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Intrinsic growth rate of *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) feed on three sweet sorghum varieties

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Abstract. Study on the intrinsic growth rate of *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidea) on three varieties of sweet sorghum carried out in the Entomology Laboratory of Indonesia Cereals Research Institute (ICERI) in Maros, lasted from August 2013 to April 2014. One of the basic information needed to support successful control of *H. zea* is knowing its bioecology. Detailed information on this is still rare in Indonesia. Integrated Pest Management (IPM) is control strategy with the ecological approach with a basic knowledge of bioecology (biotic potential) of a pest. Biotic potential of a pest can be expressed quantitatively by a parameter called the intrinsic growth rate. This study was aimed to determine the intrinsic growth rate of *H. zea* on 3 varieties of sweet sorghum - *Sorghum bicolor* L. Moench (Super 1, Super 2 and Numbu). Larvae and pupae were collected from sweet sorghum crop in ICERI Experimental Farm, and then propagated in the laboratory in plastic containers individually. Each larvae was fed according to the origin of the larvae have been collected. Larvae and pupae were maintained until become a moth, and then allowed to mate and lay eggs. The moths were feed with 10% honey solution. The mass reared insect would be used on the study of life probability and fecundity of *H. zea*. The life probability study performed by means of: 300 newly laid eggs (F1), kept up to become adults. Each egg put in a container and maintained until became larvae. The neonate larvae fed on Super 1, Super 2, and Numbu sweet sorghum grain (100 larvae each variety). Observations were made every day, by counting the number of eggs hatched, larvae, pupae and moths alived. The study on fecundity of *H. zea* moth was done by: a pair of *H. zea* (F1) from each variety put in container for egg laying. This activity was carried out with 5 replications. Observations were made each day by counting the number of eggs laid until the female moths were died. Sex ratio is determined by observing all the eggs are laid until they became larvae, pupae and moths from 3 pairs per variety. The analysis results showed that the intrinsic growth rate (r) of *H. zea* at Super 1, Super 2, and Numbu were 0.107, 0.152, and 0.149 individuals per day respectively. Net reproductive rate (R_0) at Super 1, Super 2, and Numbu were 29.09, 117.45, and 104.17 times/generation respectively. Average length of life cycle (T) at Super 1, Super 2, and Numbu were 31.24, 31.32, and 31.17 days respectively. The growth rate model was $N_t = N_0.e^{rt}$, so that a moth of *H. zea* can develop into 44 females for 35 days on Super 1, 206 females for 35 days on Super 2, and 184 females for 35 days on Numbu.
Key Words: life tables, life probability, fecundity, Super 1, Super 2, Numbu.

Introduction. Corn earworm, *Helicoverpa zea* (Boddie) (syn. *Heliothis zea*) beside as a major pest of corn (*Zea mays* L.), it is also known as major pests of sorghum (*Sorghum bicolor* L. Moench) (CABI 2004). Chamberlin & All (1991) reported that *H. zea* and *Spodoptera frugiperda* are the most damaging lepidopterous pests on sorghum during whorl-stage. Since it is a polyphagous, it has many different common names (Kalshoven 1981; Capinera 2005, 2007). When the larvae feed on corn is known as corn earworm, larvae feed on cotton known as the cotton bollworm, the larvae feed on tomatoes known as the tomato fruitworm, and when the larvae feed on sorghum known as sorghum headworm (CABI 2004). Field observations on sweet sorghum grown in Pangkep former mining land of PT Semen Tonasa during the dry season in 2012 discovered the attack of *H. zea* with high population (Pabendon, personal communication). Similarly, based on direct observation on sweet sorghum crop in the Indonesian Cereals Research Institute (ICERI) Experimental Farm, *H. zea* population was 6-16 larvae per hill on Numbu variety, and 7-9 larvae per hill on varieties Super 1 and Super 2.

According to CABI (2004) and Soper et al (2013), *H. zea* is a pest that has important economic significance, the second place in North America. Soper et al (2013) suggested that in the suitable condition, *H. zea* populations could cause significant yield reduction when the larvae feed on grain sorghum during the grain-filling phase. Teetes & Pendleton (2000) mentioned that the economic threshold of *H. zea* on sorghum is 1-3 larvae/panicle (Teetes & Pendleton 2000; Knutson & Cronholm 2007).

