COMBINED SUBSOILING AND SNOW MANAGEMENT FOR DROUGHT ATTENUATION

R.J. Granger\(^1\) and D.M. Gray\(^2\)

ABSTRACT

The paper summarizes the results of field studies on the snowmelt infiltration characteristics of frozen Prairie soils and their application in the use of snow management practices for increasing soil water reserves. It is demonstrated that the low infiltration properties of uncracked, frozen soils put in question the strategy of expecting large increases in soil water from snow management alone.

The need for combining some operation, such as subsoiling, that increases the macropore content of the soil at the time of melt, with a snow management practice in order to effect significant augmentation of soil water reserves by meltwater infiltration is emphasized. Data are presented to demonstrate that "ripping" a soil to a depth of 600 mm increases the water intake on average by 6-8 times the amount to an undisturbed stubble, depending on the available snowcover water equivalent. The increases are of the same order of magnitude found in soils in the natural state when in a cracked condition. Subsoiling, in addition to increasing infiltration, enhances drought attenuation by allowing meltwater to percolate deep into the root zone where it is less susceptible to evaporation and retained for use by a crop later in the growing season.

Suggested depths and spacings of the rips are given. As well, a preliminary assessment of the viability of the practices, subsoiling and snow management, in terms of improved yields is presented.

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The importance of water to the production of cereal grains under dryland farming is well-recognized. For the Canadian Prairies, the Saskatchewan Advisory Council on Soils and Agronomy (1982) recommends that root-zone water reserves of 125 mm and 100 mm are needed in the Brown and Dark Brown soil zones, respectively, at the time of seeding to achieve average yields. The recommendation is based on the expectation of normal, or near normal rainfall amounts throughout the growing period. Dyck and Granger (1982) summarized the general precipitation statistics for two sites, Bad Lake in the Brown soil zone, and Saskatoon in the Dark Brown zone (see Table 1) and show an average growing season rainfall for Bad Lake of 176 mm and 195 mm for Saskatoon. Combined with the recommended reserves, the amounts suggest that the moisture requirement for growing an average crop is approximately 300 mm. This was confirmed by Dyck and Granger (1982) who showed that the evapotranspiration from a wheat crop at Bad Lake in 1980 was approximately 320 mm.

The data in Table 1 show that the average annual precipitation at the two locations is adequate to produce an average crop. However, they also indicate a major loss usually occurs during the winter; only 20-35% of the water that falls as snow enters the soil during the spring, most of the snow water being lost to evaporation, to transport and sublimation during blowing events, and to runoff. The result is that, following a growing season where the soil moisture content of the root zone has been depleted to near the wilting point, the expected water inputs (fall rain, snowmelt infiltration to stubble, and spring rain (72-90 mm)) are not sufficient to meet the recommended pre-seeding moisture reserves, and hence a growing season with average precipitation would not likely produce an average crop.

Table 1. Average annual precipitation and infiltration amounts (mm) for sites in the Brown and Dark Brown soil zones of Saskatchewan.

<table>
<thead>
<tr>
<th></th>
<th>Brown Soil Zone (Bad Lake)</th>
<th>Dark Brown Soil Zone (Saskatoon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall rain</td>
<td>26.1</td>
<td>44.3</td>
</tr>
<tr>
<td>Winter snow water</td>
<td>93.6</td>
<td>118.4</td>
</tr>
<tr>
<td>Snowmelt INF: stubble</td>
<td>33.0&lt;sup&gt;b&lt;/sup&gt;(18)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>23.8 (27)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16.7 (7)</td>
</tr>
<tr>
<td>Spring rain</td>
<td>13.7</td>
<td>11.3</td>
</tr>
<tr>
<td>Growing season rain</td>
<td>176.2</td>
<td>195.0</td>
</tr>
<tr>
<td>Total precipitation</td>
<td>309.6</td>
<td>369.0</td>
</tr>
<tr>
<td>Ratio: Snow/Total</td>
<td>.30</td>
<td>.32</td>
</tr>
</tbody>
</table>

<sup>a</sup>Precipitation values are averages for the period 1968-81 (after Dyck and Granger, 1982).

<sup>b</sup>Average infiltration 1978-1985.

