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Population fluctuation of *Sternechus subsignatus* Boheman (Coleoptera: Curculionidae) at its different development stages associated with soybean crop cycle in Tucumán, Argentina

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ABSTRACT

Soybean stalk weevil *Sternechus subsignatus* Boheman 1836 (Coleoptera: Curculionidae) population fluctuation was assessed during a three-year period in Northwestern Argentina (NOA). Both population fluctuation of adults, eggs and active larvae on soybean [*Glycine max* (L) Merr] host plants, as well as overwintering forms in soil (larvae, pupae and adults), were recorded. *S. subsignatus* is a univoltine species, so its life cycle is annual and comprises an active phase, when the pest attacks soybean crops and another dormancy phase, when it remains buried in the soil. Adults were first observed in the crop from late November up to early March. From then onwards, *S. subsignatus* development stages where it remained associated with the host plant took place at definite times. The eggs appeared on plants from mid-January to the end of March. Larval period lasted from the end of January to the end of April, when larvae jumped onto the ground and buried themselves to spend the winter. Pupae were observed towards the end of September, and adults first appeared as October was drawing to a close. A new cicle began, with adults emerging in late November or early December. Thus, it was observed that *S. subsignatus* in the NOA region presents a single annual generation.

Palabras clave: pest management, weevils, population ecology.

RESUMEN

Fluctuación poblacional de *Sternechus subsignatus* Boheman (Coleoptera: Curculionidae) en sus diferentes estados de desarrollo asociados con el ciclo del cultivo de soja en Tucumán, R. Argentina

La dinámica poblacional del picudo del tallo de la soja *Sternechus subsignatus* Boheman 1836 (Coleoptera: Curculionidae) fue evaluada durante un periodo de estudio de tres años en el Noroeste Argentino (NOA). Se registró la fluctuación de adultos, huevos y larvas activas en el hospedero soja, además de las formas hibernantes en suelo, larva, pupa y adulto. El ciclo de vida de *S. subsignatus* es anual y comprende una fase activa, asociada al cultivo de la soja [*Glycine max* (L) Merr], y otra fase de latencia, durante la cual la plaga permanece en el suelo, sin entrar en contacto con el cultivo. Los primeros adultos se observan en campo desde finales de noviembre y hasta los primeros días de marzo. A partir de allí, los diferentes estadios de desarrollo asociados al hospedero ocurren en tiempos bien definidos. Los huevos en planta aparecen en la segunda mitad de enero y continúan apareciendo durante todo el mes de marzo. El periodo larval se extiende desde los últimos días de enero hasta los últimos días de abril, cuando las larvas saltan al suelo y se entierran para pasar el invierno. Se observan las primeras pupas en los últimos días de septiembre y los adultos, a partir de los últimos días de octubre. Un nuevo ciclo comienza con la emergencia de los adultos, a fines de noviembre o principios de diciembre. Así, se observa que *S. subsignatus* en la región NOA presenta una generación anual.

Key words: manejo de plagas, gorgojos, ecología de poblaciones.

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INTRODUCTION

The soybean stalk weevil *Sternechus subsignatus* Boheman, 1836 (Curculionidae: Sternechini) is one of the most important soybean pests in Northwestern Argentina (Casmuz *et al*., 2009a) and is also present in Bolivia, Brazil and Paraguay (Costilla y Venditti, 1990; Hoffmann-Campo *et al*., 1990; Hoffmann-Campo *et al*., 1991; Sosa Gomez *et al*., 2008). This Neotropical pest (Hoffmann-Campo *et al*., 1990) is oligophagous and has a diet restricted to certain leguminous species (Hoffmann-Campo *et al*., 1991; Lorini *et al*., 1997; da Silva, 1997), such as soybean (*Glycine max* L.), bean (*Phaseolus vulgaris* L.), grandull (*Cajanus cajan* L.) and dolichos (*Dolichos lablab* L.). These related species are the preferred hosts and cause an increase in *S. subsignatus* population (da Silva, 1997).

The soybean stalk weevil is highly harmful since both larvae and adults damage soybean (da Silva *et al*., 1998). Adults feed on stem tissues and if this occurs during soybean early vegetative stages, the plant may die. Gravid females girdle around the main stem, fraying the epidermis and cortex to lay one egg, which is then covered with fiber and tissue pieces. Soon after eclosion, the larva penetrates the stem and feeds on the medulla, remaining at the oviposition site, and as it develops, a gall is formed in the girdled part (Hoffmann-Campo *et al*., 1991). Larval feeding results in a reduction or interruption of sap circulation in the main stem, which can reduce plant productivity. Depending on pest density, more than one oviposition can occur on the same plant, resulting in up to eleven rings. After larval development, and close to soybean harvest period, the fifth instar larvae jump onto the ground and enter hibernation, protected in chambers formed with soil particles (Hoffmann-Campo *et al*., 1990). The hibernating larvae remain in the chambers until pupation and adult emergence.

Several combinations of cultural and chemical alternatives are available for soybean weevil control and management. Among the most widely chosen cultural alternatives, rotation with grass species is used to decrease insect populations, since these crops are not hosts of the weevil (da Silva, 1996, 1997). In combination with this strategy, delaying soybean sowing dates in plots with important precedents of this problem results in a desynchronization between weevils that emerge early in the season and early soybean development stages (Casmuz *et al*., 2009b). Among chemical control alternatives, seed treatments are used to protect the crop in its early development stages (Casmuz *et al*., 2009a). Foliar insecticides constitute another alternative, but they only provide short-lived protection, since continuous adult emergence leads to rapid crop reinfestation (Hoffmann-Campo *et al*., 1991; Casmuz *et al*., 2010). Besides, the nocturnal habits of the adults and the fact that larvae remain protected inside soybean stems make its management rather difficult. Moreover, no-tillage system or minimum tillage facilitates the survival of *S. subsignatus* hibernating larvae, increasing pest population levels (Hoffmann-Campo *et al*., 1991).

Knowledge of *S. subsignatus* biological cycle and the temporal and space fluctuation of each one of its development stages allows implementing management strategies that contribute to decreasing the incidence of this pest on crops and also reducing progeny numbers for the following seasons. Thus, monitoring the soil some months before soybean sowing will enable estimations of the density of adults in the field and the adoption of appropriate measures to control the pest, such as adjusting sowing dates or opting for seed treatments with insecticides. By knowing probable dates for adult emergence in soybean plots, it is possible to adopt strategies or implement cultural management alternatives to reduce *S. subsignatus* dispersion and permanence along the season. Likewise, knowing the definite times for egg laying, it is possible to deploy adult control strategies to stop or minimize egg laying, and thereby reduce its offspring.

