnaeus, 1758) (Lepidoptera: Plutellidae) on Different Brassicaceous Plants &**

**Abstract**

The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is an important worldwide pest of Brassicaceous plants. Determining age-stage and two-sex life parameters are important to development more effective control strategies. However, it is also crucial to determine the preferred host for the larval rearing of *P. xylostella*. The aim of this work is to investigate the preferred Brassicaceous plant by examining the biological characteristics on different hosts and to reveal age-stage and two-sex life parameters. GGE Biplot analyzes were created using the biological characteristics and the different hosts. Two-Sex MSChart program is used to report age-stage and two-sex life table parameters. In GGE Biplot analyzes, suitable host for *P. xylostella* was determined as cauliflower. GRR and R0 were the higher in cauliflower (106.25±27.56 and 96.88±25.59 offspring/individual) and less in canola (22.93±10.18 and 15.76±6.79 offspring/individual).  $\lambda$  value and r were higher in collard (1.27±0.02 and 0.24±0.02 days) while decreased in white cabbage (1.13±0.01 and 0.12±0.01 days) and canola (1.13±0.03 and 0.12±0.02 days). The highest daily fecundity (mx) was on cauliflower (18.47 eggs) and on collard (3.05 eggs) as lowest. The presented results will be useful in estimating population density and the damages to Brassicaceous plants in order to develop new management strategies.

**Key words:** *Plutella xylostella*, Diamondback moth, Two sex life table, GGE Biplot, biology.

## Introduction

The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is one of the most important pests of Brassicaceous plants and oilseed crops worldwide (Li et al., 2016). It is the most universally distributed insect among lepidopteran pest insects. Since Brassicae plants are thought to be European origin, it is accepted that the diamondback moth also originated in this region and distributed worldwide wherever brassicae plants grown (Meyricks, 1928; Furlong et al., 2013).

The diamondback moth is known as the oligophagous and feeds on Brassicaceous plants that contain glycosides known as phagostimulants (Gupta and Thorsteinson, 1960; Golizadeh et al., 2009). In Turkey, it was first reported in Artvin, Murgul district in 1965 (Alkan, 1965) then Avcı and Özbek (1990) reported the diamondback moth in Brassicaceous cultivated areas in Erzurum and recently Atay et al. (2019) was reported the pest in Çanakkale province.

The diamondback moth is reported as the most important pest in 145 countries in the world, about 90% yield loss with having about \$ 4-5 billion management cost (Saeed et al., 2010; Jaleel et al., 2019). It has been reported to injure to cabbage and other Crussiferae crops in many countries (Talekar et al., 1985; Avcı and Özbek, 1995) and has become resistant to *Bacillus thuringiensis* and chemicals in management of the diamondback moth (Talekar et al., 1990; Tabashnik et al., 1990).

Considering the interaction with the environment in efficiency trials, it is important to test performance stability which is an important parameter that affects the course of the research. There are several measurement methods for performance stability (Lin et al., 1986; Bhan et al., 2005). The "GGE Biplot Analysis" has been developed to reveal the experimental results more easily and graphically (Yan and Kang, 2003). It was used to evaluate average performance, test locations (Fan et al., 2007), genotype selection and stability (Yan et al., 2000), genotype and environment interactions and evaluation (Akçura, 2021; Blanche and Myers, 2006; Kang, 1998). GGE Biplot analysis is a part of the variation used in the evaluation of cultivars when the genotype was considered as the main factor (G), and consisted of the combination of genotype X environment interaction (GE) (Yan & Falk, 2002). Here, we used GGE Biplot analysis to understand the preference of the larval host plants for the diamondback moth rearing in the laboratory.

The Two-Sex MS Chart program is used to perform statistical analysis along with graphs and tables, using two-sexual life charts specific to age and stages. It develops data using both the two-

sexes and the pre-adult periods. It also helps to understand the role of both sexes in terms of total damages of the host plants which is important to decide the control methods against the insect pests (Chi, 1988; Chi, 2018; Atlıhan et al., 2018).

Revealing the life history characteristics of a pest would be useful to understand population dynamics. Without this information, it is not possible to determine the pest population growth rate, damage level, management and times of management. In addition, it is important to know the biological characteristics of the pest in order to estimate the time to release natural enemies for biological control and to apply chemicals.

The objective of this study was to report the suitability of GGE Biplot analysis for evaluating host preferences and investigating the age-stage two sex life table of the diamondback moth under controlled conditions.

## Material and Methods

### Plant materials

Several host plant leaves such as white cabbage (*Brassica oleracea* var. *capitata*), red cabbage (*Brassica oleracea* var. *capitata* f. *rubra*), cauliflower (*Brassica oleracea* var. *botrytis*), broccoli (*Brassica oleracea* var. *italica*), collard (*Brassica oleracea* var. *viridis*), canola (*Brassica napus*), cress (*Nasturtium officinale*) and rocket (*Eruca vesicaria*) were collected from local fields and brought to the laboratory to rear larval stages of the diamondback moth.

### Laboratory maintenance of the diamondback moth

Different biological stages were collected from infested Brassicae fields in Çanakkale in October and November 2019 then were brought to the laboratory to establish a colony. Cabbage leaves were wrapped with moistened cotton then placed in tupperware containers with collected larvae from Brassicae fields. Larvae were reared until pupation. The pupae were collected with the help of soft-tipped forceps and transferred into the petri dish. The adult rearing cages (45x45x45 cm) were set up with white chiffon cloth, having host leaves for oviposition and cotton soaked 10% honey water solution as adult food. The colony was established on cabbage leaves and reared for 3-4 generations before setting up the experiments. All experiments were directed under controlled conditions at 20±1°C, 50% relative humidity and 16: 8 (L:D) photoperiod.

### Life cycle properties

A total of 200 randomly selected eggs were transferred to a moistened filter paper in a petri dish. The length and width measurements of the eggs were made under the Olympus SZX9 stereozoom microscope and weighed on a precision scale. Newly hatched larvae were used to test host preferences in all experiments. Each host plant leaves were wrapped with a pieces of moistened cotton and placed in 0.8 ml containers to test. Neonate larvae were carefully transferred onto the leaves with a camel brush. Trials were performed in 25 replications for each tested host leaves. They were checked and replaced with fresh leaves as needed.

