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Comparative effect of natural diets and semi synthetics diet on *Helicoverpa armigera* (Hubner) in development and growth index

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Abstract
The present study was conducted to evaluate the comparative effect of natural diets and semi synthetics diet on *Helicoverpa armigera* (Hubner) in development and growth index. Among all the six different diets on the growth and development of the larvae of gram pod borer (*H. armigera*), The artificial diets (chickpea flour based diets) to be the most suitable which resulted longer larval period, pre-pupal period, pupal period. Maximum percent adult emergence, highest fecundity, sex ratio, growth index, pupal index, survival index and ovipositional index along with success index of different stage of *H. armigera* compared to the main diets of chickpea, mungbean and urdbean leaves and pods (control).

Keywords: Artificial diet, semi synthetics diet, *Helicoverpa armigera*, chickpea flour based diets

Introduction
Pulses, the food legumes, have been grown by farmers since millennia providing nutritionally balanced food to the people of India (Nene, 2006) [15] and many other countries in the world. Pulses are important dietary component in South Asia and growing legume pulses enriches soil health due to the root nodule fixing atmospheric nitrogen in soil and thus play a vital role in sustainable agriculture (Kannaiyan, 1999) [13]. India is the largest producer and consumer of pulses in the world both in terms of area as well as production covering 43.30 per cent of land area under pulses with 33.15 per cent production (AICRPC, 2012-13) [2]. Though India has the distinction of being the world's largest producer of pulses, the average productivity is very low because of the abiotic and biotic stresses. Due to decline in productivity, the net availability of pulses has come down from 60g/day/person in 1951 to 33g/day/person in 2012 (Biyan, 2013) [8]. Annually about 2.0 to 2.4 million tonnes of pulses with approximate monetary value of Rs. 6000 crores are lost due to the damage caused by insect pests (Reddy, 2009) [18].
Growth and development on natural host plant as well as artificial diets (semi synthetics diet play vital role in mass production of target insect pest. The basic requirement can be met effectively if a suitable and economical diet is available for insect. The utility of development of a satisfactory artificial diet for mass rearing of insect has occupied an important place because (1) the host plants may not be available throughout the year, (2) chances of contamination by micro-organism, parasites etc. in insects reared on artificial diet, (3) large scale mass rearing on its natural host is expensive in terms of labour, space mass requirements. Therefore, it becomes clear that development of a suitable medium of diet is a pre-requisite in any entomological studies. Keeping these issues in mind effect of food plant species on rearing performance of *H. armigera* was undertaken to complete developmental behavior of this insect. Gram pod borer *H. armigera* (Hübner) is considered a serious pest of a variety of leguminous crops. Therefore, it becomes necessary to formulate a highly suitable semi synthetic diet of this insect so that physiologically uniform populations can be obtained by mass rearing of this insect for conducting a variety of studies (Cabello *et al.*, 1984) [9].

Materials and Methods
An experiment was carried out to study the growth and development of gram pod borer (*Helicoverpa armigera*) in Pulse Laboratory, Department of Entomology, G. B. Pant University of Agriculture & Technology, Pantnagar during 2014-15. The immature stages of insect were collected from the field crops and reared in the laboratory for adult emergence to get the culture. The experiment was performed at constant temperature The insect was reared

for about 4-5 generations on artificial diets under controlled conditions of temperature (28±5°C) and relative humidity of (65±5%) in the Biological Oxygen Demand (B. O. D) incubator of the laboratory before starting the experiment. Fresh larvae of *Helicoverpa armigera* were collected from chickpea, mungbean and urdbean crops for their culture maintain through 4-5 generations on natural chickpea, mungbean and urdbean leaves and pods. Emerged adults were kept into separate jar to get eggs and neonate larvae. Three semi synthetic diets were prepared with different basic ingredients including flour of chickpea (*Cicer arietinum* L), mungbean (*Vigna radiate* L.) and urdbean (*Vigna mungo* L.) crops mixed in a common mixture which carried following process such as: (Hamed, M. and Nadeem, S, 2008) [12].

