Artículos

Biological parameters of the cotton bollworm *Helicoverpa armigera* (Lepidoptera: Noctuidae) reared on different artificial diets and their nutrients prominence

Parámetros biológicos del gusano cogollero del algodón *Helicoverpa armigera* (Lepidoptera: Noctuidae) criado con diferentes dietas artificiales y la importancia de sus nutrientes

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Abstract: The cottonbollworm *Helicoverpa armigera* Hubner, is one of the most cosmopolitan key insect pests and its rearing is vital for integrated pest management. The goal of this research is to assess three diverse artificial diets for *H. armigera* rearing using common bean seed flour, chickpea seed flour or cotton seed flour, as basic constituent, along with other ingredients in similar proportions. Cotton flour-based artificial diet offered higher viability in egg, larva, prepupa, pupa and adult stages, and less developmental time (38.25 days) than chickpea flour-based (43.60 days) and bean flour-based (48.00 days) diets. Neonates reared on the cottonseed flour-based diet obtained excellent nutrition because cotton seeds have high contents of protein, oil, fibre and starch along with other minor compounds, compared to chickpea and bean seed-derived flours. The net reproductive rate, intrinsic rate of increase and finite rate of increase on the cotton-based diet were also superior for successive generations. It is concluded that although *H. armigera* larvae developed faster on cotton flour-based diet, results obtained on chickpea and bean flour-based diets tested can also be considered reasonably adequate for short and long periods of mass rearing.
Keywords: Growth Indices, Life Table, Mass Rearing, Parameter Optimization, Reproductive Parameters, Standardization.
Resumen: El gusano del algodonero, *Helicoverpa armigera* Hubner, es una de las plagas de insectos clave más cosmopolitas y su cría es vital para el manejo integrado de plagas. El objetivo de esta investigación es evaluar tres dietas artificiales diversas para la cría de *H. armigera* utilizando harina de poroto, harina de garbanzo y harina de algodón, como constituyente básico, junto con otros ingredientes en

proporciones similares. La dieta artificial a base de harina de algodón ofreció mayor viabilidad en los estados de huevo, larva, prepupa, pupa y adulto, y menor tiempo de desarrollo (38,25 días) que las dietas a base de harina de garbanzo (43,60 días) y harina de poroto (48,00 días). Los neonatos criados con una dieta a base de algodón obtuvieron una excelente nutrición debido a que la harina derivada de la semilla de algodón presenta altos contenidos de proteína, aceite, fibra y almidón junto con otros compuestos menores, en comparación con las harinas derivadas de los granos de garbanzo y poroto. La tasa neta de reproducción, la tasa intrínseca de crecimiento y la tasa finita de crecimiento en la dieta a base de algodón también fueron superiores en las siguientes generaciones. Se concluye que, aunque las larvas de *H. armigera* presentaron mejor desarrollo en la dieta a base de harina de algodón, los resultados obtenidos con las dietas a base de harina de garbanzo y de poroto también pueden considerarse razonablemente adecuados para proponer el uso de estos ingredientes para períodos cortos y largos de cría en masa.
Palabras clave: Cría masiva, Estandarización, Índices de crecimiento, Optimización de parámetros, Parámetros reproductivos, Tabla de vida.

INTRODUCTION

The cottonbollworm *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae), also known as the African or American bollworm, corn earworm, gram pod borer, tobacco budworm, tomato worm, tomato grub or scarce bordered straw worm, is a highly polyphagous, damaging, prevalent and dreaded insect pest species. Its larvae feed on approximately 217 plant species comprised in 50 families, including Leguminosae, Malvaceae, Asteraceae, Fabaceae, Poaceae and Solanaceae (Nibouche et al., 1998; Dourado et al., 2021; Yadav et al., 2022; Sarwar, 2023). In Pakistan, the states of Punjab and Sindh are described to have significant damage by *H. armigera,* with estimations differing from crop to crop and year to year (Sarwar et al.,2011), and losses in infested crops can reach 30-40 % (Riaz et al., 2021).

Larvae of *H. armigera* feed on nitrogen-rich harvestable fruiting portions of valued crops such as cotton, tobacco, tomato, potato, maize, flax, rice, soybean, sorghum, lucerne, bean, chickpea, cowpea, pigeon pea, groundnut, okra, pea, soybean, numerous fruits and forest trees, ornamental plants and flowers, as well as a wide array of vegetables and wild plant species. Its caterpillars prefer to forage on reproductive portions of hosts (fruits and flowers); however, they can forage on foliage as well. Foraging injury produces holes in the plant, which allows the development of secondary pathogens such as fungi and bacteria. Such secondary contaminations through bacteria and fungi are common and can result in decaying of reproductive parts. Damage to budding tips of plants can disrupt their growth and fruits can drop (Joneset al., 2019).

