Performance of a generalist predator, *Podisus maculiventris* (say) (Hemiptera:Pentatomidae) fed with adult grain moth *Sitotroga cerealella* (Oliver) Lepidoptera:Pyralidae) at late nymphal and adult stages

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**Abstract.** The predatory heteropteran bug *Podisus maculiventris* is the one of the most effective predators of coleopteran and lepidopteran pests. Here we assessed the effects of switching the prey of *Galleria mellonella*, with two treatments of *Sitotroga cerealella* moths at 1\(^\text{st}\) (2days) and 2\(^\text{nd}\) (4days). There were no significant differences in survival between 1\(^\text{st}\) variant of moths when it introduced to the 4\(^\text{th}\) nymph instar and adult’s stages or 2\(^\text{nd}\) variant for adult pairs compared with control. Generally, the grain moth diet had no negative effect on developmental time for both males and females. Adult’s longevity dropped remarkably at the 2\(^\text{nd}\) treatment, at the same time it was similar to control at both treatments with adults. Fecundity data indicated slight differences in both treatments at adult stages. The egg mass production decreased 3.8 fold in 1\(^\text{st}\) treatment at the 4\(^\text{th}\) nymph stage. No significant differences were observed in egg viability in most treatments except 2days grain moths with 4\(^\text{th}\) nymph instar. Although significant differences were found in total eggs’ numbers within treatments, no significant differences were recorded in adult stage for both treatments as compared to control. We can conclude that using Angoumois grain moth adults as alternative factious prey to feed immature stages and adults of predatory solider bugs need more attention in mass rearing technology.

1. **Introduction**

Podisus spp have a promise results in biological control programs in different countries; Eastern Europe as well as Russia due to its effective performance in controlling lepidopteran and coleopteran pests \[1, 2\].

Recently, rearing up predatory bugs requires a simple and cost-effective method of cultivation in laboratory conditions. This is most often used caterpillars of Lepidoptera \[3\], Rearing predatory bugs requires a simple and cost-effective method for cultivation under laboratory conditions. Lepidopteran larvae are used most often for this purpose. Production technology in insectary requires tri-trophic system which is quite expensive and not always reliable. Efforts to reduce the rearing costs of *P. maculiventris* have included the search for adequate prey species that are easier to culture \[4\]. The effects of natural hosts and artificial diets on development, survival and reproduction of Podisus spp,
have been studied under laboratory. It is concluded that it is necessary to use food of natural origin, as artificial media only can’t sustain mass breeding of Podisus [3].

The larvae of greater wax moth Galleria mellonella L. are enough good prey for polyphagous predatory bugs. Usually mass rearing of greater wax moth is carried out on artificial diet, which includes expensive components such as honey and natural wax [5].

The grain moths' eggs are widely used in Russia as a source of nutrition for beneficial insects, principally Trichogramma spp. Technology of breeding the grain moths tends to discard moths after oviposition, so it offers a cheap source of nutrients supply. The adult grain moths, Sitotroga cerealella O., have already been tested as a main component in artificial media for feeding Podisus spp [6].

The purpose of this study is to estimate the effects of feeding of the late instar bug nymphs or adults with moths of Angoumois grain moth S. cerealella to detect the suitability of factitious prey for the bug rearing under laboratory conditions.

2. Material and method
The study was conducted at the Biological control laboratory of All Russian Institute of Plant Protection (VIZR), Pushkin, Saint Petersburg, Russia.

2.1. Prey & Predator colony
The Angoumois grain moth was propagated at large scale under laboratory conditions according to Richard 1985. The adult moths were collected, dated and separated in a labelled sieve (25 diameters and 10 cm high). Sticky cards (3.5 × 4.5cm) were used to collect adult moth (2 or 4 days’ post emergence) and to feed the predatory bug starting from 4th, nymph instar, 5th nymph instar or adults (while the earlier stages were fed with G. mellonella moths). The greater wax moth fed to the bug throughout its development was used as a control. Plastic cups 500 ml supplied with wet cotton and filter paper were inhabited with 10-11 nymphs (three replications per treatment) and 500 ml plastic containers were used for mating and oviposition of the adult bug (number of examined insect N= 29-32) at sex ratio of 1:1.

Laboratory mass rearing of P. maculiventris was maintained for at least 8 generations at 23 ± 2 °C, 70 ± 5 % RH, and 14L:10 D photoperiod in plastic containers (5 L). The stock culture of the predatory bug was maintained on larvae of G. mellonella.

2.2. Survival & Development
The mortality rates were documented throughout the experimental feeding. The newly moulted nymphs were transferred to a new container to fed adults of grain moth till death. Fresh weight of newly emerged adult males and females was recorded using VIBRA HT120 S balance (Sartorius, Goettingen, Germany).

