Impacts of Crop Residue on Damage by Sugarcane Pests During the Tillering Phase in Argentina

Authors: Isas, Marcos, Pérez, María L. del P., Salvatore, Analia, Gastaminza, Gerardo, Willink, Eduardo, et al.

Source: Florida Entomologist, 99(1) : 1-5

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.099.0102

Research

Impacts of crop residue on damage by sugarcane pests during the tillering phase in Argentina

Marcos Isas[1,], María L. del P. Pérez[1], Analia Salvatore[1], Gerardo Gastaminza[1], Eduardo Willink[1], and William White[2]*

Abstract

One of the most important recent changes in sugarcane cultural practices in Tucumán, Argentina, is the adoption of the practice of green-cane harvesting, which involves harvesting the sugarcane crop in the absence of burning. The objective of this study was to assess the impact of the post-harvest crop residue (also sometimes known as "trash blanket") on *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Pyralidae) and *Pseudaletia unipuncta* Haworth (Lepidoptera: Noctuidae) population dynamics in sugarcane. The study was conducted in ratoon crops for 3 growing seasons (2011, 2012, and 2013) and at 3 locations in the state of Tucumán, Argentina. The treatments consisted of rows with the crop residue burned and the crop residue retained. Removal of the crop residue by burning, compared with retention, resulted in significantly greater crop damage by *E. lignosellus* in all locations and years. In contrast, damage by *P. unipuncta* was observed exclusively on plots where crop residue was retained. Comparing the pest status of 2 insects, *E. lignosellus* seems to be more consistently deleterious to sugarcane yield than *P. unipuncta*, and chemical control of this species is not very effective. Therefore, leaving the crop residue in place seems to be the most appropriate crop management approach, although it is important also to monitor *P. unipuncta* populations in order to implement control should it be necessary.

Key Words: true armyworm; lesser cornstalk borer; green harvest; trash blanket; stubble

Resumen

Uno de los cambios recientes más importantes en el manejo del cultivo de la caña de azúcar fue la adopción de la cosecha "en verde". En este sistema, se cosecha el cultivo de caña de azúcar sin quemar dejandro una cobertura de rastrojos sobre el suelo. El objetivo de este estudio fue evaluar el efecto de la cobertura sobre la dinámica poblacional de *Elasmopalpus lignosellus* (Zeller) (Lepidotera: Pyralidae) y *Pseudaletia unipuncta* Haworth (Lepidoptera: Noctuidae). Se realizó el estudio en lotes con caña soca, durante tres campañas (2011, 2012 y 2013), en tres localidades de la provincia de Tucumán. Los tratamientos consistieron en dos tipos de manejo: conservación del rastrojo sin quemar y quema del rastrojo. Los niveles de daño correspondientes a cada plaga se determinaron mediante el muestreo de 6 puntos de 2 m de surco, en cada parcela. Para el análisis de los datos se usó ANOVA, y Test-*t*. Para *E. lignosellus*, la remoción del rastrojo mediante la quema resultó en niveles de daño significativamente mayores en todas las localidades y años. Con respecto a *P. unipuncta* sólo se observó niveles de daño significativos en el tratamiento con cobertura en todos los años y localidades evaluadas. La frecuencia del daño de *E. lignosellus* y *P. unipuncta* fue del 100% en lotes con y sin quema del rastrojo, respectivamente. Comparando el status de plaga de ambas especies, los ataques de *E. lignosellus* son más perjudiciales para el rendimiento de la caña de azúcar que los ataques de *P. unipuncta* y su control químico no es efectivo. Por esto, dejar el rastrojo en superficie sería el manejo más apropiado, realizando monitoreos de *P. unipuncta* para implementar medidas de control si fuera necesario.

