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Evaluation of the attack rates and level of damages by the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), affecting corn-crops in the northeast of Argentina

Evaluación de las tasas de ataque y el nivel de daños por el gusano cogollero del maíz, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), en el noreste de Argentina

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ABSTRACT

The fall armyworm (FAW) is the most important threat to corn crops in Argentina, and there exists very little up-to-date information on its actual pest status because the available literature was published more than 20 years ago. Therefore, field surveys were carried out in the northeast of Argentina, in order to establish the attack rates and injury levels of the pest in relation to the crop phenology. The study was carried out at two localities: Colonia Benítez, an agricultural region, and Tapenagá, a cattle-raising area. At each site two 1-ha plots were sown either with a *Bt*-corn expressing *Cry* 1F protein or with an untransformed corn germplasm. Optimal and late sowing was assayed and FAW larval abundance, relative age composition, attack rates and level of damage to corn were recorded. At the moment of the field experiments, *Bt*-corn was not affected by FAW larvae. However, untransformed germplasms were severely affected by FAW larvae, with an average of attacked plants of 18% or more. In

RESUMEN

El cogollero es la plaga más importante del maíz en Argentina, siendo escasa y desactualizada la información sobre su estatus como plaga en los últimos 20 años. Se llevaron a cabo estudios de campo a fin de establecer las tasas de ataque y los niveles de daño de la plaga en relación con la fenología del cultivo en el noreste de Argentina. El estudio se realizó en dos localidades: Colonia Benítez, zona agrícola, y Tapenagá, zona ganadera. En cada localidad se sembraron dos parcelas de una hectárea, una con maíz transgénico expresando la proteína *Bt Cry* 1F y la otra con su correspondiente isogénico no transformado. Se registraron para dos fechas de siembra: cantidad de larvas, composición relativa de edades, tasa de ataque y nivel de daño al cultivo. En el momento del ensayo de campo, el maíz *Bt* no fue afectado por la plaga; sin embargo, el isogénico (sin gen *Bt*) fue atacado con una media superior al 18% de plantas dañadas. Comparando con datos obtenidos hace 30 años

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contrast to data obtained 30 years ago, higher values of FAW density were registered. Levels of damage to corn plants were higher after the V_4 stage. It was found that the sowing date affected the infestation levels and early seeding avoided high armyworm densities that develop later in the season; in northern Argentina, this was only relevant in agricultural areas.

en esta región, se obtuvieron mayores valores de densidad de larvas/planta. Los niveles de daño fueron mayores después de V_4. La fecha de siembra incide en los niveles de infestación: siembras tempranas evitan las altas densidades del cogollero que se desarrollan durante el verano, pero para la región estudiada esto solo fue relevante en la zona agrícola.

Keywords

fall armyworm • *Zea mays* • noctuid • pest levels • crop injuries • Argentina • *Bt*-corn

Palabras clave

gusano cogollero • *Zea mays* • noctuidos • niveles poblacionales • daño al cultivo • Argentina • maíz *Bt*

INTRODUCTION

The fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lep.: Noctuidae), is a polyphagous pest that causes important damage in different regions of America, mainly affecting corn crops in both tropical and subtropical areas (18, 23). In Argentina, the southern distribution limit of the FAW, it is the most important threat to corn crops (21, 22, 25, 26). The presence of the fall armyworm is normally important in the early stage of the crop, and damage to the plants can be visually shocking (1, 16).

Contributions carried out in other areas of distribution of the pest indicated that continuous infestation by FAW larvae can cause maize yield losses as much as 70% (4, 11). In Argentina, previous studies demonstrated that the attack levels are higher when the sowing date is delayed, and a single attack during the vegetative development can cause average losses of 12.7% (26). Currently, control relies on both chemical pesticides and/or transgenic plants, but adoption of *Bt* corn technology is not economically attractive to small farmers due to the high costs of seeds and because yields are not higher than conventional maize (24).

