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# Biology, predatory potential and growth parameters of the syrphid fly, *Scaeva pyrastri* (L.) (Diptera: Syrphidae) feeding on the cabbage aphid, *Brevicoryne brassicae* (L.)

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**Abstract**

**Background:** *Scaeva pyrastri* (L.) (Diptera: Syrphidae) is a large-size Palaearctic region syrphid fly. The larval stage of *S. pyrastri* is aphidophagous in nature, while the adults are efficient pollinators of various crops. Therefore, this study was carried out to investigate the predation efficacy, biology and population growth parameters of *S. pyrastri* on the cabbage aphid, *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae) as prey using age–stage-specific two-sex fertility table.

**Results:** The results showed that the mean total larval development duration was 8.31 days and the pre-adult stage was 19.82 ± 0.25 days long. In the adult stage, the mean longevity of female (18.57 ± 0.37 days) was longer than that of the male (15.50 ± 0.17 days). The adult pre-ovipositional, ovipositional and post-ovipositional periods were 4.25 ± 0.25, 8.50 ± 0.46 and 3.25 ± 0.31 days, respectively, and the mean female's fecundity was 37.75 ± 1.16 eggs per female. The two-sex fertility table indicated that the age-specific fecundity ($m_x$) increased gradually peaking at the 27th day of pivotal age (2.71 eggs per day) and decreased thereafter. The life expectancy of female was observed on the 18th (20.25 days) and 19th day (16.44 days) in the female and male flies, respectively. The female attained the maximum reproductive value ($v_{xj}$) on the 25th day, which was 26.05 eggs needed to produce one individual. The population growth parameters indicated that the population had a net reproduction rate of 15.10 ± 4.19 offspring per individual and a true generation time of 28.86 ± 0.28 days. The intrinsic rate of increase was greater than zero (0.093 ± 0.011) and the finite rate of increase ($\lambda$) was greater than one (1.098 ± 0.012), which indicated that *B. brassicae* was the suitable prey for *S. pyrastri*. The values related to the number of aphids consumed by the larvae were: a net predation rate ($C_o$) of 377.06 ± 26.54 nymphs and finite predation rate ($\omega$) of 19.58 ± 0.78.

**Conclusions:** *Scaeva pyrastri* had a considerable predatory potential and fitted well for the biological control of aphids, especially *B. brassicae*. However the field potential is still unknown; thus, this study will be helpful in determining the field efficacy of *S. pyrastri* against *B. brassicae*.

**Keywords:** *Scaeva pyrastri*, *Brevicoryne brassicae*, Life table parameters, Two-sex fertility table

## Background

Aphids are considered as important pests of many crops causing severe qualitative and quantitative damages (Rajabpour and Yarahmadi 2012). As there are many concerns in applications of the chemicals including insecticide resistance, side effects on non-target organisms,

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secondary pest outbreaks, etc. (Zandi-Sohani et al. 2018). Biological control by natural enemies, especially predators, is an eco-friendly strategy for suitable pest control in integrated pest management (IPM) (Safaei et al. 2016).

Syrphid flies are active predators of aphids, and females prefer to oviposit in response to aphid density (van Rijn et al. 2006). Adults of syrphid flies act as pollinators of different crops (Dunn et al. 2020). Among various syrphids, genus *Scaeva* is one of the genera in the subfamily of Syrphinae, which has large-size species. *Scaeva pyrastri* (L.) is aphidophagous syrphid, which is distributed from the south of Palaearctic to north of Oriental region (Laska et al. 2006). The adults of *S. pyrastri* can be distinguished from the presence of three white comma shape marking on the abdomen, whereas the larvae are light green colour with white dorsal median longitudinal stripe (Laska et al. 2006). Irshad (2014) reported that each female of *S. pyrastri* laid an average of 235 eggs in its lifetime, with 65% hatchability. The larvae of *S. pyrastri* consumed hundreds of aphids during its development and quickly suppressed the aphid population by 84% after 25 days of release. Therefore, it is a promising species of aphidophagous syrphid fly for the control of aphids. Thus, species may fit well in the biocontrol program and reduce the dependence of chemicals for controlling the aphids.

