SNOW RIDGING TO INCREASE SOIL WATER[1]

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SNOW TRANSPORT AND RIDGING

Winter winds on the Prairies often carry large quantities of water in the form of snow. Steppuhn and Gray estimated that a maximum of 8.9 tonnes of snow per metre width of wind-flow could have passed in horizontal transport over the cultivated fields near Bickleigh (45 km southwest of Rosetown) Saskatchewan during the winter of 1974-75. Based on local weather conditions, their estimate assumed an unlimited supply of snow from snowfall or from the friable snow covering the ground. If only a fraction of their estimated quantity actually ever moved with the wind, such movement would still present one of the few opportunities to control and manage directly a natural source of water for benefit to crop production.

In most years, increases in available soil water will boost crop yields, provided fertility is not limiting. According to tests at Swift Current, Saskatchewan by Janzen et al (1960) the probability of harvesting 25 or more bushels per acre (1.68 tonnes/ha) increases proportionately from 10 per cent to 60 per cent as the depth of moist soil at seeding time ranges from 20-27 inch to 46 inch or more (from 50.8-68.6 cm to 116.8 cm or more). Generally, hay crops also benefit from a full supply of spring moisture. Another possibility for increasing crop production rests with the judicious reduction of summerfallow. Certainly, in such an effort, soil water additions resulting from snow management would assist the growth of stubble-seeded crops. In projecting the future grain-growing potential in Saskatchewan, Rennie (1976) who favors reducing summerfallow, strongly emphasized the need to devise methods of increasing the utilization of snow resources. Thus, the challenge for applied research centers on the development and evaluation of techniques by which producers can derive maximum utilization from the snow water transmitted across or deposited on their fields.

The forces which keep a particle of snow air-borne in a horizontally-moving stream of air result from the turbulent character of wind. Turbulence insures that a flow of air will occur in all directions, left, right, down, up and even in reverse. That is, any molecule of air may move in any

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direction in any instant. The overall wind flow, however, develops in that direction in which the majority of the molecules move. When the upward component of this turbulent motion combined with buoyancy of the fluid exceeds the gravitational force acting on a particle of snow it will become suspended in the air. Thus, the capacity of an air stream to carry (suspend) snow depends on the flow turbulence which relates to wind speed and the character of the landscape over which the air-mass travels.

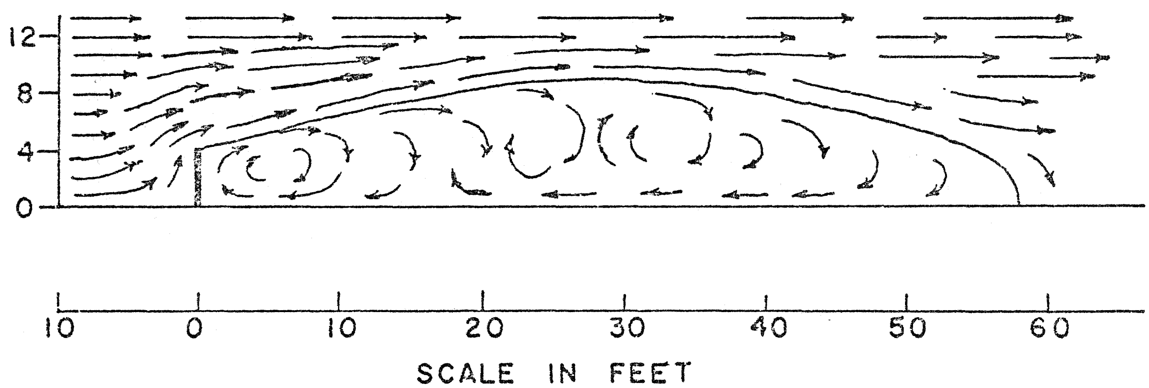
Control over deposition of the wind-borne snow involves an interference with the horizontal flow of air. Placement of an obstruction, say a fence or a hay bale, in the wind stream causes the air to compress and accelerate as it flows over and around the object. As the air passes the obstruction the fluid expands and reduces speed. This reduction in speed along with a downward and reverse orientation of flow causes what is referred to as a separation in flow. Within this zone of separation occurs the bulk of the snow deposition (Figure 1). The faster the wind speed or the more abrupt the flow-obstruction, the larger the separation and the greater the deposition.

