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Growth Performance of the Red-Stripe Weevil *Rhynchophorus schach* Oliv. (Insecta: Coleoptera: Curculionidae) on Meridic Diets

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Abstract: Biology and growth performance of Red Stripe Weevil, *Rhynchophorus schach* Oliv. were studied using meridic diets. The diets consisted of sugarcane (*Saccharum officinarum* L.) bagasse, copra (*Cocos nucifera* L.) cake and sago (*Metroxylon sagus* Rottb.) flour as main ingredients. Larvae or locally known as sagoworm, in copra cake diet exhibited the fastest growth with maximum weight gain of 1609 mg in week 5, while those of sugarcane bagasse diet had slowest growth with peak weight gain of 1024 mg in week 9. Sago flour diet gave the longest larval period at 96.3 days with the highest final larval weight of 8132.1 mg. The *R. schach* larvae had 8 instars. Head capsule width within each instar was constant irrespective of diets given. Instar period was dependent on diets given and varied from 6.3-12 days. Pupal duration ranged from 38.5-41 days. Adult emergence was 90%. Sago flour diet had the heaviest pupae and adults. Male weevils emerged earlier than the females, but females lived 10-13 days longer. Fecundity was low at 67 eggs per female but the hatchability was 92%. Life cycle for the insect ranged from 130.2-138.8 days, with a lifespan of 178.2-183.8 days. Larvae raised on sago flour diet had the highest fat content at 57.8% but with the lowest fiber at 4.7%. Larvae were generally rich in Mg, Ca, Zn and Fe, but low in Cu. This study showed that sago flour constituted the most suitable diet. The results also suggested that growth and development of the weevil could be further improved by incorporating copra cake and sugarcane bagasse into the sago flour diet. Larvae could be readily mass produced as a source of nutritious food, besides its potential use as a laboratory test organism.

Key words: Red stripe weevil, sagoworm, *Rhynchophorus schach*, curculionidae, life cycle

INTRODUCTION

The palm weevils, *Rhynchophorus* species are members of the family Curculionidae which is the largest family of insects. It is a potentially lethal pest of agriculture crops. *Rhynchophorus ferrugineus* (Ol.) in southeastern Asia and Melanesia, *R. schach* Oliv. in Malaysia, *R. phoenicis* (F.) in Africa and *R. palmarum* (L.) in the western tropics were the most important species as pests[1]. The *Rhynchophorus* spp. normally attacked the coconut (*Cocos nucifera* L.), oil palm (*Elaeis guineensis* Jacq.), sago (*Metroxylon sagus* Rottb.), sugarcane (*Saccharum officinarum* L.) and pineapple (*Ananas comosus* Merr.)[2,3]. The red stripes palm weevil, *R. schach* Oliv. is a serious pest of sago and coconut[4,5].

Rhynchophorus weevils lay their eggs, which are oblong in shape and 2-3 mm long, on cut or damaged surfaces of palms. The eggs hatch in three days and the larvae tunnel into the crown and trunk. The tissues around the growing point then begin to decay and the palm may be killed. The external symptoms of attack include leaves which show a gradually increasing chlorosis and fracture in strong winds[6].

The larvae or the grub of *R. schach* is often referred to as sagoworm. Sagoworm is not only a pest; it is also considered a delicacy and consumed by some ethnic communities in Malaysia such as the Melanau and Dayak and in Africa and Asia for their source of protein. On dry matter basis, the worm contains 63.7 fat, 14.3 protein and 22.0% water and others[7]. There was a marked lack of information on the biology of *R. schach*. Published information was mostly related to the *Rhynchophorus* spp. as a pest or food but information on their biology were incomplete. There was no information on the number of instars and larval growth

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performance as it was difficult to assess the life cycle of this insect in the wild. Hence, this study was conducted to study the biology notably the growth performance of *R. schach* in the laboratory by using meridic diets.

MATERIALS AND METHODS

Source of insects: Larvae of *R. schach* were obtained from infested wild sago logs along the Kemena River of Bintulu, Sarawak and cultured initially on sugarcane in the laboratory. After being transferred to 2-node fresh sugarcane, the larvae gnawed and bored into the cane. Fine fibers were extruded from the hole but when pupation was near, coarse fibers were produced to be plaited into a cocoon. The pupae in the cocoon were incubated in the dark at 26±2°C. Upon emergence, the adults were fed with fresh sugar cane and later allowed to mate.