Cabbage aphid, *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae), is one of the serious pests of cruciferous crops, which infests and causes damage directly through sap sucking from phloem tissues as well as indirectly by transmitting several plant viruses (Imenes and Ide 2002). The *S. pyrastri* is the most persistent and consistent aphidophagous syrphid fly attacking the cabbage aphid. Therefore, to enhance the efficacy of *S. pyrastri* as a predator in biological control, the fitness of a predator was evaluated by the age-specific fertility tables. It summarizes the main biological traits of the predator such as age-specific survival, life expectancy and reproductive value at each stage and age (Tazerouni et al. 2016). The traditional female age-specific fertility table ignores the male populations (Birch 1948), which may have failed to describe the stage differentiation and also are incapable of determining the predation efficiency of a predator due to the variation in the consumption rate among the predatory and non-predatory stages of a predator. Chi et al. (2020) developed two-sex age-specific fertility table by considering both the sexes to understand the fitness of predator on its prey (Huang and Chi 2012). Several studies reported the fitness of different species of aphidophagous syrphid flies for the different aphid species (Jiang et al. 2022). Therefore, the present study was carried out to understand the predator–prey interactions using the two-sex age-specific fertility tables to calculate the biology, population growth parameters and predatory potential of *S. pyrastri* feeding on the cabbage aphid, *B. brassicae*.

## Methods

### Rearing of host insect and predator

The pure culture of cabbage aphid was maintained at the Biocontrol Laboratory and in the glasshouse in the field at Entomology Research Farm of Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India (30.85° N; 77.16° E), on the cruciferous plants.

The pure culture of *S. pyrastri* was maintained in the same laboratory. For the initial culture, the fertilized female adults of the *S. pyrastri* were collected from the aphid infested plants of cruciferous crop in the Entomology Farm, using a sweep net, which is active during January–February with the maximum and minimum temperatures being 21.7 and 3.6 °C, while the relative humidity and total rainfall values were 59.4% and 81 mm, respectively. Each female was enclosed separately in the rearing cage ($45 \times 45 \times 45$ cm) in the laboratory at $25 \pm 2$ °C, 60–70% RH and 13L: 11D photoperiod for one generation on the cabbage aphid, *B. brassicae* before starting the experiments**.** The *S. pyrastri* adult was identified using standard identification keys given by van Veen (2004) and Miranda et al., (2013) and this identification was also confirmed by Dr. Anooj S S, Assistant Professor, Department of Entomology, Kerala Agricultural University, Kasaragod, Kerala, India.

### Developmental biology and population growth parameters of *S. pyrastri* on *B. brassicae*

#### *Developmental biology of S. pyrastri on B. brassicae*

For studying the biology of *S. pyrastri*, eggs of *S. pyrastri* were collected from the general population and transferred separately in single Petri plates (10 cm diameter $\times$ 1.5 cm height). The eggs were picked up with the help of a camel hair brush within two hours of egg laying. The egg developmental period was recorded. After hatching, the first, second and third instars were provided with 20, 50 and 100 cabbage aphids daily, respectively, until reaching the pupal stage at room temperature. The observation was recorded on 10 larvae of each syrphid instar on cabbage aphid. Third instar ready for pupation was provided with additional leaves in the Petri plates for pupation, and the total duration of pupal period was recorded. The fecundity of syrphid females on cabbage aphid was determined by providing them cauliflower bloom (for fresh pollen) and 10% honey solution. The total number of eggs laid by the female during its life time was recorded daily. Observation was made on ten females of *S. pyrastri*.

Observation was recorded on pre-ovipositional, ovipositional and post-ovipositional periods. The longevity of the male and female was recorded by enclosing them in glass chimneys (10 × 14.5 cm) and providing them with cauliflower bloom (Fresh pollen source) along with 10% honey solution. The sex ratio (Male: Female) was also counted at the time of emergence of adult stage.