Control of this pest from year to year undergone a revolution that started with traditional way and now the use of synthetic pesticides with broad scale. With the use of ineffective pesticide, it was resulting in impacts on environments. According to Miller (2004), over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, because they are sprayed or spread across entire agricultural fields. Therefore it is recommended to control *H. zea* with an ecological approach in accordance with the concept of Integrated Pest Management (IPM). This method has the basic bio-ecology considering the control tactics to bring the least possible disruption to the environment. One of the basic information needed to support the success on controlling *H. zea* is by knowing the bioecology of the pest. Research on various aspects of bio-ecology of *H. zea*, especially regarding its biotic potential can be expressed quantitatively by a parameter called the intrinsic growth rate (r) (Southwood 1978; Weisstein 2014). Intrinsic rate of growth (r) is the growth rate of individual insects in a certain physical condition in an infinite environment and its effect of the increase in insect populations are not taken into account. Population growth in an unlimited environment follows an exponential model (Tarumingkeng 1994; Weisstein 2014).

This study was aimed to determine the intrinsic growth rate of *H. zea* on three sweet sorghum varieties: Super 1, Super 2, and Numbu.

Material and Method

Mass rearing of Helicoverpa zea. This study was conducted at the Indonesia Cereals Research Institute (ICERI) Entomology Laboratory, which lasted from August 2013 to April 2014. Sorghum grain of Super 1, Super 2, and Numbu as feed of larvae were taken from the fields at the Maros Experimental Farm. *H. zea* larvae and pupae were collected from sweet sorghum crop in the field. Based on characteristics of egg, larvae, pupae, and adult morphologies, it was identified that the species was *H. zea.* Collected larvae and pupae were taken to the laboratory to be propagated individually in a plastic container with the size of 6 cm in diameter and a height of 7 cm, the center of the hole in the container lid was covered with a gauze for ventilation. In each container the larvae was feed with soft-dough phase sweet sorghum grain in accordance with the origin of the larvae collected.

Feeding and cleaning of containers was done in every 2 days, until the larvae become pupae and then become moths. The newly formed moths were mated in a plastic box with the size of 15 cm in height and 23 cm in diameter, the center of the container lid perforated for ventilation gauze. Inner side of the container coated with filter paper, and then put the silk of young corncobs as a place for the female moths to lay eggs. Ten percent honey solution was put into a container as feed and replaced every 2 days. Eggs laid on corn silk and paper filters as a batch of cohort from each variety were collected and counted, put into a container with the size of 37 cm x 29 cm x 8 cm, fed with grain of Super 1, Super 2, and Numbu (according to the original feed of the larvae).

Life probability of Helicoverpa zea. To determine the life probability of eggs, larvae, pupae and moths of *H. zea*, observed by means of: 100 of newly laid eggs maintained until became larva, pupa and moth. Eggs were put in the containers (6 cm height and 7 cm diameter) individually. On the fourth day after eggs laid, the egg hatched became neonate larvae. Neonate larvae were fed with sorghum grain of Super 1, Super 2, and Numbu (3 panicles/varieties/100 larvae). Observations and feeding was done every day until the larvae become moths.

Fecundity of Helicoverpa zea moths. To determine the pre-egg laying period, egg laying period, the post-egg laying period, and the number of eggs laid, done by: 2 virgin females and 1 male adult were put in a plastic container. The moths used were taken from mass rearing on Super 1, Super 2, and Numbu. Observation of the number of eggs laid by female counted every day until the female died. Each treatment (Super 1, Super 2, and Numbu) repeated 5 times. Observation was done on number of egg laid by a female and counted everyday until the female was dead. To determine the sex ratio, number of male and female moths from Super 1, Super 2, and Numbu was calculated. Parameters observed: the eggs were hatched and non-hatched, larval stadia, pupal and moth stadia.