In order to determine the larval stages, diameters of head capsules were measured and old skin or exivuae were observed after molted (Saran and Genç, 2021). The durations of larval and pupal stages were reported for each tested hosts. Mature larvae were sexed based on the distinct color change in the dorsal appearance of the 8<sup>th</sup> abdominal segment in male larvae (Liu and Tabashnik, 1997; Saran and Genç, 2021). Adult emergence, fecundity and survivorships were determined. According to single pair mating groups (1♀: 1♂) in adult cages (15x15 cm), pre-oviposition, oviposition and post-oviposition and the numbers of laid eggs were determined for a female. The number of hatched eggs and egg incubation periods were also reported. Data on durations of all biological stages were used to generate graphs by Two-Sex MSChart program. All reported measurements and durations were used for GGE Biplot analysis.

### Statistical analysis

Data were analyzed statistically using the SAS software, according to PROC GLM procedure, LSD (Least Significant Difference) test (version 9.1.3; SAS Institute, Cary, NC) (1990). Obtained data were used for GGE Biplot Analysis program for each tested larval hosts. The graphs are basically two ways and the principal component analysis is consisted of the first principal component (PC1) and the second principal component (PC2) component contributions to the total sum of squares in GGE biplots. In GGE Biplot analysis, 43 biological properties of *P. xylostella* reared in 8 different hosts were evaluated. In this study, the host plants used in the GGE Biplot analysis were accepted as the genotype and the biological characters examined as the environment (Kang and Gauch, 1996; Yan et al., 2000; Kang, 1998). In addition, the vectorial lengths and biological properties were used for the selection of preferred host plants. Since biological properties are considered as environment, GGE Biplot analysis have been created to determine

which biological properties are better in which host plant, the state of the relationships between biological properties, and the effect of the host plants on life properties.

With the Two-Sex MSChart program, the data were evaluated statistically based on female and male. The graphs and tables were prevailed with SigmaPlot 14.0 program (Systat Software Inc., Erkrath, Germany) (Chi and Su, 2006).

Age-stage-specific life expectancy ( $ex_j$ ) is calculated with the formula;

$$ex_j = \sum_{i=x}^{\infty} \sum_{y=j}^m S'_{iy}$$

and where  $s_{xj}$  is, representing the survival rate of the individual who has reached the age of  $x$  until the age  $i$  and stage  $j$ , the calculation is made pretending  $s_{xj} = 1$  (Chi and Su, 2006).

Age-stage-specific reproductive value ( $vx_j$ ) is calculated by, using the formula

$$V_{xj} = \frac{e^{r(x+1)}}{S_{xj}} \sum_{i=x}^{\infty} e^{-r(i+1)} \sum_{y=j}^k S'_{iy} f_{iy}$$

the addition of the specimen at the age of  $x$  to the next population in stage  $j$  is calculated (Abbas et al., 2014).

The age specific survival rate ( $lx$ ), for each matrix  $S$ ,

$$lx = \sum_{j=1}^m S_{xj}$$

for each age group, using the age-specific fecundity ( $mx$ ),

$$mx = \left( \sum_{j=1}^m S_{xj} f_{xj} \right) / \sum_{j=1}^m S_{xj}$$

with the formula,

$$\sum_{x=1}^k e^{-rx} lx mx = \sum_{x=1}^k \left( e^{-rx} \sum_{j=1}^m f_{xj} s_{xj} \right) = 1$$

the intrinsic rate of increase ( $r$ ), the infinite rate of increase ( $\lambda$ ) and the mean length of a generation ( $T$ ) are calculated (Chi and Liu, 1985).

### Results and Discussion

The eggs were laid on all tested host plants in the laboratory conditions. There was no statistically difference in the measurements of egg width, length and weight. The average was  $0.3 \pm 0.001$  mm in width,  $0.472 \pm 0.001$  mm in length and  $0.0056 \pm 0.001$  mg in weight. The longest development time for eggs was  $5.00 \pm 0.01$  days comparison to the tested hosts (Table 1).

No difference was found in the measurements of neonates between the hosts. The average was  $0.16 \pm 0.001$  mm in width and  $0.01 \pm 0.001$  mg in weight. The length of neonates was  $0.88 \pm 0.05$  mm on cauliflower while shorter on canola,  $0.79 \pm 0.04$  mm. Duration of neonates was in  $4.27 \pm 0.75$  days on white cabbage and  $1.88 \pm 0.47$  days on rocket leaves (Table 1).

In second instar, the average weight was  $0.1 \pm 0.001$  mg in white cabbage and  $0.03 \pm 0.01$  mg in rocket leaves. The width measurement was about  $0.32 \pm 0.01$  mm on cauliflower, red cabbage and canola, and  $0.27 \pm 0.04$  mm on white cabbage leaves.

The length was  $2.05 \pm 0.22$  mm on cauliflower and  $1.52 \pm 0.12$  mm on the cress leaves. Duration was in  $3.11 \pm 0.75$  days on cress and  $1.83 \pm 0.38$  days on rocket leaves (Table 1).

In third instar, the average weight was  $0.54 \pm 0.11$  mg on broccoli leaves and  $0.36 \pm 0.25$  mg on rocket. The width measurement was about  $0.55 \pm 0.06$  mm on broccoli and  $0.45 \pm 0.07$  mm on cress. The length was  $3.59 \pm 0.39$  mm on cauliflower and  $2.99 \pm 0.36$  mm on white cabbage. Duration was in  $3.05 \pm 1.30$  days on cress and  $1.66 \pm 0.48$  days rocket (Table 1).

In fourth instar, the average weight was  $2.77 \pm 1.21$  mg on collard and  $1.42 \pm 0.59$  mg on cress. The width measurement was about  $0.95 \pm 0.17$  mm on collard and  $0.76 \pm 0.11$  mm on cress leaves. The length was  $6.00 \pm 0.41$  mm on cauliflower and  $4.69 \pm 0.73$  mm on cress leaves. Duration was in  $4.27 \pm 0.75$  days on cabbage and  $1.44 \pm 0.51$  days on collards (Table 1).