### *Population growth parameters of syrphids*

For studying the population growth parameters, fertility tables were constructed. One pair of *S. pyrastri* was released in a glass chimney (10 × 14.5 cm) along with aphid infested leaf dipped in water in a small plastic vial and a cotton swab soaked with 10% honey solution, and fresh pollen was provided as feeding material. After the egg laying, the eggs were picked up with the help of a camel hair brush and placed individually on fresh host plant leaves and transferred to the Petri plates (10 cm diameter × 1.5 cm height). Freshly hatched larvae were kept singly on host plant leaf along with counted number of cabbage aphids (50–100) in the Petri plates ; then after 24 h, numbers of sound aphids were counted and the old batch of aphids was replaced with a new batch and the process continued until all adults died. The Petri plates were cleaned daily by 70% ethanol to provide a hygiene condition to developing larvae. The life-history data of individuals were examined by using TWO-SEX-MS Chart program based on the age stage, two-sex life table theories (Chi 2018). Following population growth parameters were studied by using the following variables:

$s_{xj}$ = probability that a newly laid egg can survive to age *x* and stage *j*.

$f_{xj}$ = number of hatched eggs produced by female adult at age *x*.

$$l_x = \sum_{j=1}^{m} s_{xj}$$

$$m_x = \frac{\sum_{j=1}^{m} s_{xj} f_{xj}}{l_x}$$

By using the above variables, the following population growth parameters were calculated:

Gross reproductive rate (GRR): The total number of female eggs laid per female and is calculated as:

$$\mathrm{GRR} = \Sigma \mathrm{m}_x$$

Net Reproductive rate ($R_o$): The average number of offspring that a female produces during her lifetime. It is calculated by the formula:

$$R_0 = \sum_{x=0}^{\infty} \sum_{j=1}^{m} s_{xj} f_{xj}$$

$$m_x = \sum_{x=0}^{\infty} l_x$$

True intrinsic rate of increase ($r_m$): The actual rate of increase of a population under specified environmental conditions in which space and food are unlimited.

$$\sum_{j=1}^{m} e^{-r(x+1)} l_{xj} = 1$$

True generation time (*T*): The mean period elapsing from the birth of parents to the birth of off-springs. It is calculated by the formula:

$$T = \frac{\log_e \mathrm{R_o}}{\mathrm{r_m}}$$

The finite rate of natural increase ($\lambda$): The number of times the population increases per unit time. The value is calculated by the formula:

$$\lambda = e^r$$

The doubling time (DT): The time taken by a species to double its population and is calculated by the formula:

$$\mathrm{DT} = \frac{\log_e 2}{r_m}$$

## Age–stage-specific life expectancy ($e_{xj}$):

The length of duration or time that an individual of age x and stage j is predicted to live and is calculated by the method of Chi and Su (2006).

$$e_{xj} = \sum_{i=x}^{\infty} \sum_{y=j}^{m} s'_{iy}$$

where $s'_{iy}$ is defined as the probability that individuals of x and j were survive to age i and stage y.

Reproductive value ($v_{xy}$): The contribution of individuals of age x and stage j to the future population (Yang et al. 2015).

$$v_{xj} = \frac{e^{r(x+1)}}{s_{xj}} \sum_{i=x}^{\infty} e^{-r(i+1)} \sum_{y=j}^{m} s'_{iy} f_{iy}$$

### Predatory potential and host kill parameters

Predatory potential of different developmental instars of *S. pyrastri* was studied against cabbage aphid. Newly hatched larvae of *S. pyrastri* of the same age were shifted individually to the Petri plate (10 cm diameter × 1.5 cm height) containing counted number of aphids (50–100) of equal age. The data on aphid consumption by *S. pyrastri* larvae were recorded every 24 h until they entered the next instar. Each treatment was replicated 10 times and observed daily until the pupal stage. The data on daily survival and prey consumption of each individual were analysed, using the CONSUME-MS Chart (Chi 2020), and host kill parameters of the predators were calculated as per van Lanteren et al. (2019).

$c_{xj}$ = mean consumption rate of an individual of age $x$ and stage $j$.

$s_{xj}$ = probability that a newly laid egg can survive to age $x$ and stage $j$.

Age-specific predation rate ($k_x$): The number of hosts killed by the predators of individuals at age x and is calculated as follows:

$$k_x = \frac{\sum_{j=1}^{m} s_{xj}c_{xj}}{\sum_{j=1}^{m} s_{xj}}$$

Age-specific net predation rate ($q_x$): When the age-specific survival rate $lx$, which is the number of individuals which survive to age $x$, was taken into consideration, the net age-specific predation rate is calculated as:

$$q_x = k_x l_x$$

Net consumption rate ($C_o$): The number of hosts killed by a predator from birth to age x and it is calculated as follows:

$$C_0 = \sum_{x=0}^{\infty}\sum_{j=1}^{\beta} s_{xj}c_{xj}$$

Transformation rate ($Q_P$): The mean number of preys a predator needs to kill to produce one offspring is calculated as:

$Q_p = \frac{C_0}{R_0}$.

