II.4 A Review of Chemical Sprays in Cooperative Rangeland Control Programs

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NOTE: Acephate is no longer approved by EPA for rangeland grasshopper control.

The chemical sprays used against rangeland grasshoppers today and the current cooperative rangeland grasshopper management program are both results of an evolving solution to an age-old problem. That problem is one of how best to control or suppress damaging populations of grasshoppers over widespread areas. The following chapter will review the history and evolution of chemical sprays in rangeland grasshopper control to the present day.

History

In the United States, the history of grasshopper control is interwoven with that of the Mormon cricket. Control was conducted primarily to protect crops, but rangeland also was treated to save forage and prevent insect migration to nearby cropland. During the first half of the 20th century, control relied almost exclusively on poison baits. Although sprays such as paris green and sodium arsenate were used, these compounds fell from favor because the poisoned vegetation endangered livestock (Parker 1952). Both State and Federal assistance were provided for organizing and financing control efforts, particularly during outbreak years.

In the late 1940's and early 1950's, several major developments occurred that significantly changed the way grasshoppers were controlled.

1. Perhaps the most important was the development of the chlorinated hydrocarbon insecticides. They were extremely effective in small amounts against grasshoppers. They could easily be formulated into baits, acted quickly, and had a longer residual effect than previously used baits. Because of these qualities, chlordane and toxaphene in 1949 and aldrin in 1951 quickly replaced previous baits (Parker 1952).

2. Large-scale (thousands of acres) aerial application of bait became more commonplace. Compared to older wet baits, the new compounds could be formulated dry, which made distribution easier. In Montana and Wyoming during 1949–50, aerial application of chlordane and toxaphene baits were the major tools used against grasshoppers (Parker 1952).

3. Sprays of these compounds were also developed at the same time. In addition to being extremely effective, they were much cheaper than baits. Sprays of chlordane, toxaphene, and aldrin first were used in grasshopper control programs in 1947, 1948, and 1950, respectively (Parker 1952).

4. Organized, large-scale programs to control rangeland grasshoppers were started. In 1949, a cooperative program provided for the aerial treatment of toxaphene and chlordane baits to 40,000 acres in Wyoming. Within 2 years, the cooperative program had switched to aldrin spray (Pfadt and Hardy 1987).

5. In 1952, several State departments of agriculture and the U.S. Department of Agriculture (USDA) formed an agreement through a memorandum of understanding that the cooperative grasshopper control programs would be reserved for rangeland. Because of the low cost of the chlorinated hydrocarbons, treatment for crop protection could be borne by the private sector. In the past, government involvement in the form of direct financial aid had been available for treatment to both crop and rangeland. The federally sponsored cooperative grasshopper control program was now focused only on rangeland, both private and public (Dick S. Jackson, personal communication).

The acceptance of these new chlorinated hydrocarbon compounds was short lived. Almost as quickly as they appeared for control of rangeland grasshoppers, their use was discontinued. One of the initially attractive features of the chlorinated hydrocarbons, that of longevity, began to be recognized as a problem. The compounds began to accumulate in the food chain and thus posed a threat to not only the pests they were designed for but to nontarget organisms also. In 1962, Dieldrin, which had been used in cooperative rangeland grasshopper spray programs in 1960–62, was discontinued for use, along with other chlorinated hydrocarbons (Dick S. Jackson, personal communication).

In 1962, carbaryl in the form of the Sevin® 80 S spray formulation became available for use in the cooperative rangeland grasshopper programs. It was used on about 4,000 to 36,000 acres of rangeland annually from 1962 through 1967 (Foster et al. 1983). However, during this time, control was not as high or as consistent as that previously expected of the chlorinated hydrocarbons, and compatibility problems between the spray and aerial spraying systems were commonplace.

In the early 1960's, ultralow-volume (ULV) application—defined as less than 0.5 gal/acre (Maas 1971)—was refined for grasshopper control in the United States. By 1964, Malathion ULV® Concentrate had become the most frequently applied chemical spray for controlling grasshoppers on cooperative rangeland programs.

By 1972, the formulation of carbaryl had been greatly improved and the Sevin 4-Oil® formulation replaced the 80 S formulation as a recommended treatment in the rangeland grasshopper programs.

From 1979 through 1982, research led to the development of formulations of acephate sprays for use against grasshoppers. Acephate in the form of the Orthene® 75 S formulation was adopted as an option for controlling grasshoppers in the cooperative programs in 1982. However, it has been rarely used in the control programs to date. Compared to carbaryl and malathion, the mixing required for acephate made it less desirable.

