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ISSN 2146-0035-E-ISSN 2548-1002 ***Orijinal araştırma* (*Original article*)**

Seed-damaging insects on dwarf mesquite [*Prosopis farcta* (Banks & Sol.) Macbride][1]

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Çeti [*Prosopis farcta* (Banks & Sol.) Macbride]'nin tohumlarına zarar veren böcekler

Öz: Çeti **[***Prosopis farcta* (Banks & Sol.) Macbide], Fabaceae familyasına bağlı çok yıllık bir yabancı ot türüdür. Çalışma, Türkiye'nin Akdeniz bölgesinde yer alan ve tarım alanlarını kaplayarak problem oluşturduğu Adana ilinde yürütülmüştür. Çalışma, Çetinin biyolojik mücadelesine yönelik olarak, Çeti meyvesi üzerinde beslenen herbivor böcek türlerinin belirlenmesi ve bu türlerin meyve üzerine etkisinin ortaya konması amacıyla yapılmıştır. Adana'da üç farklı lokasyon seçilerek, tarla kenarlarından Çeti meyveleri toplanıp laboratuvara getirilmiş daha sonra, tohumlar üzerindeki böceklerin etkisi değerlendirilmiştir. Popülasyonlar arasında meyve başına ortalama tohum sayısında önemli farklar görülmüştür. Sonuç olarak, farklı böcek familyalarına bağlı, birçok böcek türü tespit edilmiştir. İncelenen meyvelerin %50'sinden fazlası böcekler tarafından zararlandırılmıştır. Bu böcekler arasında beş adet Bruchid türü tespit edilmiş, bunun Çeti için potansiyel yerli bir biyolojik mücadele etmeni olabileceği düşünülmektedir.

Anahtar kelimeler: Herbivor böcekler, Bruchidae, *Prosopis farcta,* Biyolojik mücadele

Abstract: Dwarf mesquite [*Prosopis farcta* (Banks & Sol.) Macbride] is a widespread perennial weed species in the bean (Fabaceae) family. This study was conducted in Adana Province in the Mediterranean region of Turkey where the plant covers a large area and constitutes a major constraint to crop production. The study aimed to identify the herbivorous insects feeding on dwarf mesquite and their seasonal impact on this weed as potential agents in its biological control. For that purpose, mature pods were collected from the field margins at three different sites and brought to the laboratory. Seed production and the damage caused by insects were assessed. There were significant differences in the mean number of seeds per pod between the three sites. Species representing different insect families were collected feeding inside the pods and seeds. Five bruchid species were identified and they are considered potential native biological control agents for dwarf mesquite.

Keywords: Herbivores, Bruchidae, *Prosopis farcta*, Biological control

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Introduction

Prosopis, a genus of flowering plants belonging to the family Fabaceae, contains 44 known species. They are most commonly found in the arid and semi-arid regions of Western Asia, Africa and America (Burkart, 1976). Dwarf mesquite [*Prosopis farcta* (Banks & Sol.) Mac.] is a species of *Prosopis* originally from Asia. The plant has spread from Iran and India to the Middle East, Cyprus, Turkey, The Ukraine and North Africa (Pasiecznik et al., 2004). Dwarf mesquite is one of the most challenging invasive species because of its tolerance to high temperatures, humidity and salinity (Pasiecznik, 2004; Qasem, 2007). In Turkey, the plant is widespread in the southern part of the country, including Adana, Mardin, Diyarbakır, Elazığ, Hatay, Mersin, Kahramanmaraş, Muş and Şanlıurfa Provinces, posing a serious threat to the productivity of agricultural and pasture lands (Yücel, 1994; Bükün et al, 1995). *Prosopis farcta* is a declared noxious weed in the United States and principal weed species in many parts of the world (Holm, 1991; USDA, 2016). This weeds mainly reproduces via seeds once annually and also produces root sprouts. Dwarf mesquite in grass pastures, non-crop areas and vegetable fields can be controlled to some degree with systemic herbicides, mostly 2,4-D and glyphosate formulations, which are often applied in combination with other chemically related active ingredients (Qasem, 2007). The biological and chemical control of this weed has been investigated by many researchers (Qasem, 2007; Khoramabadi et al., 2016). Glyphosate-based formulations have been the predominately applied herbicides in the majority of chemical control studies. Despite this research, control of this weed is still challenging to land managers and crop producers. For example, one of the most important practical challenges currently facing herbicide use as the dominant tool in dwarf mesquite control is that this weed has underground storage organs (rhizomes with buds), and while many herbicides will kill the plant parts above ground, the plant will rapidly develop a new shoot from the underground portion. In Turkey, although dwarf mesquite is increasing its range and posing a serious threat to agriculture, there have been relatively few studies on its biological and/or chemical control (Akkuzu 2012). However, there are some insects attacking the reproductive parts of this plant by penetrating the seed capsule and feeding on the endosperm as the main component of their diet (Sertkaya et al., 2005). As an initial step, the present study aimed to determine which herbivorous insect species damage dwarf mesquite seeds and how much damage they are causing, to assess their potential as biological control agents.