Palabras Clave: orugas militares; gusano perforador del brote; cosecha en verde; rastrojo

Sugarcane (*Saccharum* species; Poales: Poaceae) cultivation is a traditional and economically important farming activity in the northwest of Argentina. The state of Tucumán with 265,520 ha of sugarcane producing approximately 1.5 million metric tons of sugar is the leading sugarcane-producing state (Pérez et al. 2015). Sugarcane also is grown in the states of Salta, Jujuy, Santa Fe, and Misiones. The Argentinean sugarcane production area is located in a subtropical climatic zone. The occurrence of frost is a common phenomenon in this area. The annual average rainfall exceeds 1,000 mm but can be surpassed by evapotranspiration in some areas. Rainfall is concentrated during the warm months (Oct to Apr) with an extended dry period during the winter and the beginning of spring (Zuccardi & Fadda 1985). The sugarcane harvest season generally begins in May (when rainfall decreases), and ends in Oct or Nov (Romero et al. 2009). The most common and economical cropping cycle of sugarcane production in Tucumán is 5 yr in length. In the 1st year, the crop is planted. For the subsequent 4 yr (ratoon crops), the crop is allowed to re-grow from the unharvested stubble.

[1]Instituto de Tecnología Agroindustrial del Noroeste Argentino (ITANOA), Estación Experimental Agroindustrial Obispo Colombres (EEAOC), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Las Talitas, 4101, Tucumán, Argentina
[2]USDA-ARS, Sugarcane Research Laboratory, 5883 USDA Road, Houma, Louisiana 70360, USA
*Corresponding author; E-mail: mgisas@eeaoc.org.ar

During the last few decades, sugarcane cultural practices in Tucumán have changed considerably. One of the most important changes is the adoption of the practice of green-cane harvesting. In green-cane harvesting, the sugarcane crop does not receive a pre-harvest burn, with the goal of increasing harvesting efficiency and overall support of a sustainable cropping system. The amount of sugarcane harvested without burning has increased rapidly due to improved efficiency of new chopper–harvester equipment, and due to the awareness by sugarcane producers and society at large of the adverse impact of burning the sugarcane crop on the environment and human health (Fandos et al. 2014).

Chopper–harvester machinery cuts sugarcane stalks at the soil level, removes the leaves and leaf sheaths, and scatters this extraneous plant material over the field. This residue (trash) generates a covering of crop residue with a mass ranging from 6 to 30 metric tons per hectare (Digonzelli et al. 2007; Toledo et al. 2008; da Silva Neto et al. 2013) and to a depth down to 10 cm (Richard 1999), depending upon cultivar, yield, etc. The presence of this residue affects edaphic conditions both above and below the soil surface. These conditions may be adverse for the crop; however, in general, the negative aspects of the crop residue are significantly outweighed by its benefits (Cheesman 2004).

Any change in soil conditions is likely to affect the population dynamics of ground-inhabiting insect pests and their natural enemies (Gassen 2001; White et al. 2011). This phenomenon has been observed in soybean and corn, where minor or secondary pests such as slugs (Mollusca: Gastropoda) and pillbugs (Isopoda: Armadillidiidae) have become key pests with the adoption of minimum or no-tillage practices (Hammond et al. 1996; Alfaress 2012).

Among soil-dwelling pests of sugarcane, one of the most widely distributed in the western hemisphere is the lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Pyralidae). This polyphagous insect feeds on 60 species in 14 families of plants (Viana 2004) and is present in nearly all sugarcane-producing countries in the western hemisphere, ranging from Argentina to the United States. The moths lay the eggs next to sugarcane shoots at or below the soil level. Larvae bore into sugarcane shoots at and below the soil surface and produce a silken tunnel at the entrance hole outward into the soil from where they attack the plants. Dead-heart symptoms are produced when larvae reach the center of the shoot and damage the apical meristem (Sandhu et al. 2013). Due to the subterranean habit of the larval stage, the humidity and the temperature of the soil have a strong influence on their development and survival (Viana 2004).

Another ground-inhabiting pest of sugarcane is the true armyworm, *Pseudaletia unipuncta* Haworth (Lepidoptera: Noctuidae) (Long & Hensley 1972), which is present throughout North and South America, southern Europe, central Africa and western Asia. This insect prefers to oviposit and feed on gramineous plants, both weeds and crops (Capinera 2006). The larvae consume the leaves, reducing the photosynthetic area of the plant. If the pest attacks newly emerging plants, the larvae consume the entire plant, thereby reducing plant stand.

