Spatial Distribution of Listroderes costirostris and Hypera postica (Curculionidae: Cyclominae, Hyperinae) on a Celery Crop in Mexico's Northwest Region

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Scientific Notes

Spatial distribution of *Listroderes costirostris* and *Hypera postica* (Curculionidae: Cyclominae, Hyperinae) on a celery crop in Mexico's Northwest Region

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Celery, *Apium graveolens* L. (Apiaceae), is an essential salad ingredient in different parts of the world, and its production is mainly destined for the fresh market. Its origin is not very clear. Several wild varieties grow in certain areas of Europe and western Asia with moderate climate. However, celery became a domesticated crop in the eastern Mediterranean region (Malhotra 2006). In Mexico, celery is one of the most important vegetable crops. Guanajuato, Mexico, is the largest producer, followed by Baja California, Mexico, with more than 405 planted ha (SIAP 2019). Some of the principal pests of this crop include *Philophylla heraclei* L. (Diptera: Tephritidae), *Spodoptera exigua* Hübner (Lepidoptera: Noctuidae), *Liriomyza trifolii* Burgess (Diptera: Agromyzidae), *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae) (IICA 2007; Eckman & Tesoriero 2015), and *Listroderes costirostris* Schönherr (Coleoptera: Curculionidae) (Morrone 2013).

Listroderes costirostris is an exotic parthenogenetic species with broad distribution in Argentina, Brazil, Chile, Paraguay, and Uruguay. The report of its introduction into the USA dates back to 1922. Both adults and larvae cause different types of damage to the aerial parts of apiaceous, brassicaceous, polygonaceous, solanaceous, and caryophyllaceous plants (Morrone 1993, 2011).

Hypera postica (Gyllenhal) (Coleoptera: Curculionidae) is an invading species from Palearctica. It was discovered in Utah, USA, in 1904, and has been expanding to other regions of the American continent since then. *Hypera postica* feeds on legumes, such as *Medicago* species (Fabaceae), but the main host is *Medicago sativa* L. (Fabaceae) in North America. Without natural enemies in that area, *H. postica* became the principal pest affecting alfalfa crops. Both adults and larvae feed on leaves, but larval instars cause the greatest damage (Iwase et al. 2015; Pellissier et al. 2017). *Hypera postica* infests legume weeds (Meyer 1975; Iwase et al. 2015).

Interaction among species may affect several of them in terms of abundance, distribution, growth rate, and reproduction rate, apart from having important evolutionary consequences (Soler 2002; Smith & Smith 2007; Price et al. 2011). The relationship among 2 or more species may affect 1 or several species in a negative way. In many cases, the competing species do not interact directly, but their interaction depends on the availability of resources, which is decreased by the presence and consumption of other species (Smith & Smith 2007).

Spatial distribution of a given population is one of the most important aspects in descriptive ecology, and it is an essential property of living systems (De los Santos et al. 1982). Measuring the species aggregation rate is a core topic in ecology and applied biology, especially in sampling and density surveys (Gutiérrez 1996). The spatial distribution of a given population may be modified by the same species, as well as by other species competing for the same space and food, or by natural enemies (Smith & Smith 2007). The purpose of this research work was to assess the degree of infestation, the spatial distribution, and the association between *H. postica* and *L. costirostris* on *A. graveolens* in Mexico's northwest region.

This research work was conducted at "San Quintín Valley Farms" ranch, located at 30.640880°N, 115.964802°W, and 120 masl. We used 1 ha of a commercial field planted with *A. graveolens* to design 4 random quadrants of 20 m^2.

In order to determine the weevils' presence and the degree of infestation, we sampled 100 plants at random in each quadrant. We collected 22 samplings in each quadrant. The samplings took place from 15 Jan to 20 Mar 2018. We collected and counted the larvae and adults of the specimens, and we preserved them in a labeled flask (Veravitrum, Santiago de Queretaro, Queretaro, Mexico) with ethyl alcohol at 70% (v/v) before transferring them to the Parasitology Laboratory of

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the Faculty of Engineering and Business in the Autonomous University of Baja California, San Quintin, Baja California, Mexico, for identification. The species confirmation was done by "Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias" (National Institute of Forestry, Agricultural and Livestock Research) in the Experimental Station of Zaragoza, Coahuila, Mexico. The specimens were placed on white cardboard triangles for observation, and the species were identified with the help of a stereoscopic microscope (Carl Zeiss, Oberkochen, Germany), using the keys of Morrone (1993), Salsbury (2000), and Anderson (2002). The specimens remained at the Insect Collection of "Universidad Autónoma de Baja California" and at the Curculionidae Collection of Zaragoza Experimental Station, Zaragoza, Coahuila, Mexico.

