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by

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VEGETATIVE BARRIERS AND ARTIFICIAL FENCES FOR MANAGING SNOW IN THE CENTRAL AND NORTHERN PLAINS[1]

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Abstract: During the 1960 to 1969 period, experiments were conducted at Akron, Colorado and Sidney, Montana utilizing vegetative barriers and wood-slat fences in an attempt to manage snow for water conservation purposes. Tall wheatgrass barriers spaced 30 and 60 feet apart at Sidney, Montana, and sorghum-sudangrass stubble barriers spaced 25 and 50 feet apart at Akron, Colorado, were effective in trapping and distributing blowing snow in a reasonably uniform pattern between barriers. Both barrier systems significantly increased soil water supplies. For effective snow deposition and distribution, vegetative barriers should possess the following characteristics: (a) strong, flexible stalks exceeding 18 inches, but not so tall that lodging becomes a problem, (b) double-row instead of single-row plantings to eliminate airflow gaps, and (c) stalk populations to provide air porosities of 65 to 75%. At Akron, Colorado, wood-slat snow fences with 70- to 80% air porosities induced snow deposition in low profile drifts several times each winter as far leeward as 60+ feet. Snowmelt from these drifts supplemented stored soil water that could be used to aid establishment and growth of new shelterbelts, to grow adaptable vegetative habitat for game birds, and to provide additional browse-type vegetation for wildlife in dry mountain valleys.

Introduction

Blowing snow caused by high winds has always been a major hazard to rural people as well as livestock and wildlife in the Great Plains. From the Northern and Central Plains south to the fortieth parallel, snowfall provides 18 to 33% of the total precipitation, averaging 20 to 36 inches per season. However, below the fortieth parallel, snowfall diminishes rapidly. Until recent years, phenomena such as snowstorm frequency, snowdrift volume and density, water content, and snowmelt storage efficiency have not been systematically measured.

Various agricultural and forestry stations in the United States, Canada, and the U.S.S.R. have tested shelterbelts as a possible method of controlling wind and blowing snow in a semiarid environment. More recently, criteria for design, adaptable species, and also the advantages and limitations of shelterbelts have been examined by Greb and Black (1961b), Siddoway (1969), Staple and Lehane (1965), and Stoeckeler (1962). Shelterbelts appear to be less effective in the semiarid Great Plains because the water requirements and lard area needed for effective shelterbelts are relatively high (Siddoway 1969); in addition, their downwind effectiveness may

[1]Contribution from the Northern Plains Branch, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, and the Colorado and Montana Agricultural Experiment Stations.

be small and root extensions into adjacent cropland may be great (Greb and Black 1961b, Siddoway 1969). For these reasons, snow management systems other than shelterbelts are needed in the Great Plains.

Smika and Whitfield (1966) found that undisturbed small grain stubble, particularly wheat, was effective in trapping snow uniformly and increasing soil water recharge from snowmelt infiltration. Wheat stubble occupies over 40 million acres in the Plains of the United States. However, in this area where an alternate wheat-fallow rotation system of farming is prevalent, 30 million acres of cultivated land are bare each winter with little or no obstruction to the sweep of blowing snow.

Beginning in the late 1950's, some research interests were shifted to explore the feasibility of using vegetative barrier systems for managing snow in cultivated fields, primarily to increase the total water supply for wheat. It was in 1959 at Akron, Colorado, that Greb and Black (1961a) first attempted the use of sorghum barriers (*Sorghum vulgare*) to manage snow in cultivated fields. This approach was later refined to include sudangrass (*Sorghum sudanense*) barriers at Akron (Greb et al. 1965) and tall wheatgrass (*Agropyron elongatum*) barriers at Sidney, Montana (Black and Siddoway 1971).

Research using artificial snow fences is being conducted in the plains of Siberia (Komarov 1963a, 1963b). The results of four snow Management experiments involving the use of vegetative barriers as well as artificial fences are reported here.

Methods and Materials

Tall Wheatgrass Barriers, Sidney, Montana (1965-1969)

In the fall of 1964, double-row barriers of tall wheatgrass were established 36 inches apart on Williams loam soil near Sidney, Montana. The 250-foot-long barriers were laid out south to north at 30- and 60-foot intervals to include random plots of continuous wheat versus alternate wheat-fallow within the parallel barrier system. Eight check plots were placed outside the barrier area. Soil water content measurements to 5-foot depths, before and after each winter season, were taken within and outside the barrier system; and wind velocity, snowfall, snowdrift, and snow water content measurements were likewise taken within and outside the barrier system.

Sorghum-Sudangrass Barriers, Akron, Colorado (1960-1964)

In 1959, Greb and Black (1961a) established exploratory double rows of sorghum (RS-501) at 25- and 50-foot intervals. Following combining, these stalks, about 20 inches in height, showed some potential for uniformly distributing snow between barriers for wheat production; but the stalks of this sorghum variety tended to lodge excessively.

