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# Development of chemosensory attractants for white-tailed deer (*Odocoileus virginianus*)

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White-tailed deer (*Odocoileus* spp.) overpopulate many areas of the United States. Browse damage to agricultural crops, forest regeneration and landscaping can be severe. Human and animal health also are threatened by Lyme disease, which is spread by the deer tick (*Ixodes dammini*). Although sterilants to reduce and/or slow the growth of deer populations and vaccines against Lyme disease may soon become available, efficient and economical techniques to inoculate large numbers of deer have not been developed. Oral baits represent one promising possibility. In experiment 1, salt blocks and several olfactory lures were evaluated as potential lures for use in deer baits. Plain salt blocks were attractive and odour stimuli such as acorn, apple and peanut butter significantly enhanced effectiveness. Apple was the best stimulus in an old field; peanut butter and acorn were the best stimuli in a bottomland habitat. In experiment 2, blocks of minerals, salt, molasses, and mineral–molasses were presented; all were scented with apple extract. Mineral blocks were the most attractive, followed by salt blocks and mineral–molasses blocks; molasses blocks were the least attractive. In experiment 3, mixtures of apple, acorn and peanut butter extracts were presented with mineral blocks. None of the combinations was more attractive than the others and none was more attractive than mineral blocks presented with apple extract only.

**Keywords:** crop damage; attractants; deer; *Odocoileus virginianus*; olfaction; taste

Deer (*Odocoileus* spp.) are blamed for more agricultural damage than any other vertebrate species in the United States (Conover and Decker, 1991). In New Jersey alone, the Farm Bureau estimates that white-tailed deer (*Odocoileus virginianus*) caused more than US\$20 × $10^6$ damage to various food and non-food crops in 1990 (New Jersey Farm Bureau, 1990). During that same year, New Jersey white-tails were involved in 8000 collisions with automobiles (New Jersey Farm Bureau, 1990). Burgeoning deer populations also pose a growing threat to human and animal health and safety because deer are an important reservoir for breeding deer ticks (*Ixodes dammini*), arachnids that are the primary vector for transmission of the Lyme disease bacterium (Anderson, 1988).

To date, deer control activities have focused on increasing hunter access to private lands (e.g. New Jersey Agricultural Statistics Service, 1990; Atwill, 1991), manipulating hunting seasons (Conover and Decker, 1991), erecting deer fences (Boggess, 1982), and developing repellents to protect localized areas from severe browse damage (Conover, 1984, 1987; Scott and Townsend, 1985). These techniques are effective, but lethal control may not be feasible in many suburban and urban areas. As a result, deer herds have grown so large that repellents now have little effect.

Non-lethal methods to reduce deer numbers and/or to slow population growth in suburban and urban areas are being sought (Kirkpatrick and Turner, 1985). Chemical and immunosterilants probably will become available within 3–5 years (Turner, Liu and Kirkpatrick, 1990), but the problem of inoculating large numbers of deer remains. Silastic implants (e.g. Plotka and Seal, 1989) and direct intramuscular injections (Harder and Peterle, 1974) are neither economical nor efficient. Although oral vaccines would be both inexpensive and relatively easy to use, no bait formulations are currently available. The experiments described in this paper were designed to uncover chemosensory attractants or lures that could be used to enhance the effectiveness of such formulations.

Experiment 1 was designed to evaluate the relative attractiveness of apple, acorn, sweet corn and peanut butter odours to white-tailed deer. Experiment 2 explored the attractiveness of blocks of salt, minerals, molasses and mineral–molasses; all block types were presented in combination with apple extract. In experiment 3, mixtures of apple, acorn, and peanut butter odours were presented with mineral blocks. The aim

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was to assess whether synergisms might occur among olfactory attractants.