1. Rearing of *H. armigera* on natural food

To study the growth and development of *H. armigera*, eggs were collected from laboratory culture, after hatching the larvae were reared separately in the clean plastic jar (15 x 10 cm). Small pieces of fresh leaves of chickpea, mungbean and urdbean were provided daily as food for the larvae. Grown up larvae were transferred into the 15 plastic jar (one larvae/ jar) one third of the jar was filled with moist soil to provide the appropriate site for pupation to the full grown up larvae. After pupation, the pupae were kept as such in jar containing soil till the emergence of adults. A pair of newly emerged male and female moths was then transferred to new oviposition jar along with blotting paper and fresh leaf for egg laying. The jars were covered with perforated lid to prevent the escape of the adults. Five percent honey solution was also provided as food to the adults soaked on a piece of cotton with honey solution. The cotton was changed daily. Fresh healthy leaves were provided in the boxes for egg laying. The muslin cloth, paper and jars were observed every morning for egg laying. These eggs were then transferred to petriptates with the help of fine camel hair brush (Babu *et al*., 2014) [5].

2. Rearing of *H. armigera* on semi synthetic diet

Eggs were collected from laboratory culture. After hatching the larvae were transferred individually to sterilized capsule vial (2.5 cm in diameter & 5.5 cm height) containing semi synthetic diet with the help of sterilized camel hair brush. After which the vial was plugged with a sterilized cotton wool to provide an exchange of air but not to allow the drying of the diet. A number of sets each comprising 15 vials (one larvae/vial) were used to study the growth and development of *H. armigera* on semi synthetic diet.

3. Observation on the growth and development of *H. armigera* on semi synthetic diet and natural diet

i. Egg: The size of egg was measured under microscope using a micrometer

ii. Larva: Observations were recorded on number of larval instars, larval period and percent larval survival. The size of individual larvae was observed daily

iii. Pre pupa and Pupa

The size of pre pupa and pupa was measured by using a millimeter scale. Pre pupal (time elapsed between cessation of feeding and shedding of the last larval skin) and pupal period was considered from the date of formation of pupa to the date of emergence of adult from the pupa. Sex of the adult emerged from the pupa was differentiated from the markings of genital and anal region.

iv. Adult: The size of newly emerged male and female with wing expansion was measured using millimeter scale.

v. Pre-oviposition, oviposition and post-oviposition periods

The freshly emerged male and female from pupae were paired and confined in small jars separately for mating. They were provided with five percent honey solution soaked in cotton for adults as food. Fresh leaves of chickpea/mungbean/urdbean were provided along with a swab soaked with honey solution and collected on the basis for estimating the number of eggs laid. The pre-oviposition, oviposition and post-oviposition periods were observed with the respect to each replication and the average was taken from there.

vi. Fecundity

Number of eggs laid by a female was recorded daily till the death of the female. Average fecundity of the *H. armigera* was worked out by taking the average from each replication.

vii. Longevity

Longevity of male and female was calculated separately from the date of emergence to the date of death of the adults.

viii. Duration of total life cycle

Total duration of life history of *H. armigera* was calculated by recording the number of days taken by the insect to complete their different stages *i.e.,* from egg to adult. The duration of life cycle was recorded separately for male and female.

ix. Index values

The artificial diets and natural diets were also evaluated on the basis of various developmental indices like growth index value (Pant, 1956) [16]. Larval period index, pupal period index, pupation index, survival index and success index (Prasad and Bhattacharya, 1975) [17]. These parameters were calculated by using the following equation.

Growth index (GI) = N/Av

Where, N= Percent adult emergence

Av= Average development period, which were included larval and pupal periods.

$$\text{Larval period index (LPI)} = \frac{\text{Larval period (days)on standard diet}}{\text{Larval period (days)on test diet}}$$

$$\text{Pupal period index (PPI)} = \frac{\text{Pupal period (days)on standard diet}}{\text{Pupal period (days)on test diet}}$$

$$\text{Pupation index (PI)} = \frac{\text{Percent pupation on test diet}}{\text{Percent pupation on standard diet}}$$

$$\text{Survival index (Sur. I)} = \frac{\text{Percent adult emergence on test diet}}{\text{Percent adult emergence on standard diet}}$$

$$\text{Ovipositional index (OI)} = \frac{\text{Average number of eggs on test diet}}{\text{Average numebr of adults on standard diet}}$$

$$\text{Success index (Suc. I)} = \frac{\text{LPI} + \text{PPI} + \text{PI} + \text{Sur. I}}{4}$$

For understanding the role of success index, it was decided to give a hypothetical value of one to the standard diet. If the calculated value was found to be less than one, then diet was classified inferior the standard diet. On the other hand diets showing more than value one, were classified as superior diets, while diet showing 1=1 value was classified as at par with standard diets. This type of classification gives the idea about the quality of a diet.

