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Numerical Response of *Hippodamia variegata* and *Coccinella septempunctata* (Coleoptera: Coccinellidae)

Hippodamia variegata ve *Coccinella septempunctata* (Coleoptera: Coccinellidae)'nın Sayısal Tepkisi

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Numerical Response of *Hippodamia variegata* and *Coccinella septempunctata* (Coleoptera: Coccinellidae)

ABSTRACT

Determining the predator-prey relationship and the reproductive abilities of predators depending on prey density is very important in terms of biological control. In this study, numerical responses of *Hippodamia variegata* (Goeze) and *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) predators of aphids on black bean aphid and pea aphid were tested. In these trials, reproductive abilities of predators at different prey densities were identified. All of the studies were carried out in climate rooms set at 27±1 °C, 65±5% relative humidity and long daylight conditions. In these experiments, it was determined that the number of eggs laid and the reproductive responses (ECI) of both predators on their food increased adhere to the prey densities. It was concluded that both predators, especially in the late development stages, had high reproductive consumption and reproductive capacities on *A. fabae* and *A. pisum*, and it is considered that both predators may be effective on these aphids.

Keywords- Hippodamia Variegata, Coccinella Septempunctata, Numerical Response, Coccinellid, Biological Control

Highlights

- The study aimed to determine the numerical responses of *Hippodamia variegata* and *Coccinella septempunctata* to different prey densities.
- Consumption and reproductive capacities of both species increased with prey density.
- The highest values were obtained at the 80-prey density.
- *H. variegata* showed higher consumption and fecundity than *C. septempunctata*.
- Both species showed potential to suppress aphid populations at high prey densities.

Hippodamia variegata ve *Coccinella septempunctata* (Coleoptera: Coccinellidae)'nın Sayısal Tepkisi

ÖZ

Avcı-av ilişkisini ve av yoğunluğuna bağlı olarak avcıların üreme yeteneklerini belirlemek, biyolojik mücadele açısıdan oldukça önemlidir. Bu çalışmada, bakla yaprak biti ve bezelye yaprak biti üzerinde yaşayan yaban arısı *Hippodamia variegata* (Goeze) ve *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) gibi yaprak bitleri avcılarının sayısal tepkileri test edilmiştir. Bu denemelerde, av yoğunluğuna bağlı olarak avcıların üreme kapasiteleri belirlenmiştir. Tüm çalışmalar, sıcaklığın 25±1°C, bağıl nemin %65±5 olduğu ve uzun gündüz süresine (16:8) sahip iklim odalarında gerçekleştirilmiştir. Bu deneylerde, her iki avcının da *A. fabae* ve *A. pisum* üzerinde bıraktığı yumurta sayısı ve üreme tepkilerinin (ECI) av yoğunluğuna bağlı olarak arttığı belirlenmiştir. Elde edilen verilere göre, her iki avcının özellikle gelişimin geç evrelerinde, *A.* fabae ve *A. pisum* üzerinde yüksek üreme tüketimi ve üreme kapasitelerine sahip olduğu ve bu yaprak bitleri üzerinde etkili olabileceği düşünülmektedir.

Anahtar Kelimeler- Hippodamia Variegata, Coccinella Septempunctata, Sayısal Tepki, Coccinellid, Biyolojik Mücadele

Öne Çıkanlar

- Çalışma, *Hippodamia variegata* ve *Coccinella septempunctata*'nın farklı av yoğunluklarına sayısal tepkilerini belirlemeyi amaçlamıştır.
- Her iki türün tüketim ve üreme kapasiteleri artan av yoğunluğuyla yükselmiştir.
- En yüksek değerler 80 av yoğunluğunda elde edilmiştir.
- *H. variegata*, *C. septempunctata*'ya göre daha yüksek tüketim ve yumurta verimine sahip olmuştur.
- Her iki tür de yüksek yoğunlukta yaprak biti popülasyonlarını baskılayabilecek potansiyele sahiptir.

I. INTRODUCTION

Chemical control is mostly preferred in the control diseases and pests in agricultural. However, every year, pests develop different resistances against newly emerging chemicals, which means more chemical use. Chemicals used on agricultural pests negatively affect the environment and human health. For this reason, alternative control methods have been emphasized in recent years [1]. To avoid these negativities, alternative methods have been emphasized in recent years. There is continuity in the "Biological Control" method, which is one of these methods. In addition, when we look at the studies, it has been reported that it does not cause environmental pollution and does not harm human or wildlife [2, 3]. Coccinellidae, a family belonging to the order Coleoptera, is important for alternative control methods of pests. When we look at the world, it is known that there are 5200 species [4]. *Hippodamia variegata* (Goeze) (Coleoptera: Coccinellidae) commonly found in the Palearctic region is a polyphagous species. While they prefer aphids, which are generally effective on weeds in their diet; it has been determined that it feeds on species belonging to the families Aleyrodidae (Hem.) and Chaitophoridae (Hem.) [5-10]. It has been reported that *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) is a major predator of aphids [11].

Aphids are herbivores that cause economic losses on a large number of plants [12]. In addition to causing damage by sucking the plant sap [13], this group of living things also indirectly damages plants due to their toxic substance secretion and virus diseases [8, 14-16]. *Aphis fabae* (Scopoli) (Hemiptera: Aphididae) causes losses on more than 200 wild plants as well as many vegetables, broad beans, beans, sunflowers and tomatoes [17-19]. *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae) is known to cause damage to different agricultural products as well as being a pest of weeds [20, 21].

As can be seen in the researches carried out around the world, aphids are agricultural pests and have to be controlled. Due to their high reproductive capacity, they cause great damage to plants. In the fight against these pests, manufacturers prefer chemical control intensively. As a result, the natural balance is negatively affected by this. In order to turn this into a positive, even if small, alternative combat methods are needed. Therefore, it is necessary to determine the responses of *H. variegata* and *C. septempunctata* on the aphids in the study. For this reason, numerical responses of *H. variegata* and *C. septempunctata*, which are predators of aphids, were tested. In these trials, development times, daily consumption amounts and reproductive abilities of hunters at varying prey densities were also determined.