One method of inducing separation and the deposition of snow over cultivated fields and pastures involves plowing parallel ridges of freshly-fallen snow prior to redistribution by wind. The ridges protrude into the horizontal wind stream causing air-borne snow to drop from suspension and deposit in the furrows between ridges. The most effective ridges are tall and oriented perpendicular to the dominant snow-laden wind. The height of ridges and the spacing separating them vary with availability of snow, width of plow, and the speed of the ridging operation.

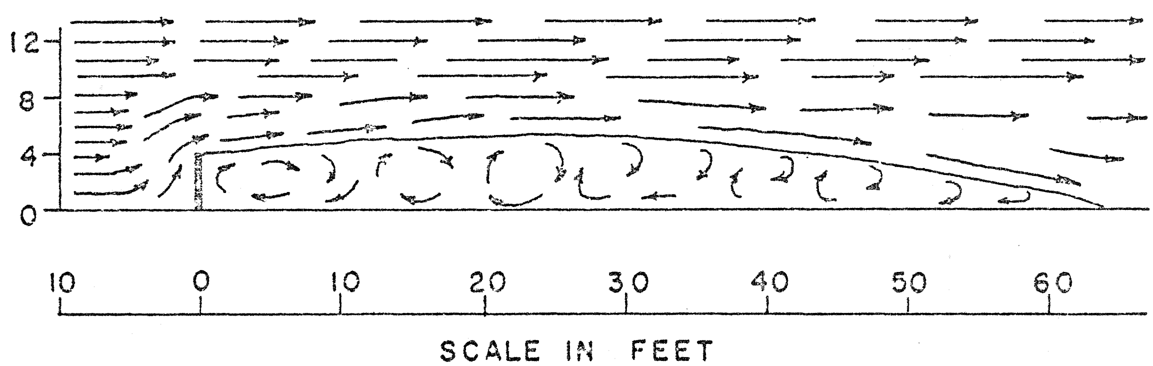
PREVIOUS TESTS AND TRIALS WITH RIDGING

Snow ridging is rather well known. The technique has frequent application in the control of snow drifting across railroads and highways. In some years, ridges surround a number of farmsteads and corrals. However, as an agronomic practice to increase water reserves in the soil, ridging requires an economic decision based on limited knowledge as to its benefits. Thus, understandably, very few producers choose to ridge.

On the Prairies, snow ridging first received considerable attention during the 1930's. Matthews (1940) reported on ridging tests conducted on the Dominion Experimental Farm at Scott, Saskatchewan during 1937-39 using a pull-type snow plow. In their tests, ridging increased the natural accumulation of snow by 100% in the ridges and 30% between them. However, gains in soil water, except in pastures, were not as dramatic and probably explain the modest advances in crop yields. Matthews concluded that snow ridging would definitely



(a) Solid Fence



(b) Vertically-Slotted Fence, 50% Porosity

Figure 1. The resultant air flow pattern over fences in a wind stream, (a) solid fence, (b) vertically-slotted fence with 50% porosity. Taken from wind tunnel tests by Finney (1934).

increase yields for some crops and generally reduce potential soil erosion by maintaining a wetter surface longer into the summer.

Snowcover management has received similar attention in the USSR. Working in the Steppe Region of Siberia, Kibasov (1955) reviewed various snow retention techniques. In summary, he favored the technique of snow ridging, citing the 58% increase in snow depth following two ridging treatments. Referring to additional ridging trials in northern Kazakhstan, Hockensmith and Harrison (1964) reported soil water additions equalling 1000 tonnes per hectare, a quantity equivalent to the complete infiltration of 100-mm (4 inch) rain. According to Bakaev (1970) the practice of ridging winter snow in the USSR still continues, most commonly on fields in winter stubble.