Nutrient content of three sweet sorghum varieties. This activity was carried out in the Center for Postharvest Laboratory Testing. The type of analysis performed was the analysis of water content and ash content by gravimetric method, fat content by Soxhlet method, protein content by the Kjeldahl method, carbohydrates content by different methods, and amylose and tannin content by Spectro.

Data analisys. Data were analyzed based on Birch (1948), Tarumingkeng (1994), and Weisstein (2014) methods containing age range (x), number of a life individual at age x (lx), and number of female off-springs at age x (mx). By his mean, intrinsic growth rate (r), net reproductive rate (R_0), average period of one generation (T), a moment birth value (b), a moment death value (d), limited growth rate (λ) could be calculated using formula as follows:

Net reproductive rate (R_0):

$$R_0 = \sum lxmx$$

Average period of one generation (T):

$$T = \sum xlxmx / \sum lxmx$$

Intrinsic growth rate (r):

$$r = LnR_0/T$$

Limited birth value (β):

$$\frac{1}{\beta} = \sum_{x=0}^{m} lx.e^{-r(x+1)}$$

A moment birth value (b):

$$b = \frac{r\beta}{e^r - 1}$$

A moment death value (d):

$$d = b - r$$

Limited growth rate (λ):

$$\lambda = \text{antilog } e^r$$

Results and Discussion. The result of species identification based on its morphology, it was known that the collected larvae from the field were *H. zea* (Teetes et al 1983; CABI 2004). The results also showed that *H. zea* female adults laid eggs after copulation on the third day as an adult. Eggs were laid on the silk of corn or on filter paper lining the containers. Number of eggs laid by a female every day was listed in Table 1. A female laid eggs on sweet sorghum varieties Super 1, Super 2, and Numburanging from 5-217, 15-357, and 7-301 respectively (Table 1). The eggs hatched on day 4 after laid, hatched during the day between 10:00 to 12:00 a.m. Blanco et al (2010) suggested that a female of *H. zea* can lay eggs between 450-3000 and will hatch within 2-5 days. Furthermore Teetes et al (1983) and Mayer et al (2003) suggested that a female of *H. zea* can lay eggs between 350-3000 and will hatch within 2-5 days. When newly laid, the eggs are light green to red in colour and then turn into a greyish at time before the hatch (Figure 1). CABI (2004) suggested that *H. zea* eggs subspherical, radially ribbed and placed on the panicle and grain sorghum.

Table 1

Number of eggs laid everyday by a female of *H. zea*. Temperature 24.17-26.64^{o}C. Entomology Lab, ICERI

Varieties	*Egg period*	*Number of egg laid*		*Standard deviation*
		Range	*Average*	
Super 1	1st day	87-217	165.4	46.47
	2nd day	103-149	120.2	16.33
	3rd day	0-182	66.6	64.13
	4th day	0-5	1.4	1.96
Super 2	1st day	217-357	280.4	70.47
	2nd day	133,216	169.4	31.00
	3rd day	15-197	87.6	59.76
	4th day	0-65	21.4	23.74
Numbu	1st day	215-301	275.4	33.48
	2nd day	79-283	180.2	65.84
	3rd day	11-132	49.0	44.23
	4th day	0-7	2.8	2.79

Figure 1. Three days old of *Helicoverpa zea* eggs. Temperature 24.17-26.64^{o}C. Entomology Lab, ICRI.