II. MATERIAL AND METHOD

The main materials of this study are green parts of broad bean (*Vicia faba* L.), different herbivores (*A. fabae* and *A. pisum*) and two predators (*H. variegata* and *C. septempunctata*).

A. Production of Broad Bean

The broad bean was produced in soil, peat, perlite mixture. 200 ml plastic pots were used in the plant growing stages. The climate room for the production of plants was set at 27±1 °C, 65±5% relative humidity and long daylight conditions.

B. Production of Aphis fabae and Acyrthosiphon pisum

The initial individuals of aphids used in the study were obtained from laboratory production. Separate cages were used to prevent cross-contamination of the aphids. When the plants lifespan expired, new ones were added, and this process continued periodically. This production was achieved in climate rooms with the same conditions as the production rooms.

C. Culture of Predator Insects

Predatory insects (*H. variegata* and *C. septempunctata*) used in the study were collected from different habitats and then identified. In these trials, in order to prevent a mistake due to prey differences, predatory insects were reared separately in the foods they were to be tested. The productions of the predator insects were realized in climate rooms with the same conditions as the production rooms.

D. Experimental Design

At this stage, the eggs of the predator insects that were produced were placed in separate Petri dishes, and the larvae were allowed to hatch. Afterward, a certain number of 2nd and 3rd instar aphids (*A. fabae* and *A. pisum*) were provided (5, 10, 20, 40, 80, 160 individuals). Following this, the development stages of *H. variegata* and *C. septempunctata* were monitored, and the number of aphids consumed by the predators were saved daily. Aphids were added in the number of aphids consumed by the predatory insects to petri dishes. This process continued until the individual's reached adulthood, at which point they were placed in the same environment to lay eggs. The number of eggs laid by the combined individuals was enrolled, and the process was concluded when the individuals died. In these experiments, all stages of *H. variegata* and *C. septempunctata* were used, the trials were repeated 50 times. The experiments were realized in climate rooms with the same conditions as the production rooms. The following formulas were used to calculate the reproductive response (ECI) [22] and the prey consumption efficiency (PUE) [23] of female predators at different food densities:

ECI (%) = (Number of eggs laid)/(Consumption amounts of preys)×100 (1)

PUE(%) = (Consumption amounts of preys)/(Number of food given)×100 (2)

Analysis of variance (ANOVA) was used to compare the statistical analyzes performed. The statistical significance level of the differences between the means was revealed according to the TUKEY multiple comparison test. Minitab (ver. 16) and SPSS (Ver. 17) were used in statistical evaluations. In addition to these statistical analyses, life chart parameters were obtained at varying prey densities of predatory insects by using daily recorded data.

E. Parameters of Life Tables

At this stage of the trials, age-related life schedules of both *H. variegata* and *C. septempunctata* fed at different concentrations of *A. fabae* and *A. pisum* were created based on the Euler-Lotka equation [24-26]. All parameters obtained here were calculated using the RmStat-3 program [25]. Analysis of variance (ANOVA) was used to determine the differences in the results obtained, and the statistical significance level of the differences between the means was revealed according to the TUKEY multiple comparison test. Parameters used for the life tables:

Intrinsic Rate of Increase (**r_m**), $\square\, e^{(-r_m \cdot x)} . l_x . m_x = 1$ (3)

Net Reproductive Rate, **R_0** $= \sum l_x m_x$

Mean Generation Time, **T_0** $= \log_e R_0 / r_m$

Total Productivity rate, $GRR = \square\, m_x$ (4)

Doubling Time, **DT**, $T_2 = \dfrac{\ln 2}{r_m}$ (5)

Daily maximum reproductive value, **λ**; $\lambda = e^{r_m}$ (6)

III. RESULTS AND DISCUSSION

A. Daily Consumption Amounts

According to this study, the amount consumed by both predators increased as the development periods progressed depending on the prey density. It was determined that the consumption amount at 80 prey density in the first three development periods of predatory insects was different compared to other densities. When the total development times were examined, it was determined that the consumption amounts were similar at 80 and 160 prey density (Table 1).

Table 1. Daily consumption amounts of different biological periods of *Hippodamia variegata* and *Coccinella septempunctata* on *Aphis fabae* and *Acyrthosiphon pisum*

