DEVELOPMENT OF *Helicoverpa armigera* HÜBNER, 1805 AND *Spodoptera frugiperda* SMITH, 1797 IN WINTER FORAGES

DESENVOLVIMENTO DE Helicoverpa armigera *HÜBNER, 1805 E* Spodoptera frugiperda *SMITH, 1797 EM FORRAGEIRAS DE INVERNO*

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ABSTRACT: *Helicoverpa armigera* Hübner, 1805 and *Spodoptera frugiperda* Smith, 1797 are polyphagous pests of great agricultural importance in subtropical and temperate climate regions. The usual management of production areas in the southern region of Brazil occurs after the harvesting of summer crops, and the areas are sown with pasture. Thus, forages recommended for grazing are azevém (*Lolium multiflorum* Lam.) and cornichão (*Lotus corniculatus* L.) due to their nutritional benefits, good palatability, regrowth, and hardiness. Considering the high degree of polyphagia of *H. armigera* and *S. frugiperda,* and the impact of maintaining continuous feeding areas (green bridges) in the management of these species, this work aimed to evaluate the development of *H. armigera* and *S. frugiperda* fed leaves of azevém and cornichão under laboratory conditions. The insects were collected in the city of Capão do Leão/RS in corn and soybean plantations. For each forage species, 130 newly hatched caterpillars were each placed in autoclaved glass tubes, with one-third of the tube length containing forage. The tubes were capped with waterproof cotton and placed in a climate-controlled room at 25 ± 1°C, 70 ± 10% relative humidity, and a 12-h photophase. The food was replenished daily until the caterpillars entered the pupae stage. The pupae were sexed and weighed, and the newly emerged adults were placed in pairs in PVC cages, lined with white A4 sulfite paper. The papers used as a laying substrate were removed and changed daily, and eggs were counted. The number of instars was determined by the linearized Dyar rule model. The complete randomization design was employed for the variables biological cycle length and viability of egg, caterpillar, pre-pupa, pupa, adult, and pre-oviposition phases and weight of caterpillars on the 14th day and pupae after 24 h. Based on the results obtained, a fertility life table was prepared. *H. armigera* did not complete the cycle, with only three instars and a duration of 22.1 and 24.6 days in azevém and cornichão, respectively. When evaluated in *S. frugiperda* caterpillars, development in forage species was observed, with five and six instars and duration of 51.7 and 45.1 days in azevém and cornichão, respectively. The azevém was distinguished by interference in the development cycle of the species, reducing the effect of the green bridge. In addition, surviving insects were susceptible to the effects of the agroecosystem due to the low-quality food source.

KEYWORDS: Covering plants. Insect resistance management. Cultural management. Constitutive resistance. Resistance of plants.

INTRODUCTION

Tropical and subtropical agricultural production systems are characterized by the presence of plants throughout the year, with cultivation during the off-season. Thus, green bridges can be formed, favoring the survival of insect pests and the infestation of subsequent crops (ÁVILA; VIVAN; TOMQUEISKI, 2013; ROSA et al., 2014).

In the state of Rio Grande do Sul (RS), agriculture is characterized by the predominance of spring-summer crops, which represent more than 90% of total grain production (BINI; CANEVER, 2015). Irrigated rice is the most important crop in the state and is in rotation with pastures during the off-season (SANTOS, 2018). Corn and soybean crop also play relevant socioeconomic roles in the state, especially for small farmers involved in the production of swine, poultry, and dairy cattle (MACHADO; FONTANELI, 2014; BERNARDES et al., 2015).

The most commonly used temperate forage species is azevém (*Lolium multiflorum*, Lam.) (Poaceae) consortium with a legume, which is usually cornichão (*Lotus corniculatus*, L.)

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(Fabaceae). These plants adapt to the climate, have rusticity to grazing, are easy to plant, have resistance to diseases, and versatility when used in combination. In addition to consortium use, this increases the quality and diversification of the diet consumed by the animals (ROCHA et al., 2007; FONTANELI et al., 2012).

Thus, the predominant agricultural produce in the state of RS is that of rice, corn, and soybean grains during the hottest times of the year, and at lower temperatures (off-season), these are replaced by winter forages (ROCHA et al., 2007). Thus, highly polyphagous species, such as *Spodoptera frugiperda* Smith, 1797 (Lepidoptera: Noctuidae) and *Helicoverpa armigera* Hübner, 1808 (Lepidoptera: Noctuidae) can use this crop succession as a way of ensuring their year with greater impact on annual crops, in which they are better adapted.

The objective of this study was to evaluate the development of *H. armigera* and *S. frugiperda* fed leaves of azevém (BRS Ponteio) and cornichão (BRS Posteiro) under laboratory conditions, aiming to improve the management of these insect pests in intensive cropping systems.

MATERIAL AND METHODS

The experiments were conducted at the Embrapa Temperate Climate Bioefficiency Nucleus located in Capão do Leão – RS, Brazil, in an air-conditioned room at 25 ± 1°C with relative humidity (RH) of 70 ± 10% and a 12-h photophase.

Collection and breeding of insects

The insects were collected at the Terras Baixas Experimental Station in the municipality of Capão do Leão – RS, Brazil (S 31°49.268'S, 52°27.472'W, altitude 7 m) in corn and soybean crops in the 2015/2016 harvest, and were maintained on an artificial diet as reported by Greene, Leppla and Dickerson (1976) for three generations. Then, 150 eggs were collected from *H. armigera* and *S. frugiperda* and placed in two Petri dishes, 9 cm diameter, with moistened cotton fixed to the lid and sealed with plastic film (PVC). Dishes were kept in an air-conditioned room at 25 ± 1°C, RH of 70 ± 10%, and a 12-h photophase until the caterpillars hatched.

Obtaining winter forages

The plants used were azevém (BRS Ponteio) and cornichão (BRS Posteiro), with approximately 15 days. These species were sowed in pots with a capacity of 20 L and natural substrate based on humus, fiber, and clay (West Garden®).

Laboratory experiments

For each forage species, 130 newly hatched caterpillars were each placed in an autoclaved glass tube (2.5 cm diameter and 8.0 cm height) with one-third of their length containing the respective forage and moistened filter paper in distilled water. The tubes were capped with water-repellent cotton and placed in an air-conditioned room at 25 ± 1°C with RH of 70 ± 10% and a 12-h photophase.