Material and methods

Study site

Adana Province is located in the central part of the Mediterranean Region of Turkey. The province has a Mediterranean climate, with warm, dry summers and cool, rainy winters. According to long-term meteorological data, the average annual precipitation in Adana is 654.4 mm (Anonymous 2017). The area was chosen because of its high levels of dwarf mesquite infestation, despite the use of herbicides and the activity of native insect herbivores. Three representative fields were selected to determine the impact of herbivorous insects on the seed pods of dwarf mesquite.

Mesquite pod collection

Sample collection was carried out in three different locations of a climatically similar area in Adana Province, namely, Çatalan, Karaomerli and Çiriş Gediği villages, with dwarf mesquite-infested fields. In April 2016, fully mature pods were picked by hand from *P. farcta* plants. Because of difficulties in separating irrigated fields from non-irrigated fields, the irrigation factor was not considered an independent variable. Sampling events were therefore conducted in both irrigated and non-irrigated fields. Collections were made from a field of about 0.4-0.5 ha at each of the three sites. Since the plant was more abundant in the field margins than in the field centers, samples were mostly collected from the field margins throughout the sampling period. Ten to twenty plants were sampled in each field and a total of 501 pods were collected randomly from the three sites. Samples were placed in paper bags, brought to the laboratory and carefully enveloped with plastic material to prevent the insects from escaping until dissection. Throughout this report, the collection sites at Çatalan, Karaomerli and Çiriş Gediği are referred to as sites A, B and C, respectively

Mesquite pod dissection

The pods from each location were categorized into two batches: (1) pods showing insect entrance/exit holes - ‘Infested pods’, and (2), pods without any visible holes - ‘Healthy pods’. The number of holes per pod was then recorded. Pod diameters were measured with calipers and the following characters were recorded: pod length (cm) and pod width (cm). Secateurs were used to carefully dissect the pods by removing the capsule without crushing the seeds, to be able to identify what the insects inside. Finally, the internal sections of pods were visually examined for evidence of insect feeding with the aid of a hand lens. After a thorough examination, seeds without insect exit holes were classified as healthy, seeds with insect exit holes were classified as damaged, and those completely empty or shrunken and/or wrinkled were classified as undeveloped. Therefore, the seeds in this study were classified into three categories: healthy, damaged and undeveloped. Later, the number of pods and seeds in each category were recorded (Uygur et al., 2012). In addition, microphotographs of all specimens were taken from different angles with a microscope and digital camera. The specimens were then preserved in plastic jars containing 70 % isopropyl alcohol. All specimens were identified to species level by Abüzer Yucel, a taxonomist at Harran University, Şanlıurfa, Turkey.

Data analysis

Data for infested and healthy pods and the total number of seeds per infested and healthy pod were analyzed with the SAS statistical software version 9.1.3 (SAS, 2004). To compare the differences in infestation rates among the three sites, the mean numbers of infested pods and the mean numbers of healthy pods were analyzed separately with Fisher's least significant difference test (LSD) with the level of significance set at $p = 0.05$.

Results and discussion

Approximately 51% of the mesquite pods across the three sites was infested by insect herbivores (Table 1), with a mean infestation rate of three exit holes per pod.

Table 1. Infestation of dwarf mesquite pods by insect herbivores in Adana Province, Turkey

	Site A	Site B	Site C
Damaged pods (%)	49.10a	52.70a	50.90a
Healthy pods (%)	50.90a	47.30a	49.10a

Means in the same column or row with the same letter are not significantly different at $p<0.05$.

At sites A, B and C, a total of 6.6, 7.4 and 9.9 seeds per pod and 6.7, 6.5 and 8.7 seeds per pod were produced by infested and healthy pods, respectively, with seed production significantly higher at site C ($p < 0.05$) (Fig. 1).