It is apparent that the management of the post-harvest crop residue (burning or retention) can influence the ecological conditions above and below the soil surface. The objective of this study was to assess the impact of residue burning or retention on damage by *E. lignosellus* and *P. unipuncta* in sugarcane.

Materials and Methods

STUDY AREA AND EXPERIMENTAL DESIGN

The study was conducted in ratoon crops for 3 growing seasons (2011, 2012, and 2013) and at 3 locations in Tucumán State, Argentina. These locations were representative of the 3 primary regions where sugarcane is grown in Argentina (Zuccardi & Fadda 1985). These sites were: (1) Fronterita (26.8122222°S, 65.0477778°W), Famaillá, representing the Humid Piedmont region (soils rich in organic matter and variable texture; positive hydric balance); (2) Simoca (27.2594444°S, 65.3177778°W), in the Depressed Plain region (slow-draining soils; negative hydric balance); and (3) Luisiana (27.0341667°S, 65.4730556°W), Cruz Alta, located in the "Chaco Pampeana" Plain region (soils moderately rich in organic matter; negative hydric balance).

All test fields were planted with the sugarcane variety LCP 85-384. Two lines of sugarcane were planted per row, plants were 50 cm apart, and rows were separated by 1.60 m. This row configuration is commonly used by growers of this region. During the 3 yr study, the plots at Fronterita and Luisiana were harvested in Sep, whereas the rows at Simoca were cut in Jul. All sugarcane was cut with a chopper–harvester. A paired plot design was used for the study. Three plots of 100 m (70 rows) by 100 m were established per site for each treatment. The treatments consisted of rows with the crop residue burned, and not burned. For the burned plots, the crop residue was eliminated by burning approximately 2 wk after harvest, whereas in the unburned treatment plots, crop residue was allowed to remain undisturbed during the remainder of the sugarcane growing season. The experimental plots were surrounded by sugarcane fields harvested unburned, and without post-harvest burning of the resulting crop residue. However, at the Luisiana location in 2011, a substantial area of pre-harvest burning occurred near experimental plots.

INJURY LEVELS ASSESSMENT

In the spring following harvest, when *E. lignosellus* and *P. unipuncta* infestations began, injury levels by each pest were determined in both "residue retained" and "residue burned" plots. The amount of injury ascribed to these 2 pests was determined by sampling 6 row sections, each 2 m long, at each plot. Tillers were considered damaged by *E. lignosellus* when they expressed the dead-heart symptom, and confirmed by the presence of holes under or at ground level. *Pseudaletia unipuncta* was recognized by partial or complete defoliation of sprouts and confirmed by the presence of larvae and/or their frass.

DATA ANALYSES

For both pests, an ANOVA was used to analyze the main treatment effect (residue management), the year, the location, and their interactions. The statistical analyses were performed using Infostat® software (di Rienzo et al. 2013). The heteroscedastic structure of *E. lignosellus* data was assessed using an *F*-test for homogeneity of variances. Due to significant interactions, the effect of the treatment was analyzed separately for years and locations. Subsequent analyses for the 2 pests were performed independently.

Elasmopalpus lignosellus. For Fronterita and Simoca, a 1-sample *t*-test (H_0: $\mu = 0$) was used for the "residue burned" treatment because of the absence of damage in the "residue retained" treatment. For Luisiana, a 2-sample *t*-test was used to compare the means of the treatments.

Pseudaletia unipuncta. A 1-sample *t*-test (H_0: $\mu = 0$) was run only on the "residue retained" treatment data for each location and year due to the absence of damage in the "residue burned" treatment.

Results

Elasmopalpus lignosellus

Removal of the crop residue by burning resulted in significantly greater insect-inflicted damage in all locations and years compared with residue retention; all burned plots received damage by *E. lignosellus*. The main effect (treatment of crop residue) was the most important source of variation (F = 139.5; df = 1; P < 0.0001), far exceeding the year effect (F = 5.08; df = 2; P = 0.0027) and the location effect (F = 3.73; df = 2; P = 0.0228). The year*treatment interaction was marginally significant (F = 2.38; df = 2; P = 0.0815) (Table 1).

