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Immature stages of *Spodoptera cosmioides* (Lepidoptera: Noctuidae): developmental parameters and host plants

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ABSTRACT. The goal of this study was to detail the temporal and morphological parameters of the immature stages of *Spodoptera cosmioides* (Walker, 1858) and to gather information about their larval host plants. Larvae were reared on artificial diet and under controlled conditions (25 ± 1°C, 70 ± 10% RH and 14 hour photophase). The viability of eggs, larvae (pre-pupae period inclusive) and pupae were 98.97, 97.33, 97.95 and 94.76%, respectively. The average duration of egg, larval, pre-pupal and pupal stages was 3.82, 19.24, 3.20 and 14.81 days, respectively. A small proportion of females (9.48%) passed through seven instars, and female development was significantly slower than male development. The female larvae that developed through six and seven instars exhibited a mean growth rate of 1.63 and 1.49, respectively. Overall, female pupae were significantly larger, exhibiting slower development than males. One hundred and twenty six plants belonging to 40 families are listed as hosts of *S. cosmioides*, mainly including Solanaceae, Fabaceae, Asteraceae and Poaceae.

KEY WORDS. Armyworm, artificial diet, development, life cycle, soybean pod armyworm.

The moth *Spodoptera cosmioides* (Walker, 1858) is a native polyphagous crop pest in South America (Pogue 2002). The species used to be considered a synonym of *S. latifascia* (Walker, 1856) (e.g., Poole 1989) until Silvian & Lalanne-Cassou (1997) demonstrated that the two species are distinct, based on molecular, morphological, physiologic and pheromone characters. *Spodoptera cosmioides* occurs from Panama to southern South America, whereas *S. latifascia* occurs from Panama to southern United States, including Costa Rica and the Caribbean, except Trinidad (Silvian & Lalanne-Cassou 1997, Pogue 2002).

Spodoptera cosmioides moths are sexually dimorphic to the extent that males and females have often been misidentified as different species. Females used to be misidentified as *S. ornithogalli* (Guenée, 1852) (e.g., Biezanko et al. 1949, Biezanko & Bertholdi 1951, Bertels 1953, 1956, 1962), a species restricted to Central and North America (Pogue 2002). Males have been mistaken for *S. testaceoides* (Guenée, 1852) (Mabilde 1896) and *S. litura* (Fabricius, 1775) (Ronna 1933, 1934, Biezanko et al. 1949), and later, for *S. latifascia* (e.g., Carvalho et al. 1971, Tarragó et al. 1975, Santos et al. 1980, Habib et al. 1983, Specht & Corseuil 1996). After the distinction between *S. cosmiodes* and *S. latifascia* (Silvian & Lalanne-Cassou 1997) was made, other studies on *S. cosmioides* have followed, elaborating on its occurrence periods, morphology and biology (e.g., Specht & Corseuil 2002, Bavaresco et al. 2002, 2003, 2004, Specht et al. 2005, Zenker et al. 2007, 2010, Cabezas et al. 2013).

This study complements previous contributions on the biology of immatures and adults of *S. albula* (Walker, 1857) (Montezano et al. 2013a, 2014a), *S. eridania* (Stoll, 1782) (Montezano et al. 2013b, 2014b) and *S. dolichos* (Fabricius, 1794) (Montezano et al. 2015a, 2015b) under the same conditions. Following the guidelines of the studies above mentioned, here the biology of *S. cosmioides* is described in detail including information about their host plants.

MATERIAL AND METHODS

The immature development of *S. cosmioides* was investigated under laboratory conditions in a rearing room (25 ± 1°C, 70 ± 10% RH and 14 hour photophase). Evaluations were performed daily at 2:00 pm. The initial stock had 12 couples, from 68 caterpillars collected on *Fevillea cordifolia* Linn. (Cucurbitaceae) in the city of Planaltina, Distrito Federal, Brazil (15°36'16.85"S, 47°43'06.57"W, 1020 m a.s.l.). Couples that emerged on the same day were placed inside cylindrical plastic containers (20 cm in diameter and 15 cm high). These containers were closed using plastic film, to which long filter paper strips were attached to stimulate oviposition. The bottom part of each container was lined with filter paper and sealed with a plastic cover (20.5 cm diameter). The larval artificial diet was the same used for rearing *S. eridania*, *S. albula* and *S. dolichos* (Montezano et al. 2013a, 2014b, 2015a). Containers were examined daily to record adult survival and to remove and to count the number of eggs in each egg mass. Dead females were dissected to determine the number of spermatophores they had received from males during copulation.