In 1962, C.H. Keys of the Canada Agricultural Research Branch initiated moisture conservation and utilization studies at Scott and Loverna (near the Alberta border), Saskatchewan. Experimental plots (50 by 300 feet) at each location were designed to include 17 different treatments in four replications. The arrangement involved eight comparisons between various cropping systems, two of which tested the effects of snow ridging. Unfortunately, the fifty-foot plot spacing, satisfactory for most agronomic field trials, proved insufficient to adequately evaluate ridging effects. The physics of snow transport in air-streams is sufficiently complex to produce an inter-related areal mosaic where snowcover deposition and scour occur simultaneously. That is, deposition in one part of a field may cause unusual entrainment in another part. Nevertheless, ridging was thought to have been responsible for additional wheat yields, averaged over nine years, of 2% at Scott and 10% at Loverna, but with considerable yearly variation.

A number of producers have ridged their fields at various times to utilize the snow water resource. Ridging operations on the Prairies have included those on the Norman Foster farm north of Rosetown and the Norm Flaten farm west of Weyburn. Windrowing snow (snow ridging) has also been successfully practiced to increase wheat production on a mixed cattle-grain farm in Utah (McGill, 1976). Producer Charles Taylor credits the extra yields of five bushels per acre to an increase in snow water infiltration into the soil under Utah weather conditions. Similar conditions do not prevail on the Prairies; the most probable benefits from ridging here originate mainly from increased snow accumulation. To further evaluate the possibility of utilizing snow ridging as a Prairie agronomic practice to augment water for dryland crops, we initiated a five-year study in southwestern Saskatchewan.

RIDGING EXPERIMENTS

Ridging, as we envisioned its use by Prairie producers, would apply primarily to stubble fields scheduled for reseeding in the spring. Ridging would be used to augment water where stubble-seeding is intended. Ridging in stubble has two advantages: (1) a snow-trapping stubble quickly provides the necessary snow for ridging, and (2) the dryer soil of a stubble field possesses a large storage capacity and infiltration potential for the extra water. All of our ridging trials involved areas of one acre (.405 ha) or more and were designed with minimum interactions caused by terrain, snow sources (such as from fallowed fields), field edges (bushes and weeds), treatments on controls and vice versa. The ridging experiments were conducted during the five year period; 1972/73-1976/77. The specific tests and results for each year are indicated below.

1972-73

Ridges were established during the last week of December on one acre (.405 ha) test blocks at three locations near Fiske, Saskatchewan (35 km southwest of Rosetown). An eight-foot (2.4 m) wide V-plow, push-type, (specifically designed for snow plowing) mounted on a Case-830 tractor proved adequate. Passes in opposite directions gave ridges spaced 10-12 feet (3.05-3.66 m) apart. The ridges were oriented in a north-northeast to south-southeast direction. Within two days of completing the field operations, a two-day blizzard flattened every ridge, terminating testing for that year.

1973-74

Snow ridge testing was confined to one field of first-year barley stubble owned by Mr. Willis White and located approximately 5 miles (8 km) north-east of Bickleigh, Saskatchewan. Four, one-acre (.405 ha), square blocks each separated by 200 feet (61 m) in a north-south line were established in the field. The field was relatively flat measuring 700 by 3400 feet (213 by 1037 m). Parallel fallow fields, 700 feet wide, flanked the field to the west and east. Land located to the north and south of the established blocks were in winter stubble. The soil, a sandy-clay loam, was sampled for water content from depths of 15(6), 30.5(12) and 61 cm (24 inch) at eight sites per block.