Food was replenished daily until the caterpillars entered the pupa stage. At 24 h, pupae were sexed (BUTT; CANTU, 1962) and weighed (Shimadzu AUY-220). After weighing, the pupae were kept in autoclaved tubes as previously described, with moistened filter paper and were identified with the respective treatment until the emergence of adults.

Thirty couples of newly emerged adults were placed in PVC cages (10 cm diameter and 20 cm height), lined with white A4 sulphite paper (used as an oviposition substrate). A Petri dish with filter paper was placed in the lower part of the cage and the top was sealed with voile fabric. To feed the adults, hydrophilic cotton was moistened with a 10% honey solution and placed in a polystyrene Petri dish (49 × 12 mm) at the bottom of the cage.

The papers used as an oviposition substrate were removed and changed daily. The eggs were counted using a stereoscopic microscope (Leica - S8 APO). Eggs on the top layer were counted and multiplied by the total number of layers. The eggs were placed in an air-conditioned room at 25 ± 1°C with RH of 70 ± 10% and a 12-h photophase for the evaluation of viability.

Experimental design

The number of surviving insects was compared between treatments by the Long-Rank test and the Kaplan-Meier method (Proc Lifetest) (SAS, 2014). The number of instars was determined graphically, and hypotheses were formulated and tested using the linearized model of the Dyar rule (DYAR, 1980) with the software Mobae (Biostatistics Models for Entomology) to generate the growth rate (K) and coefficient of determination (R2) (HADDAD; MORAES; PARRA, 1995).

The design was completely randomized (DIC) for the variables-duration of biological cycle and viability of the egg, caterpillar, pre-pupa, pupae, adult, and pre-oviposition phases, caterpillar to day 14, and pupae after 24 h. The data were submitted to Bartlett 's tests to assess homoscedasticity, and to

Cramer von Mise for assessment of normality (Proc Univariate), by presenting variance heterogeneity transformed into $\sqrt{x+0.5}$. Then, data were subjected to analysis of variance (Proc Anova), and the means of the treatments (azevém/cornichão) were compared by a *t*-test ($P \leq 0.05$) (SAS, 2014).

Based on the results obtained, a fertility life table was produced, where x = the mean point of each age of the parental females; lx = life expectancy up to age x; mx = specific fertility or number of offspring per female produced at age x that will result in females; lxmx = total number of females born at age x (Silveira-Neto et al., 1976).

Using the information from the life table, the following parameters were estimated for each treatment: Ro (net rate of reproduction), T (average generation time), rm (intrinsic rate of population growth), λe (finite rate of population increase), and DT (time needed for the population to double). Then, these values were used to obtain the extrinsic growth rate, rm, and the generation interval, T, by the interactive method (SOUTHWOOD, 1995).

Fertility life table parameters and their confidence intervals were estimated using the Jacknife technique (MEYER et al., 1986) and the means were compared by the unilateral *t*-test ($P \leq 0.05$) using the software "Lifetable.sas" (MAIA; LUIZ; CAMPANHOLA, 2000) in the "SAS System" environment (SAS, 2014). A completely randomized design, with 20 replicates (one female = one replicate) per treatment (each forage = one treatment), was employed.

RESULTS AND DISCUSSION

Helicoverpa armigera fed on winter forage species did not complete larval development (Fig. 1). Barbosa et al. (2016) observed an average larval period of 12.7 days when fed an artificial diet, whereas a prolonged larval period was observed with forages such as wheat (14.3 days), black oats (19.0 days), and turnip (20.1 days) (SUZANA et al., 2015). An extended larval period is considered to be a compensatory action when the species is fed a host of low nutritional quality forages (SILVA et al., 2012). In this study, even though azevém (41.5 days) and cornichão (40.1 days) presented an extended larval period, *H. armigera* did not reach adulthood, indicating that this food had a detrimental effect on development.

Food scarcity may induce migration, which is an adaptive response by insects seeking shelter for survival and reproduction (CHAPMAN, 2012; DINGLE, 2014; ALVES, 2017). Under field conditions, populations of *H. armigera* are migratory and can travel long distances. Therefore, they can settle in other areas, and cause damage due to polyphagia of the species and their ability to adapt to adverse environments. A principle step of integrated pest management is area monitoring, which is indispensable for decision-making. Implementation of this method should involve the cooperation of nearby properties to prevent possible infestations in the adjacent areas (SCOTT et al., 2005; ÁVILA; VIVAN; TOMQUEISKI, 2013; ALVES, 2017).

The Wilcoxon test revealed no significant difference in the survival of *H. armigera* between the diets studied (Fig. 1). Studies evaluating the biology of *H. armigera* in different hosts have verified the development of caterpillars fed corn, which belongs to the same family as azevém. However, the physical, chemical, and physicochemical properties of the host plant may reduce the digestibility and interfere with the development of the insect pest (RODRIGUES, 2004; MENDES et al., 2016).

Black oats (*Avena strigosa* Schreb.), white oats (*Avena sativa* L.), and turnip (*Raphanus sativus* L.), prolonged the larval phase of *H. armigera* due to the inadequacy of these host plants (KOUHI; NASERI; GOLIZADEH, 2014; SUZANA et al., 2015). Mendes et al. (2016) evaluated the development of *H. armigera* in leaves of invading buva (*Conizia sp.*) for 35 days, but without completion of larval development. The above-mentioned forages are adapted to subtropical and temperate regions and can be intercropped with azevém and cornichão, which present late development cycles (FONTANELI et al., 2012). Thus, cultural management with species that present reduced nutritional quality can help to suppress insect pests.

Multimodal frequency distribution curves of cephalic capsule growth (mm), and with a determination coefficient (R^2) of 100%, revealed three cephalic capsule growth frequency peaks (Fig. 2 A; 2 B).

Regarding the growth rates (K) and the three-instar hypothesis, the values ranged from 1.6 (cornichão) to 1.8 (azevém). Therefore, the distribution of values for the width of cephalic capsules of *H. armigera* follows the Dyar rule (DYAR, 1980); the cephalic capsule of the caterpillars grows in geometric progression, ranging from 1.1 to 1.9 at each ecdise.