Although FAW is the major pest of maize crops in northern Argentina, there are no recent contributions concerning the injury level caused by the pest to the crop; the available information was published about 20 years ago (19, 26). During the last two decades, the landscape of the Argentine Chaco has undergone major changes like massive cultivation of soybean associated with the incorporation of new technologies (conservation tillage, crop rotation, cover cropping, transgenic crops, etc.) (15). This situation has led to radical transformation of the traditional maize farming and it has possibly changed the FAW status in the area. In addition, there is no information linking the different phenological stages of the maize crop, pest population levels, attack rates and injury levels in the plants.

Among other authors, Dent (5) has emphasized the need for data about interrelationships of insect pests, crops and the environment in order to develop effective management strategies, particularly in the integrated pest management

approach. The aim of the present contribution was to establish the attack rates and injury levels of the pest in relation to the crop phenology during two different sowing dates in order to update the FAW pest status in the northeast of Argentina.

MATERIALS AND METHODS

The current study was carried out in two localities in the Chaco province, Argentina: Colonia Benítez (1° de Mayo department: 27°17'48.1" S - 58°57'10.8" W, elevation: 58 masl) and Tapenagá (Tapenagá department: 27°56'38.1" S - 59°30'49.5" W, elevation: 69 masl). Colonia Benítez is a typical agricultural region, with a large crop diversification and thus elevated use of agricultural inputs, while Tapenagá is located in a cattle-raising area with extended grasslands and crops are rare. No corn crops were cultivated within a radius of at least 45 km around Tapenagá.

In each locality, two plots of 1 ha each were either sown with MASS 636 HX ® germplasm, expressing the *Cry* 1F gene, or with the non-*Bt* Dow 8480 ® isoline hybrid. Each corn crop was surrounded by at least 7 m of wild vegetation. The seeding density was 57,000 plants/ha. All the seeds were previously treated with the neonicotinoid "Imidacloprid", and the crops received all conventional cultural practices recommended for corn in the region, except that no insecticides were applied. Plots were not irrigated.

Studies were performed in 2007 during two different dates: optimal sowing in spring: September 28th in Colonia Benítez and October 4th in Tapenagá, and late sowing in summer: January 29th in Colonia Benítez and February 3rd in Tapenagá. At both sites, the same plots were used in the two sowing dates.

Eight samples were taken during optimal sowing, and seven during late sowing. Sampling took place weekly in whorl-stage corn and was finished before the reproductive stage was reached, because the early growth stages are more susceptible to FAW attacks (this is when most of the damage occurs) (3, 26).

During each sampling, 100 maize plants (10 groups of 10 plants) randomly taken were searched for FAW larvae (these groups of 10 plants only were considered during sample collection in order to avoid biasing towards damaged plants). Individual plants were thoroughly inspected, and only larvae feeding on those plants were collected. Particular regard was taken collecting the samples from different areas of the plot in each monitoring date. All samples were taken between 9:00 and 12:00 o'clock AM.

FAW larvae were collected from the plants, placed individually in glass tubes (15 cm high x 2 cm diameter), fed an artificial diet (17), and transported to the laboratory for examination. The number of larvae per plant, their relative size [small (I- II instar), medium (III-IV instar) or large (V-VI instar)] and the level of plant damage on a visual scale of 1 to 5 according to Fernández & Expósito (9) (table 1, page 4) were recorded simultaneously. The foliar damage estimated with the visual scale allows the development of models by means of regression analysis to calculate economic injury levels and economic thresholds in corn crops (8).

Table 1. Visual scale to estimate the level of plant damage by FAW according to Fernández & Expósito (9).
Tabla 1. Escala visual para estimar el daño ocasionado en plantas por el gusano cogollero según Fernández & Expósito (9).

Degree	Foliar damage characteristics
1	No evident damage, or less than 1-3 pinhole type injuries
2	More than 3 pinhole type injuries, and/or 1-3 injuries less than 10 mm each
3	More than 3 injuries less than 10 mm, and/or 1-3 injuries larger than 10 mm each (shothole type injuries)
4	3 to 6 shothole type injuries, and/or at least 50% of the whorl destroyed
5	More than 6 shothole type injuries, and/or whorl totally destroyed

The FAW attack rate was defined as follows:
Attack rate = (number of affected plants / total number of revised plants) x 100,
in which "affected plants" were reviewed plants with at least one living FAW larva.

