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Efficacy of the repellent RO-PEL® in reducing damage by the rock hyrax (*Procavia capensis*) to fruit trees

(*Keywords:* herbivore repellents, wildlife damage, rock hyrax, *Procavia capensis*, RO-PEL®, denatonium benzoate)

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Abstract. The rock hyrax (*Procavia capensis*) lives in Israel in natural crevices of rocky terrain and in long heaps or terraces of rocks that were uprooted in the process of rocky ground reclamation and dumped around newly-planted fruit orchards. The hyraxes browse on rows of deciduous and subtropical fruit trees adjacent to the animals' rocky shelter. Fruit trees thereby lose most of their leaves, and branches or stems of seedlings are bent and broken under the weight of the animals. The commercial repellent, RO-PEL®, was tested in probe and field trials. RO-PEL®-sprayed and unsprayed avocado and mango seedlings were placed in a pen into which three hyraxes were introduced. Most of the leaves of both sprayed and unsprayed seedlings were consumed in 4 and 11 days (avocado and mango seedlings respectively). However, a field trial was conducted in a citrus orchard, in which the rows of seedlings adjacent to rock terraces had been damaged by the hyraxes. On the sprayed and the unsprayed seedlings the leaves were counted during the experiments; there was a significant difference in the numbers of sprayed and unsprayed leaves consumed ($P = 0{\cdot}01$), with reduction of the damage on the sprayed trees being 42·6%. Later, when new leaves had sprouted, the hyraxes consumed the leaves irrespective of whether they had or had not been sprayed. Consequently the feasibility of using RO-PEL® to repel the rock hyrax remains problematic.

1. Introduction

The rock hyrax, *Procavia capensis* (Hyracoidea: Procaviidae), is distributed in Israel in the Negev, Dead Sea Valley, Mount Gilboa, mountains of Galilee and Mount Carmel (Maeltzer, 1973). Rock hyraxes live in families in rocky terrain which is rich in natural crevices, where they can roam and find shelter from predators and adverse weather conditions. They climb trees easily (Maeltzer, 1973; Maeltzer and Livneh, 1982).

In the mountains of Galilee and Gilboa, agricultural plots have been reclaimed from rocky ground by uprooting rocks, which are subsequently pushed into long heaps or terraces bordering the plots, thus creating suitable refuges for the rock hyraxes. These reclaimed plots have been planted with fruit orchards, some of them deciduous fruit, mainly *Pyrus* spp., others subtropical, such as avocado (*Persea americana*), persimmon (*Diospyros kaki*), and mango (*Mangifera indica*), and some—*Citrus* spp. Hyraxes living in the terraces, or in nearby natural rock crevices, enter the plots and browse on the rows of trees adjacent to their rocky shelter, inflicting serious damage. Adult trees which have been defoliated yield almost no crop and degenerate. Seedlings of subtropical fruit or grapefruit trees up to 2 years old lose most of their leaves, their development is seriously impeded, and many die. The weight of the hyraxes feeding on deciduous seedlings breaks the branches or the stem (Moran *et al.*, 1987).

RO-PEL® [1985 EPA registered label] tastes very bitter to humans. Its active ingredients are denatonium saccharide (0·065%) and thymol (0·035%). It is claimed by the manufacturers to be efficient as a repellent to herbivores. Therefore, it was evaluated as a potential repellent for the rock hyrax.

2. Methods and materials

2.1. Probe pen trial

Three adult rock hyraxes were housed in a wooden cabinet in the centre of a 200 m^2 outdoor pen, with a 3·0 m high wire net ceiling. The trial was performed in August 1990, when the pen ground was barren and dry. Rabbit pellets and water were provided *ad libitum*. Six containers, three with avocado seedlings, and three with mango seedlings, were placed at random in half a circle around the wooden cabinet, 1·5–2·0 m apart. Two mango and two avocado seedlings, selected at random, were sprayed with RO-PEL® (Burlington Bio-Medical & Scientific Corp., Farmindale, NY) at the recommended rate: all surfaces of the leaves were sprayed until runoff. The trees were monitored daily, and the percentage of foliage consumed was estimated by visual observation.