<sup>c</sup>Numbers in parentheses represent the number of observations.
The 50-100 mm of snow water that does not infiltrate (Table 1) represents water lost and unavailable for attenuating the effects of a drought and increasing yield. Staple and Lehane (1954) have suggested that soil water additions above a certain base level increase yield in varying amounts; e.g., each additional 25 mm of water above a moisture reserve of 262 mm to a maximum near 412 mm increased wheat yields by 230-400 kg/ha. Similarly, de Jong and Rennie (1969) reported increases in the yield of spring wheat in the range of 200-275 kg/ha for each additional 25 mm of water above the long-term normal precipitation for the sub-humid, east-central region of the province of Saskatchewan.

This strong dependency of yield on available water, considered with the general statistics given in Table 1 evince the recognized need for efficient water conservation measures in agriculture, particularly in view of the trend to minimum, zero-till and continuous cropping practices. Throughout the Prairie region, neglecting large-scale water diversions and the development of irrigation schemes, snow represents the major source of manageable fresh water. The fact that on average snowfall represents approximately 30% of the total annual precipitation demonstrates the importance of this resource.

SNOW MANAGEMENT PRACTICES

Recently, there has been increased interest in the potential of "managing" snow to increase soil water reserves. Because of the types of crops grown and the nature of the farming operations on the Prairies, the non-competitive method of snow trapping by stubble management appears to be the most acceptable snow management practice. The most popular methods include: (1) Tall stubble - a practice which is usually employed when the crop can be straight-combined to leave a stand of uniform, tall stubble, (2) Alternate-height stubble - this practice involves harvesting a crop to leave bands of "low and high" stubble throughout a field with each band being the width of the swather and (3) Deflector strips - a practice that leaves narrow strips of tall stubble, usually 400-600 mm in width on a spacing approximately equal to the width of the swather.

The amount of evidence showing that snow management practices can be used to increase the depth of snowcover and snow water is indisputable. For example, Nicholaichuk et al. (1984) reported on the relative amounts of snow trapped by different stubble management practices at Swift Current, Saskatchewan. They found: (1) for the 12 year period, 1972-1984, an average annual increase of ~12 mm of snow water on plots with "alternate-height" stubble compared with uniform stubble, with a maximum increase of 42 mm, and (2) for the three year period, 1981-1984, average percentages of the annual snowfall trapped by uniform stubble, "deflector" and "clipped" strips (similar to deflector strips but the strips are formed by clipping the heads with a separate clipping device) of 60, 84 and 99%, respectively.

The effectiveness of a snow management practice in trapping snow depends on a number of factors. However, the availability of snow and wind
for transporting the snow are the major climatological variables. When snow, fetch and wind conditions are favorable, the accumulation pattern will be such that the snow will tend to fill the vegetation, as is the case with regular, tall and alternate height stubble, or fill the space between barriers, as with deflector strips.

The basic premise underlying the use of a snow management practice for increasing soil moisture is that an increase in snow water, the result of an increase in depth, density or both snowcover properties, will result in increased snowmelt infiltration. However, the potential for erosion and other problems associated with excessive runoff dictate that the decision to employ snow management practices be based on some knowledge of the soil infiltration characteristics or be accompanied by some technique that will ensure that most of the meltwater infiltrates.

INFILTRATION TO FROZEN SOILS

Infiltration to frozen soils involves the complex phenomenon of coupled heat and mass transfer through porous media. The process is affected by many factors including: the hydrophysical and thermal properties of the soil; the soil moisture and temperature regimes; the rate of release of water from the snowcover and the energy content of the infiltrating water. In the absence of major structural deformations in a soil profile, e.g. cracks or other macropores, the most important hydrophysical property of a frozen soil which governs its ability to absorb and transmit water is its moisture content. An inverse relationship between infiltration and the moisture (ice) content of frozen soils has been demonstrated or postulated by many investigators (Gillies, 1968; Motovilov, 1979; Kane, 1980 and Granger et al., 1984).

Granger et al. (1984) undertook an extensive field study of snowmelt infiltration to frozen, medium to fine-textured soils in central Saskatchewan. The study resulted in the development of a simple physically-based model describing snowmelt infiltration to frozen soils (Gray et al., 1985a). Conceptually, the model groups frozen soils into three broad categories with regard to their infiltration potential, namely: Restricted, Limited and Unlimited.