Statistical analysis
The data obtain from experiments were subjected to the analysis of variance using Simple Randomized Block Design (RBD) and Complete Randomized Block Design (CRD) programme. The Growth and development which included larval period, pupal period, percent pupation and percent adult emergence were analyzed by using a Complete Randomized Block Design (Gomez and Gomez, 1984) [11]. Data were analyzed in Complete Randomized Block Design with the help of a computer program developed in this university (Anonymous, 2004) [4].

Results and Discussion
The results obtained from the present investigation as well as relevant discussion have been summarized under the following heads:

Effect of different diets on the growth and development of *H. armigera*
The study was conducted to find out the effect of different diets on the growth and development of *H. armigera* is presented in Table 1. The development periods, reproduction, longevity, growth index, survival and success index of the gram pod borer (*Helicoverpa armigera*) and artificial diets (chickpea, mungbean and urdbean flour based diets) were studied in the Pulse laboratory of department of Entomology, College of Agriculture. A perusal of data reveals that the growth and development of different instar larvae of *H. armigera* significantly influenced when they were fed on different diets.

Duration of different life stages of *H. armigera*
Egg
Incubation period of *H. armigera* ranged from 3.06 to 3.77 days periods. The minimum incubation period of *H .armigera* (3.06 days) was recorded on urdbean leaves and pods (control). The maximum incubation period (3.77 days) was recorded in chickpea flour based diets which was statistically non-significantly from other diets. (Table 1).

Larva
In total, six larval instars were recorded on all diets (Table 1). The developmental period of first instar larva reared on different diets. There was no significant variation in the developmental period of first instar larvae and ranged from 2.95 to 3.81 days on different diets. The minimum developmental period of 2.29 days were recorded in mungbean leaves and pods which statistically non-significantly from other diets. The maximum periods of 3.81 days was recorded on chickpea leaves and pods followed by urdbean leaves and pods (3.75 days). However, the developmental period of subsequent instars showed a significantly variation in all diets. The developmental period of subsequent instars III, IV, V and VI was recorded more or less similar trends of results in all diets studied.

Table 1: Development periods of eggs and larvae of *Helicoverpa armigera* (Hubner) on different diets