## Materials and methods

### Study sites

Four sites (each 25 ha) within 10 km of Poughkeepsie, NY, USA were selected. Each represented a different habitat type: the first site was an annually mowed field, the second, an old field with scattered apple trees, the third, a woodlot dominated by maple (*Acer* spp.) and the fourth, a bottomland dominated by sweetgum (*Liquidamber* spp.), sycamore (*Platanus occidentalis*) and maple. All sites were separated from one another by several kilometres and bounded by heavily travelled streets and housing subdivisions. Between ten and 20 deer were regularly observed at all sites during the 4 weeks before the experiment.

### Experiment 1

Apple odour was obtained from International Flavors and Fragrances (Union Beach, NJ, USA). Peanut butter extract was donated by Hercules Flavour Company (Middletown, NY, USA). Acorn and sweet corn odours were purchased from the M & M Fur Company (Bridgewater, SD, USA). Each odour was diluted in propylene glycol to produce 2.0% (w/w) stimulus concentrations.

We chose to examine extracts and not foods, *per se*, for two reasons: first, we expected that the extracts would be more durable in the field; second, there is evidence that extracts of preferred foods are attractive to captive deer and increase ingestion even when presented out of context. For example, food odours in solution enhance drinking (Rice and Church, 1974).

Similarly, we chose to examine food odours instead of semiochemical odours (e.g. urine, glandular secretions) for two reasons: first, we wanted to promote ingestion, and not merely investigation [semiochemicals typically result in the latter, but only rarely the former (e.g. R. A. Mugford, Pedigree Petfoods, personal communication; D. Passe, Quaker Oats Pet Products, personal communication) ]; second we wanted to attract both males and females and we surmised that food odours would be superior to social odours in this respect.

A priori, we chose salt as the principal ingredient in our formulations for the following reasons: first, we have found that it is relatively easy to incorporate a variety of pharmaceutical chemicals into a salt matrix; second, as herbivores, deer are chronically sodium deficient (Belovsky, 1981) and, therefore, they avidly consume salt (Jones and Hanson, 1985); third, the use of salt provided a measure of species specificity because, unlike herbivores, carnivores and many omnivores consume diets that are sodium replete, and meat eaters rarely show strong salt preferences (Beauchamp and Mason, 1991).

Testing occurred during November and December, 1991. At each of the four experimental sites, eight testing locations were randomly selected, with one qualification – that no location could be situated along an existing deer trail. Four of these locations were randomly assigned to the odour condition (one odour per location); the remaining locations were assigned to the control condition.

On Mondays of each of the next 4 weeks, one odour location and one control location was randomly selected (sampling without replacement) at each experimental site. At odour locations, a 1.8 kg salt block (Cargill Inc., Minneapolis, MN, USA) was suspended 1 m from the ground in a holder attached to a metal stake. A metal deflector was attached to the stake above the block to shield it against precipitation. Stakes were positioned so that there was a large tree immediately behind them; these trees served to block extraneous activity records (see below). Next, one of the odour stimuli was randomly selected (sampling without replacement) and 10 ml was placed in a glass scintillation vial. The vial was attached to the stake just below the salt block. At control locations, 10 ml of the propylene glycol diluent was placed in a vial and the vial was attached to stakes, as described above. Wicks (3 cm of braided cotton) were inserted through holes in the lids of the vials, so that 1.5 cm of the wick was exposed to the environment; these controlled the escape of stimulus odours.

Infrared motion detectors (Trailmaster, Inc., St Paul, MN, USA) were mounted 1 m above the ground and 2 m from the lure block on trees at each test and control location. The units were tuned to record the time and date of visits by deer. Each unit detected activity only by moving objects at least 60 cm in diameter within 0.5 m of the salt block. As a result, they were essentially insensitive to smaller animals and to activity on either side of the trees against which the lure blocks were placed. In addition to visit data, the weight of the salt blocks was recorded weekly, as were animal tracks within 2 m of the blocks. To record weight changes of the blocks, the salt was returned to the laboratory and placed in a drying oven at 40°C for 48 h. The block was then weighed, and this weight was subtracted from the dry weight of the block before testing. Fresh dry blocks were used for each 7-day test session.

### Experiment 2

Salt blocks, mineral blocks, molasses–mineral blocks and molasses blocks served as stimuli (*Table 1*). All were presented in combination with apple odour.