Biological Stages	Prey Densities (*Aphis fabae*) (Consumption of *Hippodamia variegata*)					
	5	10	20	40	80	160
Instar1	4.17±0,04 **f**	6.90±0.04 **e**	7,90±0.07 **d**	8.97±0.08 **c**	11.21±0.10 **a**	10.25±0.11 **b**
Instar2	4.75±0.04 **e**	8.40±0.06 **d**	13.84±0.16 **b**	14.36±0.13 **a**	14.30±0.08 **a**	12.89±0.08 **c**
Instar3	4.98±0.02 **f**	9.05±0.07 **e**	18.12±0.12 **d**	19.58±0.13 **c**	31.63±0.15 **a**	29.31±0.23 **b**
Instar4	----	9.71±0.05 **e**	19.16±0.12 **d**	30.34±0.18 **c**	53.30±0.22 **a**	50.88±0.30 **b**
Adult	----	9.77±0.02 **d**	19.71±0.02 **c**	33.97±0.06 **b**	51.91±0.05 **a**	51.87±0.05 **a**
Total	27.53±1.9 **d**	164±31.4 **cd**	755±94.0 **c**	1480±163.0**b**	3138±259.0**a**	3337±235.0**a**
Biological Stages	**Prey Densities (*Acyrthosiphon pisum*) (Consumption of *Hippodamia variegata*)**					
	5	10	20	40	80	160
Instar1	4.10±0,05 **f**	6.86±0.04 **e**	7,80±0.08 **d**	9.04±0.09 **c**	11.26±0.13 **a**	10.47±0.11 **b**
Instar2	4.63±0.05 **d**	8.20±0.06 **c**	13.19±0.16 **b**	13.91±0.26 **a**	14.13±0.10 **a**	13.07±0.21 **b**
Instar3	4.92±0.03 **f**	8.92±0.05 **e**	17.63±0.15 **d**	18.96±0.25 **c**	30.80±0.29 **a**	29.76±0.35 **b**
Instar4	----	9.64±0.05 **d**	18.84±0.13 **c**	29.05±0.35 **b**	48.88±0.66 **a**	49.35±0.49 **a**
Adult	----	9.65±0.02 **e**	19.62±0.02 **d**	33.77±0.06 **c**	51.66±0.05 **a**	51.37±0.06 **b**
Total	27.46±1.8 **d**	178±31.8 **cd**	722±91.2 **c**	1425±164.0**b**	3316±249.0**a**	3268±230.0**a**
Biological Stages	**Prey Densities (*Aphis fabae*) (Consumption of *Coccinella septempunctata*)**					
	5	10	20	40	80	160
Instar1	4.32±0.04 **f**	7.32±0.06 **e**	8.25±0.06 **d**	9.06±0.07 **c**	11.58±0.10 **a**	10.09±0.08 **b**
Instar2	4.88±0.03 **e**	8.47±0.05 **d**	13.74±0.12 **c**	14.89±0.14 **b**	16.29±0.12 **a**	14.67±0.12 **b**
Instar3	5.00±0.00 **f**	9.45±0.05 **e**	19.02±0.10 **d**	21.88±0.16 **c**	31.90±0.10 **a**	29.12±0.16 **b**
Instar4	----	9.89±0.03 **d**	19.95±0.03 **c**	33.10±0.19 **b**	52.10±0.19 **a**	51.69±0.20 **a**
Adult	----	9.86±0.02 **d**	19.84±0.02 **c**	33.83±0.07 **b**	52.13±0.05 **a**	52.16±0.06 **a**
Total	36.16±1.6 **d**	189.50±30.0 **cd**	577.80±69.0 **c**	1276±135.0**b**	3077±209.0**a**	2903±221.0**a**
Biological Stages	**Prey Densities (*Acyrthosiphon pisum*) (Consumption of *Coccinella septempunctata*)**					
	5	10	20	40	80	160
Instar1	4.20±0.04 **f**	7.04±0.06 **e**	7.96±0.08 **d**	8.80±0.06 **c**	11.40±0.10 **a**	9.91±0.08 **b**
Instar2	4.80±0.04 **f**	8.32±0.06 **e**	13.49±0.13 **d**	14.67±0.15 **c**	15.95±0.10 **a**	14.20±0.13 **b**
Instar3	4.99±0.10 **f**	9.24±0.06 **e**	18.60±0.13 **d**	21.19±0.21 **c**	31.17±0.19 **a**	28.64±0.19 **b**
Instar4	----	9.81±0.04 **d**	19.65±0.08 **c**	32.40±0.24 **b**	51.56±0.23 **a**	50.81±0.26 **a**
Adult	----	9.78±0.02 **d**	19.77±0.02 **c**	33.56±0.08 **b**	52.00±0.05 **a**	52.02±0.06 **a**
Total	35.5±1.7 **d**	188.1±30.1**cd**	575.8±70.1 **c**	1273±135.0**b**	3066±208.0**a**	2897±221.0**a**

B. Prey Utilization Efficiency

The prey utilization efficiency of the predator insects was calculated depending on the amount of food at different densities. Accordingly, at low densities (5, 10 and 20), this efficiency was observed to be over 90% for both predators. It is seen that the productivity remains around 30% at 160 prey densities, which is the highest value among the prey densities. Although the productivity obtained at forty and 80 prey densities were close, it was determined that the productivity of *H. variegata* was higher than that of C. *septempunctata* (Figure 1).

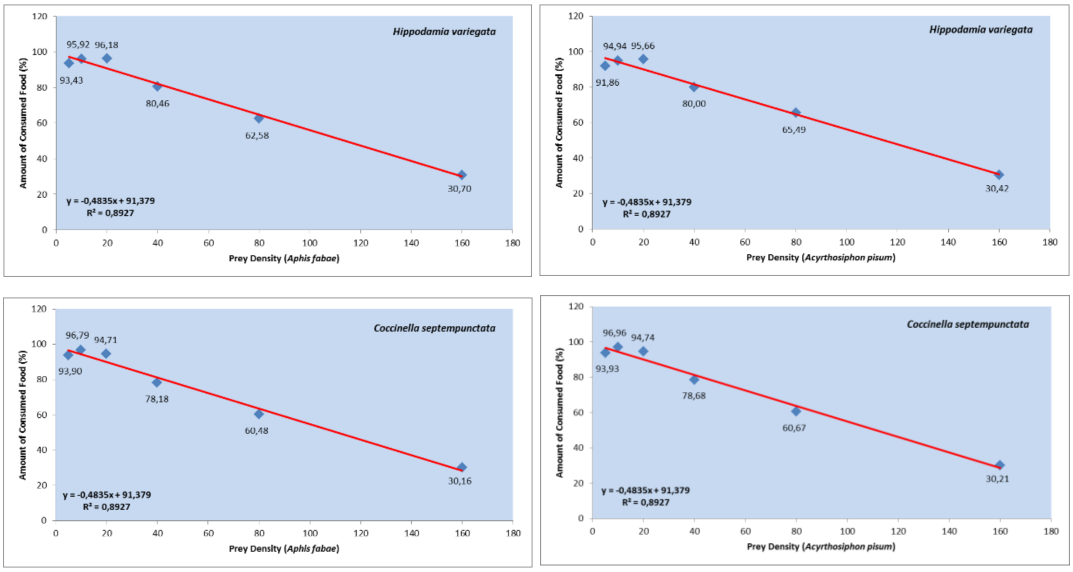

Figure 1. Amount of consumed food of *Hippodamia variegata* and *Coccinella septempunctata* on different aphids