Restricted - infiltration is impeded by an impermeable layer, such as an ice lense at the soil surface or within the soil near the surface. For practical purposes the amount of meltwater infiltration can be assumed to be negligible and most of the snow water goes to direct runoff and evaporation.

Limited - infiltration is governed primarily by the snowcover water equivalent and the frozen water content of a shallow layer of soil, 0-300 mm.

Unlimited - a soil in this condition contains a high percentage of large, air-filled, non-capillary pores or macropores at the time of melt and
most or all of the snow water will infiltrate. Examples of such soils are dry, heavily-cracked clays and coarse, dry sands.

Granger et al. (1984) found for medium to fine-textured, uncracked frozen soils in which entry of meltwater is not impeded by ice layers (i.e. the Limited case) that: (a) the average depth water penetrated a soil during the melt period was 260 mm (standard deviation = 100 mm), (b) infiltration to frozen soils was relatively independent of soil texture and landuse and (c) the amount of snowmelt infiltration was inversely related to the average moisture content of the soil layer, 0-300 mm, at the time of melt. Based on these findings, they derived a set of equations defining the relationship between snowmelt infiltration (INF), snowcover water equivalent (SWE) and the pre-melt moisture content of the 0-300 mm soil layer (θ_p). For practical purposes, and cases where SWE > INF these results can be approximated by the equation:

\[ INF = 5(1-\theta_p)SWE^{0.584}, \]

in which INF and SWE are in mm and θ_p is the degree of pore saturation, mm^3/mm^3. The relationship has a correlation coefficient of 0.85 and a standard error of estimate of 7.7 mm.

Figure 1 shows field measurements to support the infiltration model. By definition the 1:1 line in the figures represents infiltration for the Unlimited case, while the horizontal axis (INF = 0) represents the Restricted case. For the sake of clarity, Fig. 1(b) (Limited) shows only the family of curves, for various values of θ_p described by Eq. 1. The curves in Fig. 1(b) serve to demonstrate the dilemma in attempting to obtain substantial increases in soil water reserves through snow management practices on uncracked frozen soils. The figure shows that for a frozen soil at a given moisture content the incremental increase in snowmelt infiltration per unit increase in snowcover water equivalent decreases with an increase in SWE; as well there is a decrease in the ratio of INF to SWE. In other words the data suggest there is a defined depth of snow water which may be accumulated on an uncracked, frozen soil in a given moisture condition above which the losses to direct runoff and evaporation per unit increase in SWE exceed the gains by infiltration. Gray et al. (1985b), used these data to demonstrate that if a producer wanted at least 60% of the snow water to infiltrate an extremely dry soil (θ_p = 0.25) the maximum depth of snow recommended would be about 325 mm (SWE = 81 mm). The major part of snow additions above this depth would likely be lost. Given the fact that throughout much of the semi-arid region of the Prairies the average annual snowfall water equivalent is in the range 75 to 120 mm, it is unrealistic to expect large increases in soil water replenishment and increased yields on undisturbed and uncracked frozen soils from snow management. This is not to suggest that stubble management, by assuring a reasonable depth of snowcover each year, would not have the effect of increasing the average long-term yield.
(a) RESTRICTED: INF is low, runoff potential is high.

(b) LIMITED: INF is a function of SWE and soil moisture.

(c) UNLIMITED: All or most of SWE infiltrates.

Figure 1. Measured infiltration for the different infiltration classes of frozen Prairie soils: (a) Restricted, (b) Limited and (c) Unlimited. (Note: $\theta_p$ is the relative degree of saturation expressed in m$^3$/m$^3$).
INFILTRATION TO CRACKED SOIL

Figure 1(c) (Unlimited case) shows that cracked soils have the capacity to infiltrate most or all of the water equivalent of an average snowcover and depending on the number, density and physical dimensions of the cracks even heavy snowcovers encountered on the Prairies. These soils then offer a high potential for increased infiltration from increased snowcover and, as such, represent an ideal situation for the implementation of a snow management practice.

Table 2 presents average infiltration amounts to frozen, cracked soils of different texture. The data suggest that the ability of a cracked soil to infiltrate meltwater is directly related to its susceptibility to cracking; i.e.: heavy clay soils produce wide and deep cracks and thus can take in a greater quantity of water. It is interesting to compare the infiltration amounts with those listed for uncracked stubble (see Table 1). For the Bad Lake site (silty clay) infiltration to cracked soil represents an average increase of approximately 60 mm of water over that infiltrating uncracked stubble, while for the Saskatoon site (silty loam) the equivalent increase is approximately 50 mm.