The phenological states of the samples were named, adopting the $V_{(n)}$ nomenclature, where "V" stands for vegetative and the subscript the number of fully expanded leaves.

After a test of normality (Shapiro-Wilks), the parameters were evaluated by the student's *t*-test at 0.05 level of significance, using InfoStat Professional ®.

Voucher specimens were deposited in the IMLA (M. Lillo Institute & Foundation, Tucumán, Argentina) entomological collection.

RESULTS

Although the occurrence of egg masses on plants was not assayed in particular, it could be observed that FAW females deposited similar numbers of masses in both isogenic and transgenic plants. In transgenic plants, newerly emerged larvae only scraped the cuticle of leaves and then they died or left the crop, and larvae of the second instar were never found in these plots. Consequently, no FAW larvae were registered causing damage to transgenic corn in the two sampled localities and during the two sowing dates.

Although several noctuid larvae were captured affecting the whorl of transgenic corn none were identified as *Spodoptera frugiperda*.

Optimal sowing (spring)

During the optimal sowing date, a total of 931 FAW larvae was collected in Colonia Benítez (agricultural region) affecting the non-*Bt* corn crop (a mean of 1.16 larvae/ plant), while in Tapenagá (cattle-raising area), 226 larvae were collected during the vegetative phenological stage (a mean of 0.28 larvae/plant). In both locations, the larval abundance was highest in early stages of development when corn plants have two or three fully expanded leaves (table 2). As could be expected, small larvae were predominant in the early stages of the crop (until V_{4-5}) and medium and larger ones prevailed towards the end of the vegetative stage (table 2, page 5).

Table 2. Abundance and relative age composition of *Spodoptera frugiperda* larvae registered after the optimal sowing date (September) and during the vegetative development of non-*Bt* crops planted in two different localities, Colonia Benítez (agricultural region) and Tapenagá (cattle-raising area), in the Argentine Chaco.

Tabla 2. Cantidad y composición etaria de larvas de *Spodoptera frugiperda* registrada después de la fecha óptima de siembra (septiembre) y durante el desarrollo vegetativo de los cultivos no-*Bt* sembrados en dos localidades diferentes, Colonia Benítez (región agrícola) y Tapenagá (zona ganadera), en Chaco, Argentina.

	Colonia Benítez					Tapenagá				
Vegetative stage	Range of larvae/plant	Average N° of larvae/plant (± SD)	Larval size (%)			Range of larvae/plant	Average N° of larvae/plant (± SD)	Larval size (%)		
			small	medium	large			small	medium	large
V_1	0	0 (-)	0	0	0	0	0 (-)	0	0	0
V_{2-3}	0-11	3.25 (± 2.74)	99.69	0.31	0	0-6	0.66 (± 1.06)	100	0	0
V_{4-5}	0-5	1.09 (± 1.01)	55.05	44.95	0	0-1	0.06 (± 0.24)	100	0	0
V_5	0-3	0.68 (± 0.72)	16.18	54.41	29.41	0-3	0.18 (± 0.5)	38.89	50.00	11.11
V_6	0-5	1.05 (± 1.06)	21.90	45.71	32.38	0-3	0.37 (± 0.66)	40.54	40.54	18.92
V_{6-7}	0-6	1.14 (± 1.46)	36.43	37.14	26.43	0-5	0.35 (± 0.81)	42.86	42.86	14.29
V_7	0-4	0.88 (± 0.97)	20.45	43.18	36.36	0-4	0.56 (± 0.69)	3.57	48.21	48.21
V_9	0-7	0.96 (± 1.21)	11.46	56.25	32.29	0-2	0.08 (± 0.31)	0	87.50	12.50

The mean FAW attack rate in Colonia Benítez was 55% and only 20.75% in Tapenagá. Considering the entire sowing period the pest level in the two crops was significantly different (t = 18.16; df = 155; p < 0.0001) for the two sites. In Colonia Benítez, the FAW larval attack was first observed during V_{2-3} with 82% and during vegetative growth, larval attack tended to decrease, reaching 53% of affected plants during the V_9 stage. In Tapenagá the situation was fluctuating, with two periods of maximum attack: V_{2-3} with 40% and V_8 with 48% of affected plants (table 3).