C. Number of Eggs Laid

The average number of eggs laid by *H. variegata* fed with distinct intensities of *A. fabae* (5, 10, 20, 40, 80, 160) was found to be 0, 47.33, 236.86, 627.06, 1448.79, and 1325.40, respectively. It was determined that the number of eggs laid by the same predator when *A. pisum* was fed at different densities was 0, 56.86, 239.92, 641.53, 1478.60 and 1353.70, respectively. The number of eggs laid by *C. septempunctata*, when fed at different concentrations of *A. fabae* was calculated as 0, 42.86, 140.83, 561.19, 1219.50 and 1178.80, respectively. It was determined that the number of eggs laid by same predator when fed at different densities of *A. pisum* was 0, 45.25, 143.00, 568.44, 1223.78 and 1169.50. Considering the data obtained, it is seen that the number of eggs laid by *H. variegata* is higher for both preys than *C. septempunctata* (Figure 2).

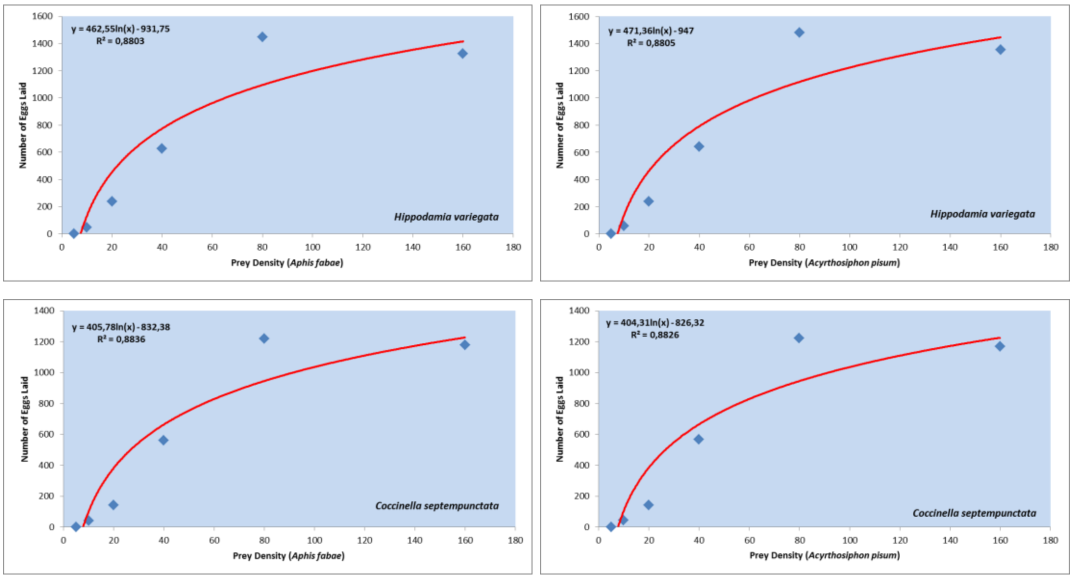

Figure 2. Number of eggs laid of *Hippodamia variegata* and *Coccinella septempunctata* on different aphids

D. Reproductive Response

In this study, the reproductive responses of the female *C. septempunctata* and *H. variegata* were defined. Accordingly, reproductive responses (%) of *H. variegata* females on *A. fabae* were calculated depending on their prey density (5, 10, 20, 40, 80 and 160), as 0, 8.81, 17.90, 26.55, 33.94 and 31.94, respectively. The reproductive responses of *H. variegata* on *A. pisum* were observed to be 0, 10.72, 18.28, 27.31, 34.76 and 33.08, respectively, depending on their prey densities. The reproductive responses of *C. septempunctata* female individuals fed on *A.*

fabae were calculated as 0, 7.85, 13.03, 27.45, 32.18 and 31.22, respectively. It was observed that the reproductive responses of this insect on *A. pisum* were 0, 8.30, 13.20, 27.60, 32.07 and 30.98, respectively (Figure 3).

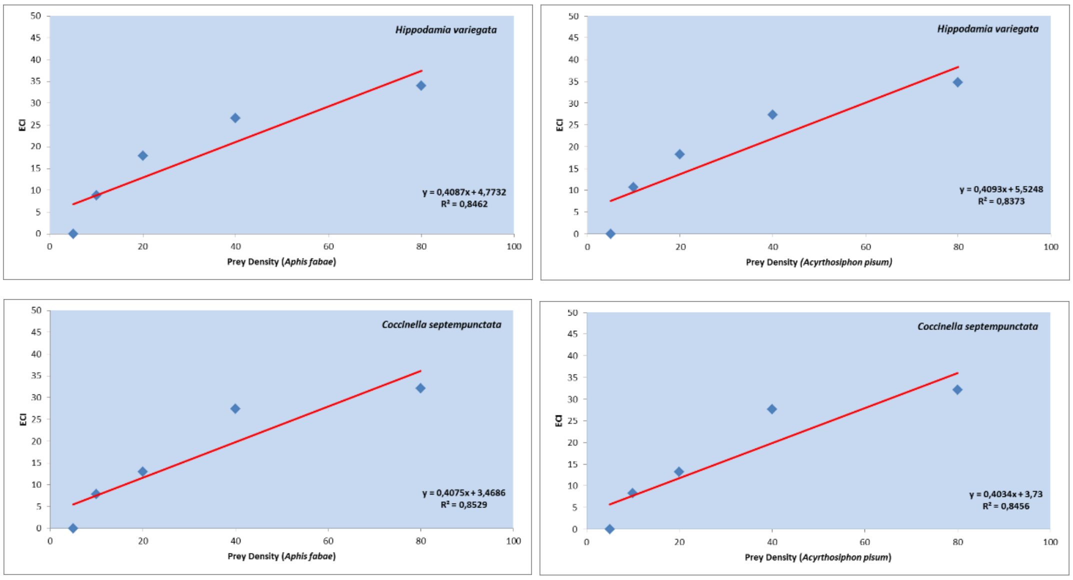

Figure 3. Reproductive responses of *Hippodamia variegata* and *Coccinella septempunctata* females fed at different prey densities

