

STAGE SPECIFIC FEEDING ATTRIBUTES OF PARTHENIUM BEETLE, *ZYGOGRAMMA BICOLORATA* PALLISTER (COLEOPTERA : CHRYSOMELIDAE) UNDER FLUCTUATING FOOD QUALITY

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ABSTRACT : The food is the foremost need for the existence of all living organisms and the fluctuations in its availability strongly affects the population dynamics of both the primary and secondary consumers. In the present study we have investigated the effect of food (Parthenium weed) resource fluctuations, in terms of quality, on the feeding attributes of the Parthenium beetle, *Zygogramma bicolorata* Pallister (Coleoptera : Chrysomelidae). This beetle is an effective biological control agent of the noxious weed, *Parthenium hysterophorus* L. We have abruptly changed the fourth instars and adult females of *Z. bicolorata* from their rearing condition of mature leaves to an experimental condition of early leaves or *vice versa*; and observed the effect of sudden change of food on their consumption rate, conversion efficiency and growth rates. The results revealed no significant effect of rearing and experimental conditions on the feeding attributes of fourth instars and adult females of *Z. bicolorata* by sudden fluctuation in the food quality. However, the fourth instars had higher feeding attributes than the adult females, proving them to be the better biocontrol agents of Parthenium weed than the adult females. However, field based studies are still needed to validate the present findings.

Key words : Resource fluctuation, feeding attributes, Parthenium beetle, biocontrol.

INTRODUCTION

Food is the foremost need for the existence of all living organisms, though its availability is rarely constant in the natural environment. The variation in the frequency and magnitude of food supply leads to the alternation of low and high food availability (Rosenzweig, 1995; Ostfeld and Keesing, 2000). As a result, the population dynamics of both the primary and secondary consumers are strongly influenced, because the fluctuations in food availability significantly affect their growth and development (Ostfeld and Keesing, 2000; Bieber and Ruf, 2005). Many studies have quantified the effects of fluctuating food conditions on predation, developmental and reproductive attributes of the beetles of family Coccinellidae (Dixon and Guo, 1993; Schüder *et al*, 2004; Phoofolo *et al*, 2007; Dmitriev *et al*, 2009; Chaudhary *et al*, 2015; Patel *et al*, 2017a, b). However, hardly any study has revealed the influence of fluctuating food conditions on life attributes of the Parthenium beetle of family Chrysomelidae, which is employed in the management of the Parthenium weed.

In the present study we have investigated the effect of food (Parthenium weed) resource fluctuations in terms of quality on the feeding attributes of the Parthenium beetle, *Z. bicolorata*. This beetle is an effective biological control agent of the noxious weed, *Parthenium*

hysterophorus L. (Family-Asteraceae) (Jayanth, 1987; Dhileepan *et al*, 2000), which is native to tropical and South America, and certain parts of Asia and Australia (Navie *et al*, 1996). This weed possibly got entry into India from USA through imported food grains (Vartak, 1968) or through cereals obtained for experimental purposes (Lonkar *et al*, 1974). It causes hay fever, asthma, nasal-dermal and naso-bronchial diseases, allergic rhinitis, allergic reactions, allergic papules, fatigue and severe dermatitis in humans (McFadyen, 1995; Das *et al*, 2007). Moreover, the weed is not palatable to livestock due to its irritating odour, taste and presence of trichomes.

In India, the Parthenium beetle, *Z. bicolorata* was introduced first in 1983 by the Indian Institute of Horticultural Research (IIHR), Bangalore for the management of Parthenium weed (Jayanth and Nagarkatti, 1987). The newly hatched larvae of *Z. bicolorata* feed voraciously on apical young leaves of Parthenium, burrow into the soil for pupation and complete their life cycle in about 23-30 days (Dhileepan *et al*, 2000). In this study, we abruptly changed the fourth instars or adult females of *Z. bicolorata* from their rearing condition of mature leaves to an experimental condition of early leaves or *vice versa*; and observed the

effect of sudden change of food on their consumption rate, conversion efficiency and growth rates. It was assumed that the larvae reared on mature leaves would have better feeding attributes when switched over to early leaves than in the reverse scenario. Therefore, the study would not only provide information on the behaviour of the feeding stages of *Z. bicolorata*, but would also help in assessing their energy budget for various biological activities. Moreover, the study would facilitate the mass multiplication of these chrysomelid beetles in laboratories for the biological control of the Parthenium weed.

MATERIALS AND METHODS

Stock maintenance

Adult males and females of *Z. bicolorata* were collected from the Agricultural fields of Varanasi, India (25°20'N, 83°0'E) and paired randomly in plastic Petri dishes (9.0 × 1.5 cm²). They were reared under constant abiotic conditions (27±2°C; 65±5% relative humidity; 14:10 light: dark hours) in BOD Incubator (NSW-152; Narang Scientific Works Pvt. Ltd., New Delhi, India) on daily replenished supply of the leaves of Parthenium weed. The eggs laid were collected every 24 hours and subsequent first instars were used for further experimentation.

