1872 Spatial Distribution Pattern of Lepidopteron Cotton Pests in Argentine

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The spatial density of lepidopteron populations is heterogeneous. Defining in mathematical terms the distribution form allows determining the dispersion pattern (regular, random or aggregated). The object of this work was to describe distribution patterns of lepidopteron cotton pest in Argentine and fit mathematical models. Weekly captures in light traps of cotton leafworm and caterpillar complex adults in different localities, were analyzed by variance/mean relation index (tested by Rogers´ T test). Negative Binomial and Poisson distributions were adjusted by Chi-square test. Cotton leafworm variance/mean index over unit ($\alpha<0{,}000$), indicates aggregated distribution adjusted to Negative Binomial. Along the crop season, values of *k* constant indicates uniform aggregation, *p* values increasing indicates higher probability of infestation ending the season. For caterpillar complex species, variance/mean index over unit ($\alpha<0{,}000$), indicates aggregated distribution adjusted to Negative Binomial. Aggregation *K* parameter increasing in autumn, indicates less aggregation coincident with small probability of infestation. In winter, relation variance/mean become equal to unit ($\alpha>0{,}05$), distribution become random fitting to Poisson distribution. In Argentine cotton region throughout all the crop cycle, *Alabama argillacea* populations are aggregated, fitting to Negative Binomial, with constant aggregation in time and higher probability at the end of the season. During most of the year, populations of *Heliothis virescens*, *Helicoverpa gelotopoeon* and *Spodoptera frugiperda* are aggregated, fitting to Negative Binomial, but in winter (with very low captures), distribution becomes random fitting to Poisson models.

Key words: Negative Binomial, Poisson distribution, cotton leafworm, caterpillar complex, tobacco budworm, cotton bollworm, fall armyworm.

Introduction

The most important cotton pests in Argentina cotton region are lepidopteron caterpillars (Lepidoptera: Noctuidae). Cotton leafworm (*Alabama argillacea*, Hübn) is the most constant cotton pest in the region; it is present during all the crop period, with a large dispersion in the area. Tobacco budworm (*Heliothis virescens*, Fab.), cotton bollworm (*Helicoverpa gelotopoeon*, Dyar) and fall armyworm (*Spodoptera frugiperda*, Smith) are not specific cotton pest but cause important damages to cotton crops (Saini, 2002).

Spatial density of lepidopteron populations is heterogeneous and the knowledge of spatial distribution pattern is necessary to develop pest management plans (Liebhold *et al.*, 1991; Nestel & Klein, 1995). Spatial distribution pattern is a no dimensional characteristic of space arrangement that describes the location of a set of objects or individuals respect to the other ones. In order to determine the ecological meaning of the distribution when the dispersion of a particular set of points is regular, random or aggregated, it is necessary to define in mathematical terms the form of the distribution (Rogers, 1974; Young & Young, 1998).

A random pattern defines the geographic disposition of points in a surface where each point has equal probability of being occupied by one individual; the position of a point is independent of any other. Poisson distribution is associated with random phenomena and implies the development of organisms in a surface completely independent one from another. At low population densities, Poisson distribution frequently presents an adequate adjustment (Pielou, 1977; Rogers, 1974; Young & Young, 1998). This distribution is not usually found when organisms are sampled, but has been reported for some crop pest (Ahmadi *et al.*, 2005).

A parameterization of Poisson distribution is (1):

$$P_{(r)} = \exp(-\lambda a)\frac{(\lambda a)^r}{r!} \quad (r=0, 1, 2, ...,) \qquad (1)$$

$$E_{(r)} = \lambda a \qquad (2)$$

$$Var_{(r)} = \lambda a \qquad (3)$$

Where λa is the product of the event probability or average by time or space unit, by the number of units by time or space (1); $E_{(r)}$ is the expected value (2) and $Var_{(r)}$ is the variance of Poisson distribution (3). In Poisson distribution mean and variance are equal, giving a quotient variance/mean equal to the unit (Young & Young, 1998).

The analysis of aggregation indexes based on variance/mean relation is used to estimate the insects' spatial distribution (Young & Young, 1998). The dispersion of observed points can be studied in relation to its deviation of Poisson distribution, based on variance/mean relation values and the significance of its deviation from unit in one or another sense. The difference has a standard error equal to $[2/(n-1)]^{1/2}$, where n is the number of observations, its significance can be proved using a T test with (*n-1*) degrees of freedom (Rogers, 1974).