After mating the males and females were reared separately in glass jars with perforated covers, containing moistened tissue paper and a piece of split sugarcane. The female laid eggs to a depth of 2-4 mm below the surface, at an oblique angle into small holes previously made by the snout during feeding. The sugarcanes were replaced at 3 day intervals. The used sugarcanes from the females were carefully dissected and the eggs removed by fine camel hair brush for further study.

Eggs preparation: The collected eggs were surface sterilized with 0.05% sodium hypochlorite before use. After this, the eggs were transferred to 90 mm Petri dishes lined with moistened filter paper, sealed with parafilm and incubated at 26±2°C until the neonate emerged.

Meridic diet: Three formulations of the meridic diets were used to feed the larvae. Diet ingredients were determined from preliminary trials. The main ingredients included sugarcane bagasse, copra cake and sago flour, in addition to other basic ingredients (Table 1).

Table 1: Formulation of meridic diet for *R. schach* larvae

Diet ingredients	Quantity
Agar	20 g
Sugarcane bagasse (ovendried and ground)*	60 g
Yeast	20 g
Sodium benzoate	3 mL
Vitamins	2 g
Potassium sorbate	2 g
Distilled water	900 mL
Tetracycline hydrochloride (for neonate only)	0.8 g

*: Sugarcane bagasse would be replaced by either copra cake or sago flour while the other ingredients remained unchanged

Diet preparation: The sugar cane bagasse, copra cake, or sago flour were autoclaved before use. The agar was dissolved in hot water and similarly autoclaved. The main ingredient was mixed with the agar in a blender which was previously washed with boiling water and surface sterilized with 0.5% sodium hypochlorite. The mixture was blended at high speed for 2-3 min and left to cool till 50°C before the other ingredients were added and further blended. The ready diet was poured into surface sterilized 200 mL plastic food containers to a depth of about 1 cm (about 50 mL) and left to cool. About 250 mL of diet each would be required for larger larvae in 600 mL containers.

Growth of insect: Initially, 5-6 neonates were reared in each container. After about 7 days, the larvae were reared separately in individual containers. The diet was changed every 7 days. The larvae were weighed weekly. At 45 days, sterile dried coconut fibers cut to 2 cm lengths were put inside the plastic containers for construction of cocoon by the larva. One week after pupation the cocoons were taken out, put inside a clean trough and incubated in the dark at 26±2°C. Upon emergence the adult weevils were fed split fresh sugarcane as described previously. Sexes were easily differentiated by the presence of a turf of bristle on the dorsal portion near the end of the rostrum for the adult male and without the bristle for the female. The adults were allowed to mate once after which the males and females were reared separately. Eggs were harvested from the used sugarcanes of the female weevil.

Growth biology: Parameters measured were weekly weights and growth rates of larvae, larval and instars period, pupal weights, pupation period, adult emergence, sex ratio, adult weights and duration, fecundity, hatchability, life span, width of head capsules of larvae from each instar and nutrient content of larvae. Pupae were weighed individually one week after pupation. Adults were weighed within one day of eclosion.

Nutrient analysis of *R. schach* larvae: The *R. schach* larvae at 40 days old from each diet were taken for analysis of nutrients and minerals. Four larvae were taken per diet and oven dried at 105°C for 2 days. The dried larvae were cooled in desiccators before being ground into a fine powder for analysis.

Total fat analysis: The Soxtec Systems were used for total fat analysis. Fat was extracted from 2 g samples of larvae by using petroleum ether. The extracted samples were oven dried and the percent fat calculated.

Fibre analysis: Larval samples of 1 g each were extracted using the Fibertec Hot Extraction Unit. The extracted samples were put into muffle furnace at 550°C for 4 h and later cooled inside a desiccator. The ash weight was obtained for calculation of the percent fiber.

Mineral analysis: Digestion was done before the mineral analysis. A 0.2 g sample was placed in the digestion tubes and 3 mL of 69 HNO_3 and 1 mL of 97% H_2SO_4 were added. The mixture was left overnight at room temperature before being heated in a heating block initially at 70-80°C for approximately 1 h followed by 140°C for 3 h.

The color of the completely digested sample changed from dark brown to yellowish. One mililiter of digested sample was diluted with 4 mL distilled deionized water and analyzed by using Atomic Absorption Spectrophotometer for zinc, calcium, iron, copper and magnesium.