Cotton and corn are categorized as the most appropriate hosts for growth and reproduction of the cotton bollworm; with pigeon pea also known to be among the most appropriate. Other crops such as sunflower and tobacco are also considered favored hosts; while soybean and alfalfa are regarded as intermediate hosts; and linseed, pigweed and cabbage are the minimum preferred (Hou & Sheng, 2000; Trujillo et al., 2024). In cotton, the attacked blooms may open prematurely and remain unproductive. After the bolls are injured, some of these drops on the soil, while others produce lint of a poorer quality or fail to produce lint, in addition, leaves and young branches may also be used by larvae (Sarwar, 2017). In chickpea, the plant is attacked from the seedling stage until maturity, larvae of 1st, 2nd and 3rd instars feed on foliage (young leaves), prefer flowers and flower buds, while bigger larvae bore into pods and eat emerging seeds (Sarwar et al., 2009). In the case of bean, analysis of canopy pod profiles indicated that loss of pods occurs from the top of the plant downwards, pod-set stage is more sensitive to leaf loss and larvae may completely consume small pods. Relatively, larvae eat out the developing seeds, leaving the empty pod on the plant (Rogers & Brier, 2010).

Due to high reproductive capacity, and high potential for survival and dispersion even in hostile environments, *H. armigera* can complete several generations in each year. Under these circumstances, its impact on crop production strengths the need to implement control measures. The increase demand to reduce insecticide use and the numerous cases of insecticide resistance found in populations of *H. armigera* worldwide, require the implementation of other control measures (Sarwar, 2020).

Culturing of insects in research laboratories, is vital to conduct studies aimed at developing eco-friendly comprehensive strategies including the Sterile Insect Technique (SIT) under Integrated Pest Management (IPM) practices. The use of artificial diets to culture insects, provides information regarding the nutrition ecology, performance and nutritional needs of insects. In diet preparation, there are certain aspects that require attention such as the nutritional value of the ingredients, its sensory potentials, its stability and its availability. On account of misunderstanding and preconception in contrast to nutritional investigations, scientists ignore most of the crucial matters that would explain in what way certain diets and diet ingredients function or fail to function to produce high quality insects (Cohen, 2001). Experiments evaluating the proportions and amounts of nutrients in larval diets are scarce for certain species and if available, always require certain update based on the availability of local and new ingredients. Different nutrient sources may significantly influence insects biology through preventing or facilitating their growth, or else through impacting the adult stage and consequently reproductive capability (Beukeboom, 2017). Research and development of artificial diets for insects rearing is needed, and relevant in many fundamental and applied fields such as in insect pests control. For *H. armigera* a sustainable supply of individuals is necessary to conduct bioassays on insecticides, produce natural enemies and entomopathogens (Sarwar, 2013; Sarwar et al., 2013; Sarwar & Sattar, 2016). Therefore, it is vital to formalize and formulate appropriate artificial diets based on easily accessible ingredients. In this context, the objective of present research is to evaluate reproductive parameters of *H. armigera*, based on different artificial diets, in order to select the one that facilitates successful stable rearing under laboratory conditions.

MATERIAL AND METHODS

Insect sources and culturing

The colony of *H. armigera* was established from larvae collected from a cotton field. About 100 larvae were collected with the help of forceps and transferred to the laboratoryof the National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad (latitude 31.415°N and longitude 73.089°E), Pakistan. In the laboratory, larvae were individually placed into 3 cm × 5 cm × 4 cm plastic containers covered with a meshed net for aeration and held under laboratory conditions (temperature 27 ± 2 °C, relative humidity 75 ± 5 % and photoperiod of L 12: D 12 h). The larvae were nourished daily on newly cut leaves of cotton until pupation. Water was sprinkled onto leaves every other day to keep them fresh. A uniform stock of different larvae stages, pupae, adults and eggs were obtained from the F1 for diet's testing experiments.

Ingredients and procedure for preparation of artificial diets

Three artificial diets based on common bean seed flour (D_1), chickpea seed flour (D_2) or cotton seed flour (D_3) were prepared. These diets were chosen given that common bean, chickpea and cotton are the crops mainly invaded by *H. armigera* in the region. All the constituents used in artificial diets for culturing of *H. armigera* are presented in Table I.

Table I.

Constituents and quantities of three artificial diets for rearing *Helicoverpa armigera*.

Table I. Constituents of the artificial diets for culturing of armyworm *Spodoptera litura*.

