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Evaluation of three repellents for the prevention of damage to olive seedlings by deer

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Abstract The method used most extensively in Europe to prevent damage due to browsing of woody plants consists of shelter pipes made of plastic material or net. This system, however, is not practical for plants such as olive trees where it is desirable for the branches to develop more than the trunk. For this reason, in an area with a high deer (*Dama dama*) population, three liquid repellents were tested for their ability to prevent damage by cervids to olive seedlings (*Olea europaea*). Tree Guard and Eutrofit reduced the percentage of plants browsed with respect to the control by a statistically significant extent through the third week (54.5 and 40.9% reduction, respectively), while for Hot Sauce, the differences did not reach significance after the first week. Tree Guard and Eutrofit were also able to reduce the level of damage for the entire eight week period of the test, while Hot Sauce did not differ from the control in a statistically significant manner. The use of repellent substances such as Tree Guard and Eutrofit to reduce the damage caused by cervids to olive groves therefore seems a possible strategy under conditions of medium and low density of animals. Eutrofit was the most economical product from the point of view of cost effectiveness.

Keywords *Dama dama* · Repellent · Damage · Olive seedling · *Olea europaea*

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Introduction

In recent years, damage caused by ruminant ungulates and particularly by cervids has increased considerably. This family in particular, due to reduced anthropic pressure, has reappeared in many areas from which it has been absent for years.

The animals cause frequent, severe damage to woody seedlings by stripping the bark or browsing on the young plants. In the latter case, they damage vegetative sprouts (buds and leaves), which, when not serious, can cause a delay in growth, while in the more serious cases, can cause the plant's death. In Tuscany, money refunded to farmers for cervid damage to agricultural crops increased from about €155,000 in 1996 to €370,000 in 2000 (from 7 to 14% of total game species damages).

In Europe, prevention of this type of damage in forestry is carried out through the adoption of shelter pipes made of plastic material or net. This technique is not suitable for seedlings of fruit-bearing plants, which need to develop the branches more than the trunk. For this reason, we have decided to test the effectiveness of three different repellents on olive seedlings. This crop is the plant most intensively damaged by deer browsing, in particular, roe deer (*Capreolus capreolus*) and fallow deer (*Dama dama*).

The repellents utilized were Hot Sauce Animal Repellent, Tree Guard, and Eutrofit (Table 1) . The first repellent has capsaicin as its active principle, an irritant of the trigeminus extracted from red pepper. The second repellent contains Bitrex or denatonium benzoate, a chemical compound considered the bitterest tasting substance known. The third product is not a proper repellent, but rather a leaf fertilizer made from animal blood.

Products containing capsaicin have been tested extensively but with rather uneven results. In a test conducted to evaluate two types of repellent for protecting poplar woods and plantations from deer browsing (*Cervus elaphus*), Baker et al. (1999) found Hot

Table 1 Products used

Trade name	Producer	Active principle	Type of action
Tree Guard	Becker Underwood, Ames, IA, USA	Bitrex (denatonium benzoate)	Taste
Hot Sauce	Miller Chemical, Hanover, PA, USA	Capsaicin	Taste
Eutrofit	Stradi Renzo, Castelnuovo di Sotto, Italy	Animal blood	Odor

Sauce effective at a concentration as high as 6.2% for a period of 5 weeks. Andelt et al. (1994) observed that mule deer (*Odocoileus hemionus*) consumed less than 50% of apple twigs treated with Hot Sauce at 6.2% concentration with respect to the control, but failed at the 0.062% labeled rate.

More recently, Douglas-fir plantations (*Pseudotsuga menziesii*) and red alder (*Alnus rubra*) treated with Hot Sauce® at a 6.2% concentration have resisted attack by black-tailed deer (*Odocoileus hemionus columbianus*) for 2 weeks (Wagner and Nolte 2000).

