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Journal
Proceedings of the Vertebrate Pest Conference, 16(16)

ISSN
0507-6773

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Publication Date
1994

PREVENTING DEER DAMAGE WITH BARRIER, ELECTRICAL, AND BEHAVIORAL FENCING SYSTEMS

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ABSTRACT: White-tailed deer (*Odocoileus virginianus*) are responsible for damage to a variety of horticultural crops. Economic losses often require growers to implement one or more damage management methods including repellents, scare devices, hunting to control deer numbers, and fencing. A relatively small proportion of producers currently use fencing as their primary deer damage management technique due to high initial costs and other perceived shortcomings. Several fencing systems, including baited single wires, three-dimensional outriggers, and slanted and vertical fences up to 3.3 m (11 feet) in height have successfully excluded deer under some conditions, but simple designs are effective only under light deer pressure, or for relatively small (<5 ha) areas. Low-cost fences are seldom satisfactory for protecting commercial orchards or ornamental plantings during winter, especially if snow restricts normal deer foraging opportunities. Combining electric fences with either attractants or repellents can enhance their effectiveness. Recent experiments with invisible electronic fencing systems and dogs have resulted in reduced deer damage to crops, however, additional research is needed to determine dog density per unit area for reliable protection during winter. Actual costs for fence installation vary depending on site characteristics, labor quality and costs, and sources of materials. It is important for growers to calculate the annual fencing costs for an orchard or nursery based on the anticipated life-expectancy of the fence design.

Proc. 16th Vertebr. Pest Conf. (W.S. Halverson & A.C. Crabb, Eds.) Published at Univ. of Calif., Davis. 1994.

INTRODUCTION

White-tailed deer (*Odocoileus virginianus*) damage is a serious problem of increasing concern to fruit growers (Purdy et al. 1987, Scott and Townsend 1985a) and the landscape horticulture industry. The current trend toward planting higher-density orchards with dwarfing rootstocks may increase the likelihood of damage by concentrating trees and increasing the proportion of branches within reach of feeding deer (Caslick and Decker 1979). In a 1989 New York survey, about two-thirds of nursery producers and landscape firms, and one-fourth of homeowners reported deer damage to ornamentals (Sayre et al. 1992).

Parts of a plant damaged often determine the ultimate effect on that plant, as deer feed upon tree foliage, twigs, buds, and fruit (Scott and Townsend 1985a). Studies have shown that deer may significantly reduce crop yields of bearing trees by consuming fruit buds (Katsma and Rusch 1979, Austin and Urness 1989). Damage is most detrimental to the terminal buds of major branches of young trees which are within the reach of deer (Matschke et al. 1984). Deer may kill young trees outright (Boyce 1950), or may alter growth rates, interfere with scaffold-branch-training programs, and delay development of a strong central leader (Harder 1970, Scott and Townsend 1985a). A small delay or reduction in yield could have substantial impact on profitability over the life of an orchard (McAninch et al. 1985, Pomerantz et al. 1986).

Growers use a variety of damage management methods to protect crops from deer including repellents, scare devices, hunting to control deer numbers, and fencing (McAninch 1983a, Scott and Townsend 1985b). However, a relatively small proportion of producers currently use fencing as their primary deer damage management technique. For example, Scott and Townsend (1985b) reported that only 5.3% of 1,487 Ohio fruit and ornamental growers employed some form of deer deterrent fencing. Similarly, Purdy et al. (1987) indicated that 16.4% of 79 commercial orchardists in southeastern New York installed fencing around their trees. Farmers reluctance to use fencing may result from high installation costs, time and money requirements for fence maintenance and repairs, the need to remove existing perimeter rows of trees to provide turn lanes for equipment, and additional time needed to open and close gates. Because of these perceived drawbacks, growers appear willing to install fencing only when deer damage and economic losses are extremely high.