Ingredients	D_1	D_2	D_3
Corn seed flour	240.0 g	-	-
Common bean seed flour	-	240.0 g	-
Chickpea seed flour	-	-	240.0 g
Wheat germ	120.0 g	120.0 g	120.0 g
Brewer's yeast	72.0 g	72.0 g	72.0 g
Agar	20.0 g	20.0 g	20.0 g
Ascorbic acid	7.3 g	7.3 g	7.3 g
Nipagin*	4.4 g	4.4 g	4.4 g
Sorbic acid	2.4 g	2.4 g	2.4 g
Multi vitamin solution	10.0 ml	10.0 ml	10.0 ml
Formaldehyde (40%)	6.0 ml	6.0 ml	6.0 ml
Distilled water	1000 ml	1000 ml	1000 ml

*Methyl para-hydroxybenzoate

All ingredients were carefully weighted and placed in containers individually. Agar was dissolved in water within a vessel and taken to the boiling stage. Then, the entire quantity of any of the flours (common bean seed flour, chickpea seed flour or cotton seed flour) was put into the boiled agar and mixed using a blender that resulted in cooling of the blend almost to 80 °C. At that point, the other components were placed into this blend and the total ingredients were thoroughly mixed with a blender. The multi vitamin mixture was added last and the entire mass again thoroughly mixed with the blender. A volume of 5-6 ml of the diet prepared was transferred into sterilized glass vials by means of a squeeze bottle and permitted to cool and stabilize.

Rearing procedure of cotton bollworm

The insectary was held at optimum conditions of temperature 27 ± 2 °C, a relative humidity of 75 ± 5 %, and a photoperiod of L 12: D 12 h. The freshly emerged moths were placed in an insect cage (40 cm × 50 cm × 40 cm) enclosed by a net (1 mm^2 mesh dimension) on all sides to start a laboratory colony that allowed evaluating the biology of the insect. For adult moths, a cotton globule saturated by 10 % solution of sugar was provided as a liquid diet. Paper stripes about 10 cm long and 2 cm wide were put into cage to aid as oviposition substratum. Eggs laid by adult females were harvested daily and incubated till hatching. The neonate larvae were put into larval rearing cages having net covering, nourished with fresh diet and used for conducting of the experiments. For biological assessment, from freshly developed larvae, 25 caterpillars from rearing stock were taken and each caterpillar individually placed into a separate plastic cup [4 cm height × 4 cm width (top) × 2.5 cm width (bottom)] with every one given artificial diet. For each treatment (3 artificial diets) 5 replications were set up (each replicate having 5 larvae) with a total of 75 larvae evaluated for life parameters.

The development of the larvae until the pupal phase was observed daily. Caterpillars were weighted at the final instar and pupae obtained weighed prior to adults emergence. The newly pupated insects were put into glass containers (5 cm × 5 cm × 10 cm) fitted by net covers on top until adults emergence.

Life parameters of the insect were assessed for constructing life tables. The following data were considered; larva duration (days), larval weight (mg), mature larvae formation (%), prepupa formation (days), pupa duration (days), pupal weigh (mg), pupal formation (%), adult emergence (%), adults male and female moths life span/ longevity (days), and total life cycle completion (days). With this information together with daily reproductive data, female preoviposition period (days), female oviposition period (days), fecundity (eggs laid/ female), egg hatching period (days) and fertility (%), parameters were estimated. In particular, based on data analyzed as of life tables, succeeding growth parameters [net reproductive rate (R_O), intrinsic rate of increase (r_m) and finite rate of increase (λ)], were estimated by means of subsequent equations (Wittmeyer & Coudron, 2002): -

$Ro= (r/ T) \times 100$

Where, r= Instantaneous rate of Increase, T= Larval period

$r_m= \ln Ro/ t$

Where, ln= natural log, R_o= Net Reproductive rate, t= time for one generation

$\lambda = N_{t+1} / N_t$

Where, N_t=Number of larvae at t= 0, N_{t+1}= Numberof larvae at t= 1 (after one generation) [$N_{t+1} = N_t e^r$, e means log with base 10]

Statistical analysis

All the experiments were planned in completely randomized design. For assessing the impacts of diverse diets on development and reproductive parameters of *H. armigera*, one-way analysis of variance (ANOVA) subsequently followed through Least Significant Difference (LSD) test was carried out to perform systemically an analysis of comparative position of every factor. Normality of residuals was confirmed through visual inspection of histograms. Statistics software Statistix for Windows, version 10.0 (Analytical Software 2105 Miller Landing Rd Tallahassee FL, USA) was utilized for the above mentioned investigates, through a significance level of p <0.05.

RESULTS

For most of the growth and development parameters of *H. armigera* tested on three diets, there were significant differences among the three treatments. The cotton-based artificial diet performed better in comparison to chickpea-based and bean-based artificial diets (Table II).

TABLE II.

Comparative performance of the three artificial diets evaluated for rearing *Helicoverpa armigera*.