Two blocks were ridged, first in December and again in January. Ridges were oriented northeast to southwest and constructed with the same 8-foot (2.4 m) V-plow and tractor as in 1972-73. The snow in two control blocks was not ridged. The snow covering each block was sampled for depth and water equivalent on 28 March 1974 at the time of maximum accumulation. A minimum of 50 snow depth samples and 25 snow density measurements were taken in each block. Soil water was determined gravimetrically on 28 September, 1973 and 7 May, 1974. Results of these observations, outlined in Table 1, indicate that ridging trapped an additional 46 mm (1.81 inch) of snow water and 51 mm (2.01 inch) of soil water in the 0-75 cm (30 inch) root zone, which represents ridging-related water increases of 43% and 70% respectively. The discrepancy between the average snow water increase of 46 mm and the average soil water increase of 51 mm between the ridged and non-ridged blocks may in part be due to the 30 mm of rain which fell between the respective sampling dates; 28 March and 7 May 1974. The additional water derived from the ridged snow appeared to penetrate deeper into the soil. Water gains due to ridging at depths of 15, 30.5 and 61 cm were found to be 16, 39 and 226% of those for the non-ridged.

Table 1. Water Summary, 1973-74 Snow Ridging; North-east of Bickleigh, Saskatchewan

Treatment	Snow Water[a] 28 March 1974 mm(inch)	Soil Water[b] (0-72 cm) 27 Sept.1973 mm(inch)	7 May 1974 mm(inch)	Difference mm(inch)
Not Ridged (control)				
Block III	115(4.52)	162(6.38)	250(9.85)	88(3.46)
Block IV	97(3.82)	125(4.92)	181(7.13)	56(2.20)
Average	106(4.17)	143.5(5.65)	215.5(8.48)	72(2.83)
Ridged				
Block I	164(6.46)	161(6.33)	296(11.65)	136(5.35)
Block II	140(5.51)	120(4.71)	230(9.05)	110(4.33)
Average	152(5.98)	140.5(5.53)	263(10.35)	123(4.84)
Average Difference	46(1.81)	3.0(0.12)	48(1.87)	51(2.01)
Summerfallow[c]		302(11.89)	328(12.91)	26(1.02)

(a) Snow water totals were derived from a minimum of 50 depth measurement and 25 density observations per block.
(b) Soil water totals were derived from 8 observations per block.
(c) Adjacent, non-ridged field immediately west of Blocks I-IV; one observation.

1974-75

Ridging was again confined to a single wheat-stubble field owned by Mr. Willis White and located just west of the 1973-74 test site in an area approximately 5 miles (8 km) north-east of Bickleigh, Saskatchewan. Field and block dimensions followed the outline used the previous year, resulting in four one-acre (.405 ha) blocks in a north-south line. Two blocks were ridged twice, north-south in December and east-west in early February, using the same equipment as before. The densely-packed February snow proved very difficult to plow. Although completed for test purposes the second ridging would not have been feasible under normal operations. Areal snowcover averages obtained from a 9 April 1975 survey presented in Table 2, indicate an average snow water increase due to ridging of 67 mm (2.6 inch). No soil water data were obtained during this trial.

Table 2. Snowcover data averaged from two ridged and two control blocks; data derived from 9 April 1975 survey, north-east of Bickleigh, Saskatchewan, Winter 1974-75.

Blocks	Snow Depth (a) cm (inch)	Bulk Snow (b) Density cm/cm(In/In)	Snow Water mm(inch)
two controls (non-ridged)	40.8 (16.1)	.220	89.5(3.52)
two ridged	53.0 (20.9)	.296	156.5 (6.16)
% of non-ridged	130%	134%	175%

(a) Average snow depths were derived from a minimum of 50 observations per block.
(b) Average bulk snow density was derived from a minimum of 25 observations per block.

1975-76

Ridging trials were expanded to include two additional test sites, one 12 miles (19.2 km) north of Rosetown and another 20 miles (32 km) east of Leader, Saskatchewan. The area ridged at each location exceeded 13 acres (5 ha), over which only one snow-plowing operation was conducted in late December. Measurements in the ridged and control halves of each field included soil water sampling in October and May, plus a snow survey in March. Two gravimetric soil water determinations at depths of 15 cm (6 inch) and 50 cm (20 inch) were obtained from 16 or more core sites on each field half, giving estimates for the upper two feet (61 cm) of the soil profile.