E. Development Times of Immature Stages of Hippodamia variegate and Coccinella septempunctata

The durations of the immature development periods on the different preys and different densities of the predator insects used in this study were calculated. Individuals of predator insects could not pass from the third larval stage to the next stage at 5 prey densities. It was observed that the prey density in which *H. variegata* fed on *A. fabae* showed the fastest growth was 80; it was determined that this period was prolonged in other prey densities. Likewise, the prey density of *H. variegata* fed on *A. pisum* was 80; it was determined that this period was prolonged in other prey densities. A similar situation applies to *C. septempunctata*. According to the data obtained for this predator insect, it was observed that the development time obtained at 80 prey density was shorter than the other densities. It was determined that the development times obtained at 160 prey densities for both predators were longer than the values obtained at 80 prey densities. The development times of the predator individuals fed with different preys and foods in different densities are given in Table 2.

F. Development Times of Adults and Number of Eggs

In the study, besides the development period of the predator insects after they become adults, the daily and total egg numbers laid by the predators were also calculated. Accordingly, it was observed that the preoviposition and postoviposition times for both predatory insects became shorter as the prey density increased. Oviposition time was longer especially at 80 and 160 prey densities compared to other densities. When the egg numbers were examined, it was determined that the daily and total egg production increased as the prey density increased for both predators. Since adult individuals with a prey density of 5 could not be obtained for both predators, data after adulthood could not be reached. When the daily and total egg numbers for both hunters were examined, it was determined that the yield was higher at 80 and 160 prey densities than other prey densities. Considering the difference between predators, the number of eggs was higher for *H. variegata* at these densities (Table 3).

Table 2. Development times of immature stages of Hippodamia variegata on different preys and different prey densities

P.D.	Development Times (Day) of *Hippodamia variegata* on *Aphis fabae*													
	N	Egg	N	Instar1	N	Instar2	N	Instar3	N	Instar4	N	Pupa	N	Total
5	50	3.1±0.05 a	47	1.83±0.06 a	36	2.86±0.06 a	27	3.33±0.13 a	--	--	--	--	--	--
10	44	3.1±0.05 a	42	1.79±0.06 a	31	2.61±0.09 a	24	2.75±0.17 b	6	7.50±0.34 a	6	5.17±0.31 a	6	22.67±0.21 a
20	38	3.1±0.04 a	36	1.75±0.07 a	29	2.07±0.10 b	22	2.00±0.07 c	14	4.43±0.14 b	14	4.64±0.17 ab	14	17.93±0.20 b
40	36	3.0±0.06 a	34	1.65±0.08 ab	27	1.93±0.11 bc	20	1.85±0.08 c	16	3.88±0.18 bc	16	4.56±0.16 ab	16	17.06±0.23 bc

80	32	3.1±0.06 a	32	1.38±0.09 b	30	1.67±0.09 c	24	1.58±0.10 c	22	3.09±0.13 d	19	4.05±0.20 b	19	15.21±0.24 d
160	30	3.0±0.07 a	30	1.53±0.09 ab	30	1.87±0.06 bc	22	1.86±0.08 c	20	3.50±0.14 cd	20	4.20±0.20 ab	20	16.25±0.25 c
P.D.	**Development Times (Day) of *Hippodamia variegata* on *Acyrthosiphon pisum***													
	N	Egg	N	Instar1	N	Instar2	N	Instar3	N	Instar4	N	Pupa	N	Total
5	50	3.1±0.05 a	46	1.83±0.06 a	36	2.94±0.08 a	27	3.22±0.12 a	--	--	--	--	--	--
10	43	3.1±0.05 a	41	1.81±0.07 a	30	2.67±0.10 a	23	2.74±0.18 b	7	7.43±0.30 a	7	5.29±0.29 a	7	22.71±0.18 a
20	37	3.1±0.05 a	35	1.74±0.08 ab	28	2.04±0.10 b	21	1.91±0.10 c	13	4.23±0.02 b	13	4.77±0.20 ab	13	17.85±0.25 b
40	36	3.0±0.05 a	34	1.59±0.09 abc	27	1.89±0.11 b	20	1.85±0.08 c	15	3.87±0.19 bc	15	4.53±0.17 abc	15	16.87±0.31 b
80	31	3.1±0.07 a	31	1.36±0.09 c	29	1.69±0.09 b	23	1.57±0.11 c	20	3.05±0.15 d	20	3.95±0.17 c	20	15.00±0.22 c
160	30	3.0±0.07 a	30	1.47±0.09 bc	30	1.80±0.07 b	22	1.82±0.08 c	20	3.35±0.11 cd	20	4.10±0.16 bc	20	15.75±0.18 c
P.D.	**Development Times (Day) of *Coccinella septempunctata* on *Aphis fabae***													
	N	Egg	N	Instar1	N	Instar2	N	Instar3	N	Instar4	N	Pupa	N	Total
5	50	3.1±0.06 **a**	48	3.00±0.08 **a**	42	3.24±0.08 **a**	28	3.50±0.11 **a**	--	--	--	--	--	--
10	44	3.1±0.06 **a**	44	2.68±0.07 **b**	42	2.93±0.07 **b**	33	3.27±0.11 **ab**	7	4.86±0.40 **a**	7	6.71±0.18 **a**	7	24.29±0.29 **a**
20	38	3.1±0.06 **a**	38	2.63±0.08 **b**	38	2.95±0.07 **b**	33	3.12±0.10 **abc**	12	4.42±0.15 **ab**	12	6.58±0.19 **a**	12	23.58±0.19 **ab**
40	36	3.2±0.06 **a**	36	2.61±0.08 **b**	36	2.94±0.06 **ab**	33	3.03±0.12 **bc**	16	4.25±0.11 **ab**	16	6.38±0.16 **a**	12	23.00±0.09 **b**
80	32	3.1±0.07 **a**	32	2.59±0.09 **b**	32	2.53±0.09 **c**	32	2.78±0.07 **c**	22	3.96±0.08 **b**	22	5.72±0.10 **b**	22	22.14±0.14 **c**
160	32	3.1±0.06 **a**	32	2.66±0.10 **b**	32	2.87±0.08 **b**	32	3.09±0.13 **abc**	20	3.95±0.09 **b**	20	6.20±0.12 **ab**	20	22.35±0.13 **c**
P.D.	**Development Times (Day) of *Coccinella septempunctata* on *Acyrthosiphon pisum***													
	N	Egg	N	Instar1	N	Instar2	N	Instar3	N	Instar4	N	Pupa	N	Total
5	50	3.1±0.05 **a**	48	2.98±0.08 **a**	43	3.19±0.09 **a**	29	3.35±0.13 **a**	--	--	--	--	--	--
10	44	3.1±0.05 **a**	44	2.63±0.07 **b**	42	2.81±0.09 **bc**	33	3.15±0.12 **ab**	8	4.63±0.38 **a**	8	6.88±0.13 **a**	8	24.25±0.25 **a**
20	37	3.1±0.05 **a**	37	2.57±0.08 **b**	37	2.92±0.08 **ab**	33	2.91±0.10 **abc**	12	4.41±0.15 **ab**	12	6.50±0.23 **ab**	12	23.50±0.20 **a**
40	36	3.2±0.07 **a**	36	2.56±0.08 **b**	36	2.86±0.08 **abc**	33	2.85±0.09 **bc**	16	4.13±0.09 **ab**	16	6.31±0.18 **ab**	16	22.81±0.14 **b**
80	32	3.1±0.08 **a**	32	2.56±0.09 **b**	32	2.50±0.10 **c**	32	2.59±0.09 **c**	23	4.00±0.09 **b**	23	6.04±0.08 **b**	23	22.13±0.13 **c**
160	32	3.1±0.07 **a**	32	2.56±0.10 **b**	32	2.84±0.10 **abc**	32	2.81±0.11 **bc**	20	4.10±0.10 **ab**	20	6.35±0.13 **ab**	20	22.65±0.13 **bc**

