VII.3 Impact of Dimilin® on Nontarget Arthropods and Its Efficacy Against Rangeland Grasshoppers

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Introduction

Dimilin® (diflubenzuron) is a chitin-synthesis inhibitor and causes death in insects during the molting process (van Daalen et al. 1972, Post and Vincent 1973). Chitin, a nitrogenous polysaccharide, is the organic foundation of the exoskeleton of all insects and the entire phylum Arthropoda (Snodgrass 1935). Therefore, some concern exists that widespread use of diflubenzuron may affect not only the target insect pest but also nontarget arthropods that are essential for the diversity and stability of rangeland ecosystems. Other studies have shown the potential of diflubenzuron against rangeland grasshoppers (Foster et al. 1991 unpubl. and 1993 unpubl.).

Our key research objective was to determine whether diflubenzuron negatively affected the abundance and diversity of nontarget arthropods (including ants, spiders, predatory beetles, and pollinator bees) in rangelands, and if so to determine if the effect was greater than the effect of one of the current standard treatments. Another research objective was to develop additional data on the potential of diflubenzuron as an alternative insecticide against rangeland grasshoppers.

Previous studies indicate that diflubenzuron spares most nontarget arthropods. Ables et al. (1975) reported diflubenzuron to be harmless to a pupal parasitoid of the house fly. Compared to dimethoate-treated poultry farms in North Carolina, diflubenzuron-treated farms had greater parasitoid abundance and species diversity. In cotton fields, Keever et al. (1977) observed that arthropod predators belonging to orders Hemiptera, Coleoptera, and Neuroptera were not affected by diflubenzuron when it was sprayed aerially at 0.12 lb active ingredient (AI) per acre (0.14 kg AI per hectare). Wilkinson et al. (1978) evaluated various rates and formulations of diflubenzuron on adult and immature stages of selected parasitoids and predators found in cotton fields. The authors found test insects to be unaffected by diflubenzuron even at high concentrations except for immatures of a lacewing species.

In contrast, diflubenzuron may be detrimental to some freshwater crustaceans and immature aquatic insects (fig. VII.3–1). Miura and Takahashi (1974, 1975) observed temporary population reductions in tadpole shrimp, clam shrimp, water fleas, copepods, cladocerans, mayfly naiads, and midge larvae in treated (0.1 lb AI per acre) mosquito breeding areas in California. Adult aquatic beetles, spiders, and mosquito fish were not affected by diflubenzuron even at the highest rates tested. Farlow et al. (1978) studied the impact of diflubenzuron on nontarget organisms of a Louisiana coastal marsh. Those authors reported significant reductions in amphipods, dragonfly naiads, nymphs of corixid and notonectid bugs, as well as adult hydrophilid beetles in marshlands treated six times with 0.025 lb AI per acre (28 g AI per ha) over an 18-month period. On the other hand, significant increases were observed among mayfly naiads, larvae of noterid and dytiscid beetles, adult corixid bugs, and mosquito fish. Numerous immature and adult insects were listed as unaffected by the diflubenzuron treatments.

Figure VII.3–1—To minimize insecticide drift, spray booms are turned off well before this plane flies over a pond in the Great Plains. (Agricultural Research Service photo by John Kucharsky.)

The environmental fate and degradation of diflubenzuron in a laboratory model ecosystem, a soil bacterium, sheep liver microsomes, and ultraviolet light were investigated by Metcalf et al. (1975). They found diflubenzuron to be moderately persistent in organisms such as algae, snails, caterpillars, and mosquito larvae but efficiently degraded by mosquito fish, however. Ecological magnification may not be a problem: the lowest concentration of diflubenzuron was found in the mosquito fish, at the top of the model food chain. Sheep liver microsomes and the soil bacterium were not able to degrade diflubenzuron under the experimental conditions imposed.

Other studies have shown the potential of diflubenzuron against rangeland grasshoppers. Foster et al. (1991 unpubl.) reported aerial treatments of diflubenzuron spray at 0.015, 0.030, and 0.045 lb AI per acre to reduce second- and third-instar grasshoppers as well as a standard treatment of carbaryl (0.5 lb AI per acre) after 1 week. Foster's team showed reductions for all treatments in the range of 94 to 96 percent after 2 weeks. Under simulated control program operational conditions, Foster et al. (1993 unpubl.) reported two formulations of diflubenzuron at 0.0156 AI per acre and a carbaryl standard performed equally well (control ranged from 87 to 91 percent).

