J. bio-sci. 15: 15-21, 2007 **ISSN 1023-8654**
http://www.banglajol.info/index.php/JBS/index

IMPACTS OF FOOD DIVERSITY ON SOME REPRODUCTIVE ATTRIBUTES IN THE GRAY FIELD SLUG *DEROCERAS RETICULATUM* (MÜLLER)

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Abstract

Using a food choice design consisting of a single, double and multiple diets, impacts of three common vegetables *viz*. cabbage (CAB), lettuce (LET) and potato (POT) on some important reproductive attributes of the gray field slug *Deroceras reticulatum* (Müller) have been assessed. Although adult body weight was not affected by the diets, brood size was maximum in a double diet (CAB+POT), but multiple diets (CAB+LET+POT) did not enhance egg productivity. Both LET and POT had induced significantly greater number of eggs per day in comparison with CAB. Multiple diets resulted in significantly heavier eggs than the eggs from single or double diet regimes. Eggs laid on LET had the lowest and that on CAB+LET+POT had the highest developmental time but the hatch rate across the diet regimes did not differ significantly. Hatchlings from the single diet treatment were heavier than the double diet regime, but those between single *vs.* multiple or double *vs*. multiple diets did not vary statistically. The heaviest hatchlings were from LET and the lightest ones were from the CAB+LET treatments. The present results would help researchers in selecting a convenient culture medium for rearing experimental slugs in the laboratory. In addition, the data suggest that polyculture of vegetables might reduce slug damage, especially by reducing the brood size, egg production and hatchling size of *D. reticulatum* in the fields.

Key words: *Deroceras*, field slug, food diversity, reproductive attributes, alternative food source

Introduction

In recent years increased damages on agricultural and horticultural crops by the gray field slug *Deroceras reticulatum* (Müller) (Stylommatophora: Limacidae) are common in England, Europe, the United States and the former USSR (Port and Port 1986, Cook *et al*. 1996, Port and Ester 2002, Kozlowski 2005). Slugs are highly polyphagous and nocturnal pest of a variety of field crops such as lettuce, potato, cabbage, tomato, tobacco, maize, carrot, cereals, rapeseeds, sunflower and fodder lugumes (Rollo 1988, Kozlowski *et al*. 2006). Control methods of this pest by the use of molluscicides, metaldehyde and carbamates are unreliable (Garthwaite and Thomas 1996, Nash *et al*. 2007), whereas biological control agents like ciliates, trematodes, nematodes, mites and flies are not very satisfactory (Glen *et al*. 2000).

Feeding activities of *D. reticulatum* have been shown to be influenced by either the phagostimulant or the antifeedant effect of the phytochemicals present in the diet (Clark *et al.* 1997). Peters *et al*. (2000) demonstrated that the slug preferred multiple food sources more than they preferred having one food source, and this study was further elaborated by Kozlowski and Kozlowska (2003) to show that *D. reticulatum* exhibits differential preferences towards plant species as food source. Food preferences of this species for winter oilseed rape and various weed and herb species have been observed by Kozlowski and Kaluski (2004), while Brooks *et al*. (2006) recommended red clover as an alternative food source to reduce the

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amount of damage caused to winter wheat by *D. reticulatum.* Recent studies by Nash *et al*. (2007) have shown that certain vegetables show a negative response to the number of slugs whereas others are associated with an increased number of slugs in the experimental plots.

Environment-friendly farming techniques seek to increase biodiversity in the niche with the intention of encouraging greater numbers of predators that will help to control crop pests such as slugs (Symondson *et al.* 2006). Several studies imply that alternative food sources may reduce slug destructions to vegetable crops (Cook *et al.* 1996, Peters *et al*. 2000, Kozlowski and Kozlowska 2003, Brooks *et al*. 2006). As food preferences are reported to affect slug damage to vegetable crops (Peters *et al.* 2000, Gebauer 2002, Kozlowski and Kozlowska 2003), the relative palatabilities of three different food choices to *D. reticulatum* are examined here to evaluate the impacts of vegetable feeding on such vital reproductive attributes as adult body weight, eggs per day, egg weight, brood size, developmental time, hatch rate and hatchling weight. The practical implications of this study are also dealt with.