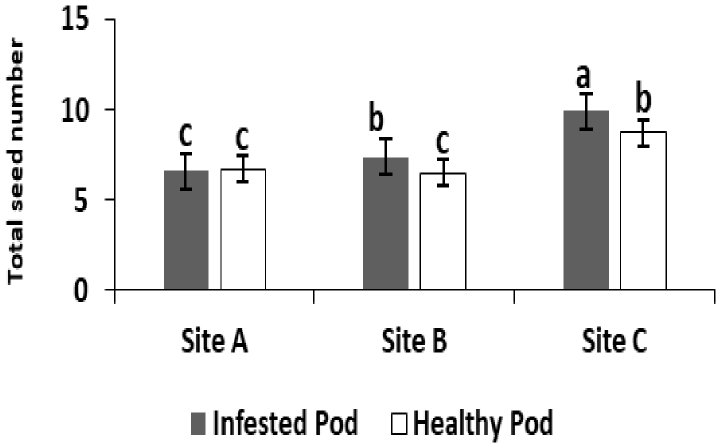

Figure 1. The total number of seeds (healthy, damaged and undeveloped) per damaged and healthy dwarf mesquite seed pod. Means labeled with the same letter are not significantly different (p = 0.05, LSD).

Significant differences in the mean number of healthy and damaged seeds per infested pod were observed among sites (F = 15.35, $p < 0.05$) (Fig. 2).

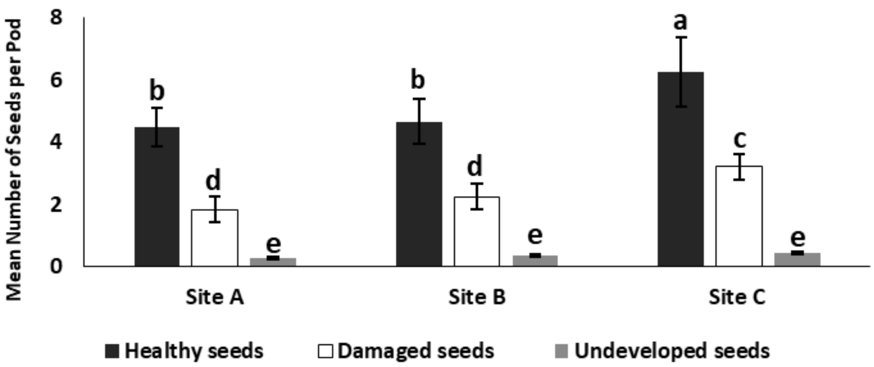

Figure 2. The mean number of healthy, damaged and undeveloped seeds per infested dwarf mesquite seed pod. Means labeled with the same letter are not significantly different at p = 0.05.

Among the three sites, the mean numbers of healthy and damaged seeds produced by the non-infested pods from site C were significantly higher than for those at sites A and B ($p<0.05$), whereas the mean number of healthy and damaged seeds/pod at sites A and B were not significantly different ($p>0.05$) (Fig. 3).

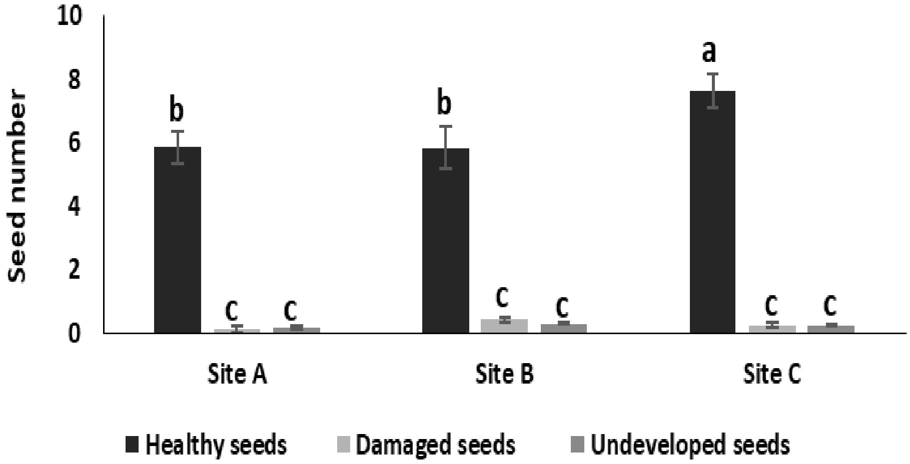

Figure 3. The mean number of healthy, damaged and undeveloped seeds per non-infested dwarf mesquite seed pod. Means labeled with the same letter are not significantly different at p = 0.05.

Significant differences were found among sites A, B and C in terms of both pod length and width ($p<0.05$). However, the herbivorous insects didn't affect the length or width of the mesquite pods (Fig. 4).