Our Study in South Dakota

Different rates and formulations of were tested in an open rangeland near Ludlow (Harding County), SD, during the 1993 season. Dimilin 2F (0.0075 and 0.015 lb AI/acre) and Dimilin 25W (0.015 lb AI/acre) were compared with Sevin® 4-Oil (0.5 lb AI/acre) and untreated plots. The lower rate of Dimilin 2F was evaluated only for efficacy against grasshoppers. The remaining treatments were evaluated for impact on nontarget arthropods *and* efficacy against grasshoppers. We used a completely randomized design with each treatment replicated four times. A fixed-wing airplane applied chemical treatments over 40-acre plots from July 2 to July 7, 1993.

Our study used pitfall traps to sample soil surface-associated nontarget arthropods (ants, spiders, predatory beetles, and scavenger beetles). A pitfall trap consisted of a wide-mouth 1- qt canning jar filled with approximately 4 inches of mineral oil. Each pitfall trap was buried so that the opening was flush with the soil surface. The oil killed and temporarily preserved crawling insects that fell into the traps. Six pitfall traps spaced 15 ft apart and arranged in hexagonal pattern were installed near the center of each 40-acre plot.

Malaise traps were used to sample flying nontarget arthropods such as parasitic and predatory wasps, lacewings, flies, and pollinator bees. Each malaise trap was a 12- by 4- by 6-ft rectangular tent made of nylon screen that intercepted and directed flying insects to killing jars. Two malaise traps were placed near the center of each 40-acre plot.

We used rings to count live grasshoppers (fig. VII.3–2). Forty aluminum rings, each 0.1 m^2, were arranged in grids near the center of each plot. We counted grasshoppers within each ring using a tally counter. Sweep-net samples determined grasshopper species and their age composition.

Figure VII.3–2—A grasshopper's eye view of the kind of ring field crews use to delimit a sampling spot before counting resident 'hoppers. (Agricultural Research Service photo by John Kucharsky.)

Sampling for nontarget arthropods was carried out before and after treatment application. The malaise and pitfall traps were run a week before treatment, then resumed 1 week after the last chemical treatment application. Traps were maintained continuously thereafter, and catches were collected at weekly intervals for 10 weeks from July to September. Plot and trap location markers remained onsite over the winter months, and an additional sample was collected about 1 year after treatment. We took grasshopper counts from rings and sweep-net samples (fig. VII.3–3) once before chemical treatment and at weekly intervals for 7 weeks after treatment. Additional grasshopper counts and samples were taken the end of season (11 weeks after treatment).

We sorted nontarget arthropod samples and counted them in the laboratory. Arthropods were identified to family level then grouped according to their biological function (such as predator, parasite, scavenger, or pollinator). Identification of ants to the species level (Wheeler and Wheeler 1963) was used to calculate a measure of species diversity referred to as the probability of interspecific encounter (PIE) (Hurlbert 1971, Washington 1984).

Figure VII.3–3—Sweep-netting grasshoppers is a labor-intensive but time-tested method for sampling insect populations. (Agricultural Research Service photo by John Kucharsky.)

Hurlbert defined PIE as the probability that two individuals encountered at random in a community will belong to different species. In our present paper, PIE may be interpreted as the probability that two individual ants randomly encountered in rangeland will be of different species. The higher the probability, the more diverse, and presumably more stable, is the ant community.

Findings and Discussion

Arthropods collected from the experimental site were grouped arbitrarily as follows: (1) soil surface-associated nontarget arthropods, (2) flying nontarget arthropods, and (3) grasshoppers. Each group was sampled using techniques appropriate for their mobility and biological characteristics.

Impact of Dimilin on Soil Surface-Associated Nontarget Arthropods.—There were four major groups of soil surface-associated arthropods: (1) ants (order Hymenoptera: family Formicidae), (2) spiders (order Araneae: families Agelenidae, Amaurobiidae, Clubionidae, Dictynidae, Gnaphosidae, Hahniidae, Lycosidae, Mimetidae, Philodromidae, Salticidae, Tetragnathidae, Theridiidae, and Thomisidae), (3) predatory beetles (order Coleoptera: families Carabidae, Cicindelidae, Histeridae, Meloidae, and Staphylinidae), and (4) scavenger beetles (order Coleoptera: families Scarabaeidae, Silphidae, and Tenebrionidae).

In terms of biological function on the rangeland ecosystem, ants may be regarded as both general predators and scavengers (Wheeler and Wheeler 1963). All spiders are predators (Kaston 1972). Beetles belonging to families Carabidae (ground beetles), Cicindelidae (tiger beetles), Staphylinidae (rove beetles), and Histeridae (hister beetles) are also general predators (Borror and DeLong 1964). Blister beetle (Meloidae) larvae feed on grasshopper eggs, but adults are considered pests of certain crops. Scavengers were composed of families Scarabaeidae (scarab beetles), Silphidae (carrion beetles), and Tenebrionidae (darkling beetles). Certain scarabs like the dung beetle feed on cattle manure; carrion beetles feed on dead animal carcasses. Darkling beetles feed on decaying plant materials but some, like the false wireworms, feed on the roots of wheat and are considered pests. All arthropods mentioned above are important components of the rangeland food chain because they are potential food for vertebrate animals like birds, frogs, mice, moles, and shrews.