Table II. Life table parameters for comparative performance of artificial diets and natural hosts in the culturing of armyworm *Spodoptera litura*.

Biological parameters	D_1	D_2	D_3
Adult male moth life span/ longevity (days)	6.00±0.13b	7.25±0.15a	7.50±0.07a
Adult female moth life span/ longevity (days)	8.40±0.16b	9.20±0.14a	9.50±0.07a
Adult female preoviposition period (days)	3.35±0.15a	2.80±0.09b	2.50±0.11b
Adult female oviposition period (days)	3.70±0.05b	4.40±0.12a	4.50±0.11a
Adult female eggs laid/ fecundity	145.00±2.23b	245.00±1.58a	250.00±1.58a
Egg hatching period (days)	3.50±0.11a	3.10±0.10b	3.00±0.00b
Egg hatchability/ fertility (%)	84.40±1.80b	90.60±0.60a	93.00±0.83a
Larval period (days)	18.00±0.44a	16.80±0.20b	16.00±0.31b
Larval weight (mg)	220.00±1.58b	286.00±1.00a	290.00±1.58a
Mature larvae formation (%)	87.60±0.74b	91.00±0.94a	93.40±0.67a
Prepupa period (days)	1.70±0.12a	1.15±0.10b	1.10±0.06b
Pupal period (days)	9.90±0.00a	9.68±0.04b	9.64±0.07b
Pupal weight (mg)	200.00±1.58b	225.00±2.73a	230.00±1.58a
Pupal formation (%)	80.60±1.12b	86.00±0.94a	89.00±0.89a
Adult emergence (%)	70.00±0.63b	80.00±1.09a	82.00±0.63a
Life cycle completion (days)	33.10±0.46a	30.73±0.28b	29.74±0.278b

Means denoted by a different letter indicate significant differences between treatments (p< 0.05).

Mean values followed by different lower-case letters in equivalent row present significant statistical difference.

Development and reproductive parameters

The average generation time of *H. armigera* on D_1 was found to be longer than on D_2 and D_3 (F= 98.1, df= 2, p< 0.0001). Females had longer life span than males with a significant effect of the diet both for males (F= 101.57, df= 2, p< 0.0001) and females (F= 57.91, df= 2, p< 0.0001). The preoviposition period was the shortest for D_3, middle for D_2 and the longest for D_3 (F= 42.70, df= 2, p< 0.0001). The oviposition period followed the same pattern; it was the shortest for D_1, middle for D_2 and the longest for D_3 (F= 43.44, df= 2, p< 0.0001).

Larval diets also influenced fecundity of female (eggs laid), which varied between 245 and 350 eggs/ female on D_1 and D_3, respectively, with intermediate value for D_2 (318 eggs) (F= 755.57, df= 2, p< 0.0001).

Embryo developmental time (egg hatching period) ranged from 3.25 to 4.00 days and differed between diets (F= 23.33, df= 2, p< 0.0001). The average egg hatch rate was 92.60, 83.60 and 81.20 % for D_3, D_2 and D_1, respectively (F= 61.57, df= 2, p< 0.0001).

Laval developmental time fluctuated from 21.6 to 25.6 days with significant differences between diets (F= 28.95, df= 2, p< 0.0001); being the fastest from D_3. The percentage of larval survival was significantly different amongst the three treatments; being higher (93.40 %) for D_3 than D_2 (87.60 %) and D_1 (81.20 %) (F= 30.52, df= 2, p< 0.0001). The weight of larva at final developmental instar was the highest for D_3 (483 mg) and reduced for the others diets, with D_2 449 mg and D_1 415 mg (F= 115.60, df= 2, p< 0.0001).

The prepupa period differed among treatments, with values of 2, 1.5 and 1 days, respectively, for the three diets (D_1, D_2 and D_3) (F= 60.00, df= 2, p= 0.00). Pupal stage duration was the lengthiest for D_1 (16.40 days), intermediate for D_2 (14.60 days) and the shortest for D_3 (12.40 days) (F= 20.76, df= 2, p= 0.0001). Pupa weight was the maximum for D_3 (349.00 mg), while the minimum (324.00 mg) for D_2 followed by 300.40 mg for D_1 (F= 39.68, df= 2, p< 0.0001). The survival percentage (pupal formation) till the end of pupal phase, differed significantly between the diets evaluated, with values 74.40, 81.00 and 90.80 % for D_1, D_2 and D_3, respectively (F= 70.44, df= 2, p= 0.00). Adults emergence was the maximum for D_3 (86.40 %) followed by D_2 (81.40 %) and the minimum in case of D_1 (72.00 %) (F= 157.22, df= 2, p< 0.0001).