Stable host kill rate ($\varphi$.): The proportion of individuals belonging to age $x$ and stage $j$ in stable age distribution ($axj$).

$$\varphi = \sum_{x=0}^{\infty} a_{xj}c_{xj}$$

Finite Host kill rate ($\omega$): To assess the host-killing potential, the finite host killing rate (ω) is calculated as follows:

$$\omega = \lambda\varphi$$

**Statistical analysis**

Developmental biology and population growth parameters were calculated using Two sex-MS Chart to minimize variation in the results. The bootstrap technique with 1,00,000 replications was used to calculate the mean and standard error of the population (Efron and Tibshirani 1993). The raw data were used to calculate the age–stage-specific survival rate ($s_{xj}$, where $x$ = age in days and $j$ = stage), age–stage-specific fecundity ($f_x$), age-specific survival rate ($l_x$), age-specific fecundity ($m_x$), age-specific net maternity ($l_x m_x$), age–stage life expectancy ($e_{xj}$), age–stage reproductive value ($v_{xj}$), and life table parameters (Huang and Chi 2012). The predation rate and host-kill parameters of *S. pyrastri* were calculated by using Consume-MS Chart (Chi 2020).

## Results

### Biology of *S. pyrastri* feeding on the *B. brassicae*

The biological parameters of *S. pyrastri* were determined on the cabbage aphid, *B. brassicae*, and are presented in table (1). The egg of *S. pyrastri* was white in colour when freshly laid and turned greenish white before hatching, and the total mean duration of egg development was 2.70 ± 0.11 days. The larvae were light green in colour with white dorsal longitudinal stripes, and mean development periods (days) of first, second and third instar larvae were 2.10 ± 0.06, 2.45 ± 0.11 and 3.76 ± 0.11, respectively. The pupal period of *S. pyrastri* was 8.65 ± 0.15 days. The total pre-adult period was completed in 19.82 ± 0.25 days. The mean total longevity of adult female was 18.57 ± 0.37 days as compared to the male adult (15.50 ± 0.17 days). The adult pre-ovipositional, ovipositional and post-ovipositional periods were 4.25 ± 0.25, 8.50 ± 0.46 and 3.25 ± 0.31 days, respectively. Total fecundity (eggs/female) was 37.75 ± 1.16. The sex ratio (male: female) was 1: 0.8 (Table 1).

### Population growth parameters of *S. pyrastri* feeding on the *B. brassicae*

#### *Age-specific fecundity*

The age-specific fecundity of *S. pyrastri* feeding on *B. brassicae* was calculated to construct the fertility table and to determine the growth parameters of *S. pyrastri*. The female of *S. pyrastri* started the egg laying at the pivotal age of 22nd days with average fecundity of 0.12 eggs/female on the same day (Fig. 1). The age-specific fecundity ($m_x$) increased gradually with peak on the 27th day of pivotal age (2.71 eggs per day) and decreased thereafter. The age–stage-specific fecundity ($f_x$) ranged from 0.25 to 0.88 eggs per day with peak (5.75 egg per day) on the 27th day (Fig. 1). Similarly, the age-specific maternity ranged from 0.10 to 2.30 eggs per day with peak on the

**Table 1** Developmental biology of *S. pyrastri* on cabbage aphid, *B. brassicae*

| Parameters | Stages (days) | Mean ± SE (n = 10) |
|---|---|---|
| Developmental period | Egg duration | 2.70 ± 0.11 |
| | First-instar larvae | 2.10 ± 0.06 |
| | Second-instar larvae | 2.45 ± 0.11 |
| | Third-instar larvae | 3.76 ± 0.11 |
| | Pupal period | 8.65 ± 0.15 |
| | Pre-adult period | 19.82 ± 0.25 |
| Adult longevity | Female longevity | 18.57 ± 0.37 |
| | Male longevity | 15.50 ± 0.17 |
| Oviposition and fecundity | Pre-oviposition period (days) | 4.25 ± 0.25 |
| | Oviposition period (days) | 8.50 ± 0.46 |
| | Post-oviposition period (days) | 3.25 ± 0.31 |
| | Fecundity (eggs/female) | 37.75 ± 1.16 |
| Sex ratio (M:F) | | 1: 0.8 |