Main diet ingredient	Egg	Period of larval instars*(Mean ± S.D)						Total larval period
		I Instar	II Instar	III Instar	IV Instar	V Instar	VI Instar	
Chickpea flour based diet	3.77^{e} ± 0.70 (2.06)	3.11^{b} ± 0.28 (1.89)	2.26^{b} ± 0.14 (1.66)	2.47^{b} ± 0.18 (1.72)	2.10^{ab} ± 0.12 (1.61)	1.63^{b} ± 0.22 (1.46)	3.50^{bc} ± 0.22 (1.99)	15.06^{ab} ± 0.47 (3.94)
Mungbean flour based diet	3.53^{d} ± 0.69 (2.00)	3.17^{bc} ± 0.20 (1.91)	2.31^{C} ± 0.12 (1.67)	2.13^{a} ± 0.19 (1.62)	2.47^{b} ± 0.19 (1.72)	2.20^{bc} ± 0.26 (1.64)	3.63^{bc} ± 0.24 (2.03)	16.04^{c}± 0.38 (4.05)
Urdbean flour based diet	3.13^{bc} ± 0.55 (1.90)	3.21^{bc} ± 0.23 (1.93)	2.58^{e} ± 0.13 (1.75)	2.64^{d} ± 0.22 (1.77)	2.57^{cd} ± 0.23 (1.75)	2.39^{c} ± 0.26 (1.69)	4.15^{c} ± 0.32 (2.15)	17.53d ± 1.05 (4.24)
Chickpea leaves & pods (control)	3.53^{d}±0.10 (2.01)	3.81^{d}±0.32 (2.07)	2.20^{a}±0.35 (1.64)	2.13^{a}±0.19 (1.62)	2.06^{a}±0.24 (1.59)	1.43^{a} ± 0.25 (1.38)	3.04^{a} ± 0.19 (1.88)	14.68^{a} ± 1.13 (3.76)
Mungbean leaves & pods (control)	3.41^{c}±0.13 (1.97)	2.95^{a}±0.30 (1.85)	2.70^{f}±0.56 (1.78)	2.61^{c}±0.21 (1.76)	2.29^{ab}±0.20 (1.67)	1.75^{ab} ± 0.28 (1.49)	3.32^{b} ± 0.17 (1.95)	15.61^{ab}± 1.04 (4.01)
Urdbean leaves & pods (control)	3.06^{a}±0.12 (1.88)	3.75^{c}±0.25 (2.06)	2.53^{d}±0.43 (1.74)	2.48^{bc}±0.16 (1.73)	2.56^{c} ±0.22 (1.75)	2.19^{b} ± 0.34 (1.63)	3.51^{bc} ± 0.19 (2.00)	17.03^{cd} ± 1.03 (4.18)
SEm±	NS	NS	0.022	0.110	0.117	0.0.156	0.131	0.520
CD(P=0.05)	NS	NS	0.076	0.341	0.361	0.480	0.403	1.603

1. NS - Non Significant
2. *Figures in parentheses are Square root transformed values
3. In a column mean(s) followed by a common letter are not significantly different at 5% in LSD

Considering the total larval period, a minimum of 14.68 days was recorded in chickpea leaves and pods which was significantly different from other diets. The maximum larval period of 17.53 days was recorded on blackgram flour based diets followed by mungbean flour based diets (16.04 days). However, in other diets the larval periods were recorded as 15.06, 15.61, 16.04 and 17.03 days on chickpea flour based diets, mungbean leaves and pods, mungbean flour based diets and urdbean leaves and pods respectively. From the above account it was evident that the period of various instars of the larvae of *H. armigera* (Pulse pod borer) were considerably increased when the larvae were fed on artificial diets in comparison to natural diets. The finding of present studies are in conformity with the results obtained by Hamed and Nadeem (2008) [12] who found that larval periods (14.5 and 15.3 days) of *H. armigera* was recorded on chickpea and mungbean flour based diets, respectively which was similar to the present observation and also showed that chickpea and mungbean flour based diets produced healthy larvae that gained maximum weight and completed development of *H. armigera*. However, Similarly, Babu *et al.*, (2014) [5] also reported that the larval survival percent was varied from 81.2 to 93.75% in modified chickpea flour diets in the first and second generation, respectively.

Pupal period and pupal percent
In laboratory, (Table 2) the full growth caterpillars pupate in soil. However, at occasions they also pupated outside soil. The pupa was broadly rounded anteriorly but tapering posteriorly. Newly form pupa was light green yellow in colour on natural diets but, on semi synthetic diets it was light yellow. Later on the pupae turned to light brown in colour on

both types of diets fed to the larvae. The minimum pupal period of *H.armigera* (10.28 days) was recorded in chickpea leaves and pods while the maximum pupal period of *H.armigera* (12.43 days) was recorded in urdbean flour based diets which were statistically significantly from other diets. The minimum percent pupation of larvae (73.31%) was recorded in urdbean leaves and pods while the maximum percent pupation (91.06%) was recorded in chickpea flour based diets which were found to be statistically significantly from other diets. The finding are in close agreement with Hamed and Nadeem (2008) [12] who reported 90.6% and 85.3% pupation of *H armigera* on chickpea and mungbean flour diets, respectively and also showed that chickpea flour based diets produced healthy larvae and pupa that gained complete development in 14.5 and 11 days, respectively which were similar to the present studies. Similarly, Amer and El-Sayed (2014)[3] also reported that the average percent pupation of different host and artificial diets were recorded as 65.00, 51.67, 80.00, 70.00, 91.67, 88.33 and 94.00% for cotton seed, maize, caster bean, okra fruit, pea, bean and artificial diets, respectively.

