W-0031

Reprinted from AGRONOMY JOURNAL
Vol. 69, Sept.-Oct. 1977, p. 769-772

Effects of Snowmobile Traffic on Several Forage Species and Winter Wheat[1]

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ABSTRACT

Experiments to determine the effects of snowmobile traffic on plant species, frequently grown in heavy snowbelt regions, were conducted over 3 years in northern Wisconsin. Plant species tested during the trials were: alfalfa (*Medicago sativa* L.); birdsfoot trefoil (*Lotus corniculatus* L.); red clover (*Trifolium pratense* L.); bromegrass (*Bromus inermis* Leyss.); orchardgrass (*Dactylis glomerata* L.); and winter wheat (*Triticum aestivum* L.). The soil is classified as a Typic Eutroboralf, very fine Illitic (mixed). Designated areas of each crop species received varying amounts of snowmobile traffic when snow depths were > 7.5 cm. Soil temperatures, snow compaction, and frost depths were measured. Forage dry matter or grain yields were taken during the following summer. Soil bulk density was determined during two growing seasons as a measure of soil compaction.

Stands of alfalfa, birdsfoot trefoil, and alfalfa/bromegrass treated for two winters with snowmobile traffic showed no detrimental effects on forage yield. Grain yields from winter wheat stands exposed to snowmobile traffic were not reduced below that of check areas. Red clover and birdsfoot trefoil/orchardgrass yields were decreased during 1 year of the trials but were unaffected by snowmobile traffic during 1 other year.

Snow was found to be compacted by snowmobile traffic and soil temperatures colder and more erratic under these areas. Frost penetrated deeper under areas subjected to snowmobile traffic. Soil compaction was not found to be increased by snowmobile traffic.

Additional index words: Recreational vehicles, Cold hardiness, Snow compaction.

SNOWMOBILING has become a popular winter sport in the northern U.S. and Canada. Snowmobile numbers have grown to over 2 million since being introduced in 1959[3]. Several reports indicate that considerable snowmobiling occurs on private land (3, 10, 14). The impact of their use on vegetation becomes increasingly important to the landowner, particularly farmers.

Research evaluating the effects of snowmobile traffic on non-forest vegetation and the underlying soil has been limited. Foresman et al. (2) in Wisconsin, reported early spring growth of Kentucky bluegrass (*Poa pratensis* L.) to be less in snowmobile track areas but no stand reduction or differences in vigor, growth, or color were present later in the growing season. Neumann and Merriam (5) noted that when snow was compacted by snowmobiles, sub-zero air temperatures penetrated soil profiles deeper than in areas without snow compaction. Wanek (12, 13) also observed colder and more variable soil temperatures under areas subjected to snowmobile traffic. His Minnesota studies showed that lower alfalfa yields were obtained in snowmobile traffic areas than from non-traffic areas. Yield reductions were attributed to the lower soil temperatures causing decreased plant survival. Walejko et al. (11) reported variable results from snowmobile traffic studies conducted on alfalfa at several locations in Wisconsin. Forage yields were reduced at two locations following snowmobiling, while no detrimental effects were noted at two other locations. Conversely, Whittaker and Wentworth (15) found no reduction in alfalfa yields due to snowmobile traffic in Maine.

The object of this research was to evaluate the effects of snowmobile traffic on several agronomic crops frequently grown in the heavy snowbelt regions of the United States.

MATERIALS AND METHODS

These snowmobile traffic studies were carried out during three winters at Ashland, Wis. (1971-74). The experiments were established in generally level fields having visually uniform stands of the following crops: alfalfa (*Medicago sativa* L.); birdsfoot trefoil (*Lotus corniculatus* L.); red clover (*Trifolium pratense* L.); mixtures of alfalfa-bromegrass (*Bromus inermis* Leyss.) and birdsfoot trefoil-orchardgrass (*Dactylis glomerata* L.); and winter wheat (*Triticum aestivum* L.). Recommended cultural practices were followed to establish and maintain all vegetation utilized during these trials.