2.2. Field trial

A recently planted Star-Rubi variety (*Citrus grandis*) orchard, at kibbutz En Harod Me'uhad, located at the foothills of Mount Gilboa, had been damaged by rock hyraxes. The trial was established in August 1990, in the middle of the dry season, when the only green food available, apart from citrus seedlings inside the test plot, was perennial bushes and trees a few metres uphill. The trial was conducted on seedlings, 7 days after planting. The intervals between the seedlings were 3·0 m, and the between-row spacing was 5·5 m. Only the marginal three rows, adjacent to the hyrax refuge uphill, were attacked; therefore, only these rows were monitored and treated. One hundred seedlings were monitored. The damage was assessed in two ways. For the first 9 days, the leaves of the seedlings (mostly 5–15 leaves) were counted. After a further 7 days new limbs and leaves sprouted in large numbers, and from days 15 to 24 the percentage of new growth devoured was estimated by visual observation.

In order to amplify the effect or RO-PEL®, the seedlings were sprayed twice; each treatment was done in two

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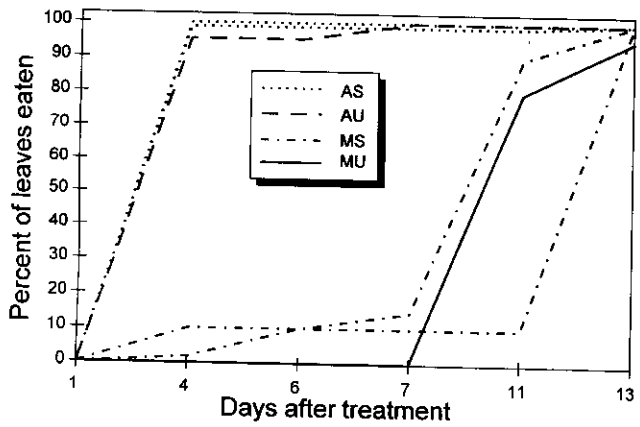

Figure 1. Cumulative consumption of leaves of seedlings, sprayed and unsprayed with RO-PEL®, by Procavia capensis *in a pen trial. Avocado seedlings: AS—sprayed; AU—unsprayed. Mango seedlings: MS—sprayed; MU—unsprayed.*

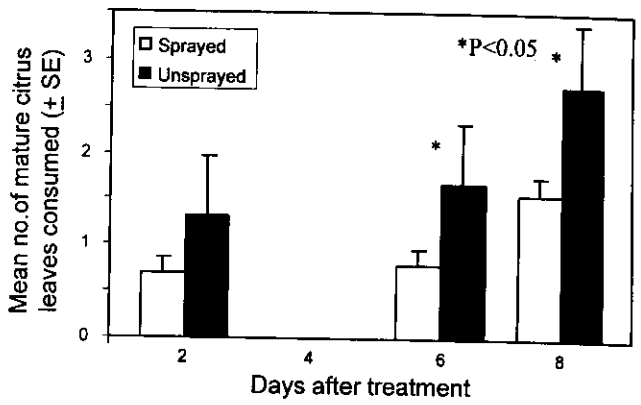

Figure 2. Repellency of RO-PEL® against Procavia capensis, *browsing on Star Rubi (*Citrus grandis *var.) seedlings in a field trial.*

successive applications, each until runoff, one hour apart. The first treatment was on 6 August, and the second—on the newly sprouted leaves—was on 23 August. Six control (unsprayed) groups of three or four trees were selected at random. The total number of sprayed seedlings was 78, and of unsprayed was 22. The differences in the numbers of the leaves between days 1 and 9 were analysed in two-way ANOVA between treatments (sprayed vs unsprayed) and between rows of seedlings.

3. Results

3.1. *Probe pen trial*

In the first 24 h the seedlings sprayed and unsprayed, remained undamaged by the hyraxes, except for one to three leaves consumed in three trees. Later, on the fourth day after treatment, heavy damage appeared in the avocado seedlings (Figure 1). The cumulative damage in the mango seedlings was at first quite small, 0–15%, but only 11–13 days after the trial started these trees were heavily damaged. Whole leaves were found on the ground under both treated and untreated mango seedlings.