Population distribution can be classified by calculating the randomized variance-mean ratio $S^2 / \overline{X}$ = 1; < 1 uniform and > 1 aggregated. The result of a randomized distribution may be proved by calculating the Index of Dispersion (ID), where *n* is the number of samples: $ID = (n - 1)S^2 / \overline{X}$. In the next stage we calculated the Z coefficient to prove the benefit of the adjustment, where v is the degree of freedom ($n - 1$). $Z = \sqrt{2I_D} - \sqrt{2v-1}$; $v = n - 1$. If 1.96 ≥ Z ≥ −1.96, the spatial distribution is randomized, but if Z < −1.96 or Z > 1.96, the distribution is either uniform or aggregated (Pedigo & Buntin 1994).

The percentage of plants infested with weevil were transformed to arc-sin $\sqrt{x/100}$ for standardization. The 1-way variance analysis and Tukey's multiple range test ($P \leq 0.05$) to separate the means were used. We used Pearson's correlation method to measure the association among species ($P \leq 0.05$) (Zar 2010). All the analyses were performed with software R (R Core Team 2018).

According to the characteristics of the collected specimens, we identified *H. postica* and *L. costirostris* weevil species (Fig. 1). Therefore, this is the first report of the *H. postica* alfalfa weevil (Fig. 1A) on *A. graveolens* plants. In Baja California, Mexico, we are currently observing the presence of both weevil species, *L. costirostris* and *H. postica*, feeding on celery plants as a shared food source.

The percentages of plants infested with the 2 species of weevils (*H. postica* and *L. costirostris*) differed in the sampled sites ($F = 28.71$; df = 3, 84; $P < 0.0001$). In quadrant 4, we observed 28.68% of the plants hosting both species. The percentage of plants infested by *L. costirostris* or *H. postica* was different in the 4 quadrants ($F = 28.15$; df = 3, 84; $P < 0.0001$; $F = 28.03$; df = 3, 84; $P < 0.0001$, respectively). Quadrant 4 had 26.18 and 10.78% of plants infested by *L. costirostris* and *H. postica*, respectively. The percentage of plants infested by *L. costirostris* was different from the percentage of plants infested by *H. postica* in every quadrant (quadrant 1: $F = 112.03$; df = 1, 42; $P < 0.0001$; quadrant 2: $F = 110.81$; df = 1, 42; $P < 0.0001$; quadrant 3: $F = 5.78$; df = 1, 42; $P = 0.0207$; quadrant 4: $F = 5.20$; df = 1, 42; $P = 0.0277$) (Table 1).

The number of weevils was different in the 4 quadrants ($F = 37.82$; df = 3, 84; $P < 0.0001$). Quadrant 4 showed the largest average (± SD) of weevils (5.27 ± 0.34). The abundance of *L. costirostris* and *H. postica* was different in the 4 quadrants ($F = 45.67$; df = 3, 84; $P < 0.0001$; $F = 10.96$; df = 3, 84; $P < 0.0001$, respectively). Quadrant 4 had the largest average of *L. costirostris* and *H. postica*. The abundance of both species was different in quadrants 1 and 2 ($F = 114.31$; df = 1, 42; $P < 0.0001$; $F = 75.16$; df = 1, 42; $P < 0.0001$, respectively), whereas in quadrants 3 and 4 there were no differences between these 2 species ($F = 3.92$; df = 1, 42; $P = 0.0544$; $F = 2.97$; df = 1, 42; $P = 0.0923$, respectively) (Table 1).

Listroderes costirostris and *H. postica* showed significant association in each sampling quadrant (quadrant 1: $r = 0.6605$; $t = 3.9345$; df = 20; $P < 0.001$; quadrant 2: $r = 0.6514$; $t = 3.8395$; df = 20; $P = 0.001$; quadrant 3: $r = 0.9574$; $t = 14.832$; df = 20; $P < 0.0001$; quadrant 4: $r = 0.9779$; $t = 20.918$; df = 20; $P < 0.0001$). In general, *H. postica* associated with *L. costirostris* by 78.17% ($t = 11.626$; df = 86; $P < 0.0001$).

The *L. costirostris* population had an aggregated distribution pattern; this suggests that finding an individual of *L. costirostris* at one sample increases the probability of finding another individual at the same sample. *Hypera postica* had uniform distribution on celery crops (Table 2). The uniform distribution suggests that finding an individual of *H. postica* in a sample reduces the probability of finding another individual in the same sample.