A relation variance/mean superior to unit indicates a spatial process more grouped than the random one, which refers to an aggregated distribution. A relation variance/mean inferior to unit indicates a model more regular (Davis, 1994; Pielou, 1977; Rogers, 1974).

A regular dispersion assumes that the probability of a point location in a sub region of the space decreases linearly with the number of points that already exist in the sub region. This type of dispersion responds to Binomial distribution, but it is not common in biological populations (Pielou, 1977; Rogers, 1974).

An aggregated dispersion assumes that the probability of a point lodged in a sub region increases linearly with the number of existing points in this sub region. This type of dispersion responds to Negative Binomial distribution (Pielou, 1977; Rogers, 1974):

$$P_{(r)} = \binom{k+r-1}{r}\left(\frac{p}{1+p}\right)^r\left(\frac{1}{r+p}\right)^k \qquad (4)$$

Where *k* is the number of successes which is wanted to know, and *p* is the probability of a success (4).

In Negative Binomial distribution parameter *k* is known as an aggregation parameter. High values of *k* indicate less grouping of the individuals, on the contrary low values of *k* are related to more aggregated populations (Young & Young, 1998).

Aggregated patterns fitted to Negative Binomial distributions are usually found for describe pests in crop fields. Costa *et al.* (2006) encountered aggregated patterns adjusted to Negative Binomial for orthezia scale distribution in citrus orchards. Harris *et al.* (1993), Israely *et al.* (1997), Katsoyannos *et al.* (1998), Papadopoulos *et al.* (1996), Papadopoulos *et al.* (2001) and Papadopoulos *et al.* (2003), found aggregated distribution with low population density in Mediterranean fruit fly, that becomes random when population sizes increases. Failero *et al*. (2006) have encountered aggregated distribution pattern of lepidopteron rice pests' that adjust to Negative Binomial, with *K* parameter values that changes with the stage of the crops. Dawson *et al.* (2006) found highly contagious distribution for *Helicoverpa* spp. eggs on fresh market tomatoes.

In this work the spatial analysis has been used to describe the distribution pattern of *Alabama argillacea*, *Heliothis virescens*, *Helicoverpa gelotopoeon* and *Spodoptera frugiperda* adults´, captured in light traps placed in different localities of the Argentine cotton region and to fit mathematical models for these distributions.

Materials and Methods

The work was based on weekly captures in light traps of adults of *Alabama argillacea* (ALABAMA) and the complex formed by *Heliothis virescens*, *Helicoverpa gelotopoeon* and *Spodoptera frugiperda* (COMPLEX) in the Argentine cotton region. It includes information from 1995 to 2004, of the following localities: Reconquista (29º 11´S; 59º 42´O), Sáenz Peña (26º 49´S; 60º 27´O), Las Breñas (27º 05´S; 61º 07´O), Villa Ángela (27º 34´S; 60º 44´O), Tres Isletas (26º 21´S; 60º 26´O), Charata (27º 13´S; 61º 11´O), Machagay (26º 56´S; 60º 03´O), J. J. Castelli (25º 57´S, 60º 38´O), General San Martín (26º 33´S; 59º 22´O) and El Colorado (26º 19´S; 59º 22´O).

Mean, variance and variance/mean relation index were calculated for every week populations and the deviation from unit was proved by the Roger´s T test (1974). According to the values of this index, Negative Binomial and Poisson distributions were adjusted by the Chi - square test (Young & Young, 1998).

ALABAMA captures were registered only during 36 weeks coincident with the cotton crop period and COMPLEX captures were observed during the 52 weeks every year, but due to the ample rank of variance/mean index values in the different weeks, ALABAMA captures were divided in four periods (in which the index stayed relatively constant): week one to nine; ten to nineteen; twenty to twenty-seven; twenty-eight to thirty-six; and COMPLEX captures were divided in five periods: week one to thirteen; fourteen to twenty-two; twenty-three to thirty-two; thirty-three to forty; forty-one to fifty-two.

Results and Discussion

Throughout all the capture period of ALABAMA, variance/mean relation was significantly superior to the unit (α<0,000) (Figure 1).

At all the capture moments, adequate adjustments to Negative Binomial distributions were obtained. Values of Chi-square test probabilities, distributions adjusted and the corresponding parameters are in Table 1.

In most of the weeks, variance/mean relation of the COMPLEX species populations stayed significantly over the unit (α<0,000) (Figure 2).