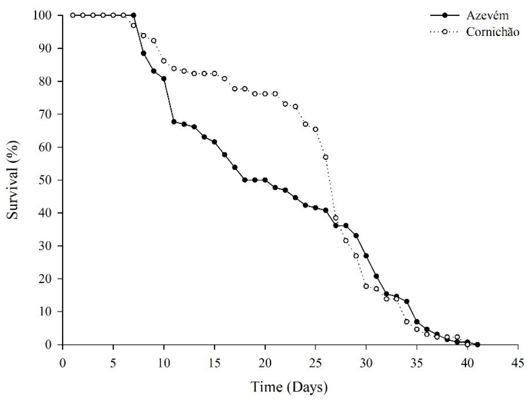

Figure 1. Survival of *Helicoverpa armigera* caterpillars fed winter forages. There is no difference between the survival curves for the caterpillars by the Wilcoxon test (GL= 1; X2 = 14.4092; PR = 0.0001 > 0.05).

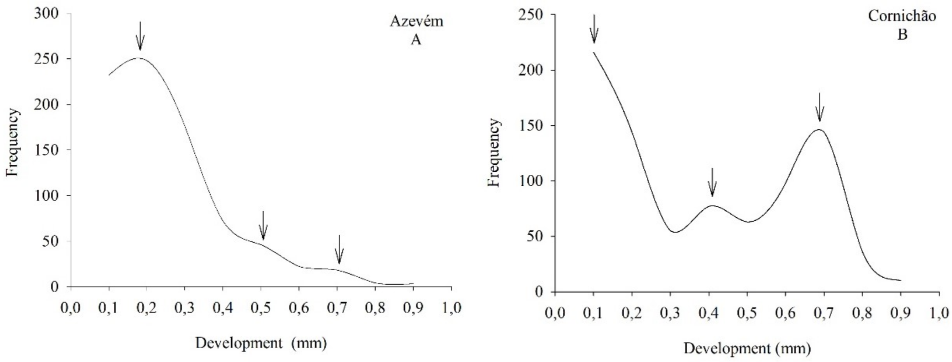

Figure 2. A. B. Multimodal frequency distribution curve of cephalic capsule growth (mm) in *Helicoverpa armigera* fed winter forages.
The arrows indicate instars.

The larval duration was significantly influenced by both forage species: azevém (22.1 days) and cornichão (24.6 days) (Table 1). This was also noted by Suzana et al. (2015), who suggested that azevém is not a suitable food for caterpillars, even without quantitative restriction due to its nutritional properties.

There was a significant difference (16.5 mg) in larval weight at day 14 between azevém (4.2 mg) and cornichão (20.7 mg) (Table 1). However, even when *H. armigera* does not complete its life cycle, it has potential as a host plant, as it develops on the host plant (PARRA, 2000; WAQUIL et al., 2008; BERNARDI et al., 2012).

Table 1. Duration (days) and weight after 14 days (mg) of *Helicoverpa armigera* fed winter forages in the laboratory at 25 ± 1°C with 70 ± 10% RH and a 12-h photophase.

Phase / Food	Azevém	Cornichão
Caterpillar	Duration (Days)	
	22.1 ± 0.89 b[1]	24.6 ± 0.73 a
	[130]	[130]
	Weight (mg)	
	4.2 ± 0.003 b[1]	20.7 ± 0.001 a
	[82]	[107]

[1]Means followed by the same letter in the line do not differ significantly from each other, by *t*-test (P < 0.05). Averages ± standard error. [ ] = number of observations.

The survival of *S. frugiperda* was higher in azevém (51.4 days) than in cornichão (45.1 days) (Figure 3).

The results of the Wilcoxon test showed that the type of diet consumed influences the biological cycle (egg-caterpillar-pupae-adult) of *S. frugiperda* (Fig. 3). In studies performed with corn and rice biotypes of *S. frugiperda* in RS, Busato et al. (2005) reported a total cycle of 32.1 and 31.3 days, respectively, which were lower than those observed in the present study. Nutritional properties of forages may have interfered in the development cycle by accelerating or lengthening one of the developmental stages.

Dias et al. (2016) reported an extended biological cycle of *S. frugiperda* in hosts less suitable to the species, especially crotalaria (*Crotalaria juncea* L.) due to the lower adaptation index. Those authors attributed the lowest rate of adaptation to phenolic compounds, which are secondary metabolites produced by plants. Tannins are also important because they present repellent and/or antinutritional actions and participate in metabolic pathways responsible for insect growth and reproduction (MONTEIRO et al., 2005).

The multimodal frequency distribution curves revealed a difference in forage function, with a coefficient of determination (R^2) of 99% reliability (Fig. 4. A; 4. B), with a growth rate (K) ranging from 1.5 (cornichão) to 1.8 (azevém). This variation in the number of instars is influenced by factors such as the population studied, which is linked to hereditary factors, nutritional quality, and food adaptability (PARRA; HADDAD, 1989; MIRANDA; MOREIRA; SIQUEIRA, 2010). Valicente and Tuelher (2009) fed *S. frugiperda* caterpillars with conventional corn and observed the presence of five well-defined instars, with the larval period averaging 15 to 25 days, depending on the temperature.

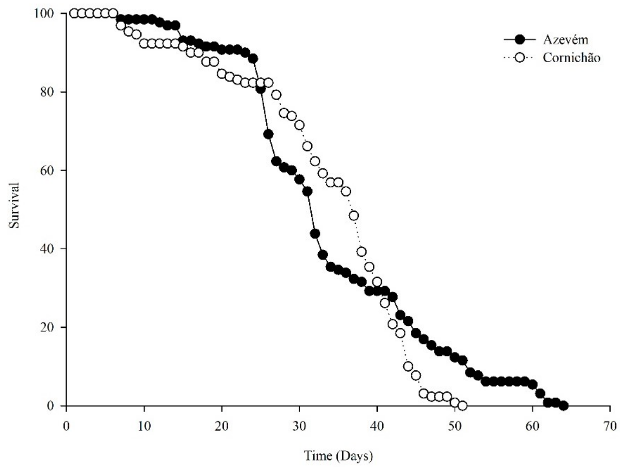

Figure 3. Survival of *Spodoptera frugiperda* caterpillars fed winter forages.

There is no difference between the survival curves for the caterpillars by the Wilcoxon test (GL= 1; X2 = 14.4092; PR = 0.0001 > 0.05).