DEVELOPING A CONTROL STRATEGY

Previous deer foraging patterns and experiences of farms within 2 km of a planting can provide insight into the potential for future damage. The decision to begin damage management in existing plantings should be based on estimated future losses at a site, not as a reaction to impacts that have already taken place (McAninch et al. 1985). Control strategies are most effective if implemented prior to crop establishment, rather than after deer feeding patterns develop. Comprehensive programs should include careful monitoring to assess losses, deer population management, and physical or chemical barriers. The purpose of this discussion is to focus on the potential for using fencing as part of an integrated approach.

For a given deer density, the potential for damage will often be greater on larger plantings than smaller ones (McAninch et al. 1983a). Consequently, large blocks often require more substantial fencing designs to achieve a level of protection similar to small areas. Based on anecdotal reports from growers and research experiences in New York, vertical electric fence designs seldom provide reliable protection for fruit tree plantings larger than 2 ha (5 acres) under intense deer foraging pressure. Slant-wire electric fencing systems can protect plantings up to 20 ha (50 acres) in size. Blocks larger than 20 ha usually require 2.4 m-high (8 foot) woven-wire fencing to reliably prevent deer from entering the planting if feeding pressure is high.

Although deer pressure and area size to be protected are the primary factors to consider when selecting a fence design, grower tolerance for deer damage is also important. When a producer's tolerance for deer damage is low (i.e., even light damage is unacceptable during the anticipated life of the fence), and deer foraging pressure is high, 2.4 m-high woven-wire fences are the only practical option regardless of area size. If this design is not economically feasible due to low crop value or other reasons, the best decision for a grower may be to avoid planting sites prone to heavy deer damage.

A wide variety of fencing systems, including baited single wires (Porter 1983, Hygnstrom and Craven 1988), three-dimensional outriggers (Tierson 1969, Caslick and Decker 1977), and slanted and vertical fences up to 3.3 m (11 feet) in height (Longhurst et al. 1962, Halls et al. 1965, Palmer et al. 1985) have successfully excluded deer under some conditions. Often simple designs are effective only under light deer pressure (Brenneman 1983, McAninch et al. 1983a,b), or for relatively small areas. Low-cost, easily-constructed fences may perform quite well for small (<5 ha) plantings during the growing season, when alternative foods are available to deer. However, these fences are seldom satisfactory for protecting commercial orchards or ornamental plantings in winter, especially if snow restricts deer from their usual foraging opportunities.

BARRIER FENCING

In this section, we discuss designs which act as physical barriers to entry by deer. These fences perform well even under intense deer pressure and represent the technique of choice for many deer damage management programs (Eadie 1961, Caslick and Decker 1979, McAninch et al. 1983a).

Individual wire cages, at least 0.5 m (1.5 feet) in diameter and 1 to 1.2 m (3 to 4 feet) in height, may be used to protect single young trees from deer browsing and antler rubbing (Longhurst et al. 1962). Wire cages may provide cost-effective, short-term protection for interplanted trees, or small orchards of standard-size trees (Caslick and Decker 1977). However, expensive installation costs, and interference with ground cover management and pruning, make individual cages impractical for commercial orchards. Similarly, plastic tubes placed over young trees (tree shelters, Potter 1988), appear to have little value for protection of orchards.

A woven-wire fence 2.4 to 3.0 m (8 to 10 feet) tall is considered the most deer-proof design, and can effectively exclude deer from areas larger than 20 ha (50 acres). In the past, these fences usually consisted of two 1.2 m (4-foot) tall sections of wire mesh joined with hog rings, with additional single wires added above (McAninch et al. 1983a). The wires are supported by pressure-treated softwood posts spaced at 6.1 to 9.1 m (20 to 30 foot) intervals. Material costs were estimated at \$6.50 to \$12.20 per linear m (\$2 to \$3.75 per linear foot; McAninch et al 1983a). During the 1990s, growers reported that it cost more than \$20,000 to enclose a 20 ha (50-acre) block of trees with high-quality fence materials. However, this cost could be prorated over the 15 to 20 year life expectancy of the fence.

