Table 1. Costs and benefits per acre from operating sprayer foam marker system.

I. BENEFITS	
1. Cost Savings	
.45 lbs. less 2,4-D × $2.50/lb.	$1.13
.225 lbs. less Atrazine × $3.00/lb.	.68
less sprayer operating time and use	.12
2. Annual Forage Increase	
.088 AUM's × $8.36/AUM[a]	.74
Total First Year Cost Savings	1.93
Total Forage Benefits (Present Value of $.74 for 10 years, 10%)	4.55
TOTAL DISCOUNTED BENEFITS PER ACRE	$6.48
II. COSTS	
Additional Spraying Labor	$ .00
Additional Fuel	.00
Additional Repairs	.03
Foam	.12
Depreciation ($.36/hr. × .208 hours)	.07
Interest ($.038/hr. × .208 hours)	.01
TOTAL COST/ACRE	$ .23
III. BENEFITS/COST ANALYSIS	
Total Discounted Benefits/Acre	$6.48
Total Foam Applicator Costs/Acre	.23
NET PRESENT VALUE PER ACRE	$6.25
BENEFIT/COST RATIO ($6.48/$.23)	

[a]Reflects the average lease rate paid for pasturing cattle on privately owned non-irrigated lands during 1982 (USDA/ARS 1982).

Because the foam marker system would eliminate most skips and areas of poor brush kill, use of the marker system could also be expected to result in additional forage production. We have estimated a conservative forage benefit of 3.5 AUM's per year for 10 years for a 40-acre plot located on big sagebrush range sites. This represents a .088 AUM benefit per acre.

Total per acre benefits of the foam marker system are estimated at $6.48. After the $.23 per acre foam marker operating and investment cost is subtracted, the net present value of using the foam marker is estimated to be $6.25 per acre. The benefit/cost ratio is estimated at 28.2:1.

The foam marker system is a very economical way to improve sagebrush kill while spraying. Just as importantly the needed investment is relatively small, approximately $1,000 for tank, compressor, and foam distribution system.

DEADLINE DATES FOR *RANGELANDS* AND *JRM*

Items such as columns, advertisements, announcements, lists, and reports must be in the Denver office by the following dates to ensure publication in the respective issues of *RANGELANDS:*

April—**March 5**
June—**May 6**
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October—**Sept. 3**
December—**October 28**

Position announcements must be in the Denver office by the following dates to be published in the respective issues of the *JOURNAL OF RANGE MANAGEMENT:*

March—**February 5**
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Publications will normally be mailed by the 11th of the month of publication. Allow at least 2 weeks for delivery in the US.

Tebuthiuron-Environmental Concerns

W.E. Emmerich

Through mismanagement, abuse and neglect, many millions of once productive rangelands have been invaded by undesirable brush species, greatly reducing rangeland productivity. The controlling of unwanted plants has been one factor in our ability to greatly increase our production of food. Herbicides represent one tool that has been used for brush control in rejuvenating deteriorated rangelands. Air Products and Chemicals, Inc. first synthesized and discovered the herbicidal properties of tebuthiuron in the early 1970's. Eli Lilly and Company, through its Elanco Division, has promoted tebuthiuron, under the trade name of Graslan®[1], as a herbicide for selective control of woody brush species on rangeland and permanent pastures. The Environmental Protection Agency (EPA) has recently registered

Editor's Note: William Emmerich is a soil scientist at the USDA-ARS, Southwest Rangeland Watershed Research Center, Tucson, Arizona. This paper is a summary of some of his research studies.

[1]This paper reports results of research only. Mention of a herbicide in this paper does not constitute a recommendation by the USDA. Mention of trademarks or proprietary products does not constitute a guarantee or warranty of the product by the USDA, and does not imply their approval to the exclusion of other products that may also be suitable.

tebuthiuron for use as a herbicide for the control of woody brush plants throughout the United States.