Beginning in 1960 and continuing through 1964, cornstalks, various forage and grain sorghum stalks, and also sudangrass were tested for snow-trapping and distribution capabilities. In four replications, each barrier material tested was planted in double rows (14-inch spacing), 300 feet in length, on a Haxton fine sandy loam. The interval between double rows of vegetative barriers was 37 feet, and the barriers were oriented east to west. The following data were collected: plant population, stalk size, air porosity of barriers, lodging losses of varieties, soil water content between barriers to 6-foot depths, snowfall, water content of snow, and crop yields. Four check plots were placed north of the barrier system.

Wood-Slat Snow Fences, Akron, Colorado (1963-1968)

In September 1963, wood-slat fences of various air porosities were installed on Weld silt loam pastureland in an attempt to produce drifts of greater length and lower profile than those observed leeward of a standard highway fence, 48 inches high with 58% air porosity. This experiment included 24- and 48-inch-high fences with 37-, 58-, 69-, 79-, and 85% air porosities. Each fence was 50 feet long and replicated twice, resulting in 1,000 feet of fence, oriented east to west, 500 feet south of an elevated railroad bed. To determine water content, duplicate soil samples to 6-foot depths were taken at 0-, 5-, 10-, 20-, 30-, 40-, 50-, and 60-foot distances leeward of each fence before and after each winter season, and also immediately following snowmelt from selected storms. In addition to obtaining standard Weather Bureau measurements from each snowstorm, measurements such as size, shape, and water content of all new snowdrifts were also obtained. Data in this paper represent five successive years when average snowfall was about 20% below normal.

Grass Production Leeward of a Wood-Slat Snow Fence, Akron, Colorado

The objectives of this experiment were twofold: One was to measure the distribution pattern of snowmelt water leeward of a 48-inch-tall wood-slat snow fence with 72% air porosity; and the other was to compare the snowmelt water-use efficiency of Russian wildrye (Elymus junceus), crested wheatgrass (Agropyron cristatum), and intermediate wheatgrass (Agropyron intermedium), with and without nitrogen fertilization, as related to dry matter production.

In the fall of 1964, a 48-inch-tall snow fence was constructed parallel with, and 400 feet south of, an elevated east-west railroad right-of-way. The 180-foot-long fence was installed to catch and hold snow on a leeward strip of recently plowed Weld silt loam soil. Each grass species was successfully established during the spring and summer of 1965 on 48 x 60-foot plots. Each of these plots was later divided into 16 x 60 foot subplots, and nitrogen was hand-broadcast as ammonium nitrate during the winter at rates of 0, 25, and 50 pounds per acre per year. Duplicate soil and plant samples as well as duplicate snow measurements were obtained at 5-, 15-, 25-, 35-, 45-, and 55-foot distances from the fence, so the water-use efficiency, yield, nitrogen uptake, and protein content of each grass species could be determined. In 1964, plots of Russian wildrye were established on a nearby non-snow-accumulating area to enable comparison of data from plots without a snow fence, with the plots of Russian wildrye leeward of a snow fence. For the plots of Russian wildrye grown without a snow fence, nitrogen was applied at only two rates -- 0 and 25 pounds per acre.

Results and Discussion

Tall Wheatgrass Barriers, Sidney, Montana

During the summer of 1965, grass barriers grew to a height of 4 to 5 feet. A relatively dense, leafy growth developed to a height of 1 foot above ground level, and seed stalks extended upward another 3 to 4 feet. Calculated from measurements of the number and diameter of stalks above 1 foot, an air porosity of 65% was estimated. Tall wheatgrass barriers proved to be very durable throughout the experiment and were also very effective in trapping and holding snow.

In the Northern Plains area where Sidney is located, snow accumulates until the spring thaw; that is, it seldom melts during the winter. The average distribution pattern of snow accumulation within the two grass-barrier intervals tested at Sidney is shown in Fig. 1. The depth of snow gradually decreased from 25 to 17 inches across each 30-foot-barrier interval, and from 21 to 8 inches across each 60-foot-barrier interval. In both instances, snow depth tended to increase immediately adjacent to the windward side of each barrier.

Depth and water content of accumulated snow within the 30- and 60-foot-barrier intervals for continuous wheat and wheat-fallow rotations during four winter seasons are given in Table 1. Average snow depth increased about 15 and 8 inches within the 30- and 60-foot-barrier systems, respectively, when compared with snow deposits outside the barrier system; this extra snow contributed about 5 and 3 inches more soil water, respectively, than the check. Within the barrier system, there was little difference in depth of snow deposits between the two cropping systems.

The capacity of a barrier system to catch and hold snow is primarily a function of windspeed reduction. The grass barrier system at Sidney, Montana, effectively reduced windspeed leeward of the barriers by an average of 83, 61, 42, and 33% at distances of 5, 11, 16, and 23 feet, respectively (Table 2).

