COMPARATIVE EVALUATION OF INSECT BIODIVERSITY IN TOMATO-MAIZE POLYCULTURE

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ABSTRACT. The results of an insect biodiversity study are shown in this paper. Three varieties of tomato (Inca-17, Inca-9-1 and Lignon) in monoculture and associations with corn systems, by using four ecological indicators (Shannon-Weaver Biodiversity, Simpson's Dominance, Pielou's Uniformity and Margaleff's Richness) were evaluated. This work was carried out on a compacted red Ferralitic soil from the experimental areas of the National Institute of Agricultural Sciences, between the beginning of January and the end of April, 1998. The treatments studied were seven: tomato-maize polyculture (cv. Inca-17), tomato-maize polyculture (cv. Inca-9-1), tomato-maize polyculture (cv. Lignon), and tomato monoculture of the former varieties and corn monoculture. Each treatment was 20 m long x 6.3 m wide, for a total of approximately 900 m^2 of the evaluated area. This study was carried out by weekly samplings in the field through visual method for counting adults, and immature phases were counted too. Parasitoid emergency was evaluated in the laboratory. Biodiversity ecological indicators presented a higher stability, richness, equilibrium and diversity and a lower dominance in the insect communities of the associations than in monocultures. A varietal effect was not detected on the behavior of these biodiversity indicators.

RESUMEN. En este trabajo se presentan los resultados de un estudio de la biodiversidad de la entomofauna en tres variedades de tomate (Inca-17, Inca-9-1 y Lignon) en sistemas de monocultivo y asociaciones con maíz, mediante la utilización de cuatro índices ecológicos (Biodiversidad de Shannon-Weaver, Dominancia de Simpson, Equitatividad de Pielou y Riqueza de Margaleff). Este se realizó en las áreas experimentales del Instituto Nacional de Ciencias Agrícolas sobre un suelo Ferralítico Rojo compactado, en la fecha comprendida entre principios de enero de 1998 y las postrimerías de abril del mismo año. Los tratamientos estudiados fueron siete: policultivo tomate-maíz de la variedad Inca-17, policultivo tomate-maíz de la variedad Inca-9-1, policultivo tomate-maíz de la variedad Lignon, monocultivo de tomate de las variedades citadas y monocultivo de maíz. Cada tratamiento tuvo una dimensión de 20 m de largo x 6.3 m de ancho, para un total de aproximadamente 900 m^2 de extensión del área evaluada. Este estudio fue realizado mediante muestreos semanales en el campo por el método visual para la observación de adultos y se observaron las fases inmaduras y la emergencia de parasitoides en el laboratorio. Se encontró que los índices ecológicos de biodiversidad manifestaron una mayor estabilidad, riqueza, equilibrio y diversidad, y una menor dominancia en las comunidades insectiles de las asociaciones que en las de los monocultivos. No se detectó un efecto varietal sobre el comportamiento de estos indicadores de biodiversidad.

Key words: biodiversity, companion crops, plant pests, natural enemies, maize, tomato, harmful insects

Palabras clave: biodiversidad, cultivos asociados, plagas de plantas, enemigos naturales, maíz, tomate, insectos dañinos

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a worldwide well-known vegetable for its potential production with an annual production volume surpassing 70 million tons. Only 15 % of the worldwide tomato production is from the tropical countries whereas the major production (50 %) is from the United States, India, China, Italy and Turkey; in Cuba, tomato crop represents the main horticultural plant, due to the increasing demand of its fruits for consumption, as much as fresh for the preservation industry. Thus, a great priority has been given to its development.

Polycultures usually benefit pest reduction. Agroecosystemic performance is generally linked to its diversification, so much from the biodiversity point of view as the cultural and environmental diversity. The diversity of any habitat and scale reaches its maximum when a great number of species coexists with about the same abundance per species (1).

Species diversity probably gives stability providing alternating canals for energy flow and nutrients through the ecosystem. Another possible advantage of the high number of species in a community is that fewer empty niches exist, therefore, fewer opportunities of new species invasion (2).