In the egg stage, the viability and embryonic period of 10,542 eggs (from 87 eggs masses) were evaluated. The egg masses were obtained from the couples outlined above and were representative of the oviposition period (including the first and last oviposition). Copulation was confirmed by the number of spermatophores in the bursa copulatrix, the egg masses from females with one (n = 7), two (n = 4) and three (n = 1) spermatophores were used. Every day, egg masses were individually placed into Petri dishes (10 cm diameter and 1.5 cm height) lined with filter paper moistened with distilled water until eclosion.

Larval development was studied using 300 neonates. The artificial diet used to rear the larvae was adapted from Greene et al. (1976), according to Montezano et al. (2013a, 2014b, 2015a). Neonates were placed in individual plastic containers (300 ml). A small wad of cotton (~1 cm in diameter) moistened with distilled water to maintain humidity and a ~1 cm^3 piece of artificial diet were deposited into the plastic container. Daily observations were made to verify the survival and development of the larvae by collecting shed head capsules. The head capsules of each larva were individually stored in micro tubes and measured using a microscope. When the head capsule was consumed by the larva and therefore could not be recovered, changes in instars were documented by comparing the size of the larva in question with other, contemporaneous larvae. The diet and the moist cotton of each vial were replaced daily.

Head capsules were measured based on the distance between the frontal setae (Podoler & Klein 1978), instead of the traditional method of measuring the distance between genas (Pérez et al. 2005). The distance between the frontal setae was used to compare development of the larvae that went through six and seven instars. The distance between genas was only measured in the first and in the last instars, to allow comparison with data available in the literature.

When the larvae reached the prepupal period, characterized by a decrease in size and interruption of feeding activities, the insects were transferred to another container (translucent plastic container, 10 cm diameter, 5 cm height) with expanded vermiculite moistened with distilled water. The prepupa builds the pupal chamber attached to the wall of the container, which makes it possible to observe metamorphosis and to determine the end of the prepupal period.

Growth ratio was determined by measuring the frontal setae of each instar of 30 randomly sampled larvae (15 of each sex) that reached the sixth instar. All larvae in the seventh instar (n = 13) had their frontal setae measured for each instar (Table 3). The mean growth ratio for each instar was calculated by subtracting the value obtained for that instar from the previous instar.

Considering the polyphagous habits f *S. cosmioides* and the fact that a compilation of its larval hosts is not available, a survey of its host plants was conducted based on literature records. In this survey, the hosts recorded for misidentified *S. cosmioides* in Argentina, Brazil and Uruguay (cited as *S. latifascia*, *S. litura* and *S. ornithogalli*) were also considered. The host list includes the family, scientific and common names and references of each putative host. Furthermore, new records of host plants in Brazil are included, from surveys conducted by the authors, who collected suspect larvae feeding in the field and subsequently identified the adults in the laboratory.

The pupae were kept in the same container and under the same conditions as the prepupae. Moisture was controlled daily. Sex determination was performed on the second day after pupation, when the cuticle was further hardened, following Angulo & Jana (1982). Pupal weight was measured using a high precision semi analytical balance. Considering that precise sex determination is only possible during the pupal stage, each neonate was individualized throughout the study up to pupae, to guarantee that its sex could be determined and traced back to the larval stages.

The biological parameters, such as stage duration, size and weight were analyzed using descriptive statistics, after calculation of means and standard deviations. When necessary, means were compared using a t-test assuming unequal variances, at a significance level of 5%.

RESULTS

The overall survival of the immature stages of *S. cosmioides* was approximately 90% (Table 1). The duration of the embryonic period varied from three to four days (Table 1).