Table 3. FAW attack rates and level of damage (according to a 1 to 5 visual scale by Fernández & Expósito -8-; see table 1, page 4) after optimal sowing and during the vegetative development of non-*Bt* corn crops in two sampling sites: Colonia Benítez (agricultural zone) and Tapenagá (cattle-raising area).

Tabla 3. Tasas de ataque y el nivel de daño (de acuerdo con una escala visual de 1 a 5 de Fernández y Expósito -8-; ver tabla 1, pág. 4) después de la siembra óptima y durante el desarrollo vegetativo de los cultivos de maíz no *Bt* en dos sitios de muestreo: Colonia Benítez (zona agrícola) y Tapenagá (zona ganadera).

Pheno-logical Stage	Colonia Benítez						Tapenagá					
	attack rates	Injury level					attack rates	Injury level				
		1	2	3	4	5		1	2	3	4	5
V_1	0	100	0	0	0	0	0	100	0	0	0	0
V_{2-3}	82	96	4	0	0	0	40	92	8	0	0	0
V_{4-5}	69	3	20	69	8	0	6	80	20	0	0	0
V_5	54	21	23	43	11	2	14	72	16	10	2	0
V_6	63	25	4	18	32	21	28	36	35	11	16	2
V_{6-7}	62	31	4	19	21	25	23	52	26	14	7	1
V_7	57	21	7	23	31	18	48	46	13	36	5	0
V_9	53	20	9	28	36	7	7	54	21	18	7	0

The injuries by FAW larvae were first observed when the majority of plants had reached the vegetative stage of three developed leaves (V_3). In Colonia Benítez, injuries including 3-6 shotholes (> 10 mm each, table 1, page 4) to totally destroyed whorl affected 53% of the plants in the V_6 stage and maintained levels of over 40% until the end of the vegetative stage of the crop. On the contrary, no serious damage was observed in the plants assayed in Tapenagá, and only 18% was affected with type 4 and/or 5 injuries during the V_6 stage (table 3).

Late sowing (summer)

In the agricultural area, Colonia Benítez, the number of FAW larvae collected during the sampling period from non-*Bt* corn was 987 (a mean of 1.65 larvae/plant), while in the cattle-raising area 181 larvae were collected (a mean of 0.26 larvae/ plant). In both locations, the larval abundance was highest during the first stages of crop development, V_2 to V_4 at Colonia Benitez and V_2 to V_3 at Tapenagá. In Tapenagá, the abundance of FAW larvae was very low at the end of the vegetative stage (table 4, page 7). Larval age distribution (sorted by length) is also shown in table 4 (page 7), and it can be seen that small larvae predominated during the first stages of the crop.

Table 4. Abundance and relative age composition of Spodoptera frugiperda larvae registered after the late sowing date (February) and during the vegetative development of non-Bt corn planted in two different localities, Colonia Benítez (agricultural region) and Tapenagá (cattle-raising area) in the Argentine Chaco. n/d: no data.

Tabla 4. Cantidad y composición etaria de larvas de Spodoptera frugiperda registrada en siembra tardía (febrero) y durante el desarrollo vegetativo del maíz no Bt sembrados en dos localidades diferentes, Colonia Benítez (zona agrícola) y Tapenagá (zona ganadera) en el Chaco, Argentina. n/d: sin datos.

	Colonia Benítez					Tapenagá				
Vegetative stage	Range of larvae/plant	Average N° of larvae/plant (± SD)	Larval size (%)			Range of larvae/plant	Average Nº of larvae/plant (± SD)	Larval size (%)		
			small	medium	large			small	medium	large
V_1	n/d	n/d	n/d	n/d	n/d	0-2	0.07 (±0.29)	71.4	28.6	0
V_2	0-14	1.94 (±2.17)	99.5	0.5	0	0-7	0.66 (±1.10)	93.9	6.1	0
V_3	0-8	2.39 (±1.86)	66.1	30.5	3.3	0-3	0.63 (±0.80)	22.2	52.4	25.4
V_4	0-12	3.59 (±2.61)	47.6	43.5	8.9	0-2	0.33 (±0.55)	3.0	48.5	48.5
V_5	0-4	1.42 (±1.15)	11.3	33.8	54.9	0-2	0.10 (±0.33)	20.0	40.0	40.0
V_7	0-2	0.38 (±0.58)	0	18.4	81.6	0	0 (-)	0	0	0
V_{8-9}	0-2	0.15 (±0.44)	0	20.0	80.0	0-1	0.02 (±0.14)	0	0	100