There is currently a lack of information on *S. subsignatus* biology and behavior and its relation to soybean and other possible crop hosts in Northwestern Argentina. This information would certainly shed light on more efficient management strategies to control this pest. Therefore, as an important first step towards optimizing *S. subsignatus* management, our primary objective was to determine its population fluctuation in soybean fields in two areas of Tucumán province, while considering its different development stages. We also aimed to determine *S. subsignatus* life cycle duration under field conditions as a secondary objective.

MATERIALS AND METHODS

Study sites

Surveys were carried out in two areas of Tucumán province (Argentina): the Eastern Zone (Burruyacu and Cruz Alta departments) and the Southern Zone (La Cocha department) during the winter of three soybean seasons (2007/2008, 2008/2009 and 2009/2010). In the 2007/2008 season, surveys were conducted on two commercial farms (27° 46' 48.41" S, 65° 30' 22.01" W and 27° 47' 8.85" S, 65° 29' 27.30" W) for the Southern Zone, and on one commercial farm (26° 44' S, 65° 44' W; Burruyacu department) for the Eastern Zone. For the other two crop seasons, surveys continued on one farm in the South, whereas in the East, they were carried out at experimental fields of Estación Experimental Agroindustrial Obispo Colombres (EEAOC) in Monte Redondo (26° 49' S, 64° 51' W; Cruz Alta department). Sowing dates and varieties used in each year and area are shown in Table 1. Plots were kept under conventional management, with fungicide, herbicide and insecticide applications.

Table 1. Sowing dates and soybean varieties used in the three studied seasons, for both East and South Areas.

Soybean season	Zone	Farm	Soybean variety	Sowing date
2007-2008	East	Commercial farm	A 7636 RG	21/12/2007
	South	Commercial farm 1	A 8100 RG	29/12/2007
		Commercial farm 2	A 7636 RG	21/12/2007
2008-2009	East	Monte Redondo sub-station	Munasqa RR	17/12/2008
	South	Commercial farm 2	A 8000 RG	28/12/2008
2009-2010	East	Monte Redondo sub-station	Munasqa RR	23/12/2009
	South	Commercial farm 2	A 7636 RG	14/12/2009

Insect sampling

S. subsignatus population fluctuation and progress through its different development stages was studied throughout three seasons. The period of adult emergence from the soil was determined by a weekly checking of 20 circular metalic cages that had been distributed randomly in a 2 ha area in each zone under study. Cage surfaces were 0.52 m^2 and were covered with a thin cotton cloth to prevent insects from escaping.

Insect presence (including adults, eggs and developing larvae) was estimated by indirect evidence in the plant during crop season (Figure 1) and by sampling overwintering non-active forms (late instar larvae, pupae and pre-emerging adults) from the soil after harvest. As this species has crepuscular habits, indirect evidence was necessary for estimating adult stage development. Adult presence was inferred from the visualization of the characteristic damage caused by their feeding, whereas egg and larval presence was inferred from the existence of rings on the plants made by females, and from the number of galls in plants, respectively. Finally, the number of plants showing open galls was indicative that the larvae had jumped onto the ground to start hibernation.

At each sampling date, 30 randomly distributed one-meter lines were monitored on each farm in an area of 2 ha. The monitoring was performed every week, starting at the V3 phenological stage (Fehr and Caviness, 1977), given that soybean plants have lost the insecticide effect of seed treatments by then, and continued until the end of the crop cycle.

Overwintering forms were sampled from the soil during autumn, winter and part of spring on a fortnightly basis. Ten randomly selected plots of the soybean plantations of the previous season were sampled on each farm. Each plot was 1 x 0.30 x 0.20 m in length, width and depth respectively. Monitoring consisted in sieving the soil sample and recording development stages observed and the total number of hibernating forms (larva/pupa/adult).

Data analysis

To describe population fluctuation, the values of all sampling dates were averaged to obtain an estimated mean number of development stages succeeding one another in one year of study. Descriptive analysis of data was performed by using Infostat (2003) statistical package.

RESULTS

Active forms

2007/2008 season

In both studied areas, the active phase started with adult emergence in late November and early December and extended up to mid-February (Figure 2). Emergence from the ground reached its peak at the close of December and lasted the whole of the following month. The number of plants damaged by *S. subsignatus* and the fluctuation of its active forms for the Eastern and Southern Zones can be observed in Figure 3. Although plants were damaged throughout most of soybean crop cycle, plant damage mostly concentrated on the vegetative and early reproductive stages. The egg period was similar in both areas, starting in the last week of January and finishing on the first days of March. Egg laying peak was observed in the first fortnight of February, regardless of its density. It was observed that larval period began on the last few days of January and first few days of February, lasting up to April. Larval peaks occurred during the last weeks of February and the first ones of March. Larvae that first jumped down onto the soil started to be observed during the first weeks of March. The duration of each period is shown in Table 2.

2008/2009 season

Damage levels in soybean plants were high from the first vegetative stage onwards, with an increase in intensity in subsequent stages of the phenological cycle (Figure 4). Adult emergence started at the end of November and the third week of December for the Eastern and Southern Zones, respectively, stretching up to the close of February (Figure 2). The Eastern Zone showed two emergence peaks, whereas the Southern Zone only showed one which coincided with the second one for the Eastern Zone. The duration of the period was similar in