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Natural ecosystems can be considered models for the development of pest management strategies in agroecosystems. Preservation of natural enemies and at the same time pest management could be designed by previous comprehension of natural environment and habitat manipulation as a way to enhance natural enemy control.

Corn, sorghum and grass, like nurse crops, have a beneficial influence by reducing pest affluence to tomato crop (3). Similar results were found (4) with tomato-maize association, in which corn behaved as a living barrier against white fly (*Bemisia tabaci* Guennadius) and a natural enemy shelter. Similar outputs were also found for pest behavior (5, 6, 7, 8). Other authors have reported noncoincident outputs with the former, so it was stated that corn worked as shelter of *Frankliniella schultzei* (9) which is vector of a tospovirus affecting tomato crop.

These results show that when these crop association systems are studied, independently of the same crop combination and with a similar space design pattern, there should be kept in mind the multiple component factors of agroecosystems, like herbivorous species and their natural enemies, climatic characteristics of the region, plant matrix and surrounding crops, as well as the management technologies applied to these crops, which make the interactions influencing the design outputs of these cultural control techniques much more complex.

White flies are one of the most important pests in tomato crop. The main significance of this insect in Cuba, from the economical point of view, is attributed to its high efficiency as geminivirus transmitter in tomato and bean, that affected in 1990-1993 a 27-41.6 % of the cultivated tomato area (10). This insect is a potential transmitter of a high number of viruses and of the TYLCV virus in tomato. This problem constitutes a complex patho-system, due to the interaction white fly-geminivirus-host plants at a high diversity of plants in the agroecosystems where vegetables, grains, tubers and roots are regularly cultivated (10, 11).

In reference to its natural enemies, more than 34 predator species are reported within the Coleoptera order, Heteroptera, Diptera, Neuroptera and Acarina. Parasitoid spectrum is higher, belonging all to the Hymenoptera order in the Plastygasteridae, Aphelinidae and Eulophidae families.

A natural enemy inventory of this insect was carried out (12) in Cuba and the existence of four parasitoids (*Encarsia luteola* Howard, *E. nigricephala* Dozier, *E. quaintancei* Howard and *Eretmocerus* sp.), five predators (*Theridula gonygaster* Simon and *Theridula* sp., *Delphalstus pallidus* Lec, *Chrysopa external* Navas and *Cyrtopeltis varians* Dist.) and an entomopathogenic fungus (*Paecilomyces fumosoroseus* Wise) determined. According to some authors (3), 12 bio-regulators of the populations of *Bemisia* spp. exist; also they reported *Paecilomyces fumosoroseus* Wise and *Verticillium lecanii* (Zimm), with an effectiveness of 84-90 % respectively.

Another important herbivorous in tomato crop is leaf miner (*Liriomyza* spp.). This species is known as a secondary pest and it has been proved to produce outbreaks due to the indiscriminated use of pesticides.

The females perforate leaf surface and feed from cell juices. Their tiny larvae (less than 2 mm) make serpentine mines, feeding from leaf mesophyll. The promoted damage reduces leaf photosynthetic capacity and just in case of strong attacks, it provokes a substantial leaf loss, with the consequence that fruits are smaller and have less quality (13).

Four parasitoid species: *Diglyphus* sp. and *Chrysocharis* sp. (Hymenoptera:Eulophidae), *Opius* sp. and *Oenonogastra* sp. (Hymenoptera:Braconidae) were reported (14). *Diglyphus* sp. is a larval ectoparasitoid of many miner species of Diptera order (15, 16). Four parasitoids of this pest were also reported (16), which are: *Neochrysocharis* sp. (Hymenoptera:Eulophidae), *Opius forticornis* (Hymenoptera:Braconidae), *Gonaspidium utilis* (Beardsley) (Hymenoptera:Eucoilidae), *Disorygna pacifies* (Yoshimoto) (Hymenoptera:Eucoilidae), all endoparasitoids and the three last pupal-larval.

Diabrotica balteata (Le Conte) has also been reported causing considerate damages in tomato. It is commonly called as Diabrotica or common Crisomelid and belongs to Coleoptera order, family Chrysomelidae.

