Sulfonylureas Target ALS Enzyme to Control Grasses, Broadleaf Weeds

By Sowmya Mitra

The herbicidal properties of sulfonylureas (SU's) were first reported in 1966 (Koog, 1966). The early SU's were derivatives of triazine herbicides. George Levitt of DuPont noted that SU's having aniline as the aryl group exhibited weak plant-growth regulatory activity while the aminopyrimidine derivative displayed very high biological activity (Levitt, 1983; Sauers and Levitt, 1984).

Soon companies produced SU herbicides having up to 100 times the activity of conventional herbicides, prompting one of the most exciting breakthroughs in the field of herbicide research in several decades (Kearney and Kaufman 1988). All the SU herbicides have a general backbone consisting of an aryl group, a SU bridge and a nitrogen-containing heterocycle. Most of the SU herbicides have low acute oral, dermal and inhalation toxicity in mammals. The acute oral lethal dose (LD_{50}) value of table salt in rats is 3,000 milligram per kilogram while most of the SU herbicides have LD_{50} values greater than 4,000 milligram per kilogram of body weight (Sax Irving, 1979). Most SU's are not mutagenic or teratogenic, and they exhibit low toxicity to fish, wildlife, honeybees and dogs (Kearney and Kaufman, 1988). Low toxicity, combined with very low application rates of the SU's (2 to 35 grams actual ingredient per hectare), makes them especially attractive from an environmental and human health standpoint.

The potential of ground water contamination through seepage, percolation, run-off or infiltration is low.

How do they work?

SU's are potent inhibitors of plant growth, root and shoot growth in sensitive seedlings. Depending on the plant species, dose and environmental conditions, various secondary plant responses often develop. Secondary responses as enhanced anthocyanin formation, loss of leaf nyctinasty, abscission, vein discoloration, terminal bud death, chlorosis and necrosis have been reported (Kearney and Kaufman, 1988). These secondary effects are often slow to develop and sometimes do not occur until a couple of weeks or more following treatment.

A study of the mode of action of SU's was first reported by Ray (1982) and Hatzios and Howe (1982). Concentrations of various SU herbicides as low as 2.8 nM (1 ppb) significantly inhibited root growth, and higher concentrations effectively reduced shoot growth within two to four hours of treatment.

SU herbicides inhibit the activity of an enzyme called acetolactate synthase (ALS), also known as acetohydroxyacid synthase (AHAS), which is a key enzyme in the branched chain amino acid biosynthetic pathway of bacteria, fungi and higher plants. The branched chain amino acid pathway is responsible in producing three essential amino acids, valine, isoleucine and leucine.

All the SU herbicides display unusual "slow-binding" behavior with the enzyme, and this behavior may help explain the efficacy of the herbicides. These herbicides are also called as ALS or AHAS herbicides.

Herbicide selectivity

The differential response of SU herbicides to different plants led to the study of selectivity of these classes of herbicides. Differences in sensitivity to chlorsulfuron of up to 4,000-fold were observed between highly sensitive broadleaf plants, such as mustard, sugar beet, soybean and cotton (Sweetser et. al., 1982).

These large differences in sensitivity could not be explained in terms of differences in penetration or translocation; nor could they be explained by differences in the sensitivities of the ALS enzymes from these plants to chlorsulfuron (Ray, 1984).

Resistance to these herbicides has been developed through a number of different procedures, and the mechanism of resistance is through changes in sensitivity of the enzyme to the herbicides (Stidham, 1991). The herbicides

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Sulfonylureas promise to be a great tool to control sedges, such as those in this photograph from a sod farm in Australia.

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have been reported to be competitive with the amino acids for binding to the enzyme.

Acetolactate synthase inhibiting herbicides bind to the regulatory site on the enzyme (Subramanian et. al., 1991).

In 1987 an SU herbicide-resistant prickly lettuce biotype was identified in a no-till, continuous winter wheat field that had been treated with SU's for five years near Lewiton, Idaho, in April 1987 (Mallory-Smith et. al., 1990).

SU resistance has also been reported in natural populations of kochia [*Kochia scoparia* (L.) Schrad.], Russian thistle (*Salsola iberica*, Sennen and Pau), common chickweed [*Stellaria media* (L.) Vill.] (Thill et. al., 1989), perennial ryegrass (*Lolium perenne* L.) (Smith et. al., 1990) and rigid ryegrass (*Lolium rigidum* Gaudin) (Heap and Knight, 1986). Mallory-Smith et. al., (1990) reported that the SU herbicide resistance trait was controlled by a single nuclear gene.