The survival of the larval stage, including the prepupal period, was 95.33%, a little more than observed for the pupa. Most larvae (95.20%) went through six instars, but 13 females (4.80%) had seven instars (Table 2)

The total development time of the female larvae that went through six instars was significantly longer than the total development time of male larvae (Table 2). The development time of the third instar was the same for both sexes.

Female larvae that went through seven instars took longer to complete their development than female larvae that completed six instars (Table 2). However, through the fourth instar, larval development time was the same for the two groups. The prepupal development time did not differ between the sexes or between larvae that went through six and seven instars (Table 2).

Differences between the sexes were only detected at the end of the larval development, in the sixth instar, when female

Table 1. Survival and duration of the immature stages of *Spodoptera cosmioides* on artificial diet under controlled conditions (25 ± 1°C, 70 ± 10% RH and 14 hour photophase).

Stage	N (initial-final)	Survival (%)	Duration (days)	Range (days)
Egg	10,542-10,433	98.966	3.819 ± 0.387	3-4
Larval	300-292	97.333	19.238 ± 2.847	16-36
Prepupal	292-286	97.945	3.197 ± 0.755	2-5
Pupal	286-271	94.755	14.807 ± 2.283	10-26
Overall		89.399	41.061 ± 5.248	

Table 2. Mean larval duration (days) of *Spodoptera cosmioides,* during each instar, including the larvae of each sex which developed for six and seven instars, fed with an artificial diet, under controlled conditions (25 ± 1°C, 70 ± 10% RH and 14 hour photophase). (A) Student t-test considering variances between means of females and males with six instars; (B) same but between females with six and seven instars.

Developmental period	Six instars			Seven instars	
	Females (124)	Males (134)		Females (13)	
	Mean ± SD	Mean ± SD	A	Mean ± SD	B
Larval instars					
I	3.430 ± 0.497	3.413 ± 0.494	a	3.444 ± 0.506	a
II	3.041 ± 0.436	3.017 ± 0.316	a	3.037 ± 0.338	a
III	3.231 ± 0.569	3.190 ± 0.505	a	3.037 ± 0.437	a
IV	3.512 ± 0.828	3.264 ± 0.783	b	3.444 ± 0.751	a
V	3.777 ± 1.375	3.314 ± 0.796	c	3.333 ± 1.074	b
VI	2.843 ± 0.992	1.893 ± 0.616	c	3.185 ± 1.241	b
VII	–	–		2.222 ± 0.801	
Prepupal	3.124 ± 0.640	3.240 ± 0.847	a	3.333 ± 0.784	a
Total	22.959 ± 3.051	21.331 ± 2.797	c	25.037 ± 4.381	c
Pupal	13.760 ± 2.480	15.860 ± 2.321	b	14.788 ± 2.293	a
Larval + Pupal	36.719 ± 5.177	37.190 ± 4.877	a	39.815 ± 6.499	b

Significance level of 95%: a = p > 0.01, b = p < 0.01, c = p < 0.001.

larvae became larger than their male counterparts (Table 3). In addition, females that went through six instars were significantly larger than those that underwent seven instars (Table 3). These size differences were significant during the fifth and sixth instars. However, the thirteen larvae that went through seven instars ended up larger (Table 3). The growth rate of female larvae that underwent six instars was faster than male larvae with the same number of instars. The growth rate of females that underwent seven instars was slower in comparison (Table 3).

The cephalic capsule of first instar larvae was 0.289 ± 0.014 mm in width, and this did not vary between the sexes or between the six and seven instar larval groups. The mean width cephalic capsule of all last instar larvae was 3.232 ± 0.172 mm (n = 75). However, the mean width of the cephalic capsule of the last larval instar varied between females that went through six instars (3.350 ± 0.152 mm, n = 25), seven instars (3.241 ± 0.160 mm, n = 25), and males (3.104 ± 0.104 mm, n = 25). The mean width cephalic capsule of all last instar larvae was 3.232 ± 0.172 mm (n = 75).

Table 3. Distance between frontal setae (mm) of *Spodoptera cosmioides* larvae at each instar and respective growth ratios, including larvae which developed through six (15 females and 15 males) and seven instars (13 females), fed with an artificial diet, under controlled conditions (25 ± 1°C, 70 ± 10% RH and 14 hour photophase). A. Student t-test considering variances between means of females and males with six instars; B. Same but between females with six and seven instars.