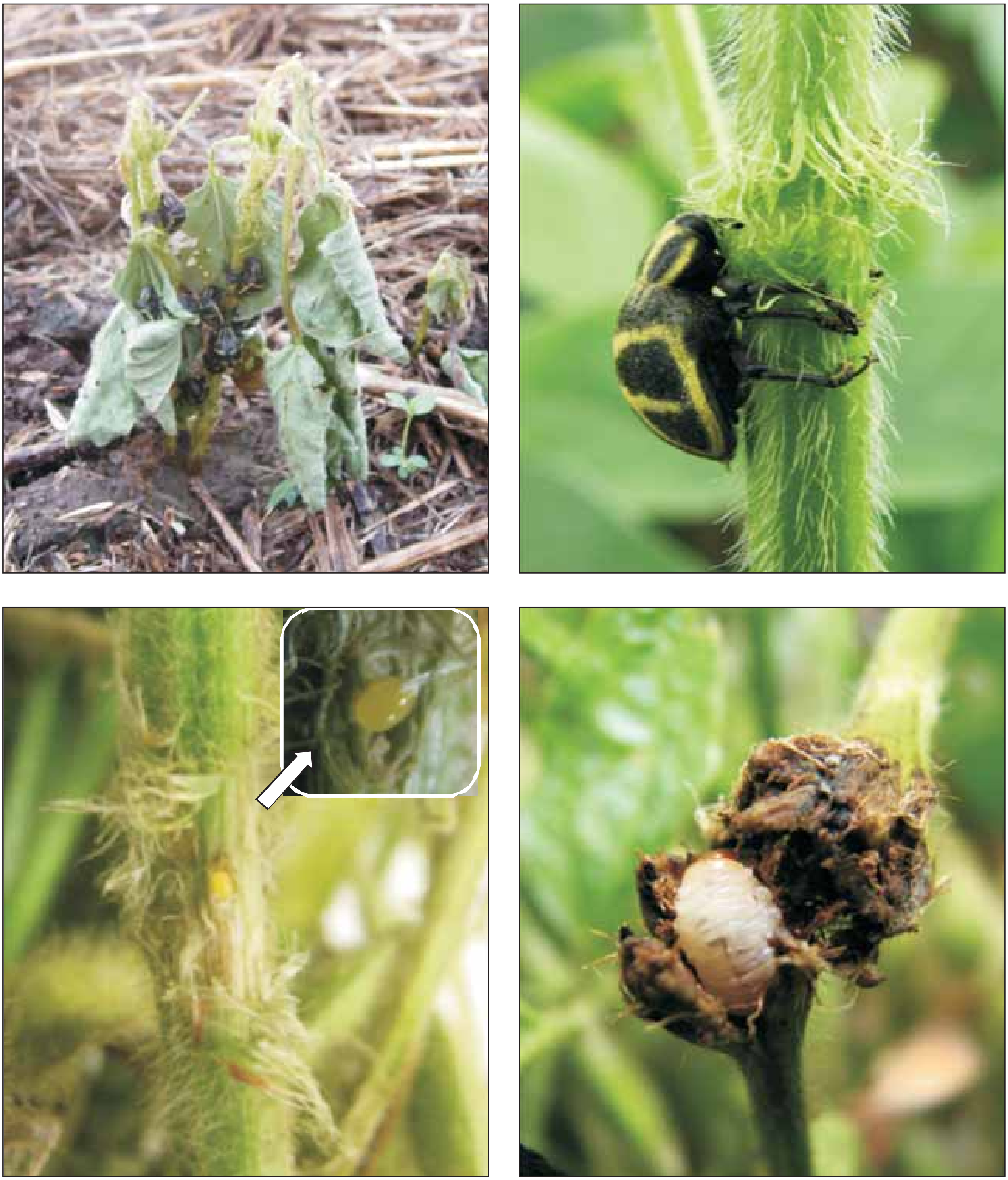

Figure 1. Top left: *Sternechus subsignatus* adults feeding on soybean plants. Top right: a female fraying soybean tissues to lay eggs. This circular fray constitutes the characteristic "ring" left by the weevil. Bottom left: an egg inside the ring. Bottom right: a larva inside a gall, ready to jump onto the ground.

both areas and also resembled the duration recorded for the previous season in both areas (Table 2). Egg period was similar in both areas, and started in the middle of January. Egg period lasted until early March, with the egg laying peak taking place in the second week of February.

Active larvae feeding inside galls were observed between the second fortnight of February and the end of April, even though the highest numbers were registered during late February and the first week of March for the Eastern Zone and the last few weeks of March for the Southern Zone.

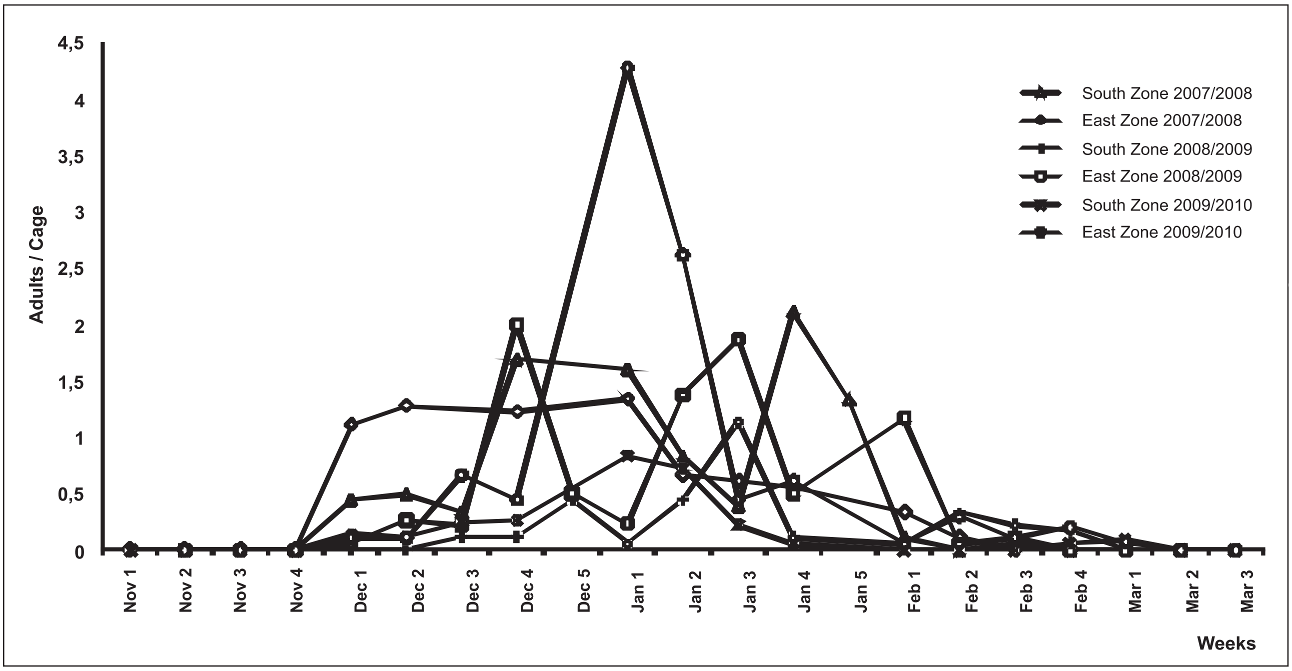

Figure 2. *Sternechus subsignatus* adult emergence during the 2007/2008, 2008/2009 and 2009/2010 soybean seasons in the Eastern and Southern Zones in Tucumán. Dates without point markers represent situations where access to the farm was not possible.

Table 2. Duration (days) of *Sternechus subsignatus* development stages in soybean fields. The values are absolute and were calculated using data collected from the first to the last observation of each development stage during weekly (summer) and fortnightly (winter) monitorings.