In general, Dimilin 2F (0.015 lb AI/acre), Dimilin 25W (0.015 lb AI/acre), and Sevin 4-Oil (0.5 lb AI/acre) did not significantly reduce the number of ants, spiders, predatory beetles, or scavenger beetles from 7 to 76 days after treatment (DAT). Even at 1 year after treatment (350 to 357 DAT), no significant reductions in any of the soil surface-associated arthropods were detected. Ant numbers temporarily (49 to 55 DAT) declined after Dimilin 2F and Sevin 4-Oil treatments by 43 and 56 percent, respectively. The temporary decline in ant numbers may or may not be due to chance alone. What is important is that ant numbers rebounded immediately and that in most of the sampling periods, the Dimilin and Sevin treatments were consistently shown to have no detrimental effects on ant numbers. Additionally, ant diversity (based on PIE calculations) was not significantly affected by the Dimilin or Sevin treatments from 7 to 357 DAT. This result may indicate that no ant species was particularly susceptible to the Dimilin and Sevin treatments at the dosages studied.

Impact of Dimilin on Flying Nontarget Arthropods.— The arthropods collected in malaise traps were subdivided into the following 3 groups: (1) pollinator bees (order Hymenoptera: families Apidae, Halictidae, Colletidae, Andrenidae, and Megachilidae), (2) predators (order Hymenoptera: families Sphecidae, Pompilidae, and Vespidae; order Diptera: families Asilidae and Therevidae; order Coleoptera: family Coccinelidae; order Neuroptera: families Chrysopidae, Hemerobiidae, and Myrmeleontidae), and (3) parasites (order Hymenoptera: families Ichneumonidae, Braconidae, Tiphiidae, Chalcididae, Chrysididae, Mutillidae, Proctotrupidae, and Pteromalidae; order Diptera: families Bombyliidae and Nemestrinidae).

In general, no significant reductions in flying nontarget arthropods were observed in the Dimilin 2F, Dimilin 25W and Sevin 4-Oil treatments. Dimilin 25W reduced predator numbers during the 15- to 20-DAT period by 59 percent. Predator numbers subsequently recovered, and in most of the sampling periods, no significant reductions in predator numbers were observed. A temporary decline of 18 percent in parasite numbers was recorded in the Dimilin 2F treatment at 35 to 41 DAT. No significant reductions were observed in the number of pollinator bees. About 1 year after treatment (350 to 357 DAT), no significant reductions in numbers of predators, parasites or pollinators were observed for any treatment.

Efficacy of Dimilin Against Rangeland Grasshoppers.—Nineteen grasshopper species were present on the 800-acre experimental area immediately before spraying (0 DAT). *Melanoplus sanguinipes* F., *M. infantilis* Scudder, and *Trachyrhachys kiowa* Thomas were the dominant grasshopper species. Grasshopper age structure was 46.8, 24.6, 23.5, 3.7, 0.2, and 0.1 percent for 1st, 2d, 3d, 4th, and 5th instars and adults, respectively, at 0 DAT. This age composition was ideal for a chitin-synthesis inhibitor like Dimilin because the majority of grasshoppers had several molts remaining in their life cycle.

All Dimilin treatments were comparable to Sevin 4-Oil starting at 14 DAT. From 14 DAT to 49 DAT, grasshopper numbers in the Dimilin- and Sevin-treated plots were significantly lower than those of the untreated plots. Dimilin provided consistent grasshopper control from 14 DAT to 49 DAT; Sevin-treated plots revealed temporarily elevated grasshopper numbers at 35 DAT and 42 DAT. No differences between plots treated with Dimilin at different rates or formulations were detected after 14 DAT.

Dimilin was not as effective as Sevin at 7 DAT. This delayed response is most likely due to its mode of action. Dimilin exerts its effect at molting while Sevin (a cholinesterase inhibitor) acts at any time of development. Grasshopper population reductions (adjusted for natural population changes) in Dimilin-treated plots ranged from 65 percent to 90 percent from 14 DAT to 49 DAT. In this study, all treatments lost effectiveness against grasshoppers by 76 DAT. For more information about diflubenzuron efficacy on rangeland grasshoppers, see chapter VII.2, “Dimilin Spray for Reducing Rangeland Grasshopper Populations.”

In summary, our study showed that Dimilin and Sevin sprays did not appear to significantly reduce the abundance of soil-surface-associated or flying nontarget arthropods while providing good grasshopper control in rangeland. Our observations extended only through about 1 year after treatment. Interpretation of our results is limited to this period.

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