Instar	Six instars					Seven instars		
	Females		Males			Females		
	Mean ± SE	Growth ratio	Mean ± SE	Growth ratio	A	Mean ± SE	Growth ratio	B
I	0.121 ± 0.009	–	0.122 ± 0.010	–	a	0.123 ± 0.009	–	a
II	0.203 ± 0.008	1.680	0.200 ± 0.010	1.640	a	0.204 ± 0.011	1.660	a
III	0.342 ± 0.014	1.710	0.328 ± 0.019	1.680	a	0.339 ± 0.017	1.690	a
IV	0.584 ± 0.033	1.670	0.551 ± 0.025	1.630	a	0.573 ± 0.027	1.570	a
V	0.975 ± 0.025	1.570	0.899 ± 0.079	1.540	a	0.899 ± 0.017	1.480	b
VI	1.531 ± 0.034	1.520	1.384 ± 0.022	1.510	c	1.331 ± 0.021	1.420	c
VII	–	–	–	–		1.890 ± 0.048	1.109	–
Mean	–	1.630	–	1.600		–	1.488	–

Significance level of 95%: a = p > 0.01, b = p < 0.01, c = p< 0.001.

Based on literature records, larvae of *S. cosmioides* can utilize 51 host plants. Additional surveys conducted by the authors of this paper identified 75 new host plants. Most of these new records come from two population outbreaks in the state of Rio Grande do Sul, in the Spring of 1997 and 2004. The host list includes 126 plants of 40 families (Table 4). The botanical families with the greatest number of host plants include Solanaceae (15), Fabaceae (14), Asteraceae (10) and Poaceae (8). The current list of host plants of *S. cosmioides* includes cultivated and natural species, with an increase in the number of species that are considered weeds (Table 4).

The sex ratio, determined from 137 females and 134 males in the pupal stage, was 0.51, which does not differ significantly from a 1:1 ratio ($\chi^2 = 0.07$, p = 0.796).

Pupal weights varied within each sex, and some pupae weighted approximately half of the others (Table 5). Pupae from females with six instars were heavier than their male. Pupae from females with seventh instar, on average, were the heaviest (Table 5).

DISCUSSION

In the present study, the overall survival of immature *S. cosmioides* reared on artificial diet under controlled conditions and minimal interference was approximately 90% (Table 1). This demonstrates that the diet and methodology used in this study to rear *S. cosmioides* are appropriate, as they were for *S. albula*, *S. eridania* and *S. dolichos* (Montezano et al. 2013a, 2014b, 2015a). The survival rate of all these species was higher than 75%, recognized by Singh (1983) as a threshold for artificial diets to mass rearing insects.

Table 4. Checklist of natural host plants of *Spodoptera cosmioides* larvae recorded in several bibliographic sources of South America and new records from Rio Grande do Sul State, Brazil, largely based on the mountainous region from two population outbreaks, during the springs of 1997 and 2004.