Table 3. Development times of mature stages and number of eggs of *Hippodamia variegata* and *Coccinella septempunctata* on *Aphis fabae* and *Acyrthosiphon pisum*

P.D.	**Development times of mature stages and number of eggs of *Hippodamia variegata* on *Aphis fabae***									
	N	Preovi. Times	N	Ovi. Times	N	Postovi. Times	N	DNE	N	TNE
5	---	---	---	---	---	---	---	---	---	---
10	6	4.67±0.33**a**	6	30.50±0.34**e**	6	6.50±0.34**a**	6	1.14±0.032**c**	6	47.33±1.41**c**
20	14	3.86±0.18**ab**	14	48.64±0.36**d**	14	6.07±0.20**a**	14	4.06±0.18**c**	14	236.86±8.91**c**
40	16	3.63±0.16**bc**	16	54.69±0.38**c**	16	5.63±0.16**ab**	16	9.80±0.38**b**	16	627.06±25.35**b**
80	19	3.32±0.15**bc**	19	68.63±0.39**b**	19	5.26±0.15**b**	19	18.77±0.99**a**	19	1448.79±75.74**a**
160	20	3.10±0.14**c**	20	67.15±0.32**a**	20	5.30±0.19**b**	20	17.56±0.94**a**	20	1325.40±70.13**a**
P.D.	**Development times of mature stages and number of eggs of *Hippodamia variegata* on *Acyrthosiphon pisum***									
	N	Preovi. Times	N	Ovi. Times	N	Postovi. Times	N	DNE	N	TNE
5	---	---	---	---	---	---	---	---	---	---
10	7	4.57±0.37**a**	7	30.57±0.43**e**	7	6.25±0.30**a**	7	1.37±0.03**c**	7	56.86±1.18**c**
20	13	3.77±0.20**ab**	13	48.92±0.31**d**	13	5.85±0.15**ab**	13	4.11±0.17**c**	13	239.92±8.94**c**

40	15	3.47±0.17**bc**	15	55.40±0.51**c**	15	5.27±0.21**bc**	15	9.99±0.40**b**	15	641.53±27.12**b**
80	20	3.30±0.15**bc**	20	69.40±0.37**a**	20	4.90±0.12**c**	20	19.05±0.90**a**	20	1478.60±69.93**a**
160	20	2.90±0.10**c**	20	67.45±0.31**b**	20	5.20±0.21**bc**	20	17.93±0.91**a**	20	1353.70±68.16**a**

P.D.	**Development times of mature stages and number of eggs of *Coccinella septempunctata* on *Aphis fabae***									
	N	Preovi. Times	N	Ovi. Times	N	Postovi. Times	N	DNE	N	TNE
5	---	---	---	---	---	---	---	---	---	---
10	7	10.57±0.20**a**	7	23.86±0.14**d**	7	7.29 ±0.36**a**	7	1.03±0.02**d**	7	42.86±1.32**c**
20	12	10.08±0.19**ab**	12	26.25±0.62**c**	12	7.00±0.46**a**	12	3.25±0.10**c**	12	140.83±4.48**c**
40	16	9.81±0.25**abc**	16	35.44±0.35**b**	16	6.75±0.21**a**	16	10.79±0.38**b**	16	561.20±20.50**b**
80	22	9.27±0.14**c**	22	51.14±0.40**a**	22	5.14±0.19**b**	22	18.62±0.32**a**	22	1219.50±19.10**a**
160	20	9.50±0.17**bc**	20	50.55±0.41**a**	20	5.25±0.25**b**	20	18.06±0.34**a**	20	1178.80±21.80**a**