2.3. Reproduction
The newly weighted adults were paired and transferred to a labelled plastic container volume (10 cm, 5cm, and 4cm) and provided with prey. Main reproductive responses to the diets were evaluated on a daily basis: pre-oviposition period, oviposition rate and longevity of adults on each of the two diets. Egg viability was calculated during the experiment. Egg number per female was estimated until the end of egg laying or death. Females that died within the first week of the experiment were discarded from the experimental design.

2.4. Data analysis
Data were subjected to normality and homogeneity of variance testing with Duncan test and then subjected to the analysis of variance (ANOVA). Nymphs and adults fed with different diet were analysed by means of Student's t-test.

The differences between treatments were considered significant at the level of p>0.05.

For a quantitative comparison of the effects of the nutritional diets on the tested parameters of the predator, the changes with respect to the control were calculated according to the formulas: \( X = (C - \)
Emerged females of 4th Angoumois grain moth were evaluated under laboratory facilities and results shown in tables (1-4).

3.1 Immature duration of development and mortality

Presented data shown in table 1 and 2 revealed that no significant differences in percentage of survival when feeding the adults of bug predator with adults 2 or 4 days’ grain moth compared with control, at the same time, no significant differences in survival of predator nymphs (4th instars) fed grain moth adults (2 days) compared with grater wax moth only. Our results in accordance with the results of introducing moths of Spodoptera exigua for nymphs of two stink bug predators, survival didn’t affect and survival reach to 90-100%, but the authors stated that it is not practical in the field as moths tend to fly when the predator attack it [7]. At the same time the authors also, stated prolongation of developmental time for both predators with the diet of moths.

Under open field ecosystem, Podisus bugs can attack insect of smaller size such as aphids and whiteflies to develop and survive [8, 9] but under laboratory conditions the effects of offering sub-optimal prey to aspoineae bugs are unknown, so we try to understand the capabilities of a general predator to survive and develop when it feeds on substitute hosts for a part of its life cycle.

Table 1. Biological responses (means± SE) of P. maculiventris fed 2-days age of S. cerealella adults at 4th, 5th nymph instar and adult stages.

| Item          | Survival, % | Development, days | Weight of adults, mg | Longevity, days, |   |
|---------------|-------------|-------------------|----------------------|------------------|---|
|               |             | females | males | females | males | females | males |             |   |
| G. mellonella |             |         |       |         |       |         |       |             |   |
| 4th nymph instar | 100 ±3,07 | a 30,5 ± 0,35 | 31,0 ± 0,19 | 76,3 ± 2,86 | e 58,5 ± 1,73 | h1 78,8 ± 4,51 | B 89,8 ± 1,73 |   |
| 5th nymph instar | 100 ±4,00 | a 30,7 ± 0,41 | 31,1 ± 0,36 | 66,3 ± 1,85 | f 49,4 ± 0,92 | k 65,0 ± 2,47 | D 71,9 ± 4,27 |   |
| Adult stage   | 100 ±4,35 | a 30,3 ± 0,55 | 30,6 ± 0,32 | 72,5 ± 4,32 | e 56,5 ± 1,36 | i 65,6 ± 4,62 | C 68,4 ± 5,17 | BCD   |

Means followed by the same letter (within a column) are not significantly different (p>0.05)

The biological aspects refer to that weights of fresh females/ males had no significant differences compared with control in both treatments (p < 0.001). Emerged females of 4th instars nymphs which fed 2 or 4 days’ grain moth weighed 66,3± 1,85, and 62,1± 1,62 mg, respectively. While females' weight (which fed 2 or 4 days’ grain moth adult in5th nymph instars) was 62,1± 2,86 and 54,7± 2,58, respectively (p < 0,01). Predator males' weight which emerged from nymphs 4th or 5th instars didn't reflect any significant differences (p>0.05). The average weight for both females and males reached to the lower level in case of using 4 days’ adults grain moth as a prey for 5th instar of bug predator. The prey selection by the predator could be related to the predator-predy size ratio more than to its nutritional value or quality [10, 11].
The fecundity decreased to 3.8 fold when the 4th days adult grain moth to fed adults’ prey. The predation may be of less importance with control. Adults with grain moth adults compared with control. Differences recorded in case of feeding predatory females. Adults with grain moth adults compared with control. Although the pentatomids readily attacked and fed on pupae and adults of S. exigua, such predation may be of less importance in practice because pupae usually reside in the soil and because moths are expected to escape of attacks by flying away [7]. Feeding the stink bug Podisus sp on different prey lead to enhance the physiological characteristics of digestive system as the predator can depend on enzyme in different host [14].