Testing occurred during December 1991 and January 1992 at eight new randomly selected sites. The procedures followed were identical to those described for experiment 1.

### Experiment 3

Mineral blocks were presented in combination with

Table 1. Contents of stimulus blocks used in experiment 2

| Type | Manufacturer | Contents |
|---|---|---|
| Salt | Cargill, Minneapolis, Minnesota, USA | Sodium chloride, white mineral oil |
| Mineral | Cargill, Minneapolis, Minnesota, USA | Sodium chloride, white mineral oil, 0.2% manganese, 0.1% iron, 0.1% magnesium, 0.05% sulfur, 0.025% copper, 0.01% cobalt, 0.008% zinc, 0.007% iodine |
| Molasses | Trophy Feeds, Walled Lake, Minnesota, USA | Corn syrup, molasses, sucrose, peanuts, cracked corn, hydrogenated vegetable oil, lecithin |
| Mineral–Molasses | PM Ag Products, San Francisco, California, USA | 52% sodium chloride, 1.5% calcium, 0.4% phosphorus, 2.75% magnesium, 1.0% potassium, 0.0003% iodine, 0.03% iron, 0.00025% selenium, cane molasses, cotton seed meal |

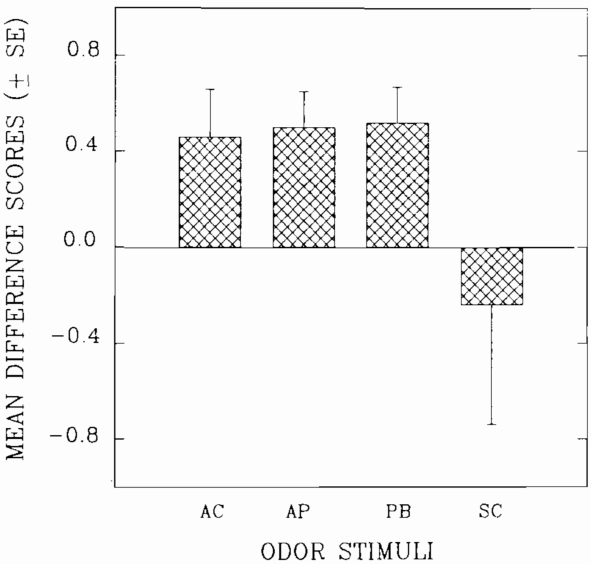


Figure 1. Mean difference scores for log visits of white-tailed deer to each odour (AC, acorn; AP, apple; PB, peanut butter; SC, sweet corn) presented in experiment 1. Capped vertical bars represent s.e.m.

apple extract only, or paired extracts (apple–acorn, apple–peanut butter, or acorn–peanut butter). Testing occurred during January and February 1992 at eight new randomly selected sites. The procedures followed were identical to those described for experiments 1 and 2.

### Analyses

For all three experiments, visit data were found to be heterogeneous (Bartlett's test; von Eye, 1990); data were those of raccoons and mice. There were significant because of high variability. To simplify the analyses, difference scores were created from the transformed data set by subtracting control location values from test location values at each site. Because the attractants were serially exposed, we analysed the data using two-way repeated measures analyses of variance: the within-subjects (repeated measure) was attractant; the between-subjects effect was habitat type. Tukey post-hoc tests (Winer, 1962) were used to isolate significant differences among means, with the significance level set at $p < 0.05$.

Although stimulus weights were collected in all experiments, lengthy periods of severe wet weather eroded blocks, regardless of the deflectors mounted above the blocks on the stakes. This erosion obscured accurate measurements of consumption, and for this reason, these data are not reported here.

## Results

### Experiment 1

Numerous deer tracks were observed at all experimental and control sites. The only other tracks observed were those of raccoons and mice. There were significant differences among odour stimuli ($F = 3.6$; 3,72 d.f.; $p < 0.02$), and an interaction between odour stimuli and habitat type ($F = 2.2$; 9,72 d.f.; $p < 0.03$). Post-hoc tests showed that, relative to controls, deer visited apple, acorn and peanut butter locations more frequently than sweet corn locations (*Figure 1*).

