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Studies on the efficacy of various diet formulations on growth and development of Rice Moth, *Corcyra cephalonica* (Stainton), an important host of various parasitoids

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Abstract
Five experimental dietary formulations (D1-D5) were prepared which composed of sorghum, millet and maize as base diet to rear and maintain the rice moth, *Corcyra cephalonica* under laboratory conditions. The base composition was supplemented with groundnut in case of D2; and with vitamin B, H and E in D3, D4 and D5 respectively. The parameters studied in the present work were larval as well as adult male and female weight, total developmental period, percent moth emergence, fecundity, weight of eggs and food efficiency index. The Diet D5 was found to outperform other dietary formulations as it resulted in highest larval weight (60.4 mg), adult male weight (17.2 mg), adult female weight (38.4 mg), fecundity (399.2) and food efficiency index (8.45). Diet D2 was also found to yield better result when other parameters like total developmental period and percentage of moth emergence were taken into consideration. The obtained results provide suitable diets for mass rearing, thus contributing significantly for the large scale production of *C. cephalonica*.

Keywords: *C. cephalonica*, diets, vitamins, growth, food efficiency index.

1. Introduction
Rice moth, *Corcyra cephalonica* is being utilized in various bio-control research, developmental and extension units for mass production of number of natural enemies [8]. For the mass production of rice moth nutritional requirements have to be taken into account because nutritional deficiencies have been linked with such vague symptoms like poor growth rate, lowered fecundity or reduced body weight [3]. It is one of the most factitious hosts for *Trichogramma* production in several countries of the world [16]. *Trichogramma* species are used worldwide in biological control against insect pests [13]. Biological control should be regarded as the backbone of any IPM programme and about 90% of all potential pests are already under biological control [21]. The host rearing diet is potentially important to the nutritional quality of host eggs and the survival of parasitoids released into the environment as biological control agent [6]. There are different diet formulations for rearing *C. cephalonica* in the laboratory, so as to permit the rearing of this host for parasitoid mass production.
Several food materials like rice, sorghum, groundnut, maize, cashew nut, wheat finger and millet etc. have been used for the mass production of *C. cephalonica* [18, 20, 22, 12]. Rearing *C. cephalonica* on efficient food media resulted in production of robust moths and robust eggs. The size of the egg is considered as one of the important criteria for assessing the health of the insect. Rearing of egg parasitoids, such as *Trichogramma* spp., with utilization of robust host eggs is important [17]. Cereal based media supplemented with groundnut enhanced fecundity and other biological parameters compared to the yeast fortified media [19].
Nathen *et al*., [15] reported that rearing *C. cephalonica* on a high quality nutrient source resulted in high quality eggs, which ultimately resulted in high quality production of *Trichogramma* reared on such host eggs. *C. cephalonica* is industrialized for many of the natural enemies, mass bred in the laboratory for use in field against crop pests, which are dependent on either egg or larval stages of *C. cephalonica* because it is easier and cheaper to produce natural enemies on different stages of *C. cephalonica* than on their original hosts. *C. cephalonica* ranks first in the mass culturing of entomophagous insects due to its amenability to mass production, adaptability to varied rearing conditions and its positive influence on the progeny of the natural enemies [11]. Good quality egg parasitoid, *T. chilonis* could be utilized through inundative release for the management of many lepidopterous insect pest [2, 4].
The present study aims to develop an 'improved diet formulation' that could substantially

increase the body weight, survival rate, adult longevity and reproductive potential of *C. cephalonica*. In this direction, various dietary formulations were developed in the present study with a combination of sorghum, millet, maize and groundnut along with different vitamins and the effects of these formulations on the growth, development and reproduction of *C. cephalonica* were also evaluated in laboratory conditions.

2. Materials and Methods

2.1 Culture and Maintenance of *C. cephalonica*

For the present work, the culture of *C. cephalonica* was maintained under laboratory condition on dietary medium composed of coarsely ground sorghum, millet and maize. Streptomycin was used as an antibiotic. The rearing jars were maintained as 26 ± 1 °C and 75 ± 5 % RH. The eggs of *C. cephalonica* were obtained from Forest Research Institute, Dehradun.