The mean FAW attack rate in Colonia Benítez was 52% compared to only 18.6% in Tapenagá. Considering the entire sowing period, pest levels were significantly different for both areas (t = 17.8, df = 126, p < 0.001). FAW larval attack rates were highest during the 3rd and 5th vegetative stage, with 89% of the plants affected in the agricultural region. In Tapenagá, the highest levels of affected plants were registered between V_2 and V_4, reaching 46% in the V_3 stage (table 5).

Table 5. FAW attack rates and level of damage (according the visual scale by Fernández & Expósito) (9), after late sowing and during the vegetative development of non-Bt corn in two sites: Colonia Benítez (agricultural zone) and Tapenagá (cattle-raising area). n / d: no data.

Tabla 5. Tasas de ataque y el nivel de daños por el cogollero (según la escala visual de Fernández y Expósito) (9), en siembra tardía y durante el desarrollo vegetativo del maíz no-Bt en dos localidades: Colonia Benítez (zona agrícola) y Tapenagá (zona ganado). n / d: sin datos.

Pheno-logical Stage	Colonia Benítez						Tapenagá					
	attack rates	Level of damage					attack rates	Level of damage				
		1	2	3	4	5		1	2	3	4	5
V1	n/d	n/d	n/d	n/d	n/d	n/d	6	96	4	0	0	0
V2	66	59	34	7	0	0	38	64	30	6	0	0
V3	89	7	17	58	18	0	46	25	18	34	23	0
V4	86	6	1	23	52	18	29	9	9	42	24	16
V5	76	7	5	17	19	52	9	25	20	24	28	3
V7	33	10	3	15	35	37	0	16	38	37	9	0
V8-9	12	13	11	49	25	2	2	12	25	59	4	0

The level of injuries by FAW larvae became important during the V_4 stage, as 40 and 70% of the plants were affected with injuries corresponding to level 4 and 5 in Tapenagá and Colonia Benítez, respectively. After that time, foraging activity of *S. frugiperda* in Tapenagá became less, but in the agricultural area (Colonia Benítez), extremely significant levels of damage remained with 71 and 72% for V_5 and V_7 phenological stages, respectively (table 5).

Comparison of sowing dates

For each locality, the total number of FAW larvae/group of 10 plants (during the entire sampling period) was analyzed by means of the t-test. The results revealed that the number of larvae occurring during late sowing in Colonia Benítez was significantly higher than that during optimal sowing (t = -4.77; df = 1107; p < 0.0001). In Tapenagá, (cattle area) this parameter was not significantly different for the two sowing dates (t = 0.71; df= 1498; p: 0.48): during optimal sowing a total of 226 larvae was registered (from 800 revised plants) while during late sowing 181 larvae (700 plants) were found.

In addition, the influence of the sowing date was assessed for each locality considering different parameters like the density of larvae/plant, average attack rate and proportion of plants affected with type 4 or 5 damage (table 6, page 9).

Table 6. Summarized information obtained from two corn-sowing dates in two different localities: Colonia Benítez and Tapenagá (Chaco province, Argentina).

Tabla 6. Información resumida obtenida a partir de dos fechas de siembra de maíz en dos localidades diferentes: Colonia Benítez y Tapenagá (Provincia de Chaco, Argentina).

Sampling site	Colonia Benítez (agricultural zone)		Tapenagá (cattle-raising area)	
	Optimal sowing	Late sowing	Optimal sowing	Late sowing
Number of revised plants	800	600	800	700
Total FAW larvae collected	931	987	226	181
Mean density of larvae/plant	1.16	1.65	0.28	0.26
Mean FAW attack rate (%)	55.0	52.0	20.7	18.6
Plants with type 4 or 5 injuries (%)	26.5	43.0	5.0	15.3

DISCUSSION

This study has updated the information about the level of attack of the FAW on corn crops in a region, which, in the last 20 years, has seen major changes in land use, mostly due to soybean plantations, which requires a high input of industrial agriculture, and incorporation of *Bt*-corn germplasms. Our findings allow us to confirm that, at the moment of the field experiments, *Bt*-corn expressing *Cry* 1F protein was not affected by FAW larvae. As has been demonstrated by several authors like Fernandes *et al.* (7), transgenic corn expressing *Cry* proteins significantly reduced infestation by *S. frugiperda* larvae and subsequently injuries to plant whorl to low levels, compared to untransformed corn. With respect to traditional corn, crops were differentially affected according to the region and the date they were seeded.