			Active forms			Soil forms		
Soybean season	Zone	Farm	Adults emergence	Eggs	Larvae	Larvae	Pupa	Adults
2007/2008	East	Commercial farm	73	36	41	……	36	116
	South	Commercial farm 1	……	43	82	……	35	127
		Commercial farm 2	62	28	64	……	44	134
2008/2009	East	Monte Redondo sub-station	69	73	77	196	28	140
	South	Commercial farm 2	71	49	70	167	20	109
2009/2010	East	Monte Redondo sub-station	84	55	60	225	35	143
	South	Commercial farm 2	89	48	81	207	45	115

The first larval jumps occurred in late February and early days of March. The duration of each period is shown in Table 2.

2009/2010 season

Damage caused by adults was severe throughout the crop cycle, keeping an average of four and seven damaged plants/m linear crop (Figure 5). Adult emergence started on the last days of November in the Southern Zone and the first week of December in the Eastern Zone, and it concluded in the first week of March (Figure 2). Emergence peak occurred in the first fortnight of January in both areas. Adults were present in soybean fields until days before harvest. Although emergence period was similar in both areas, egg period started earlier in the Southern Zone, showing ring peaks earlier than in the Eastern Zone. Larval period was also observed earlier in the field in the Southern Zone, as well as gall peak, which occurred a month earlier than in the Eastern Zone. Overall, even though the Southern Zone showed an early appearance of *S. subsignatus* active forms on soybean, the areas did not differ in what concerns duration of periods, as shown in Table 2.

Soil overwintering forms
Winter 2008

Table 2 shows the duration of *S. subsignatus* development stages spent buried in the soil. There was an overlap between development stages during the last few days of September and early October, when it was possible to find larvae, pupae and adults on the ground in both the Eastern and Southern Zones (Figure 6). In mid-October only pupae and adults coexisted in the soil, although with a

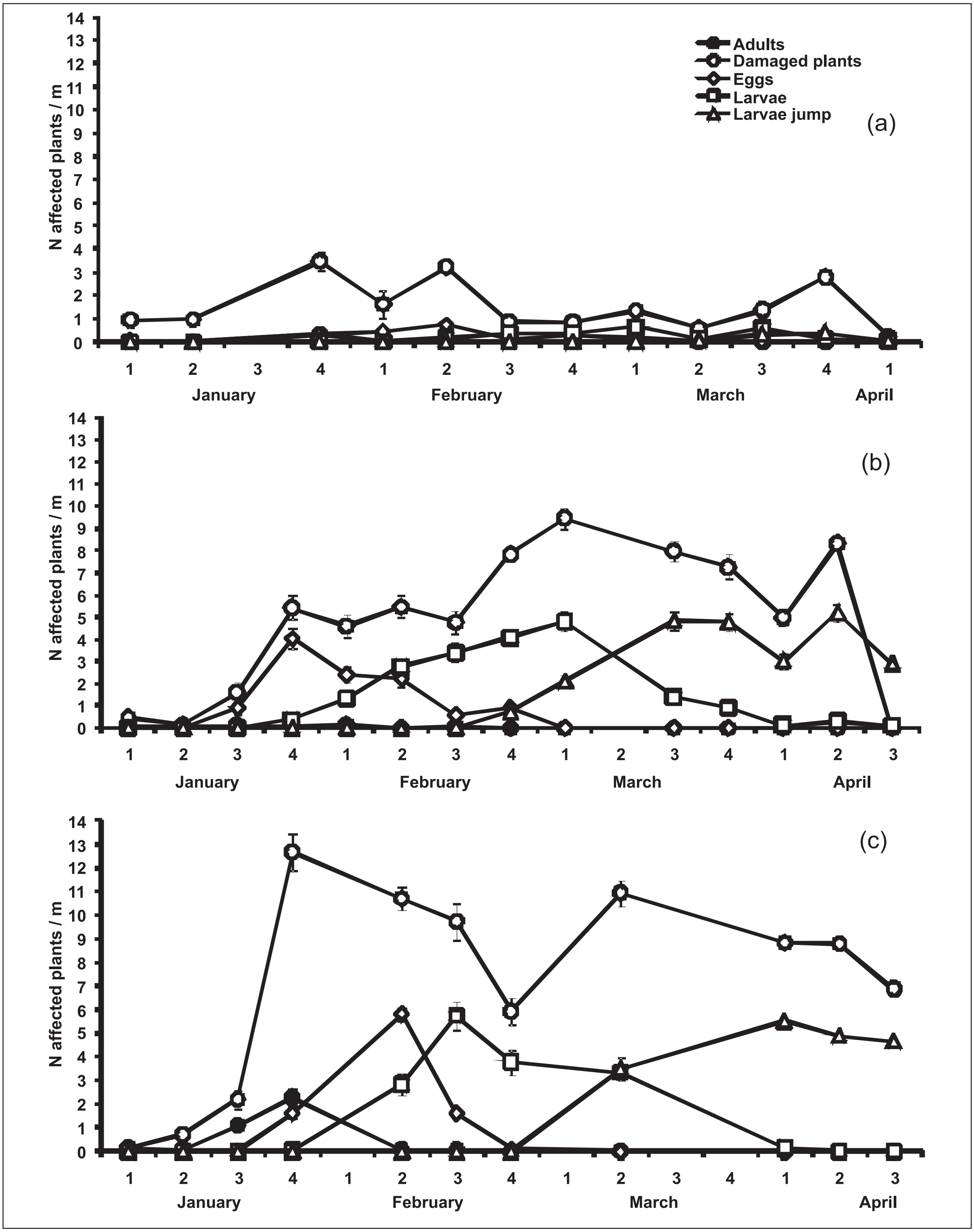

Figure 3. Population fluctuation of *Sternechus subsignatus* adults, eggs and larvae during the 2007/2008 soybean season in Tucumán. (a) Eastern Zone farm; (b) commercial farm 1 and (c) commercial farm 2 for the Southern Zone. Damaged plants constitute an indirect sign of adult abundance, whereas adults were directly observed in the field (density of adults directly observed in the field was very low due to their crepuscular habits, but it is still shown in the graphics). Dates without point markers represent situations where access to the farm was not possible.