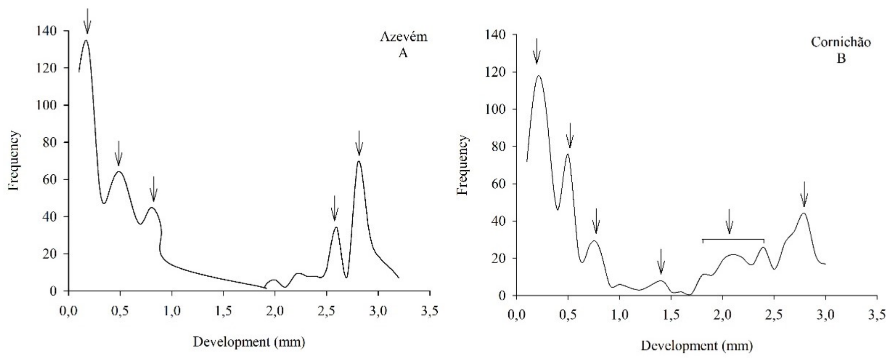

Figure 4. A. B. Multimodal distribution curve of the cephalic capsule growth (mm) in *Spodoptera frugiperda* fed winter forages.

The arrows indicate the instars.

Nutrition can directly affect the biology and abundance of insects and is influenced by field conditions (PANIZZI; PARRA, 2009). This was observed in the present study when the insects entered the pre-pupae stage, with a reduction in the number of individuals by 45.3% for azevém and 15.3% for cornichão (Table 2). Dias et al. (2016) reported larval development in *S. frugiperda* between 15.6 and 19.4 days, which was shorter than that found in the present study (Table 2). Furthermore, those authors reported a reduction in the transition from the caterpillar phase to the pre-pupa to sunflower (*Helianthus annuus* L.) (43.7%) and brachiaria (*Urochloa decumbes* Stapf) (54.1%), which cover plants in the southeast, central-west, and northeast regions.

The amount and quality of food consumed during the larval stage can interfere with biological parameters, such as growth rate, development time, body weight, survival, fecundity, longevity, movement, and capacity for competition among adults (PARRA, 1991). In addition, hosts that provide a shorter life cycle are considered optimal for the development of individuals, because the most adequate food usually results in short development phases and high survival (PARRA, 2000).

No differences in winter forages were observed in the pre-pupal and pupae stages (Table 2). In studies with corn and several cover crops, the pre-pupal period extended from 1.3 to 2.1 days, and the pupal phase from 7.8 to 15.0 days for *S. frugiperda* (BUSATO et al., 2004; BUSATO et al., 2005; BOREGAS et al., 2013; ROEL et al., 2017). Variation of food for *S. frugiperda* affects the duration of the pre-pupal and pupae phase, with a greater influence on pupae weight, nutrition in the larval phase and the amount of water retained is due to feeding at this stage (PARRA, 2000).

In this study, adult longevity was 6.7 (azevém) and 5 days (cornichão) (Table 2). In studies with corn strains, Rosa et al. (2012) found that the duration of the adult phase was 14 days for the M89601 lineage and 21 days for the M89287 lineage. This may be related to tannin present in the food ingested during the larval stage, leading to increased longevity of adults (LUGINBILL, 1928).

No difference was observed in the pre-oviposition period of *S. frugiperda* among winter forages (Table 2). These results are comparable to those found by Busato et al. (2004), who reported a minimum duration of 2.7 days in rice and a maximum duration of 3.8 days in corn.

The winter forages did not influence the incubation period of *S. frugiperda* eggs, which was 3.7 days in the present study (Table 2). Velez and Sifuentes (1967) performed a study with corn leaves, the preferred food of the insect and concluded that the incubation period of *S. frugiperda* was 4 days. In other studies, feeding two populations of *S. frugiperda* with Pioneer 30F33 corn, the authors observed an incubation period of 2.4 and 2.7 days, which reached 3.3 and 3.2 days with the strains M89601 and M89420, respectively (BUSATO et al., 2005; ROSA et al., 2012).

These differences are likely due to several factors, such as temperature, RH, photoperiod, and food, which is a determinant factor for insect biology (RODRIGUES, 2004). Another important factor is the difference between the *S. frugiperda* populations studied. In the United States, *S. frugiperda* was divided into two biotypes, "corn" and "rice". According to Drès and Mallet (2002), the biotypes represent cryptic species associated with host plants due to differences in reproductive compatibility. In Brazil, Busato et al. (2005) reported that these two populations cause crop damage in the southern region of the country. The authors attributed this to physiological differences observed between the insects collected in corn and irrigated rice, with the "rice" biotype having greater potential to respond to the selection pressures imposed by the environment, presenting a greater pre-disposition to make physiological adjustments.

In this study, the complete biological cycle of *S. frugiperda* ranged from 51.7 to 45.1 days (Table 2). Results with other crops such as cassava (39.9 days), rice (31.9 days), and corn (31.5 days) reported a shorter development time, demonstrating that prolongation of development phases may compensate for the low-quality feeding of winter forages (GIOLO et al., 2002; LOPES et al., 2008).

Viability of the egg phase differed between treatments, with a lower percentage of insects fed azevém (Table 2). In rice plants and rice grass, the viabilities exceeded 80.0% (BOTTON et al., 1998). Fernandes et al. (2017) observed a viability of 79.0% in the cultivar Attack TL and stated that among the phases of the biological cycle, larval viability plays an important role in insect development, since sufficient energy from food is accumulated during this stage for physical transmutation.

This was observed in the larval phase in the present study, due to the low-quality food source, azevém (Table 2). This represented the lowest value in the whole biological cycle, harming the developmental phases, and was not observed with the cornichão. Therefore, *S. frugiperda* caterpillars fed azevém survive less than those fed cornichão due to its palatability and digestibility properties. Some studies have addressed the antinutritional aspect of some plants with high levels of tannins and their resistance to insect pests. The acceptability is reduced because the tannins are astringent, a relevant property when picking fodder in the field (TIRELLI et al., 2010; GOMES et al., 2017).

The biomass of *S. frugiperda* caterpillars evaluated at day 14 was around 280.9 and 145.3 mg for azevém and cornichão, respectively (Table 2). These results differ from those obtained for insects fed corn DKB 390 (450.7 mg) (MENDES et al., 2011). In other studies with corn, grain sorghum, wild sorghum, brachiaria, and soybean, the means also differed, with biomass exceeding 400.0 mg for caterpillars evaluated on day 14 (SÁ et al., 2009). Variations in caterpillar biomass may be related to the constitutive resistance of the plants.