Perdiguero *et al.* (19) determined the density of FAW larvae in the agricultural region in Chaco a long time ago, obtaining a density of 0.5 larvae/plant in September (optimum sowing date) and 1.3 in January (late). They also calculated a mean attack rate of about 37% for early and 80% for late sowing. Colonia Benítez, a location with similar characteristics to the site studied by Perdiguero *et al.* (19), revealed higher values of FAW density, with a mean of 1.16 larvae/plant in September and 1.65 during late sowing dates.

Larval densities for *S. frugiperda* are usually low (between 1 and 2 per plant), due to cannibalistic behavior after reaching the third instar (2). With regard to the average attack rates observed by Perdiguero *et al.* (19), our results were higher for the optimal sowing date (55 *vs.* 37%) and lower for late sowing (52 *vs.* 80%). However, unlike our methodological approach, Perdiguero *et al.* (19) considered plants with signs of damage as affected, regardless whether they presented active larvae or not. In Tapenagá, the cattle area, the level of pest attack was significantly lower with a mean of 20.7% of affected plants during the optimal sowing date and 18.6% during late sowing. It is known that both the local community diversity and abundance can

be explained from the regional species composition and habitat structure (10, 12). In general, grazing sites have lower specific diversity (both plants and animals) than agricultural landscapes (6), and in the latter areas, the relative proportion of crops and their distribution play an important role as a refuge and source of specimens for crop colonization and recolonization (20). This could be the reason for the lower levels of density, plant attack rates and injury levels by FAW in Tapenagá.

In the two studied sites the presence of the pest was important, always exceeding an average of 18% of attacked plants. During the first sowing date (September), small plants were not infected, possibly because they were protected by Imidacloprid. From the V_2 stage, the attack levels were very high in the agricultural area (over 53% of plants affected), while in the cattle-raising area the presence of infested plants was somewhat lower and variable, with peaks between 40 and 48%. During the second sowing date, higher attack levels were observed from the V_2 to V_5 phenological stages with more than 65% of affected plants in the agricultural zone, and during the V_2 to V_4 stages levels were more than 25% in the livestock area. The FAW attack rates depend on several factors such as cultivars, sowing date, weather conditions during the crop growth period, presence of infected cultures in the area or occurrence of antagonistic species. Therefore, it is impossible to generalize about a relationship between the levels of damage caused by FAW and the phenological stage of the corn crop. In addition, older larvae cause extensive defoliation, often leaving only the ribs and stalks of corn plants, or a ragged, torn appearance.

During the optimal sowing date in Colonia Benítez, damage levels (measured with the visual scale) were more important after the V_6 stage with more than 40% of affected plants showing type 4 or 5 damage. In contrast, during the same sowing date in Tapenagá only 18% of the plants reached this damage level. As was expected, late sowing showed higher damage: in the agricultural zone the proportion of plants affected by type 4 or 5 injuries was always over 60% during the V_4-V_7 stages, while in the livestock area the highest values were recorded during V_4 and V_5 (40 and 31%, respectively). It has been found that severe attacks of FAW destroyed the meristematic tissues in corn plants, which as a result could stop growing or even die. Field observations showed that only plants with type 4 or 5 leaf damage underwent such profound changes (9).