At the Simoca location for the 3 yr of the study, no dead hearts were found on those rows where the crop residue was allowed to remain unburned. At Fronterita, the unburned plots showed some injury during the 2011 season, although this level of damage did not differ significantly from zero. Conversely, the 1-sample t-test in all burned plots from Simoca and Fronterita showed that the levels of damaged shoots were significantly different from zero, with maximum values of 17 and 23%, respectively (Fig. 1a).

In Luisiana, the injury levels observed in both "residue burned" and "residue retained" plots were significantly different from zero. The 2-sample t-test showed that damage was greater in the "residue burned" treatment during the 3 yr of the study: year 2011 (t = 2.92; df = 22; P = 0.0079), year 2012 (t = 5.14; df = 11; P = 0.0003), and year 2013 (t = 4.72; df = 13; P = 0.0004). Maximum injury levels were 23 and 8% for "residue retained" and "residue burned" treatments, respectively (Fig. 1a).

Pseudaletia unipuncta

The retention of crop residue resulted in significantly greater insect-inflicted damage in all locations and years; all unburned plots received damage by *P. unipuncta*. The treatment effect was the greatest source of variation (F = 107.3; df = 1; P < 0.0001), greatly surpassing the year effect (F = 5.99; df = 2; P = 0.0027) and the location effect (F = 2.98; df = 2; P = 0.0538). The interactions year*treatment and location*treatment were significant at P < 0.05 and P < 0.10, respectively (Table 1).

Damage by *P. unipuncta* was observed only in the "residue retained" treatment at the 3 locations evaluated during the entire period of the study. The 1-sample t-test showed that damage was significantly different from zero in all locations and years. The "residue burned" plots showed no damage by *P. unipuncta* during the course of the study. Maximum injury levels obtained were 9, 16 and 16% in Fronterita, Luisiana, and Simoca, respectively (Fig. 1b).

Discussion

The importance of treatment (burned vs. unburned) as a source of variation across years and locations indicates that the 2 examined insect pests were affected primarily by those local conditions created following implementation of the management practice rather than by those pre-existing conditions found at each location and in each year.

Table 1. Mean square (MS), F-values, and P-values of main effects from 3 locations in 3 yr for *Elasmopalpus lignosellus* and *Pseudaletia unipuncta*.

	E. lignosellus			*P. unipuncta*		
Source of variation	MS	F	P	MS	F	P
Treatment	11,600.39	139.54	<0.0001	5,460.09	107.29	<0.0001
Year	422.09	5.08	0.0027	295.34	5.80	0.0027
Location	310.41	3.73	0.0228	151.58	2.98	0.0538
Year*Treatment	197.62	2.38	0.0815	304.70	5.99	0.0029
Location*Treatment	56.96	0.69	0.4987	150.49	2.96	0.0538