### Table 2. Biological responses (means± SE) of P. maculiventris fed 4-days age of S. cerealella adults at 4th, 5th nymph instar and adult stages.

| Item                      | Survival, % | Development, days | Weight of adults, mg | Longevity, days. |
|---------------------------|-------------|-------------------|----------------------|-----------------|
|                           | Females-n   | Males-n           | females              | males           |
| G. mellonella             |             |                   |                      |                 |
| 4th nymph instar          | 100±3,07    | 30,5± 0,35        | 31,0± 0,19           | 76,3± 2,86      | 58,5± 1,73      | 78,8± 4,51      | 89,8± 1,73      |
| 5th nymph instar          | 91,7± 5,64  | 31,0± 0,51        | 30,4± 0,28           | 62,1± 1,62      | 50,1± 1,24      | 43,8± 4,50      | 49,0± 3,71      |
| Adult stage               | 102±3,0    | 30,7± 0,52        | 30,7± 0,28           | 77,7± 2,66      | 55,2± 2,45      | 73,9± 2,20      | 74,3± 2,85      |

Means followed by the same letter (within a column) are not significantly different (p>0.05).

### Table 3. Reproductive potential (means± SE) of P. maculiventris fed 2-days age S. cerealella adults at 4th, 5th nymph instar and adult stages.

| Item                      | Fecundity,   | Hatchability, % | Pre-oviposition, Days | Vol. Egg-batches first | Vol. Egg-batches average | No. Egg-batches |
|---------------------------|--------------|-----------------|-----------------------|------------------------|--------------------------|-----------------|
| G. mellonella             | 536±61,7     | 87,3± 3,18      | 6,9± 0,61             | 21,5± 3,42             | 32,1± 0,97               | 16,7± 1,46     |
| 4th nymph instar          | 296±23,7     | 80,0± 2,76      | 11,1± 0,52            | 14,5± 3,00             | 26,3± 1,27               | 11,3± 0,75     |
| 5th nymph instar          | 205±15,7     | 87,4± 3,27      | 10,8± 0,77            | 18,4± 2,71             | 23,5± 1,38               | 8,8± 0,56      |
| Adult stage               | 320±32,5     | 84,0± 2,73      | 11,4± 0,81            | 23,4± 3,09             | 26,0± 1,22               | 12,3± 1,21     |

Means followed by the same letter (within a column) are not significantly different (p>0.05).

3.2 The reproductive potential

On the other hand, females’ fecundity revealed differences in most cases compared with control at (p < 0.001). The results of fecundity indicated slightly differences between 2 or 4 days grain moth adults as a prey for adult of bug predator, while there is no significant difference between fecundity of feeding 4 days adult grain moth to fed adults’ predator bug compared with control. The fecundity decreased to 3.8 fold when the 4th instar of the predator fed with prey 4 days.

No significant differences in egg viability percentages of both grain moth prey 2 and 4 days, but 4th nymph instars which fed 2 or 4 days prey moth badly affected. However, significant differences in pre-oviposition period within most treatments, the first eggs’ count hadn’t been negatively affected. Although, there are significant differences in number of egg batches within treatments, no significant differences recorded in case of feeding predatory females. Adults with grain moth adults compared with control. Although the pentatomids readily attacked and fed on pupae and adults of S. exigua, such predation may be of less importance in practice because pupae usually reside in the soil and because moths are expected to escape of attacks by flying away [7]. Feeding the stink bug Podisus sp on different prey lead to enhance the physiological characteristics of digestive system as the predator can depend on enzyme in different host [14].
Table 4. Reproductive potential (means ± SE) of *P. maculiventris* fed 4-days age *S. cerealella* adults at 4th, 5th nymph instar and adult stages.

| Item               | Fecundity | Hatchability, % | Pre-oviposition, Days | Vol. Egg-batches first | Vol. Egg-batches average | No. Egg-batches |
|--------------------|-----------|-----------------|-----------------------|------------------------|--------------------------|-----------------|
| *G. mellonella* () | 536 ± 61,7 | 87,3 ± 3,18     | 6,9 ± 0,61            | 21,5 ± 3,42            | 32,1 ± 0,97              | 16,7 ± 1,46     |
| 4th instar         | 141 ± 29,2 | 73,9 ± 4,58     | 13,2 ± 1,19           | 20,0 ± 3,66            | 24,7 ± 1,99              | 6,7 ± 0,80      |
| 5th instar         | 258 ± 70,0 | 84,1 ± 3,18     | 8,4 ± 2,48            | 22,0 ± 3,30            | 31,2 ± 1,75              | 8,3 ± 2,25      |
| Adult stage        | 443 ± 22,0 | 87,4 ± 2,57     | 6,4 ± 0,90            | 18,1 ± 2,11            | 31,8 ± 1,43              | 13,9 ± 0,59     |

Means followed by the same letter (within a column) are not significantly different (p>0.05).

4. Conclusion
We can conclude that using Angoumois grain moth adults as alternative factious prey to fed late nymphs and adults of predatory soldier bugs need more attention in mass rearing technology especially, in mixed food system MFS and the emerged adults from such diet could be effective to control insect pest under protected agricultural system or in the open field as well. Future studies to improve the efficacy of such prey can be achieved by the artificial selection.

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