Statistical analysis: Experiments were conducted in laboratory using a Completely Randomized Design with five replications. Data were analyzed by using Statistical Analysis System (SAS Institute, Cary, NC). Treatment means were separated by the Student Newman-Keuls' test (SNKT) at $p = 0.05$.

RESULTS

Growth of larvae on different diets: The eggs which were whitish-yellow, ovo-cylindrical in shape and measured 2.4 mm long and 0.9 mm wide, hatched in 4 days. Neonates were creamy white in color, apodal, active and bore into the diet within a few hours after hatching. The larvae fed voraciously in the dark. They became restless and fed less in a brightly lit area.

The mean weekly larval growth rates for *R. schach* are presented in Fig. 1. Among the 3 diets larvae fed copra cake diet had the fastest growth rate, achieving maximum weight gain at 1609 mg in week 5 and thereafter, declined sharply to 282 mg in week 7 before going into the prepupa stage.

In the sago flour diet, the larval growth rate peaked at 1209 mg in week 7 after which the rate decreased gradually to 483 mg in week 14 prior to pupation. Growth of larvae fed sugarcane bagasse was slowest among the 3 diets, with the highest weight gain of 1024 mg in week 9 and declined to 409 mg in week 12.

However, the larvae of copra cake diet did not pupate successfully even though they had the fastest weight gain. Larvae of sugarcane bagasse and sago flour diets successfully pupated. Similar trends were exhibited by the weekly cumulative weights of the larvae (Table 2).

From week 1 until week 7, the larvae fed on copra cake diet showed significantly higher cumulative weight as compared to sugarcane bagasse and sago flour diets. In week 8, larvae of copra cake diet began to pupate, while larvae of the other 2 diets were still growing.

The weight of the final instar larvae of sago flour diet was 8132.0 mg which was almost twice that of the final instar larvae of sugarcane bagasse at 4340.5 mg and higher than that of the copra cake diet at 5382.8 mg.

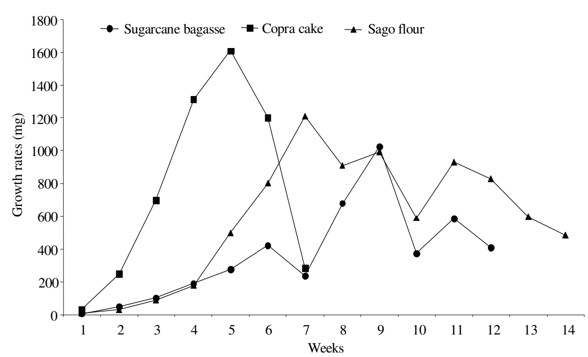

Fig. 1: Mean weekly growth rates of *R. schach* larvae fed different diets

Table 2: Mean weekly weights of *R. schach* larvae grown on different diets

Diet	Mean weekly larval weight (mg)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sugarcane bagasse	2.5^{a}	6.6^{b}	52.7^{b}	154.5^{b}	344.1^{b}	616.9^{b}	1038.0^{b}	1272.0^{b}	1949.5^{a}	2974.0^{a}	2556.2^{a}	3360.9^{a}	4340.5^{a}	-	-
Copra cake	2.6^{a}	31.2^{a}	279.9^{a}	978.0^{a}	2290.6^{a}	3900.3^{a}	5101.0^{a}	5382.8^{a}	-	-	-	-	-	-	-
Sago flour	2.3^{a}	7.9^{b}	38.3^{b}	124.2^{b}	300.4^{b}	796.7^{b}	1599.0^{b}	2807.8^{b}	3716.8^{a}	4709.5^{a}	5298.5^{b}	6226.7^{b}	7154.9^{b}	7644.0	8132.0

Week 0-7: Means within columns with same superscripts are not significantly different at $p = 0.05$ (Student Newman-Keuls' test)
Week 8-12: Means within columns with same superscripts are not significantly different at $p = 0.05$ (t-test)

Larval period: Mean of *R. schach* larval period for different diets are shown in Table 3. The copra cake diet larval period was significantly shorter than those of sugarcane bagasse diet and sago flour diet, taking only 43.8 days to complete the larval stage. The larval periods of sugar cane bagasse diet and sago flour diet were not significantly different at 85.2 days and 96.3 days, respectively.

Instar period: The mean larval instar periods of *R. schach* treated with different diets are given in Table 4. Eight instars each were recorded for larvae fed sago flour diet and sugarcane bagasse diet, while those given copra cake diet had 7 instars.