Fernández (8) observed that the percentage of plants with type 4-5 injuries during the first six weeks after germination explained 46% of the variability in the final density of plants/ha. The author also stated that corn plants were able to recover from relatively high levels of leaf damage if the whorl was not seriously affected (type 4 or 5 damage on the visual scale used in the contribution). Cruz & Turping (3) found that susceptibility of maize plants to FAW attacks depended on their size. Plants with 8 to 10 leaves, about 40 days after seeding, represented the most susceptible stage. Severe leaf damage does not directly involve major crop yield losses, because the reduction depends on the stage of development of the affected plant. Marenco *et al*. (13) reported similar observations in a study on the effects of FAW injuries to early vegetative growth of sweet corn in Florida. They found that the early whorl stage was the least sensitive

to injury, the mid-whorl stage intermediate, and the late whorl stage was the most sensitive to injury. Furthermore, they observed that mean densities of 0.2 to 0.8 larvae per plant during the late whorl stage reduced the yield by 5 to 20%.

Tests have shown that, in addition to the influence of the surrounding environment (agriculture or cattle raising), the sowing date plays a key role in the infestation levels. In order to control FAW attacks the most important cultural practice, employed widely, is early seeding and/or the use of early maturing varieties. Early harvest allows many corn plants to avoid high armyworm densities that develop later in the season (14). In northern Argentina, however, we have observed that this is only relevant in agricultural areas with permanent colonization events of the pest from adjacent cornfields. In cattle-raising areas, this was partly confirmed because corn plots showed major damage during late sowing, but in fact, the average density of larvae/plant was not significantly different.

CONCLUSIONS

In Chaco and throughout the study, the *Bt*-corn expressing *Cry* 1F protein was not affected by FAW larvae. In contrast, traditional corn crops were differentially affected by the pest according to the region and the date they were seeded.

Actually, untransformed germplasm (traditional crops) were severely affected by FAW larvae, in contrast with data obtained 30 or more years ago in the same agricultural area.

The sowing date affected the FAW infestation levels, and early seeding avoided high armyworm densities that develop later in the season. Generally, levels of damage to corn plants were higher after the V4 stage.

In Chaco, FAW only is a relevant pest in corn crops located in agricultural areas.

REFERENCES

1. Alonso-Álvarez, R. 1991. Reseña histórica y aspectos bioecológicos del gusano cogollero del maíz *Spodoptera frugiperda* (J. E. Smith). En Seminario *Spodoptera frugiperda* (El gusano cogollero) en sorgo, maíz y otros cultivos. Zuluaga, J. L.; Muñoz, G.(comp.,ed.) Cali, Colombia. 96 p. 12-14.
2. Capinera, J. L. 2008. Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (Insecta: Lepidoptera: Noctuidae). Univ. of Florida IFAS extension document EENY098. 6 p. Disponible en: http://entnemdept.ifas.ufl.edu/(last acceded may 28, 2011).
3. Cruz, I.; Turpin, F. T. 1982. Efeito da *Spodoptera frugiperda* em diferentes estádios de crescimento da cultura de milho. Pesq Agropec Bras. 17(3): 355-359.
4. Cruz, I.; Turpin, F. T. 1983. Yield impact of larval infestation of the fall armyworm *Spodoptera frugiperda* (J. E. Smith) to mid-whorl growth stage of corn. J Econ Entomol. 76(5): 1052-1054.
5. Dent, D. 1995. Insect pest management. Chapman & Hall, London. 356 p.
6. Fahrig L.; Baudry, J.; Brotons, L.; Burel, F. G.; Crist, T. O.; Fuller, R. J.; Sirami, C.; Siriwardena, G. M.; Martin, J. 2011. Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. Ecology Letters. 14: 101-112.