Pupal weight

The minimum pupal weight of *H.armigera* (229.09 mg) was recorded in urdbean leaves and pods while the maximum pupal periods of *H.armigera* (371.56 mg) was recorded in chickpea flour based diets which were found to be statistically non-significant to other diets. However, in other diets the pupal weights were recorded as 243.36, 279.63, 343.24 and 349.69 mg on mungbean leaves and pods, chickpea leaves and pods, urdbean flour based diets and mungbean flour based diets, respectively. The finding are in close agreement with Hamed and Nadeem (2008) [12] who reported that chickpea and mungbean flour based diets produced healthy pupa that gained complete development and maximum weight in 380.5 mg and 357.60 mg, respectively and chickpea leaves and pod (control) was recorded as 259.9 mg pupal weight in natural diet which were similar to the present observation. The findings are in agreement with Kumar (2011) [14] also reported that 85.67, 75.08, 76.95, 78.24 and 91.86% pupation on chickpea (grain), tomato (fruit), Pigeon pea (grain), pea (grain) and artificial diets, respectively (Table 2).

Percent adult emergence

The minimum percent adult emergence (66.67%) was recorded in urdbean leaves and pods followed by mungbean leaves and pods (68.86%) while the maximum percent adult emergence (85.33%) was recorded in chickpea leaves and pods which were found to be statistically significant to other diets. However, in other diets the percent adult emergence were recorded as 68.86, 71.01, 71.06 and 82.20% on mungbean leaves and pods, chickpea leaves and pods, urdbean flour based diets and mungbean flour based diets, respectively. These finding are in close agreement with Ahmad *et al*., (1998) [1] who reported that the biology of *H. armigera* reared on the modified diet for up to six consecutive generations indicate that the pupal recovery percentage ranged from 71.2 to 83.7 and the adult emergence percentage varied from 59.6 to 78.4. Similarly, Babu *et al*., (2014) [5] also reported that adult emergence ranged from 68.7 to 83.3% and 60.4 to 81.2% respectively in the first and second generations of rearing of *H. armigera* while the highest adult emergence was observed in insects reared on modified chickpea flour diets (83.3%) followed by those reared on the wheat germ diet which were similar to the present observation.

Total life cycle

The total life cycle of *H. armigera* from egg to adult was recorded as 39.69 to 45 days on all hosts. However, the minimum total life cycle of male *H. armigera* (38.83 days) was recorded in urdbean leaves and pods while the maximum total life cycle of male *H. armigera* (39.69 days) was recorded in urdbean flour based diets which were found to be statistically non-significant to other diets. On the other hand, the minimum total life cycle of female *H. armigera* (41.93 days) was recorded in urdbean leaves and pods while the maximum total life cycle of female *H. armigera* (45.00 days) was recorded in urdbean flour based diets which were found to be statistically non-significant to other diets. The findings are in close agreement with Kumar (2011) [14] who reported that the pre oviposition, oviposition and post oviposition periods of the moth were found more in artificial diets (3.33, 5.78 and 2.13 days, respectively) followed by chickpea (3.11, 5.58 and 2.08 days, respectively), pea (2.62, 5.19 and 1.98 days, respectively) and pigeon pea (2.61, 4.55 and 1.53 days, respectively).

Table 2: Development periods of eggs and larvae of *H. armigera* (Hubner) on different diets