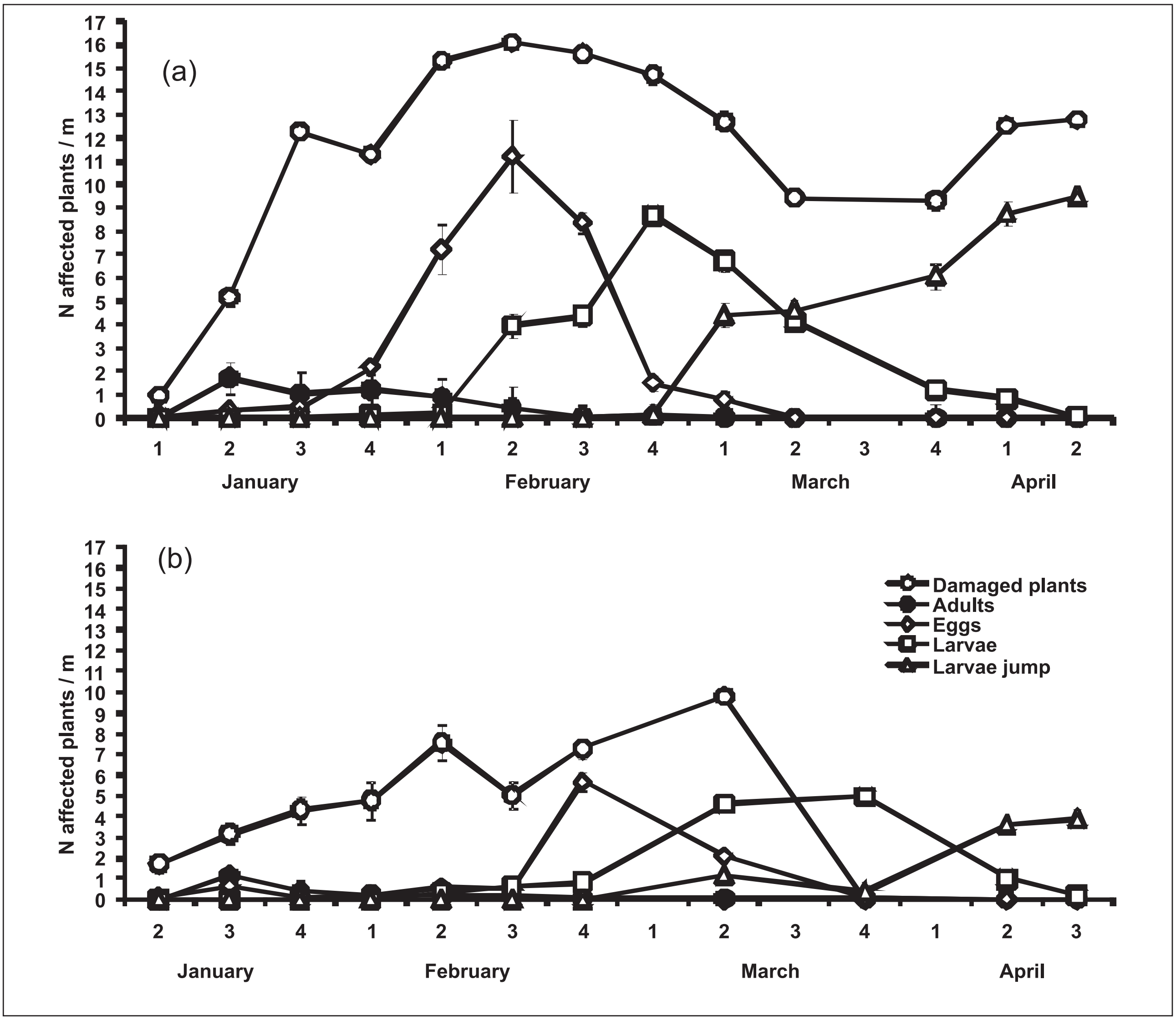

Figure 4. Population fluctuation of *Sternechus subsignatus* adults, eggs and larvae during the 2008/2009 soybean season in Tucumán. (a) Eastern Zone farm; (b) Southern Zone farm. Damaged plants constitute an indirect sign of adult abundance, whereas adults were directly observed in the field (density of adults directly observed in the field was very low due to their crepuscular habits, but it is still shown in the graphics). Dates without point markers represent situations where access to the farm was not possible.

greater proportion of the latter. From late October to the end of the period during which *S. subsignatus* remained in the soil, the only visible forms were adults.

Winter 2009

Table 2 shows the duration of *S. subsignatus* development stages that took place in the field for Eastern and Southern Zones. In both areas, larval stage in the soil extended from the jump (generalized in April) to early October. From mid-September onwards, the first pupae were recorded, and this stage continued throughout October. Adults became visible in mid-October and constituted the only visible forms on the ground from November up to adult emergence in the first few days of December (Figure 7).

Winter 2010

The Eastern and Southern Zones showed a similar fluctuation pattern of overwintering forms found in the soil, with an overlap between development stages (Figure 8). During the first half of October hibernating larvae, pupae and adults were observed in the soil, even though the first two forms were found in a generally much smaller number than adults. After jumping, overwintering larvae were observed until the middle of October. Pupae were found in the ground from mid-September and mid-October in the Eastern and Southern Zones, respectively. The predominant following form was the overwintering adults, observed from the second half of October onwards. It actually became the only form visible in November, until adult emergence in December.