Ridging on the Willis White farm near Bickleigh was again accomplished with a front-mounted 8-foot (2.4 m) V-plow. A 13.5 acre (5.5 ha) ridging block was established in the north end of a relatively level field of wheat stubble. The control block occupied another 13.5 acres (5.5 ha) to the south. Land use north and south of the test field was stubble, while fallow fields lay to the east and west. Ridges, oriented from north to south and about 24 inches (61 cm) high, were formed from the 8-inch (20.3 cm) December snowcover. It should be noted that a 1 to 3 ratio between snowcover depth and ridge height was common to all ridging operations with the V-blade push-plow.

Ridging on the Norman Foster farm north of Rosetown extended over a 30-acre (12 ha) barley stubble field. Stubble land surrounded the field on all sides. East-west oriented ridges were plowed in December of 1975 using an angled straight-blade mounted on a Case 930 tractor. The 50 acre (20 ha) field of barley stubble selected for a non-ridged comparison lay 1/2 mile (0.8 km) to the north. Soils in both fields are a heavy clay and form a portion of a broad level plain.

Snow ridges on the Erickson farm east of Leader extended over 80 acres (32 ha). The snow covering the south half of a quarter-section in wheat stubble was ridged, while the north half was left as a control. Topography over the quarter forms a gently undulating plain with a heavy-clay soil texture. An angle-mounted, straight-blade plow successfully pushed the snow into ridges. The field operation followed a continuous, concentric path around the field, similar to a swathing operation. All ridges for the first and only field operation of the Winter 1975-76 were completed by December.

Very little snow fell during January 1976. Instead, air temperatures rose and snow melted. The ridges at all locations, which had as yet trapped practically no snow, sustained considerable melt loss and deformity. Melt had been sufficient to add appreciable quantities to soil water reserves before snow fell again in February. A second ridging of the new snow was judged a poor investment and withheld, leaving only inefficient remnants to trap the new snow. Snowcover measurements in March generally reflected the magnitude of the February and March snowfall. These data, in Table 3, still showed a slight edge in magnitude for snowcover over the ridged fields.

The water data listed in Table 3 should be compared with caution. Because of the mid-winter melt, measured snowcover quantities do not reflect the total water available for infiltration to the given soil. Ridging did not appear to have increased soil water gains; however, very little could have been expected, given the diminished condition of the ridges caused by the January melt. Nevertheless, soil water improvements from snow occurred on both the ridged and the control fields, especially within the heavy-clay soils in which April water reserves were nearly equal in the four fields regardless of their October status. With such relatively large soil water quantities, the possibility also existed that significant amounts of rain and snow water may have percolated below the 61-cm (2-foot) deep soil zone sampled.

Table 3. Water Summary, 1975-76 Snow Ridging at three Saskatchewan locations.

Location, Treatment	Snow Water[a,b] March 1976	Soil Water[c] (0-61 cm profile)		
		Oct.1975	April 1976	Winter Gain
	mm (inch)	mm (inch)	mm (inch)	mm (inch)
Bickleigh (Sandy clay loam)				
Ridged	66 (2.58)	190 (7.49)	261 (10.27)	70.6 (2.78)
Not Ridged	49 (1.94)	164 (6.45)	237 (9.35)	73.6 (2.90)
Rosetown (Heavy clay)				
Ridged	92 (3.63)	255 (10.05)	408 (16.08)	153 (6.02)
Not ridged	79 (3.10)	227 (8.94)	386 (15.20)	159 (6.36)
Leader (Heavy clay)				
Ridged	69 (2.72)	300 (11.83)	378 (14.88)	77.6 (3.06)
Not ridged	54 (2.11)	308 (12.11)	386 (15.20)	78.5 (3.09)

(a) Considerable snow had melted before measurement.
(b) Snow water totals were derived from a minimum of 72 depth measurements and 10 density observations per field.
(c) Soil water totals were derived from a minimum of 16 observations per field.

1976-77

Plans to continue ridging trials as in 1975-76 were formulated. Unfortunately, significant snow did not fall until late December, and even then, snowcover amounted to only half the average stubble height. January continued to be dry and warm, providing no opportunity for ridging. Snow finally fell in mid-February, but never in large amounts and often followed by warm melt periods. Thus, the 1976-77 winter throughout the Dark Brown and Brown Soil Zones of Saskatchewan could be described as one in which snowcover was insufficient to form functional ridges.