In the fall of 1984 an attempt was made to measure the extent of soil cracking on stubble fields in heavy clay. The length of cracks exposed at the surface in a 1 m² area was used as the index. From field measurements taken on randomly-selected plots, it was found the length ranged from 0.87 m to 2.64 m, with a mean of 1.75 m per m². These findings were used to estimate the area represented by measurements made with a twin probe density meter with the crack centered between the source and detector. Assuming uniform moisture conditions along a crack, the length of the soil cube sampled by the system is 0.25 m and a crack-length:area ratio of 1.75 m/m², the point measurement would be representative of an area of 0.44 m²/m².

Table 2. Average infiltration to cracked soils.

<table>
<thead>
<tr>
<th>Soil type</th>
<th>no. obs.</th>
<th>Crack depth</th>
<th>Average infiltration amount</th>
<th>Infiltration depth</th>
<th>SWE</th>
<th>&quot;Areal&quot; infiltration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy clay</td>
<td>7</td>
<td>.90</td>
<td>106.1</td>
<td>.95</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td>Silty clay</td>
<td>19</td>
<td>.81</td>
<td>92.9</td>
<td>.87</td>
<td>66</td>
<td>63</td>
</tr>
<tr>
<td>Silty clay loam</td>
<td>3</td>
<td>.73</td>
<td>77.8</td>
<td>.76</td>
<td>62</td>
<td>56</td>
</tr>
<tr>
<td>Silty loam</td>
<td>3</td>
<td>.72</td>
<td>74.1</td>
<td>.75</td>
<td>57</td>
<td>54</td>
</tr>
</tbody>
</table>

*a Infiltration amounts determined from measurements of soil moisture increases made with a twin probe meter with the crack centered between source and detector.

*b Areal infiltration based on the assumption that point measurements at cracked sites are representative of 44% of the area.
Table 2 shows the average snowcover water equivalent and "areal" infiltration estimated using the assumption that the measurement of infiltration is representative of 44% of the area and that infiltration to the remaining area is the amount to uncracked stubble ($\theta_p \leq .45$). The average "areal" infiltration (60 mm) represents an increase of approximately 30 mm of water over that infiltrating uncracked stubble. This increase, obtained without the use of snow management practices, is greater than the soil moisture increases obtained with snow management on uncracked stubble reported by Nicholaichuk, et al. (1984).

**SUBSOILING FOR INCREASED SNOWMELT INFILTRATION**

It is evident from the above discussion that the augmentation of soil water by snow management is significantly improved when it is practised on frozen soils of the "unlimited" class. In the absence of natural cracks major benefits are most likely when a management practice is used in combination with some mechanical treatment (subsoiling or other) which significantly alters the soil structure so as to increase the number of large macropores which will allow more meltwater to percolate deep into the root zone.

Two subsoiling practices, a Killefer plow (a deep, chisel subsoiler) and a Paraplow\(^1\) were tested for increasing snowmelt infiltration to uncracked frozen soils. At Kerrobert, a Killefer plow was used to "rip" a glacial clay loam. This subsoiler consists of a single, wheel-mounted cultivator shank 25 mm in thickness, 200 mm in width and 970 mm in length having a wedge-shaped chisel (75 mm in width) attached to the bottom. When pulled through the soil it produces a slit (rip) to a depth of about 600 mm; however, fracturing of the soil by the chisel can extend to depths of 800 mm. The rips were made on a spacing of approximately 1.85 m (the draw bar spacing of the power unit). Subsoiling was performed in the fall of 1983 and repeated on an adjacent area of the same field in 1984. At Saskatoon (a lacustrine silty clay) plots were "Paraplowed" in the fall of 1983. The Paraplow has a shank or "bottom" with physical features similar to a mold-board plow. However, rather than inverting the furrow it lifts, shears, and fractures the soil to a depth of 300 to 500 mm, leaving a standing stubble or trash cover on the surface.

Estimates of snowmelt infiltration were obtained from changes in soil moisture monitored with a two-probe density meter. This system provides non-destructive sampling of the soil profile with a vertical resolution of 20 mm. The method is described in detail by Granger et al. (1984).