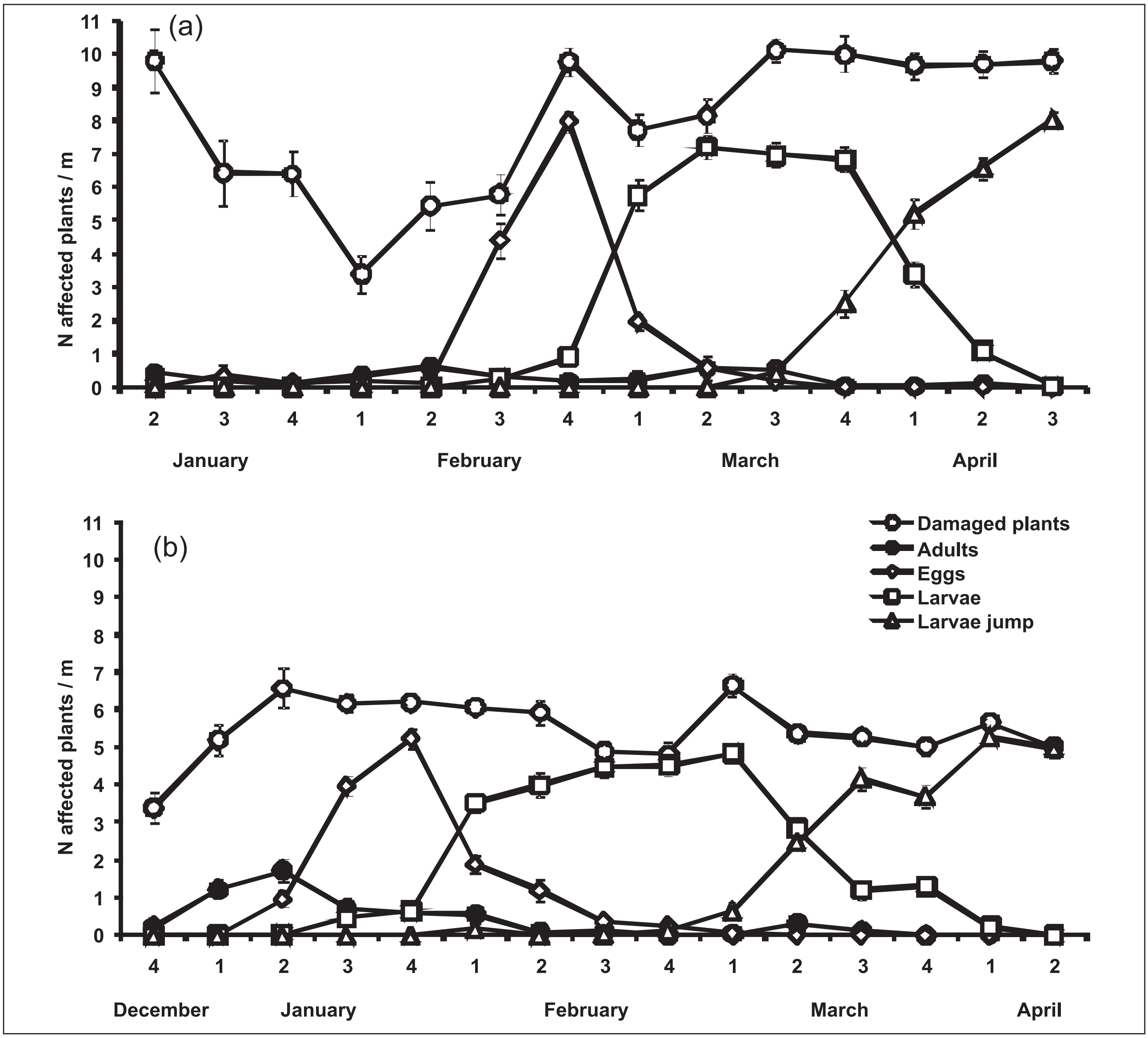

Figure 5. Population fluctuation of *Sternechus subsignatus* adults, eggs and larvae during the 2009/2010 soybean season in Tucumán. (a) Eastern Zone farm; (b) Southern Zone farm. Damaged plants constitute an indirect sign of adult abundance, whereas adults were directly observed in the field (density of adults directly observed in the field was very low due to their crepuscular habits, but it is still shown in the graphics). Dates without point markers represent situations where access to the farm was not possible.

DISCUSSION

Although *S. subsignatus* population fluctuation has been examined previously, all these previous studies were conducted in Brazil, under different agroecological conditions. In this study, we examined *S. subsignatus* population fluctuation in connection to soybean crops in Northwestern Argentina. *S. subsignatus* presence in the region was analyzed in order to provide relevant information regarding its behavior and seasonal activity. We found that this weevil is active from early soybean development stages up to its harvesting period, presenting high population density levels in all the surveyed areas. Data of this study suggest that adults emerge and oviposit over several weeks and this leads to an increase in the duration of egg and larva periods in the field. The information also suggests that *S. subsignatus* would present a generation per year, with an annual life cycle.

Curculionidae lifetime cycle and the number of larval stages vary depending on both the species and environmental conditions. Furthermore, variations are observed mainly depending on temperature and food availability (Lanteri *et al*., 2002). Studying the fluctuation of resources availability and its effect on insect populations, Dempster and Pollard (1981) claimed that a resource limitation has a preponderant role in determining population size. Moreover, variations in food availability determine changes in the number of progenies from generation to generation. In the case of the soybean stalk weevil, adults generally appear in high densities in areas where a severe