In addition to high installation costs, woven-wire fences have been plagued by wire deterioration and considerable expense for repairing damaged sections. These problems may be reduced by constructing fences with new high-tensile woven wire, which is now the material of choice for deer fences, replacing conventional wire mesh. This material is low-stretch, high-elastic, 11-14.5 gauge wire with tensile strength up to 121.5 kg/cm2 (200,000 lbs per square inch), and breaking strength up to 816 kg (1,800 pounds; United States Steel 1980). The strong, elastic nature of the wire reduces stretch, sagging, and damage when objects contact the fence. In addition, quality high-tensile wire receives Type III galvanizing, which can extend wire life up to 35 years in humid climates.

ELECTRICAL FENCING

Electrical, smooth-wire fence designs are not complete physical barriers, but rely on electric shock to aversively condition animals to avoid the fence (McKillop and Silby 1988). An electric fence is an unfamiliar object, and a deer investigating it for the first time often will touch the fence with its nose (Prior 1983). However, a deer foraging at night may not see the fence, and could touch the wires with its neck, back, or chest (Tierson 1969). If an animal has almost crossed the fence before an electric pulse is generated, it will likely complete the crossing. Deer are reported to have learned to avoid receiving shocks by jumping through electrified fences (Tierson 1969).

Electric current is supplied by low-impedance, high-voltage chargers, which provide regularly-timed pulses (45 to 65 per minute) of short duration (0.0003 second), followed by a relatively long period without current flow (United States Steel 1980). The short-duration, high-energy pulses provide sufficient energy (>3,000 volts) to deter deer, while still allowing an adequate period without current to allow humans and animals to free themselves from the electrified wires. Plug-in and battery/solar-operated chargers are available to maintain in excess of 5,000 volts on several kilometers of fencing. Electric fences should always be adequately marked with warning signs, and barbed wire should never be electrified.

Multi-strand, electrified, high-tensile, smooth-wire fences consist of several individual wires fastened to braced wooden assemblies, with wires tightened to 68 to 114 kg (150 to 250 lbs) of tension (McAninch et al. 1983a, Palmer et al. 1985). Sturdy, well-braced corner and end assemblies are needed to support these wire tensions. However, posts between brace assemblies can be widely separated (20 to 30 m), and can be constructed from smaller, less-expensive materials. Spacer-battens, located between line posts, are lightweight components whose main purpose is to maintain wire spacings. Several vertical, six- or seven-wire, high-tensile fences have been found to effectively control deer damage for small areas (McAninch et al 1983a, WVU Committee on Deer Damage Control 1985). These fences represent modified versions of the Penn State five-wire vertical fence (Palmer et al. 1985). Costs for materials ranged from $1.14 to $1.80 per m ($0.35 to $0.55 per foot; McAninch et al. 1983a).

The seven-wire, slanted, electrified, high-tensile, smooth-wire fence is an effective barrier for protecting larger areas with moderate to high deer pressure (McAninch et al. 1983a). The fence covers approximately 2 m (6 feet) of horizontal space and presents deer with a confusing three-dimensional barrier as well as a shock when touched. Costs for materials were estimated at $2.28 to $2.93 per m ($0.70-$0.90 per foot; McAninch et al 1983a). Although the slanted design appears more effective than comparable vertical electric fences (McAninch et al. 1983b, McAninch et al. 1985), it is also more complicated to construct, and requires additional vegetation-control efforts.

COMBINATION FENCING

Combining electric fences with either attractants or repellents may encourage deer to touch the fence with their nose or mouth, thereby enhancing aversive conditioning behavior. Early studies by Kinsey (1976) and Porter (1983) used aluminum flags coated with peanut butter to attract deer to an electrified, single-strand smooth wire. This design was reported to be effective for sites <5 ha with light to moderate foraging pressure by deer. Hygnstrom and Craven (1988) used fences constructed from an electrified ribbon, and treated the entire length with a peanut butter-oil mixture. Corn fields protected by these fences experienced significantly less deer damage than controls or fields treated with commercial deer repellents.

Jordan and Richmond (1992) evaluated the relative effectiveness of attractants vs. repellents for excluding deer with a three-wire, vertical, electric fence system. The electric fence with a repellent was penetrated by deer only once (0.9% of 116 exposure days). The electric fence with peanut butter was penetrated nine times (7.8% of 116 exposure days), and an electric fence with no attractants or repellents was crossed 13 times (11% of 116 exposure days). All three designs experienced significantly less damage than non-electrified control fences (37 deer encroachments, or 32% of 116 exposure days), and the electric fence with repellents was the most effective barrier.