Among the diets, larvae fed sugarcane bagasse diet had the longest instar period, spending 11.25-12 days in each instar beginning from the 2nd instar. Instar period of sago diet were rather inconsistent ranging from 8.5-11.75 days, when compared to those of sugarcane bagasse and copra cake.

Width of larval head capsule: The width of head capsule of different larval instars of *R. schach* are indicated in Table 5. There was no significant difference in head capsule width within the same instar among the 3 diets, except in the 8th instar where the capsule of sago flour diet larvae was significantly wider than that of the sugarcane bagasse diet.

Pupa and adult: Pupae and adults of the sago flour diet were significantly heavier than those of the sugarcane bagasse diet (Table 6). However, in both diets there was no significant difference between the weights of the adult male and female although the female generally appeared to be more robust.

There was no significant difference in terms of pupation period and adult longevity and eclosion between the two diets. Adult emergence was more than 90%. The sex ratio was 1 male to 2.3 females. However, in both cases, male eclosion occurred earlier than the female. Females were observed to live 10-13 days longer than the males. The mean fecundity was 67 eggs per female with a mean hatchability of 92%.

Table 3: Mean of *R. schach* larval period on different diets

	Duration (days)	
Diet	Larval period	Range of duration
Sugarcane bagasse	85.2[a]	83-88
Copra cake	43.8[b]	37-54
Sago flour	96.3[a]	90-104

Mean values followed by similar superscript letter (s) in the same column are not significantly different at p = 0.05 (Student Newman-Keuls' test)

Table 4: Instar periods of *R. schach* reared on different diets

	Mean of instar period (days)							
Diet	1st	2nd	3rd	4th	5th	6th	7th	8th
Sugarcane bagasse	3.7[a]	11.5[a]	11.5[a]	11.8[a]	11.5[a]	11.3[a]	12.0[a]	12.0[a]
Copra cake	3.2[a]	6.3[c]	6.7[b]	6.5[b]	6.8[c]	7.0[b]	7.2[b]	-
Sago flour	5.8[a]	9.3[b]	8.5[b]	8.5[b]	9.5[b]	10.2[a]	11.7[a]	10.3[a]

Instar 1st-7th: Means within columns with same superscripts are not significantly different at p = 0.05 (Student Newman-Keuls' test)
Instar 8th: No significant different at p = 0.05 (t-test)

Table 5: Mean width of head capsule of different instars of *R. schach* larvae

	Mean width of head capsule of different instars (mm)							
Diet	1st	2nd	3rd	4th	5th	6th	7th	8th
Sugarcane bagasse	1.05[a]	1.61[a]	1.81[a]	2.35[a]	3.08[a]	3.67[a]	4.53[a]	5.06[a]
Copra cake	0.69[a]	1.80[a]	2.30[a]	3.01[a]	3.88[a]	4.01[a]	5.60[a]	-
Sago flour	0.75[a]	1.32[a]	1.99[a]	2.70[a]	3.13[a]	4.03[a]	4.78[a]	6.39[b]

Instar 1st-7th: Means within columns with same superscripts are not significantly different at p = 0.05 (Student Newman-Keuls' test)
Instar 8th: Significantly different at p = 0.05 (t-test)

Table 6: Mean weights and durations of *R. schach* pupae and adults

	Weight (mg)			Duration (days)		
Diet	Pupa	Adult male	Adult female	Pupa	Adult male	Adult female
Sugarcane bagasse	1589.1[a]	1150.8[a]	1281.0[a]	41.0[a]	38.0[a]	48.0[a]
Sago flour	2977.2[b]	2156.1[b]	2400.1[b]	38.5[a]	32.0[a]	45.0[a]

Mean values followed by similar superscript letter (s) in the same column are not significantly different at p = 0.05 (t-test)

Lifespan: There was no significant difference in the total developmental period from egg to pupa on both sugarcane bagasse and sago flour (Table 7). Similar trends were observed in the total lifespan of the insect in both diets. However, the female weevils had longer lifespan than the male.

Nutrient analysis: The composition of fiber, fat and 5 minerals for *R. schach* larvae among the sugarcane bagasse, copra cake and sago diets are shown in Table 8. Larvae on sago diet had the lowest fiber content compared to those of sugarcane bagasse and copra cake which were more than 7 times higher than the former. However in terms of fat content, larvae fed sago diet had the highest content of fat (57.8%), followed by copra cake (42.6%) and sugarcane bagasse (30.5%).