Main diet ingredient	Period of development* (Mean ± S.D)							Total life period (Days)	
	Larval weight (mg)	Larval survival Percent #	Pre-pupal period (days)	Pupal period (days)	Percent pupation	Pupal weight (mg)	Percent Adult emergence #	Male	Female
Chickpea flour based diet	$417.63^{f} \pm 15.17$ (21.04)	93.53^{f} (75.29)	$2.17^{d} \pm 0.15$ (1.63)	$11.37^{ab} \pm 0.26$ (3.44)	91.06^{f} (72.78)	$371.56^{d} \pm 20.58$ (19.28)	85.33^{c} (67.49)	39.69	43.38
Mungbean flour based diet	$395.60^{e} \pm 28.42$ (19.89)	88.86^{e} (70.53)	$1.83^{ab} \pm 0.11$ (1.53)	$11.59^{ab} \pm 0.45$ (3.47)	83.53^{e} (68.53)	$349.69^{cd} \pm 17.62$ (18.73)	82.20^{b} (65.11)	39.77	43.23
Urdbean flour based diet	$389.24^{c} \pm 16.93$ (19.63)	86.67^{d} (68.68)	$1.95^{b} \pm 0.13$ (1.56)	$12.43^{c} \pm 0.22$ (3.59)	79.50^{d} (63.09)	$343.24^{c} \pm 16.75$ (18.64)	71.06^{ab} (57.45)	41.67	45.00
Chickpea leaves & pods (control)	$387.75^{d} \pm 16.89$ (19.70)	85.67^{c} (67.83)	$2.03^{c} \pm 0.09$ (1.60)	$10.28^{a} \pm 0.25$ (3.43)	77.73^{c} (61.84)	$279.63^{b} \pm 7.19$ (17.43)	71.01^{ab} (57.46)	36.53	40.45
Mungbean leaves & pods (control)	$364.00^{b} \pm 15.42$ (19.09)	82.20^{b} (65.07)	$1.78^{ab} \pm 0.03$ (1.51)	$11.31^{ab} \pm 0.33$ (3.47)	75.53^{b} (60.35)	$243.36^{ab} \pm 5.14$ (15.61)	68.86^{ab} (56.14)	37.43	40.91
Urdbean leaves & pods (control)	$353.00^{a} \pm 29.67$ (18.80)	80.00^{a} (63.47)	$1.65^{a} \pm 0.07$ (1.47)	$12.27^{b} \pm 0.31$ (3.58)	73.31^{a} (58.90)	$229.09^{a} \pm 4.54$ (15.15)	66.67^{a} (54.74)	38.83	41.93
SEm±	NS	1.068	0.059	0.181	1.185	NS	1.36	NS	NS
CD(P=0.05)	NS	3.292	0.184	0.558	4.097	NS	5.31	NS	NS

NS - Non Significant, # Data given in parentheses are Angular transformed values

*Data in the parentheses are Square root transformed values

In a column mean(s) followed by a same alphabet are non-significantly different at 5% in LSD

Table 3: Effect of different hosts on pre oviposition, oviposition, post oviposition periods, fecundity, longevity, and sex ratio of *H. armigera*

Main diet ingredient	Period of development *(Mean ± S.D)						
	Pre oviposition period (days)	Oviposition period (days)	post oviposition period (days)	Fecundity Egg/female)	Longevity (days)		Sex Ratio (M : F)
					Male	Female	
Chickpea flour based diet	$3.19^{c} \pm 0.20$ (1.92)	$5.53^{d} \pm 0.53$ (2.45)	$2.05^{ab} \pm 0.08$ (1.59)	$459.00^{e} \pm 19.23$ (21.43)	$7.77^{f} \pm 0.28$ (2.87)	$10.31^{d} \pm 0.28$ (3.29)	1: 1.72
Mungbean flour based diet	$2.43^{ab} \pm 0.24$ (1.71)	$5.29^{cd} \pm 0.30$ (2.41)	$2.27^{b} \pm 0.09$ (1.66)	$395.00^{cd} \pm 21.86$ (19.61)	$6.87^{d} \pm 0.29$ (2.71)	$9.83^{d} \pm 0.43$ (3.21)	1:1.23
Urdbean flour based diet	$2.53^{ab} \pm 0.27$ (1.74)	$5.23^{c} \pm 0.29$ (2.39)	$2.30^{c} \pm 0.03$ (1.67)	$363.00^{e} \pm 22.87$ (19.06)	$6.73^{c} \pm 0.31$ (2.68)	$8.85^{c} \pm 0.28$ (3.05)	1:1.19
Chickpea leaves & pods (control)	$3.05^{b} \pm 0.15$ (1.88)	$5.17^{bc} \pm 0.15$ (2.38)	$1.95^{a} \pm 0.06$ (1.56)	$386.70^{d} \pm 17.22$ (19.67)	$7.41^{e} \pm 0.33$ (2.81)	$9.63^{cd} \pm 0.30$ (3.18)	1: 1.51
Mungbean leaves & pods (control)	$2.38^{a} \pm 0.14$ (1.69)	$4.95^{b} \pm 0.13$ (2.33)	$2.03^{ab} \pm 0.04$ (1.59)	$375.00^{b} \pm 16.22$ (19.37)	$6.63^{b} \pm 0.16$ (2.67)	$8.71^{b} \pm 0.37$ (3.03)	1:1.17
Urdbean leaves & pods (control)	$2.41^{ab} \pm 0.17$ (1.72)	$4.73^{a} \pm 0.12$ (2.28)	$2.17^{ab} \pm 0.05$ (1.63)	$359.00^{a} \pm 20.53$ (18.95)	$5.59^{a} \pm 0.13$ (2.46)	$7.69^{a} \pm 0.31$ (2.86)	1:1.11
SEm±	0.115	Ns	0.159	0.196	0.027	0.027	ns
CD(P=0.05)	0.357	Ns	0.492	0.603	0.085	0.083	ns