Materials and Methods

Collection and rearing of D. reticulatum: Slug specimens were collected from the Experimental Field Station, Kentucky University, during October-November 2004, and transported to the laboratory for rearing. All specimens were from the similar age-group as indicted by their size and body weight. The slugs were maintained in an incubator at 22±1ºC and reared initially on a single diet, lettuce (Fig. 1) for six weeks until they were subjected to differential diet tests.

Fig.1. *D. reticulatum* feeding on lettuce leaf

Diet regimes: Seven treatment groups, consisting of a single diet of cabbage (CAB), lettuce (LET) and potato (POT); double diets of cabbage and lettuce (CAB+LET), cabbage and potato (CAB+POT) and lettuce and potato (LET+POT); and multiple diets of cabbage, lettuce and potato (CAB+LET+POT) were used to assess their effects on slug reproduction.

Reproductive attributes: Effects of differential diets on seven vital reproductive attributes relevant to the survival and propagation of the pest biology were studied. These were: adult body weight (g), developmental time (d), hatch rate (%), brood size (=fecundity), eggs per day (=daily oviposition), egg weight (mg) and hatchling weight (mg).

Experimental design: Twelve adult slugs per treatment group were used. Eggs were collected daily over a period of 6 consecutive weeks from January to March 2005. Egg weight and hatchling weight were recorded using an electronic balance. Data for brood size, egg weight, developmental time and hatchling weight showing normality were subjected to parametric tests namely, ANOVA followed by Bonferroni's multiple comparisons. Whereas data for body weight, eggs per day and hatch rate that failed to show normality were subjected to non-parametric tests *viz.,* Kruskal-Wallis one-way ANOVA followed by Mann-Whitney *U*-tests. A statistical package (SPSS version 11.0) was used to analyze the data.

Results and Discussion

Results of the impacts of differential diet regimes on seven reproductive parameters of *D. reticulatum* are described below.

Body weight: Adult weights did not differ significantly across the seven treatment groups, suggesting that the diets had negligible effect on the body weight of the experimental slugs (Table 1).

Table 1. Effects of differential diets on adult body weight, developmental time and hatch rate (mean ± SE) in *D. reticulatum*

Treatment Groups	Body wt (g)	Developmental time (days)	Hatch rate (%)
Single diet			
CAB	0.34±0.04^{a}	13.9±0.23^{ab}	93.03±2.44^{a}
LET	0.26±0.02^{a}	13.3±0.22^{a}	87.74±3.83^{a}
POT	0.22±0.02^{a}	13.6±0.11^{a}	84.36±3.06^{a}
Double diets			
CAB+LET	0.22±0.03^{a}	13.5±0.18^{a}	78.33±6.61^{a}
CAB+POT	0.26±0.04^{a}	13.8±0.11^{ab}	87.10±3.07^{a}
LET+POT	0.29±0.05^{a}	13.8±0.13^{ab}	74.36±10.59^{a}
Multiple diets			
CAB+LET+POT	0.28±0.05^{a}	14.4±0.19^{b}	85.30±5.04^{a}

CAB= cabbage, LET= lettuce, POT= potato; Means followed by same letters in the same column are not significantly different (P>0.05). Kruskal-Wallis one-way ANOVA followed by Mann-Whitney *U* tests for body weight and hatch rate, and ANOVA followed by Bonferroni's post-hoc comparisons for developmental time, were used.

Developmental time: Eggs laid on LET had the lowest and that on CAB+LET+POT had the highest developmental time (Table 1). Both single and double diets had an effect on enhancing developmental time compared to the multiple diets ($P < 0.0001$ and $P < 0.004$, respectively). Eggs on LET ($P < 0.001$), POT ($P < 0.014$) and CAB+LET ($P < 0.011$) hatched significantly earlier than CAB+LET+POT treatment. It is apparent from the results that the developmental time was negatively influenced by the diet regimes under study.

Hatch rate: Apart from a slight variation, hatch rate across the diet regimes did not differ significantly (Table 1), indicating that the three vegetables did not affect the percentage of hatching in this species.

Brood size (=fecundity): Average brood size in POT was higher than that in CAB or LET, while CAB+POT produced the maximum brood size compared to the rest of the treatments (Fig. 2). Multiple diets (CAB+LET+POT) did not enhance egg productivity. Both single and double diets yielded significantly higher number of eggs compared to the multiple diets ($P < 0.007$), but the difference in productivity for single *vs.* double diet regimes was not a significant one ($P = 1.00$). Therefore, fecundity in the slugs was affected by the diets available to them.