Sorghum-Sudangrass Barriers, Akron, Colorado

By 1962, preliminary testing of corn, sudangrass, and various sorghum varieties showed that sudangrass, Coes dual-purpose sorghum, FS-1A forage sorghum, and Sudax all had good qualities as vegetative stubble barriers for managing snow. In terms of simplicity of culture, flexibility and strength of stalks, and resistance to lodging, sudangrass performed more consistently than other vegetative materials tested. It was also found that, regardless of variety, double-row stalks should be sufficiently dense to provide not more than 78% air porosity, and that air porosities of 65 to 75% were optimum for distributing snow uniformly as far leeward as 12 times the height of the barriers. Wind and wet moving snow tended to cause the barrier stalks taller than 26 inches to lodge excessively; therefore, to be effective, stalks should be between 18 to 26 inches tall. The ability of sudangrass to catch and hold snow in a wheatfield is shown in Fig. 2.

In 4 years of testing from 1960 through 1964, average snow deposition within stubble barriers composed of sorghum and/or sudangrass was 6 inches more than corresponding averages outside the barrier system; and by spring within this barrier system, average soil water storage was 1.5 inches more than corresponding averages outside the system. Similarly, average grain and straw yields per year within the barrier system were 230 and 370 pounds per acre more, respectively, than corresponding averages outside the system, as calculated on an area basis including the 10% land space occupied by the barriers (Fig. 3).

Wood-Slat Snow Fences, Akron, Colorado (1963-1968)

During the five successive winter seasons from 1963 through 1968, the number of snowstorms averaged 10.2 per winter, depositing an average of 22.5 inches of total snowfall, 2.2 inches of snow per storm, and 0.27 inches of precipitation per storm (Table 3). The average snowfall for the five winters was about 5.5 inches below the long-term average.

Surprisingly, only 39% of the snowfall events that occurred were accompanied by winds of sufficient velocity to cause drifting; however, the drift-producing storms that did occur deposited 63% of the total snow and 71% of the total precipitation per winter season. The water content of snow by volume during these drift-producing storms averaged about 14% compared with only 10% for the nondrift-type storms (Table 3).

The characteristics of new snowdrifts leeward of a standard snow fence with 58% air porosity are given in Table 4. The data demonstrate that fences, even during subnormal snowfall seasons, do catch and hold a considerable amount of snow. The average depth of a seasonal snow deposit containing 15.4 inches of water was 78 inches at a point 15 feet leeward of a standard snow fence with 58% air porosity. In the Northern Plain-, snow commonly stockpiles until the spring thaw, whereas in the Central Plains, it usually melts between storms. Therefore, at Akron it was easy to compare the water content of new snowdrifts with the water content of nondrifted, level snow from the same storm. Measurements from 19 drift-forming storms showed that the average water content from new drifts was 1.4 times that of adjacent level snow (Table 4).

Snow deposits at specific distances leeward of the five 48-inch-tall experimental fences are given in Table 5. Although not shown, 66% of all water in the snow was accounted for as soil water the succeeding spring; the 34% not accounted for was presumed lost through sublimation, evaporation, or deep percolation. There was no evidence of snowmelt water loss through runoff.

The largest snow deposit, in terms of volume, was found leeward of a snow fence with 79% air porosity, after receiving 8 inches of snowfall in a 14-hour storm accompanied by 30- to 40-mile per hour winds; whereas, the largest deposit, in terms of depth, was found leeward of a fence with 58% air porosity (Fig. 4). However, the most desirable or beneficial snow deposit, in terms of depth, uniformity of distribution, as well as length, was found leeward of fences with 69- and 79% air porosities as shown in Fig. 4 and Table 5. This was quite noticeable when a storm with a 10- to

15-mile per hour wind deposited about 3 inches of snow. Storms of this type are quite common in the Akron area.

Additional testing included the use of a standard snow fence from which every third slat had been removed. Inasmuch as the air porosity of a standard snow fence is 58%, removing every third slat increased the porosity of the fence to 72%. Such a standard snow fence, after the removal of every third slat, induced deposition patterns with relatively small variations in depth, thereby enhancing uniform soil water recharge from snowmelt.

The strategic use of low profile snowdrifts could greatly assist the establishment of shelterbelts in semiarid areas where water is normally insufficient.

Grass Production Leeward of a Wood-Slat Snow Fence, Akron Colorado

Net soil water gains from snowdrifts leeward of the snow fence to a distance of 55 feet averaged 2.72 inches during four relatively dry winter seasons (Fig. 5). All grasses produced an average of 1,660 pounds per acre of dry matter. Average grass yields as related to snowmelt and water use at specific distances leeward of the snow fence are illustrated in Figs. 5 and 6.