Larvae eat the roots and can promote rot and loss of plants. The adults eat leaves, buds and flowers, making irregular holes. Some authors suppose that upon producing its lesions, this crisomelid transmits viral diseases. Bacteria and fungi also penetrate through leaf lesions.

This work was based on the above background with the objective of comparing the insect biodiversity in the tomato-maize system polyculture or associations and monocultures of the previously mentioned tomato varieties.

MATERIALS AND METHODS

This experiment was carried out at the National Institute of Agricultural Sciences (INCA) on a compacted red Ferralitic soil, from the beginning of January, 1998 to the end of April of the same year, on an altitude of 135 m above sea level. The mean temperatures ranged from 17.9 to 22.2°C, mean relative humidity from 79.4 to 86.1 % and the accumulated rainfall 77 mm.

The tomato was firstly seeded in seedbeds and samplings were weekly performed in order to detect possible pest attacks. No considerable damages in this crop phase were observed, nor virus symptoms.

The tomato was subsequently transplanted and corn was seeded in 20-m-long bands at a space arrangement of three rows of tomato with two rows of corn in each border of the strip. Three varieties of tomato were used: Inca-17, Inca-9-1 and Lignon, so that seven treatments were made up: three tomato- corn polycultures and three monocultures of each tomato variety, besides corn monocultures. The evaluated area was of 900 m^2.

Plant spacing for the tomato was 0.9 m x 0.3 m whereas for corn-sowing 0.9 m x 0.3 m. Bands had a perpendicular orientation towards the predominant wind direction.

Farming practices to both crops followed the Technical Patterns (17,18) except that pesticides were not applied.

Evaluation methods. The tomato crop was weekly sampled, selecting 20 plants (repetitions) at random in each strip, counting the white fly adults (*Bemisia* spp.) present at the three levels of the plant (high, medium and low), that is, a leaf per stratum. A leaflet was taken from each leaf in order to count the immature phases of this pest (white fly) with a stereoscopic microscope and the rest herbivorous (nymphs of the green stinking bug *Nezara viridula* L. and tomato leaf miner larvae, *Liriomyza* spp.) as well as the natural enemies (*Chrysopa* spp. eggs).

Adults of the common crisomelid (*Diabrotica balteata* Le Conte) were sampled by means of an entomological net bag. Early in the morning, at six points diagonally distributed in each band, net bags were passed ten times per point and its individuals captured in flight were recorded.

Parasitoid emergency. A test was made to the selected leaflets every two weeks in order to determine the presence of parasitoids, which consisted of placing ten leaflets of each treatment in Petri dishes with individuals of white fly and tomato leaf miner, counting the parasited individuals and the emerged parasitoids, also classifying them taxonomically. From the counting of parasited individuals, the parasitism percentage was calculated in order to further carry out the pertinent comparisons between the studied treatments.

Result processing and analysis

Ecological indicators. In samplings I, III, V and VII to evaluate the insect community biodiversity in each treatment (based on the genera taxonomic category of herbivorous and their natural enemies), the following ecological indicators were calculated:

Shannon- Weaver's Index $$H' = \sum_{j=1}^{s} \frac{n_j}{N} \log \frac{n_j}{N}$$

Where n_j is the number of individuals of the genera 1, 2, 3. . s; N is the total number of individuals of all genera and s the number of genera.

Pielou's Uniformity Index $$J' = \frac{H'}{H'_{max}}$$

Where H' is the calculated biodiversity for the communities in study and $H'max$ the maximal biodiversity for the number of genera present in the community ($log_{10}\ s$).

Simpson Dominance Index $$D_s = \sum_{j=1}^{s} \left(\frac{n_j}{N} \right)^2$$

Where n_j is the number of individuals of the genera 1, 2, 3.s; N is the number of individuals of all genera.

Margaleff's Richness Index $$Rm = \frac{(s-1)}{\log N}$$

Where s is the total number of genera and N the total number of individuals of all genera.