Applications in turfgrasses

SU's can be used for selective post-emergence control of certain sedges, grasses and broadleaf weeds in warm-season turfgrasses like bermudagrass and zyosiagrass (Yelverton, 2004). These herbicides can also be used as tools in a successful overseeding program.

They can be used on the bermudagrass before overseeding with cool-season turfgrasses like perennial ryegrass or *Poa trivialis* in the fall or can be used during spring transition to remove the cool-season turfgrass in the spring.

Several SU herbicides have been registered for use on golf courses, such as metsulfuron (Manor or Blade), chlorsulfuron (Corsair), foramsulfuron (Revolver), halosulfuron (Manage), rimsulfuron (TranXit GTA), flazasulfuron (Katana), and sulfosulfuron (Certainty). Another new herbicide, bispyribac-sodium (Velocity), has also been introduced which works on the same ALS enzyme.

SU herbicides are translocated via the phloem in the plants to the storage organs like rhizomes, stolons, tubers or bulbs and hence they are very effective in controlling hard-to-control weeds like quackgrass (*Elytrigia repens*) or different sedges.

Herbicides like trifloxysulfuron (Monument) have been reported to control yellow (*Cyperus esculentus*) and purple nutsedge (*C. rotundus*) as well as green kyllinga (*Kyllinga brevifolia*) and false green kyllinga (*K. gracillima*) (Yelverton, 2004).

Sulfosulfuron (Certainty), bispyribac-sodium (Velocity), and trifloxysulfuron (Monument) have been reported to effectively control annual bluegrass in non-overseeded bermudagrass stands.

Benefits of using SU's

These herbicides have very low rates of application, low mammalian toxicity and are very selective in nature. They can be used to control sedges, grasses and broadleaf weeds with single or sequential applications.

Since these herbicides effect the production of essential amino acids, the symptoms develop slowly and the speed at which they control cool-season grasses or weeds during overseeding can vary based on the products and environmental conditions.

Superintendents, sports turf managers, and landscape maintenance managers can use these herbicides as tools to achieve a successful overseeding program or spring transition or control various difficult-to-control weeds.

Some of the SU herbicides absorb very strongly on clay and organic matter under low pH conditions so they are quite safe under slightly acidic conditions. Under alkaline pH conditions these herbicides are desorbed into the soil solution and can be taken up by the turfgrasses leading to injury. The portion of the herbicide present in the soil solution generally causes phytoxicity since it is easily taken up by the turfgrass roots.

Lateral movement or tracking of these herbicides might injure sensitive turf. Turfgrasses grown on coarse textured soils like sandy soils and low organic matter soils are more prone to injury with SU herbicides. Applications should be made to actively growing weeds in order to get optimum weed control since the herbicide

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has to be absorbed and translocated by plant tissues to work effectively.

SU herbicides or any other ALS or AHAS inhibiting herbicides should not be used continuously over a long period of time. These herbicides should be rotated with other herbicides which have different modes of action, such as pronamide (Kerb), which inhibits mitotic cell division in sensitive plants.

Conclusions

The discovery of SU herbicides is one of the most exciting breakthroughs in the field of herbicide research in several decades.

With their unprecedented herbicidal activity, the application rates have plummeted to grams rather than kilograms per hectare. Thus the potential of groundwater contamination through seepage, percolation or infiltration is also very low.

The site of action of the SU's has been pinpointed as the enzyme acetolactate synthase (ALS). Inhibition of this enzyme results in cessation of production of the three essential amino acids — valine, leucine and isoleucine. This leads to retarded growth and eventually plant death. The absence of this enzyme in mammals helps explain low toxicity of the SU's. Hence, they can be regarded as safe herbicides (LD_{50} greater than 4,100 milligram per kilogram of body weight).

All plants contain the target enzyme, making them prone to attack, but the ability of these herbicides to control grasses in a stand of monocotyledonous plants like turfgrasses has been a challenging job. Plant tolerance has been credited to the ability of some plants to rapidly convert the herbicide to inactive products. This inactivation occurs so rapidly that the active molecule never reaches the enzyme in sufficient quantities to effectively inhibit it.

SU's degrade under field conditions at rates similar to and often faster than conventional herbicides. Chemical hydrolysis and microbial breakdown are the main modes of dissipation.

The SU's are weak acids and under acidic soil conditions often undergo rapid dissipation by chemical hydrolysis. Under alkaline soil conditions microbial breakdown is the predominant dissipation method.

With the help of mutant forms of the acetolactate synthase gene that codes for insensitive forms of the enzyme, it is possible to work on genetic engineering of plants with high levels of SU resistance.

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