**Table 1.** Duration of egg and larval stages on different hosts (Mean $\pm$ SE, N=25) \*

Hosts	Egg (day)	1st Instar (day)	2st Instar (day)	3st Instar (day)	4st Instar (day)
Cauliflower	$5.00 \pm 0.01a$	$2.00 \pm 0.01ef$	$3.05 \pm 0.23a$	$2.77 \pm 0.54a$	$3.72 \pm 0.46b$
Broccoli	$4.10 \pm 0.21b$	$3.33 \pm 0.48c$	$2.88 \pm 0.47a$	$3.00 \pm 0.01a$	$3.00 \pm 1.08c$
R. Cabbage	$4.90 \pm 0.84a$	$3.83 \pm 0.70b$	$2.88 \pm 0.58a$	$2.77 \pm 0.42a$	$3.00 \pm 0.48c$
W. Cabbage	$4.70 \pm 0.42a$	$4.27 \pm 0.75a$	$2.44 \pm 0.51b$	$2.83 \pm 0.38a$	$4.27 \pm 0.75a$
Cress	$2.90 \pm 0.45c$	$3.72 \pm 0.89bc$	$3.11 \pm 0.75a$	$3.05 \pm 1.30a$	$3.11 \pm 0.83c$
Canola	$2.30 \pm 0.42d$	$2.72 \pm 0.75d$	$2.50 \pm 0.51b$	$2.22 \pm 0.54b$	$2.38 \pm 1.28d$
Collard	$2.40 \pm 0.45d$	$2.38 \pm 0.77de$	$1.94 \pm 0.41c$	$1.77 \pm 0.54c$	$1.44 \pm 0.51e$
Rocket	$2.10 \pm 0.31d$	$1.88 \pm 0.47f$	$1.83 \pm 0.38c$	$1.66 \pm 0.48c$	$1.50 \pm 0.51e$

\*Within rows, different letters show significant differences between mean values ( $P < 0.05$ , LSD test)

In female pupae, the average weight was  $8.17 \pm 0.86$  mg on cauliflower and  $4.50 \pm 0.34$  mg on canola. The width measurement was about  $1.50 \pm 0.07$  mm on broccoli and  $1.30 \pm 0.03$  mm on canola. The length was  $6.16 \pm 0.36$  mm on cabbage and  $5.49 \pm 0.11$  mm on canola. Duration was in  $6.83 \pm 0.75$  days on broccoli and  $3.33 \pm 0.51$  days on rocket (Table 2).

In male pupae, the average weight was  $7.02 \pm 0.56$  mg on broccoli and  $3.58 \pm 0.40$  mg on canola. The width measurement was about  $1.44 \pm 0.06$  mm on cauliflower and  $1.16 \pm 0.06$  mm on canola. The length was  $6.08 \pm 0.14$  mm on broccoli and  $4.97 \pm 0.19$  mm on canola. Duration was in  $8.33 \pm 0.51$  days on white cabbage and  $3.83 \pm 0.40$  days on collard (Table 2).

**Table 2.** Duration of prepupal and pupal stages on different hosts (Mean $\pm$ SE)\*

Hosts	Female Prepupa (day)	Male Prepupa (day)	Female Pupa (day)	Male Pupa (day)
Cauliflower	$1.00 \pm 0.01 b$	$1.33 \pm 0.51 b$	$5.33 \pm 0.51 b$	$6.50 \pm 0.54 c$
Broccoli	$1.33 \pm 0.51 a$	$1.66 \pm 0.51 a$	$6.83 \pm 0.75 a$	$7.50 \pm 0.83 b$
R. Cabbage	$1.16 \pm 0.40ab$	$1.00 \pm 0.01 c$	$5.16 \pm 0.40 b$	$5.83 \pm 0.75cd$
W. Cabbage	$1.16 \pm 0.40ab$	$1.00 \pm 0.01 c$	$6.66 \pm 0.81 a$	$8.33 \pm 0.51 a$
Cress	$1.00 \pm 0.01 b$	$1.00 \pm 0.01 c$	$4.50 \pm 1.37bc$	$5.16 \pm 1.32 d$
Canola	$1.00 \pm 0.01 b$	$1.00 \pm 0.01 c$	$4.16 \pm 0.40cd$	$4.16 \pm 0.40 e$
Collard	$1.00 \pm 0.01 b$	$1.00 \pm 0.01 c$	$3.66 \pm 0.81cd$	$3.83 \pm 0.40 e$

\*Within rows, different letters show significant differences between mean values ( $P < 0.05$ , LSD test)

In adult female, the measurement of wing span was  $13.40 \pm 0.54$  mm on cauliflower and  $10.40 \pm 0.89$  mm on rocket. The weight was  $2.38 \pm 0.39$  mg on canola and  $1.16 \pm 0.36$  mg on red cabbage (Table 3).

In adult male, the measurement of wing span was  $12.60 \pm 0.54$  mm on broccoli and  $9.60 \pm 0.89$  mm on rocket. The weight was  $2.08 \pm 0.19$  mg on collard and  $1.08 \pm 0.13$  mg on red cabbage. The adult female longevity was longer on cauliflower

( $30.00 \pm 9.23$  days) than those of the other hosts (Table 3).

Duration of pre-oviposition was in  $7.2 \pm 11.20$  days on broccoli leaves and  $1.00 \pm 0.001$  days on canola and collard leaves. Duration of oviposition in  $12.50 \pm 5.50$  days on canola and  $7.00 \pm 6.27$  days on broccoli. Post oviposition period was in  $10.25 \pm 5.37$  days in red cabbage and  $0.50 \pm 1.00$  days on broccoli. The longevity was in  $25.33 \pm 5.98$  days on red cabbage host and  $9.66 \pm 5.53$  days on collard leaves (Table 3).

**Table 3.** Duration of pre-oviposition, oviposition and post-oviposition on various hosts (days, Mean $\pm$ SE)\*

Hosts	Pre-oviposition	Oviposition	Post-oviposition	Longevity	
				Female Adult	Male Adult
Cauliflower	$1.25 \pm 0.50$ ab	$10.00 \pm 3.74$ a	$5.00 \pm 2.94$ bc	$19.83 \pm 12.8$ ab	$30.00 \pm 9.23$ a
Broccoli	$7.25 \pm 11.20$ a	$7.00 \pm 6.27$ a	$0.50 \pm 1.00$ c	$13.66 \pm 7.58$ bc	$24.00 \pm 7.48$ ab
R. Cabbage	$1.25 \pm 0.50$ ab	$11.25 \pm 2.98$ a	$10.25 \pm 5.37$ a	$25.33 \pm 5.98$ a	$30.00 \pm 7.76$ a
W. Cabbage	$3.75 \pm 4.27$ ab	$11.50 \pm 8.26$ a	$4.50 \pm 4.65$ bc	$17.66 \pm 6.77$ abc	$17.57 \pm 7.76$ bc
Cress	$1.50 \pm 1.00$ ab	$12.25 \pm 2.87$ a	$6.25 \pm 2.62$ ab	$18.66 \pm 4.88$ abc	$14.14 \pm 11.32$ c
Canola	$1.00 \pm 0.01$ b	$12.50 \pm 5.50$ a	$3.25 \pm 3.30$ bc	$14.00 \pm 7.79$ bc	$12.71 \pm 6.70$ c
Collard	$1.00 \pm 0.01$ b	$7.25 \pm 2.50$ a	$3.50 \pm 3.41$ bc	$9.66 \pm 5.53$ c	$9.85 \pm 6.51$ c
Rocket	$1.50 \pm 1.00$ ab	$8.75 \pm 1.70$ a	$4.50 \pm 3.10$ bc	$10.16 \pm 8.32$ c	$11.14 \pm 9.44$ c

\*Within rows, different letters show significant differences between mean values ( $P < 0.05$ , LSD test)

Higher fecundity was recorded on cauliflower ( $309.25 \pm 60.99$  eggs) than on canola

( $89.75 \pm 27.20$  eggs) (Table 4). The ratio of hatched eggs was highest on white cabbage (75.82%) than on rocket leavaes (36.30%) (Table 4).