In the calculation and analysis of these indexes, the following genera were included: *Bemisia*, *Liriomyza*, *Nezara, Diabrotica, Chrysopa, Dygliphus* and *Heteroschema*. The first four are herbivorous and the last three natural enemies (*Chrysopa* spp. of *Bemisia* and *Dygliphus* and *Heteroschema* sp. of *Liriomyza*).

The first two indexes (Shannon-Weaver Biodiversity and Pielou's Uniformity) were calculated by means of the Ecoindex software, manufactured by "José Antonio Echevarría" Higher Polytechnic Institute, the logarithmic base used to calculate both indexes was decimal; the other two indexes (Simpson's Dominance and Margaleff's Richness) were implemented in Microsoft Excel from Microsoft Office '97. The logarithmic base employed to calculate Margaleff's Richness Index was also decimal.

A comparison of the studied treatments (polycultures and monocultures of the three varieties) was carried out for each index by a variance analysis based on a randomized block design refered to samplings, that is, each sampling constituted a replication per each treatment, making up six treatments with four replications each.

RESULTS AND DISCUSSION

These indexes clearly showed that increasing crop biodiversity in an agroecosystem influences biodiversity of the higher trophic levels, that is to say, the genera of herbivorous and their natural enemies (parasitoids and predators). The variance analysis showed significant differences among the treatments studied in all indexes applied to the insect communities.

Shannon- Weaver's Index (H'). Significant differences were found among the treatments concerned to crop systems (polyculture and monoculture), not among the varieties in any of them (Table I). This demonstrates that in this association there was a greater abundance of genera and the relative number, that is to say, its relative distribution or homogeneity, so much from the space as the temporal points of view is more balanced and stable than in monoculture systems, since the association systems offer greater food resources (pollen, nectar, ligamase), shelter, alternating prays to pests natural enemies, which enable to diminish its population densities and, therefore, to balance them, giving a more equitable distribution to these insect pests, also avoiding that one of them reaches a climbing preponderance and its densities intolerable from the economical point of view (Table I).

Table I. Ecological indexes in the associations and monocultures of varieties Inca-17, Inca-9-1 and Lignon

Treatment	Shannon's Biodiversity Index	Pielous's Uniformity Index	Simpson's Dominance Index	Margaleff's Richness Index
PI-17	0.77 a	0.83 a	0.22 c	3.41 a
PI-9-1	0.72 a	0.78 ab	0.26 bc	3.78 a
Plignon	0.64 a	0.71 ab	0.32 bc	3.67 a
MI-17	0.48 b	0.67 bc	0.40 ab	2.31 b
MI-9-1	0.44 b	0.64 bc	0.47 a	1.92 b
Mlignon	0.42 b	0.56 c	0.50 a	2.21 b
Significance	***	**	**	***
Mean standard error	0.042	0.039	0.047	0.219

Means with common letters in each column do not differ significantly according to Duncan's multiple range test (p<5 %)

Pielou's Uniformity Index (J'). When calculating this index, results had a similar arrangement to the former one, although with more gradual significant differences, which were evident with a significance (99 %) between the association and monoculture systems of the varieties Inca-17 and Lignon. In case of Inca-9-1 variety, the crop systems (polyculture and monoculture) had not differentiated values from the statistical point of view. Despite this, one could affirm, keeping in mind the outputs from the other two varieties, that in this study polycultures had more uniformly distributed communities, so much from the space as the temporal points of view. Differences between varieties in any of the two crop systems were not appreciated (Table I).

Dominance Index (Ds). This index showed a similar arrangement of mean values of the treatments to the two previous indexes, but in a reverse sense, due to its higher values show less diversity, uniformity and equilibrium in the simplified agroecosystems of monocultures; the pests are submitted to a less control of the biotic mortality factors (parasitoids and predators) and, therefore, some pests or herbivorous acquire dominant agroecosystem positions with reference to the other species and they become even more pernicious due to their higher densities; therefore, greater levels of damages to the crops, specifically the tomato are recorded. Significant differences are observed between polycultures and monocultures, but not between the varieties of any system (Table I).