Among the mineral composition analyzed, larvae of sugarcane bagasse diet had significantly higher contents of Zn (188.83 µg g^{-1}) and Fe (118.80 µg g^{-1}) than larvae of other diets. Larvae of both copra cake and sago diets had significantly higher Cu than that of sugarcane bagasse diet. There were no significant differences in the contents for Ca and Mg among larvae of all 3 diets.

DISCUSSION

Growth of larvae: Growth and development of *R. schach* larvae were affected by different diets. Among the three diets, the best growth rate was from copra cake diet. This was probably because copra cake was a valuable protein and carbohydrate source which helps to improve the larval growth rate[8]. Unfortunately, larvae of copra cake diet failed to pupate. The reason could be the lack of ecdysone produced by the prothoracic glands or corresponding tissues and by the ovaries of female insects. This hormone initiates the molting process and thereby indirectly regulates growth and morphogenesis[9].

The sterols which must come from the diet for molting purpose could be lacking in copra cake diet[10]. However, the mixing of copra cake and sugarcane was successful as a main ingredient for culture of *R. cruentatus*[11]. The larvae of sugarcane bagasse diet gave the slowest growth rate and smallest larvae although they pupated successfully. This showed that sugarcane bagasse had the dietary requirements for growth and development of the insect, but the quantities were probably below optimum leading to smaller larvae. The sago flour which was extracted from the insect's natural host produced the largest healthy larvae which were almost twice the size of those reared in sugarcane bagasse diet and pupated well.

Larval period: The short larval period of copra cake diet was probably attributed to the different nutritional value of copra cake when compared to that of sugar cane and sago flour. Similar findings were obtained from the oligidic diets for culture of *R. cruentatus*[12]. In the sugarcane bagasse and sago flour diets the high sugar or carbohydrate contents probably prolonged the larval period resulting in the significantly long larval period.

Instar period: The larvae from copra cake and sago flour diets developed in 8 instars and produced normal pupae but the larvae fed copra cake diet only molted 7 times. Since the total number of instars is genetically determined and constant regardless of environmental conditions[10], the larval stages of copra cake diet were incomplete. The deficiency of sterol in the copra cake could have caused the rapid molting duration of larvae when compared to that of sugarcane bagasse and sago flour diets.

Width of larval head capsule: Within the instar stages and across the diets, the head capsule widths were constant even though the diets differed. This gave strong indication that the head capsule size of each larval instar was genetically controlled and not influenced by environmental conditions such

Table 7: Lifespan of *R. schach* on different diets

Diet	Developmental period (days)	Lifespan (days) Male	Lifespan (days) Female
Sugarcane bagasse	130.2[a]	168.2[a]	178.2[a]
Sago flour	138.8[a]	170.8[a]	183.8[a]

Mean values followed by similar superscript letter (s) in the same column are not significantly different at p = 0.05 (t-test)

Table 8: Nutrient analyses of *R. schach* larvae on different diets

Diet	Fiber (%)	Fat (%)	Mineral Composition (µg g^{-1}) Ca	Mg	Fe	Cu	Zn
Sugarcane bagasse	35.21[a]	30.52[c]	169.63[a]	501.03[a]	118.8[a]	1.38[b]	188.83[a]
Copra cake	35.30[a]	42.65[b]	190.45[a]	554.80[a]	90.83[b]	6.65[a]	122.50[b]
Sago	4.69[b]	57.77[a]	183.68[a]	485.23[a]	72.28[b]	5.20[a]	96.73[b]

Mean values followed by similar superscript letter (s) in the same column are not significantly different at p = 0.05 (Student Newman-Keuls' test) as different diets. It is thus possible to determine the instar stage of larvae from the wild by measuring the width of head capsule.

Pupa and adult: Among the 3 diets, normal pupation occurred in the sugarcane bagasse and sago flour while larvae of copra cake diet failed to pupate. Both sugarcane bagasse and sago flour were similar in terms of pupation period, adult emergence and adult longevity, although the latter produced larger pupae and correspondingly larger adults. However, in both treatments the fecundity was low when compared to that of weevils caught from the wild (123 eggs per female) although the hatchability was good. The reason was that wild weevils were generally larger (male at 2439 mg and female at 2715 mg) than those raised from meridic diets. Fecundity is influenced by the size of females in many groups of insects where females which were 50% larger than the smallest female, could potentially lay about five times more eggs[13]. The sex ratio was skewed towards the female and this could be attributed to the presence of young female individuals which sometimes lay unfertilized eggs and produce exclusively female progeny[9].