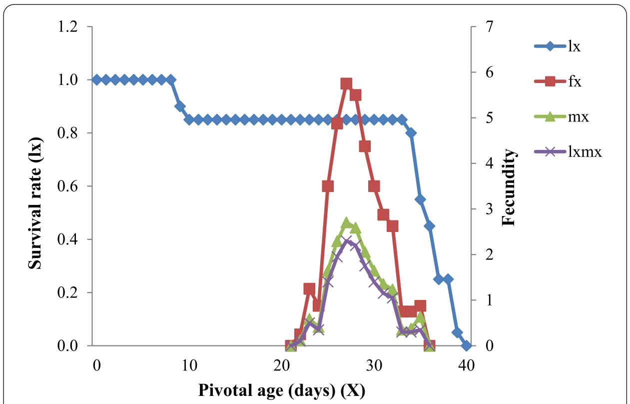


**Fig. 1** Age-specific survival rate ($l_x$), female age-specific fecundity ($f_x$), age-specific fecundity ($m_x$) and age-specific maternity ($l_xm_x$) of *S. pyrastri* on *B. brassicae*

27th day (2.30 eggs per day). After attaining the peak, the $f_x$, $m_x$ and $l_xm_x$ declined gradually to zero on the 30th day (Fig. 1).

### *Age-specific survival rate*

The age–stage survival rate ($s_{xj}$) of *S. pyrastri* is shown in Fig. 2, where the curve predicted that the probability of newly hatched predator will survive to age $x$ and stage $j$ of *S. pyrastri* feeding on the *B. brassicae*. The survival rate continued to be 100% until the 9th day of pivotal age (up to second-instar larvae), thereafter decreasing with age (Fig. 2). The survival rate of female and male remained constant until the 35th day and 33rd day for female and male life cycle, respectively (Fig. 2). The overlapping curve for different developmental stages of *S. pyrastri* represented the variation in the survival rate for each specific stage.

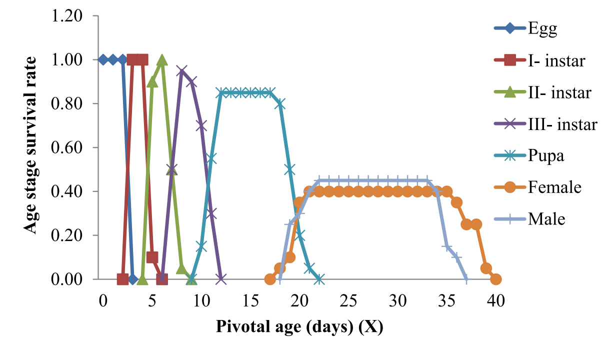


**Fig. 2** Age-specific survival rate ($s_{xj}$) of *S. pyrastri* on *B. brassicae*

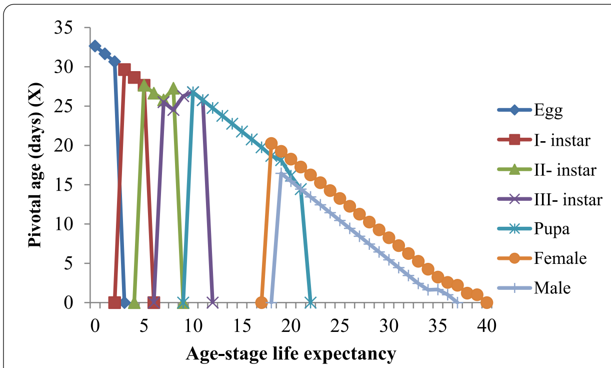


**Fig. 3** Age-specific life expectancy ($e_{xj}$) of *S. pyrastri on B. brassicae*

### *Age-specific life expectancy*

The age–stage-specific life expectancy ($e_{xj}$) is estimation of the lifespan remaining for an individual of age $x$ and stage $j$ (Fig. 3). The age-specific life expectancy of *S. pyrastri* at the time of birth was 32.65 days and later decreased with time. The life expectancy of larval stage (29.65 to 25.76) was highest than the adults. The maximum life expectancy of female was highest (20.25 days) on the 18th day, while the maximum life expectancy of male was 16.44 days on the 19th day of pivotal age. The life expectancy of adult on the day of egg laying started (22nd day of pivotal age) was 14.76 days. Thereafter, the life expectancy decreased with age.