**Table 4.** Fecundity, number of hatched eggs and egg percentage on different hosts (Mean $\pm$ SE)\*

Hosts	Fecundity (Number)	Number of Eggs Hatched	Hatched Egg (%)
Cauliflower	$309.25 \pm 60.99$ a	$233.00 \pm 61.21$ a	75.34
Broccoli	$231.75 \pm 159.69$ ab	$132.75 \pm 93.82$ b	57.28
Red Cabbage	$195.00 \pm 27.90$ abc	$90.50 \pm 33.75$ b	46.41
White Cabbage	$190.25 \pm 64.93$ bc	$144.25 \pm 52.11$ b	75.82
Cress	$197.75 \pm 75.50$ abc	$142.00 \pm 63.34$ b	71.80
Canola	$89.75 \pm 27.20$ c	$61.50 \pm 19.77$ b	68.52
Collard	$179.50 \pm 17.69$ bc	$134.50 \pm 41.62$ b	74.93
Rocket	$168.00 \pm 103.92$ bc	$61.00 \pm 71.92$ b	36.30

\*Within rows, different letters show significant differences between mean values ( $P < 0.05$ , LSD test)

The effects of tested hosts on the life cycle properties of the diamondback moth were shown in Figure 1 and 2, based on GGE Biplot Analysis. The graphs are basically two-way and the principal component analysis consists of PC1 and PC2 components. It showed that as the total value of both components approaches 100%, the coefficients of the examined parameters are high in

determining the variation (Yan et al., 2000). In this report, a value of 47.6% for the first principal component (PC1) and 19% for the second principal component (PC2) were determined and 66.6% of the variation in total was explained. In GGE Biplot analysis was used to select the most favorable host for the diamondback moth based on the results of this work and graphically showed in Figure 1.

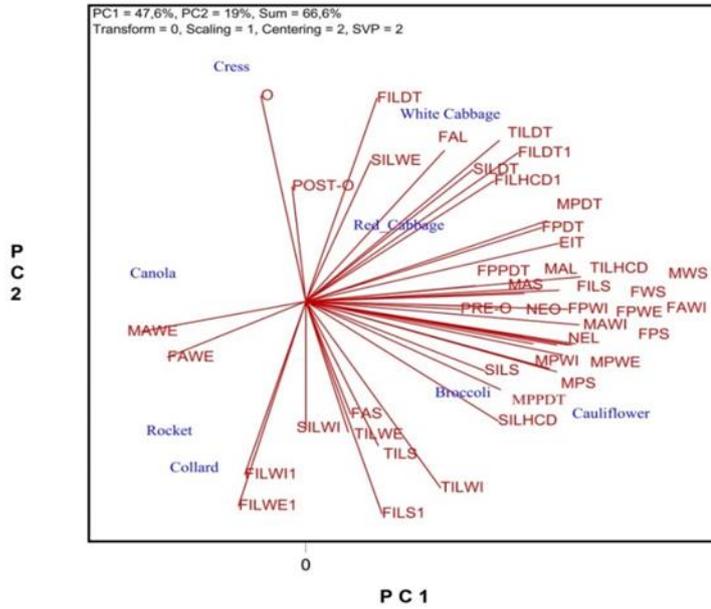


Figure 1. The effects of different host plants on the biological properties of *Plutella xylostella* based on GGE biplot graph

The hosts in the same direction and in the same circle showed that they have values close to each other (Figure 2). In other words, cauliflower

and broccoli were found to be the most suitable hosts for almost all biological characteristics examined for each biological stage (Figures 1 and 2).

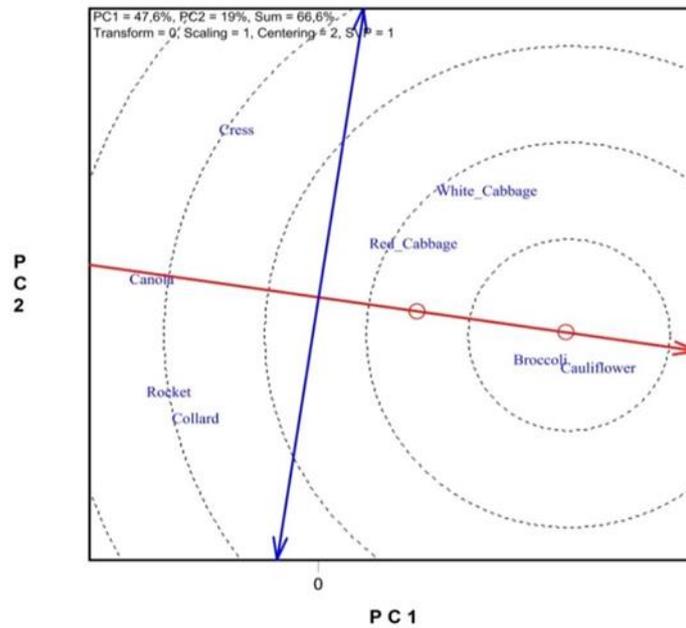


Figure 2. GGE biplot graph shows the ideal host plants for *Plutella xylostella*

In the data obtained using the GGE Biplot Analysis program, the difference between the hosts was found to be statistically significant in the characteristics examined for different biological stages of the *P. xylostella* reared in different hosts.

Gross reproductive rate (GRR) and the net reproductive rate (R0) were the higher in

cauliflower and less in canola. Finite rate of increase ( $\lambda$ ) value and the intrinsic rate of increase ( $r$ ) were higher in collard while decreased in white cabbage and canola. The mean generation time (T) was decreased from  $31.68 \pm 0.87$  to  $16.16 \pm 0.86$  days when the larval host was white cabbage to rocket or canola (Table 5).

