GLYPHOSATE AND 2,4-D: THE IMPACT OF TWO HERBICIDES ON MOOSE BROWSE IN FOREST PLANTATIONS

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Conifer plantations in northeastern Minnesota are important browse areas for moose (*Alces alces*). The U.S. Forest Service has recently shifted to glyphosate (Roundup) as the predominate herbicide for controlling hardwood shrub and tree competition in plantations. Glyphosate is a systemic herbicide that usually kills the entire plant, so little resprouting occurs. The previously preferred herbicide, 2,4-D, generally left roots alive that resprouted.

We sampled available browse in glyphosate and 2,4-D treated plantations. Three years after spraying, the glyphosate treated plantations averaged only half the available browse as the 2,4-D treated plantations. Grass and raspberries (*Rubus* spp.) are not controled the year after spraying with glyphosate because this herbicide has no residual effects. We could not measure long-term comparative effects because glyphosate was not used in this region before 1981. This report covers only the first year of a 2-year study.

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In forest management, herbicides are used to control herbaceous and shrub species that compete with planted conifers. In this paper the term "shrub" refers to deciduous shrubs and young trees. Herbicides used for competition control often indirectly impact wildlife by altering the existing plant community, hence the browse supply. In our study area, winter track counts showed moose were

attracted to conifer plantations (Weil 1983). Herbicides are usually applied at least once during the life of a plantation. Impact on vegetation varies widely among different herbicides. Carefully planned herbicide treatments can increase browse production (Krefting and Hansen 1969, Mueggler 1966). Conversely, some herbicides kill most broad-leaf woody plants. In fact Braathe (1978) suggested controlling high moose populations in Norway by reducing their food supply with the herbicide glyphosate.

Glyphosate, N-(phosphonomethyl)glycine, (product name Roundup®), was first available for experiment in 1971 and was first registered in Canada in 1976 for agricultural use (Sutton 1978). Forestry applications were soon explored. In Norway, glyphosate replaced 2,4,5-T as the most commonly used herbicide for competition control after the latter was banned in 1973. By 1979, glyphosate was applied over approximately 10,000 ha/year there by helicopter, tractor, or hand-held equipment (Lund-Hoie 1980). In the U.S., after 2,4,5-T was banned by the federal government for shrub control, 2,4-D became the predominate forest management herbicide. Glyphosate was first registered in the U.S. for non-crop uses and made commercially available in 1974. Sutton (1978) reported that glyphosate had good potential for forestry use because it is only about one tenth as toxic to people and wildlife as 2,4-D, is strongly immoblized by soils, and is readily biodegradable. Glyphosate is now widely used in U.S., Canadian, and Norwegian forest management.

Glyphosate is a systemic herbicide taken up through the leaves and translocated throughout the plant with no soil or root uptake

(Newton and Knight 1981). If applied properly, it kills the entire plant, eliminating later sprouting from the roots. Weather conditions and target plant status for maximum control include an air temperature of 18-20° C, high relative humidity, and active transpiration (Lund-Hoie 1980, Weed Sci. Soc. 1983). Rainfall within a few hours after application may reduce or eliminate effectiveness (Weed Sci. Soc. 1983). Glyphosate has a clear threshold effect; the result is either full effect or none at all (Lund-Hoie 1980).

Several studies (Lund-Hoie 1980, Newton and Knight 1981, Sutton 1978, USDA 1977, Wendel and Kochenderfer 1982) demonstrated that glyphosate provides long-lasting control of a wide range of competing shrubs. Full effect or deterioration of woody tissue may take 1 to 2 years (Lund-Hoie 1980). Glyphosate does not control herbacious species as effectively, because it has no residual activity and plants such as raspberry, grass and bush honeysuckle (*Diervilla lonicera*) germinate soon after treatment. These and other herbaceous weeds seem to grow especially well in the absence of shrub competition (Campbell 1984, Sutton 1978).