The pupal biomass was significantly different between the treatments (Table 2). In studies evaluating the development of *S. frugiperda* in cassava leaves, Lopes et al. (2008) reported a pupal biomass around 229.5 mg. In other studies with *S. frugiperda*-resistant corn cultivars, the mean values varied from 100.0 to 117.0 mg (FERNANDES et al., 2017). These studies exemplify the lower biomass of pupae reared on azevém and cornichão, supporting the low nutritional quality of the winter forages.

Table 2. Duration (days) of the development stages of *Spodoptera frugiperda* fed winter forages in the laboratory at 25 ± 1°C with 70 ± 10% RH and a 12 h photophase.

Phase/Food	Azevém	Cornichão
Duration (Days)		
Egg	3.7 ± 0.001 a[1] [3995]	3.7 ± 0.006 a [6170]
Caterpillar	26.5 ± 0.51 a [130]	22.9 ± 0.48 b [130]
Pre-Pupae	1.5 ± 0.06 a [71]	1.0 ± 0.05 a [110]
Pupae	10.4 ± 0.58 a [46]	9.0 ± 0.36 a [98]
Adult	6.7 ± 0.39 a [45]	5.0 ± 0.27 b [78]
Pre-Oviposition	2.9 ± 0.0002 a [3995]	3.5 ± 0.0005 a [6170]
Total	51.7	45.1
Viability (%)		
Egg	64.7 ± 0.75 b[1]	80.2 ± 0.54 a
Caterpillar	56.9 ± 0.42 b	84.6 ± 0.23 a
Pre-Pupae	76.0 ± 0.12 b	89.0 ± 0.53 a
Pupae	86.9 ± 0.34 a	80.6 ± 0.54 a
Adult	64.7 ± 0.23 b	80.2 ± 0.14 a
Total	69.8 ± 0.49 b	82.9 ± 0.43 a
Weight (mg)		
Caterpillar	280.9 ± 0.01 a[1] [122]	145.3 ± 0.006 b [119]
Pupae	120.3 ± 0.004 b [48]	140.9 ± 0.002 a [98]

[1]Means followed by the same letter in a row do not differ significantly, by *t*-test ($P < 0.05$). Averages ± standard error. [ ] = number of observations.

In relation to the fertility life table of *S. frugiperda*, there were no differences in any of the parameters analyzed (Table 3). The results were lower than those found by Barros, Torres and Bueno (2010), who fed *S. frugiperda* with corn. Those authors showed that life table parameters with corn were superior to those with cotton, millet, and soybean, which can enter the rotation system with winter forages because they present characteristics that make the development of pest insects difficult. According to Giolo et al. (2002), the performance of *S. frugiperda* in different food sources depends on larval survival during the colonization phase for the success of the species. This was observed from the duration of development stages, viability of the biological cycle, weight, and life table of *S. frugiperda* caterpillars fed azevém.

Table 3. Parameters of the fertility life table of *Spodoptera frugiperda* fed winter forages.

Forages	R_o [(♀)(♀)$^{-1}$]	T (Days)	r_m [(♀)(♀)$^{-1}$ (Days)$^{-1}$]	λ^e [(♀) (Days)$^{-1}$]	DT (Days)
Azevém	11.6 (6.76–16.57)[1]	6.3 (5.63–6.95)	0.4 (0.314–0.492)	1.5 (1.37–1.62)	1.6 (1.11–2.17)
Cornichão	24.5 (9.88–39.23)	7.0 (5.68–8.36)	0.4 (0.352–0.565)	1.6 (1.41–1.75)	1.5 (1.13–1.85)

[1]Averages (confidence interval) Student's t-test ($P < 0.05$). Ro = net reproduction rate (female/female). T = average generation time (days). rm = intrinsic rate of population growth. λe = finite rate of population growth (females/day) .TD = time required for the population to double in number.

Considering the criterion that prevents the formation of a green bridge and allows the use of subsequent crops, azevém is the most suitable forage species for rotation, because it presents low colonization capacity by insects and interferes with the performance of the biological cycle.

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RESUMO: *Helicoverpa armigera* Hübner, 1805 e *Spodoptera frugiperda* Smith, 1797 são pragas polífagas de grande importância agrícola, em regiões de clima subtropical e temperado. Após a colheita das culturas de verão no sul do Brasil, as áreas são utilizadas como pastagem. Com isso, as forrageiras recomendadas ao pastoreio são cornichão (*Lotus corniculatus* L.) e azevém (*Lolium multiflorum* Lam.) por apresentarem benefícios nutricional, palatabilidade, rebrota e rusticidade. Devido ao alto grau de polifagia de *H. armigera* e *S. frugiperda* e o impacto de áreas continuas de alimento (pontes verdes) no manejo destas espécies, este trabalho objetivou-se avaliar o desenvolvimento de *H. armigera* e *S. frugiperda* alimentadas com azevém e cornichão em condições de laboratório. Os insetos foram coletados no município de Capão do Leão/RS em plantios de milho e soja. Para cada espécie forrageira foram individualizadas 130 lagartas recém-eclodidas em tubos de vidro autoclavados, com um terço (1/3) do seu comprimento contendo a respectiva forrageira. Os tubos foram tampados com algodão hidrófugo e levados para a sala climatizada a 25 ± 1°C, UR de 70 ± 10% e 12 horas de fotofase. Diariamente, o alimento foi reposto até que as lagartas entrarem em estágio de pupa. As pupas foram sexadas e pesadas e os adultos recém-emergidos foram individualizados em casais em gaiolas de PVC, forradas com papel sulfite A4 branco no seu interior. Os papéis utilizados como substrato de postura foram retirados e trocados diariamente e os ovos foram contabilizados. O número de instares foi determinado pelo modelo linearizado da regra de Dyar. O delineamento utilizado foi inteiramente casualizado (DIC) para as variáveis duração do ciclo biológico e viabilidade das fases de ovo, lagarta, pré-pupa, pupa, adultos e pré-oviposição, peso de lagartas ao decimo quarto (14°) dia e pupas após 24 horas. Com base nos resultados obtidos, foi elaborada tabela de vida de fertilidade. *H. armigera* não completou o ciclo, com apenas três instares e duração de 22,1 e 24,6 dias em azevém e cornichão, respectivamente. Quando avaliado em lagartas de *S. frugiperda* observou o desenvolvimento nas espécies forrageiras, com 5 e 6 instares e duração de 51,7 e 45,1 dias em azevém e cornichão, respectivamente. Contudo, considerando o critério que evite a formação de ponte verde, azevém destacou-se por interferir no ciclo de desenvolvimento das espécies. Onde, mesmos os que sobrevivem, estão suscetíveis aos efeitos do agroecossitema devido a fonte alimentar ser de baixa qualidade.