2.2 Preparation of Different Diet Formulations

Different diets were developed with a combination of sorghum, millet, maize and groundnut along with different vitamins. The proportions of ingredients of various diets (D1, D2, D3, D4 and D5) are shown in Table 1 300 grams of food containing various dietary formulations was taken in insect rearing jars to which about 200 eggs of *C. cephalonica* were introduced. Over-crowding was avoided for proper growth of insects.

Table 1: Different diets used for rearing *C. cephalonica*

S. No.	DIETS	Composition	Proportion
1.	**D1**	Sorghum, Millet and Maize	In equal proportion
2.	**D2**	D1 + Groundnut	D1 (90%) and Groundnut (10%)
3.	**D3**	D2 + Vitamin B	D2 (99.5%) and Vit. B (0.5%)
4.	**D4**	D2 + Vitamin H	D2 (99.5%) and Vit. H (0.5%)
5.	**D5**	D2 +Vitamin E	D2 (99.5%) and Vit. E (0.5%)

2.3 Insect Growth Parameters

In the present study the following parameters were considered for each treatment: larval weight, adult male weight, adult female weight, egg weight, fecundity, life cycle and percent moth emergence. Weight of last larval instar, adult males and females was recorded by electronic balance. Male and female moths were identified with the help of labial palp and body size. For measuring fecundity ten pairs of newly emerged adults were selected randomly from each diet combination and were placed in egg collecting apparatus which consisted of a plastic box, the base of which was replaced by a fine plastic mesh connected to a beaker for egg collection. From this, eggs were collected and counted daily. The developmental period from eggs to adult of *C. cephalonica* was calculated on the basis of date of charging the rearing jar up to the date of first moth emergence from each treatment [12].

From these observations, food efficiency index was calculated as [17],

$$\text{Food efficiency index} = \frac{\text{Percentage moth emerged} \times \text{Weight of 100 eggs}}{\text{Average development period.}}$$

2.4 Statistical Analysis:

Statistical analysis was performed using MS-excel and SPSS (16.0 version). Data was submitted to analysis of variance (ANOVA) and mean comparison was done by using Duncan multiple range test in the same program.

3. Results and Discussion

3.1 Effects on the larval and adult weight of *C. cephalonica* reared on different diets

The results obtained in present study varied in each diet. Table 2 indicates that larval weight was highest (60.4 mg) in diet D5; and moderate larval weights were recorded in diet D2 and D3, i.e. 58.8 mg and 51.2 mg respectively. In diet D1 lowest larval weight was recorded (44.4 mg). As expected diet D5 produced heavier adult males and females as shown in Table 2 and Fig 1. Lowest weight for both adult male and female was recorded in diet D1 (14.8 mg and 24.6 mg respectively). The results obtained in this study are comparable to other workers. Ingle *et al*., [7] reported maximum weight of *C. cephalonica* larvae reared in bajra + groundnut (61.1 mg), bajra + mustard (58.9 mg) and bajra + cotton (57.1 mg). Medium larval weight was recorded in sorghum + groundnut (55.7 mg), sorghum + mustard (53.7 mg) and sorghum + cotton (51.7 mg) and they also recorded lowest larval weight in maize + groundnut (49.7 mg), maize + mustard (48.9 mg) and maize + cotton (46.2 mg). In the present study different vitamins were added in diets consisting of sorghum, millet, maize and groundnut, and the results were encouragingly efficient and the values obtained were comparatively better than those found by Bernardi *et al*., [1] who reported 17.3 mg and 32.3 mg for males and females of *C. cephalonica* respectively. Relation between Food efficiency index and female weight is shown in Fig 2.

Table 2: Weight of larvae, adult male and female of *C. cephalonica* reared on different diets

Diets	Larval weight (mg)* (Mean±SE)	Adult Male weight (mg)* (Mean±SE)	Adult Female weight (mg)* (Mean±SE)
D1	44.4±0.68^{a}	14.8±0.37^{a}	24.6±0.24^{a}
D2	58.8±0.37^{d}	16.6±0.50^{bc}	37.0±0.45^{cd}
D3	51.2±0.58^{c}	17.0±0.45^{bc}	36.4±0.50^{c}
D4	48.4±0.24^{b}	15.8±0.66^{ab}	30.8±1.15^{b}
D5	60.4±0.51^{e}	17.2±0.86^{c}	38.4±0.67^{d}