Post-hoc examination of the interaction term revealed the following pattern of effects: apple odour elicited

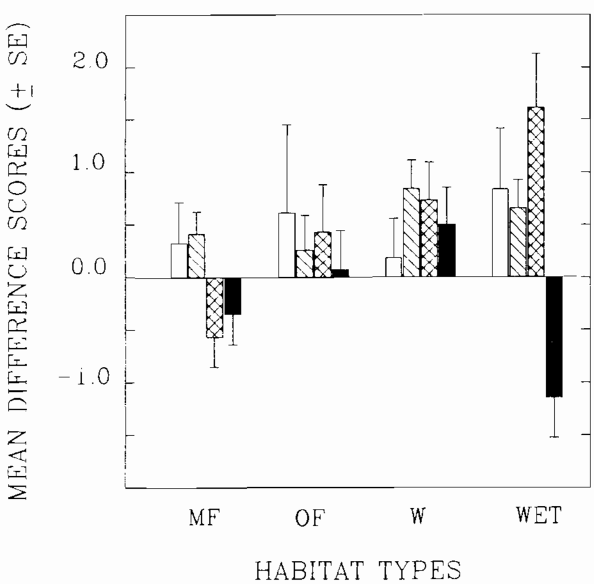


Figure 2. Mean difference scores for visits of white-tailed deer to each odour (■, sweet corn; ▨, peanut butter; ▩, acorn; □, apple) in annually mowed field (MF), old field (OF), woodlot (W), and bottomland (WET). Capped vertical bars represent s.e.m.

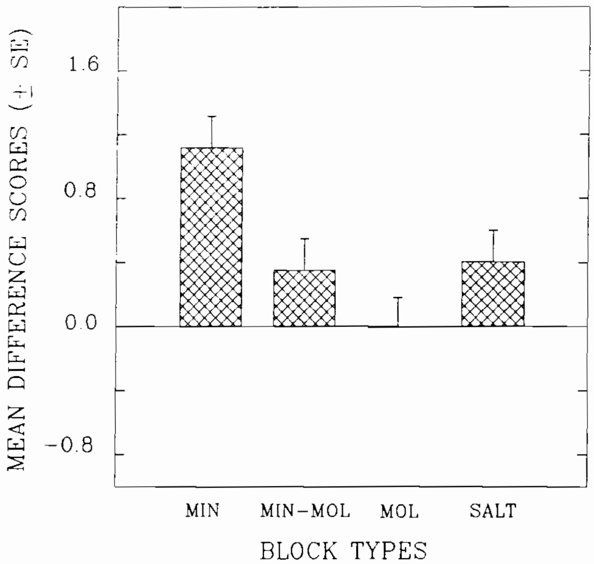


Figure 3. Mean difference scores for log visits of white-tailed deer to block stimuli (MIN, mineral blocks; MIN–MOL, mineral–molasses blocks; MOL, molasses blocks; SALT, salt blocks) presented in experiment 2. Capped vertical bars represent s.e.m.

more visits than any other odour in the old field habitat ($p < 0.05$); peanut butter and acorn were more attractive than the other stimuli in the bottomland ($p < 0.05$, *Figure 2*). Acorn, apple and peanut butter were equally effective in the annually mowed field or the woodlot.

### Experiment 2

Numerous deer tracks were observed at all experimental and control sites. The tracks of small passerines and raccoons were also present occasionally. There were significant differences among stimuli ($F = 4.9$; 3,72 d.f.; $p < 0.004$). Post-hoc tests showed that mineral blocks were significantly more attractive than salt blocks or mineral–molasses blocks ($p < 0.05$); the least attractive stimulus was molasses block (*Figure 3*); otherwise, there were no significant effects.