3.2. *Field trial*

The differences between the sprayed and the unsprayed leaves were not significant until the sixth day after treatment (d.a.t.) ($F_{1,96} = 4{\cdot}85$; $P = 0{\cdot}030$) and the eighth d.a.t. ($F_{1,96} = 6{\cdot}88$; $P = 0{\cdot}010$) (Figure 2). No significant differences were found between the three rows of the seedlings in the second, sixth and eighth d.a.t. The ratio between the total number of leaves consumed in the treated trees and the number consumed in the untreated ones, on the eighth d.a.t., was 42·6%.

Later, when the new leaves sprouted, most of the damaged trees were concentrated near the edge of the plot (tree nos 1–9) (Figure 3), in contrast to the scattered distribution at the beginning of the trial. The percentage of sprayed seedlings damaged was 23·1% (18 seedlings), and the percentage of unsprayed ones damaged was 27·3% (six seedlings).

4. Discussion

The preliminary pen trial demonstrated that the rock hyraxes did not discriminate between the sprayed and unsprayed seedlings. There was a difference in the attitude of the animals to the two types of trees, i.e. avocado and mango. The animals attacked the mango seedlings 7 days after defoliating the avocado; many leaves were not consumed—they were dropped down under the trees. It is obvious that the hyraxes discriminated between these plants, but, at the end, when the avocado trees were stripped of their leaves, they attacked, though somewhat repelled, the mango trees. Orchards of both fruit trees are damaged by the rock hyraxes (Moran and Keidar, 1993), but it is noteworthy that none of the damaged mango orchards recorded were adjacent to avocado orchards.

In the field trial, the pattern of consumption of mature citrus leaves was in a rather scattered pattern in the first three rows. Some of the trees were stripped of most of their leaves, and some became totally leafless (both control and treated trees). The application of RO-PEL® resulted in a significant repellency, but of a low economic value (damage reduction was only 42·6%). Later, when the new growth became available, the hyraxes stopped eating the mature leaves. Damage was then concentrated adjacent to the hyraxes' shelter in the rock crevices, and the seedlings' leaves were consumed irrespective of previous treatment. I conclude that the mature leaves are less palatable to the animals than the new growth, the scattered damage reflecting a searching behaviour. When the fresh leaves are available, the hyraxes became more selective—browsing in front of their refuge in the rocks, and causing damage typical of the orchards bordered by rock heaps (S. Moran, unpublished data). The damage to the trees was greater in the first row, as the rock hyraxes tend to graze near the refuge rocks (Maeltzer and Livneh, 1982).

The results of this research are inconsistent with the claim that RO-PEL® is an efficient repellent to herbivores. This has also been concluded with white-tailed deer (*Odocoileus virginianus*) Swihart and Conover, 1990; Andelt *et al.*, 1991), elk (*Cervus elaphus nelsoni*) (Andelt *et al.*, 1992), and brush-tailed possum (*Trichosorus vulpecila*) (Woolhouse and Morgan, 1995). Guinea pigs (*Cavia porcellus*) were indifferent to the denatonium compounds that are used as the principal