*Means followed by the same letter are not significantly different at P <0.05 (Duncan test)

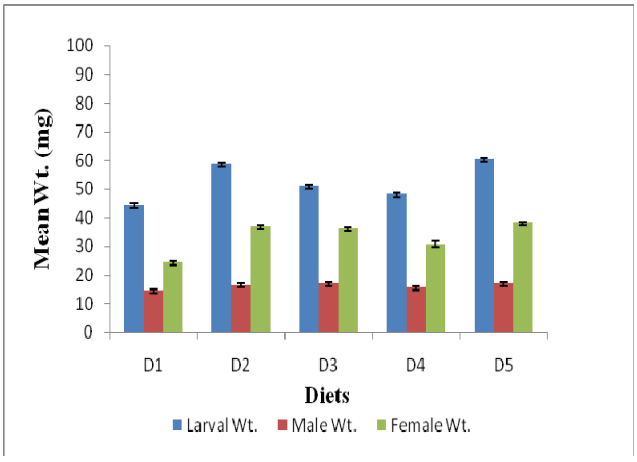

Fig 1: Mean larval, adult male and female weight reared on different diets.

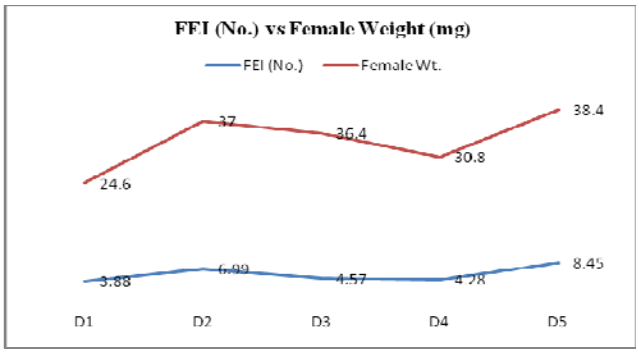

Fig 2: Relation between female weight and FEI.

3.2 Effects on the developmental period (days) and percent moth emergence of *C. cephalonica* reared on different diets

Shortest developmental period is considered as an important factor for mass production of any insect. Results obtained in current study indicated that development of *C. cephalonica* was faster in diet D2 and D5 in comparison to other diets (Table 3). Egg to adult emergence was faster in diet D2 and D5; and both these diets were found to perform better as compared to other diets in other parameters like fecundity, female weight, food efficiency index and egg weight.

Maximum moth emergence i.e. 66.2% was observed in diet D2 followed by diet D5 having moth emergence of 64.6%. Diet D1, D3, and D4 showed lower moth emergence i.e. 50.0%, 50.8% and 50.6% respectively (Table 3). Pathak *et al.*, [17] found maximum of 37.02% moth emergence when reared on sorghum only and Mehendale *et al.*, [14] reported that maximum of 52% moth emergence occurred when reared on sorghum, groundnut and powdered yeast. Kumar and Kumar [10] reported 37.04% moth emergence from sorghum (2 kg) with 4000 *C. cephalonica* eggs and 31.99% in pearl millet. So diet formulation, wherein different vitamin supplements were added, showed better results than most of the previously reported findings.

Table 3: Total developmental period and moth emergence of *C. cephalonica* reared on different diets

Diets	Total developmental period (days)* (Mean±SE)	% Moth emergence* (Mean±SE)
D1	41.2±0.37 ^{c}	50.0±0.32 ^{a}
D2	37.6±0.51 ^{a}	66.2±0.58 ^{c}
D3	40.0±0.45 ^{c}	50.8±0.37 ^{a}
D4	40.2±0.20 ^{c}	50.6±0.24 ^{a}
D5	38.8±0.37 ^{b}	64.6±0.40^{b}

*Means followed by the same letter are not significantly different at P <0.05 (Duncan test)

3.3 Effects on the fecundity and weight of eggs of *C. cephalonica* reared on different diets

Results obtained in present study showed that highest fecundity was recorded in diet D5 (399.2) followed by diet D2 (397.2) and diet D4 (290.8) (Table 4). Kumar [9] recorded the fecundity of 364.4, 160.2, 111.2, 438.2, 438, 384.4 and 329.6 eggs per female in case of *C. cephalonica* reared on gram, sorghum, wheat, mustard, cotton, sesamum and groundnut, respectively indicating higher egg laying in protein rich media than in cereals alone. Haritha *et al.*, [5] recorded average fecundity of 211 eggs per female in case of groundnut. Lowest fecundity in diet D1 might be due to absence of vitamins and the highest fecundity in diet D5 showed the importance of vitamin E in rearing media.