Water-use efficiency during the growing season averaged 323, 227, and 192 pounds per acre, per acre inch of water; and grass yields averaged 1,995, 1,698, and 1,292 pounds per acre for crested wheatgrass, intermediate wheatgrass, and Russian wildrye, respectively (Table 6). Nitrogen applications of 25 and 50 pounds per acre significantly increased yields and water-use efficiency of all three grasses. The average yield increase was 490 and 805 pounds per acre for the 25- and 50-pound per acre rates of nitrogen, respectively. However, the grasses used in this study failed to utilize all stored soil water and later summer rainfall efficiently because of their early cool season-growth characteristics. The use of a snow fence increased both the soil water storage and production of Russian wildrye; specifically, the increase in soil water storage was 2.11 inches, and the increase in production was 445 pounds per acre, when compared with corresponding measurements from plots without a snow fence. Percentage of crude protein and total nitrogen uptake of grasses increased progressively as the rate of applied nitrogen increased (Table 6).

It is thought that sweet clover would utilize stored snowmelt water leeward of snow fences more efficiently than most vegetation because of its deeper rooting system. Moreover, the good growth characteristics of this legume could provide excellent nesting habitat for game birds.

Interpretation

Although the snow management systems tested at Sidney, Montana and Akron, Colorado were designed primarily to conserve water for crop production, these systems appear to have a potential for other uses too; they may benefit game birds. For example, the more snow that is distributed over a large cultivated field by the use of vegetative barriers, the less snow that will migrate to a downwind border fence or ditch, thereby reducing the hazard of game birds being smothered and their food supplies buried. Furthermore, vegetative barrier systems would provide additional cover and feed for game birds, thus enlarging their habitat and increasing their chance of survival from hunters, predatory animals, and hailstorms.

Perennial grass barriers and wood-slat snow fences of various heights and porosities can be utilized to grow adaptable nesting vegetation for game birds, to provide sufficient water for shelterbelt establishment, and to provide water for browse-type vegetative species in mountain valleys.

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Table 1. Snow depth and equivalent water content, as influenced by tall wheatgrass barriers and cropping sequence, Sidney, Montana (from Black and Siddoway 1971).

Winter period	No barrier: Snow depth	No barrier: Water content of snow	30 feet between barriers: Snow depth	30 feet between barriers: Water content of snow	60 feet between barriers: Snow depth	60 feet between barriers: Water content of snow
	Inches					
			Continuous wheat			
1965-66	8.7	2.6	19.2	7.4	13.2	5.1
1966-67	6.7	1.9	24.7	8.5	14.9	4.6
1967-68	6.3	1.7	18.5	5.6	13.5	4.1
1968-69	2.8	0.9	21.5	6.9	15.5	4.9
Average	6.1	1.8	21.0	7.0	14.3	4.7
			Wheat-fallow			
1965-66	8.7	2.6	19.2	7.4	13.2	4.6
1966-67*	3.9	0.9	21.9	7.4	12.8	4.0
1967-68	6.3	1.7	18.5	5.6	13.5	4.1
1968-69*	1.6	0.4	21.5	6.9	15.5	4.9
Average	5.1	1.4	20.1	6.8	13.8	4.4

* Second winter of fallow with no standing stubble.

Table 2. Windspeed reduction leeward of tall wheatgrass barriers at 12 inches above ground surface for 30-foot barrier intervals, Sidney, Montana (from Black and Siddoway 1971).

Distance leeward of barrier	Windspeed* reduction leeward of successive 30-foot barrier intervals: 1	2	3	4	Average reduction
Feet	%				
5	85	78	84	85	83
11	73	51	59	62	61
16	39	35	46	49	42
23	27	28	37	41	33

*Each value is an average of three 10-minute measurements taken simultaneously within and outside the barrier system.

Table 3. Characteristics of snowstorms at Akron, Colorado (1964-1968).

Snowfall conditions	Average per winter season
All storms	
Number per season	10.2
Total snowfall	22.5 inches
Largest single snow	8.0 inches
Average deposit per storm	2.2 inches
Average water content	12.4 percent
Average precipitation as level snow	2.75 inches
Type of storm	
Drift-forming storms	39.0 percent
Nondrift-forming storms	61.0 "
Snow deposit from drift-forming storms	14.2 inches
Percent of total deposit	63.0 percent
Snow deposit from nondrift-type storms	8.3 inches
Percent of total deposit	37.0 percent
Water content, average per drift-type storm	13.9 "
Water content, average per nondrift-type storm	9.7 "
Water contribution, drift-type storm	71.0 "
Water contribution, nondrift-type storms	29.0 "

Table 4. Characteristics of new snowdrifts 15 feet leeward of a standard 48-inch-tall wood-slat snow fence with 58% air porosity, Akron, Colorado.

Winter season	Drift-forming storms	Total depth of level snow	Total depth of maximum drift	Water content of level snow	Water content of drift	Total water of maximum drift
	Number	Inches	Inches	Percent	Percent	Inches
1963-64	5	22.8	124	14	20	24.8
1964-65	3	13.0	60	11	18	10.6
1965-66	3	9.4	69	15	21	14.6
1966-67	4	11.0	72	18	24	17.3
1967-68	4	14.6	66	12	15	9.8
Total or average	19	14.2	78	14	20	15.4

Table 5. Average snow deposition leeward of experimental snow fences at Akron, Colorado (1964-1968).