Eggs per day: Both LET and POT had greater number of daily oviposition in comparison with CAB ($P < 0.038$ and $P < 0.005$, respectively); while LET+POT had significantly fewer number of eggs per day than CAB+LET ($P < 0.039$) and CAB+POT ($P < 0.001$). Like brood size, daily oviposition in *D. reticulatum* was also influenced by the diet on which it feeds (Fig. 2).

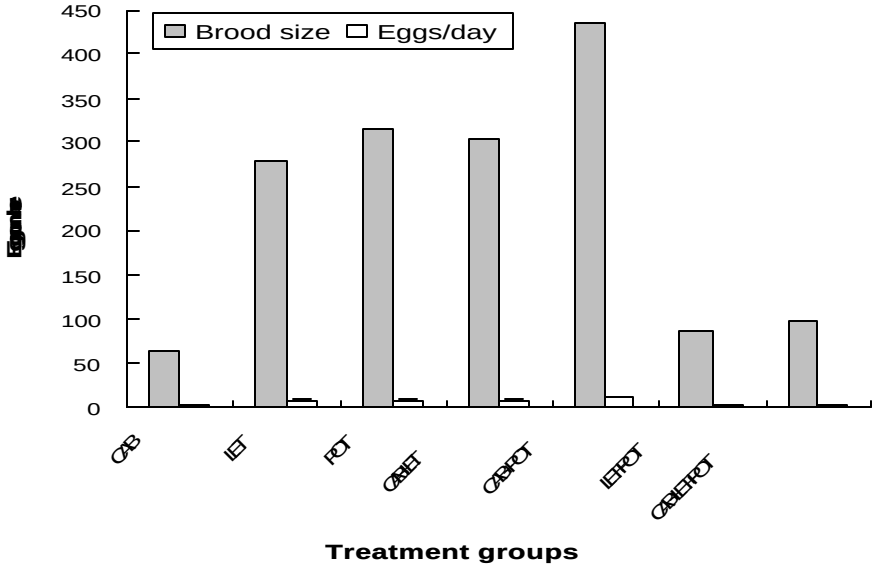

Fig. 2. Effects of differential diets on the brood size (=fecundity) and eggs per day (=daily oviposition) in *D. reticulatum*

Egg weight: On average, POT and CAB+POT produced lighter but CAB+LET+POT produced heavier eggs (Fig. 3). Also, multiple diets resulted in significantly heavier eggs than the eggs from single ($P < 0.033$) or double ($P < 0.034$) diet regimes. So, differential diets had substantial impacts on the egg weight in *D. reticulatum.*

Hatchling weight: Weights of the day-old hatchlings varied across the treatment groups. Hatchlings from the single diet regime were heavier than the double diet regime ($P < 0.0001$), but those between single *vs.* multiple ($P = 0.643$) or double *vs.* multiple ($P = 0.511$) diets did not differ statistically. The heaviest hatchlings were from LET and the lightest ones were from the CAB+LET treatments (Fig. 3).

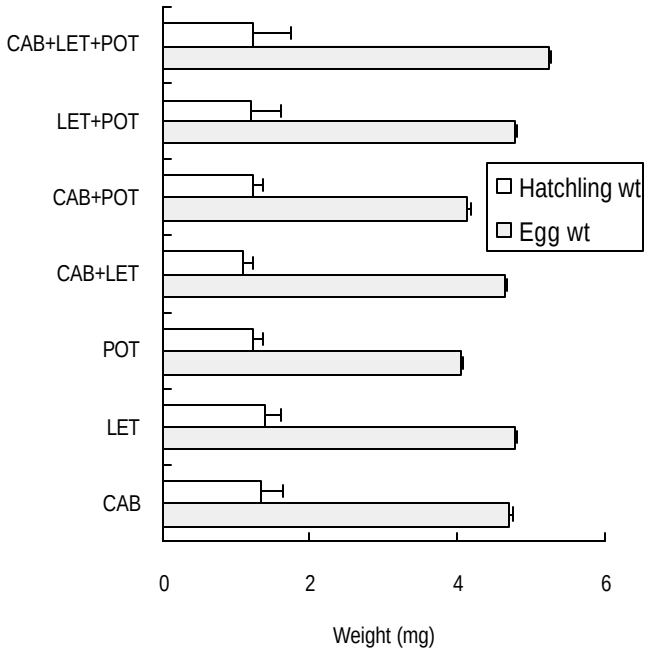

Fig. 3 Effects of diet regimes on the egg weight and hatchling weight in *D. reticulatum*