The products made from denatonium benzoate have not been tested as extensively owing to their recent formulation. This compound has been found to effectively reduce cable damage caused by gnawing of rats and gophers (Shumake et al. 1999, 2000). In contrast, there was no reduction of damage caused by northern pocket gophers (*Thomoides talpoides*) to coniferous nurseries (Witmer et al. 1998). Nolte (1998) reported reduced effectiveness of a repellent based on denatonium benzoate in protecting conifer seedlings from mule deer (*Odocoileus hemionus*) compared with other preparations. Wagner and Nolte (2001) reported a reduction of damage to cedar seedlings by black-tailed deer (*Odocoileus hemionus columbianus*) compared to untreated plants, but products based on organic matter were more effective. Roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) fed with fodder treated with denatonium benzoate reduced feed intake when other fodders were available. When no fodder was available but the treated type, no variation in the quantity of fodder eaten was recorded. Therefore, it seems that cervids are able to detect the bitter taste and to guide their food choices accordingly (Wright and Milne 1996).

It seems that the effect of the products based on animal blood depends on the fact that they exude a sulfurous odor, which is associated with the presence of predators (Nolte 1998) or with toxic substances present in plants (Mason 1997), but we cannot exclude a simple taste alteration. In a study conducted on Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) seedlings, the plants treated with a blood meal product (Gyllebo) showed a significant reduction of browsing by roe deer (*Capreolus capreolus*). This product also caused a significant phytotoxic effect. (Berquist and Orlander 1996). Plantskidd, a blood meal product, has reduced damage by deer in two other studies (Nolte 1998;Wagner and Nolte 2001).

Materials and methods

Area description

The test was carried out in March 2001at San Rossore, the Estate Park of the President of the Italian Republic; it covers an area of 4,800 ha and is part of the Natural Park of San Rossore, Migliarino, and Massaciuccoli, which covers a total area of 24,000 ha. Of the 4,800 ha of the estate, about 1,800 are fenced and therefore cannot be entered by large mammals.

The ungulates present on the estate are fallow deer (*Dama dama*) and wild boar (*Sus scrofa*). In the year 2000, the park wardens counted 799 fallow deer of an estimated total of about 1,000–1,100 animals. The density is therefore approximately 33–36 deer km^{-2}. The area was also surveyed at night, with a 100-W halogen spotlight, to observe the presence of deer in the zone of the experiment at the beginning and end of the test. An average of 45 deer were counted on an area of about 10 ha. Among the mammals, the wild rabbit (*Oryctolagus cuniculus*) was also observed.

The test was carried out in February and March 2001. During this period, there was a total rainfall of 175 mm for a daily average of 3.02 mm.

Repellents

Tree Guard was used without any dilution (as specified by the manufacturer). Hot Sauce was diluted in water to a concentration of 6.2%. Eutrofit was diluted in water to a concentration of 3.5%. The products were applied to the plants immediately after transplanting, using a manual knapsack-type sprayer. The cost per plant and

Table 2 Cost of repellents (not including application)

Product	Cost of package (€)	Size of package in liters	Cost per liter (€)	Dilution (%)	No. of seedlings treatable per liter	Cost per ha (€)	Cost per seedling (€)
Tree Guard	72.47	9.5	9.15	0	50	45.67	0.16
Hot Sauce	206.58	3.78	54.65	6.20	806	18.98	0.07
Eutrofit	129.11	25	5.16	3.50	1429	1.01	0.004

per hectare of each product was calculated without considering the cost of application (Table 2).

Procedure

The plants used for the test were olive cuttings of the *frantoio* variety, 1 year old, about 20 cm in height. The trees were planted in a field in the Cascina Vecchia area of the estate. Three repellents and an untreated control were tested according to a random block experimental design; 25 plants were used for each treatment, i.e., 5 plants for each treatment replicated in 5 blocks. The blocks were spaced 6 m from each other and plants were placed about 2 m apart. The plants were all marked with tags indicating the type of repellent used and an identification number. The height of the plants was measured at the beginning and end of the test period. Damage was checked once a week. Four classes of damage were measured:

Class 0: no browsing
Class 1: browsing up to 30% of the foliage
Class 2: browsing between 30 and 60%
Class 3: browsing over 60%.