Life tables and population parameters

The three diets D_1, D_2 and D_3 also gave rise to a dissimilar growth pattern of *H. armigera* just like the differences in life table parameters. As for development, D_3 performed better than D_1 and D_2, wherein D_1 had lower and D_2 intermediate values. This was evident for the net reproduction rate (R_o), the intrinsic rate of increase (r_m) and the finite rate of increase (λ) (Table III).

Table III.

Life table parameters of *Helicoverpa armigera* reared of diverse diets.

Table III. Growth parameters of armyworm *Spodoptera litura* reared of different diets.

Biological parameters	D_1	D_2	D_3
Net reproductive rate (R_o)	$0.031 \pm 8.46 \times 10^{-04}$b	$0.046 \pm 1.32 \times 10^{-03}$a	$0.049 \pm 1.38 \times 10^{-03}$a
Intrinsic rate of increase (r_m)	3.466±0.10b	4.978±0.13a	5.345±0.11a
Finite rate of increase (λ)	1.241±0.03b	1.603±0.02a	1.675±0.02a

Ro: net reproductive rate; rm: intrinsic rate of increase; λ: finite rate of increase. Average values trailed within a row followed by different letters are significantly different.

DISCUSSION

The present study evaluated three different artificial diets differing in one ingredient aiming to determine which is better for *H. armigera* artificial rearing. Results showed that *H. armigera* performed better in the cottonflour-based diet. We discuss their relevance to improve artificial rearing to allow further research towards developing IPM strategies (Ahmad & Sarwar, 2013; Sarwar,2019a).

Based on the life history parameters and reproductive parameters of pest examined, cotton seed flour-based diet was more adequate and led to a faster developmental time than bean-based and chickpea-based diets. Generally, the use of artificial diets, is found acceptable for mass rearing when performance of various insect stages is more than 75 % (Singh, 1983). Hence, the artificial diets evaluated in this study are suitable for laboratory rearing conditions, because viability values of larvae were 81.2, 87.6 and 93.4 % for bean, chickpea and cotton flour-based diets, respectively.

Our results also showed that duration of the adult stage, both for female and male moths was affected significantly by the type of diet. In addition, asynchrony was detected in adults emergence, by the females developing earlier to males. Prospectively, this might be owing to the fact that females have to move in search of suitable hosts, and when sexually mature, prepare themselves to release the sexual pheromone to attract males from the same cohorts that on an average developed two days later and need only to find these females (Zalucki et al., 1986).

A high pupa weight of *H. armigera* is linked to more suitable food consumed by larva that generally leads to an improved reproductive performancein adult moths (Liu et al., 2004). Thus, the present observations are in accordance with this earlier study reported, wherein the higher larval and pupal weights were achieved in cotton seed flour-based diet that was more adequate and caused in a quicker generation period of *H. armigera* than bean-based and chickpea-based diets. The results indicated that the maximum increases in egg deposition, percent of eggs hatching, male and female emergence as well as their survival were observed, and caused minimum abnormalities for any generation. These outcomes are in accordance with the annotations found by Sarate et al. (2012), who detected that the diets rich in carbohydrates or proteins gave rise to heavier larvae and a shorter duration of the larval stage.

The shorter developmental time on the cotton flour-based diet suggest that *H. armigera* might have additional generations per year, whereas on the both other diets, this pest would have less generations per year; at least under the environmental conditions studied. These facts can be taken into account when scheduling insect rearing under the laboratory setting. Alternatively, these artificial diets are suitable to overcome the any drawback during the growth process and can be helpful in obtaining appropriate successive generations of *H. armigera* (Krishnareddy & Hanur, 2015).

The intrinsic growth rate (r_m) was also variable according to the diets evaluated. This value is the core element for construction of a fertility life table, showing that higher the value of intrinsic growth rate is, the more prolific the species would be (Jat et al., 2020).

The utmost vital nutritious aspects are carbohydrate and protein levels, particularly their amounts, which are essential constituents to promote changes in growth and development, and therefore, can modify life parameters of insects, for instance, their increasing capacity (Pedigo & Zeiss, 1996). Our results are in agreement with previous studies where diets comprising high quantity of protein performed better for *H. armigera* rearing. A variety of nutrients, vitamins and valuable chemicals are required for a successful artificial diet, and a sound diet plays a key role in enhancing better growth, health and safety of an insect (Truzi et al., 2019). Cottonseed kernels contain protein, oil and starch along with various compounds, while cottonseed meal and hulls are one of the most abundant natural sources of protein, fiber and other minor compounds. Cottonseed mealis a good source of protein and characterized by a high amino acid profile as acceptable ingredients of diet. Cottonseed hulls are an excellent source of cotton linters, which are cellulose, and provide nutrients with a high protein, crude fiber and high energy. Cottonseed oil also has high fiber content and distinctive fatty acid profile (saturated, polyunsaturated and monounsaturated) (Siddiqui et al., 2019; 2023*;* Khanet al., 2020). Thus, owing to variable nutritional values for every gram of diets that larva consumed, these contributed potentially important changes, which might affected insect growth (Cohen, 2003).

