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Investigations

Estimate of Damage on Mesquite Pods and Seeds (*Prosopis laevigata* (Willd) M.C. Johnst) (Mimosoideae) Caused by Bruchids (COLEOPTERA) in the Municipality of Durango, Durango, Mexico

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Abstract: Damage caused by weevils or bruchids in mesquite plants (*Prosopis laevigata*), in the municipality of Durango was established by infestation index. Immature and mature pods were obtained from 22 bushes during the months of June to September 2013. The pods were placed in emergence chambers, maintained at a temperature of 35±2°C and 70±10% RH, until adults were obtained. In June, 1,761 immature pods were obtained of which 76% were damaged (perforations); in August 713 mature pods were obtained with 90% damage. Observed bruchids species feeding on the pods and seed of mesquite were *Algarobius prosopis* and *Mimosestes amicus* (Bruchinae) with relative abundance of 76 and 19% respectively and an average infestation index of 83,2% on pods. Natural enemies that were present were the parasitoids *Urosigalphus* sp. (Braconidae) and *Horismenus missouriensis* (Chalcidoidea: Eulophidae) with 2% relative abundance. From the total 105 pods damaged by insects, 1, 188 seeds had 69, 2% bruchid damage. Bruchids control is necessary in order to be able to obtain benefits from the mesquite pods and this can be done mainly through parasitoids that are associated with them. This electronic document is a "live" template. The various components of your paper [title, text, tables, figures and references] are already defined on the style sheet, as illustrated by the portions given in this document.

Keywords: Infestation Index, *Algarobius prosopis*, *Mimosestes amicus*, Parasitoids

Introduction

The *Prosopis* genus has approximately 45 species distributed in the arid and semi-arid areas of America, Africa and West Asia (Burkart, 1976; Palacios *et al*., 2000); of these, 43 species are found in America in two large regions: Mexico-Texas and Argentina-Paraguay-Chile (Carrillo, 2006; Loeza, 2007). In Mexico, 15 species have been reported distributed in 26 States (Arellano, 1996; Carrillo, 2006; Palacios, 2006; Ruiz, 2011; Garcia-Andrade *et al*., 2013) and of these, two species are located in Durango: *Prosopis glandulosa* Torr and *P. laevigata* (Willd) M.C. Johnst). This last one is found in 15 States of the Mexican Republic. In this country, mesquite and carob species are known for their ecological distribution, evolution, economic, social and ethnobotanical importance, amongst others (Meza and Osuna, 2003; Díaz *et al*., 2004; Carrillo, 2006; Alvarez and Villagra, 2009; Ruiz, 2011). Nevertheless, there have been losses of this resource and economic yield reduction due to over-harvesting, human impingement on the habitat, fires, climatic change and lack of a management plan, which in turn causes weakening of the mesquite making it vulnerable to pests and diseases (Flores-Flores *et al*., 2006; Rodriguez *et al*., 2014).

Worldwide, there have been some studies on parasites of foliage, blossoms, sheaths, pods and seeds, of which we can mention the studies by (Moran *et al*., 1993; Zachariades *et al*., 2011), carried out in South Africa, where damage to mesquite can be up to 90%. Yet, this is good for this country since the mesquite, for them, is an invasive plant and they free specimens of *A. prosopis* and *A. bottimeri* Kingsolver as biological controls. Diaz (1995) mentioned that the Peruvian boll weevil *Anthonomus vestitus* Bohm causes damage to blooms and shoots of the carob tree. Likewise, Amdor *et al*. (2006) found that *Algarobius bottimeri* Kingsolver and *Minosestes amicus* (Horn) bruchids on *Prosopis glandulosa* var. *glandulosa* Torr. with a density of 97 and 3% respectively in Texas where both oviposit in mature and immature pods, yet M. amicus prefers green pods.

In Mexico, Salas-Araiza *et al*. (2001), found 44% damage in seeds of *P. leavigata* caused by *Algarobius johnsoni* Kingsolver, in Guanajuato, in the area known as el Bajio. Flores-Flores *et al*. (2006) carried out a study in Coahuila, finding that the main pest of mesquite is the twig girdler *Oncideres cingulata* (Say) and the next pest in importance is *Dinoderus* sp. known as the borer of shoots and twigs.