Aggregated distributions were observed and Negative Binomial distributions fitted. Between weeks twenty three and thirty two, a relation variance/mean statistically equal to unit was observed (α>0,05) (Figure 2) and adjustments to Poisson distributions obtained. Values of Chi-square test probabilities, distributions adjusted and the corresponding parameters are in Table 2.

Throughout all the period of capture of cotton leafworm, a variance/mean relation significantly superior to the unit (α<0,000) allows to reject the hypothesis of a Poisson distribution and indicates the existence of a contagious or aggregated distribution that adjust to a Negative Binomial model, according to the established by Davis (1994), Pielou (1977), Rogers (1974) and Young & Young (1998).

Contrary with the founded by Harris & Lee (1986, 1987), Harris *et al*. (1993, Israely *et al*. (1997), Katsoyannos *et al*. (1998), Nishida *et al*. (1985), Papadopoulos *et al*. (1996, 2001, 2003) and Vargas *et al*. (1983) for Mediterranean fruit fly, the spatial distribution of cotton leafworm response to contagious patterns throughout all the period of presence of this specie in Argentine cotton region (Figure 1). These results are according with Costa *et al.* (2006) and Dawson *et al.* (2006) that found aggregated patterns which adjust to Negative Binomial for orthezia scale in citrus orchards and highly contagious distribution for *Helicoverpa* spp. eggs on fresh market tomatoes respectively.

In accordance with the crop station advances, the value of parameter *k* remains relatively constant showing a uniform aggregation along the time, which, in agreement with Young & Young (1998), indicates that the aggregation stays uniforms, nevertheless the values of *p* are increased remarkably, which indicates an increase of the probability of finding captures at the end of the crop season. These results indicates a behaviour different of lepidopteron rice pests' detected by Failero *et al*. (2006), that have found aggregated distribution pattern that adjust to Negative Binomial, but *K* parameter value changes with the stage of the crops.

Variance/mean relation of the populations of caterpillar complex species (*Heliothis virescens*, *Helicoverpa gelotopoeon* and *Spodoptera frugiperda*), in most of the time stays significantly over the unit (α<0,000). This result lead to reject the hypothesis of a random distribution fitted to a model of Poisson and contributes evidence to a contagious or aggregated distribution that could adjust to a Negative Binomial model (Davis, 1994; Pielou, 1977; Rogers, 1974). Negative Binomial models adjusted have parameter *K* relatively constant during summer, which implies according with Young & Young (1998), an uniform aggregation along the season (Figure 2).

In autumn Negative Binomial models were adjusted but values of *K* increases remarkably, indicating according to Young & Young (1998), a diminution of the aggregation coincident with very small values of *p*, which reflects low probability of capture. This moment is immediately followed for a period with very low captures in winter, when a relation variance/mean statistically equal to unit is observed (α>0,05) and distribution becomes random, fitting to the Poisson distribution (Figure 2) (Davis, 1994; Pielou, 1977; Rogers, 1974).

Contrary to Harris & Lee (1986, 1987), Harris *et al.* (1993), Israely *et al.* (1997), Katsoyannos *et al.* (1998), Nishida *et al.* (1985), Papadopoulos *et al.* (1996, 2001, 2003) and Vargas *et al.* (1983) results in Mediterranean fruit fly, with low population densities, the space distribution of the caterpillar complex species (*Heliothis virescens*, *Helicoverpa gelotopoeon* and *Spodoptera frugiperda*) in the Argentinean cotton region respond to random patterns with low densities and become contagious when densities increases.

In conclusion, in Argentine cotton region throughout al the cotton crop cycle, populations of *Alabama argillacea* present an aggregated distribution, with constant aggregation along the cotton cycle and higher probability at the end of the season, fitting to Negative Binomial distributions.

During most of the year, populations of *Heliothis virescens*, *Helicoverpa gelotopoeon* and *Spodoptera frugiperda* in the cotton region of Argentina present an aggregated distribution, fitting to Negative Binomial distributions. In winter, a moment with very low captures, distribution becomes random fitting to a Poisson model.

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Table 1. *Alabama argillacea* spatial distribution.

Distributions adjusted, parameter estimations and p-values of Chi-square lack of fit tests.