The lx curve or survivorship curves give an idea of the level of mortality of individuals in the population. *H. zea* mortality rate was the same in all feeding: Super 1, Super 2, and Numbu. All of them could survive up to 35 days (Figures 2a, 2b, and 2c). Figure 2a shown that the life probability (lx) of *H. zea* initially a flat line means that there was no mortality of eggs and young larval stages (1st and 2nd stages). Furthermore lx curve declined slowly on day 12 after the third stage larvae (mortality 12%), then a steep decline at day 15 (4^{th} and 5^{th} larval stages) means that the larval mortality as high as 59%, then lx curve leveled at the pupal stage means no pupal mortality. In Figure 2b, it is seen that the curve of lx initially a flat line means the chances of survival of the egg stage, 1^{st} and 2^{nd} stage of larvae was 100%. Furthermore lx curve decreases slowly on day 12, which means there was a mortality of 3^{rd} stage larvae as much as 12%. Furthermore lx curve on day 16 decreased the mean mortality of 4^{th} and 5^{th} stage of larvae as high as 41%. In the pupa stage, lx curve became horizontally means no pupal mortality. Furthermore lx curve declined drastically to the point of zero after becoming a moth. This means that adult (both male and female) mortalities occurred after copulation and lay eggs. In Figure 2c, it is seen that the curve of lx initially a flat line means that there was no mortality of eggs and young larval stages (1^{st} and 2^{nd} stages). Furthermore lx curve decreases slowly on day 12 after the 3^{rd} stage larvae (10% mortality). Furthermore lx curve steep decline at day 15 when the larval stages 4 and 5, with a mortality of 31% and 42% respectively. On day 21 (pupal stage), the lx curve became flat means no pupal mortality. The lx curve declined drastically to zero after becoming adult. This means that adult (both male and female) mortalities occurred after copulation and lay eggs. The life probability of larvae fed on Super 1 steep decline more rather than the larvae fed on Super 2 and Numbu (Figures 2a, 2b, and 2c). This was caused by high levels of mortality in the larval stage 3, 4, and 5 are: 59 percent.

Figures 2a, 2b, 2c also showed the fecundity (mx) of *H. zea* feed Super 1, Super 2, and Numbu. The mx curve is a curve which gives an idea of the number of female offspring produced by a female moth that lived between ages x to x+1 in a given time. On the figures, it was seen only one peak of mx on all varieties, that occurred on day 31^{st} (the first egg laying). After that the curve declined slowly until it reaches the zero point. In such a situation the female and male moths approaching death (Figures 2a, 2b, 2c). In all varieties, pre-reproductive period was 3 days, the reproductive period was 3-4 days, post-reproductive was 3-4 days. This means that different feed did not affect the fecundity of *H. zea*.

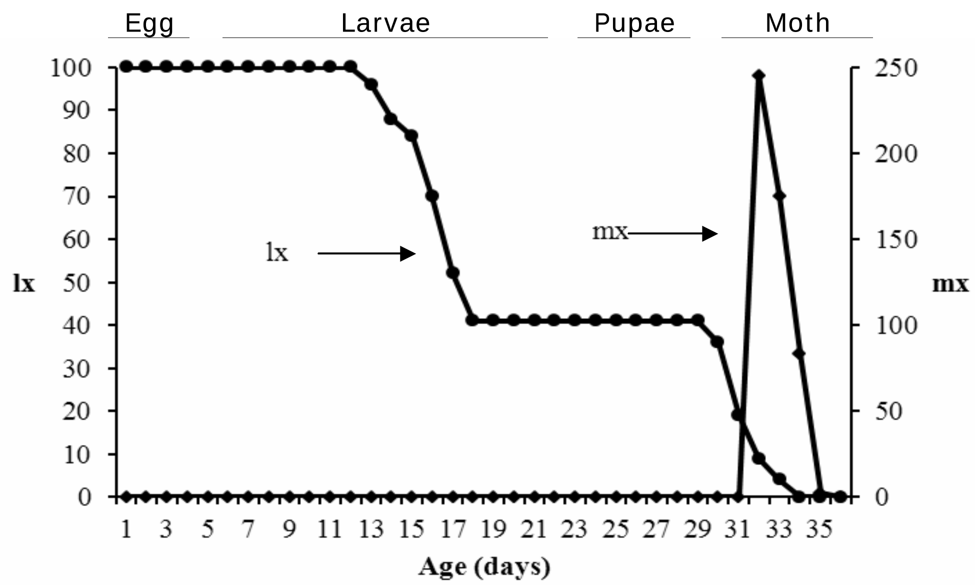

Figure 2a. Life probability (l_x) and fecundity (mx) curves of *H. zea* on Super 1. Temperature 24.17-26.64^{o}C. Entomology Lab, ICRI.