There are relatively few studies carried out in the State of Durango, on this subject. We can mention the study by (Solorio *et al*., 2004), who assessed the damage produced by *Algarobius prosopis* LeConte, in two locations of Durango: Rancho Meraz, Tlahualilo and Ejido San Isidro, Mapimi, where damage was observed with an average of 41.2% in covered pods and 46.9% in naked pods. Meanwhile, in the Meraz ranch, the damage percentage was 36.5% in covered pods and 32.1% in the naked ones. Likewise, Ramirez (2011), in Bermejillo, Durango, observed *Heterospilus* sp. and *Urosigalphus* sp. as natural enemies of *Algarobius* sp. and *Acanthoselides* sp. found on mesquite. Reyes *et al*. (2012) reported the *Megacyllene antennata* (White) borer as a potential pest of recently cut round wood used as posts for fences, in the mesquite zones, of the State of Durango.

Of the insect species described for mesquite, the Bruchidae family is the one that is most harmful for the fruit. There are five genus that feed exclusively on the seeds of this shrub: *Algarobius* (from North America to Venezuela and Hawaii), *Neltumius* (Southwest of the United States and North of Mexico), *Pectinibruchus* (Argentina), Rhipibruchus (Argentina, Chile and Uruguay) and *Scutobruchus* (Argentina, Chile, Peru and Ecuador) (Johnson, 1983; Rodriguez *et al*., 2014).

In the State of Durango, there are 44,211 hectares of mesquite, distributed in 14 municipalities. In 1992, the municipality of Durango, had mesquite on 444 ha, which have gradually been reduced to 371 ha in 2002, mainly because it has been used as firewood to produce charcoal (Trucios-Caciano *et al*., 2012) and also due to changes in land use, agricultural activities, encroachment by human dwellings, induced grazing lands and portions without apparent vegetation (Vallejo *et al*., 2012). In this municipality, diverse types of damage have been observed affecting *P. laevigata* populations; stalks with black spots from which a reddish gum or resin drips and harm to the pods and seeds that show insect bites and malformations amongst others (*Personal Observations*). What insects are causing this damage to the pods and a seed is unknown and the objective of this study was to identify the bruchid species, as well as assess the damage done, by means of the Infestation Index of mesquite pods and seeds, in the Ejido Aquiles Serdan of the Durango Municipality.

Materials and Methods

Study area. The study was carried out in the Ejido Aquiles Serdan, of the Durango municipality, that is located at 23°55’32.54” latitude north and 104°34’10.55” longitude west, at elevation 1892 m, with an average annual rainfall of 518.88 mm. Temperatures, for the year 2013, were 9.5°C minimum and 25.6°C maximum with a mean annual temperature of 17.4°C (INIFAP, 2013). The sampling period occurred during the development of the immature pods, in the month of June and from the mature pods, in August of 2013.

A surface of 10 ha^{-1} was stratified for sampling on surfaces where the shrubs in the mesquite population were approximately four meters high. The surface was divided into 220 quadrants (strata), of 30 by 30 m. Ten percent of these were randomly selected as study sites. In each site, the number of shrubs was quantified and one was randomly selected reaching a total of 22 shrubs, which were marked and labeled in order to perform insect collection from pods of each one. Likewise, each site was georeferenced with GPS TeK (Global Positioning System) Garmin.

Pod collection. At the beginning of foliage development, two branches were chosen from each marked shrub, one for the collection of immature pods and another for the collection of mature ones and each were in turn marked and labeled. In June and August, the immature and mature pods were respectively cut and placed in glazed paper bags, then labelled with their respective field information. Samples were then taken to the laboratory for total quantification of pods, separating the ones harmed (with perforations by the emergence of adult bruchids) from the healthy ones.

Collection of bruchids from immature and mature pods. Mature and immature pods that showed harm were maintained, during approximately two months, in emergence chambers (plastic containers with lid and breathing hole) in order to allow the emergence of adults. Once or twice a week the adults were taken from the containers, in order to avoid oviposition by the females and overgrowth of the pest population. Afterwards, the taxonomic classification was performed and the amounts of individuals per species were counted. Coleoptera order was classified using the taxonomic keys described by (Moron and Terron, 1988; Johnson, 1983). Dr. J. Refugio Lomeli Flores identified the parasitoid *Horismenus missouriensis* and Dr. Gabriela

Castaño Meneses classified the formicidae species. Insects were deposited in the Entomological Collection of the Interdisciplinary Research Center for Regional Integral Development, Durango Unit, of the National Polytechnic Institute (CIIDIR-IPN, Durango Unit).