P.D.	**Development times of mature stages and number of eggs of *Coccinella septempunctata* on *Acyrthosiphon pisum***									
	N	Preovi. Times	N	Ovi. Times	N	Postovi. Times	N	DNE	N	TNE
5	---	---	---	---	---	---	---	---	---	---
10	8	10.50±0.19**a**	8	23.75±0.16**d**	8	7.38±0.32**a**	8	1.09±0.02**d**	8	45.25±0.86**c**
20	12	10.00±0.17**ab**	12	26.42±0.56**c**	12	7.00±0.46**a**	12	3.30±0.10**c**	12	143.00±4.09**c**
40	16	9.88±0.30**ab**	16	35.56±0.37**b**	16	6.75±0.21**a**	16	10.89±0.38**b**	16	568.40±20.30**b**
80	23	9.26±0.13**b**	23	51.22±0.39**a**	23	5.17±0.19**b**	23	18.65±0.30**a**	23	1223.80±18.00**a**
160	20	9.40±0.18**b**	20	50.35±0.41**a**	20	5.30±0.28**b**	20	17.98±0.34**a**	20	1169.50±21.50**a**

* P.D.: Prey Densities, Preovi.: Preoviposition, Ovi.: Oviposition, Postovi.: Postoviposition, DNE: Daily Number of Eggs, TNE: Total Number of Eggs.

G. Life Table Parameters

In the study, the life schedule parameters of *H. variegata* and C. *septempunctata* fed with different densities of food (hereditary reproductive ability, net reproductive power, mean reproductive period, total reproduction rate, population doubling time, and reproductive power limit) were also calculated. According to the data obtained, it was observed that the hereditary reproductive ability, net reproductive power and the prey density with the highest total reproduction rate were 80 for both predator insects. It was determined that the values obtained at 160 prey densities, which is the highest density, were lower than 80 prey densities. When evaluated in terms of the doubling time of the population, the time is long at low prey densities; as the prey density increased, the duration shortened and the shortest time was at 80 prey density (Table 4).

Table 4. Life table parameters of *Hippodamia variegata* and *Coccinella septempunctata* on different preys

P.D.	**Life Table Paramaters of *Hippodamia variegata* on *Aphis fabae***					
	r_m	**R_0**	**T_0**	**GRR**	**T_2**	**λ**
5	---	---	---	---	---	---
10	0.028	3.227	41.396	23.667	24.490	1.029
20	0.096	46.988	40.101	127.538	7.220	1.101
40	0.124	146.637	40.386	334.443	5.597	1.132
80	**0.147**	**441.734**	**41.363**	**743.976**	**4.707**	**1.159**
160	**0.146**	**441.800**	**41.703**	**662.700**	**4.746**	**1.157**

P.D.	**Life Table Paramaters of *Hippodamia variegata* on *Acyrthosiphon pisum***					
	r_m	**R_0**	**T_0**	**GRR**	**T_2**	**λ**
5	---	---	---	---	---	---
10	0.036	4.628	42.184	28.429	19.085	1.037
20	0.093	42.149	40.349	119.962	7.476	1.097
40	0.123	138.276	40.218	331.862	5.655	1.130
80	**0.153**	**489.198**	**40.394**	**758.267**	**4.521**	**1.166**
160	**0.151**	**451.233**	**40.404**	**676.850**	**4.582**	**1.163**

P.D.	**Life Table Paramaters of *Coccinella septempunctata* on *Aphis fabae***

	r_m	R_0	T_0	GRR	T_2	λ
5	---	---	---	---	---	---
10	0.028	3.671	46.706	23.077	24.892	1.028
20	0.068	22.237	45.389	70.417	10.143	1.071
40	0.103	133.022	47.585	299.300	6.744	1.108
80	**0.120**	**461.123**	**51.187**	**670.727**	**5.784**	**1.127**
160	**0.117**	**387.763**	**50.976**	**620.421**	**5.928**	**1.124**
P.D.	**Life Table Paramaters of *Coccinella septempunctata* on *Acyrthosiphon pisum***					
	r_m	R_0	T_0	GRR	T_2	λ
5	---	---	---	---	---	---
10	0.033	4.701	46.243	25.857	20.708	1.034
20	0.068	22.262	45.323	68.640	10.125	1.071
40	0.103	134.741	47.560	303.167	6.723	1.109
80	**0.121**	**493.431**	**51.263**	**686.514**	**5.730**	**1.129**
160	**0.117**	**384.704**	**50.988**	**615.526**	**5.937**	**1.124**

* (R_m: Intrinsic Rate of Increase; R_0: Net Reproductive Rate; T_0: Mean Generation Time; GRR: Total Productivity rate; T_2: Doubling Time; λ: Daily maximum reproductive value; P.D.: Prey Densities)

It was defined that the consumption of different preys and densities increased as the periods developed in both predatory insects. Consumption increased as the amount of food increased in the same development period for each predatory insect. Consumption amount is close in the two highest aphid intensities used in present trial; however, the consumption at the highest intensity decreased slightly. In a study conducted responses of *Scymnus apetzi* (Mulsant) (Coleoptera: Coccinellidae) on *Hyalopterus pruni* (Hemiptera: Aphididae) were determined as well as the duration of starvation. According to the study, different instar larvae of *S. apetzi* increased the amount they consumed according to the amount of prey in the environment. The same situation was observed in adult individuals of the species [27]. In a different study, the amounts consumed by larvae and adults of *C. septempunctata* feeding on *Macrosiphum euphorbiae* were determined. Accordingly, adults consumed an average of 8750.1 preys at 25 °C and an average of 10736 preys at 30 °C [28]. In a study examining the daily and total *A. nerii* consumption of *Rhyzobius lophanthae* under laboratory conditions, the consumption averages of different larval stages and adult females were determined. Accordingly, while a female consumed 1.2 preys, larval stages consumed 2.2, 7.5 and 24.6 preys, respectively. Looking at the total number; one male individual was fed with 390.6 and a female individual with 672.3 adult *A. nerii* throughout his life. In addition to these results, the total productivity of a female is 633.7; The number of eggs she gave per day was calculated as 18-25 [29]. In addition to these studies, there are also studies on the effects of different predatory insects found in the same habitat with ladybugs on aphids. According to these data, as the larval stages passed, the amount of A. nerii consumed also increased [30-35].