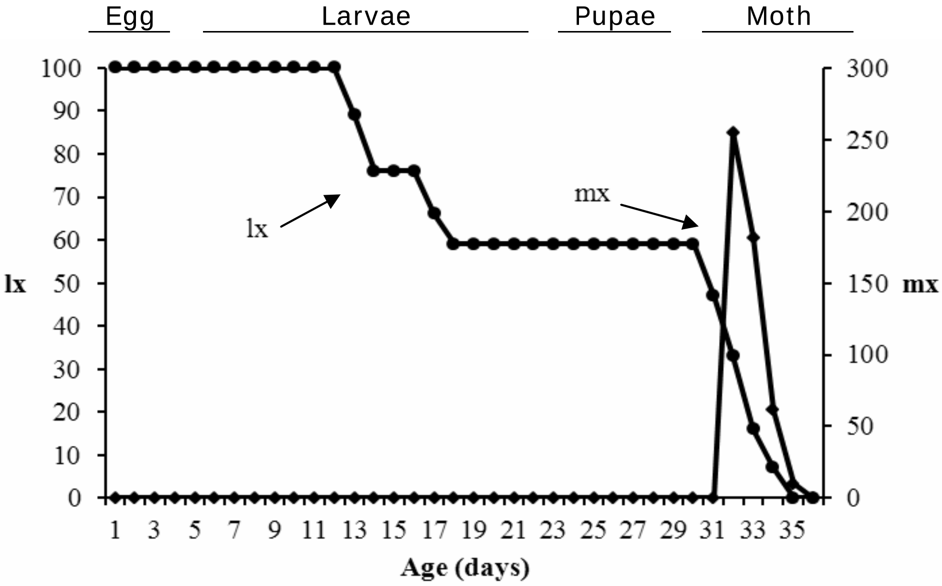

Figure 2b. Life probability (l_x) and fecundity (mx) curves of *H. zea* on Super 2. Temperature 24.17-26.64^{o}C. Entomology Lab, ICRI.

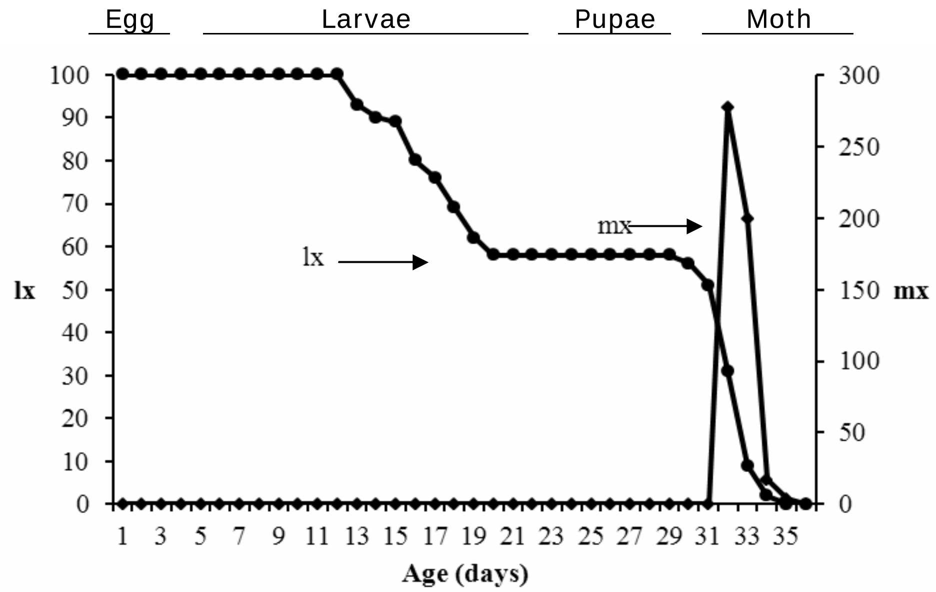

Figure 2c. Life probability (l_x) and fecundity (mx) curves of *H. zea* on Numbu. Temperature 24.17-26.64^{o}C. Entomology Lab, ICRI.