Air porosity of snow fence	Snow deposit* Feet leeward of fence 5	10	20	30	40	50	60	Average to 60 feet**	Relative volume
%	Inches								%
85	21	26	30	19	13	9	6	16.7	60
79	19	33	39	28	17	11	8	21.5	77
69	41	56	47	28	16	9	7	25.8	93
58	54	72	49	25	16	8	7	27.8	100
37	78	58	33	20	10	5	3	23.0	83
Average	43	49	40	24	14	8	6	23.0	83

* See Table 3 for snow conditions.

** Average of 5- and 10-foot distances leeward were used in conjunction with remaining 10-foot distances to calculate average to 60 feet leeward of fence.

Table 6. Average water-use efficiency, yield, nitrogen uptake, and protein content of grasses, leeward of a wood-slat snow fence with 72% air porosity, as influenced by nitrogen fertilization (1966-1969), Akron, Colorado (Greb 1970).

Grass species	N rates	Grass yield	Water-use efficiency	Total ET*	N uptake	Protein content
	Lb/A	Lb/A	Lb/A-inch	Inches	Lb/A	%
			With snow fence			
Russian Wildrye	0	850	135	6.28	15	11.1
	25	1,380	180	7.64	27	12.1
	50	1,645	260	6.33	36	13.7
Average		1,292	192	6.75	26	12.3
Intermediate Wheatgrass	0	1,270	170	7.36	20	9.9
	25	1,800	245	7.32	33	11.6
	50	2,025	265	7.60	39	12.2
Average		1,698	227	7.43	31	11.2
Crested Wheatgrass	0	1,570	255	6.21	26	10.3
	25	1,985	320	6.25	35	10.9
	50	2,430	395	6.16	49	12.7
Average		1,995	323	6.21	37	11.3
All Grasses - Average	0	1,230	185	6.62	20	10.4
	25	1,720	250	7.07	32	11.5
	50	2,035	305	6.70	41	12.9
			Without snow fence			
Russian Wildrye	0	500	105	4.78	10	12.0
	25	840	170	4.92	18	13.4
Average		670	138	4.85	14	12.7
			With snow fence			
Russian Wildrye - Average gain		445	20	2.11	7	-1.1

* Total evapotranspiration (ET) of each grass species, based on the average stored soil water used, plus precipitation received during the growing season.