Period (week of the year)	Distribution Adjusted	Parameter estimation	p
1 to 9	Negative Binomial	P =17 *k* = 18	0,99995
10 to 19	Negative Binomial	*P* = 196 *k* = 21	0,99989
20 to 27	Negative Binomial	*P* = 522 *k* = 21	0,99999
28 to 36	Negative Binomial	*P* = 534 *k* = 17	0,97709

Table 2. Caterpillar complex spatial distribution.

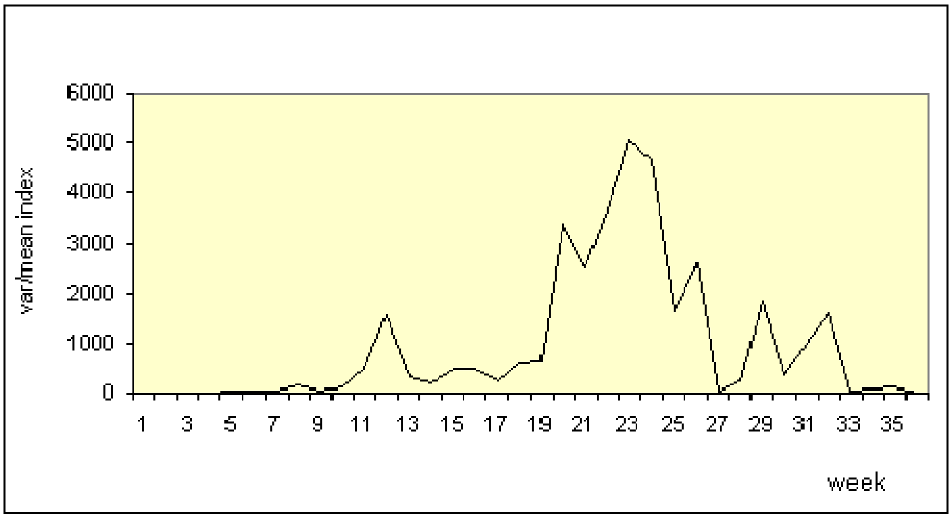
Distributions adjusted, parameter estimations and p-values of Chi-square lack of fit tests.

Period (week of the year)	Distribution Adjusted	Parameters estimation	P
Weeks 1 to 13	Negative Binomial	P = 14 *k* = 1	0,8936
Weeks 14 to 22	Negative Binomial	*p* = 0,31 *k* = 20	0,38943
Weeks 23 to 32	Poisson	λ = *5*	0,96312
Weeks 33 to 40	Negative Binomial	*p* = 45 *k* = 1	0,08965
Weeks 41 to 52	Negative Binomial	*p* = 48 *k* = 0,8	0,05659

List of captions for Figures:

Figure 1. Variance/mean relation indexes of *Alabama argillacea* captures in light traps, in different localities in the Argentine cotton region along the crop season.

Figure 2. Variance/mean relation indexes of caterpillar complex captures in light traps, in different localities in the Argentine cotton region along the crop season.



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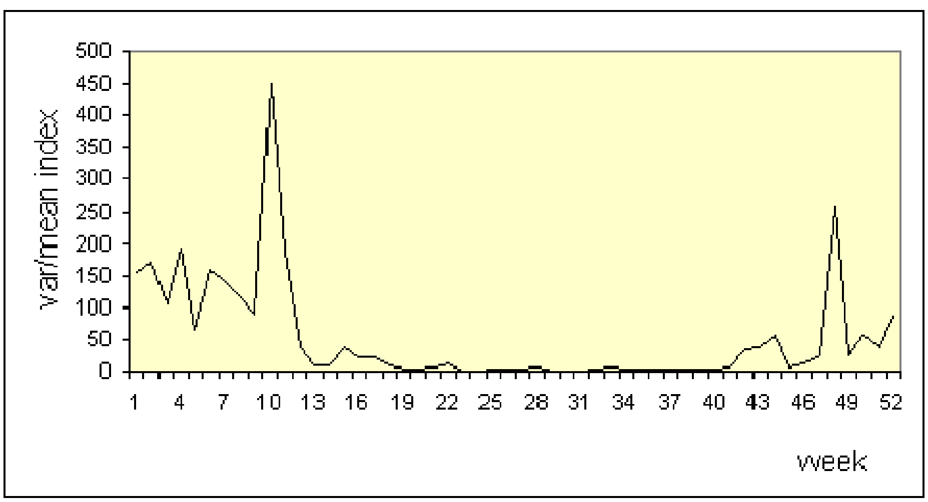
Spatial Distribution…

Figure 1.



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Spatial Distribution…

Figure 2.