In Minnesota and Wisconsin, a survey of current forest herbicide users showed Roundup was frequently used for competition control in red pine (*Pinus resinosa*), white spruce (*Picea glauca*), and black spruce (*Picea mariana*) plantations (Alm 1984). The users reported excellent control for most shrubs such as quaking aspen (*Populus tremuloides*), beaked hazel (*Corylus cornuta*), and cherry (*Prunus*

spp.), and more limited control for raspberry and grass. In northern Minnesota, public and private forestry operators together estimated that in 1983 glyphosate was used to release 3642 ha (9000 acres) of conifer plantations.

In 1981, Superior National Forest first used glyphosate for shrub control; up to that time 2,4-D had been the predominate herbicide. Between 1981 and 1985, approximately 803 ha (2000 aces)/year were treated with glyphosate.

Little information exists on the impacts of glyphosate on forage. This study investigates the effects of two herbicides, glyphosate and 2,4-D, on moose browse. The study was started in the summer of 1984 on the Tofte and Gunflint districts of the Superior National Forest. This is a preliminary report on the first year of a 2 year study.

STUDY AREA

The Tofte and Gunflint Districts of Superior National Forest in northeastern Minnesota are within the "boreal conifer lake forest" (Maycock and Curtis 1960, Peek et al. 1976). The study area is located 48° 30' N lat., 90° 30' W long. and elevation ranges from 425-520 m (1,400-1,700 feet). Within the forest, many plantations have been intensively managed for conifer production. Many clearcuts have been replanted with white spruce or red pine and received one or two herbicide release sprays. Recently, Superior National Forest has shifted emphasis to aspen management, and natural regeneration will predominate by 1986.

The Forest Service sprays plantations that are judged to be threatened by competition. These release treatments are conducted in late summer or early fall before deciduous plants become dormant and after the conifer buds set, reducing the possibility of conifer damage. In the study plantations, herbicides were applied from a helicoptor at a rate of 4.7 l/ha (2 quarts/acre) for Roundup and 3.4 kg/ha (3 pounds/acre) for 2,4-D. Since 1984, Superior National Forest has applied all herbicides with ground spray equipment.

METHODS

Biomass of available browse was estimated from sampling 20 plantations ($\bar{x}$= 13 ha) with similar soil types. Available broadleaf browse was defined as all current-season, living-leaves (summer browse) and twigs (winter browse) between 0.5 and 3 m high on those shrub species moose are known to use (Peek et al. 1976). Each area had been clearcut and tractor scarified in preparation for planting, then planted to white spruce or red pine. Conifers were 4-17 years old at sampling (1984). Nine stands had been aerially sprayed once with 2,4-D and 11 once with Roundup either 1 year (1983), 2 years (1982), or 3 years (1981) before (Table 1). Only stands having had no other

Table 1. Number of stands sampled by year and treatment type.

Year Sprayed	Herbicide Glyphosate	2,4-D
1981	5	3
1982	3	3
1983	3	3

herbicide treatment before or after planting were used.

Pilot sampling of browse distribution and biomass was conducted on a sub-set of stands for an approximation of variances in browse density by treatment-year. From these, appropriate sample size was determined: for 2,4-D plantations, 50 plots each and for Roundup plantations, where spatial heterogeneity was greater, 75 each. Sampling was in late summer after growth was complete.

Because of great variability within shrub stands, a stratified sampling scheme was developed to increase efficiency. Browse density strata were identified from an initial extensive sampling; from these, mean densities were estimated. Sampling intensity was allocated in proportion to these means. The design is similar to that of Jordan and Martin (1978) and Crete and Jordan (1982). The objective was to estimate density of available browse for each species in each plantation.

First, at each of the 2-m^2 plots laid out uniformly in each plantation, number and height of stems, by species, were recorded. A stem was defined as growth originating from under the surface. Visual inspection indicated a close relationship between plant form and height: generally those of 0.5-1 m had only current apical growth, those 1-2 m had many laterals, and those 2-3 m had mutiple branching at the base, each branch with many laterals. These height classes were used as strata, and the initial data were partitioned by strata, species, and treatment-year to obtain frequency distributions. A rough estimate of browse density was made by applying wet-weight values to species and height-strata data.