All damages were attributed to deer because rabbits were not observed in the experimental field.

Statistical analysis

To analyze the differences among the percentages of plants browsed, the χ^2 test was used. For differences in the browsing score, a non-parametric test was used (Kruskal-Wallis test). The final height of the plants was analyzed by ANCOVA (final height covariated by the initial height).

Results and Discussion

A week after the beginning of the treatment, Eutrofit had reduced the percentage of plants browsed by 100% ($P = 0.0006$), Tree Guard by 81.8% ($P = 0.0099$) and Hot Sauce by 63.6% ($P = 0.0641$). After the second week the reduction was 82.4% for Tree Guard ($P = 0.0002$), 70.6% for Eutrofit ($P = 0.0017$), and 11.8% for Hot Sauce ($P = 0.7683$), while after 3 weeks the percentage of reduction was 54.5% for Tree Guard ($P = 0.0012$), 40.9% for Eutrofit ($P = 0.0136$), and 9.1% for Hot Sauce ($P = 0.6997$). From the fourth week on, the differences compared to the control were no longer significant for any of the three products used. It appears, therefore, that only Tree Guard and Eutrofit can significantly reduce the percentage of plants browsed for 3 weeks (Table 3).

If the level of damage to the plants is considered, however, those treated with Tree Guard and Eutrofit exhibited a significantly lower score than those treated with Hot Sauce and those not treated at all, for the entire 8 weeks of the test (Table 4, Fig. 1).

There was no difference between the height at the beginning and end of the test of the plants treated with Eutrofit. All the other plants had lost some height (Table 5). This was probably due to the fertilizing action of this product, which enabled the less damaged plants to grow more.

The differences in the effectiveness of the three products tested are not easy to interpret. It is possible, however, that the poor results obtained with Hot Sauce

Table 3 Reduction of number of plants damaged during test[a]

Product	1st Week		2nd Week		3rd Week		4th Week	
	No. of plants browsed	Reduction with respect to control (%)	No. of plants browsed	Reduction with respect to control (%)	No. of plants browsed	Reduction with respect to control (%)	No. of plants browsed	Reduction with respect to control (%)
Eutrofit	0	100.0***	5	70.6**	13	40.9*	20	16.7
Hot Sauce	4	63.6	15	11.8	20	9.1	24	0.0
Tree Guard	2	81.8**	3	82.4***	10	54.5**	20	16.7

[a]Significance with respect to control: * $P < 0.05$, ** $P < 0.001$, *** $P < 0.0001$; unmarked are not significant

Table 4 Average level of damage to seedlings during test[a]

Product	Control	Eutrofit	Hot Sauce	Tree Guard
1st Week	0.56 ± 0.77 A	0.00 ± 0.00 B	0.16 ± 0.37 B	0.37 ± 0.44 B
2nd Week	1.04 ± 0.93 A	0.24 ± 0.52 B	0.76 ± 0.78 A	0.28 ± 0.74 B
3rd Week	2.16 ± 0.99 A	0.72 ± 0.79 B	1.52 ± 1.01 A	0.56 ± 0.82 B
4th Week	2.76 ± 0.72 A	1.56 ± 0.96 B	2.68 ± 0.48 A	1.64 ± 1.04 B
5th Week	2.84 ± 0.47 A	1.92 ± 0.70 B	2.68 ± 0.48 A	2.12 ± 0.78 B
6th Week	2.88 ± 0.48 A	2.08 ± 0.76 B	2.72 ± 0.46 A	2.20 ± 0.76 B
7th Week	2.92 ± 0.40 A	2.12 ± 0.78 B	2.72 ± 0.46 A	2.20 ± 0.76 B
8th Week	2.96 ± 0.20 A	2.12 ± 0.78 B	2.72 ± 0.46 A	2.28 ± 0.79 B