Despite a minor flaw in the present experimental design that the exact reproductive age of the slugs under study was not known at the time of setting the experiment, inferences drawn from this pilot experiment are of much interest. Diets were found to have significant effects on such reproductive parameters as egg-laying, brood size, developmental time and hatchling weight. Experiments on differential diets revealed that *D. reticulatum* preferred wheat to palatable weed species *i.e.* they ate more wheat than the palatable weeds (Cook *et al.* 1996). This study implied that weeds could potentially act as a readily available source of alternative food for slugs in the field as part of an IPM programme for this pest species. But the degree of protection offered to a wheat crop could depend on the palatability of the weed species present in the field. Similar to the present results, Cook *et al.* (1996) did not find a clear correlation between slug weight and amount of the diet consumed. Clark *et al.* (1997) recorded the feeding activities of *D. reticulatum* on ten materials, where the phagostimulant effect of sucrose and antifeedant effect of the herb terragon (*Artemisia dracunculus*) was confirmed. That *D. reticulatum* preferred multiple food sources more than they preferred having any one food source was demonstrated by Peters *et al.* (2000), where overall consumption increased 270% in multiple foods. The slugs consumed fewer legumes and grasses and more non-leguminous forbs when given a choice. The present results, on the contrary, demonstrate clearly that the productivity of *D. reticulatum* is negatively associated with the food diversity, thus indicating that multiple diets reduce vital reproductive parameters.

Gebauer (2002) assessed survival, feeding activity and weight change in *D. reticulatum* under laboratory conditions and showed that weight change is very variable due to high egg production of some slugs. When offered a choice of three seed types, most slugs preferred to feed on a mixture of seeds, but the highest feeding activity was recorded in the pea seeds. Palatability of 20 plant species as food source for *D. reticulatum* under laboratory conditions in tests with multiple choices and without choice was evaluated by

Kozlowski and Kozlowska (2003), where slugs showed differential preferences towards some plant species as food source. Later on, Kozlowski and Kaluski (2004) showed preferences of *D. reticulatum* for winter oilseed rape to various weed and herb species, while Kozlowski (2005) observed highly significant differences in feeding response of slugs between the common bean plants and the leaf vegetables. These findings lend support to the present results in that *D. reticulatum* preferred single diets like POT and LET or double diets such as CAB+LET or CAB+POT perhaps owing to favourable reproduction in these vegetables.

Recently Brooks *et al.* (2006) investigated the use of red clover as an alternative food source to reduce the amount of damage caused to winter wheat by *D. reticulatum*. Under laboratory conditions, red clover was consumed in greater quantities than wheat, even when wheat was presented as a novel food. Kozlowski *et al*. (2006) noted that the greatest loss by slugs was the common bean plants while leaf vegetables, mustard and onion plants showed the lowest preference. There was no difference between lettuce and dill in the losses of plant mass resulting from slug feeding. These finding are very much similar to the present data in that *D. reticulatum* preferred POT and LET as single diet, or CAB+POT and CAB+LET as double diets to other diet regimes for maximum feeding and egg-laying.

Effects of food diversity on a prey-pest community have recently been assayed by Symondson *et al.* (2006), who demonstrated that the presence of alternative prey of carabid beetles reduces predation on slug populations, thus enhancing the slug survivorship and reproduction in patches where carabids have access to alternative prey. Findings by Nash *et al.* (2007) also point to a similar situation of food diversity affecting slug populations: canola seedling densities showed a negative response to *D. reticulatum* numbers whereas thistles and other vegetation were associated with increased numbers of slugs. In agreement with these results, the present data are suggestive of the food diversity in field situations that *D. reticulatum* would chose to reproduce less vigorously in terms of eggs per day and total fecundity, for example, on multiple diets compared to a single or double diets. These results would help researchers in selecting culture medium for a efficient rearing of experimental slugs in the laboratory. Moreover, the present findings indicate that polyculture of vegetables in the fields might reduce slug damage, especially by reducing the brood size, egg production and hatchling size of the slugs.

Acknowledgements

The author is grateful to Professor John Obrycki, Chair, Department of Entomology, University of Kentucky, USA, for financial assistance, and to the University of Rajshahi, Bangladesh, for granting him leave. Logistic and technical support provided by Dr James Harwood is also thankfully acknowledged.

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