PALAVRAS-CHAVE: Plantas de cobertura. Manejo de resistência de insetos. Manejo cultural. Resistência constitutiva. Resistência de plantas

REFERENCES

ALVES, C. A. **Impacto de diferentes temperaturas nas características biológicas de *Helicoverpa armigera* (Hübner, 1808) (Lepidoptera: Noctuidae) durante três gerações**. 2017. 52 p. Dissertação (Mestrado em Proteção de Plantas) - Universidade Estadual Paulista, Faculdade de Ciências Agronômicas, Botucatu. https://repositorio.unesp.br/handle/11449/150066

ÁVILA, C. J.; VIVAN, L. M.; TOMQUEISKI, G. V. Ocorrência, aspectos biológicos, danos e estratégias de manejo de *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) nos sistemas de produção agrícolas. **Dourados: Embrapa Agropecuária Oeste**, 2013, 12p. (Embrapa Agropecuária Oeste. Circular técnica, 23). https://ainfo.cnptia.embrapa.br/digital/bitstream/item/96040/1/CT201323-REVAT-ONLINE.pdf

BARBOSA, T. A. N.; MENDES, S. M.; RODRIGUES, G. T.; RIBEIRO, P. E. de A.; SANTOS, C. A. dos; VALICENTE, F. H.; OLIVEIRA, C. M. Comparison of biology between *Helicoverpa zea* and *Helicoverpa armigera* (Lepidoptera: Noctuidae) reared on artificial diets. **Florida Entomologist**, Flórida, v. 99, n. 1, 2016. http://dx.doi.org/10.1653/024.099.0113

BARROS, E. M.; TORRES, J. B.; BUENO, A. F. Oviposição, desenvolvimento e reprodução de *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) em diferentes hospedeiros de importância econômica. **Neotropical Entomology**, Londrina, v. 39, p. 996-1001, 2010. http://dx.doi.org/10.1590/S1519-566X2010000600023

BERNARDES, G. M. C.; CARVALHO, S.; PIRES, C. C.; MOTTA, J. H.; TEIXEIRA, W. S.; BORGES L. I.; FLEIG, M.; PILECCO V. M.; FARINHA E. T.; VENTURINI, R.S. Consumo, desempenho e análise econômica da alimentação de cordeiros terminados em confinamento com o uso de dietas de alto grão. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, Belo Horizonte, v. 67, n. 6, p. 1684-1692, 2015. http://dx.doi.org/10.1590/1678-4162-7934

BERNARDI, O. **Avaliação do risco de resistência de lepidópteros-praga (Lepidoptera: Noctuidae) à proteína Cry1Ac expressa em soja MON 87701 x MON 89788 no Brasil**. 2012. 116 f. Tese (Doutorado) - Escola Superior de Agricultura "Luiz de Queiroz", São Paulo. http://10.11606/T.11.2012.tde-25042012-153518

BINI, D. A.; CANEVER, M. D. A dinâmica da área, do rendimento e dos preços sobre o valor da produção do feijão e da soja no Rio Grande do Sul e a dependência temporal entre esses componentes. **Ciência Rural**, Santa Maria, v. 45, n .6, p. 1139-1146, 2015. http://dx.doi.org/10.1590/0103-8478cr20140846

BOREGAS, K. G. B.; MENDES, S. M.; WAQUIL, J. M.; FERNANDES, G. W. Estádio de adaptação de *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) em hospedeiros alternativos. **Revista Caatinga**, Mossoró, v. 72, p. 61-70, 2013. http://dx.doi.org/10.1590/S0006-87052013000100009

BOTTON, M.; CARBONARI, J. J.; GARCIA, M. S.; MARTINS, J. F. S. Preferência alimentar e biologia de *Spodoptera Frugiperda* (J.E.Smith, 1797) (Lepidoptera: Noctuidae) em arroz e capim-arroz. **Anais da Sociedade entomológica do Brasil**, Londrina, v. 27, p. 207-212, 1998. http://dx.doi.org/10.1590/S0301-80591998000200006

BUSATO, G. R.; GRÜTZMACHER, A. D.; GARCIA, M. S.; GIOLO, F. P.; NÖRNBERG, S. D. Consumo e utilização de alimento por *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae) em duas temperaturas. **Ciência e Agrotecnologia**, Lavras, v. 28, p. 1278-1283, 2004. http://dx.doi.org/10.1590/S1413-70542004000600008

BUSATO, G. R.; GRÜTZMACHER, A. D.; GARCIA, M. S.; GIOLO, F. P.; ZOTTI, M. J.; STEFANELLO-JUNIOR, G. J. Biologia comparada de populações de *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) em folhas de milho e arroz. **Neotropical Entomology**, Londrina, v. 34, p.743-750, 2005. http://dx.doi.org/10.1590/S1519-566X2005000500005

BUTT, B. A.; CANTU, E. **Sex determination of lepidopterous pupae**. Washington, USDA, 1962, 7p. https://doi.org/10.5962/bhl.title.67261

CHAPMAN, J. W.; BELL J. R.; BURGIN, L. E.; REYNOLDS, D. R.; PETTERSSONE, L. B.; HILLF, J. K.; BONSALLG, M. B.; THOMAS, J. A. Seasonal migration to high latitudes results in major reproductive benefits in an insect. **Proceedings of the National Academy of Sciences of the United States of America**, Washington, v. 109, n. 37, p. 14924–14929, 2012. https://doi.org/10.1073/pnas.1207255109

DIAS, A. S.; MARUCCI, R. C.; MENDES, S. M.; MOREIRA, S. G.; ARAÚJO, O. G.; SANTOS, C. A.; BARBOSA, T. A. Bioecology of *Spodoptera frugiperda* (Smith, 1757) in diferente cover crops. **Bioscience Journal**, Uberlândia, v. 32, n. 2, p. 337-345, 2016. http://dx.doi.org/10.14393/BJ-v32n2a2016-29759

DINGLE, H. **Migration: The biology of life on the move**. Oxford, UK: Oxford University Press. 2014, 352p. https://doi.org/10.1093/acprof:oso/9780199640386.001.0001