The calculation of the intrinsic growth rate (r) of *H. zea* on Super 1, Super 2, and Numbu began by calculating the net reproductive rate (R_0). The development from egg to adult for all three varieties was the same that began on day 29, both males and females. Female laid eggs on day 3 after becoming an adult and copulated. The first egg laid occurred on day 31. Ratio between the number of males and females that could reach adulthood on Super 1 was 1:1.5 on Super 2, and 1:1.1, and 1:1.2 on Numbu. Early life table of moths on Super 1, Super 2, and Numbu was counted from the first time of female laid eggs (x = 31 days). On Super 1, life probability of pre-adult from egg to adult was 0.09 and female offspring at x = 31 days as much as 245.40, then the initial moth life table (l_xm_x) = 0.09 x 245.40 = 22.09. Furthermore l_xm_x value was obtained from each age group, and the amount of that value (Σ l_xm_x) = R_0, so that R_0 = 29.09. This means that the population of *H. zea* female moth increased to 29.09 times per generation on environmental conditions infinity (Table 2). On Super 2, life probability of pre-adult from egg to adult was 0.33 and female offspring at x = 31 days as much as 254.80, then the initial moth life table ($l_x m_x$) = 0.33 x 254.80 = 84.08, so that R_0 = 117.46. This means that the population of *H. zea* female moth increased to 117.46 times per generation on environmental conditions infinity (Table 2). While on Numbu, the life probability of pre-adult from egg to adult was 0.31 and female offspring at x = 31 days as much as 277.0, then the initial moth life table ($l_x m_x$) = 0.31 x 277.0 = 85.87, so that R_0 = 104.18. This means that the population of *H. zea* female moth increased to 104.18 times per generation on environmental conditions infinity (Table 2).

Comparison of populations of *H. zea* at Super 1, Super 2, and Numbu through R_0 is different, ie on Super 2 (R_0 = 117.46) it appears that the increase in the female moth population each generation is higher than that on the Super 1 (R_0 = 29.09). This is because the 3rd and 4th stage of larval mortality on Super 1 was high. These differences indicate that the Super 2 variety is the best food source for the growth of *H. zea* larvae. This result is in line with the results of Soper et al (2013) that the influence of diet of *H. zea* on sorghum grain at soft-dough stage showed a positive response, and suggests a link between the quality of the host and the growth and development of the larvae. Because the population of *H. zea* on all sorghum varieties through R_0 is different, the average time of one generation (T) on Super 1, Super 2, and Numbu also different i.e. 31.24, 31.32, and 31.17 days respectively (Table 2).

Intrinsic growth rate (r) is constant for a constant environmental condition. When environmental conditions change then r will also change. The value of r was greater in Super 2 and Numbu, compared to Super 1. Nevertheless the values are not a portrait of *H. zea* fail or succeed in the fight of its life. According to Arifin (1992), nature may have set the r value of a species. When r of a species is larger, allowing the species succeed in competing with other species. And when r value is small, means that the species can prevent a rate increase in the population, so the food reserves in the environment is not quickly exhausted.

Birch (1948), Tarumingkeng (1994), and Weisstein (2014) suggested that R_0 is analogous to λ (limited growth rate), the difference R_0 is defined as a long time = generation time T, while λ is for a specific short time range (t) which is generally days. The results of calculation after r value on Super 1, Super 2, and Numbu was counted, the value of λ on varieties Super 1, Super 2, and Numbu also known, i.e. 1.11, 1.16, and 1.16 respectively. This means that the population of *H.zea* became 1.11 times per day at the Super 1, 1.16 times per day on the Super 2, and 1.16 times per day on Numbu (Table 2). By knowing the value of r, the stable birth of the female of *H. zea* (β) at Super 1, Super 2, and Numbu can be determined, i.e. 0.1167, 0.1650, and 0.1616 respectively. A population has a birth rate (b) and death rate (d). The birth rate (b) of *H. zea* on Super 1, Super 2, and Numbu was 0.1167, 0.1527, and 0.1498 respectively. While the death rate of *H. zea* on Super 1, Super 2, and Numbu was 0.0026, 0.0006, and 0.0008 respectively (Table 2).