7. Fernandes, O. D.; Parra, J. R. P.; Neto, A. F.; Pícoli, R.; Borgatto, A. F.; Demétrio, C. G. B. 2003. Efeito do milho geneticamente modificado MON810 sobre a lagarta-do-cartucho *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae). Rev Bras Milho e Sorgo. 2(2): 25-35.
8. Fernández, J. L. 2002. Estimación de umbrales económicos para *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) en el cultivo del maíz. Invest. Agr.: Prod. Prot. Veg. 17(3): 467-474.
9. Fernández, J. L.; Expósito, I. E. 2000. Nuevo método para el muestreo de *Spodoptera frugiperda* (J. E. Smith) en el cultivo del maíz en Cuba. Centro Agrícola 27: 32-38.
10. Gaston, K. J. 2000. Global patterns in biodiversity. Nature. 405: 220-227.
11. Hruska, A. J.; Gould, F. 1997. Fall armyworm (Lepidoptera: Noctuidae) and *Diatraea lineolata* (Lepidoptera: Pyralidae): impact of larval population level and temporal occurrence on maize yield in Nicaragua. J Econ Entomol. 90(2): 611-622.
12. Lewinsohn, T. M; Novotny, V.; Basset, Y. 2005. Insects on plants: Diversity of herbivore assemblages revisited. Annu. Rev. Ecol. Evol. Syst. 36: 597-620.
13. Marenco, R. J.; Foster, R. E; Sanchez, C. A. 1992. Sweet corn response to fall armyworm (Lepidoptera: Noctuidae) damage during vegetative growth. Journal of Economic Entomology. 85:1285-1292.
14. Mitchell, E. R. 1978. Relationship of planting date to damage by earworms in commercial sweet corn in north central Florida. Florida Entomologist. 61: 251-255.
15. Morello, J. H.; Rodríguez, A. F. 2009. El Chaco sin Bosques: la pampa o el desierto del futuro. Editorial Orientación Gráfica, Buenos Aires. 402 p.
16. Murillo, A. 1991. Distribución, importancia y manejo del complejo *Spodoptera* en Colombia. In Memorial Seminario *Spodoptera frugiperda* (El gusano cogollero) en sorgo, maíz y otros cultivos. Zuluaga, J. L.; Muñoz, G. (comp. ed.) Cali, Colombia. 96 p. 15-23.
17. Murua, M. G.; Defagó, V.; Virla, E. G. 2003. Evaluación de cuatro dietas artificiales para la cría experimental de *Spodoptera frugiperda* (Lep., Noctuidae) destinada a mantener poblaciones experimentales de himenópteros parasitoides. Boletín de Sanidad vegetal "Plagas". 29: 43-52.
18. Pastrana, J. A. 2004. Los lepidópteros argentinos: sus plantas hospedadoras y otros sustratos alimenticios. Braun K., G. A. Logarzo, H. A. Cordo y O. R. Di Iorio (Coordinadores). Sociedad Entomológica Argentina. 334 p.
19. Perdiguero, J. S.; Barral, J. M.; Stacul, M. 1967. Aspectos biológicos de plagas de maíz de la región chaqueña. Evaluación de daño. INTA, Est. Exp. Agrop., Presidencia Roque Sáenz Peña, Boletín, 46: 30 p.
20. Pfiffner, L.; Luka, H. 2000. Overwintering of arthropods in soils of arable fields and adjacent semi-natural habitats. Agriculture Ecosystems and Environment. 78: 215-222.
21. Sosa, M. A. 2002. Estimación del daño por *Spodoptera frugiperda* (Smith) (Lep., Noctuidae) en maíz con infestación natural en tres fechas de siembra en el noreste santafesino. INTA, Centro Reg. Santa Fe, Información para extensión. (70): 39-45.
22. Sosa, M. A. 2002. Daño producido por *Spodoptera frugiperda* (Smith) (Lep., Noctuidae) sobre el rendimiento del cultivo de maíz en siembra directa, segun tiempos de exposición a la plaga. INTA, Centro Reg. Santa Fe, Información para extensión. (70): 46-52.
23. Sparks, A. 1979. A review of the biology of the fall armyworm. Florida Entomologist. 62: 82-87.
24. Vara, A. M. 2004. Transgénicos en Argentina: más allá del boom de la soja. Revista iberoamericana de ciencia, tecnología y sociedad. 3(1): 101-129.
25. Virla, E. G.; Colomo, M. V.; Berta, D. C.; Valverde, L. 1999. El complejo de parasitoides del "gusano cogollero" del maíz, *Spodoptera frugiperda*, en la República Argentina (Insecta, Lepidoptera). Neotropica. 45(113-114): 3-12.
26. Willink, E.; Costilla, M.; Osores, V. 1993. Daños, pérdidas y nivel de daño económico de *Spodoptera frugiperda* (Lep., Noctuidae) en maíz. Rev. Industrial Agric. Estación Experimental Agroindustrial, Obispo Colombres Tucumán. 70: 49-52.

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