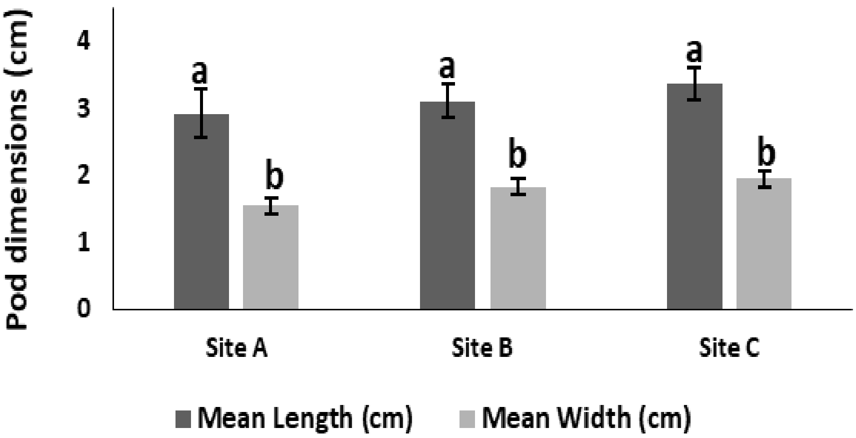

Figure 4. Mean length (cm) and width (cm) of infested dwarf mesquite seed pods. Means labeled with the same letter are not significantly different at p = 0.05.

Statistically significant ($F = 7.76$, $P < 0.05$) differences were also found among the study sites in terms of healthy pod size (length and width). The pods collected from 3rd site were larger than those pods collected from the other locations (Figure 5).

Significant differences were also found among the study sites in terms of the length and width of healthy pods (F = 7.76, P <0.05). There were no significant differences among the study sites in terms of the length and width of healthy pods (F = 7.76, P > 0.05). However, the pods collected from site C were wider than the pods collected from the other locations (Fig. 5).

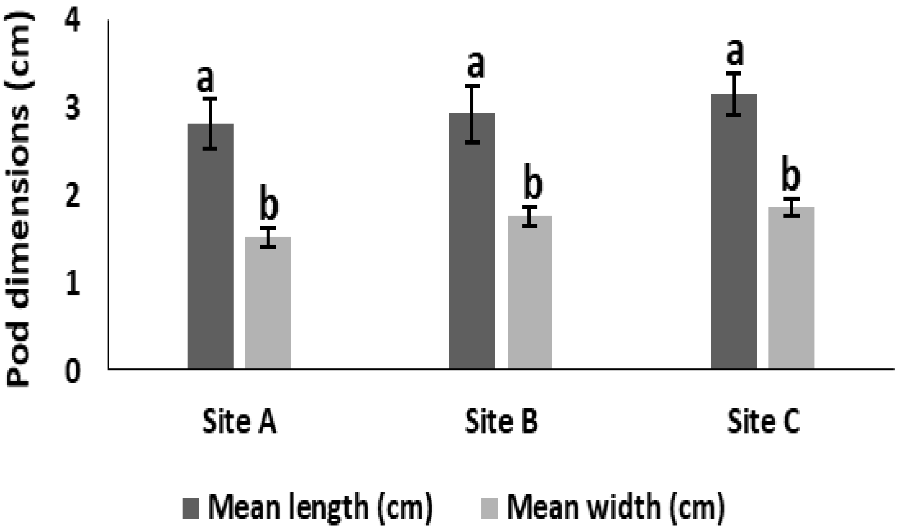

Figure 5. The mean length and width (cm) of healthy pods. Bars with the same letter indicate no significant difference at (P < 0.05).

Identification of herbivorous insects

In this study, the egg, larval and adult stages of four different insect families representing two different insect orders (Coleoptera and Hymenoptera) and mites (Acari) were collected inside the pods and seeds of the pest plant, dwarf mesquite. Members of the Family Bruchidae tended to feed principally inside the seeds. They therefore had a greater destructive impact on the potential for reproduction of dwarf mesquite which is why their identification was a priority. Five Bruchidae species, *Caryedon palestinicus* Southgate (Pachymerinae), *Pachymerus lallemanti* Marseul (Pachymerinae), *Pseudopachymerus* sp. (Pachymerinae), *Spermophagus kuesteri* Schilsky (Pachymerinae) and Bruchus atomarius L. (Bruchinae) were identified. In addition, *Latheticus oryza* Waterhouse (Coleoptera: Tenebrionidae) was also among the identified species. Only four Bruchidae species and *Latheticus oryza* Waterhouse shown in Fig. 6. with insect-damaged seeds.