Botanic family	Scientific name	Common name	References
Amaranthaceae	*Amaranthus deflexus* Linn.	Amaranth	*
	Amaranthus hibridus Linn.	Slim amaranth	7
	Amaranthus spinosus Linn.	Spiny amaranth	*
	Celosia cristata Linn.	Cockscomb	*
	Dysphania ambrosioides (Linn.) Mosyakin & Clemants	Mexican tea	*
Anacardiaceae	*Mangifera indica Linn.*	Mango	2
Apiaceae	*Daucus carota* Linn.	Carrot	*
	Daucus pusillus Michx.	American wild carrot	*
	Foeniculum vulgare Mill.	Sweet fennel	*
Aquifoliaceae	*Ilex paraguariensis* St. Hill.	Mate tea	9
Asteraceae	*Baccharis trimera* (Less.) DC	Carqueja	*
	Bidens pilosa Linn.	Hairy beggarticks	*
	Chromolaena maximilianii (Schrad. Ex DC.) R.M.King & H.Rob.	Mata-pasto	*
	Conyza bonariensis (Linn.) Cron.	Weed	*
	Helianthus annuus Linn.	Sunflower	3, 7
	Hypochaeris albiflora (Kuntze) Azevêdo-Gonç. & Matzenb.	Almeirão	*
	Lactuca sativa Linn.	Lettuce	4
	Melilotus officinalis (Linn.) Lam.	Sweetclover	7
	Sonchus oleraceus Linn	Common sowthistle	*
	Taraxacum officinalle (L.) Webber ex F.H.Wigg.	Common dandelion	*
Begoniaceae	*Begonia* sp.	Begonia	2, 7
	Begonia convolvulacea A. DC.	Morning-glory begonia	
	Begonia semperflorens Link & Otto	Begonia	*
Brassicaceae	*Coronopus didymus* (Linn.) Sm.	Lesser swinecress	*
	Brassica rapa Linn. var. *silvestris* (Lam.) Briggs.	Colza	2, 7
	Brassica oleracea Linn. var. *acephala* DC.	Kale	2
	Brassica oleracea var. *capitata* Linn.	Cabbage	2
Bromeliaceae	*Ananas comosus* (Linn.) Merril	Pineapple	2
Cactaceae	Cactaceae		2
	Opuntia ficus indica Mill.	Barbary fig	10
Caryocaraceae	*Caryocar brasiliensis* Camb.	Pequi	*
Chenopodiaceae	*Beta vulgaris* Linn.	Beet	*
	Beta vulgaris Linn. var. *Rapacea* Koch	Mangel	7
	Chenopodium quinoa Willdenow	Quinoa	*
Commelinaceae	*Tradescantia fluminensis* Vell.	Small-leaf spiderwort	*
Convolvulaceae	*Convolvulus arvensis* Linn.	Field bindweed	7
	Ipomoea batatas (Linn.) Lam.	Sweet potato	4
	Ipomoea grandiflora Linn.	Moonflower	*
Cucurbitaceae	*Cucumis anguria* Linn.	West Indian gherkin	*
	Cucumis sativus Linn.	Cucumber	2
	Cucurbita maxima Duch	Squash	*
	Fevillea cordifolia Linn.	Antidote caccoon	*
	Sechium edule (Jacq.) Sw.	Chayote	*
Euphorbiaceae	*Chamaesyce prostrata* (Aiton) Small	Prostrate sandmat	*
	Jatropha curcas Linn.	Barbados nut	11
	Ricinus communis Linn.	Castor bean	2, 11
	Vernicia fordii (Hemsl.) Airy-Shaw	Tungoil tree	11
Fabaceae	*Arachis hypogaea* Linn.	Peanut	3, 7
	Arachis villosa Benth.	Wild peanut	*
	Crotalaria breviflora DC.	Shortflower rattlebox	8
	Crotalaria spectabilis Roth.	Showy rattlebox	8
	Desmodium incanum DC.	Zarzabacoa comun	*
	Glycine max (Linn.) Merril.	Soybean	3, 4, 7

Continues

Table 4. Continued.