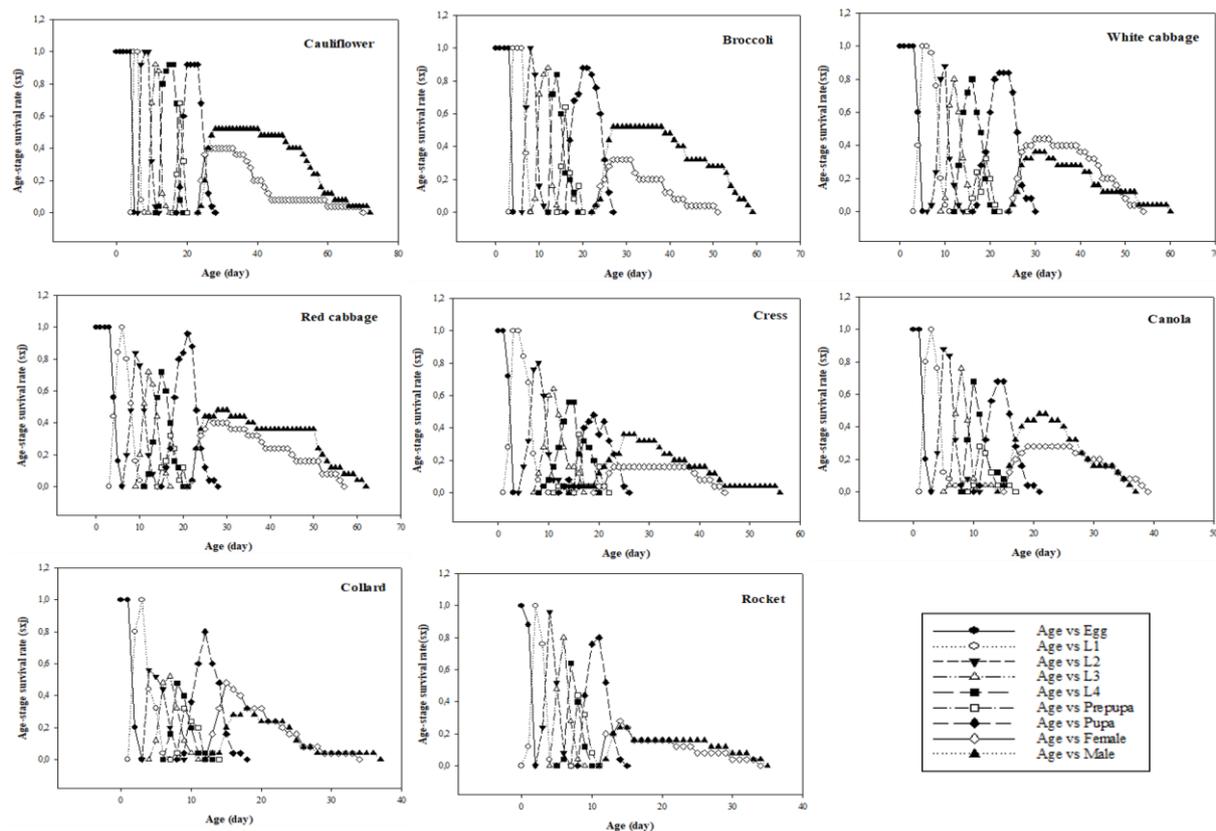
**Table 5.** Effects of different hosts on the population parameters of *Plutella xylostella* (Mean±SE, N=25)\*

Host	GRR (offspring/individual)	$\lambda$ (day)	r (day)	R <sub>0</sub> (offspring/ individual)	T (day)
Cauliflower	106.25±27.56a	1.17±0.01b	0.16±0.01b	96.88±25.59a	28.29±0.46b
Broccoli	81.08±28.99ab	1.15±0.04b	0.14±0.01b	66.80±24.14a	28.71±0.65b
R.Cabbage	77.09±19.13a	1.16±0.01b	0.15±0.01b	67.08±17.29a	27.82±0.66b
W.Cabbage	74.65±19.20a	1.13±0.01b	0.12±0.01b	55.16±16.25a	31.68±0.87a
Cress	54.89±23.87ab	1.15±0.12b	0.14±0.02b	31.72±15.07b	24.53±0.82c
Canola	22.93±10.18b	1.13±0.03b	0.12±0.02b	15.76±6.79 b	21.51±0.87d
Collard	68.22±17.96 a	1.27±0.02a	0.24±0.02a	51.76±14.38a	16.17±0.44e
Rocket	63.01±26.69 ab	1.22±0.08a	0.2±0.04ab	26.08±13.02b	16.16±0.86e

\*Within rows, different letters show significant differences between mean values (P < 0.05), r: intrinsic rate of increase  $\lambda$ : infinite rate of increase GRR: gross reproductive rate R<sub>0</sub>: net reproductive rate T: mean generation time.

The age-specific survival rate (sxj) of the diamondback moth on various host plants was indicated the survival rate of the insect to x age and j showed the probability of development. There was