The proportion contributed by each species in each height stratum was calculated from the roughly estimated browse density in each treatment-year. These proportions then were applied directly for the apportionment of intensive sampling. A total of 75 stems was to be sampled from one stand in each treatment-year. Species contributing less than 5% of the total biomass density were dropped. Intensive subsampling involved walking a transect that did not intersect existing plots, because these were being protected for future observations. Given how many stems of each species in each height class were to be sampled, the worker filled this quota on a first come basis. From each designated stem, all annual growth was clipped. Clippings were oven-dried (65 °C) and weighed (0.1 g). These data gave a reliable estimate of biomass per stem for each species in each height stratum according to treatment-year. This set was then applied to the frequency distributions from the initial plot sampling to derive the estimate of biomass density of available browse by species for each plantation.

RESULTS

Most glyphosate treated plantations contained few live woody stems but many standing dead stems with no sprouts. In contrast, plantations treated with 2,4-D had many more live shrubs with taller, multiple sprouts and few dead stems. Table 2 shows relative abundance of browse species found in the study plantations after treatment. Aerial applications were rarely uniform, with live shrubs remaining in

strips or in clumps beneath large residual trees that intercepted the spray. Some of these residual shrubs were heavily browsed. One year

Table 2. Relative abundance of deciduous browse species in the study plantations. (1 = most abundant).

1.	Mountain maple	Acer spicatum
2.	Willow	Salix spp.
3.	Quaking aspen	Populus tremuloides
4.	Beaked hazel	Corylus cornuta
5.	Paper birch	Betula papyrifera
6.	Choke cherry	Prunus virginiana
7.	Pin cherry	Prunus pensylvanica
8.	Red-osier dogwood	Cornus stolonifera
9.	Balsam poplar	Populus balsamifera
10.	Red maple	Acer rubrum
11.	Juneberry	Amelanchier spp.
12.	Mountain ash	Sorbus americana

after glyphosate application, some plants were not dead but had clumps of tiny deformed leaves clustered along the stem. All of these stems died by the following year. None of the shrub species showed significant resistance to glyphosate. Some shrubs, such as mountain maple (Acer spicatum), showed marked resistance to 2,4-D. In glyphosate treated plantations, grass and raspberries were often very abundant. Grass seemed to become quite dense without woody competition, and this may have prevented woody species from seeding in.

T-tests for populations with unequal variances showed a significant difference ($p<.05$) between the amount of available browse in glyphosate vs. 2,4-D treated plantations for the 1981 and 1983 comparisons. On the other hand, there was no significant difference between herbicide treatments in the 1982 stands. Because of a drought in 1982, probably resulting in early dormancy, applications of both herbicides were relatively ineffective. In the 1981 and 1983 treated plantations, average available browse in the 2,4-D stands was at least twice that in the glyphosate treatments (Table 3). For example, the 1981 glyphosate stands had an average of 60 kg/ha of browse, and the 2,4-D stands averaged 138 kg/ha. The smallest amount of browse in a

Table 3. Average dry weight of available browse (kg/ha), sample size and standard deviation for each treatment and year.

Year Sprayed	Glyphosate			2,4-D		
	$\bar{x}$	n	SD	$\bar{x}$	n	SD
1981	60	5	47	138	3	38
1982	110	3	61	121	3	53
1983	26	3	19	70	3	15

glyphosate stand was 5 kg/ha, while the smallest in a 2,4-D stand was 57 kg/ha. Even 3 years after spraying, the glyphosate treated plantations had only half as much browse as the 2,4-D plantations; thus glyphosate treatments may leave browse density very low for many years.

DISCUSSION

Moose are a featured species in the Superior National Forest, designated for special management consideration. They are a major attraction for tourists and hunters in a region where tourism is

economically important. Demand for moose hunting has exceeded supply for many years. Even though timber production is important to the local economy and is the most visable Forest Service activity, the agency has committed itself to integrated management.

Our study investigated glyphosate impacts on browse and focused on biomass density. In a related study, Haney and Apfelbaum (1984) examined the ecological effects of glyphosate on plant populations and successional trends in the Superior National Forest. Because they dealt with the presence or absence of species rather than biomass, their results are not comparable to ours.