GENERAL OBSERVATIONS

Experience from testing the merits of snow ridging in Southwestern Saskatchewan to increase soil water led to a number of singular observations:

* The ridging of snow in fields which have been fallowed the previous summer proved difficult and appears uneconomical owing mainly to their limited soil water storage capacity.

* The establishment of satisfactory ridges generally requires two plowing operations, one as early as permanent winter snowcover materializes (usually in December) and another in January or early February.

* Functional ridges, spaced 12 feet (3.7 m) apart, were obtained with front-mounted V or straight blade plows, 8-foot (2.4 m) wide. The average operational cost of one ridge plowing amounted to less than one cultivation in a summerfallow operation.

* No advantage in trapping efficiency could be detected for directional orientation of the ridges.

* To avoid scouring of the seedbed, the plow blade was raised 1-2 inches (3-5 cm) above the soil surface. This practice also reduced the fraction of soil found mixed into the ridge.

* Soil and crop residue incorporated with the ridge-forming snow enhanced energy absorption from radiation. Consequently, the ridged snow melted earlier and quicker than the cleaner snow deposited between the ridges.

* Following ridging the relatively bare inter-ridged soils are subject to considerable heat loss, becoming quite cold if not covered by fresh snow; later these zones take longer to thaw, reducing their infiltration capacity for the melted snow.

* Finally, snow ridging may be very cold miserable work as the optimum ridging operation is generally required just after a major snowfall when air temperatures are often lowest.

CONCLUSIONS

Once established, parallel ridges of snow spaced 12 feet (3.7 m) apart across test fields in winter stubble induces the deposition of wind-borne snow. Although solid ridges are inherently less efficient than porous barriers of equal height (Figure 1), their effectiveness in accumulating snow was demonstrated. In 1973-74, ridged blocks showed a mean snow water increase of 46 mm (43%) and an additional over-winter soil water gain of 51 mm (70%) within the 0-75 cm root zone. Hay crops, which require abundant spring moisture to produce good yields, would certainly benefit from snow-plowing. Cereal grains, however, require additional summer rain to fully and economically utilize the early spring soil water enriched by ridging.

Problems in establishing, maintaining and utilizing snow ridges certainly exist. Initially, sufficient snow must accumulate to permit formation of ridges. Typically, such a delay foregoes the opportunity to advantageously manipulate the season's first few blowing events. Occasionally, as in 1976-77, sufficient snow for ridge-formation does not occur until it is too late for effective ridges. Even after establishment, ridges are vulnerable to destructive hazards, such as by wind as in 1972-73 and by melt as in 1975-76. An additional problem results when no significant wind follows construction of the ridges. Without wind from which the snow is trapped the ridging investment produces little return to the Prairie producer.

The fate of melt waters from snow-plowed fields presents concern. Potential gains in soil water may be lost with the surface runoff or by deep drainage. If ridging exposes the soil to water-freezing temperatures, thereby reducing infiltration of melt waters, or if soil contaminated ridges melt rapidly, excess surface waters may result, contributing to losses by runoff and direct evaporation. On the other hand, if infiltration is rapid and early in the spring or if the soil contains a large fraction of unfrozen water, additions gained by ridging may percolate below effective root zones. The most ready advice relative to these problems suggests restricting snow ridging to fields which exhibit relatively dry soils. Such soils maximize water storage and minimize the percentage of frozen water which hinders infiltration.

Early experiments with snow ridging in the semi-arid Prairie indicated that benefits were inconsistent. Our trials resulted in this same conclusion. In 3 out of 5 test years, snow ridging as a method of increasing soil water proved unsuccessful. The two beneficial years did show that soil water gains were possible if the practice is well planned and coordinated. The successful snow ridger must be prepared

(1) to plow fields immediately following snowfall, (2) to assume the risk of failure with each plowing, and (3) to appreciate that the practice during some years will not bring added benefits.

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