### Experiment 3

Numerous deer tracks were observed at all sites. Raccoon tracks and the tracks of small birds were also occasionally present. There were no significant differences among stimuli ($p > 0.35$) or habitat types ($p > 0.45$) (*Figure 4*), and no significant interactions ($p > 0.25$).

## Discussion and management implications

With the exception of sweet corn, all food extracts evaluated in experiment 1 enhanced the attractiveness of salt blocks. Attractiveness was habitat specific, however, and the reasons for this are not clear. Recent feeding histories, novelty, or differences in odour dispersion in different habitat types are all plausible explanations. There may also have been concentration differences in volatiles emanating from the stimuli. Although such differences are better documented for taste stimuli (e.g. Sclafani, 1991), they undoubtedly influence the attractiveness of odours as well. Further studies are needed to resolve this issue.

In experiment 2, mineral blocks were the most attractive stimuli and molasses blocks were the least attractive. Salt blocks and mineral–molasses blocks were moderately attractive. Habitat differences appeared unimportant. These data suggest that molasses is not attractive to deer and that the presence of molasses in a formulation will decrease the attractiveness of otherwise preferred stimuli.

In experiment 3, combinations of extracts were no more effective than apple extract alone. This result was surprising because we had expected some synergy among preferred extracts. One possible explanation for this lack of effects is that the deer had had experience with each of the odour types at lure stations; naïve deer would, perhaps, have responded differently.

Although we are cautious about extrapolating from a relatively small field experiment in New York to other areas, we speculate that mineral blocks in combination with apple, acorn or peanut butter extract could provide an attractive and relatively selective lure for the delivery of sterilants or other chemicals (e.g. vaccines) to free-ranging white-tailed deer. However, a number of important research issues remain: for example, while we know that deer were visiting our sites, we do not know how many different deer actually contacted the lures, the frequency of contacts by individual deer, or the quantity of lure actually

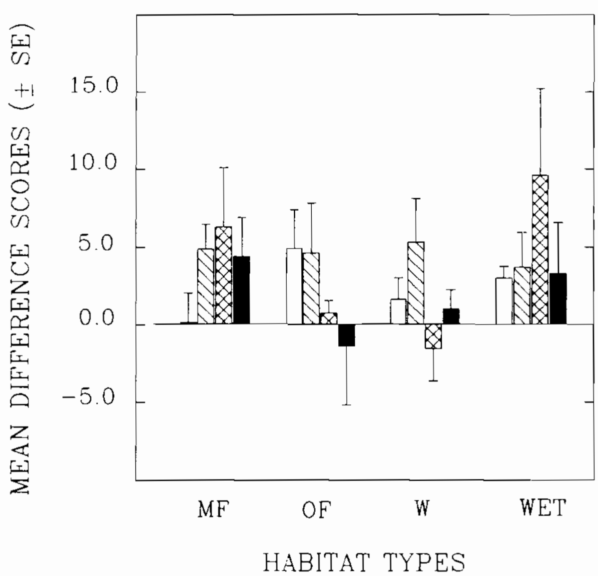


Figure 4. Mean difference scores for visits to odour pairs (■, acorn/peanut butter; ▧, apple/peanut butter; ▨, apple/acorn; □, control) presented in combination with mineral block in experiment 3. Capped vertical bars represent s.e.m. Abbreviations as in *Figure 2*

ingested. Although observations of captive deer at the Rutgers Agricultural Experiment Station in New Brunswick, NJ, have led us to conclude that lure materials were being ingested, quantitative measures in the field are needed. In addition, the number of deer in an area could affect lure effectiveness. Finally, it would not be surprising if the attractiveness of lures was seasonally and/or geographically variable (Schultz and Johnson, 1992). Browsers such as deer are even more likely to use mineral licks during the spring and early summer than during the period in which the present experiments were conducted (Weeks and Kirkpatrick, 1976; Weeks, 1978; Jones and Hanson, 1985). This seasonal effect may be more pronounced in southern latitudes (e.g. Louisiana) than in the north (Schultz and Johnson, 1992). Additional experiments to examine lure effectiveness at other times of the year are warranted.

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