Every chemical synthesized by man has the potential to be of great benefit or detriment. If the herbicide tebuthiuron is to be used on rangelands for brush control, let's look at what is known about the herbicide, its benefits, and possible environmental concerns with its usage.

Properties of Tebuthiuron

Tebuthiuron is a colorless, light-stable solid that melts about 325°F and thermally decomposes into its chemical parts at, or slightly above, its melting temperature. Its vapor pressure is extremely low, hence there is little volatilization into the atmosphere. Tebuthiuron solubility in water is 2,300 parts per million. This is higher than most other herbicides, which suggests that there is a greater potential for transport from the site of application through a soil profile or in runoff water. Formulations of tebuthiuron are an 80% active ingredient as a wettable powder, 20 and 40% active ingredient in pellets, and 14% active ingredient as Brush Bullets.™. Aerial application of tebuthiuron pellets is the most common method used for application on rangeland and pastures.

Toxicity of Tebuthiuron

Tebuthiuron is taken up through the plant roots and translocated to the leaves. Research studies, with leaf cells from navy beans, indicate that tebuthiuron inhibits photosynthesis in the leaves and prevents plants from using the sun's energy for growth. In sensitive plants, leaves become chlorotic, exhibit symptoms of aging, and are shed. Cycles of shedding and regrowth of new leaves continue until the carbohydrate energy reserves are exhausted and the plants die. Several of these cycles, which usually coincide with significant rainfall events, may occur before the death of the plants. Generally, at lower concentrations of tebuthiuron, woody brush species are much more sensitive than grasses or forbs. Also, brush species with shallow root systems, that can easily take up the surface-applied tebuthiuron, are more susceptible than deep-rooted species.

Studies with cattle fed tebuthiuron for 162 days showed no blood serum or other pathological changes. Only the cattle fed at the highest rate showed a lower weight gain than the control group. Since tebuthiuron is a soil-surface applied herbicide, cattle may ingest tebuthiuron in the grass from treated areas. The highest concentration reported in grasses is one fifth the concentration that produced the lower weight gain. Concern over cattle ingesting the tebuthiuron in grass could be eliminated by keeping the cattle off the treated areas for a longer period of time. An interesting, but unexplained, observation, that a number of researchers have made, is that cattle will graze preferentially on grass that is in a tebuthiuron-treated area of a pasture as opposed to the nontreated areas, and generally show a greater weight gain.

Toxicological studies with tebuthiuron on nontarget animal and aquatic species have indicated a low order of toxicity. A single oral dose of tebuthiuron to mice, rats, rabbits, dogs, and ducks was readily absorbed and metabolized. Essentially, all the tebuthiuron and its metabolites were excreted in the urine and feces of the animals within 96 hours, indicating no accumulation. In other single, high-oral dosage studies, it was found that 13 times more tebuthiuron than nicotine was required to produce a 50% kill of the rats in the study (LD_{50}). A 3-month study, with rats and dogs fed diets containing varying amounts of tebuthiuron, produced slower body-weight gains and reductions in growth rates only at the high dosage rate. Once the tebuthiuron was removed from the diet, they returned to normal growth patterns. A 2-year long study on rats and mice for carcinogenic properties of tebuthiuron revealed no evidence of elevated numbers of tumors and produced the same type of reduced body weights as in the 3-month study.

The potential for tebuthiuron to interfere with reproductive processes was studied with rats and rabbits over a 3-generation reproductive period to test for any carry-over effects from one generation to the next. The only effect found was recurring, slower rate of weight gain. In all of the studies with reduced weight gains, the suspected cause was a change in the pancreas. A specific study on rats has shown a change to occur in the pancreas, which is responsible for producing digestive enzymes. Once the tebuthiuron was removed from the diet, the changes in the pancreas were completely reversible, and normal weight gains were observed. Long-term toxicity of tebuthiuron of fathead minnow and rainbow trout embryolarvae was assessed with a concentration of tebuthiuron at least 50 times greater than has been found in all but one runoff study, with no observed effects.