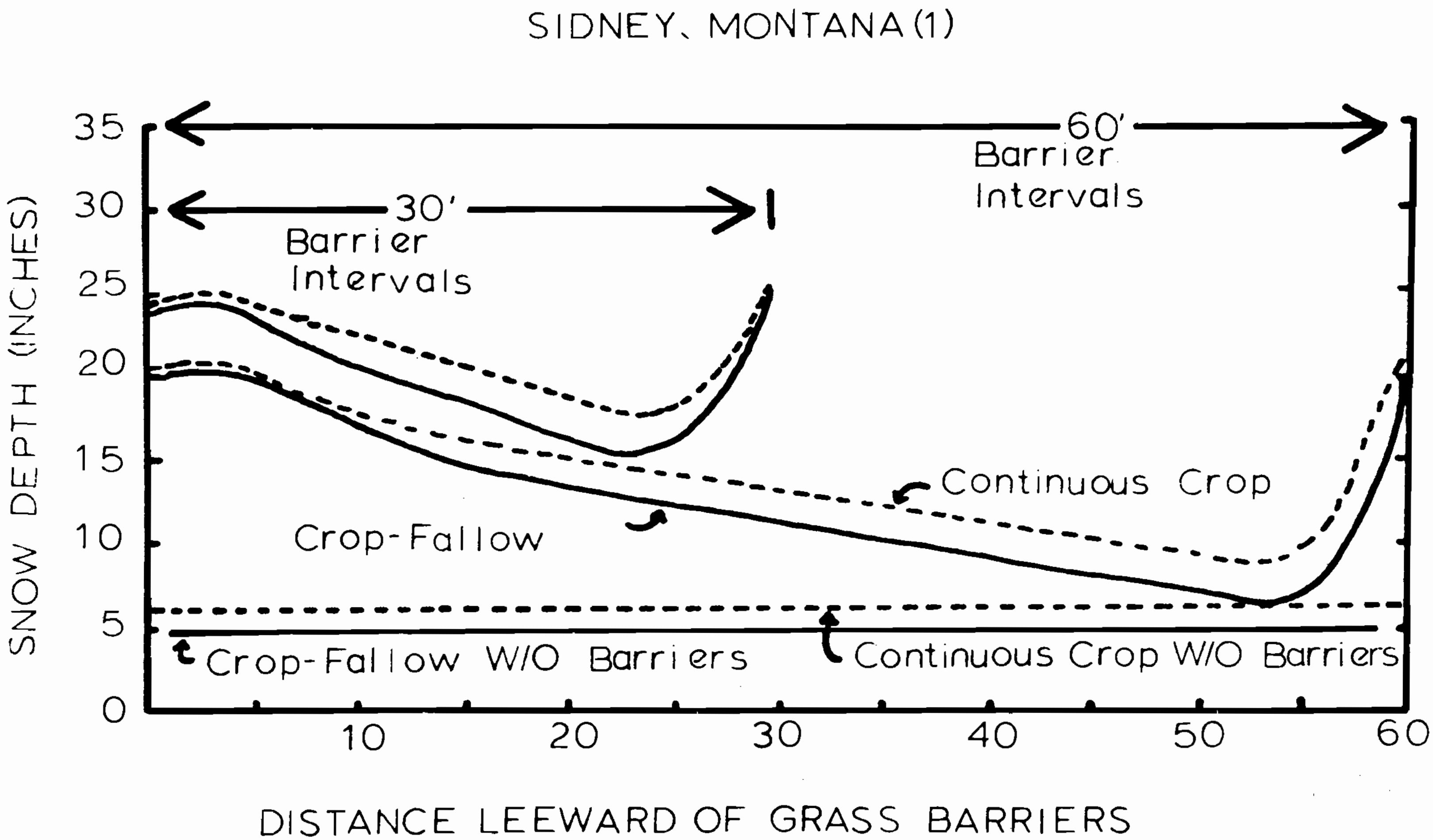

Fig. 1. Average depth of early spring snow pack with average density of 30%, as influenced by cropping sequence and width of barrier interval - Sidney, Mont. (Black and Siddoway 1971).

Fig. 2. Snow deposition on wheat leeward of 24-inch-tall sudangrass barriers with 72% air porosity, March 1964 - Akron, Colorado.

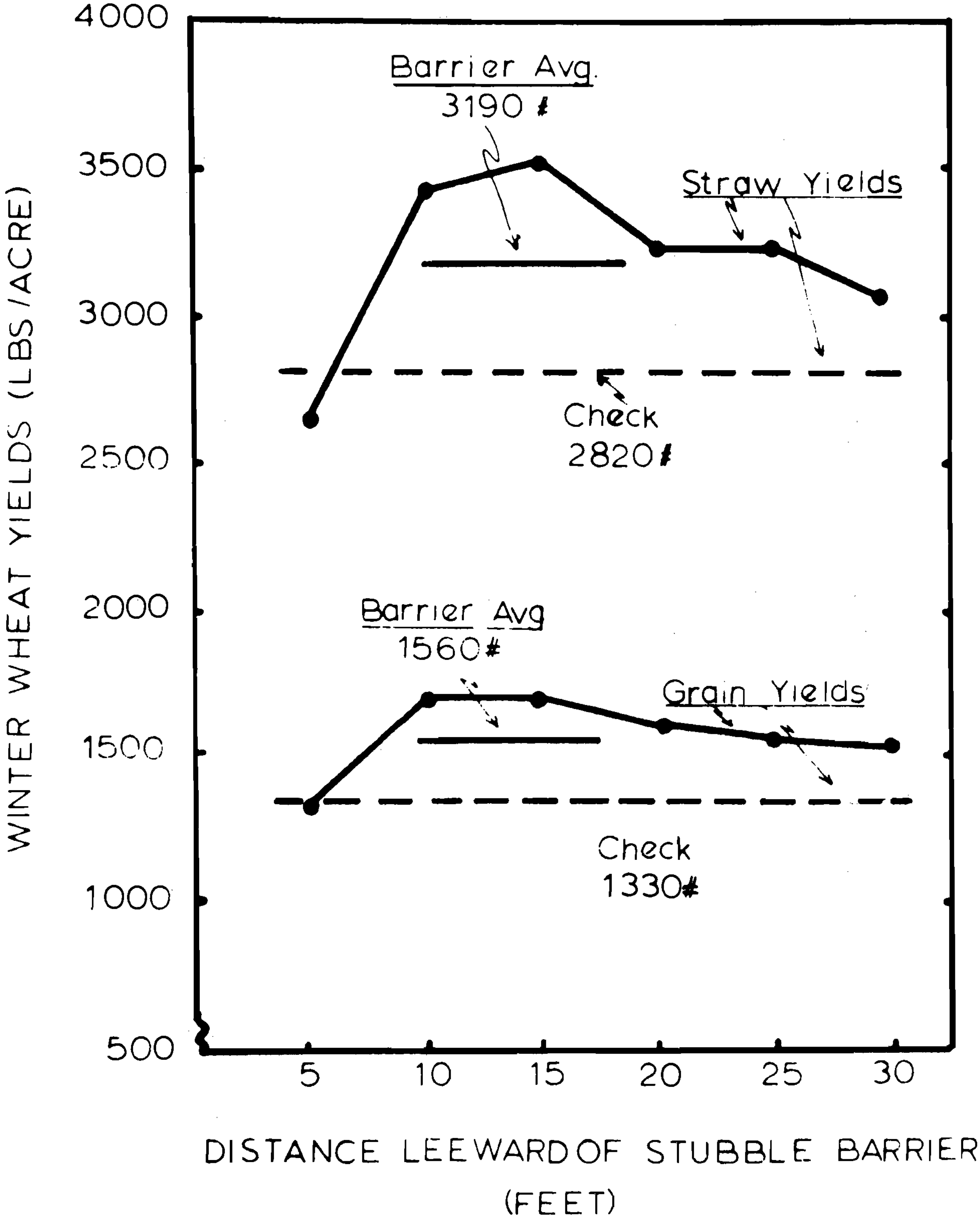

Fig. 3. Grain and straw yield of winter wheat leeward of forage sorghum stubble barriers (1960-1964) - Akron, Colorado.