### *Age-specific reproductive value*

The age–stage reproductive value ($v_{xj}$) predicted the probability of reproduction to the future population by the contribution of individuals of age $x$ and stage $j$. The age-specific reproductive value of *S. pyrastri* at the time of birth was 1.10, which gradually increased and attained peak on the 27th day and declined to zero on the 36th

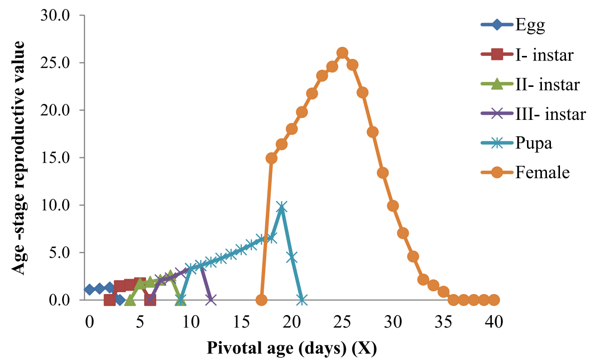


**Fig. 4** Age-specific reproductive value ($v_{xj}$) of *S. pyrastri* on *B. brassicae*

**Table 2** Population growth parameters of *S. pyrastri* on cabbage aphid, *B. brassicae*

| Population growth parameters | Mean ± SE |
|---|---|
| Gross reproductive rate (offspring per individual) (GRR) | 18.01 ± 4.64 |
| Net reproductive rate ($R_o$) | 15.10 ± 4.19 |
| Intrinsic rate of increase ($r$) | 0.093 ± 0.011 |
| Finite rate of increase ($day^{-1}$) ($\lambda$) | 1.098 ± 0.012 |
| True generation time (days) ($T$) | 28.62 ± 0.28 |
| Doubling time (days) (DT) | 7.37 ± 1.18 |

**Table 3** Feeding potential of *S. pyrastri* on cabbage aphid, *B. brassicae*

| Larvae | Consumption (Mean ± SE) | |
|---|---|---|
| | Total consumption | Daily consumption |
| First instar | 12.70 ± 0.92 | 6.05 ± 0.38 |
| Second instar | 81.53 ± 8.13 | 34.73 ± 2.91 |
| Third instar | 328.71 ± 10.61 | 87.31 ± 2.35 |

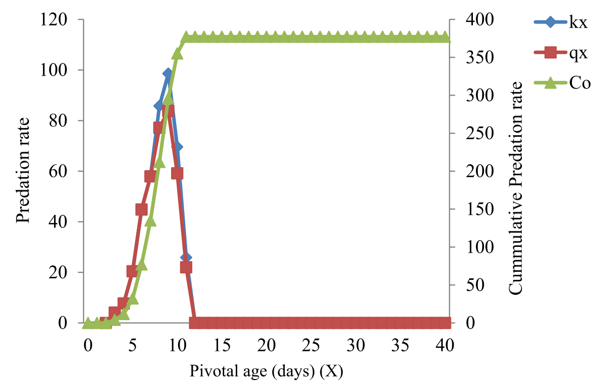


**Fig. 5** Age-specific predation rate ($k_x$), net age-specific predation rate ($q_x$) and cumulative predation rate ($C_o$) of *S. pyrastri* on *B. brassicae*

day (Fig. 4). The age stage reproductive value of egg, first, second, third instars and pupa ranged from 1.10 to 1.33, 1.46 to 1.76, 1.76 to 2.59, 2.11 to 3.64 and 3.31 to 4.51, respectively (Fig. 4). The reproductive value of female at the time of emergence was 14.93 eggs, and the highest reproductive value (26.05 eggs) was attained on the 25th day of pivotal age.