Pure stands of 'Thor' alfalfa, 'Lakeland' red clover, and 'Empire' birdsfoot trefoil were established in the spring of 1972 and treated with snowmobile traffic during the winters of 1972-73 and 1973-74. Forage mixtures of alfalfa-bromegrass and birdsfoot trefoil-orchardgrass were established in the spring of 1971 and subjected to snowmobile traffic during the winters of 1971-72 and 1972-73. The alfalfa-grass mixture was composed of 'Vernal' alfalfa and 'Lincoln' bromegrass. The birdsfoot trefoil-grass mixture cultivars were Empire birdsfoot trefoil and 'Potomac' orchardgrass. Winter wheat (cultivar 'Timwin') seeded in the fall of 1972 and 1973, received snowmobile traffic during the succeeding winters.

A modified randomized complete block design with four replications was used for all experiments. Standard statistical procedures (9) were followed to analyze the data.

Areas to receive snowmobile traffic were marked by 183-cm colored steel posts. Test areas were controlled and received desired amounts of traffic from authorized personnel. The number of runs each area received were recorded throughout each

[1] Contribution from the Dep. of Agronomy and Ashland Experimental Farm, Univ. of Wisconsin Research. Supported by the College of Agriculture and Life Sciences, Univ. of Wisconsin-Madison, and by Univ. of Wisconsin Graduate School Proj. 140776. Received 22 Nov. 1976.

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Table 1. Forage yields from pure stands of alfalfa, birdsfoot trefoil, and red clover subjected to varying snowmobile traffic the previous winters.

Snowmobile traffic intensity			Forage yield from two forage harvests					
	Total runs		Alfalfa		Birdsfoot trefoil		Red clover	
Runs/ week†	1972–73	1973–74	1973	1974	1973‡	1974	1973	1974
			metric tons/ha					
0	0	0	4.11	7.29	2.22	7.05	5.08	5.69
5	55	--	4.74	--	2.55	--	5.92	--
10	110	108	4.68	7.79	2.42	7.63	5.64	4.23
20	220	216	4.74	7.86	2.71	7.08	5.43	3.82
40	--	432	--	8.10	--	7.08	--	4.26
80	--	864	--	8.16	--	7.38	--	3.42
80§	--	850	--	7.24	--	7.22	--	2.47
L.S.D. (0.05)			NS	NS	NS	NS	NS	0.75
C.V. (%)			12.0	6.2	11.0	4.9	14.0	13.0

† Treatments 2 through 6 were applied daily (Monday through Friday). Treatment 7 was applied all 1 day (Monday). ‡ No second harvest was taken due to dry weather and poor growth after first harvest.
§ Treatment only partially completed on final day, as snow turned to slush.

Table 2. Forage yields obtained from alfalfa-bromegrass and birdsfoot trefoil-orchardgrass stands following varying snowmobile traffic the previous winters.

Snowmobile traffic intensity			Forage yield from two forage harvests			
	Total runs		Alfalfa-bromegrass		Birdsfoot trefoil-orchardgrass	
Runs/ week	1971-72	1972-73	1972	1973	1972	1973
			metric tons/ha			
0	0	0	4.74	4.18	4.41	4.19
5	--	55	--	4.34	--	4.08
6	102	--	5.05	--	3.92	--
10	170	110	5.10	4.74	3.61	4.10
20	340	220	4.91	4.32	4.04	4.26
L.S.D. (0.05)			NS	NS	0.36	NS
C.V. (%)			8.3	8.0	6.5	8.1

Table 3. Effect of snowmobile traffic on grain yield of winter wheat.

Snowmobile traffic intensity			Yield	
	Total runs			
Runs/week	1972-73	1973-74	1973	1974
			kg/ha	
0	0	0	3,146	2,281
5	55	--	3,256	--
10	110	108	3,697	2,100
20	220	216	3,377	1,772
40	--	432	--	1,948
80	--	864	--	2,204
80†	--	850	--	1,846
L.S.D. (0.05)			NS	NS
C.V.(%)			18.0	9.6

† Received runs on Monday of each week.

winter. A run consisted of one pass of the snowmobile over a plot area. Runs were made daily Monday through Friday. They were limited to snow depths > 7.5 cm to insure that mechanical damage to underlying vegetation did not occur.

Bombadier Olympic 15-hp snowmobiles with tracks 37.5 cm wide were used to administer traffic treatments during the winters of 1971-72 and 1972-73. John Deere model 300 snowmobiles with 20-hp motors and 40.0-cm track widths were used during the winter of 1973-74. Weight of the snowmobiles was approximately 168 kg. The general speed of operation ranged from 20 to 32 km/hour however speeds were reduced to 5 to 8 km/hour on some of the high use tracks because of track irregularities (moguls).