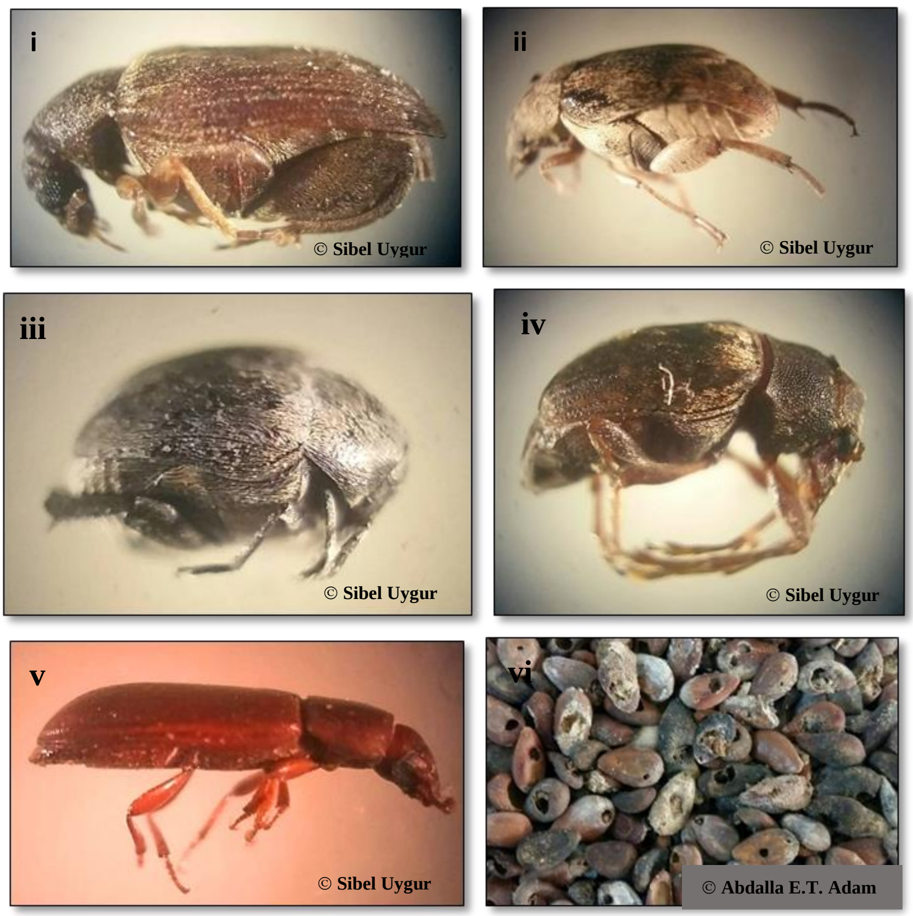

Figure 6. Micrographs of (i) *Caryedon palestinicus* Southgate (ii) *Pachymerus lallemanti* Marseul (iii) *Spermophagus Kuesteri* Schilsky (iv) *Bruchus atomarius* L. (v) *Latheticus oryza* Waterhouse (vi) Damaged seeds.

Conclusion

In this study, insect species belonging to different families and orders were collected inside both the pods and seeds of *Prosopis farcta* (dwarf mesquite) in Adana Province, Turkey. A wide range of natural enemies caused a considerable reduction in the production of viable seed, with approximately 51% of the dwarf mesquite pods infested. Bruchid species were the most effective natural enemies because they feed directly on the seeds of *P. farcta*, in many cases leaving the seeds badly damaged or at least, not viable.Since the plants at site C generally set more seeds per pod, the seed quantity might be expected to lead to insect preference for larger fruits. Another reason is that the behavior of bruchid females may be driven by the need for sufficient food resources to ensure proper growth and development of their larvae. Therefore, high infestation rates resulting in more viable seed losses could be expected in this area. Sertkaya et al. (2005) reported that *Caryedon palestinicus* is not a promising biological agent against dwarf mesquite. However, our results suggest that native species, including *C. palestinicus*, appear to be potential biological control agents. A mass rearing and augmentative release program would probably greatly improve the management of this plant. Our investigations also showed that major damage to the seeds was done in the pods containing more than three larvae, indicating that the biological efficacy of these insects needs to be enhanced by improving their environmental tolerance, reproductive capacity and host-finding ability. Klinken and White (2014) reported that pre-dispersal predation is greater on seeds inside capsules after they fall to the ground. Therefore, all seed stages on the plant and also seeds in the soil seed bank need to be investigated to estimate total seed predation in dwarf mesquite. Further research is also needed to determine if, and how, Bruchidae species affect the viability of dwarf mesquite seeds. This study reinforces the need for weed scientists and entomologists to cooperate for the improvement our understanding of functional interactions between weeds and arthropods in agroecosystems and hence provide a scientific basis for sustainable pest management strategies. Furthermore, more emphasis should be placed on the challenges and opportunities of also using organisms other than bruchids as biological control agents of dwarf mesquite.

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