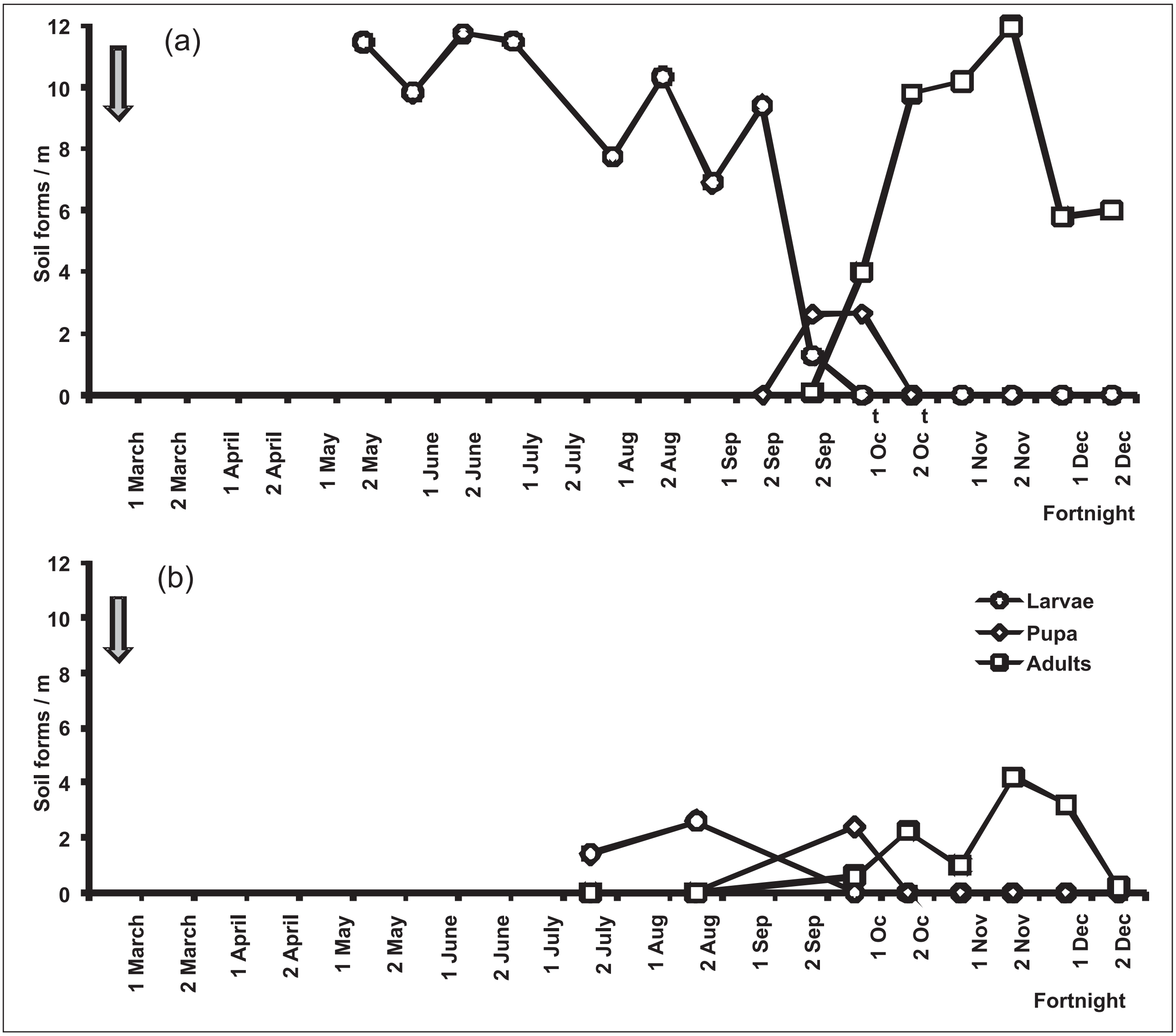

Figure 6. Fluctuation of *Sternechus subsignatus* overwintering forms, winter 2008. (a) Eastern Zone; (b) Southern Zone. Arrows indicate the beginning of larvae jumping onto the ground. Dates without point markers represent situations where access to the farm was not possible.

attack and normal rain levels were recorded in most of the previous soybean season. We found that *S. subsignatus* has an active phase associated to soybean crops and another inactive phase, which is completed in the soil. Since it was not possible to monitor the soil during the soybean seasons to verify what stage *S. subsignatus* was going through, we can only suggest that the pest presents a generation per year and an annual life cycle in Northwestern Argentina. This suggestion is supported by results of similar experiments conducted in Brazil that led to the same assumption. Our research is in agreement with that conducted by Hoffmann-Campo *et al*. (1991), da Silva (1999) and Lorini *et al*. (1997) in different regions in Brazil. We noticed that *S. subsignatus* adults emerged from the soil gradually over a long period of time, just as described by Hoffmann-Campo *et al*. (1991) for the north of Paraná State in Brazil. This continuous and prolonged adult emergence resulted in longer egg and larva periods in the field, with ovipositions uninterrupted throughout the crop cycle. Therefore while there is overlap between development stages in the field, their peak densities do not overlap in time, so larval density peak occurs after egg peak. This is clearly seen in Figures 3, 4 and 5, where insect fluctuation graphics show that the egg-in-field peak, represented by the rings on soybean stalks, was followed by galls peak, which represented the hatching of eggs and the beginning of active larval stage in the field. This situation does not agree with what was observed in Brazil. Hoffmann-Campo *et al*. (1991) observed rings on soybean plants from the end of November to the end of March, with both development stages coinciding simultaneously with their respective density peaks. Lorini *et al*. (1997) and da Silva (1999) also observed this situation of simultaneous presence of *S. subsignatus* adults and eggs in the field. Due to the fact

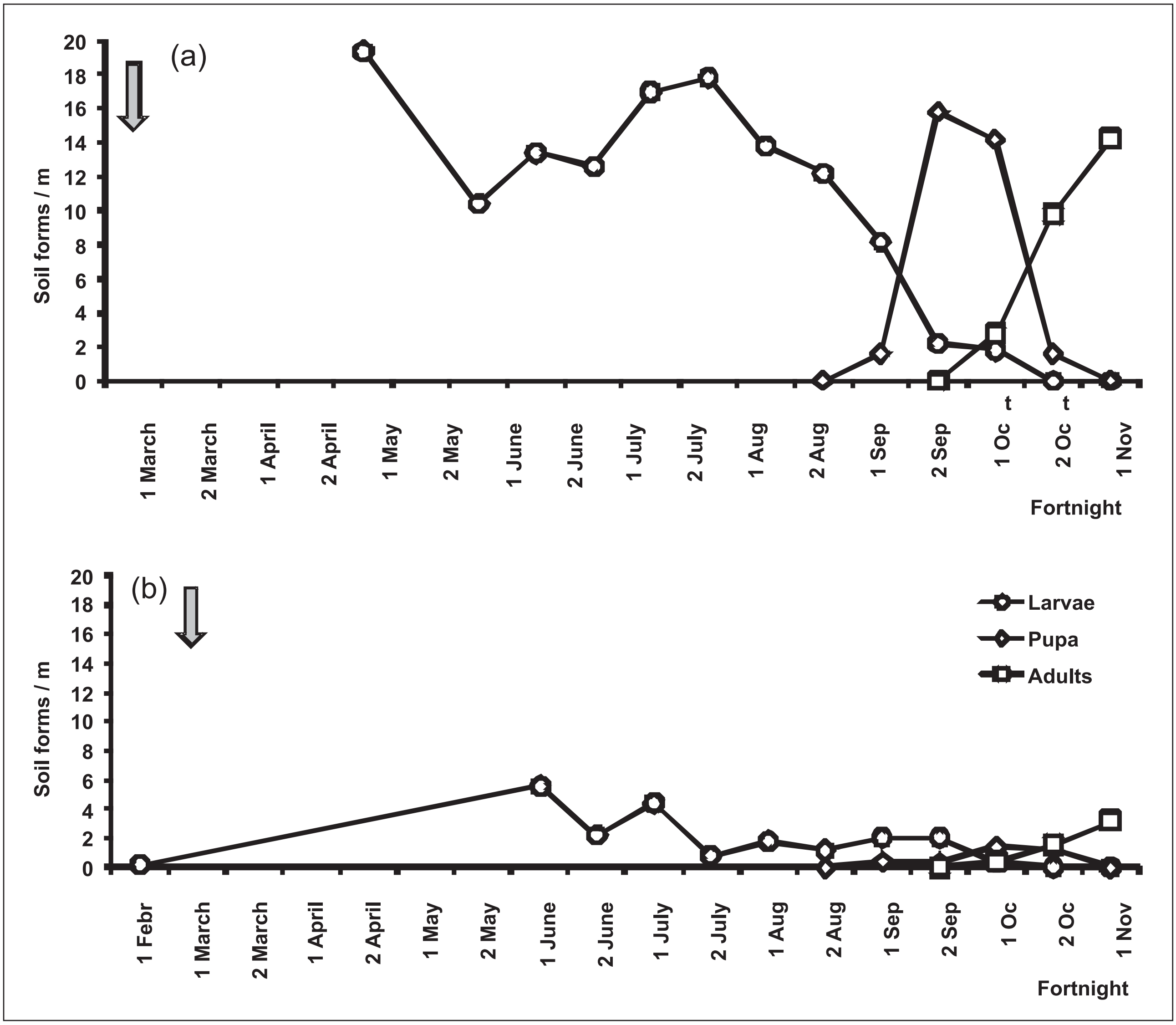

Figure 7. Fluctuation of *Sternechus subsignatus* overwintering forms, winter 2009. (a) Eastern Zone; (b) Southern Zone. Arrows indicate the beginning of larvae jump onto the ground. Dates without point markers represent situations where access to the farm was not possible.

that larvae spend five phases inside stalks for at least 30 days, it is logical to find overlapping in time between adult and egg phases. Larvae jumping onto the ground at the beginning of hibernation begins in mid-February and ends in May in Northwestern Argentina, whereas in Brazil it starts earlier, from December to March. This happens because in this country, soybean seasons begin in October and end in March. Again, this situation clearly reflects the close synchrony there exists between the pest and soybean crop cycle. da Silva (1999) considers that although variations in timing of *S. subsignatus* developmental stages can be attributed to a series of adverse factors, such as water deficit, extreme temperature conditions, lack in food, energy consumption and varying sowing dates, environmental conditions do not affect the biology of the insect.