Experimental design

The first instars of *Z. bicolorata* were individually reared on *ad libitum* biomass of either mature leaves or the early leaves up to the third instar stage under abiotic conditions similar to that of the stock culture. After the instars moulted to fourth instars, they were weighed prior to the experiment (using Analytical Balance: RA-200, Roy Electronics, Varanasi, India). Thereafter, the fourth instars from each rearing condition were divided into the following experimental groups of 10 each under the above mentioned abiotic conditions:

- (i) **Experimental group I**: Shifted from mature leaves to early leaves.
- (ii) **Experimental group II**: Shifted from mature leaves to mature leaves.
- (iii) **Experimental group III**: Shifted from early leaves to early leaves.
- (iv) **Experimental group IV**: Shifted from early leaves to mature leaves.

These conditions were maintained for 24 hours. Thereafter, the larvae and food left were weighed in each Petri dish. Thereafter, the food of the larvae was switched back to their respective rearing conditions. The same experiment was replicated for 10-day-old unmated adult females from each rearing condition under the above

mentioned abiotic conditions. The females were weighed before and after the experiment and the biomass of leaves left after 24 hours was also recorded.

Consumption rate, conversion efficiency, and growth rate of the fourth instars and the adult females were calculated using the following formulae:

1. Consumption rate (mg-day⁻¹) =

$$\frac{\text{Leaf biomass consumed by the larva / adult (mg)}}{\text{Feeding duration of the larva / adult (days)}}$$

2. Conversion efficiency =

$$\frac{\text{Increased biomass of the larva / adult (mg)}}{\text{Leaf biomass consumed by larva / adult (mg)}}$$

3. Growth rate (day⁻¹) =

$$\frac{\text{Fresh biomass gain of larva / adult (mg)}}{[(\text{Feeding duration (days)}) \times (\text{Mean biomass of larva / adult (mg)})]}$$

Where, mean body biomass is average of the initial (prior to experimentation) and final (after experimentation) biomass.

Statistical analysis

The distributions of data sets obtained in this study were checked for normality using the Kolmogorov-Smirnov test. Means were separated using Tukey's test when data were normally distributed and variances were homogeneous (Bartlett's test for equal variances). Data that were obtained were subjected to multiple-analysis of variance (MANOVA) with feeding attributes as dependent variables; and stage, rearing and experimental food conditions, and their interactions as the independent variables, followed by Tukey's *post-hoc* comparison of means. All statistical analyses were performed using MINITAB 16 (Minitab Inc., State College, Pennsylvania, United States of America).

RESULTS

In the present study, MANOVA-values revealed significant influence of the stage (fourth instars and adult females) on the consumption rate, conversion efficiency and growth rate of the fourth instars and adult females of *Z. bicolorata*. However, the effects of rearing and experimental conditions (early leaves or mature leaves)

on the feeding attributes (consumption rate, conversion efficiency and growth rate) of larvae and females were statistically insignificant. Moreover, except the interaction between the stage and the rearing condition that significantly affect the consumption rates of larvae and adults, the effects of other interactions on the feeding attributes were statistically insignificant (Table 1).

Further, the Tukey's post-hoc comparison of means revealed the values of consumption rates, conversion efficiencies and growth rates of the fourth instars to be higher than the adult females when they were switched over from their rearing condition to the experimental condition of same or different food type (Table 2).

DISCUSSION

In the present study, the constancy in the consumption rates, conversion efficiencies and growth rates of the feeding stages of *Z. bicolorata* on the two food types under the rearing and experimental conditions suggest that despite having variations at the nutrient levels of the two food types, both the feeding stages may be equally

efficient in exploiting them. The early leaves of the Parthenium weed are soft and rich in nutrients than the mature leaves, which are hard and probably rich in defensive alkaloids. Earlier chemical analysis of Parthenium leaves have reported that it is a rich source of two pseudoguaianolides namely *parthenin*, a bitter glycoside and *coronopilin* present in almost all the plant parts in addition to some minor constituents (Sethi *et al*, 1987; Kalsi *et al*, 1995; De la Fuente *et al*, 1997) such as, hysterin (Ambrosanolide), ambrosin, flavonoids, quercelagetin 3,7-dimethyl ether, 6-hydroxyl Kalmpferol 3-0 arabinoglucosid, fumaric acid, P-hydroxy benzoic acid and vanillic acid, caffeic acid, P-coumaric and ferulic acid along with sitosterol and some unidentified diterpe alcohols (Sethi *et al*, 1987; De la Fuente *et al*, 1997; Maishi *et al*, 1998; Ramesh *et al*, 2003; Venkataiah *et al*, 2003). Still both the feeding stages are equally specialized in detoxifying these harmful chemicals and efficiently metabolize them. Thus, the feeding habits of both the feeding stages of *Z. bicolorata* are possibly not influenced by the sudden fluctuations in the food quality.

Table 1 : MANOVA table showing the effect of independent variables (stage, rearing condition, experimental condition and their interactions) on the dependent variables (feeding attributes) of *Zygogramma bicolorata* under food fluctuating conditions (F-values significant at $P < 0.05$).