[a]Different letters indicate highly statistically significant differences ($P < 0.001$)

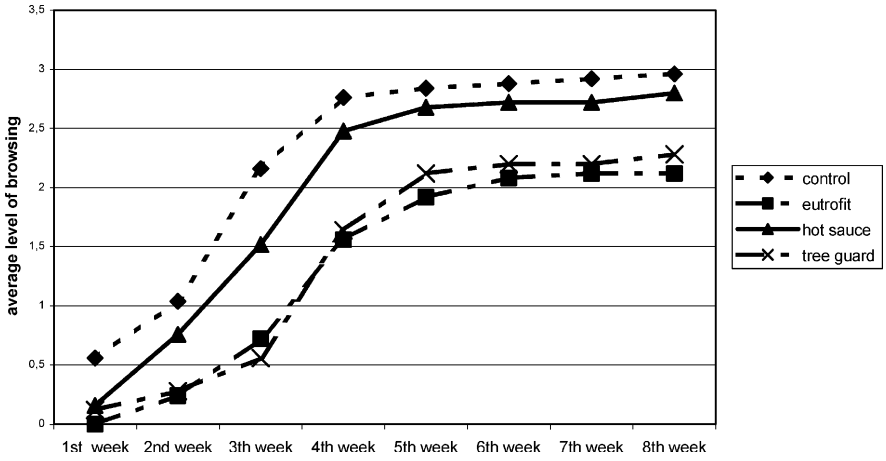

Fig. 1 Progress of average level of browsing

Table 5 Height of plants at end of test

Product	Average final height	Std Error	Increase[a]
Control	16.883	0.501	−2.60 A
Eutrofit	18.568	0.531	0.00 B
Hot Sauce	17.371	0.531	−2.38 AB
Tree Guard	16.656	0.500	−2.62 A

[a]Different letters indicate highly statistically significant differences ($P < 0.001$)

were at least partly due to the ease with which this product is eliminated by rain. Indeed, after the second week, through an empirical test of ''tasting'' the leaves, no trace of the compound was found. The manufacturer, however, has recently developed an additive designed to prevent the repellent from being washed away.

On the other hand, the whitish tint of Tree Guard made it possible to ascertain that this product remained on the plants for the entire duration of the test. The bitter taste, checked with the empirical method mentioned above, also remained until the end of the test. It seems, therefore, that the repellent action due to the bitter taste is effective as long as there are readily available alternative food sources. At the point when most of the other plants used in the experiment had already been intensely browsed, those treated with Tree Guard started to be heavily damaged.

As regards Eutrofit, it is difficult to determine whether the reduction of effectiveness over time is due more to the product being washed away or to the animals' acclimation.

Conclusions

Tree Guard and Eutrofit showed, under the experimental conditions of the test, that they could significantly reduce the damage by browsing on olive seedlings by deer. Eutrofit has a much lower cost than the other products (Table 2), and considering that it is also has a fertilizing action, it is particularly economical. Hot Sauce, to perform its action, probably needs to be combined with additives that prevent it from washing away. In short, it is possible to state that the use of repellents such as Tree Guard and Eutrofit, under conditions of medium and low animal density, can be an effective strategy to reduce the damage by cervids to olive seedlings.

It is probably advisable to make several applications frequently over a period of time in order to reinforce the conditioned aversion towards the treated plants. It is important, in any case, that the management of damage by wild animals to agricultural crops is handled in an integrated manner, including, where necessary, actions of direct control (capture or shooting) to maintain a sustainable density. It should also be borne in mind that the use of repellents on plants already bearing fruit should be carefully studied as some substances may convey an undesirable flavor to the products (Howery et al. 1999).

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