Assessment of damage percentage by means of the Infestation Index (I.I) in mature and immature pods. This index is a percentage and is an indicator of harm, estimated through the formula proposed by (Aguado and Suarez, 2006):

$$I.I = \left(\frac{\text{total harmed pods}}{\text{total pods}}\right) \times 100$$

Assessment of harmed seed percentage. Five damaged pods (perforated) were obtained from each tree from locations randomly selected. Seeds were extracted, carefully, by means of electrician´s pliers, trying not to harm them. The damaged seeds were separated from the healthy ones and counted, to establish the percentage of damaged seeds by the same formula proposed by Aguado and Suarez (2006), modified for seeds.

Statistical Analysis. Species absolute abundance (N) was detected for immature and mature pods, as well as relative abundance (%). Frequency of species occurrence, per type of pod, established the relative abundance.

Results

Total pods. In June, 1,761 immature pods were collected and in August, 713 mature pods (Fig. 1).

Bruchids from immature and mature pods. From the emergence chambers, two bruchids were obtained: *Algarobius prosopis* le Conte and *Mimosestes amicus* (Horn) (Bruchinae). Their natural enemies are the hymenopterans: *Urosigalphus* sp. (Braconidae) and *Horismenus missouriensis* Ashmead (Eulophidae). It must be mentioned that from the mature pods came also the *Crematogaster depilis* Wheeler and *Forelius pruinosus* (Roger) (Formicidae) ants and a Lepidoptera, of undetermined species, was obtained from both immature and mature pods. Table 1 shows the total amount of insects and the relative abundance of the species per collection period: June (immature pod) and August (mature pod) respectively, where the *A. prosopis* and *M. amicus* bruchids were the ones of greater relative abundance.

Infestation index of immature and mature pods. Table 2, presents the Infestation Index (I.I) of the immature and mature pods, caused by *A. prosopis* and *M. amicus* bruchids, with an average of 83.2% infested pods, where the month of August was the period with a higher infestation index.

Percentage of damaged seeds. From 105 mature pods, 1,188 seeds were obtained, of which 69.2% were damaged and 30.8% were healthy seeds.

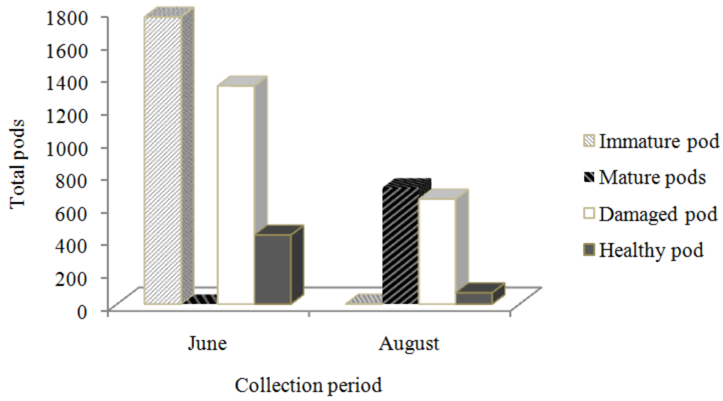

Fig. 1. Total in mature, mature, healthy and damaged pods found in the shrubs sampled during both recollection periods: June and August in the Ejido Aquiles Serdan, municipality of Durango

Table 1. Emergence (N) and relative insect abundance in mature and mature mesquite pods in the Ejido Aquiles Serdan, municipality of Durango

			Immature pod		Mature pod	
Order	Family	Genus and/or species	N	%	N	%
Coleoptera	Bruchidae	*Algarobiusprosopis*le Conte	183	73.2	1,656	77.00
		Mimosestes amicus (Horn)	21	8.4	427	19.8 0
Hymenoptera	Braconidae	*Urosigalphus* sp.	33	13.2	14	0.7 0
	Eulophidae	*Horismenusmissouriensis* Ashmead	6	2.4	41	1.9 0
	Formicidae	*Crematogasterdepilis* Wheeler	0	0.0	5	0.2 0
		Foreliuspruinosus Roger	0	0.0	1	0.05
Lepidoptera	Not specified	Not specified	7	2.8	8	0.40
Total			250	100.0	2,152	100.00