### Population growth parameters of *S. pyrastri*

The population growth parameters of *S. pyrastri* on *B. brassicae* indicated an intrinsic rate of increase ($r$) of 0.093 ± 0.011 offspring/individual/day, and a finite rate of increase ($\lambda$) was 1.098 ± 0.012 times per day (Table 2). The gross reproductive rate (offspring per individual) (GRR) was 18.01 ± 4.64, while the net reproductive rate ($R_0$) was 15.10 ± 4.19 offspring per individual. The true generation time ($T$) and the doubling times were 28.62 ± 0.28 and 7.37 ± 1.18 days, respectively.

### Predatory potential of *S. pyrastri*

The predatory potential of *S. pyrastri* was determined on the cabbage aphid, *B. brassicae*, and is summarized in Table 3. The first instar of *S. pyrastri* was poor feeder, and the capacity increased with the subsequent instar. The third instar was more voracious than the younger instar, which consumed almost 77.70% of the total consumption during the larval stage. The total consumption of the first and the second instars was 12.70 ± 0.92 and 81.53 ± 8.13 aphids with a mean daily consumption of 6.05 ± 0.38 and 34.73 ± 2.91 aphids, respectively. The total mean consumption of the third instar was 328.71 ± 10.61, while the mean daily consumption was 87.31 ± 2.35 aphids (Table 3). There was a significant difference between the total and daily consumption of all the larval stages ($F = 513.71$; df = 2, 53; $p < 0.001$).

The first instar of *S. pyrastri* started feeding on the 3rd day of pivotal age and fed on an average 4.10 aphids per day. The age-specific predation rate ($k_x$) increased up to the 9th day of pivotal age (98.59 aphids $day^{-1}$), decreased gradually and ceased on the 11th day (Fig. 5). The maximum age-specific predation rate ($k_x$) and age-specific net predation rate ($q_x$) were recorded in the third instar on the 9th day of pivotal age, which were 98.59 and 83.80 aphids per day, respectively. The age-specific cumulative predation rate ($C_o$) ranged from 4.10 to 377.06 aphids per day. The net lifetime consumption rate of *S. pyrastri* on *B. brassicae* was 377.06 ± 26.54 aphids per day. The stable host kill rate and finite host kill rate were 17.85 ± 0.66 and 19.58 ± 0.78, respectively. The transformation rate was 27.22 ± 9.82, which predicted the mean of aphids (27.22 ± 9.82) required for *S. pyrastri* to produce one offspring (Table 4).

**Table 4** Host-feeding parameters of *S. pyrastri* on cabbage aphid, *B. brassicae*

| Host-feeding parameters | (Mean ± SE) |
|---|---|
| Net consumption rate ($C_o$) | 377.06 ± 26.54 |
| Transformation rate ($Q_p$) | 27.22 ± 9.82 |
| Stable host-feeding rate (ψ) | 17.85 ± 0.66 |
| Finite host-feeding rate ($\omega$) | 19.58 ± 0.78 |

## Discussions

In the biological control, the age-specific fertility table and predatory potential play an important role to understand the fitness of a predator in relation to its prey (Aljetlawi et al. 2004). In the present study, the developmental biology of *S. pyrastri* on *B. brassicae* revealed that the total larval period and pre-adult development periods were 8.31 and 19.82 days, respectively, and females had a maximum longevity than the males. The total fecundity of *S. pyrastri* was 37.75 ± 1.16 eggs per female. According to the present study, female of *S. pyrastri* started egg laying at the age of 22nd day and then increased gradually to peak on (27th day) with a mean stage-specific fecundity of 5.75 eggs per day. The age–stage reproductive value ($v_{xj}$) curves showed that the female of *S. pyrastri* had a maximum reproductive value, which increased from the day of emergence (14.93) and attained the peak (26.05 eggs) on the 25th day of pivotal age. This result depicted that the adult females made the maximum contribution.

The survival rate ($l_x$) continued to be 100% until the 9th day of pivotal age (up to second instar) and 0.85 from the third instar to adult stage until the 33rd day. This result showed that the *S. pyrastri* had the highest survival rate from egg development to adult with the *B. brassicae*. The age–stage-specific survival rate ($s_{xj}$) curve overlapped for the different stages of *S. pyrastri* with *B. brassicae* as a prey. This may be due to the different development rates across the various stages of an individual (Liu et al. 2005). Consequently, individuals of the same age but different stage may have different life expectancies. The present study indicated that the life expectancy of *S. pyrastri* at the time of birth was 32.65 and decreased with age. The life expectancy of larval stage (29.65 to 25.76) was highest than the adults. However, the maximum life expectancy of the female was highest (20.25 days) than the male (16.44 days).