Figure 2 compares the infiltration amounts and patterns at Kerrobert in undisturbed and subsoiled stubble. Fig. 2(b) is the soil moisture change measured across the rip and Fig. 2(c) is the change measured perpendicular to the rupture at a distance between 150 and 450 mm. The measurement sites were protected against direct runoff from surrounding areas.

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\(^1\)Paraplow is a trademark of the Howard Rotovator Company.
Figure 2. Soil moisture changes due to snowmelt infiltration in an undisturbed and subsoiled clay loam at Kerrobert, Saskatchewan during spring 1985. (a) Undisturbed stubble; (b) Subsoiled stubble: line installed with a Killefer plow to a depth of 600 mm in the fall of 1984 - rip was centered between source and detector; (c) Adjacent to rip: measurement at a distance of 150-450 mm perpendicular to rip.

The figure supports the finding that on an uncracked stubble the amount and depth of infiltration are limited. With a snowcover water equivalent of 194 mm, only 27 mm of meltwater infiltrated and penetrated to a depth of -160 mm. The site that was ripped to a depth of 600 mm, showed a significant increase (173 mm) in moisture to a depth of 1 m. The penetration of meltwater below the depth of the rip can be attributed to fracturing of the soil to depth by the subsoiling operation. Also, as shown in Fig. 2(c) there was a significant moisture increase adjacent to the rip, indicating that some of the water which entered the fracture moved laterally in the soil to distances of at least 450 mm. In the spring of 1985 lateral movement was detected at distances as far as 1 m from the rips.

Table 3 lists representative values of the ratio of the amount of snowmelt infiltration into naturally-cracked and subsoiled soils to the amount into an uncracked stubble for different amounts of snowcover water equivalent. The range in values indicates that the magnitude of the ratio can vary widely. This can be attributed to the fact that the point measurement of infiltration to cracked and ripped soils can be either greater or less than the snowcover water equivalent because water can reach the measurement point through overland flow to or Interflow in the fractures.
Table 3. Ratio of the amount of snowmelt infiltration to cracked and subsoiled soil to the amount to the same soil in an uncracked or undisturbed condition for different ranges in snowcover water equivalent.

<table>
<thead>
<tr>
<th>SWE a mm</th>
<th>Cracked b Range</th>
<th>Mean</th>
<th>Subsoiled 600 mm c Range</th>
<th>Mean</th>
<th>Paraplowed Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 30</td>
<td>4.5</td>
<td></td>
<td>1.1-1.9</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-50</td>
<td>1.2-6.7</td>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-70</td>
<td>2.1-7.1</td>
<td>4.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70-100</td>
<td>2.7-9.4</td>
<td>4.7</td>
<td>6.9</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-150</td>
<td>3.0-17.1</td>
<td>7.5</td>
<td>6.3-7.3</td>
<td>6.8</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>&gt; 150</td>
<td>4.2-8.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a SWE = snowcover water equivalent

b Measurements of soil moisture changes made with the crack located between source and detector.

c Ripped to a depth of 600 mm on 1.85-m spacing with a Killefer plow; clay loam and clay soils at Kerrobert. Measurements of soil moisture changes made with the rip located between source and detector.

themselves. Nonetheless, as expected the data show a trend for the average ratio to increase with the snowcover water equivalent, reaching maximum values in cracked and ripped soils in the range of 6.5 to 7.5.

The data in Table 3 also suggest that "ripping" is a more effective method of increasing the infiltration potential of a frozen soil than "paraplowing". However the finding should be treated with caution because of the limited amount of data available. It is also probable that other factors, such as differences in the depth of the treatments could contribute to the difference.

Ripping a soil not only increases the water storage capacity and allows easy entry of meltwater to the frozen soil but also permits water to penetrate to a greater depth. Gray et al. (1984) have shown that during the period between snowmelt and seeding of annual crops much of the water held in the upper 100-200 mm soil layer is lost to evaporation. Figure 2(b) shows that at a ripped site very little meltwater was retained by this upper layer; the major part percolated to greater depths. Thus it is less available for evaporation and available for crop use later in the growing season.