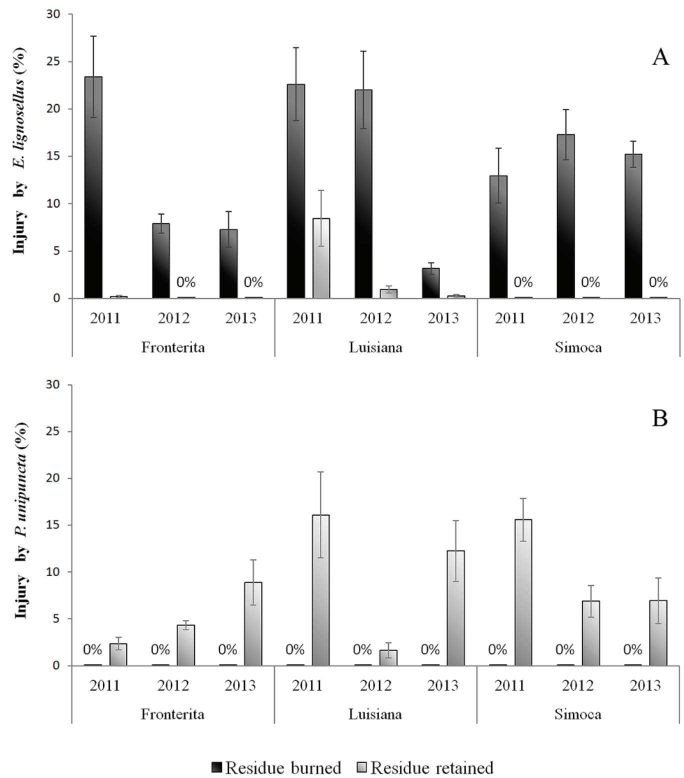

Fig. 1. Injury (proportion of damaged shoots) caused by *Elasmopalpus lignosellus* (a) and *Pseudaletia unipuncta* (b), for 2 harvest residue management schemes at 3 locations, 2011 to 2013.

Elasmopalpus lignosellus

At 2 locations (Simoca and Fronterita) *E. lignosellus* infested cane only following the "residue retained" treatment, whereas at Luisiana it infested cane in both burned and unburned plots. However, at Luisiana the level of infestation was significantly higher in burned than in unburned plots. The preference of the insect for burned plots has been suggested to be due to its attraction to smoke and the resulting dark-colored ash left on the ground following burning, as demonstrated under laboratory conditions by Viana (1981) and Magri (1999). These results are corroborated by Bennett (1962) and Salvatore et al. (2007), who observed that *E. lignosellus* was most injurious in fields burned before and after the harvest. Thus, the conditions generated by burning are attractive to lesser cornstalk borer moths regardless of the time when burning is performed. The lower level of *E. lignosellus* in unburned than in burned plots may be attributed to the absence of optimum temperature and humidity conditions, and the presence of a barrier resulting from the thick crop residue, as moths lay 99% of their eggs under or on the soil surface (Smith et al. 1981).

An injury level of 8% observed in 2011 at "residue retained" plots in Luisiana was significantly greater than in the other years. This finding may be explained by the pre-harvest burning of a large area of sugarcane in the proximity to experimental plots. As a result, the "residue retained" plots were surrounded by a substantial area of burned sugarcane. This created a confounding effect on the field matrix; apparently, the fire in the neighboring area encouraged infestations in plots with crop residue. These findings are at variance with Schaaf (1972), who observed in Jamaica that the green-cut fields suffered no damage, even with very high populations of the pest in surrounding fields.

Pseudaletia unipuncta

The crop residue undoubtedly provides the appropriate temperature and humidity conditions for larval development as well as protection against large predators (e.g., birds) and protection from dehydration. These assumptions are consistent with Carnegie & Dick (1972), Ganeshan & Rajabalee (1996), and Salas et al. (1998), who observed that attacks of the sugarcane armyworms (mainly *Mythimna* species; Lepidoptera: Noctuidae) were restricted almost entirely to areas where crop residue retention rather than burning has been practiced. However, Ridge et al. (1979) found evidence of armyworm activity in fields where a pre-harvest burning of sugarcane was performed, suggesting that the residue burning after harvest may have a greater adverse effect on *P. unipuncta* than pre-harvest burning.

Both Species

The high frequency (100%) of damage caused by *P. unipuncta* and *E. lignosellus* observed in "residue retained" and "residue burned" plots, respectively, allows us to predict the likelihood of damage by these pests. Clearly, the ecological conditions present in the burned plots seem to be unfavorable for *P. unipuncta*, because the damage was observed exclusively where the crop residue was allowed to remain. This exclusivity indicates a strong dependence of this insect pest on crop residue for its development, and/or protection from adverse ecological conditions. Conversely, damage by *E. lignosellus* was strongly associated with burning, as has been observed by many authors. Nevertheless, *E. lignosellus* showed a degree of adaptability to varying conditions, as damage also was detected in several plots with residue retained.