Larval nutritional potential: The larvae of *R. schach* is consumed as a delicacy and is used as a food supplement by certain group of people. These larvae were exclusively collected from infested trunks of wild sagopalm. The nutrient requirement of the wild larvae would be derived solely from sago starch in the trunk. In laboratory culture, larvae grown on sugarcane bagasse and copra cake diets had more than 7 times fiber content than those grown on sago. This indicated that fiber content of the larvae could be increased if larvae were fed certain proposition of either copra cake or sugarcane bagasse in addition to sago. The fat content of the larvae was generally high, with the highest content in the sago diet. On a dry matter basis, the fat content of the larvae was higher than the amount in most conventional foods like beef, chicken, eggs, herring, mackerel and milk[14]. The sagoworm was thus a good source of high energy fat. In insects, fat was important for growth, metamorphosis and reproduction in response to nutritional and hormonal signals[10].

Insects are known to be rich sources of various macro and trace elements. These elements are probably accumulated for future use in adult exoskeletal and connective tissue synthesis. Sugarcane bagasse diet had significantly higher concentration of zinc and iron than that of sago and copra cake diets. In human nutritional needs, iron was required for haemoglobin synthesis and zinc for nucleic acid and protein synthesis, cellular differentiation and replication and glucose use and insulin secretion[15]. Zinc deficiency has been known to cause poor growth and impairment of sexual development[16].

The contents of magnesium and calcium were not significantly different among the diets. However, the magnesium composition was the highest (485.23-554.8 $\mu g\ g^{-1}$) among the minerals tested for all the diets. The magnesium is required in a wide variety of fundamental cellular activities that support diverse physiological systems. However, the copper content of larvae fed meridic diets were low with the lowest being with sugarcane bagasse diet. In dietary requirements, copper is an essential element in the utilization of iron and activity of several enzymes[15].

CONCLUSION

The larvae of *Rhynchophorus schach* were successfully cultured by using the meridic or semi-artificial diets. Among the 3 diets with sugarcane bagasse, copra cake and sago flour as main ingredients, larvae in copra cake diet had the fastest growth with maximum weight gain of 1609 mg in week 5, while larvae reared on sugarcane bagasse diet had the slowest growth with peak weight gain of 1024 mg in week 9. The larvae fed with sago flour diet had the longest larval period at 96.3 days but they had the highest final larval weight of 8132.1 mg when compared to the other 2 diets. Larvae from copra diet did not pupate while those of sugarcane bagasse and sago flour pupated successfully.

The *R. schach* larva had 8 instars and the head capsule width within each instar was constant irrespective of the diet given. This was the first report confirming the number of instars and the respective larval head capsule widths in *R. schach*. It is thus possible to determine the larval stages of this insect collected from the wild. The instar period was dependent on the diet given, with durations that varied from 6.3-12 days. Larvae in sugarcane bagasse diet had the longest instar period of 11.3-12 days.

There was very little variation in the pupation period among the diets. The pupal duration ranged from 38.5-41 days. Adult emergence was good at more than 90%, indicating that the sugarcane bagasse and sago flour diets were suitable for growth and development of the insect. However, the pupae and adults of sago flour diet were almost twice as heavy as those of the sugarcane bagasse diet. In all cases, the males emerged earlier than the females, but the females lived 10-13 days longer.

The fecundity was a little low at 67 eggs per female but the hatchability was 92%. Both sugarcane bagasse diet and sago flour diet exhibited similar total developmental times for the insect at 130.2-138.8 days. Similar trends were also observed for total lifespan of the insect. Larvae raised on sago flour diet had the highest fat content among the three diets but had the lowest percent fiber.

Fiber content in the diet was not critical to normal development of the insect, since the insect was able to complete its life cycle on sago flour diet. The larvae reared on meridic diets had good mineral nutrients. Sugarcane bagasse diet had the highest content of Zn (188.83 $\mu g\ g^{-1}$) and Fe (118.8 $\mu g\ g^{-1}$) among the three diets. All larvae had good content of Mg and Ca, but were generally low in Cu.

The study showed that the most suitable diet was the sago flour diet. The results also suggested that the growth and development of the weevil can be further improved and enhanced by incorporating certain proportion of copra cake and sugarcane bagasse into the sago flour diet. Consequently, the developmental times could also be reduced. This raised the possibility that the larvae could be readily mass produced as a source of nutritious food, besides its potential use as a laboratory test organism.

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