Glyphosate, which is more expensive than 2,4-D, not only substantially reduces shrubs but may also encourage heavy stands of grass, forbs, and raspberries. For small conifer seedlings, dense herbaceous vegetation may be more severe competition than woody sprouts. Posner (1984) showed that 4-9 year-old white spruce grew well in association with low or medium shrub levels and usually grew better with some shrubs present than with none.

Even though plantations treated with herbicides comprise only a portion of the forest, moose favor these plantations for feeding in both summer and winter. They may prefer these young conifer plantations because there is usually a diversity of browse species available. Previously 2,4-D release treatments temporarily reduced total browse but did not appear to reduce long-term browse production. Our preliminary findings indicate effective application of glyphosate has the potential of reducing browse resources for many years. The lowest mean browse densities that we found after glyphosate treatments may represent the truly effective applications that some timber managers are attempting to achieve. Browse may be reduced to such a low level that moose will no longer use the stand. We believe that long-term evaluation of glyphosate effects is needed to assess impacts on moose habitat throughout the forests of eastern North America and Scandinavia.

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REFERENCES

Alm, A. A. 1984. Use of herbicides in northern Minnesota for forestry purposes. Minn. For. Research Notes. No. 291. 4 pp.

Braathe, P. 1978. Elgbeitigen ma tas alvorlig: mot mindre andel av furu i femtidsskogen? Norsk Skogbruk 24(4):12-13.

Campbell, R. A. 1984. The value of herbicides in forest management. Canadian Forest Industries 104(3):41-44.

Crete, M. and P. A. Jordan. 1982. Production and quality of forage available to moose in southwestern Quebec. Canad. J. For. Res. 12:151-159.

Haney, A. and S. I. Apfelbaum. 1984. Ecological effects of silvicultural applications of the herbicide "Roundup" in the Superior National Forest. Applied Ecological Services. Juda, Wisconsin. 28 pp.

Jordan, P. A. and F. B. Martin. 1978. A new approach to browse sampling and its application for moose at Isle Royle. N. Am. Moose Conf. 13:106.

Krefting, L. W. and H. L. Hansen. 1969. Increasing browse for deer by aerial applications of 2,4-D. J. Wildl. Manage. 33:784-790.

Lund-Hoie, K. 1980. The impact of helicopter application of glyphosate on the management of Norwegian forest plantations. In Weed control in forestry conference. Nottingham, England. pp. 73-82.

Maycock, P. F. and J. T. Curtis. 1960. The phytosociology of boreal conifer-hardwood forests of the Great Lakes Region. Ecol. Monogr. 30:1-35.

Mueggler, W. F. 1966. Herbicide treatment of browse on a big-game winter range in northern Idaho. J. Wildl. Manage. 30:141-145.

Newton, M. and F. B. Knight. 1981. Handbook of weed and insect control chemicals for forest resource managers. Timber press, Oregon. 213 pp.

Peek, J. M., D. L. Urich, and R. J. Mackie. 1976. Moose habitat selection and relationships to forest management in northeastern Minnesota. Wildl. Monogr. 48:1-65.

Posner, S. D. 1984. Effects of deciduous shrubs on young white spruce, and implications of shrub control on the supply of moose forage in northeastern Minnesota. M.S. thesis. University of Minnesota. 62 pp.

Sutton, R. F. 1978. Glyphosate herbicide: an assessment of forestry potential. For. Chron. 2:24-28.

USDA. 1977. Response of selected woody plants in the United States to herbicides. Agriculture Handbook no. 493. 101 pp.

Weed Science Society of America. 1983. Herbicide handbook of the weed science society of America. Fifth edition. Champaign, Illinois. 515 pp.

Weil, G. 1983. An aerial survey of moose track densities as an index of winter distribution of moose in the Tofte district. University of Minnesota report. 5 pp.

Wendel, G. W. and J. N. Kochender. 1982. Glyphosate controls hardwoods in West Virginia. USDA. Northeastern forest experiment station. Research paper NE-497. 7 pp.