Through the 1980's, malathion was the most frequently used spray for large-scale cooperative programs. Additional improvements in the formulation of carbaryl have increased its use so that today it is used almost as frequently as malathion in large-scale programs against grasshoppers in the United States.

The three chemical sprays currently approved by USDA's Animal and Plant Health Inspection Service (APHIS) for use on large-scale rangeland grasshopper control programs are acephate, malathion, and carbaryl.

Malathion

Malathion is the common name for the 0,0-dimethyl phosphorodithioate ester of diethyl mercaptosuccinate. It is a broad-spectrum organic phosphate insecticide–acaricide developed by American Cyanamid in 1950. Malathion is registered for control of a wide variety of insects on beef cattle, sheep, goats, swine, grain, fruit and vegetable crops, forests, rangeland, pastures, agricultural premises, poultry ranges, stored grains, and in homes and gardens.

The toxicity of chemicals is measured in relative terms by determining the amount of active ingredient (AI) (in weight) that will kill 50 percent of a test group of laboratory animals. This concept is referred to as the "acute oral LD_{50} (lethal dose)." The LD_{50} of malathion technical material on white albino rats is 1,375 mg per kg of the rats' body weight. This figure marks malathion as moderately toxic to mammals. Malathion exhibits slight to moderate toxicity to birds and moderate to high toxicity to some fish species and other aquatic organisms. It is highly toxic to most insects, including bees and all species of grasshoppers.

While several formulations of the pesticide are available, only the formulations of Cythion® ULV, Fyfanon® ULV, and Malathion ULV Concentrate have been used USDA/APHIS-managed cooperative programs.

For controlling grasshoppers on rangeland, malathion is typically sprayed at 8 fluid oz/acre. The per-acre dose of active ingredient at the application rate ranges from 0.58 lb to 0.61 lb, depending on the concentration of malathion in the particular formulation used.

Malathion provides control through both direct contact and ingestion, although when these types of mortalities are separated in experiments, ingestion results in a greater percentage of mortality (Pfadt et al. 1970).

Malathion is relatively nonpersistent in soil, water, plants, and animals. Residual activity (control) against grasshoppers can be seen for 2 to 5 days after treatment. Malathion is quick acting, usually producing high levels of control during the first and second days following application. When treatment occurs during good conditions for application, control can range from 92 to 96 percent.

Malathion should be used during warm and dry conditions. The air temperature for the expected daytime high should be higher than 80 °F, and rain should not be predicted for the day of treatment. With lower temperatures, the grasshoppers may feed less and be less likely to move into direct contact with spray droplets. Rain soon after an application can reduce mortality dramatically. Foster et al. (1981) discovered rain-related mortality rates as low as 33 percent.

An area of several thousand acres typically contains grasshoppers of as many as 40 different species. Because of the short residual activity of malathion, it is generally selected for use later in the season when the majority of the grasshopper species in an area to be treated have hatched. As a result, the earlier hatching species often have reached adulthood when the applications occur. In these cases, the overall average age of the population could typically be fourth instar to adult.

Waiting to treat a population until it is mostly made up of adults is not a problem unless the grasshoppers have started to mate and lay eggs. But once grasshoppers have reached the adult stage, by definition, forage loss in the area of treatment has taken place.

On small areas, such as "hot-spots," where only a few species may be predicted to occur or in a large area where only early season species are expected to be the problem, an earlier treatment of malathion targeted to third instars could be preferable. In outbreak years, when economic infestations of large acreages in numerous places within a State occur, timing all treatments ideally becomes difficult. In large outbreak years, malathion may be used later in the season because earlier treatments were logistically impossible. Malathion is most often used late in the season for quick control of older grasshoppers when conditions are hot and dry.

Carbaryl

Carbaryl is the common name for 1-naphthyl N-methylcarbamate. It is a broad-spectrum carbamate insecticide developed by Union Carbide in 1956. Carbaryl is registered for control of a wide variety of insects on fruit and vegetable crops, forests, rangelands, pastures, agricultural premises, poultry houses, horses, dogs, cats, and ornamental and lawn plants, and indoors. Carbaryl demonstrates low to moderate toxicity to mammals (acute oral LD_{50} of technical material on white albino rats, 500 mg/kg), low toxicity to birds, and moderate toxicity to fish, but extreme toxicity to aquatic invertebrates. It is extremely toxic to many insects, including bees and all species of grasshoppers.

The Sevin 4-Oil and Sevin 4-Oil ULV formulations of carbaryl have been used by the USDA/APHIS-managed cooperative programs. For controlling grasshoppers on rangeland, it is typically sprayed at 15 to 20 fluid oz/acre at 0.375 lb AI to 0.5 lb AI. Control is provided through both contact and ingestion, although when the types of mortalities are separated in experiments, ingestion provides the majority of the mortality (Lloyd et al. 1974).