Reproductive Response (ECI) values were also calculated in this study. The reproductive response values of both predators increased depending on the prey density in different prey. There are predator insects whose numerical responses have been studied on aphids. It was determined the functional and numerical response of the third instar larvae of *Chrysoperla carnea* (Stephens) on *Aphis fabae solanella*. There was a linear increase in the graph created depending on the prey densities [36]. It was determined the reproductive responses of the predator insect on two different foods in this numerical response study of *C. carnea* on two different foods (*A. fabae* and *A. pisum*) [35]. According to the data obtained, it was observed that the reproductive response also increased rapidly depending on the prey densities, but this increase continued with a decrease at high prey densities.

In numerical response experiments, development times can be calculated separately for each period of predatory insects fed at different densities. In our study, the development times of both predators on different foods were calculated. Accordingly, it was observed that the development times of predatory insects fed at high prey densities were shorter than those fed at low densities. This situation is even more striking when considered in terms of total development time. It was investigated the development of *Nephus includens* and *Nephus bisignatus* fed on *Planococcus citri* at different temperatures (15, 20, 25, 30, 32.5, 35, 37.5 °C) and examined the development times of the two species (Y, L1, L2, L3, L4, PP, P, PreOv). According to the results they obtained, the biological cycles of *N. includens* (Egg-Egg) were calculated as 114.32, 55.82, 34.90, 25.50, 22.80 and 25.84 days, respectively; For *N. bisignatus*, these periods were determined as 112.98, 58.06, 38.06, 30.32, 34.30 and 0.00 days, respectively [37]. Numerical responses of different predatory insects on aphids, except for the Coccinellidae family, were also investigated. According to the data obtained from these studies, it has been determined that as the prey density increases, the development times shorten [30, 32, 35, 38, 39].

In present study, the preoviposition and postoviposition times for both predators fed on different foods were partially reduced depending on the prey density, while the oviposition time increased depending on the prey density. These times, which were mentioned in the studies of the numerical responses of different predator insects on aphids, except for the Coccinellidae family, were calculated. According to the data obtained from these studies. As the prey density increased, the preoviposition and postoviposition times shortened; it was determined that the oviposition times increased in parallel with this increase in density [30, 35, 40].

In our study, both predators fed on different foods had low prey densities and the females were low in productivity, and as the food increased depending on the prey density, both the daily and the total number of eggs laid increased. In different study about *Adalia fasciatopunctata revelierei* (Mulsant) (Coleoptera: Coccinellidae) fed on *Hyalopterus pruni* (Geoffroy) (Hemiptera: Aphididae), the consumption amounts of individuals given different numbers of preys (20, 40, 80, 160 and 250 preys) were determined. As the prey density increased, the number of eggs laid also increased [41]. In a different study, the numerical response of *Nephus arcuatus* (Coleoptera: Coccinellidae) feeding on *Nipaecoccus viridis* was demonstrated. Accordingly, 2, 4, 8, 16, 50, 70, 90, 110 and 130 units for the first nymphal period, 2, 4, 6, 10, 20, 30, 40 and 50 units for the second nymphal period, 2 for the third nymphal period sensities of 4, 6, 9, 15, 21 and 27, and 1, 3, 5, 7 and 9 for adult females were preferred and paired with 10-day-old female predators for 24 hours. According to the results obtained, the number of eggs laid by the females increased nonlinearly as the prey density increased in all feeding periods and densities. According to the results of the study, it was reported that the numerical response of *N. arcuatus* was affected by different periods of *N. viridis* [42]. According to studies on different foods and different predatory insects, it has been determined that there is an increase in the number of daily and total eggs given depending on the increase in the prey density in the environment [30, 33, 35, 43, 44].

The numerical responses of *C. septempunctata* and *H. variegata* on *A. fabae* and *A. pisum* were determined separately. The response here is defined as an indicator of the reproductive ability of predators under varying prey densities. Accordingly, it has been determined that a predator insect with a high numerical response can suppress its prey [45]. Depending on the prey density, the development time of the predator insects, the daily amount of food they consume, the number of eggs they lay, their reproductive responses and their prey use efficiency were calculated. Considering the data obtained, it was observed that although the normal development times of both predators were different, the durations were shortened due to the increase in their prey density. When the consumption amounts were examined, the consumption increased for both predators as the development periods progressed and as the prey density increased. Although the amount of food consumed by *H. variegata* for both preys was close to that of *C. septempunctata* during the development stages, it was determined that the total consumption amount was higher. When the number of eggs laid by predator insects at different prey densities was examined, the number of eggs laid by *H. variegata* was higher than that of *C. septempunctata* at both different preys and densities. According to the results obtained here, when evaluated in terms of both Intrinsic Rate of Increase (r_m) and Net Reproductive Rate (R_0), it was determined that *H. variegata* had higher reproductive capacity when fed on *A. fabae* and *A. pisum*. A similar situation is in question when the reproductive response (ECI) values, which depend on the number of eggs laid, are examined. According to the results of the prey utilization efficiency, which is one of the numerical response parameters, the productivity (consumption amount) decreased as the aphid intensity increased. It has been determined that predatory insects fed with different preys and densities do not consume more than a certain amount. In fact, it was observed that both consumption and reproductive capacity decreased somewhat after certain intensity for both predators.

IV. CONCLUSIONS

In these trials, it was concluded that both predators were effective on *A. fabae* and *A. pisum* foods, their reproductive and consumption capacities were high, especially in high-density food, and they could keep the population of the specified pests under control.

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