DRÈS, M.; J. MALLET. Host races in plant-feeding insects and their importance sympatric speciation. **Philosophical Transactions Biological Sciences**, Cardiff, v. 357, n. 1, p. 471-492, 2002. http://10.1098/rstb.2002.1059

DYAR, H. G. The number of molts of lepidopterous larvae. **Psyche**, Oxford, v. 5, p. 420-422, 1980. http://dx.doi.org/10.1155/1890/23871

FERNANDES, F. O.; ABREU, J. A.; CHRISTI, L.; RODRIGUES-FILHO, J. A.; MARTINS, A.; ROSA, A. P. S. A. Desenvolvimento de *Spodoptera frugiperda* (Smith, 1797) em cultivares de milho em laboratório. **Pelotas: Embrapa Clima Temperado**, 2017. 35 p. (Embrapa Clima Temperado. Boletim de Pesquisa e Desenvolvimento, 264). https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1081680/1/Boletim264.pdf

FONTANELI, R. S.; SANTOS, H. P.; FONTANELI, R. S. Forrageiras para integração-lavoura-pecuária-floresta na região sul-brasileira. **Passo Fundo: Embrapa Trigo**, 2012, 274p. https://www.alice.cnptia.embrapa.br/bitstream/doc/1010247/1/LV2012forrageirasparaintegracaoFontaneli.pdf

FONTANELI, R. S.; SANTOS, H. P.; FONTANELI, R. S.; OLIVEIRA, J. T.; LEHMEN, R. I.; DREON, G. **Gramíneas Forrageiras Anuais De Inverno**. In: RENATO SERENA FONTANELI, R. S.; SANTOS, H. R.; FONTANELI, R. S. Forrageiras para Integração Lavoura-Pecuária-Floresta na Região Sul-Brasileira. 2. ed. - Brasília, DF: Embrapa, 2012. 544 p.

GOMES, F. H. T.; BLEICHER, E.; COSTA, J. V. T. A.; PONTES, F. S. S.; CYSNE, A. Q. Atividade inseticida de extratos vegetais sobre o pulgão preto do feijoeiro. **Revista Ciências Agroambentais**, Alta Floresta, v.15, n.1, p.43-52, 2017.

GREENE, G. L.; LEPPLA, N. C.; DICKERSON, W. A. Velvetbean caterpillar: a rearing procedure and artificial medium. **Journal Economic Entomology**, Oxford, v. 69, p. 487-497, 1976. https://doi.org/10.1093/jee/69.4.487

HADDAD, M. L.; MORAES, R. C. B.; PARRA, J. R. P. **Programa MOBAE: Modelos bioestatísticos aplicados à entomologia (software)**. ESALQ/USP, Piracicaba, 1995, 44p.

KOUHI, D.; NASERI, B.; GOLIZADEH, A. Nutritional performance of the tomato fruit borer, *Helicoverpa armigera*, on different tomato cultivars. **Journal of Insect Science**, Oxford, n. 14, p. 1-12, 2014. https://10.1673/031.014.102

LOPES, G. S.; LEMOS, R. N. S.; MACHADO, K. K. G.; MACIEL, A. A. S.; OTTATI, A. L. T. Biologia de *Spodoptera frugiperda* (J. Smith) (Lepidoptera: Noctuidae) em folhas de mandioca (*Manihot esculenta*, Crantz). **Revista Caatinga**, Campinas, v. 21, p. 134-140, 2008. https://www.redalyc.org/articulo.oa?id=237117546023

LUGINBILL, P. H. **The fall armyworm**. Washington, USDA, 1928, 73p.

MACHADO, J. R. A.; FONTANELI, R. S. **Inserção das Culturas de Milho e Sorgo na Agricultura Familiar na Região Sul Brasileira**. In: KARAM, D.; MAGALHÃES, P. C. (Ed.). Eficiência nas cadeias produtivas e o abastecimento global. Sete Lagoas: Associação Brasileira de Milho e Sorgo, cap. 19, p. 209-224, 2014.

MAIA, A. H. N.; LUIZ, A. J. B.; CAMPANHOLA, C. Statistical Inferences on associated lifetable parameters using jackknife technique: computational aspects. **Journal Economic Entomology**, Oxford, v. 93, n. 2, p. 511-518, 2000. https://10.1603/0022-0493-93.2.511

MENDES, S. M.; SILVA, A. F.; CARVALHO, S. S. S.; SOUZA, C. S. F. A buva (Conyza spp.): Pode ser considerada planta hospedeira de *Spodoptera frugiperda* e *Helicoverpa armigera*? **Sete Lagoas: Embrapa Milho e Sorgo**, 2016, 7p. (Embrapa Milho e Sorgo. Comunicado Técnico, 215). https://ainfo.cnptia.embrapa.br/digital/bitstream/item/149620/1/ct-215.pdf

MENDES, S. M.; BOREGAS, K. G. B.; LOPES, M. E.; WAQUIL, J.M.; WAQUIL, M. Respostas da lagarta-do-cartucho ao milho geneticamente modificado expressando a toxina Cry 1A(b). **Pesquisa Agropecuária Brasileira**, v. 46, p. 239-244, 2011.

MEYER, J. S.; IGERSOLL, C. G.; MACDONALD, L. L.; BOYCE, M. S. Estimating uncertainity in population growth rates: Jackknife vs. Bootstrap techniques. **Ecology**, Washington, v. 67, p. 1156-1166, 1986. https://doi.org/10.2307/1938671

MIRANDA, J. E.; MOREIRA, M. D.; SIQUEIRA, J. R. Aspectos biológicos e exigências térmicas da lagarta-militar no algodoeiro. **Revista Brasileira de Oleaginosas e Fibrosas**, Campina Grande, v. 14, p. 107-113, 2010.

MONTEIRO, J. M.; ALBUQUERQUE, U. P. P.; ARAÚJO, E. L.; AMORIM, E. L. C. Taninos: uma abordagem da química à ecologia. **Química Nova**, São Paulo, v. 28, n. 5, p. 892-896, 2005. http://dx.doi.org/10.1590/S0100-40422005000500029

PANIZZI, R. A.; PARRA, J. R. P. **Consumo e utilização do alimento para o crescimento da fase larval**. In: Panizzi R. A.; Parra J. R. P. (eds.): Bioecologia e nutrição de insetos. Embrapa Informação Tecnológica, Brasília, 2009, 1164p.