Carbaryl is relatively nonpersistent in the environment. Its residual activity against grasshoppers lasts for 14 to 21 days. Carbaryl is slower acting than malathion or acephate. Depending on conditions, mortality during the first 2 days after treatment may range from 30 to 80 percent. Under good application conditions, mortality may reach 90 percent. However, mortalities ranging from 95 to 99 percent have been recorded in experiments with excellent application conditions.

Carbaryl can be used over a broader range of general climatic conditions than malathion or acephate. Although carbaryl performs well at temperatures in the 60–80 °F range, it kills slower at lower temperatures. This trait may not be as bad as it seems. Under cooler conditions, both grasshopper development and the rate of forage destruction decrease. The Sevin 4-Oil formulation is relatively resistant to removal by rainfall after the spray has dried on the vegetation.

In two major experiments where Sevin 4-Oil was applied to wet vegetation, mortalities eventually exceeded 90 percent. Subtle changes have been made in the formulation of Sevin 4-Oil during the last few years, leading up to today's Sevin 4-Oil ULV formulation. Along with improved handling characteristics, a trend toward slightly higher mortalities has accompanied these improvements.

Because of the residual activity of the Sevin 4-Oil ULV formulation, it can generally be selected for use both early and late in the season (third instar to adults). However, care must be taken not to use it against grasshoppers that are within a few days of laying eggs because the insects may lay eggs before dying.

Use of carbaryl spray against small hot-spots may not be advantageous if quick migration from the treated area is expected. However, if additional acres adjacent to the hot-spots are treated, use of carbaryl could be acceptable, especially if additional hatch is predicted.

As circumstances dictate, the 0.5-AI dose may be used for older instars and mature grasshoppers. The 0.375-AI dose may be used where younger stages of grasshoppers are present and early treatment can be accomplished or when lower or economically marginal densities of grasshoppers exist.

Where dense vegetation or difficult topography requires greater coverage, a volume of 20 fluid oz/acre should be used. A total volume-per-acre treatment as low as 15 oz/acre may be used when vegetation is sparse. The decision can be made only on a case-by-case basis and by the local personnel involved. The Sevin–ULV spray formulation is typically used under cool conditions in years when rain in the treatment area is not unusual.

Acephate

Acephate is the common name for 0,S-dimethyl acetylphosphoramidothioate, a broad-spectrum organic phosphate insecticide developed by Chevron Chemical Co. in 1972. Acephate controls a wide variety of insects on several grain and vegetable crops, forests, rangeland, pastures, grass, trees, shrubs, cotton, and ornamentals.

Acephate demonstrates low to moderate toxicity to most terrestrial and aquatic animals, including mammals (acute oral LD_{50} of technical material on white albino rats, 866 mg/kg). It is highly toxic to many insects, including bees and all species of grasshoppers.

While several formulations of the pesticide are available, only Orthene® 75S and Orthene Specialty Concentrate® will be addressed here. For controlling grasshoppers on rangeland, acephate is typically sprayed at an application dose of 0.094 lb of AI in 32 oz of water, plus an antidrift additive such as Orthatrol or Nalcotrol (at 9 fl oz per 100 gal of mix) and unsulfured molasses (at 3 percent of the total volume). The addition of unsulfured molasses to the formulation results in slightly quicker action. It is unclear whether this is a result of attractance, additional protection from photo degradation, increased anti-evaporation qualities, or a combination of these actions. Control is provided through both contact and ingestion. When the types of mortalities are separated in experiments, ingestion results in greater mortality (Foster et al. 1984).

In soil, acephate is readily degraded through biological activity: its half life is about 11 days in soils with moisture levels and organic content comparable to those in the West and Midwest. Residual activity against grasshoppers is intermediate, between that of malathion and carbaryl. Some activity can be seen for up to 10 days, but most mortality occurs by the fourth day after treatment. When treatment occurs during good conditions for application, mortality can range from 92 to 94 percent.

With acephate, maximum mortality is reached slower than with malathion but quicker than with carbaryl. Acephate can be used during warm and dry conditions. The air temperature for the expected daytime high should be higher than 75 °F, and rain should not be predicted for the day of treatment. Because of the longer residual activity compared to malathion, acephate can be used in some cases where the lack of residual activity would be a concern for malathion. Conditions for acephate's use more closely parallel those for malathion than for carbaryl. Acephate can be used on small hot-spots where some migration is expected and on third-instar to adult grasshoppers, provided that most females are not ready to lay eggs.