As shown in Table 4, maximum weight of 100 eggs was recorded in diet D5 (4.8 mg) followed by diet D2 (4.2 mg); and lowest weight of eggs was observed in diet D1 (3.2 mg). Relation between female weight and fecundity is shown in Fig 3. Kumar and Kumar [10] studied the effect of rearing media on biological parameters of *C. cephalonica* and recorded maximum weight of 100 eggs in maize (4.57 mg), sorghum + rice husk (4.32 mg), sorghum (4.25 mg), maize + rice husk (4.11 mg) and rice (4.08 mg).

Table 4: Fecundity and weight of eggs of *C. cephalonica*

Diets	Fecundity (no. of eggs per female)* (Mean±SE)	Weight of 100 eggs (mg)* (Mean±SE)
D1	295.6±0.24 ^{b}	3.2±0.48 ^{a}
D2	397.2±0.58 ^{c}	4.2±0.37 ^{ab}
D3	294.8±0.37 ^{b}	3.6±0.40 ^{a}
D4	290.8±0.27 ^{a}	3.4±0.24 ^{a}
D5	399.2±0.66^{d}	4.8±0.37 ^{b}

*Means followed by the same letter are not significantly different at P <0.05 (Duncan test).

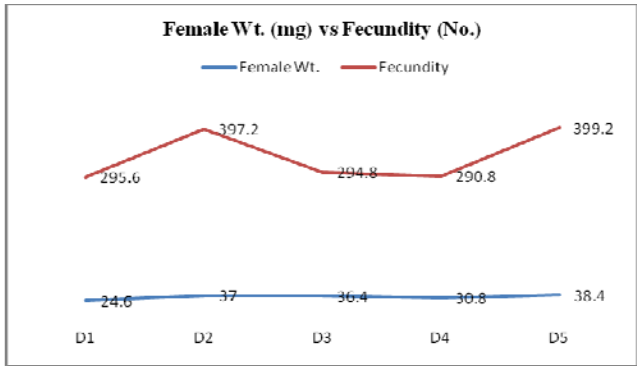

Fig 3: Relation between female weight and fecundity.

3.4 Food efficiency index of different diets

Highest food efficiency index was recorded in case of diet D5 (8.45) which indicated that diet D5 was better as compared to other diets, i.e. D1 (3.88), D2 (6.99), D3 (4.57) and D4 (4.28) (Table 5).

The comparative results of all the above parameters are shown graphically in Fig 4.

Table 5: Food efficiency index of different diets

Diets	Food efficiency index
D1	3.88
D2	6.99
D3	4.57
D4	4.28
D5	8.45

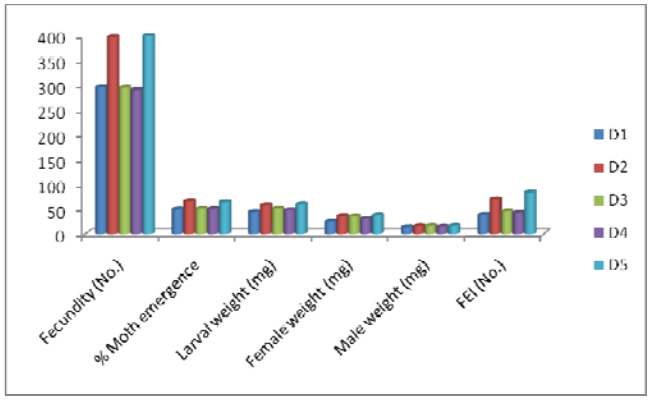

Fig 4: Comparative results obtained in different diets.

4. Conclusion

From the present study it can be concluded that growth and reproductive potential of *C. cephalonica* can be increased by providing optimum nutritional components in the diet. Present study evaluates the efficacies of various diet formulations and has successfully formulated diet combinations that not only resulted in high fecundity but also in production of robust eggs. Therefore the present findings will certainly provide input for finding out the optimum conditions for mass culturing of various parasitoids, of which *C. cephalonica* is a preferred host.

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