Botanic family	Scientific name	Common name	References
	Medicago sativa Linn.	Alfalfa	3, 7
	Phaseolus vulgaris Linn.	Bean	3, 7
	Pisum sativum Linn.	Pea	3, 7
	Senna hirsuta (Linn.) H.S.Irwin & Barneby	Woolly senna	*
	Trifolium pratense Linn.	Red clover	*
	Vicia sativa Linn.	Garden vetch	*
	Vicia villosa Roth	Winter vetch	*
	Vigna unguiculata (L.) Walp.	Caupi bean	12
Geraniaceae	*Pelargonium hortorum* L.H. Bailey	Geranium	7
Lamiaceae	*Coleus barbatus* Benth	Coleus	12
	Leonurus japonicus Houtt.	Chinese motherwort	*
	Melissa officinalis Linn.	Common balm	*
	Mentha pulegium Linn.	Pennyroyal	2,
	Ocimum basilicum Linn.	Sweet basil	12
Liliaceae	*Allium cepa* Linn.	Onion	2, 3, 7
	Allium fistulosum Linn.	Green Onion	
	Asparagus officinalis Linn.	Asparagus	3, 7
	Asparagus densiflorus (Kunth) Jessop	Sprenger's asparagus fern	3, 7
	Asparagus setaceus (Kunth) Jessop	Common asparagus fern	3
Linaceae	*Linum usitatissimum* Linn	Flax	3, 7
Lythraceae	*Cuphea calophylla* Cham.& Schlecht.	Waxweedb	*
Malvaceae	*Abelmoschus esculentus* (Linn.) Moench	Okra	*
	Gossypium herbacium Linn.	Cotton	2, 4, 7
	Malva parviflora Linn.	Mallow	*
	Sida cordifolia Linn	Heart-leaf sida	*
	Sida rhombifolia Linn.	Arrow-leaf sida	*
Myrtaceae	*Eucalyptus* sp.	Eucalyptus	*
	Psidium guajava Linn.	Apple guava	*
Nyctaginaceae	*Mirabilis jalapa* Linn.	Marvel of Peru	*
Onagraceae	*Ludwigia hyssopifolia* (G. Don) Excell	Linearleaf primrose-willow	*
Oleaceae	*Osmanthus fragrans* Lour.	Sweet osmanthus	*
Oxalidaceae	*Oxalis debilis* kunth	Pink woodsorrel	*
Phyllanthaceae	*Phyllanthus tenellus* Roxb.	Mascarene Island leaf-flower	*
Phytolaccaceae	*Phytolacca decandra* Linn.	Pokeweed	*
Poaceae	*Avena sativa* Linn.	Common oat	7
	Chloris barbata Sw.	Swollen fingergrass	*
	Lolium multiflorum Lam.	Ryegrass	6, 7
	Oryza sativa Linn.	Rice	2, 7
	Sorghum halepense (Linn.) Pers.	Johnsongrass	7
	Sorghum sp.	Sorghum	7
	Triticum aestivum Linn.	Wheat	7
	Zea mays Linn.	Corn	7
Polygonaceae	*Rumex crispus* Linn.	Curly dock	*
	Rumex obtusifolius Linn.	Broad Leaved Dock	*
Portulacaceae	*Portulaca oleracea* Linn.	Purslane	
	Talinum paniculatum (Jacq.) Gaertn.	Jewels of Opar	
Pteridaceae	*Pteridium aquilinum* (L.) Kuhn	Western brackenfern	*
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	Loquat	2
	Fragaria vesca Linn.	Strawberry	*
	Malus domestica Linn.	Apple	5
	Morus alba Linn.	White mulberry	*
Rubiaceae	*Coffea arabica* Linn.	Coffee	1
Rutaceae	*Citrus sinensis* (Linn.) Osbeck	Orange	7
Scrophulariaceae	*Verbascum virgatum* Stockes	Wand mullein	*
Solanaceae	*Capsicum annuum* Linn.	Pepper	2, 3 7

Continues

Table 4. Continued.

Botanic family	Scientific name	Common name	References
	Datura stramonium Linn.	Jimsonweed	*
	Lycopersicum esculentum Mill.	Tomato	2, 3, 7
	Nicotiana alata Link & Otto	Jasmine tobacco	3, 7
	Nicotiana tabacum Linn.	Tobacco	3, 7
	Physalis angulata Linn.	Cutleaf groundcherry	*
	Solanum acerosum Sendt.	Arrebenta-cavalo	*
	Solanum americanum Mill.	American black nightshade	*
	Solanum atropurpureum Schrank	Purple Devil	*
	Solanum melongena Linn.	Eggplant	2, 3, 7
	Solanum pseudocapsicum Linn.	Jerusalem cherry	*
	Solanum robustum H.L. Wendl.	Shrubby nightshade	*
	Solanum sisymbriifolium Lam.	Sticky nightshade	*
	Solanum tuberosum Linn.	Potato	1, 3, 7
	Solanum viarum Dunal	Tropical soda apple	*
Urticaceae	*Urera aurantiaca* Wedd.	Scratchbush	*
	Urtica dioica Linn.	Stinging nettle	*
Verbenaceae	*Lantana camara* Linn.	Lantana	*
	Stachytarpheta cayennensis (Rich.) Vahl	Cayenne porterweed	*

1. Hambleton (1939), 2. Silva et al. (1968), 3. Biezanko et al. (1974), 4. Habib et al. (1983), 5. Nora & Reis (1988), 6. Specht & Corseuil (2002), 7. Pastrana (2004), 8. Dias et al. (2009), 9. Fronza et al. (2011), 10. Teodoro et al. (2013), 11. Cabezas et al. (2013), 12. Pires et al. (2014). (*) New host plant record.