In the present study, the intrinsic rate of increase was greater than zero (0.093 ± 0.011) and finite rate of increase ($\lambda$) was greater than one (1.098 ± 0.012), which indicated that *B. brassicae* was a suitable prey for *S. pyrastri*. These results find support from Jiang et al., (2022) who reported that the intrinsic rate of increase ($r$) was 0.18, 0.19 and the finite rate of increase ($\lambda$) was 1.20 and 1.21 for *Eupeodes corollae* (Fab.) with *Aphis craccivora* and *Myzus persicae*, respectively. Sharma and Bhalla (1995) also reported the true intrinsic rate of natural increase (0.134) for *E. corollae* with *B. brassicae*. The net reproductive rate ($R_o$) of *S. pyrastri* with *B. brassicae* was 15.10 ± 4.19 eggs per female, and the average generation time was 28.62 ± 0.28 days.

The results of the present study showed a significant difference between the total and daily consumption of all the larval stages (6.05 ± 0.38, 34.73 ± 2.91 and 87.31 ± 2.35 aphids). These results were in confirmation with the findings of Fathipour et al. (2006) for *Scaeva albomaculata* reared on *Myzus persicae*. They also found significant differences in daily and total feeding rates among the first, second and third instars with per capita daily feeding rates of 8.79, 38.06 and 76.31aphids, respectively. The third-instar larvae of *S. pyrastri* consumed 328.71 aphids, whereas *I. scutellaris* consumed 268.20 aphids and *E. balteatus* (215 aphids) (Suja 2008). Krsteska (2008) also reported the total consumption of *S. pyrastri* ranged from 280 to 563 aphids of *M. persicae* in the larval stage of 8.79 days. From the present investigation, it was clear that third instars of *S. pyrastri* were more voracious than the younger instars. These findings were also supported by those of Baskaran et al., (2009) who recorded the highest predation rate by in the third instars of four syrphids species on *Aphis gossypii* Glover. The age-specific consumptive rate of *S. pyrastri* increased with age and was the highest on the 9th day of pivotal age (98.59 aphids per day) in third instar. The net consumption rate ($C_o$) was 377.06 ± 26.54, while the stable prey kill rate and finite host kill rate were 17.85 ± 0.66 and 19.58 ± 0.78, respectively. Therefore, the present study on development, reproduction and predatory potential of *S. pyrastri* feeding on the *B. brassicae* under the laboratory conditions determined that *B. brassicae* is an important suitable prey for the *S. pyrastri*. These results will serve as the basis of large-scale rearing of aphidophagous syrphid flies as potential biocontrol agents with high fitness and predation efficacy. Under the field conditions, the population of the aphidophagous syrphid flies coincided with the other predators such as green lacewing and coccinellids. Therefore, the fitness of *S. pyrastri* on *B. brassicae* studied under the laboratory conditions required an evaluation under field conditions for its effective implementation in the IPM program.

## Conclusions

This study concluded that *S. pyrastri* is a potential predator of cabbage aphid, *B. brassicae*, under laboratory conditions. The third-instar larvae of *S. pyrastri* were more voracious than the younger instars, which consumed almost 77.70% of the total consumption at the larval stage. This study considered both sexes to determine the growth parameters such as net reproductive rate, intrinsic rate of increase and finite rate of increase, which was highly significant and proved that *S. pyrastri* fitted well for the biological control program. Since the syrphid fly's larvae are the specialist predators of aphids, the detailed study including the age–stage-specific fertility and predation rate could be helpful for designing the mass rearing of syrphid flies and determining the efficacy of syrphid flies under field conditions as aphidophagous predators where the population of other aphidophagous predators is sparse.

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**Author contributions**
SP conducted the experiments, collected the data, analysis and wrote the manuscript. SCV designed the experiments and help to write the manuscript. PLS, RSC, RK and MG helped in designing the experiments and statistical analysis of data. NS and PS helped in editing the manuscript. We confirm that the manuscript has been read and approved by all named authors and also confirm that the order of authors listed in the manuscript has been approved by all of us. Corresponding author is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. All authors read and approved the final manuscript." in the "Authors' contributions

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