Table 2

Value of some population attribute of *H. zea* on 3 sweet sorghum varieties. Temperature 24.17-26.64^{o}C. Plant Pathology Lab, ICERI

Symbol	*Remark*	*Population attribute value at 3 different sorghum varieties*		
		Super 1	*Super 2*	*Numbu*
R_0	Net reproductive rate	29.09	117.46	104.18
T	Generation time (day)	31.24	31.32	31.18
r	Intrinsic rate of natural increase	0.11	0.15	0.15
λ	Limited growth rate	1.11	1.16	1.16
b	A moment birth value	0.1167	0.1527	0.1498
d	A moment death value	0.0026	0.0006	0.0008
β	Limited birth	0.1167	0.1650	0.1616

Based on the method of Birch (1948) by using the values of l_x and m_x in each age group x, it was obtained some population attribute values of *H. zea* (Figures 2a , 2b , and 2c) . Net reproductive rate R_0 on Super 1 was 29.09 lower than that on Super 2 (117.46) and Numbu (104.18). This difference was due to the high mortality of 3rd instar larvae and it was coming down drastically. Because of the differences in these values, the development and speed to achieve the maximum value of m_x and the time (T) of each generation was different for the three varieties. Intrinsic growth rate of *H. zea* on those three varieties was different, so that the exponential growth of population was also different (Figures 3a, 3b, and 3c).

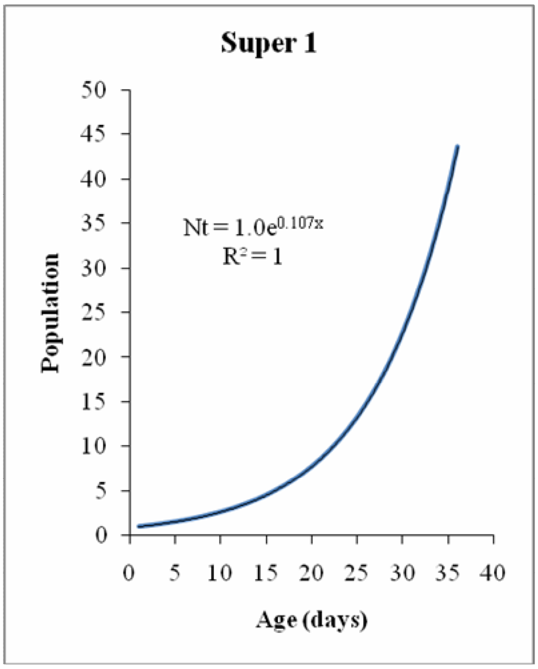

Figure 3a. Growth rate of *H. zea* population on sweet sorghum Super 1. Temperature 24.17-26.64°C. Entomology Lab, ICERI.

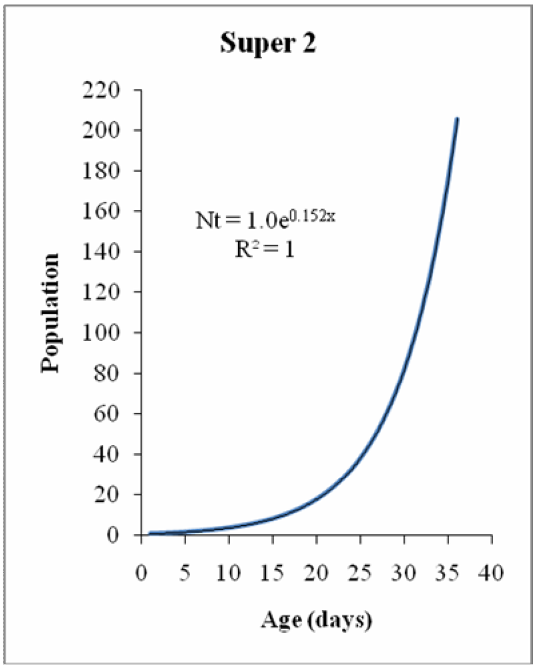

Figure 3b. Growth rate of *H. zea* population on sweet sorghum Super 2. Temperature 24.17-26.64°C. Entomology Lab, ICERI.