Independent variables	Dependent variables		
	Consumption rate	Conversion efficiency	Growth rate
Stage	F= 5.97; P= 0.017; df= 1, 80	F= 5.26; P= 0.025; df= 1, 80	F= 11.55; P= 0.001; df=1, 80
Rearing condition	F= 2.02; P= 0.159; df= 1, 80	F= 0.09; P= 0.764; df= 1, 80	F= 0.40; P= 0.532; df=1, 80
Testing condition	F= 0.67; P= 0.416; df= 1, 80	F= 0.52; P= 0.474; df= 1, 80	F= 0.64; P= 0.428; df= 1, 80
Stage × Rearing condition	F= 12.12; P= 0.001; df=1, 80	F= 0.14; P= 0.707; df= 1, 80	F= 0.02; P= 0.889; df= 1, 80
Stage × Experimental condition	F= 2.38; P= 0.128; df= 1, 80	F= 0.22; P= 0.643; df= 1, 80	F= 0.30; P= 0.583; df= 1, 80
Rearing condition × Experimental condition	F= 1.42; P= 0.237; df= 1, 80	F= 1.44; P= 0.234; df= 1, 80	F= 0.98; P= 0.325; df= 1, 80
Stage × Rearing condition × Experimental condition	F= 0.33; P= 0.568; df= 1, 80	F= 0.46; P= 0.502; df= 1, 80	F= 0.36; P= 0.551; df= 1, 80

Table 2 : Feeding attributes of fourth instars and adult females of *Zygogramma bicolorata* under food fluctuating conditions.

Stage	Rearing condition	Experimental condition	Consumption Rate (mg/day)	Conversion efficiency	Growth rate (per day)
Fourth instars	Mature leaves	Early leaves	25.24 ± 0.45 ^{bA(a)}	0.067 ± 0.014 ^{aA(b)}	0.085 ± 0.019 ^{aA(b)}
		Mature leaves	24.10 ± 0.45 ^{aA(a)}	0.065 ± 0.012 ^{aA(b)}	0.083 ± 0.016 ^{aA(b)}
	Early leaves	Early leaves	25.38 ± 0.40 ^{aA(b)}	0.063 ± 0.012 ^{aA(b)}	0.071 ± 0.013 ^{aA(b)}
		Mature leaves	25.86 ± 0.46 ^{aB(b)}	0.071 ± 0.012 ^{aA(b)}	0.079 ± 0.015 ^{aA(a)}
Adult females	Mature leaves	Early leaves	24.75 ± 0.76 ^{aB(a)}	0.049 ± 0.011 ^{aB(a)}	0.042 ± 0.010 ^{aB(a)}
		Mature leaves	25.55 ± 0.68 ^{aB(b)}	0.041 ± 0.012 ^{aA(a)}	0.039 ± 0.012 ^{aA(a)}
	Early leaves	Early leaves	22.21 ± 0.91 ^{aA(a)}	0.021 ± 0.004 ^{aA(a)}	0.017 ± 0.003 ^{aA(a)}
		Mature leaves	23.58 ± 0.89 ^{aA(a)}	0.054 ± 0.032 ^{bA(a)}	0.053 ± 0.033 ^{aA(a)}

*Small letters, large letters and small letters in parentheses represent comparison of means amongst rearing conditions, amongst experimental conditions and between feeding stages, respectively.

Moreover, the higher consumption rates, conversion efficiencies and growth rates of the fourth instars over the adult females under the food quality fluctuation conditions may be attributed to their higher metabolic costs and energy requirements associated with pupation and further metamorphosis. Thus, they consume a large amount of leaf biomass that further increases their consumption rates. The higher conversion efficiency and growth rate of fourth instars over the adult females have also been reported earlier in ladybird beetles, but on a constant food resource (Mishra *et al*, 2011; Kumar *et al*, 2013). Similarly, Kçhler *et al* (1987) reported higher conversion efficiencies for the nymphs of central European grasshoppers than the adults. However, in contrast to the results of the present study, certain studies have reported the higher consumption rates of adult females than the fourth instars in ladybird beetles may be ascribed to their high energy requirements for gonadal development and the sexual maturity (Barros-Bellanda and Zucoloto, 2002; Karsai and Hunt, 2002; Moreau *et al*, 2006; Chaudhary *et al*, 2015; Keshavarz *et al*, 2015; Rakhshan and Ahmad, 2015). Moreover, Omkar and Afaq (2011) reported higher consumption rates of fourth instars than the early instars, and the conversion efficiencies and growth rates of early instars than the fourth instar in the *Parthenium* beetle, *Z. bicolorata*.

In brief, the present study demonstrates that the feeding habits of the fourth instars and adult females of *Z. bicolorata* are not significantly influenced by the sudden fluctuations in the food quality. But the fourth instars have higher feeding attributes than the adult females, proving them to be the better biocontrol agents of *Parthenium* weed than the adult females. The present results may further be exploited to mass multiply this chrysomelid beetle in laboratories for the biological control of *Parthenium* weed. Nevertheless, field based studies are still needed to validate the present findings.

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