NS - Non Significant, # Data given in the parentheses are Angular transformed values
*Data in the parentheses are Square root transformed values
In a column mean(s) followed by a same alphabet are non-significantly different at 5% in LSD

Pre oviposition, oviposition and post oviposition periods

The pre oviposition, oviposition and post oviposition periods of the moth (Table 3) were also observed longer when the larvae were fed on artificial diet (chickpea, mungbean and urdbean flour based diets) in compared to natural diets (chickpea, mungbean and urdbean leaves and pods).

The minimum pre-oviposition periods (2.47 days) was recorded in urdbean leaves and pods while the maximum pre-oviposition periods (3.19 days) was recorded in chickpea flour based diets followed by chickpea leaves and pods (3.05 days). In period of oviposition, the minimum oviposition periods (4.73 days) was recorded in urdbean leaves and pods while the maximum oviposition periods (5.53 days) was recorded in chickpea flour based diets followed by mungbean flour diets (5.29 days). In case of Post oviposition periods, the minimum post oviposition periods (1.95 days) was recorded in chickpea leaves and pods while the maximum post oviposition (2.30 days) was recorded in urdbean flour based diets followed by mungbean flour diets (2.27 days) which were found to be statistically significant to other diets.

Longevity of adult moths

The longevity of adult male moths was found to be longer than longevity of adult female moths. However, the minimum longevity of adult male moths (5.59 days) was recorded in urdbean leaves and pods while the maximum longevity of adult male moths (7.77 days) was recorded in chickpea flour based diets followed by mungbean flour based diets (6.87 days) which were found to be statistically significantly to other diets. On the other hands, the minimum longevity of adult female moths (7.69 days) was recorded in urdbean leaves and pods while the maximum longevity of adult female moths (10.31 days) was recorded in chickpea flour based diets followed by mungbean flour based diets (9.83 days) which were found to be statistically significantly to other diets.

The finding are in close agreement with Kumar (2011) [14] who reported that the longevity of adult moth was more and recorded as 8.18 days for male and 11.18 days for female in rearing of *H. armigera* on artificial diets which were similar to the present studied.

Fecundity

The minimum average number of eggs laid per female (359.00 eggs) were recorded in urdbean leaves and pods while the maximum average number of eggs laid per female (459.00 eggs) were recorded in chickpea flour based diets followed by mungbean flour based diets (395.00 eggs) and chickpea leaves and pods (386.00 eggs) which were found to be statistically significant to other diets. The above findings are in conformity with those of Tulsi *et al*., (2008) [23] who reported larvae fed on artificial diets has been found highest fecundity (556.67 eggs/female). Devi and Singh (2004) [10] however reported highest fecundity on chickpea (772.17 eggs/ female) and lowest on Khame akhabi (417 eggs/ Female). Babu *et al.*, (2014) [5] recorded 594-680 eggs per female on modified chickpea flour based diets as compared to 326.6 egg / female recorded earlier by Ahmad *et al*., (1998)[1], Singh and Rembold (1992) [20] suggested that even through the nutritive value of soybean diet was higher but consumption rate of larvae were more on chickpea diet as compared to others. From above data it was revealed that the fecundity of *H. armigera* on semi synthetic diet in comparison to natural diets as also reported by Tiwari and Prasad (2011) [22].