Other weevils of the *Sternechus* genus also complete their life cycle in one year while spending some of their development stages in the soil, also showing a temporal syncrony with their host plants. That is the case of *S. paludatus* Casey, an insect of economic importance that has been found to injure *Robinia neomexicana* Gray and *Phaseolus vulgaris* L. in the United States of America. Development stages from egg to adult phase depend on seasonal temperature, but only one generation develops each year. *S. paludatus* larva also drops onto the ground for pupation (Shaw and Douglas, 1942). *S. uncipennis* Boheman weevil fulfills the whole of its biological cycle in association with a wild leguminous, *Canavalia* sp. in Brazil. *S. uncipennis* larvae feed on seeds and once developed, jump onto the ground and bury themselves a few centimeters deep, forming a hibernating chamber where they spend several months until reaching pupa adult stages later on (Bondar 1928; 1930).

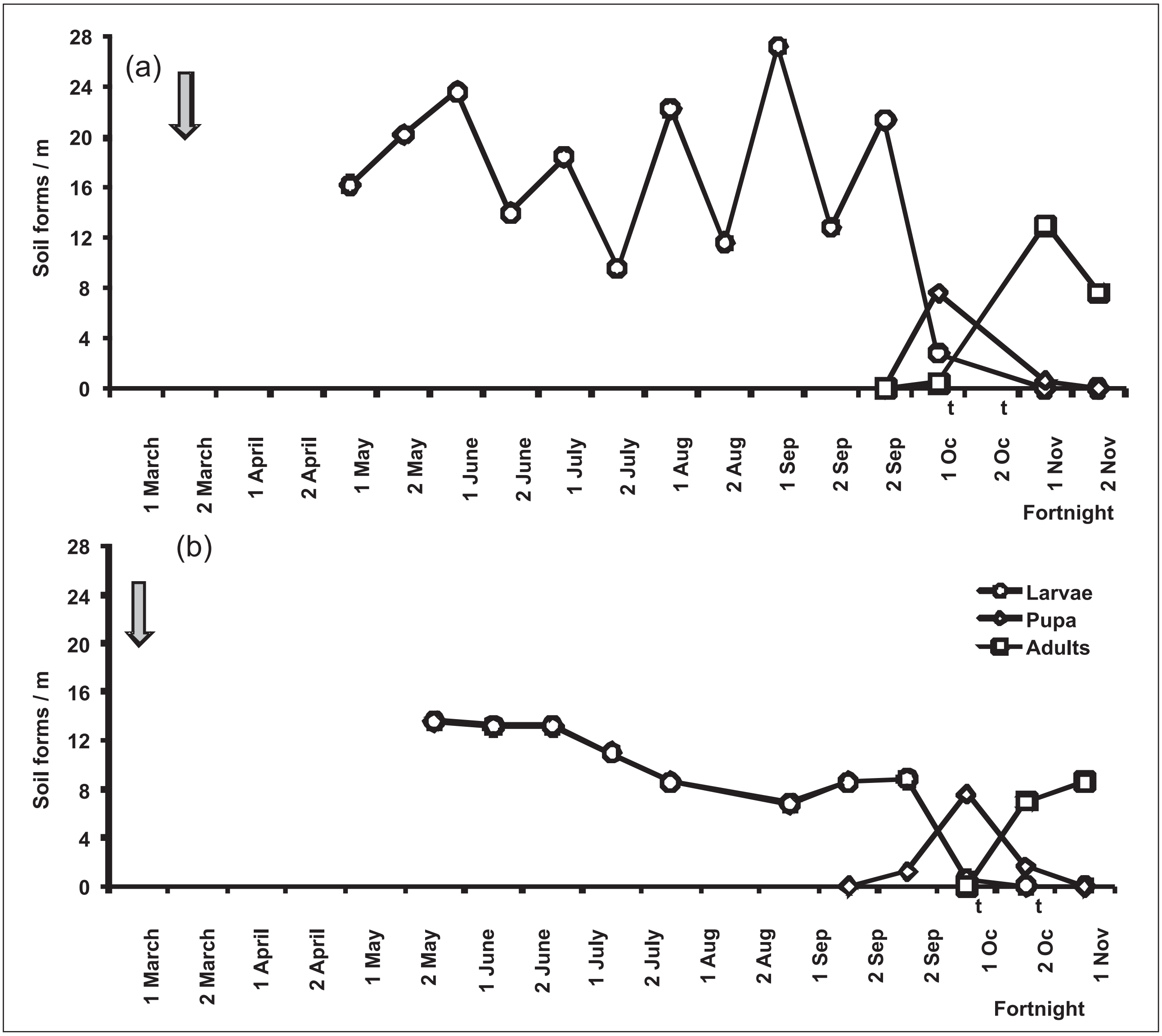

Figure 8. Fluctuation of overwintering *Sternechus subsignatus* forms, winter 2010. (a) Eastern Zone; (b) Southern Zone. Arrows indicate the beginning of larvae jump onto the ground. Dates without point markers represent situations where access to the farm was not possible.

CONCLUSIONS

S. subsignatus is active from the early soybean development stages up to its harvesting period. *S. subsignatus* presents a generation per year and an annual life cycle, with an active phase associated with soybean crops and a latency phase spent in the soil, when soybean is not available in the field. This cycle is synchronized with soybean host availability in Northwestern Argentina. The first adults are observed in the field in December, in coincidence with soybean sowing. From then onwards, subsequent development stages associated with the host occur at well defined times.

Knowledge of *S. subsignatus* population fluctuation, together with the implementation of diverse cultural and chemical management alternatives, allows accomplishing an efficient management of this pest, keeping population levels below those causing economic impact.

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