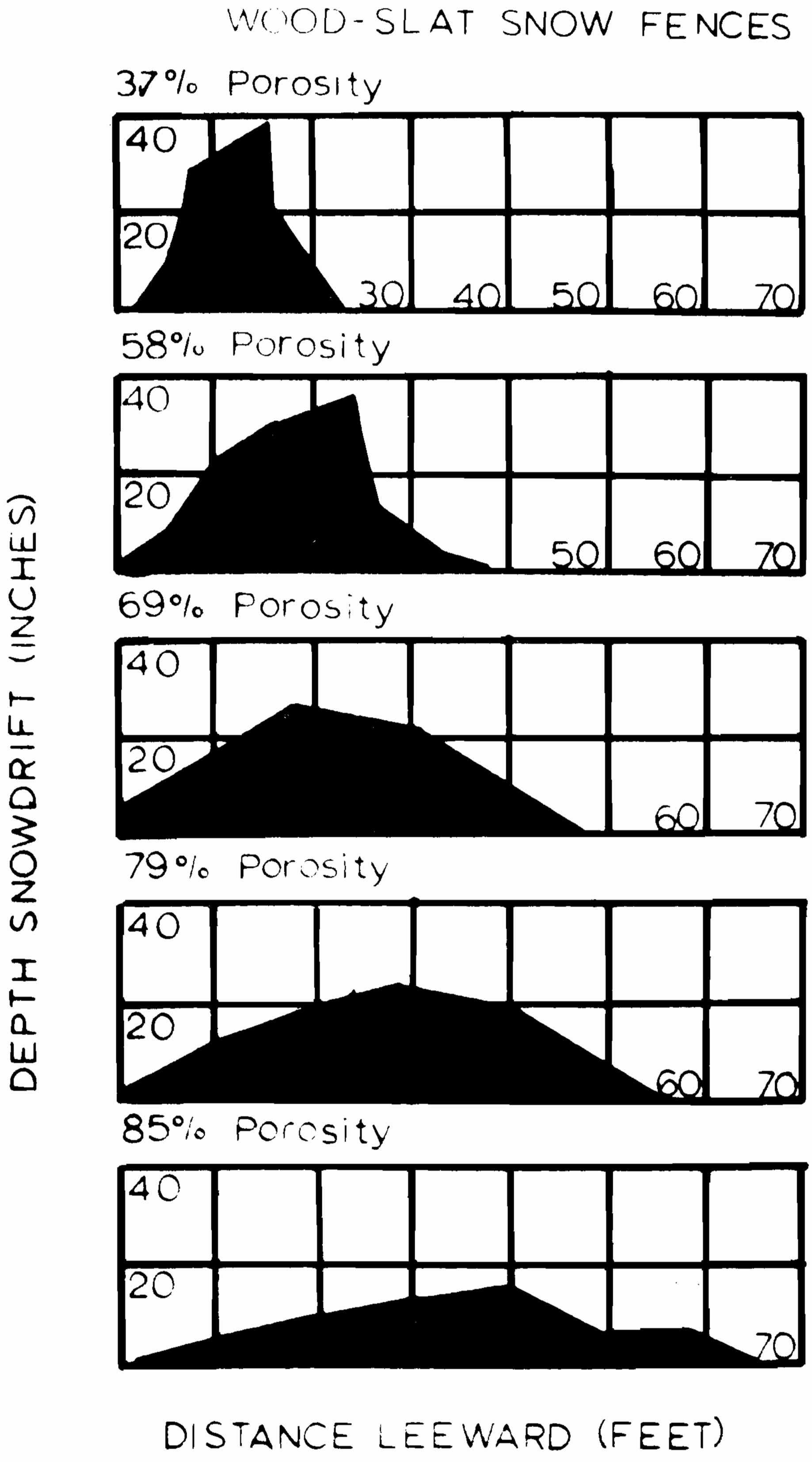

Fig. 4. Variation in depth and length of snowdrifts leeward of wood-slat snow fences with five different air porosities, January 1962 - Akron, Colorado (Greb, Mickelson, and Hinze 1965).