Both burning and retention of crop residue are linked with the presence of insect-inflicted injury in the tillering phase of sugarcane. However, when comparing the pest status of two such pests, *E. lignosellus* attacks seem to be more consistently deleterious to sugarcane yield (Sandhu et al. 2013) than *P. unipuncta* attacks (Chandler & Benson 1991). Moreover, chemical control of lesser cornstalk borer is not effective (Lapointe & Ferrufino 1991), whereas this control strategy is effective for armyworm (Salas et al. 1998). Therefore, taking into account the potential for yield losses by *E. lignosellus* and the difficulty to control this species, leaving the crop residue without burning seems to be the most appropriate management approach. Nevertheless, surveys should be performed during the spring in fields where the crop residue has been retained in order to implement control of *P. unipuncta,* should it be necessary. Although these insects create concern among growers, their impact on yield loss has not been established definitively. We therefore consider it a high priority to elucidate their bioeconomics in Tucumán, Argentina.

Acknowledgments

We thank Estación Experimental Agroindustrial Obispo Colombres (EEAOC) and Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) of Argentina for financial support. We also thank anonymous reviewers for thoughtful comments on the manuscript.

References Cited

Alfaress S. 2012. Integrated pest management strategies for a terrestrial isopod, *Armadillidium vulgare*, in no-till soybean production. Ph.D. thesis, Kansas State University, Manhattan, Kansas, USA.

Bennett FD. 1962. Outbreaks of *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Phycitidae) in sugarcane in Barbados, Jamaica, and St. Kitts. Tropical Agriculture 39: 153–156.

Capinera JL. 2006. Armyworm *Pseudaletia unipuncta* (Haworth) (Insecta: Lepidoptera: Noctuidae. Publication EENY-394, Entomology and Nematology Department, University of Florida, Gainesville, Florida, USA. http://edis.ifas.ufl.edu/in702 (last accessed 9 Sep 2015).

Carnegie AJM, Dick J. 1972. Notes on sugarcane trash caterpillars (Noctuidae) and effects of defoliation on the crop. Proceedings of the South African Sugar Technologists Association 46: 160–167.

Chandler KJ, Benson AJ. 1991. Evaluation of armyworm infestation in north Queensland sugarcane ratoon crops. Proceedings of the Australian Society of Sugar Cane Technologists 13: 157–159.

Cheesman OD. 2004. Environmental impacts of sugar production: the cultivation and processing of sugarcane and sugar beet. CABI Publishing, Wallingford, United Kingdom.

da Silva Neto HF, Modesto Homem BF, Tasso Junior LC, Marques MO. 2013. Produção de palhada por cultivares de cana-de-açúcar RB e CTC e potencial controle de plantas daninhas. Revista de Biologia e Ciências da Terra 13: 116–120.

di Rienzo JA Casanoves F, Balzarini MG, Gonzalez L, Tablada M, Robledo CW. 2013. InfoStat versión 2013. Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina. http://www.infostat.com.ar (last accessed 9 Sep 2015).

Digonzelli P, Scandaliaris J, Tonnato J, Giardina J, Casen S, Leggio Nemme F, Romero E. 2007. La caña verde: un aporte a la sustentabilidad de la producción de la caña de azúcar. II. Alternativas y equipos para el manejo del cañaveral sin quema. Avance Agroindustrial 28: 16–20.

Fandos C, Soria FJ, Carreras Baldrés JI, Scandaliaris P. 2014. Uso de teledetección y SIG para el relevamiento del área cañera quemada durante la zafra 2013 en la provincia de Tucumán, R. Argentina. XIX Reunión Técnica Nacional de la Caña de Azúcar. SATCA, 14 to 15 Apr 2014.

Ganeshan S, Rajabalee A. 1996. The *Mythimna* spp. (Lepidoptera: Noctuidae) complex on sugarcane in Mauritius. Proceedings of South African Sugar Technologists Association 70: 15–17.

Gassen DN. 2001. As pragas sob plantio direto, pp. 113–119 *In* Díaz Rosello RD [ed.], Siembra Directa en el Cono Sur. PROCISUR, Montevideo, Uruguay.

Hammond R, Smith J, Beck T. 1996. Timing of molluscicide applications for reliable control in no-tillage field crops. Journal of Economic Entomology 89: 1028–1032.