Table 5. Pupal weight (mg) of *Spodoptera cosmioides* reared on artificial diet, including individual whose larvae underwent for six and seven instars, under controlled conditions (25 ± 1°C, 70 ± 10% RH and 14 hours of photophase). A. Student t-test considering different variances between means of females and males with six larval instars; B. Same but between females with six and seven larval instars.

Larval instars	Gender	N	Mean ± SE	Range
Six	Female	124	651.201 ± 94.988	398.48-883.42
	Male	134	613.067 ± 79.379	413.03-798.55
	Significance	A	a	–
Seven	Female	13	709.375 ± 82.190	563.36-882.34
	Significance	B	a	–

Significance level of 95%: a = $p < 0.001$.

The relatively high egg viability and fecundity values observed (Table 1) are common for *Spodoptera* species. Previous studies have documented that multiple mating in *Spodoptera* enhances their reproductive capacity, including fertility (Kehat & Gordon 1975, Sadek 2001, Sadek & Anderson 2007, Busato et al. 2008, Milano et al. 2008, Montezano et al. 2013b, 2014a, 2015b, Specht et al. 2016). The incubation period of *S. cosmioides* was variable. It was longer than observed for other smaller *Spodoptera* species at the same temperatures, for instance *S. albula* (Montezano et al. 2013a) and *S. eridania* (Montezano et al. 2014b). However, it was similar to that observed for the same species (*S. cosmioides*) in the same temperature on natural host plants (Bavaresco et al. 2003, Cabezas et al. 2013) and artificial diets (Bavaresco et al. 2002), but lower than that observed for a larger species, *S. dolichos* (Montezano et al. 2015a). These observations indicate that an increase in size positively influences the duration of the embryonic period of *Spodoptera*.

The overall larval survival was also high (Table 1) and consistent with that observed for *S. albula* (Montezano et al. 2013a), *S. eridania* (Montezano et al. 2014b) and *S. dolichos* (Montezano et al. 2015a) under the same conditions. Most larvae (95.20%) completed their development in six instars and only a few *S. cosmioides* females (n = 13) completed their development in seven instars (Table 2). These results indicate that diet and rearing conditions were satisfactory for the larval development of *S. cosmioides* in the laboratory.

Additional larval instars have been reported by previous studies on *Spodoptera* species, including *S. cosmioides* (e.g., Parra et al. 1977, Santos et al. 1980, 2005), and were associated with unsuitable food plants (e.g., Mattana & Foerster 1988, Cabezas et al. 2013) or artificial diet (Bavaresco et al. 2004). In a study by Bavaresco et al. (2004), two more adequate artificial diets were used, 17.6 and 20.7% of the larvae of *S. cosmioides* experienced an additional instar, whereas on a less adequate diet, only 50% of the larvae had seven instars. They did not, however, discriminate the sexes. Typically, the number of instars tend to increase under adverse rather than favorable conditions and most common factors influencing the number of instars include temperature, photoperiod, quantity and quality of food, humidity, injuries, inheritance, and sex (Esperk et al. 2007). This observation is consistent with the compensations scenario, according to which additional instars are added under unsuitable conditions, when larvae fail to reach a species-specific threshold-size with the "normal" number of instars. The results of this study (Tables 2-3) and those using other species under the same conditions (Montezano et al. 2013a, 2014b, 2015a) indicate that females may need an additional instar because their final size is larger than males.

The larval developmental time of *S. cosmioides*, including the prepupal period (Tables 1-2), was similar to results obtained with natural host plants (Bavaresco et al. 2003) and artificial diet (Bavaresco et al. 2002, 2004). Female larvae that went through seven instars (Table 2) took the longest to develop, a correlation that was also observed in *S. albula* (Montezano et al. 2013a), *S. eridania* (Montezano et al. 2014b) and *S. dolichos* (Montezano et al. 2015a) under the same conditions. Our result is also consistent with other studies of *Spodoptera* in which an increased number of instars are associated with a longer larval development (e.g., Santos et al. 2005, Azidah & Sofian Azirun 2006, Cabezas et al. 2013).