Additionally, in this study, the life cycle period of *H. armigera* was the shorter when fed on chickpea compared to bean flour-based diet. The bean and chickpea legumes are either fruits or seeds of plant family called Fabaceae or Leguminosae. These are great sources of protein, dietary fiber, carbohydrates and dietary minerals, as well as also sources of starch that is broken down in intestine to produce short-chain fatty acids used for food energy. However, nutrition comparisons of chickpea with bean, reveals that chickpea has more magnesium, copper, phosphorus, fiber, sugar, polyunsaturated fat, monosaturated fat, vitamin E, pantothenic acid (vitamin B_5), folate (vitamin B_9), choline and zinc than bean (Sarwar,2019b). Thus, the availability of diet is an imperative aspect in mass culturing of insect, wherein the development and survival duration of *H. armigera* larvae depend on food constituents. The findings of this experiment are in accordance with the observations of Ahmed et al. (1998), who determined that chickpea flour arbitrated an imperative nourishment and other important constituents, which are vital in mass culturing of *H. armigera*. In the intervening time, this investigation revealed that using of artificial diets offered a suitable growth cycle (from egg to adult) for *H. armigera* and this species took different days to complete the cycle on the diets. The growth tended to be sluggish in insect fed on bean than those nourished with cotton and chickpea flour-based artificial diets. The findings of this experiment follow the same pattern as reported by work of Parra (1999) that the most suitable diets deliver a proper period of growth phases of insects.

In the current study, the total life cycle in case of male and female *H. armigera* was analyzed 38.25 ± 0.32 days on cotton diet. When compared, the results of present finding are contradictory to the discoveries of Gadhiya et al. (2014), who stated a different life cycle duration of *H. armigera* on an average of 49.40 ± 5.21 days on groundnut (oil seed) instead of cotton. Additional perfections for the preparation and manufacturing of basic rearing expertise and structure are possible, and this would expectedly enhance for mass culturing of *H. armigera*.Based on results, various developmental parameters indicated that artificial diets in recipes of cotton or chickpea-based food were superior as compared to other bean-based diet for shorter developmental period to support proper growth of this insect*H. armigera*. Hence, feeding an artificial diet can provide an adequate option for optimization of mass rearing, deliver an efficient methodology of the rearing procedure and may accelerate the development of insect under insectary conditions.

CONCLUSION

Insect diets science requires regular evaluation of new, locally produced or more effective ingredients, specifically considering the need to use of artificial diets to produce high quality insects. Rearing of *H. armigera* under laboratory conditions on artificial diet with the minimum genetic drift is a big challenge. This can be achieved only by standardizing an easy and effective mass rearing method. This investigation provides information aimed at identifying crucial constituents like essential nutrients, vitamins and minerals in insect's diets. Long time availability of the respective *H. armigera* insect's culture, contributes to research activities in several areas such as life history traits, behavior, toxicological and physiological studies as well as susceptibility and resistance to pesticides evaluations. In conclusion, to sustain *H. armigera* density under laboratory conditions, in an acceptable mode, it is compulsory to offer a diet that is suitable for the dietary requirements of an insect species. Consequently, cotton and chickpea flour-based artificial diets proved to be more suitable than the other diet. In all, our results may well aid researchers to make progress in an efficient mass rearing of *H. armigera* by using of cotton and chickpea as natural food sources.

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REFERENCES

Ahmed, K., Khalique, F. & Malik, B. A. (1998) Modified artificial diet for mass rearing of Chickpea Pod borer, *Helicoverpa armigera* (H.). *Pakistan Journal of Biological Sciences,* **1,** 183-187.

Ahmad, N. & Sarwar, M. (2013) The cotton bollworms: their survey, detection and management through pheromones: A review. *Journal of Agriculture and Allied Sciences*, **2(3),** 5-8.

Beukeboom, L. W. (2017) Improving pest control: Mass rearing and field performance- An introduction. *Entomologia Experimentalis et Applicata,***162**, 105-107.

Cohen, A. C. (2001) Formalizing insect rearing and artificial diet technology. *American Entomologist*, **47,** 198-206.

Cohen, A.C. (2003) *Insect Diets.Science and Technology*. CRC Press, Boca Raton.

Dourado, P.M., Pantoja-Gomez, L.M., Horikoshi, R.J., Carvalho, R.A., Omoto, C., Correa, A.S. & Head, G.P. (2021) Host plant use of *Helicoverpa* spp. (Lepidoptera: Noctuidae) in the Brazilian agricultural landscape. *Pest Management Science*, ***77*(2),** 780-794.