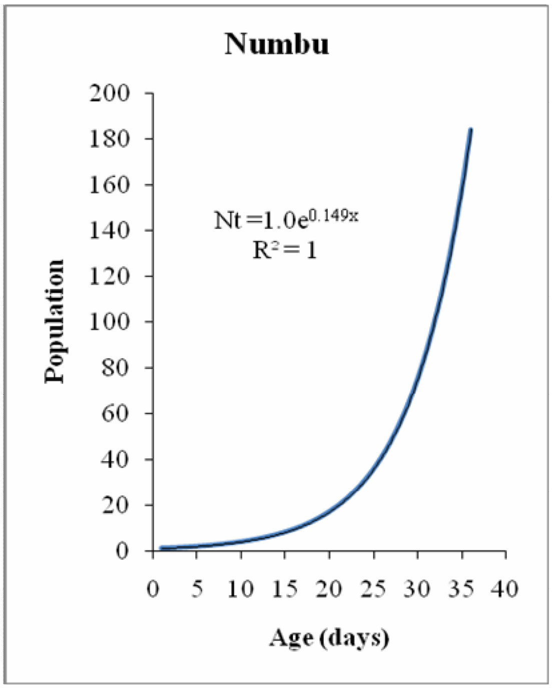

Figure 3c. Growth rate of *H. zea* population on Sweet Sorghum Numbu. Temperature 24.17-26.64°C. Entomology Lab, ICERI.

In Figures 3a, 3b and 3c it is shown that with the exponential population grow quation $N_t = N_0.e^{r.t}$, a female moth of *H. zea* on Super 1 can produce 44 female offsprings for 35 days (Figure 3a), while on Super 2, a female adult of *H. zea* can produce 206 female off springs for 35 days (Figure 3b), and on Numbu, a female moth of *H. zea* can produce 184 female offsprings for 35 days (Figure 3c). The number of female offspring produced at the Super 1 is the lowest when compared to the Super 2 and Numbu. This may be caused by high tannin content in the Super 1 ie 278.82 mg/100 g, while the Super 2 = 176.83 mg/100 g, and the Numbu = 170.05 mg/g (Table 3). According to Diawara et al (1991), chemical compounds (crude fiber concentration, acidity, and tannins) in grain sorghum at hard-dough stage is positively correlated to the resistance of *Spodoptera frugiperda*.

Selection of the host (the larvae feed) by *H. zea* can be affected by the nutrient content of plant material that is interesting or eating stimulants, or contain chemicals that are repellent (Rahmini et al 2012). The results of the nutrient content analysis of grain sorghum Super 1, Super 2, Numbu at soft-dougt stage are showed on Table 3.

Table 3

Nutrient grain contents of 3 sweet sorghum varieties at soft-dough stage

Nutrient	*Composition*		
	Super 1	*Super 2*	*Numbu*
Water content (%)	56.68	51.68	53.99
Ash content (%)	1.88	1.98	1.66
Fat content (%)	3.51	3.35	3.10
Protein content (%)	5.55	5.47	5.11
Carbohydrate (%)	32.38	37.52	36.14
Amilose (%)	1.81	1.47	1.09
Tannin (mg/100g)	278.82	176.83	170.05

Conclusions. *H. zea* is a pest with moderate potential on sweet sorghum varieties Super 1, Super 2, and Numbu. The intrinsic growth rate (r) of *H. zea* at temperatures from 24.17 to 26.64°C in the laboratory was different in three sweet sorghum varieties (Super 1, Super 2, Numbu) which were 0.10, 0.15, and 0.15 espectively. Average time of one generation (T) was different for each variety. The average time of one generation on Super 1 was 31.24 days, on Super 2 was 31.32 days, and on Numbu was 31.18 days. The limited growth rates (λ) on Super 1, Super 2, and Numbuwere 1.11, 1.16, and 1.16 times per day respectively. The birth rates (b) on Super 1, Super 2, and Numbu were 0.1167, 0.1527, and 0.1498 respectively, while the death rates on Super 1, Super 2, and Numbu were 0.0026, 0.0006, and 0.0006 respectively. A female moth of *H. zea* produced female offspring as many as 44 for 35 days on Super 1, 206 for 35 days on Super 2, and 184 for 35 days on Numbu.

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