Although the above discussions tend to suggest that the rips be placed as deep as possible, the selection of the "optimum" depth-of-installation must take into account other factors such as the rooting depth of the crop and the energy, hence cost, required to install the lines. The horizontal spacing between rips will depend mainly on the soil's ability to transmit
water laterally from the rip. This is affected by the water transmission properties of the soil and the amount of fracturing between the rips (a function of the shank design). Gray et al. (1985b), using the data in Fig. 2 and a root-zone of 1 m, suggested rips be placed at a depth less than 600 mm, in the range or 400-500 mm. Based on observations of lateral movement of water in cracked and subsoiled clay loam and clay soils, they suggest a spacing in the range of 1 to 1.5 m.

An important factor affecting the acceptance of a deep tillage treatment for enhancing snowmelt infiltration is the "life expectancy" of its effects. It was observed at Kerrobert that the "rips" tended to promote soil cracking during the growing season following their installation. The rips acted as fracture planes along which preferential cracking occurred, although secondary cracks were observed to have developed in the transverse direction. Infiltration measurements taken in the spring of 1985 also supported the visual observations of soil cracking; infiltration at an undisturbed stubble site was 27 mm (SWE was 194 mm), whereas at a site subsoiled in the fall of 1983 infiltration was 95 mm (SWE was 89 mm) and meltwater penetrated the soil to a depth of 600 mm, the depth of the treatment. It is evident from these data that some of the beneficial effects of water entry by subsoiling were retained over the eighteen-month period following installation of the lines.

One of the major effects of a drought is of course the dramatic reduction in crop yields and the ensuing economic losses which accompany the occurrence. The bottom line then for any drought attenuation measure must be tangible evidence of an offsetting or compensating effect. Table 4 lists wheat yields on undisturbed stubble, subsoiled stubble and fallow measured at Kerrobert in 1984 and 1985. The data show: (a) an increase on fallow of 500-600 kg/ha over stubble in each year; (b) an average increase on subsoiled stubble (first-year) over stubble of 225 kg/ha; and (c) the second-year lines gave a yield increase of 184 kg/ha over continuous stubble. These data are provided solely to serve as indices of the relative increases in yield as a result of the subsoiling practice. They must not be considered the optimum gains which may be expected because snow management and fertilizer treatments were not applied to the subsoiled plots and it is known that the depth and spacing of the rips did not provide the most efficient distribution of soil water. On small land units within the subsoiled plots where snow management practices were applied, the average yield of 2000 kg/ha obtained from 1-m² samples was greater than that from fallow.

| Table 4. Wheat yields (kg/ha) from combined plots (1200 m²) at Kerrobert. |
|-------------------|---|---|
|                   | 1984 | 1985 |
| Stubble           | 1143a | 1046b |
| Subsoiled 1983    | 1412a | 1230b |
| Subsoiled 1984    | 1323b |     |
| Fallow            | 1614  | 1636  |

a Second year stubble, b Third year stubble
SUMMARY

The paper summarizes the results of field studies on the phenomenon of snowmelt infiltration to frozen Prairie soils. Specific attention is given to the potential of "combined" snow management and "subsoiling" practices for drought attenuation through augmentation of soil water reserves by increasing meltwater infiltration.

Data are presented to show that "ripped" (subsoiled) soils and "naturally-cracked" heavy clays infiltrate up to 6-8 times the amount to "undisturbed" stubble, depending on the available snow water. In addition to the increased infiltration, the meltwater penetrates deep into the root zone where it is less susceptible to evaporation losses and available to the crop later in the growing season.

The need for combining a snow management practice with some operation that increases the macropore content of a frozen soil at the time of melt in order to obtain optimum soil moisture recharge is discussed. Initial estimates of the optimum depth and spacing for the subsoiling operation are suggested.

Measurements of increases in the yield of wheat from subsoiling, without snow management and fertilizer treatments, over continuous stubble averaged -200 kg/ha over a two-year period. Point (1 m²) measurements of 2000 kg/ha on the subsoiled areas under snow management were found to be greater than on adjacent fields in summer fallow (1640 kg/ha).

REFERENCES


SASKATCHEWAN ADVISORY COUNCIL ON SOILS AND AGRONOMY. 1982. Saskatchewan fertilizer and cropping practices 1982-83. Saskatchewan Department of Agriculture and Extension Division, University of Saskatchewan, Saskatoon, SK.