Lapointe SL, Ferrufíno A. 1991. Plagas que atacan los pastos tropicales durante su establecimiento, pp. 81–102 *In* Lascano CE [ed.]. Establecimiento y renovación de pasturas: conceptos, experiencias y enfoque de la investigación. Centro Internacional de Agricultura Tropical, Cali, Colombia.

Long WH, Hensley SD. 1972. Insect pests of sugar cane. Annual Review of Entomology 17: 149–176.

Magri DC. 1999. Efeito de fumaça e de cinzas na biologia reprodutiva de *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Pyralidae). Doctoral dissertation, Universidade Federal de Viçosa, Minas Gerais, Brazil.

Pérez D, Paredes V, Rodriguez G, Scandaliaris J. 2015. Estadísticas, costos y margen bruto del cultivo de caña de azúcar, campaña 2012/13 vs 2013/14 y gasto de plantación para la zafra 2015 en Tucumán. Reporte Agroindustrial EEAOC 103: 2–4.

Richard Jr EP. 1999. Management of chopper harvester–generated green cane trash blankets: a new concern for Louisiana. Proceedings of the International Society of Sugar Cane Technologists 13: 52–60.

Ridge DR, Hurney AP, Chandler KL. 1979. Trash disposal after green cane harvesting. Proceedings of the Australian Society of Sugar Cane Technologists 1: 89–93.

Romero R, Scandaliaris J, Digonzelli P, Tonatto J, Fernández de Ullivarri J, Giardina J, Alonso L, Casen S, Leggio Neme F. 2009. Cosecha de la caña de azúcar, pp. 159–174 *In* Romero ER, Digonzelli PA, Scandaliaris J [eds.], Manual del cañero. Estación Experimental Agroindustrial Obispo Colombres, Las Talitas, Argentina.

Salas H, Sotillo S, Navarro F, Gramajo MC, Willink E. 1998. Complejo de orugas militares en caña de azúcar. Avance Agroindustrial 19: 13–16.

Salvatore AR, Acosta EM, Lopez G, Willink E. 2007. Impact of the lesser cornstalk borer, *Elasmopalpus lignosellus*, on sugarcane in Tucumán, Argentina. Proceedings of the International Society of Sugar Cane Technologists 26: 815–820.

Sandhu HS, Nuessly GS, Webb SE, Cherry RH, Gilbert RA. 2013. Temperature-dependent development and life table of *Elasmopalpus lignosellus* (Lepidoptera: Pyralidae) on sugarcane. Florida Entomologist 96: 380–390.

Schaaf AC. 1972. A survey of the damage caused by *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Phycitidae) to sugarcane in Jamaica. Proceedings of the 14th Congress of the International Society of Sugar Cane Technologists, New Orleans, Louisiana, USA, 22 Oct to 5 Nov 1971, pp. 488–497.

Smith JW, Johnson SJ, Sams RL. 1981. Spatial distribution of lesser cornstalk borer eggs in peanuts. Environmental Entomology 10: 192–193.

Toledo E, Cabrera CJA, Leyva CA, Pohlan HAJ. 2008. Estimación de la producción de residuos agrícolas en agroecosistemas de caña de azúcar. Cultivos Tropicales 29: 17–21.

Viana PA. 1981. Effect of soil moisture, substrate color and smoke on the population dynamics and behavior of the lesser cornstalk borer, *Elasmopalpus lignosellus*, Zeller 1848 (Lepidoptera: Pyralidae). Master's thesis, Purdue University, West Lafayette, Indiana, USA.

Viana PA. 2004. Lagarta-Elasmo, pp. 379–408 *In* Salvadori JR, Ávila CJ, Braga da Silva MT [eds.], Pragas de Solo no Brasil. Embrapa Trigo, Dourados, Brazil.

White WH, Viator RP, White PM. 2011. Effect of post-harvest residue and methods of residue removal on ground inhabiting arthropod predators in sugarcane. Journal of the American Society of Sugar Cane Technologists 31: 39–50.

Zuccardi R, Fadda G. 1985. Bosquejo Agroecológico de la Provincia de Tucumán. Miscelánea N° 86. Universidad Nacional de Tucumán, Facultad de Agronomía y Zootecnia, Tucumán, Argentina.