Table 2. Infestation of mesquite pods *P. laevigata*, by *A. prosopis* and *M. amicus* bruchids in the Ejido Aquiles Serdan, Municipality of Durango, Durango

Pod development	Pods (N)	Healthy pods	Damaged pods	I. I.* (%)
Immature	1,761	423	1,338	75.9
Mature	713	69	644	90.3
Total	2,472	492	1,982	83.2

* I..I. = Infestation Index

Discussion

Total amount of pods. The total amount of pods (2,472) was less than what was collected by Aguado and Suarez (2006). This difference exists because said authors collected in 14 sites and they collected pods from the trees and the ground. Likewise, Aubeterre *et al*. (2012) mentioned that they collected a total of 3,600 pods from nine places in the State of Lara-Venezuela and they quantified damages but they do not mention the total amount of these damages. They only indicated that damage by bruchids was detected. To know what pods come from the trees is indispensable in order to determine production by tree and hectare and thus be able to discard those that are damaged and use and store production better.

Bruchids from immature and mature pods. *A. prosopis* was the most abundant (Table 1) and perhaps that is due to the fact that the species limits it's feeding to *Prosopis* or as is mentioned by Kingsolver (2004), this species is the main bruchid that attacks mesquite pods. Likewise, it has been stated that the *A. prosopis* female deposits its eggs within clefts or openings of the pod and that the oviposition period begins in May, when the immature pods start to form. They continue to do so until the pod reaches its maturity and the larvae possibly feed from the sweet juice of the pods until the cotyledon is developed (Johnson and Siemens, 1997). Likewise, it has been mentioned that this bruchid introduces itself into the pods and into the first seed it may find, slithering through the pulp of the pod, until it finds a seed. (Johnson, 1983; Johnson and Siemens, 1997).

The second species in relative abundance was *M. amicus*, which oviposits only on green pods and their emergence perforations are used by other bruchid species to oviposit. Their reproduction is more probable in *Parkinsonia* and *Acacia* seeds, although it is also abundant in *Prosopis* seeds (Ramirez, 2013). Likewise the *M. amicus* female deposits eggs in June, only on immature pods, that have well developed cotyledons; it places the eggs randomly on the pod and occasionally, superposes eggs one on top of the other and the larvae penetrate the pod directly from the lower part of the egg (Johnson, 1983).

When comparing the insect abundance, with the results obtained by Aguado and Suarez (2006), in Santa Marta, Colombia, the difference that they obtained was a minimum of 65 individuals of *Algarobius riochama* Kingsolver and a maximum of 1,156 in 100 pods of *P. juliflora*; while in this study the total amount of bruchids was higher (Table 1). This is probably due to environmental conditions, different fruiting stages, total of collected pods and types of collection of both studies.

Infestation index. Results of this study differed with what other authors have found, such as Silva *et al*. (2000) who found damages in the Chaco region in Argentina on *Prosopis chilensis* (Molina) Stuntz carob trees, depending on the month of the year, with values of 1.78, 14, 58 and 85.6% for the months of February, March, April and May, respectively. Also, Solorio *et al*. (2004) assessed damages produced by *A. prosopis*, on mesquite pods, in two areas of the State of Durango, observing values of 48 and 32% damages, caused by only one species of bruchids. Furthermore, Aguado and Suarez (2006) assessed damages caused by *A. riochama* in *P. juliflora* pods in Colombia, in 14 different sites that ranged from 32.3 to 91.6%, with a 55.9% damages average.

Percentage of harmed seed. *A. prosopis* larvae, present on mature pods, may introduce themselves into the first seed they find and cause harm, attacking the plant from the moment the immature pods begin to develop and continue even after the pods have matured and shall continue to feed until most of the pod has been destroyed (Johnson, 1983; Trujillo, 1993; Rodriguez *et al*., 2014). In Patagonia, Argentina, Cariaga *et al*. (2005), reported that *Prosopis alpataco* Phil seeds were infested 87% and *P. denudans* Benth 25%, by the bruchid *Rhipibruchus prosopis* Kingsolver. Additionally, Palleres (2007), who assessed damage by insects on the seed of *Prosopis flexuosa* DC, found a total of 360 seeds of which 16% had lesions by *Apion* sp. and 4% was affected by *Scutobruchus vinalicola* Kingsolver and 80% had healthy seeds, with less damage. This situation could have been due to the amount of seeds and plant development as well as the environmental conditions of the zone, since said author carried out his research in Argentina. Likewise, Araiza *et al*. (2011) found that damages in *Algarobius johnsoni* Kingsolver seeds continue to increase until 44% is reached in the month of August.