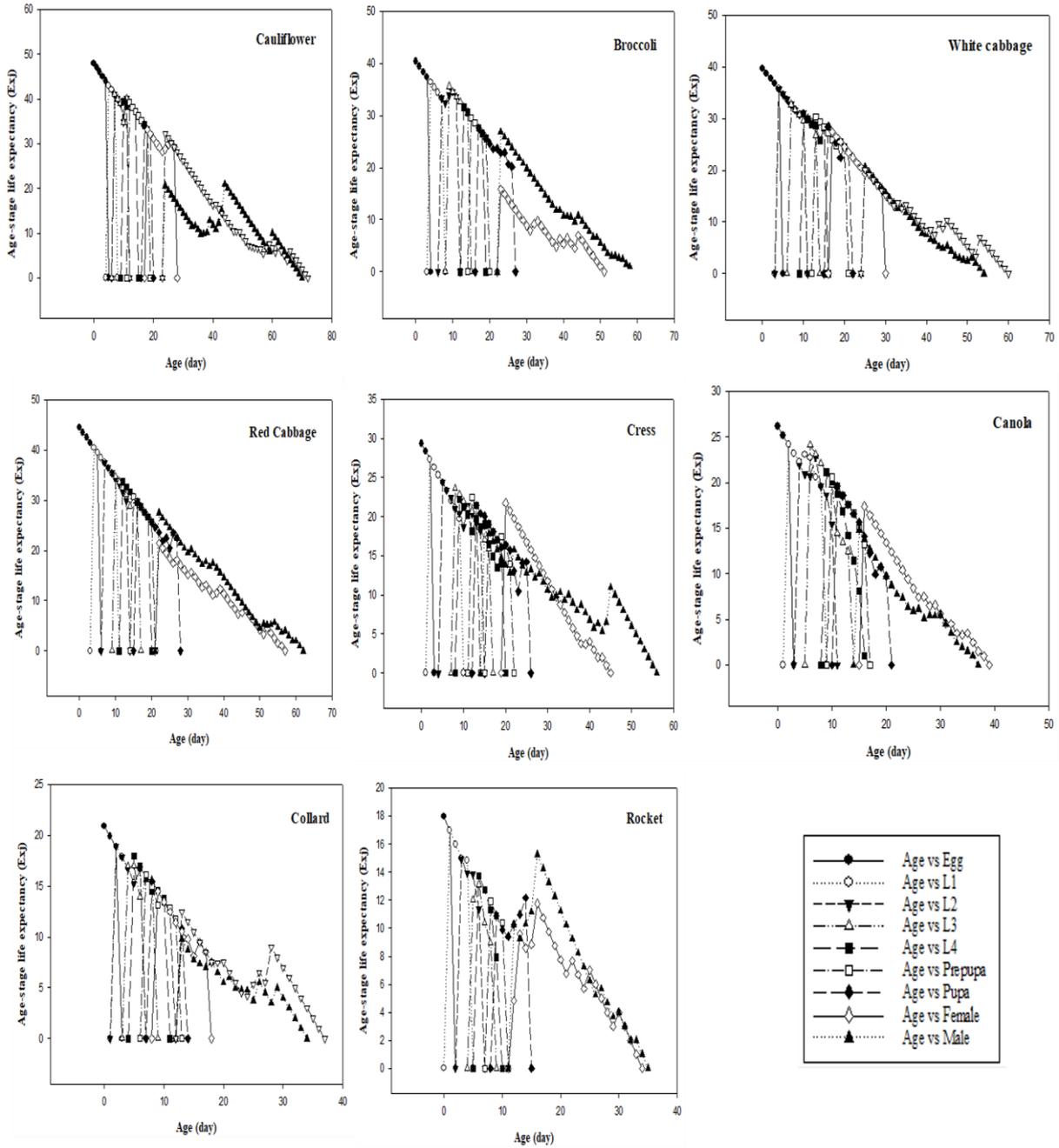
a difference in survival rate of egg to adult with higher rate 0.48 for females on collard and 0.52 for males on cauliflower and lowest 0.16 for females on cress and 0.24 for males on rocket (Figure 3).



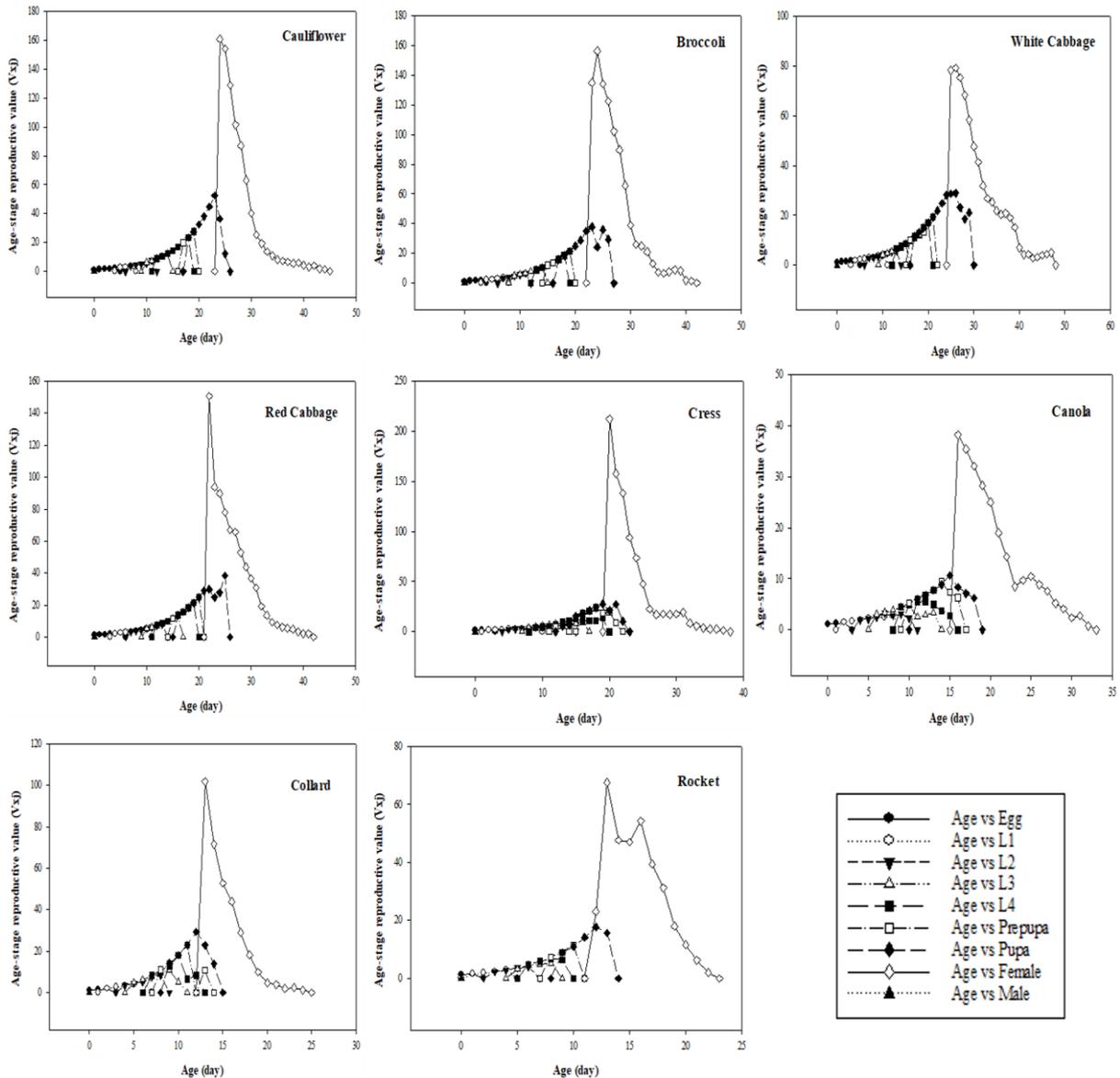
**Figure 3.** The age-stage survival rate (sxj) of the diamondback moth on different hosts. \*L1 = 1<sup>st</sup> Instar, L2 = 2<sup>nd</sup> Instar, L3 = 3<sup>rd</sup> Instar, L4 = 4<sup>th</sup> Instar.