PARRA, J. R. P.; HADDAD, M. L. **Determinação do número de instares de insetos**. ESALQ/FEALQ, Piracicaba, 1989, 49p.

PARRA, J. R. P. **Consumo e utilização de alimentos por insetos**. In: PANIZZI, A. R.; PARRA, J. R. P. (eds.): Ecologia nutricional de insetos e suas implicações no manejo de pragas. Manole, São Paulo, 1991, 237p.

PARRA, J. R. P. **Técnicas de criação de insetos para programas de controle biológico**. ESALQ/FEALQ, Piracicaba, 2000, 138p.

ROCHA, M. G.; QUADROS, F. L. F.; GLIENKE, C. L.; CONFORTIN, C. C.; COSTA, V. G.; ROSSI, G. E. Avaliação de espécies forrageiras de inverno na depressão central do Rio Grande do Sul. **Revista Brasileira de Zootecnia**, Viçosa, v. 36, n. 7, p. 1990-1999, 2007. http://dx.doi.org/10.1590/S1516-35982007000900007

RODRIGUES, W. C. Fatores que influenciam no Desenvolvimento dos Insetos. **Info Insetos**, Rio de Janeiro, v. 1, n. 4, p. 1-4, 2004.

ROEL, A. R.; SOARES, J. A. L.; PERUCA, R. D.; PEREIRA, L. C.; JADOSKI, C. J. Occurrence in field and development lab *Spodoptera frugiperda* (J.E. Smith) (Noctuidae) in corn with organic fertilizer and chemical. **Applied Research & Agrotechnology**, Guarapuava, v. 10, p. 67-73, 2017. https://doi.org/10.5935/PAeT.V10.N01.07

ROSA, A. P. S. A.; TRECHA, C. O.; ALVES, A. C.; GARCIA, L.; GONÇALVES, V. P. Biologia e tabela de vida de fertilidade de S*podoptera frugiperda* (J.E. Smith) em linhagens de milho. **Arquivo do Instituto Biológico**, Campinas, v. 79, p. 39-45, 2012. http://dx.doi.org/10.1590/S1808-16572012000100006

ROSA, A.P.S.A.; TEIXEIRA, H.B.; MEDINA, L.B.; HELLWIG, L.; FIPKE, M.V. Ponte Verde para *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae) em terras baixas. **Pelotas: Embrapa Clima Temperado**, 2014, 5p. (Embrapa Clima Temperado. Comunicado Técnico, 317). https://ainfo.cnptia.embrapa.br/digital/bitstream/item/126188/1/Comunicado-317.pdf

SÁ, V. G. M.; FONSECA, B. V. C.; BOREGAS, K. G. B.; WAQUIL, J. M. Sobrevivência e Desenvolvimento Larval de *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae) em Hospedeiros Alternativos. **Neotropical Entomology**, Londrina, v. 38, p. 108-115, 2009. http://dx.doi.org/10.1590/S1519-566X2009000100012

SANTOS, A. B. Árvore do conhecimento: Arroz. **Agência Embrapa de Informação Tecnológica (AGEITEC)**. Disponível em: <http://www.agencia.cnptia.embrapa.br/gestor/arroz/arvore/CONT000g1wcnzza02wx5ok0ha2lipwbeel46.html>. Acesso em: 25 de março de 2018.

SAS. 2014: **SAS® 9.4 Statements**. Third Edition SAS Instit. Inc., USA. Disponível em: < https://www.sas.com/en_us/software/university-edition.html>. Acesso em: 08 de setembro de 2019.

SCOTT, K.D.; WILKINSON, K.S.; LAWRENCE, N.; LANGE, C. L.; SCOTT, L. J.; MERRITT, M. A.; LOWE, A. J.; GRAHAM, G. C. Gene-flow between populations of cotton bollworm *Helicoverpa armigera* (Lepidoptera: Noctuidae) is highly variable between years. **Bulletin of Entomological Research**, Cambridge, v. 95, n. 4, p. 381-392. 2005. https://doi.org/10.1079/BER2005369

SILVA, D. M.; HOFFMANN-CAMPO, C. B.; BUENO A. F.; BUENO, R. C. O. F.; OLIVEIRA, M. C. N.; MOSCARDI, F. Biological characteristics of *Anticarsia gemmatalis* (Lepidoptera: Noctuidae) for three consecutive generations under different temperatures: understanding the possible impact of global warming on a soybean pest. **Bulletin of Entomological Research**, Cambrigde, v. 102, p. 285–292, 2012. https://10.1017/S0007485311000642

SOUTHWOOD, T. R. E. **Ecological methods**. Chapman & Hall, London, 1995, 524p.

SUZANA, C. S.; DAMIANI, R.; FORTUNA, L. S.; SALVADORI, J. R. Desempenho de larvas de *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) em diferentes fontes alimentares. **Pesquisa Agropecuária Tropical**, Goiás, n. 45, p. 480-485, 2015. http://dx.doi.org/10.1590/1983-40632015v4536733

TIRELLI, A. A.; ALVES, D. S.; CARVALHO, G. A.; SÂMIA, R. R.; BRUM, S. S.; GUERREIRO, M. C. Effect of tanical fractions on biological and nutritional parameters of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). **Ciência Agrotecnologia**, Lavras, v. 34, n. 6, p. 1417-1424, nov./dez., 2010. http://dx.doi.org/10.1590/S1413-70542010000600009

VALICENTE, F. H.; TUELHER, E. S. Controle biológico da lagarta-do-cartucho *Spodoptera frugiperda* com Baculovírus. **Sete Lagoas: Embrapa Milho e Sorgo**, 2009, 14p. (Embrapa Milho e Sorgo. Circular Técnica, 14).

VELEZ, C. M.; SIFUENTES, J. A. El gusano cogollero de maiz: su combate com insecticidas granulados em el valle Apatzingan, Midi. **Agricultura Técnica en México**, México, v. 2, p. 315-317, 1967.

WAQUIL, J. M.; BOREGAS, K. G. B.; MENDES, S. M. Viabilidade do uso de hospedeiros alternativos como área de refúgio para o manejo da resistência da lagarta-do-cartucho, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) no cultivo do milho-*Bt*. **Sete Lagoas: Embrapa Milho e Sorgo**, 2008. 68p. (Embrapa Milho e Sorgo. Circular Técnica, 160). https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/491779/1/Com160.pdf