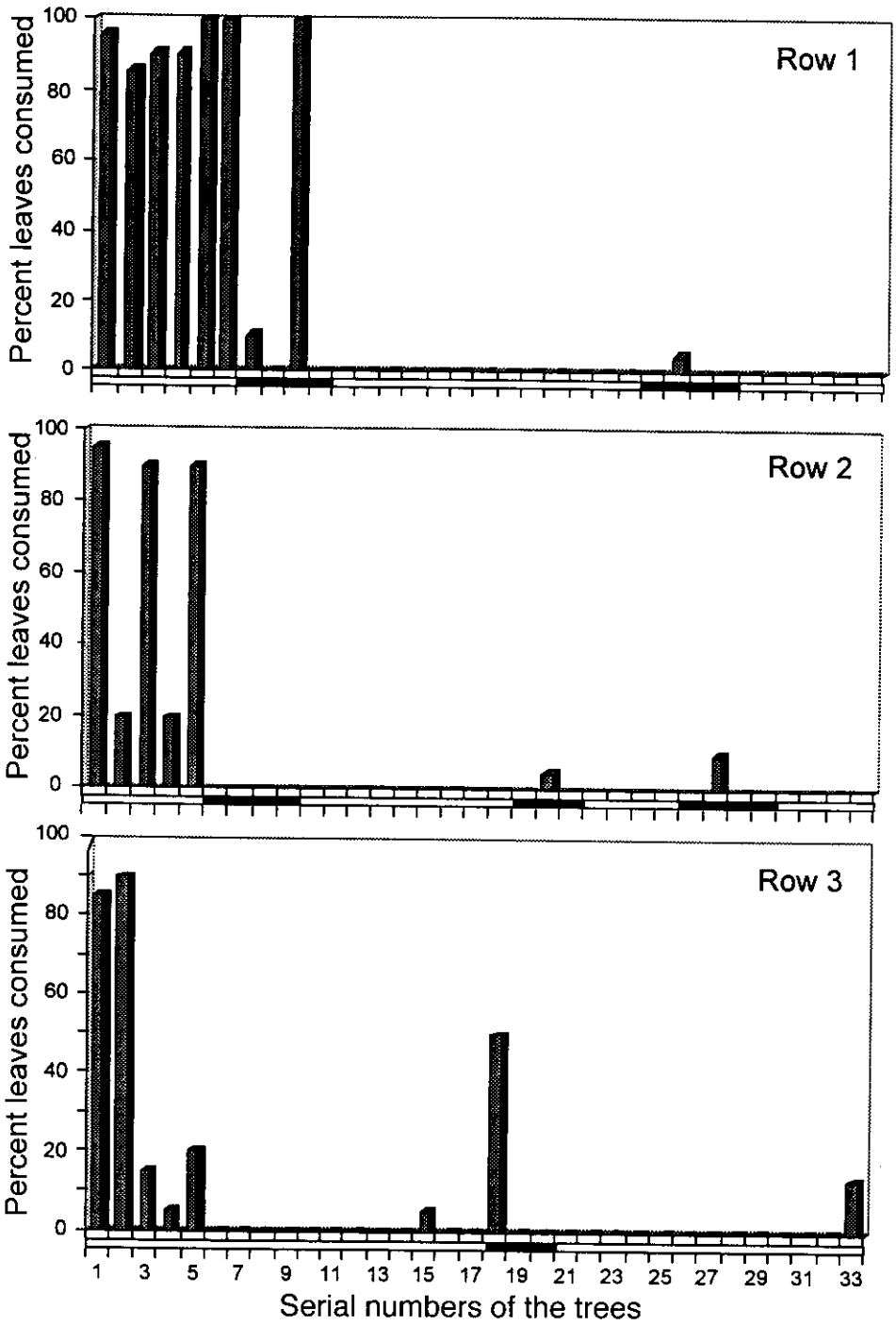

*Figure 3. Consumption of Star Rubi (*Citrus grandis *var.) new leaves by* Procavia capensis *after being sprayed with RO-PEL®. Shaded patches new under the abscissa—unsprayed seedlings; unshaded patches—sprayed.*

active ingredient in some commercial repellents (including RO-PEL®) (Nolte *et al.*, 1994a), the same as in tests with other bitter agents. Nolte *et al.* (1994b) hypothesized that herbivore species failed to differentiate between forage treated with these products and untreated plants, but this is not a general phenomenon (e.g. the findings of Woolhouse and Morgan (1995) on the repellency of denatonium benzoate to the possum). Nevertheless, as the hyraxes eat almost all the plants (including the poisonous ones) that occur in their territory (Maeltzer, 1973), maybe the theory of Nolte *et al.* (1994b) suits this species.

To sum up, the advantage of RO-PEL® as a rock hyrax repellent is uncertain, and a more effective hyrax repellent is needed.

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