Snow depths were measured on untreated areas on days when snowmobiles were run. Air temperatures were recorded at the

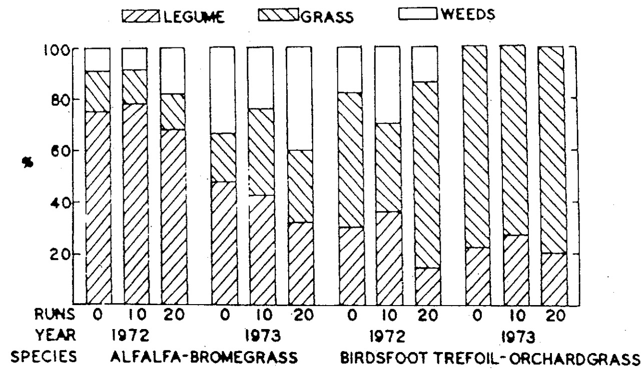

Fig. 1. Effect of snowmobile traffic on the botanical composition of forage taken at first harvest each year from the legume-grass mixtures.

time treatments were made. Soil temperatures at 2.5 cm below the soil's surface were monitored continuously during the 1973-74 winter using Weather Measure three point thermographs with mercury filled sensor probes (Model No. T603). Control and heaviest traffic areas (80 runs/week) were monitored. Frost depths were measured in late winter with a soil auger during 2 years. Snow compaction data were obtained in the late winter of 1973 by melting a core of snow 10.0 × 26.3 cm from each track area to determine water content.

Snowmobiles were run 85 (14 December to 10 April), 55 (21 December to 7 March), and 54 (26 December to 11 March) total days during the winters of 1971-72, 1972-73, and 1973-74, respectively. Traffic intensities were increased during the 3rd year of the trial (1973-74) to 80 runs on Monday of each week to simulate heavy trail use that might be received on a weekend.

The forage plots were harvested twice each summer at the recommended stage of maturity to measure crop production. Samples to determine botanical composition of the forage mixtures were taken at first harvest from control and track areas of each plot. A heavy-duty rotary mower was used to harvest an area 0.5 × 7.1 m from each track area. Samples of fresh plant material were taken from each plot at harvest, weighed, dried, and reweighed to determine percent moisture. A forced-air oven was used to dry the samples at 64 C. Winter wheat plots were harvested using a sickle mower and threshed with a stationary experimental plot thresher.

The soil type at the test site was a Ontonagon silty clay loam. Soil compaction estimates were calculated for the control and heaviest traffic areas by obtaining soil bulk density readings using a modification of the method of Wilde et al. (16).

RESULTS

Forage yields from the pure stands of alfalfa and birdsfoot trefoil in 1973 and 1974 and red clover stands in 1973 were not reduced by snowmobile traffic (Table 1). However, 2nd year forage yields of the red clover stand were reduced seriously by all traffic treatments with the losses generally greater as traffic intensity increased. Visual observations of the red clover plot area in 1974 indicated a stand reduction of up to 70% in traffic areas.

Snowmobile traffic over the legume-grass mixtures did not reduce forage yields from the alfalfa-bromegrass stand during 2 years or from the birdsfoot trefoil-orchardgrass stand in 1973 (Table 2). The birdsfoot trefoil-orchardgrass mixture yielded less forage in 1972 from plots receiving snowmobile traffic the previous winter than control areas.

Hand separations taken at the time of the first harvest from the alfalfa-bromegrass mixture in both 1972 and 1973 revealed a slight decrease in alfalfa from the heaviest traffic treatment (Fig. 1). Less birdsfoot tre-

Table 4. Effect of snowmobile traffic on snow density (early March), depth of frost penetration (early April), and bulk density of surface soil in June.

Snowmobile traffic	Snow compaction 1973	Frost penetration 1972	Frost penetration 1973	Bulk density 1972	Bulk density 1973
	ml	cm	cm	g/cm³	g/cm³
Check (no traffic)	11	20.3	45.0	1.51	1.39
10 runs/week	22	61.0	72.5	--	--
20 runs/week	22	50.8	70.0	1.47	1.36

† Milliters of water from a 10.0 × 26.3-cm core of snow.

foil was noted in 1972 in the heaviest traffic area and less grass in the moderate traffic area when compared with the control of the birdsfoot trefoil-orchardgrass mixture. The following year's stand was about equal over the entire plot area.