There was a significant difference in the overall developmental time between male and female larvae of *S. cosmioides* that underwent six instars (Table 2). The sex differences in the duration of the stages was significant from the fourth instar and agree with reported for *S. albula*, *S. eridania* and *S. dolichos* reared under same conditions (Montezano et al. 2013a, 2014b, 2015a).

The mean width of the larval head capsule of 75 specimens in the first (0.289 mm, SD = 0.014) and last [sixth] instars (3.232 mm, SD = 0.172) is similar to that observed by Zenker et al. (2007). This indicates that mature larvae of *S. cosmioides* are larger than *S. albula* (Montezano et al. 2013a), *S. eridania* (e.g., Parra et al. 1977, Mattana & Foerster 1988, Montezano et al. 2014b) and *S. frugiperda* (e.g., Lopes et al. 2008). The immature larvae of *S. cosmioides* are, however, smaller than *S. dolichos* (Montezano et al. 2015a).

The growth rate decreased progressively until the last instar (Table 3). This decrease in rate was similar for both sexes and was especially noticeable in female larvae that underwent seven instars. A similar decrease in growth rate was also observed for *S. eridania* (Mayer & Babers 1944, Parra et al. 1977, Valverde & Sarmiento 1987, Mattana & Foerster 1988, Montezano et al. 2014b), *S. albula* (Montezano et al. 2013a) and *S. dolichos* (Montezano et al. 2015a).

The 126 host plants documented for *S. cosmioides* (Table 4) corroborate the polyphagy habit described by several authors (e.g., Silva et al. 1968, Pastrana 2004, Pogue 2002). The large number of host plants utilized by *S. cosmioides* (Table 4) is comparable to the number of hosts of *S. albula* (Montezano et al. 2013a), *S. eridania* (Montezano et al. 2014b), *S. dolichos* (Montezano et al. 2015a) and *S. frugiperda* (Casmuz et al. 2010). However, different species seem to prefer hosts in certain families: *S. albula* have a preference for Fabaceae (Montezano et al. 2013a), *S. eridania* for Asteraceae (Montezano et al. 2014b), *S. frugiperda* for Poaceae (Casmuz et al 2010), *S. dolichos* (Montezano et al. 2015a) for Solanaceae and, in this study, *S. cosmioides* for Asteraceae and Solanaceae (Table 4).

The larval development times obtained for female *S. cosmioides* were slower than for males (Table 2), which again is consistent with what has been observed in several *Spodoptera* species (e.g., Bavaresco et al. 2004, Farahani et al. 2011, Nagoshi 2011, Montezano et al. 2013a, 2014b, 2015a). However, the delay on the development of females during the larval stage was compensated by a shorter pupal period. In the end, males and females emerged as adults during the same period. This result demonstrates how important it is to account for larval developmental time differences between males and females.

The weight difference between the sexes during the pupal stage is relatively well documented among *Spodoptera* (e.g., Habib et al. 1983, Mattana & Foerster 1988, Bavaresco et al. 2004, Santos et al. 2005, Xue et al. 2010, Montezano et al. 2013a, 2014b, 2015a) and other Lepidoptera. The larger size of females that went through seven instars (Table 5) is attributed to the additional instar (e.g., Esperk et al. 2007, Nagoshi 2011, Montezano et al. 2013a, 2014b, 2015a).

This study increases the biological knowledge of *S. cosmioides*, an important pest of native and exotic plants of South America (e.g., Silva et al. 1968, Biezanko et al. 1974, Pastrana 2004). Detailed information about its biology is critical, particularly with respect to the larval stage, which has the potential to cause economic loss in several commercial crops such as agroenergy plants, cotton, eucalyptus seedlings and soybean (e.g., Santos et al. 1980, Habib et al. 1983, Santos et al. 2005, Cabezas et al. 2013).

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