Two parasitoid species were found: *Urosigalphus* sp. and *Horismenus missouriensis* of *A. prosopis* and *M. amicus* bruchids. The highest abundance for both species happened when the pods were immature (Table 2). Also, it is mentioned that *Urosigalphus* Ashmead is one of the most common genus of the Brachistini tribe (Braconidae: Helconinae) with approximately 100 species restricted to the western hemisphere. These are small endoparasitoid wasps, mainly of the Curculionid and Chrysomelidae (Bruchinae) (Arias-Penna, 2007), with a great variety of plant hosts (Aebi *et al*., 2008). There are references that some species of this genus prefer attacking bruchid eggs, on immature pods and during adult emergence, more than when the pod has matured; and therefore, they prosper when the bruchid females oviposit at the end of pod maturation (Traveset, 1991).

Horismenus sp. and *Urosigalphus* sp. species were also observed in mesquite weevils, in Bermejillo, Durango, where *Urosigalphus* sp. was more abundant (Ramirez, 2011). Likewise, *H. missouriensis* has been observed as a parasitoid of the Bruchidae family (Hansson *et al*., 2004) and of Lepidoptera (Bautista-Martinez *et al*., 1998) and it has been found as a parasite of different *Acanthoscelides* species, in beans, in Morelos and Michoacan (Bonet, 2008). Johnson (1983) mentions that *Urosigalphus bruchi* Crawford (Hymenoptera: Braconidae) destroys 4 to 7% of *Prosopis* spp. bruchid larvae and *Urosigalphus* sp. has been observed parasitizing nanche (*Malpighia mexicana*), in Oaxaca (Jarquin, 2007). *H. missouriensis*, has been found in *Ipomoea parasitica* (Kunth) G. Donn seeds as parasitoids of *Megacerus tricolor* (Suffrian) and *Megacerus callirhips* (Sharp) bruchids; the same parasitoid was found in seeds of *Acacia coulteri* A. Grey, on *Merobruchus santarosae* Kingsolver and *Stator limbatus* (Horn) and in seeds of *Lysiloma acapulcense* (Kunth) Benth as parasitoid of *Acanthoscelides mimosicola* Johnson and *Sennius morosus* (Sharp) (Romero, 2008).

It must be mentioned that 15 Lepidoptera larvae were collected from the pod, nevertheless, only one exemplar reached the adult stage and the species could not be determined, even though harm on various species of *Prosopis* by various species of Lepidoptera have been reported (Ward *et al*., 1977).

In relation with Formicidae that emerged from the pods, it could be said that these individuals entered through pod holes when the pods were immature and remained there feeding from the endocarp until the pod matured and then they emerged. *Crematogaster depilis* has been reported for *Prosopis* sp. *Acacia* sp., *Larrea* and *Ocotillo*; and three *Forelius* species for *P. glandulosa*, *P. laevigata* and *P. nigra* (Ward *et al*., 1977).

Conclusion

Bruchids cause important damage to *P. laevigata* causing losses of pods and seeds in different development stages (immature and mature pods). Furthermore, there is a reduction of fruit quality and therefore they are not ideal for animal consumption.

When *Algarobius prosopis*, *Mimosestes amicus* is present, feeding itself from the internal part of the mesquite pod and seeds, there is difficulty in the detection and assessment of harm, as well as in their control. Nevertheless, when parasitoids are present, it is recommended that biology and ecology studies be carried out, on these natural enemies, in order to establish an integral handling plan for these bruchids.

A good recommendation is the removal of pods that are on the floor and on trees, after the mesquites enter into their dormancy stage, in order to avoid oviposition by bruchids on those pods, establishing thus a reservoir of these insects, in the mesquite areas. The plants should be supervised annuals, in order to monitor bruchid presence and continue establishing its behavior and infestation proportion, in pods and seeds, contributing thus to the biological knowledge of bruchids, including their adaptability to the environmental conditions during each year and season, in the study area.

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Author's Contributions

The authors of this research paper participated directly in the planning, execution and preparation of the manuscript.

Ethics

This paper is original and contains unpublished material. Authors have read and approved the manuscript and there is no conflict of interest for any of them.

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