Herbivores have shown a general aversion to volatile substances in predator urine (Sullivan 1986, Sullivan and Crump 1986). During summer 1993, Curtis and Petzoldt (1994) tested a single-strand, electrified, plastic ribbon fence treated with bobcat (*Felis rufus*) urine, for preventing woodchuck (*Marmota monax*) damage to a cabbage field. In a two-choice trial, only 1% of 100 cabbage plants monitored within the fence sustained woodchuck feeding damage. However, 100% of 100 cabbages outside the fence sustained damage by woodchucks, with 94% of the plants exhibiting severe heart injury making them unmarketable. During a one-choice trial where no cabbage plants were available outside the fence, only 8% of 100 cabbages sustained severe heart injury. Based on success with a similar fence design reported by Hygnstrom and Craven (1988), this plastic ribbon fence treated with predator urine may significantly reduce deer damage to a variety of fruit, vegetable, and forage crops during the growing season. Additional field trials are necessary to test this hypothesis.

Another type of combination fence was used successfully by an orchardist in British Columbia, Canada. The grower had placed 1.2 m (4 feet) of woven-wire on the bottom portion of the fence, and then added electrified, high-tensile, smooth wires at 0.3 m (1 foot) spacings on posts above the woven-wire to increase the overall fence height to 2.4 m (8 feet). This design provides additional protection for sites that experience deep snows during winter, but is lower in cost than a complete physical barrier with woven-wire.

BEHAVIORAL FENCING

Recently, growers (Torrice 1993) and researchers (Beringer et al. 1994) have initiated experimentation with invisible fencing systems and dogs for reducing deer damage to crops. Anecdotal reports from nursery producers in southeastern New York who had installed invisible fencing systems on their property for containing dogs indicated deer damage to ornamentals within the fence was substantially reduced. Beringer et al. (1994) documented that two dogs within an invisible fence were more effective for protecting 2-ha (5-acre) plots of white pine (*Pinus strobus*) seedlings from deer damage than a commercial deer repellent.

Information collected during a pilot study in New York indicated two dogs contained within an invisible fence afforded protection to apple trees within about 500 m of their kennel (approximately 25 ha, or 60 acres) during summer, but the effective radius was reduced to about 4 ha (10 acres) during winter when snow restricted movement of the dogs (Curtis and Rieckenberg, unpubl. rep.). During this initial experiment, it cost approximately $4,000 to install the perimeter fence around 40 ha (100 acres) of orchard, and provide the charging unit and collars for the dogs. Advantages of this system included a perimeter wire that was completely buried providing easy equipment access, no gates were needed, snowfall did not affect operation of the electronics, and costs were much lower than other electronic fencing systems. Additional research is needed to further explore this approach, and determine the density of dogs required per unit area of orchard during different seasons.

ESTIMATING FENCING COSTS

Actual fence installation costs for all designs vary depending on site characteristics, labor quality and costs, and sources of materials. Per ha costs, particularly for high-tensile, smooth-wire fences, decreases as unit-area size increases (Brenneman 1983, McAninch et al. 1983a). Ellingwood and McAninch (1984) found that materials generally accounted for 60% of total fence costs, regardless of the design used. Labor accounted for 30% of the investment, while equipment costs (i.e., bulldozing, etc.) made up approximately 10% of the installation costs.

It is important to calculate the annual fencing costs for an orchard or nursery (including depreciation, maintenance, repairs, taxes, and insurance) based on the anticipated life-expectancy of the fence (Caslick and Decker 1979). With planting densities of 1,957 trees/ha (792 trees/acre), 2.4 m-high woven-wire fences may be practical if deer damage exceeds a few cents/tree/year. Growers should carefully calculate anticipated economic losses from deer when deciding on a control strategy. If deer foraging pressure is moderate to high and commercial crops will be protected, then barrier fencing may be the most cost-effective management option.

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