Running snowmobiles over stands of winter wheat during the winters of 1972-73 and 1973-74 did not reduce grain yields taken the following summer (Table 3).

Snowmobiling has been reported to compact snow and reduce insulation for underlying vegetation (5, 12, 13). Measurements of snow compaction, soil temperature, and frost depth confirm these observations (Table 4, Fig. 2). Snow compaction measurements taken in 1973 indicated 100% more water in snow from areas receiving snowmobile traffic as compared to the check areas. Lower and more variable temperatures at the 2.5-cm soil depth in track areas than adjacent non-track areas (Fig. 2) indicated that the compacted snow resulted in reduced insulation. The interesting cross-over of temperatures from the check and traffic areas in mid-March followed a few days of warm temperatures which melted all the snow from the check areas but not from the compacted snow on track areas. A cold front with low temperatures followed causing the soil temperatures in the unprotected check areas to drop below the traffic areas. Frost depth in early April was 2.5 to 3.5 times deeper in the snowmobile traffic areas than in non-traffic areas in 1972, and approximately 60% greater in 1973 (Table 4).

No indication of soil compaction was found due to snowmobile traffic. Bulk density measurements taken in track and non-track areas during the summer were essentially the same (Table 4). Walejko et al. (11) also reported no increase in soil compaction due to snowmobile traffic.

DISCUSSION

Snowcover is important for survival of overwintering plants in northern areas such as Wisconsin (4). Increasing snow depths offer underlying vegetation greater insulation from freezing temperatures. Snow conditions in northern Wisconsin are usually favorable for crop survival during the winter (Fig. 3).

Decreased insulation, caused by snowmobile compaction of the snow, resulted in reduced forage yields from the red clover study in 1974. Direct exposure of plant crowns and roots to temperatures as low as —10 to —15 C for short periods of time can cause injury or even death (1, 6). Examination of daily soil temperatures taken during the red clover study in the winter of 1973-74 revealed a low temperature of —10 C recorded on 12 January from the 80-run per week treatment. Another possibility is that prolonged exposure of the plants in traffic areas to the colder temperatures, caused a reduction of stored food reserves. Reductions may have reached a point where many of the plants were unable to grow the following spring. The different response from red clover stands to snowmobile traffic in 1974 versus 1973 may also be due to differences in stand age. Red clover normally is more susceptible to winter injury after the second growing season (7).

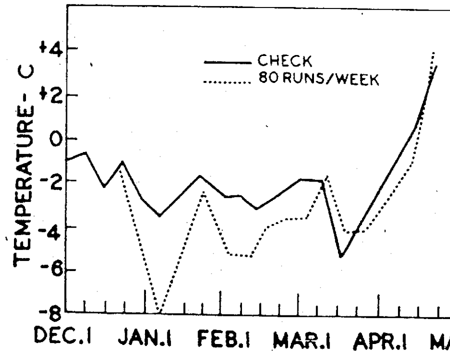

Fig. 2. Average weekly minimum soil temperatures (2.5 cm depth) from red clover stands under check treatment and under the track receiving 80 snowmobile runs per week, 1973-74.

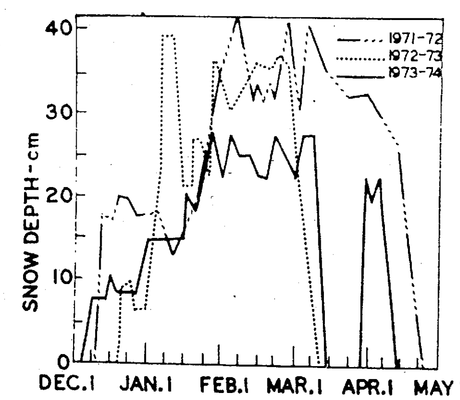

Fig. 3. Snow depth as measured in check areas for three winters at Ashland, Wis.