Age stage life expectancy (exj) of the diamondback moth, an insect at age x and stage j were predicted to survival. Age stage life expectancy was affected by hosts.

It was increased from 35 days on cauliflower to 72 days on rocket (Figure 4). Age stage reproductive value (vxj) of *P. xylostella* was showed prediction of the population (Figure 5).



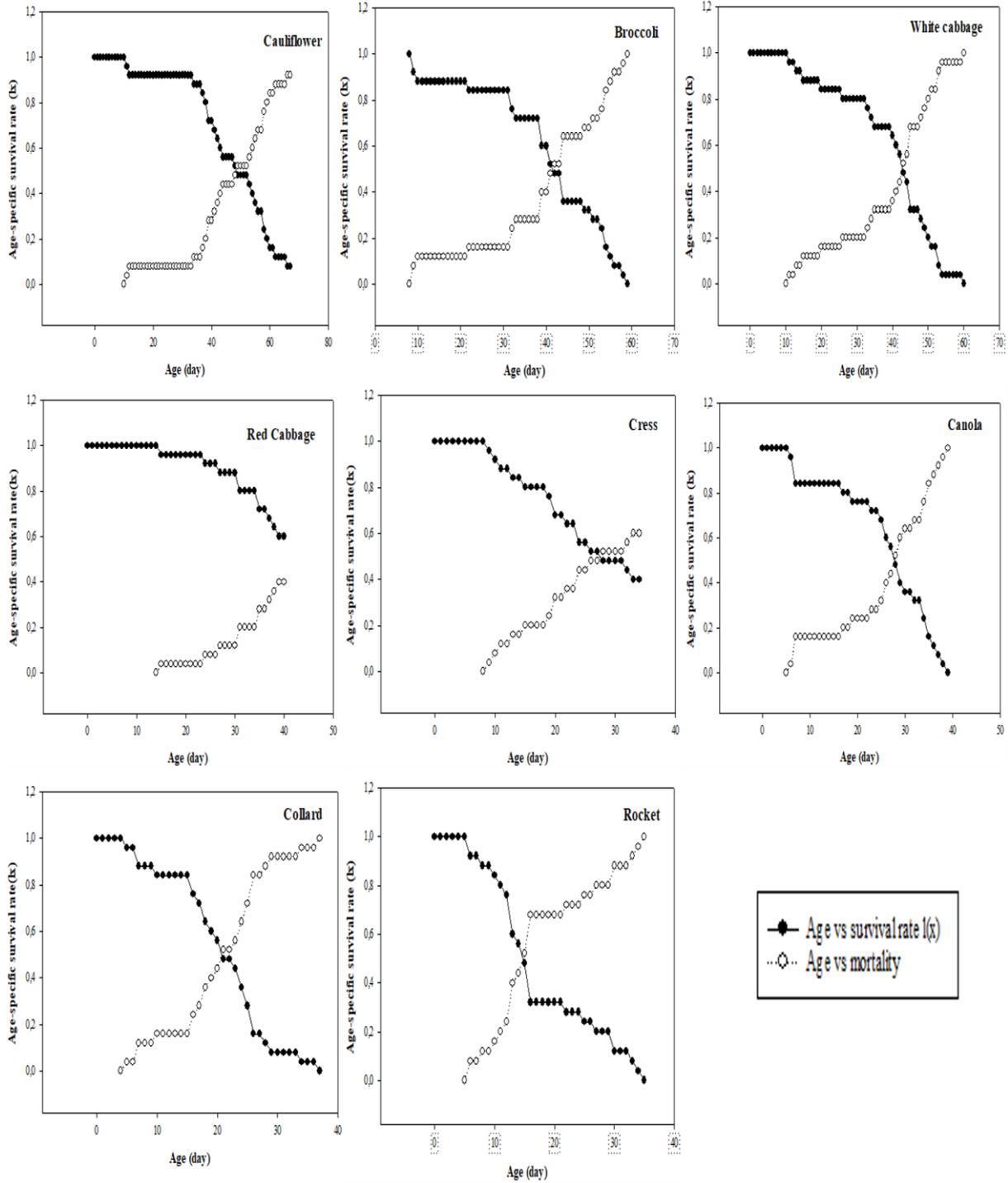
**Figure 4.** The age-stage life expectancy ( $ex_j$ ) of the diamondback moth on different hosts. \*L1 = 1<sup>st</sup> Instar, L2 = 2<sup>nd</sup> Instar, L3 = 3<sup>rd</sup> Instar, L4 = 4<sup>th</sup> Instar.



**Figure 5.** The age-stage reproductive value ( $v_{xj}$ ) of the diamondback moth on different hosts. \*L1 = 1<sup>st</sup> Instar, L2 = 2<sup>nd</sup> Instar, L3 = 3<sup>rd</sup> Instar, L4 = 4<sup>th</sup> Instar.

The slopes of reproductive value on each host decreased 26 days (white cabbage) to 13 days (rockets) depended on tested hosts. These results showed that female adults made the highest contribution to the population when compared to the other biological stages. Ignoring the