Margaleff's Richness Index (Rm). This index corroborates even more the previous outputs since differences between polycultures and monocultures are still evident; although they do not have the same gradation because this indicator is more sensitive to the richness of taxa (genera) than to proportions between them in the studied communities, it is clear that in polycultures there existed a greater biodiversity than in the systems with simplified vegetation (Table I).

The fact that a larger insect diversity had been manifested in polycultures upon studying these four biodiversity indicators corroborate even more the former outputs exposed in a previous work (19), in which the densities of insect pest and their natural enemies were valued, since in them there was a bigger presence of pests in monoculture systems than in polycultures; however, there were more natural enemies in polycultures than in simplified systems. The existence of a higher diversity denotes a major stability in the communities of these systems (polycultures) and at the same time less probability of pest population outbreaks, longer trophic chains and more numerous cases of natural enemies (in polycultures were manifested all the parasitoid insects from leaf miner and all the reported white fly predators in this work, while in monocultures this was more limited, since only two parasitoids were observed and only one predator, besides its lower quantity).

The varieties do not show differences between them within each system, since differences are recorded in relation to the densities of insects studied, they are balanced between them upon studying their proportionality, that is to say, the space or niche that is not occupied by any species is occupied by another for diverse reasons, like the different features of these tomato phenotypes, different palatability, leaf surface texture, color, etc.

The maturity degree of an ecosystem is given by the saturation present in its ecological niches, while more species have arrived to it, there are more possibilities to find interspecific interactions as competition, depredation, parasitism, symbiosis and others.

In younger ecosystems, prevalent organisms are those of the first trophic levels (autotrophies and herbivorous), especially the settlers. They are characterized by a high reproduction and dispersion rate, a smaller size and a limited competition skill. These are responsible of transforming and preparing the environment for the arrival of other organisms; this is modifying the substrate and microclimatic conditions.

With time, a succession takes place in which other species begin to enter. These take advantage of the work developed by the settlers, finding more favorable substrates for its development that the existing ones at the beginning of the process and consuming the foods elaborated by the succession beginners. Some of the species that colonized the ecosystem in its virgin state are displaced by those that have further arrived, which are characterized to possess more competition skills, a bigger size and energy concentration.

With the ecosystem maturation and therefore a bigger species affluence in it, biodiversity should logically increase. The use of resources and particularly the energy becomes more fragmented, because it flows in smaller volumes through a bigger number of branches of the trophic nets. This slow energy flow denotes that changes taking place by rough population increase are more difficult and in turn the same happens with the extinction of certain species in these ecosystems showing a considerably longer developing time than those beginning to populate.

Mature ecosystems are thus more stable and balanced than those that are in a pristine state of colonization or succession. Monocultures can be qualified as an artificial state of an ecological succession at the begining, for their high simplification degree (a single crop species), which makes microclimatic conditions and resources of feeding, shelter, mating more uniform and scarce. These crop systems are more fragile and inclined to abrupt changes demanding interventions with inputs that favor to balance these conditions, a not very frequent fact.

Polycultures are an approach to the natural conditions which resemble much more to the mature ecosystems of advanced ecological successions or close to a balance state than in case of monocultures. It is logical that a general tendency in these systems is the existence of more stable conditions due to a bigger amount of crop species as well as the multiple and variable resources such biodiversity offers. The more dissimilar these species are from the genetic point of view, the higher tendency these systems should have toward a natural functionality, characterized by the balance in temporary distribution of species and its population stability.

Tomato-corn polyculture is a good example of these kind of diversified systems; of course, the fact to have a high biologic diversity explains in certain way the performance or good health of the diversified system.

The fact of having a high biodiversity does not offer a complete explanation about the agroecosystem performance from the point of view of crop protection. This is palpable in pests that are disease vectors, which crops are notably sensitive; for example, in tomato crop the white flies are very efficient geminivirus vectors, able to drastically diminish yields, low population densities are enough to spray the disease and inflict loss of consideration. However, in case of tomato-corn polyculture, although this measurement doesn not keep permanently such pest under control, it diminishes its increment and immigration rates, delaying the application of other control measured and diminishing pesticide charge in the environment.

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