Forage yield reductions noted for the birdsfoot trefoil-orchardgrass traffic areas in 1972 are believed due to slow spring recovery of the stand caused by weakened or injured plants. Surprisingly, snowmobile traffic on the same areas the following winter did not affect forage yields in 1973. This indicates that snowmobile effects on overwintering vegetation can vary from year to year.

Ice sheet formation on overwintering crops can increase plant injury not only from reduced insulation but also through smothering of plants (8). Even though the snow in the traffic areas was in a compacted state it was never considered to be as crystalline as ice and smothering of overwintering plants was not believed to be a factor. Warmer areas that receive less snowfall may be affected differently. Walejko (11) noted ice sheet formation on an alfalfa stand due to snowmobile traffic at one southern Wisconsin location. Light snowfall and certain weather conditions (freezing and thawing) in combination with snowmobile traffic were cited as reasons for this occurrence.

During these trials many variables were included and many physical measurements taken to determine snowmobile effects on overwintering crop species. Treatments involved traffic intensities lower than found on established snowmobile trails. However, it is believed that 800 runs per winter in several of the treatments would surpass traffic intensities ordinarily received on open agricultural lands. Instances of reduced forage yield or plant damage due to snowmobile traffic were infrequent, but did occur under some conditions.

Our original objective was to identify these specific conditions and thus predict when snowmobiles would or would not cause damage to underlying vegetation. This objective was not fully realized because each winter and each snowstorm has unique characteristics. The common practice of snowmobiles using a narrow trail along the edge of a field having crop vegetation seems an appropriate compromise.

LITERATURE CITED

1. Carroll, J. C. 1943. Effects of drought, temperature and nitrogen on turf grasses. Plant Physiol. 18:19-36.
2. Foresman, C. L., D. K. Ryerson, R. N. Walejko, W. H. Paulson, and J. W. Pendleton. 1976. Effect of snowmobile traffic on bluegrass (*Poa pratensis* L.). J. Environ. Qual. 5:129-131.
3. Lanier, L. L. 1971. Michigan's 1970 snowmobile study. Snowmobile and off the road vehicle research symposium. Mich. State Univ. Tech. Rep. 8:55-71.
4. Nelson, N. T., and L. F. Graber. 1923. Lack of snow causes heavy alfalfa losses. Wis. Agric. Exp. Stn. Bull. 352:37-40.
5. Neumann, P. W., and H. G. Merriam. 1972. Ecological effects of snowmobiles. Can. Field Nat. 86 (3):207-212.
6. Smith, Dale. 1964. Winter injury and the survival of forage plants. Herb. Abstr. 34:203-209.
7. ———. 1975. Forage management in the North, 3rd Ed. Kendall/Hunt Publishing Co. p. 101-111.
8. Sprague, M. A., and L. F. Graber. 1943. Ice sheet injury to alfalfa. J. Am. Soc. Agron. 35:881-894.
9. Steele, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc. N.Y.
10. Vila, J. J. 1971. Ontario's 1970 snowmobile study. Snowmobile and off the road vehicle research symposium. Mich. State Univ. Tech. Rep. 8:30-42.
11. Walejko, R. N., J. W. Pendleton, W. H. Paulson, R. E. Rand, G. H. Tenpas, and D. A. Schlough. 1973. Effect of snowmobile traffic on alfalfa. J. Soil and Water Conserv. 28 (6): 272-273.
12. Wanek, W. J. 1972. A continuing study of snowmobiling in northern Minnesota (final research report for 1971-72). The Center for Environmental Study. Bemidji State College. Bemidji, Minn.
13. ———. 1973. A continuing study of snowmobiling in northern Minnesota (final research report for 1972-73). The Center for Environmental Study. Bemidji State College. Bemidji, Minn.
14. Whittaker, J. C., and D. S. Wentworth. 1972. Maine Snowmobile Owners. Univ. of Maine. Orono, Maine. Life Sci. and Agric. Exp. Stn. Bull. 2, Vol. 20.
15. ———., and ———. 1972. Snowmobile compaction and forage grass yield in Maine. Univ. of Maine. Orono, Maine. Life Sci. and Agric. Exp. Stn. Misc. Rep. 1213.
16. Wilde, S. A., G. K. Voigt, and J. G. Iyer. 1972. Soil and plant analysis for tree culutre, 4th Revised Ed. Oxford and IBH Pub. Co. New Delhi. p. 15-17.