Fate of Tebuthiuron

With the release of any chemical into the environment, there is concern as to its fate. With tebuthiuron, the major concerns are its transport from the site of application and persistence in the soil. Movement of tebuthiuron from the soil surface can occur in three ways: (1) volatilization into the atmosphere, (2) in surface runoff water, and (3) in water moving through the soil. Because of its low vapor pressure, volatilization into the atmosphere is low. Also, because tebuthiuron is a solid, which is applied to rangelands almost exclusively in pellet form, there is little chance for drift, as with aerially applied liquids.

The relatively high solubility of tebuthiuron in water, compared to other herbicides, makes it possible for easier transport in surface runoff water or by leaching through a soil profile. The highest concentration reported in runoff water from a tebuthiuron-treated watershed was 5 parts per million. This high concentration was the result of a 1.1 inch rainfall event that occurred only 2 days after application. Even this high concentration was one half the concentration used to test the long-term toxicity to fathead minnow and rainbow trout embryolarvae. Almost all of the other runoff studies had maximum concentrations in the runoff water at 0.1 part per million or less. Of the studies that determined the total amounts of tebuthiuron removed in runoff water, the maximum was 2% of the total applied. These studies do indicate that tebuthiuron is transported in runoff water from treated areas, but that the concentrations and total amounts were small.

The transport of tebuthiuron through a soil profile has been investigated in a number of studies. The deepest reported movement in a soil profile was 24 inches in 2 years, after a total of 91 inches of precipitation. Movement of tebuthiuron in soils seems to be controlled by the amount of clay, organic matter, and total precipitation. As the clay and organic matter content of a soil increases, the mobility of tebuthiuron in the soil decreases; but greater precipitation increases tebuthiuron movement through the soil. Potential ground water pollution from this small amount of tebuthiuron movement in the soil seems highly unlikely. Also, tebuthiuron is not applied on a yearly basis, as are many herbicides and insecticides; hence, there is no continual source for movement or accumulation in the soil. Some movement of the tebuthiuron in soils is necessary for the herbicide to move to the plant roots for uptake.

Once tebuthiuron has leached into the soil surface layers, the environmental concern is how long it will be there. The decomposition rate of tebuthiuron in soil can be extremely variable. The reported half-life of tebuthiuron in soil (time required for half of the tebuthiuron to decompose in soil) has a range of 11 to 61 months. The factors that seem to control the rate of decomposition of tebuthiuron are soil temperature and moisture. The general trend is that the higher the soil temperature and moisture, the greater the decomposition rate. In a relatively low precipitation area of Arizona, it has been estimated that the time required for tebuthiuron to reach a nondetectable level in soils from decomposition is between 3 and 7 years. The reason for this large time range is that two methods, conservative and liberal, were used. The two methods were believed to then bracket the possible time required for decomposition to take place because of the large variability in precipitation and temperature that can occur. Slow decomposition rates in soils can be advantageous in that less tebuthiuron is needed to kill the brush and new brush seedling establishment is suppressed or prevented. From an environmental standpoint, a chemical that stays in the soil for a long period of time is not desirable, even if this characteristic increases its effectiveness. At least with tebuthiuron, its movement in the soil is minimal.

Conclusions

Tebuthiuron can control many brush species on rangelands, and may greatly increase forage production; but, as with the use of any herbicide, there is always a certain amount of risk involved for the benefits we derive. Every day, millions of people drive to work in their automobiles with the risk of getting into an accident, but also with the benefit of fast, convenient transportation. Our present scientific knowledge indicates that, for tebuthiuron, the risk is low and, as with safe driving, careful use of the herbicide can lower the risk even more. We must continue to study all possible areas where the use of tebuthiuron, or any other herbicide, may cause problems. Let's look at it this way: scientific studies have shown that nicotine is 13 times more toxic to rats than tebuthiuron. How many millions of Americans are smoking every day, and dying from it? The user of tebuthiuron must decide if the benefit from its use is worth the risk.

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