Gadhiya, H.A., Borad, P.K. & Bhut, J.B. (2014) Bionomics and evaluation of different bio pesticides against *Helicoverpa armigera* (Hubner) Hardwick infesting groundnut. *The Bioscan*, 9, 183-187.

Hou, M. & Sheng, C. (2000) Effects of different foods on growth, development, and reproduction of cotton bollworm, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae). *Acta Entomologica Sinica*, **43(2),** 168-175.

Jat, B.L., Dahiya, K.K., Rolania, K. & Yadav, S.S. (2020) Standardization of artificial diet for the mass rearing of *Helicoverpa armigera*. *Ind.Journal of Plant Protection*, **48(1 & 2),** 55-63.

Jones, C.M., Parry, H., Tay, W.T., Reynolds, D.R. & Chapman, J.W. (2019) Movement Ecology of Pest *Helicoverpa*: Implications for Ongoing Spread. *Annual Review of Entomology*, **64(1)**, 277-295.

Khan, M.H., Jander, G., Mukhtar, Z., Arshad, M., Sarwar, M. & Asad, S. (2020) Comparison of in Vitro and in Planta Toxicity of Vip3A for

Lepidopteran Herbivores. *Journal of Economic Entomology,* **113(6)**, 2959-2971.

Krishnareddy, B. & Hanur, V.S. (2015) Enhanced synthetic diet for rearing *H. armigera* under laboratory conditions. *Journal of Entomology and Zoology Studies*, **3(1)**, 165-167.

Liu, Z., Li, D., Gong, P. & Wu, K. (2004) Life table studies of the cotton bollworm, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae), on different host plants. *Environmental Entomologist*, **33**, 1570-1576.

Nibouche, S., Bues, R., Toubon, J. F. & Poitout, S. (1998) Allozyme polymorphism in the cotton bollworm *Helicoverpa armigera* (Lepidoptera: Noctuidae): Comparison of African and European populations. *Heredity*, **80,** 438-445.

Parra, J.R.P. (1999) *Tecnicas de criacao de insetos para programa de controle biologico* (Edit. 4). ESALQ/ FEALQ. Piracicaba.

Pedigo, L.P. & Zeiss, M.R. (1996) *Analyses in Insect Ecology and Management*. Iowa State University Press, Ames, IA.

Riaz, S., Johnson, J.B., Ahmad, M., Fitt, G.P. & Naiker, M. (2021) A review on biological interactions and management of the cotton bollworm, *Helicoverpa armigera* (Lepidoptera: Noctuidae). *Journal of Applied Entomology,* **145(6),** 467-498.

Rogers, D.J. & Brier, H.B. (2010) Pest-damage relationships for *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) on soybean (*Glycine max*) and dry bean (*Phaseolus vulgaris*) during pod-fill. *Crop Protection,* **29(1)**, 47-57.

Sarate, P.J., Tamhane, V.A., Kotkar, H.M., Ratnakaran, N., Susan, N., Gupta, V.S. & Giri, A.P. (2012) Developmental and digestive flexibilities in the midgut of a polyphagous pest, the cotton bollworm, *Helicoverpa armigera*. *Journal of Insect Science*, 12, 1-16.

Sarwar, M., Ahmad, N. & Tofique, M. (2009) Host plant resistance relationships in chickpea (*Cicer arietinum* L.) against gram pod borer (*Helicoverpa armigera*) (Hubner). *Pakistan Journal of Botany*, **41(6)**, 3047-3052.

Sarwar, M., Ahmad, N. & Tofique, M. (2011) Identification of susceptible and tolerant gram (*Cicer arietinum* L.) genotypes against gram pod borer (*Helicoverpa armigera*) (Hubner). *Pakistan Journal of Botany*, **43(2)**, 1265-1270.

Sarwar, M. (2013) Management of Spider Mite *Tetranychus cinnabarinus* (Boisduval) (Tetranychidae) Infestation in Cotton by Releasing the Predatory Mite *Neoseiulus pseudolongispinosus* (Xin, Liang and Ke) (Phytoseiidae). *Biological Control*, **65(1),** 37-42.

Sarwar, M., Hamed, M., Yousaf, M. & Hussain, M. (2013) Identification of Resistance to Insect Pests Infestations in Cotton (*Gossypium hirsutum* L.) Varieties Evaluated in the Field Experiment. *Journal of Scientific Research in Environmental Sciences*, **1(11)**, 317-323.

Sarwar, M. & Sattar, M. (2016) An Analysis of Comparative Efficacies of Various Insecticides on the Densities of Important Insect Pests and the Natural Enemies of Cotton, *Gossypium hirsutum* L. *Pakistan Journal of Zoology*, **48(1),** 131-136.