While competing for food and space, individuals from a certain species inhibit the population's growth of other species (Smith & Smith 2007; Price et al. 2011). *Hypera postica* and *L. costirostris* feeding on celery share the same resources. If such resources are scarce, the Curculionidae compete for those limited resources, usually leading to extreme consequences in terms of physical conditions. This gives a result of an asymmetric variation of the competitive interaction among these species, where *H. postica* was affected by having a lesser abundance. Both species may live on celery plants without crossing, and they have exactly the same ecological needs. Under this set of conditions, if the *H. postica* population increases at a slower rate than the *L. costirostris* population, *H. postica* will exceed the population of *L. costirostris* and this latter species will become extinct on those celery plants. In this regard, Soler (2002) mentions that 2 species competing for the same resources cannot coexist indefinitely and one of them will die; however, if they compete for a series of more or less varied resources, those resources can be distributed and both will survive. Neverthe-

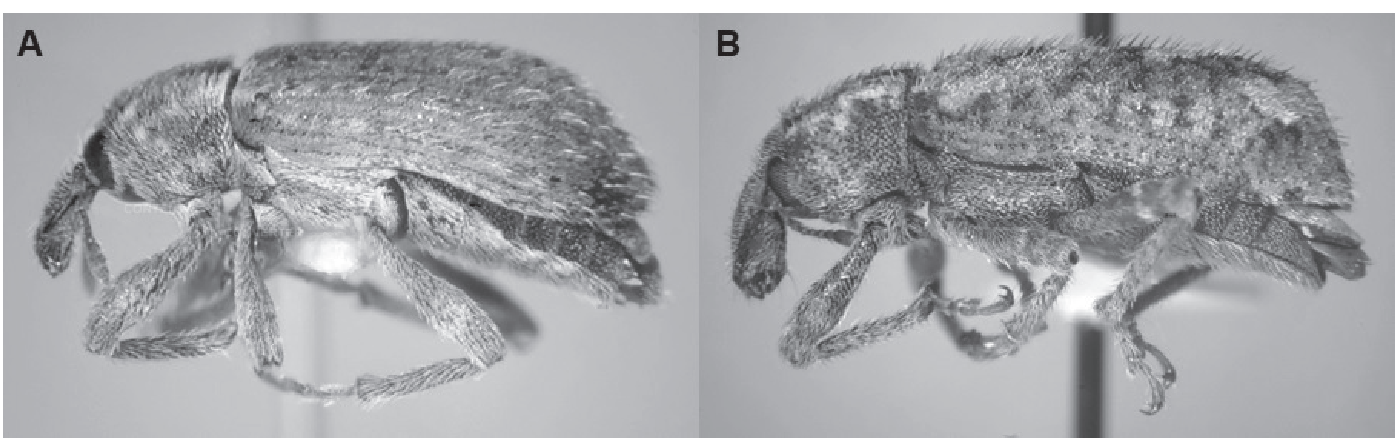

Fig. 1. Weevil species collected on *Apium graveolens* in Baja California, Mexico: (A) *Hypera postica* and (B) *Listroderes costirostris*.

Table 1. Abundance of *Lisžtroderes costirostris* and *Hypera postica* on *Apium graveolens*.

Quadrant	*H. postica* + *L. costirostris*	*L. costirostris*	*H. postica*
Presence (% ± SE)			
1	28.68 ± 1.47 a	26.18 ± 1.35 aA	10.78 ± 0.55 aB
2	26.27 ± 1.32 a	23.91 ± 1.20 aA	10.14 ± 0.52 aB
3	10.34 ± 2.27 b	9.49 ± 2.08 bA	4.04 ± 0.89 bB
4	9.57 ± 2.30 b	8.81 ± 2.12 bA	3.58 ± 0.86 bB
Abundance (average ± SE)			
1	5.27 ± 0.55 a	4.31 ± 0.31 aA	0.95 ± 0.05 aB
2	3.77 ± 0.52 b	2.72 ± 0.20 bA	0.95 ± 0.05 aB
3	1.50 ± 0.89 c	1.00 ± 0.23 cA	0.50 ± 0.11 bA
4	1.31 ± 0.86 c	0.86 ± 0.21 cA	0.45 ± 0.11 bA

Means within a column and row followed by different lowercase and uppercase letters, respectively, are significantly different (*P* £ 0.05; ANOVA and Tukey's HSD).

less, as the population density of *L. costirostris* increases, the time will come where the resources will be insufficient to maintain both species. The individuals that compete by fighting will eat less food, which in turn will reduce the growth rate and will inhibit reproduction (Smith & Smith 2007).