More is known about the efficacy of lower doses of acephate against grasshoppers than that of low-dose malathion or carbaryl. In some cases, such knowledge may allow greater flexibility in selecting lower dosages to fulfill economic considerations.

Duration of Control

When landowners or managers consider directly investing money to control grasshoppers on rangeland, one of the major questions is how long control will last following treatment. The question would not apply if large-scale outbreaks lasted for only 1 year, but they often last several years. The main question of control duration may be further divided into four basic questions:

1. What are the chances that grasshopper populations will remain as high or go higher next year?

2. If control measures are not applied and grasshoppers remain high, how long are they likely to stay high?

3. If control is used during an outbreak, how long are the benefits likely to continue?

4. What are some things that can jeopardize the length of control expected?

The answers to these questions vary with where you live and where your acreage is in the outbreak cycle. In the past, ranchers with rangeland prone to grasshopper infestations had to base decisions on intuition and experience. Now, particularly with the development of the Grasshopper Integrated Pest Management (GHIPM) Project, quantifiable data are available to provide a more precise decisionmaking process.

Kemp (1987) and Lockwood and Kemp (1987) and Lockwood et al. (1988) have published information on questions 1 and 2 for some counties of Montana and Wyoming. Their data are important. They found that the likelihood of grasshopper populations staying high or increasing from 1 year to the next is only about 56 percent in Garfield County, MT, but 96 percent in Johnson County, WY. In the absence of control, high populations are likely to stay high for 2.25 years in Gallatin County, MT, but up to 23 years in Sheridan County, WY.

Blickenstaff et al. (1974) and Pfadt and Hardy (1987) provided important clues to "best case scenario" answers to the question of control duration. In a study of the time interval between treatment and required retreatment of 1,200,000 acres of Wyoming rangeland, Blickenstaff's team reported an average retreatment rate of 3.8 percent per year. In other words, about 96 percent of the treated area probably enjoyed benefits for only 1 year, 92 percent for 2 years, and 81 percent likely received some benefits for at least 5 years. Similarly, Pfadt and Hardy (1987) reported at least partial protection of treated range for 3 to 6 years after treatment.

The above reports establish beyond doubt that the concept of multiple-year benefits is valid in some large cooperative programs conducted by State and Federal personnel. Such benefits are not guaranteed. Blickenstaff et al. (1974) reported six mechanisms that can negate, in total or part, the potential for future benefits:

1. Reinvasion by flight. This occurrence is a distinct possibility for highly mobile species like *Melanoplus sanguinipes,* which is a major component of infestation in some areas, like Arizona (Nerney 1960) or eastern Montana (Kemp 1992). However, in other areas, such as Platte and Goshen counties in Wyoming, *M. sanguinipes* comprised less than 5 percent of infestations that were suppressed for 3 to 6 years by treatments (Pfadt 1977).

2. Natural declines in untreated populations. The probability of this event is 100 percent minus the chances that infestation will stay the same or go up.

3. Occurrence of 2-year life cycles at high altitudes.

4. Extended hatching periods (note that this would be aggravated by poor timing of treatment or improper selection of a short-lived chemical when persistence is required).

5. Ability of survivors to increase rapidly (note that this would be aggravated by low levels of control).

6. Failure to treat infested areas in their entirety (note that APHIS prefers to treat entire infestations and has special provisions to allow such treatment).

In any one particular case, protection beyond the year of treatment depends on where in the outbreak cycle (buildup or decline) the program is conducted. If control tactics are not initiated until the populations are on the decrease, then protection is limited to the year of treatment because the population would be of no concern the next year (smaller or negligible population because of the continuing decrease). However, many large-scale treatments occur during the early or middle years of an outbreak. In these cases, multiple years of protection are expected and usually realized.

Conclusions

Traditionally, the use of chemical sprays against grasshoppers on rangeland has been that of a corrective tool. Sprays were used against grasshoppers in outbreak crisis situations as a last resort where the objective was to control the greatest number of grasshoppers.

With the development of the integrated pest management approach and the emerging technologies resulting from the GHIPM Project, chemical sprays are positioned for an expanded role in controlling grasshoppers. This new role will be preventive as well as corrective. Grasshopper treatments should be considered while populations are building. The historical mindset was one where managers waited for the pests to reach outbreak numbers before anything was done. In the future, the use of chemical sprays will be integrated with other strategies, such as managed livestock grazing and treatment of hot-spots for reducing damaging and outbreak-threatening populations of grasshoppers.

While enjoying an expanded role, the traditional use of sprays in emergencies probably never will be eliminated. Chemical sprays are but one weapon in the fight against grasshoppers, and pesticides will remain as an excellent insurance against damaging populations that require immediate attention in the form of fast-acting chemical control.

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