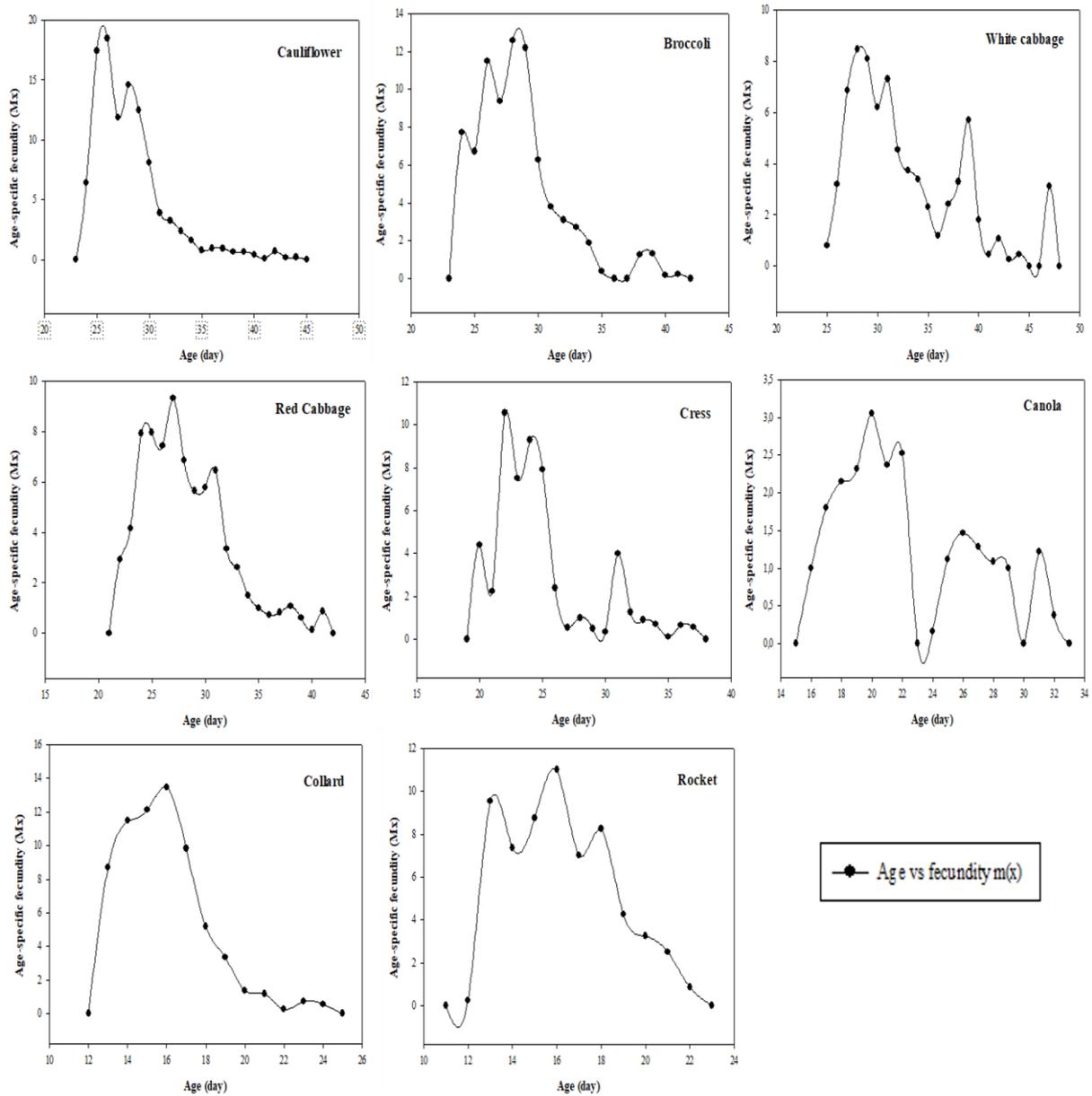
differentiation of biological stages, the age-stage survival rate ( $l_x$ ) was indicated the probability of survival of the egg laid by the female adult up to the age of  $x$ . The age stage survival rate ( $l_x$ ) was recorded as higher on cauliflower (66 days) and less on cress (34 days) (Figure 6).



**Figure 6.** The age-specific survival rate ( $l_x$ ) of the diamondback moth on different hosts

The highest daily fecundity ( $m_x$ ) was on cauliflower (18.47 eggs, at the age 26 days old) and

on collard (3.05 eggs, at the age of 16 days old) as lowest (Figure 7).



**Figure 7.** Age specific fecundity (Mx) of the diamondback moth on different hosts

Host preference and suitable of pest insects differ in terms of biological stages, survival, reproduction and female: male ratios (Saeed et al., 2010). This study reported life traits of biological stages of the diamondback moth and revealed the preferred hosts based on GGE Biplot analysis. It is also investigated two-sex life table properties with age-stage on different hosts. It is reported in various studies that duration of larval stages, development, survival and fecundity are important biological properties to describe population rate of the diamondback moth (Saeed et al., 2010; Zalucki et al., 2012). This study concluded that population rate was highest on cauliflower. Jaleel et al. (2019) also indicated cauliflower as the preferred host based on fecundity and population rate.

It is quite known that the GGE Biplot analysis is a perfect tool for visual representation of biological data (Yan et al., 2000). It provides an advantage for users to obtain the results graphically and interpret the two principal components, PC1 and PC2 (Bhan et al., 2005). GGE Biplot analysis is mostly used to study genotype x environment interaction in plants (Akçura, 2021). In this study, different host plants belonging to the Brassicaceous family were used to examine the effects on some biological properties of *P. xylostella*. GGE Biplot analysis showed the correlation of host plants based on the life properties of the diamondback moth, as well as the importance of testing and comparison to select the specific and preferred host plant for this insect. According to the results obtained from this analysis, the hosts with higher performance for

almost all biological characteristics were cauliflower and broccoli.

The bootstrap technique (n=100000) was used to predict the mean of population parameters and the variation among tested hosts. The intrinsic rate of growth is one of the fundamental parameters. It provides a determinant for the possible rate of growth under different physical conditions, as well as a measurement for the fitness of different host plants (Birch, 1948). The ability of an insect to survive in a particular environment may depend on its intrinsic rate of increase, reaching a certain minimum value. It does not mean that the insect will perform the best in a host with the highest intrinsic growth rate. Because evolution is also important to select strains that are both large enough to successfully compete with other species and have an intrinsic rate of increase that is small enough to avoid a multiplication rate consuming food supply in the environment (Birch, 1948).

Population growth rate  $r$  and net reproduction number  $R_0$  are two basic composite parameters that determine the fate of a population in the long term (Chi and Su, 2006). In this study, while the host with the highest intrinsic increase was collard,  $R_0$  (net reproductive rate) was reported

in the cauliflower plant with the highest rate. Jaleel et al. (2019) studied the age-stage, two-sex life table of the diamondback moth on three hosts, such as cauliflower, napa cabbage and white cabbage. It has been revealed that cauliflower had a shorter development time and more fecundity than napa cabbage and white cabbage. In this study, it was observed that the net reproductive rate ( $R_0$ ) and the internal rate of increase were higher in those fed on cauliflower. Saeed et al. (2010) reported the fitness parameters of *P. xylostella* on various hosts. It was observed that the net reproductive rate ( $R_0$ ) value and intrinsic rate of natural increase ( $r$ ) was higher in cauliflower than in other hosts. Mean generation time ( $T$ ) was reported in the shortest on rocket plant, and the highest mortality was also reported on rocket plant. This data led to conclude that the rocket plant is not a suitable host for *P. xylostella* rearing in the laboratory. There are many biotic and abiotic factors that is important for host preferences and suitability including seasonal changes in nutrient content of the hosts and environmental conditions. The present study showed clearly that cauliflower is an appropriate host for laboratory rearing of the diamondback moth.

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