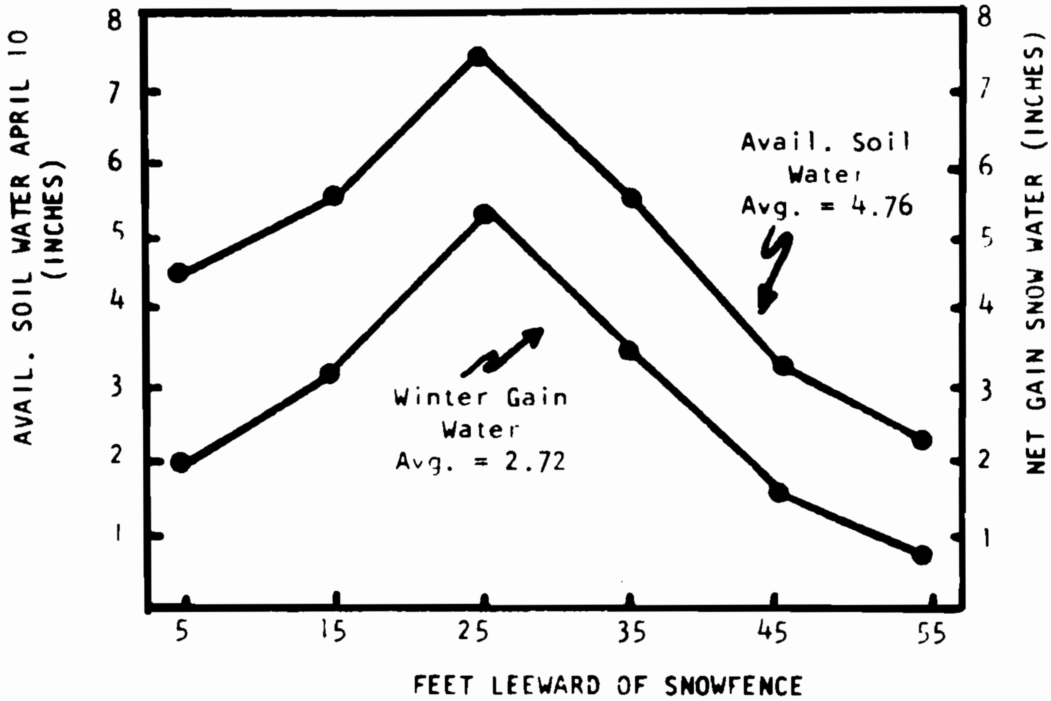

Fig. 5. Over-winter soil water gains leeward of a wood-slat snow fence with 72% air porosity - Akron, Colorado (Greb 1970).

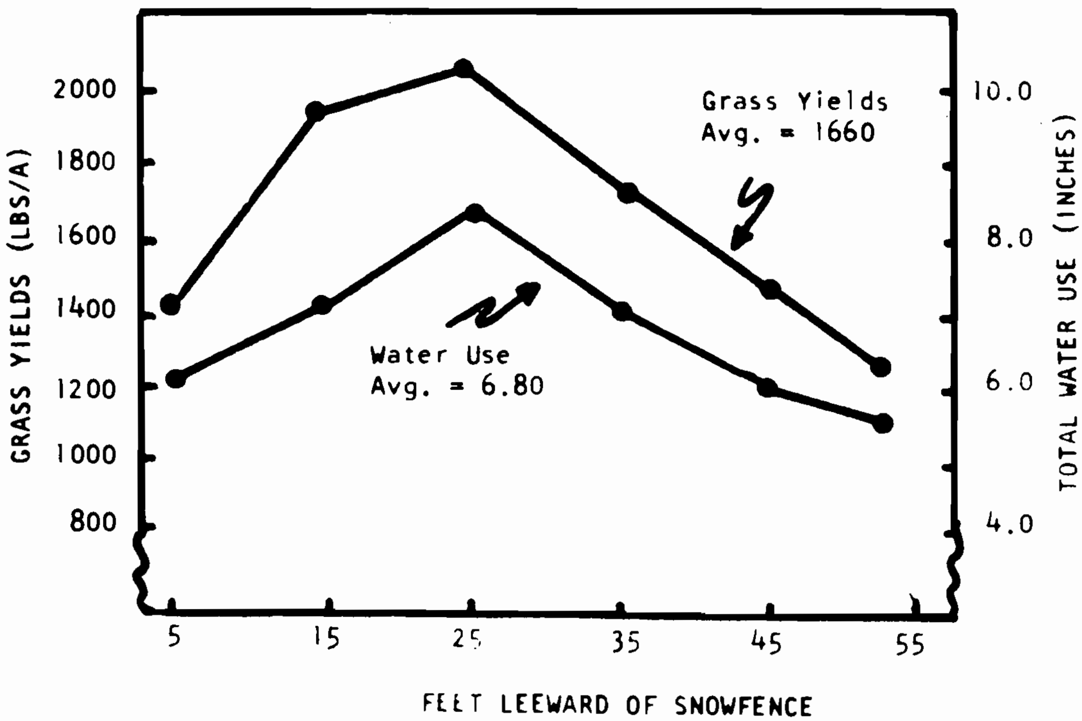

Fig. 6. Relationship of total water use to grass yield leeward of a wood-slat snow fence with 72% air porosity - Akron, Colorado (Greb 1970).