Sarwar, M. (2017) Cotton Bollworm *Helicoverpa armigera* (Hubner, 1809) (Lepidoptera: Noctuidae) and Development of Integrated Pest Management Platform. *Scholars Journal of Research in Agriculture and Biology*, **2(1)**, 63-70.

Sarwar, M. (2019a) Multiple Integrated Pest Management (IPM) and Area-Wide Management (AWM) Approaches for Insect Pests of Chickpea *Cicer arietinum* (L.) Walp Crop. In: Handbook of Chickpeas: Nutritional Value, Health Benefits and Management, A. T. Lund and N. D. Schultz (Eds.). *Nova Science Publishers, Inc., New York*. pp. 237-263.

Sarwar, M. (2019b) Multiple Insect Pests Management Options for Chickpea (*Cicer arietinum* L.) Walp Grain with Reference to Storage. In: Handbook of Chickpeas: Nutritional Value, Health Benefits and Management, A. T. Lund and N. D. Schultz (Eds.). *Nova Science Publishers, Inc., New York*. pp. 265-302.

Sarwar, M. (2020) Insect Pests that Negatively Impact Bell Peppers *Capsicum annuum* L., and Schemes for Crop Protection. *Capsicum: Production, Varieties and Nutrition* (ed. Norris, P.), pp. 172. Nova Science Publishers, New York.

Sarwar, M. (2023) Startup of Climate-Smart Integrated Pest Management Against Corn Earworm *Helicoverpa zea* (Boddie) in Maize (*Zea mays* L.) for Altering Insect Risk. *Global Research in Environment and Sustainability*, **1(8)**, 1-19.

Siddiqui, H.A., Asif, M., Asad, S., Naqvi, R.Z., Ajaz, S., Umer, N., Anjum, N., Rauf, I., Sarwar, M., Arshad, M. B., Imran, A., Saeed, M., Mukhtar, Z., Bashir, A. & Mansoor, S. (2019) Development and evaluation of double gene transgenic cotton lines expressing Cry toxins for protection against chewing insect pests. *Scientific Reports*, **9(1)**, 11774.

Siddiqui, H.A., Asif, M., Naqvi, R.Z., Shehzad, A., Sarwar, M., Imran, I. & Mansoor, S. (2023) Development of modified Cry1Ac for the control of resistant insect pest of cotton, *Pectinophora gossypiella*. *Gene*, **856,** 147113.

Singh, P. (1983) A general purpose laboratory diet mixture for rearing insects. *International Journal of Tropical Insect Science*, **4**, 357-362.

Trujillo, D., Mastrangelo, T., Jensen, C.E., Rodrigues J.C. V., Lawrie, R. & Massey, S.E. (2024) Accurate identification of *Helicoverpa armigera-Helicoverpa zea* hybrids using genome admixture analysis: Implications for genomic surveillance. *Frontier inInsect Science*, **4**: 1339143.

Truzi, C.C., Holzhausen, H., Alvaro, J., de Laurentis, V.L., Vieira, N.F., Vacari, A.M. & De Bortoli, S.A. (2019) Food Consumption Utilization, and Life History Parameters of *Helicoverpa armigera* (Lepidoptera: Noctuidae) Reared on Diets of Varying Protein Level. *Journal of Insect Science*, **19(1)** 1-7.

Wittmeyer, J.L. & Coudron, T.A. (2002) Life Table Parameters, Reproductive Rate, Intrinsic Rate of Increase, and Estimated Cost of Rearing *Podisus maculiventris* (Heteroptera: Pentatomidae) on an Artificial Diet. *Journal of Economic Entomology*, 94(6), 1344-1352.

Yadav, S.P.S., Lahutiya, V. & Paudel, P. (2022) A review on the biology, ecology, and management tactics of *Helicoverpa armigera* (Lepidoptera: Noctuidae). *Turkish Journal of Agriculture-Food Science and Technology*, **10(12)**, 2467-2476.

Zalucki, M.P., Daglish, G., Firempong, S. & Twine, P. (1986) The biology and ecology of *Heliothis armigera* (Hubner) and *Heliothis punctigera* Wallengren (Lepidoptera, Noctuidae) in Australia-What do we know?. *Australian Journal of Ecology*, **34**, 779-814.

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Biological parameters of the cotton bollworm *Helicoverpa armigera* (Lepidoptera: Noctuidae) reared on different artificial diets and their nutrients prominence

Parámetros biológicos del gusano cogollero del algodón *Helicoverpa armigera* (Lepidoptera: Noctuidae) criado con diferentes dietas artificiales y la importancia de sus nutrientes

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