We registered an aggregated distribution pattern of *L. costirostris* on a celery crop. This distribution pattern is common in insects and mites (Badii 1994). Whereas *H. postica* has uniform distribution, this type of distribution usually results from the interaction effect between species, such as competing for food and space (Smith & Smith 2007). The lack of resources (food and space) due to the *L. costirostris* high population density forces *H. postica* adult females to scatter and search for new habitats, leading to uniform distribution.

In conclusion, the *L. costirostris* weevil infests celery plants more frequently. *Hypera postica* spatial distribution is possibly the result of competing for food and space with *L. costirostris*. Under this premise, it is necessary to conduct more research work on the ecology of *H. postica* and *L. costirostris* in other host plants of agricultural importance, as well as in other weed hosts, so as to learn more about the behavior and interaction between these Curculionidae.

Summary

Celery, *Apium graveolens* L. (Apiaceae), is an essential salad ingredient in different parts of the world, and production is principally destined for the fresh market. Celery hosts several insect species, including the weevil *Listroderes costirostris* Schoenher (Coleoptera: Curculionidae). *Listroderes costirostris* currently is present in the San Quintin Valle, Baja California, Mexico, on commercial celery crops. *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae) feeds on several plants of the Fabaceae family and is the principal pest affecting *Medicago sativa* L. (Fabaceae) alfalfa crops. The purpose of this work was to assess the degree of infestation, spatial distribution, and the association between *L. costirostris* and *H. postica* on *A. graveolens*, in Baja California, Mexico. We established 4 quadrants in 1 ha, and we sampled 100 plants per quadrant in each sample. We collected 22 samplings, counting the larvae and adults of both species. *Hypera postica* was reported herein for the first time feeding on *A. graveolens* plants. Between 9.57% and 28.68% of the celery plants served as hosts to both species. *Listroderes costirostris* had the highest percentage of infested plants. The competitive interaction of these 2 species affected *H. postica*, which showed lesser abundance. Both species were associated in all the sample quadrants. *Listroderes costirostris* registered an aggregated distribution pattern, whereas *H. postica* presented a uniform distribution. The spatial distribution of *H. postica* is the result of competing for food and space with *L. costirostris*.

Key Words: new record; host; interaction; spatial distribution; weevils

Table 2. Spatial distribution parameters of *Listroderes costirostris* and *Hypera posticaon* on *Apium graveolens*.

	$\bar{x}$	S^2	$S^2/\bar{x}$	ID	Z
Listroderes costirostris	2.2273	3.2581	1.46	127.27	2.80
Hypera postica	0.7160	0.2057	0.2874	25.00	−6.08

Sumario

El apio, *Apium graveolens* L. (Apiaceae), es un ingrediente esencial para ensaladas en diferentes partes del mundo, y la producción está principalmente destinada al mercado de productos frescos. El apio hospeda a varias especies de insectos, incluido el gorgojo *Listroderes costirostris* Schoenher (Coleoptera: Curculionidae). *Listroderes costirostris* actualmente está presente en el Valle de San Quintín, Baja California, México, en cultivos comerciales de apio. *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae) se alimenta de varias plantas de la familia Fabaceae y es la principal plaga que afecta al cultivo de alfalfa de *Medicago sativa* L. (Fabaceae). El propósito de este trabajo fue evaluar el grado de infestación, distribución espacial y la asociación entre *L. costirostris* y *H. postica* en *A. graveolens*, en Baja California, México. Establecimos 4 cuadrantes en 1 ha, y muestreamos 100 plantas por cuadrante en cada muestra. Recolectamos 22 muestras, contando las larvas y adultos de ambas especies. Se registra por primera vez a *Hypera postica* alimentarse de plantas de *A. graveolens*. Entre el 9.57% y 28.68% de las plantas de apio sirvieron como hospederos de ambas especies. *Listroderes costirostris* tuvo el mayor porcentaje de plantas infestadas. La interacción competitiva de estas 2 especies afectó a *H. postica*, cual mostró menor abundancia. Ambas especies se asociaron en todos los cuadrantes de la muestra. *Listroderes costirostris* registró un patrón de distribución agregada, mientras que *H. postica* presentó una distribución uniforme. La distribución espacial de *H. postica* es el resultado de competir por alimentos y espacio con *L. costirostris*.

Palabras Clave: nuevo registro; hospedero; interacción; distribución espacial; picudos

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