Sex Ratio

Considering the effect of different larval diets on the sex ratio of chickpea pod borer, it was evident that population of females outnumbered the males in artificial and natural flour diets. The highest sex ratio of 1:1.72 was obtained with chickpea flour based diets followed by 1:1.23 and 1: 1.19 for mungbean and urdbean flour based diets, respectively. However, the lowest sex ratio (1:1.11) was found in urdbean leaves and pods followed by mungbean (1:1.17) and chickpea (1: 1.51) leaves and pods. The present findings are in accordance with Tulsi *et al.*, (2008) [23] who also reported highest sex ratio was found on artificial diets. The findings are in close argument with Bisane (2013) [7] reported that the highest sex ratio of 1:1.2 was found with artificial diets of chickpea flour in comparison to natural diets (1: 1).

Table 4: Development indices of *H. armigera* on different diets

Diets	Growth Index	Larval period index	Pupal period index	Pupal index	Ovipositional index	Survival index	Success index
Chickpea flour based diet	3.328	1.000	1.000	1.145	1.264	1.200	1.086
Mungbean flour based diet	2.989	0.944	0.981	1.062	1.058	1.157	1.049
Urdbean flour based diet	2.521	0.859	0.932	1.000	1.000	1.000	0.948
Chickpea leaves & pods (control)	2.735	1.000	1.000	1.060	1.077	1.066	1.040
Mungbean leaves & pods (control)	2.537	0.940	0.891	1.029	1.045	1.032	0.973
Urdbean leaves & pods (control)	2.267	0.862	0.831	1.000	1.000	1.000	0.943
SEm±	0.053						
CD(P=0.05)	0.181						

Growth indices values on different diets

The lowest growth index (2.267) was found in urdbean leaves and pods followed by mungbean leaves and pods (2.537) and chickpea leaves and pods (2.735) (Table 4). The highest growth index (4.230) was recorded with Chickpea flour based diets which were found to be superior to rest of the treatments followed by (3.014) growth index of mungbean flour based diets. These results are comparable to the findings of Shahid *et al.* (1990) [19] and Devi and Singh (2004) [10] who obtained highest growth indices of (4.82) when the larvae were fed on chickpea flour diets and also observed that more than one unit was found in ovipositional index of chickpea pod borer on artificial diet. Similarly, Surana *et al.*, (2004) [21] also reported that the highest growth index of *H. armigera* on chickpea and lowest on linseed. The larval period index, pupal period index on mungbean and urdbean did not exceed unity and therefore appeared to be inferior host plants as compared to chickpea. However, success index showed more than value one was classified as superior diets, while diets showing 1=1 value was classified as at par with standard diet. These results agree with our findings that artificial diet of chickpea showed more than one value (1.086) and at par with artificial diet of mungbean (1.036).

Observation on the growth and development of *H. armigera* on different diets showed that artificial diets (chickpea, mungbean and urdbean flour based diets) had relatively longer larval period, pre-pupal period percent pre-pupa and pupal period as compared to natural diets (chickpea, mungbean and urdbean leaves and pods). Moreover, larval weight and pupal weight also observed highest on artificial diets (chickpea, mungbean and urdbean flour based diets) followed by natural diets (chickpea, mungbean and urdbean leaves and pods). Percent pupation and adult emergence was also recorded highest in artificial diet followed by chickpea leaves and pods and lowest on urdbean leaves and pods. Effect of different tested diets on pre-oviposition, oviposition, post oviposition and fecundity was also found better in artificial diets followed by chickpea, mungbean and urdbean leaves and pods (control). However, the sex ration obtained after feeding the larvae on different diets differ significantly. The growth index, larval period index, pupal period index, pupal index, ovipositional index, survival index and success index value were found highest with artificial diets followed by Natural diets (chickpea, mungbean and urdbean leaves and pods). The overall growth index and development of H. armigera was also judged on the basis of general growth index, and success index which reveal that artificial diets (chickpea flour based diets) were highly suitable for rearing larvae of *H. armigera* followed by mungbean flour based diets used for rearing of *H. armigera*.

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