SUBSOILING FOR SOIL AND WATER CONSERVATION

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INTRODUCTION

Subsoiling refers to noninverting tillage below the normal tillage depth. Working to depths above about 30 cm with a narrow tool is often called chiseling while ripping refers to tilling to lower soil depths. Deep plowing is a completely different operation than subsoiling since the objective of deep plowing is to mix the soil throughout the depth of working.

Water is the greatest single limitation to crop growth on the prairies. In this region the greatest opportunity for augmenting the water available for crop growth lies in increasing the conservation of precipitation which falls outside the growing season.

On the prairies, considerable benefit could be realized from subsoiling if the infiltration of snowmelt was increased. Using deep tillage for the purpose of increasing the infiltration of rainfall probably can not be justified because rainfall intensity rarely exceeds the natural infiltration rate of most prairie soils (Chanasyk and Woytowich, 1983; Toogood, 1963; Nicholaichuk, 1967). Much of the water which enters the soil from snowmelt or rain outside of the growing season merely moistens the soil near the surface and so is lost to evaporation before the crop can use it. Conserving water for crop use could also be increased if subsoiling brought about deeper penetration of the water into the soil.

In the semiarid Brown and Dark Brown soil zones of the prairies, water conservation and soil conservation are strongly related. Increasing the water available to the crop will normally increase the amount of crop residue available to protect the soil surface from erosion. More importantly, improved water conservation can improve the feasibility of extended rotations by increasing stubble yields. Reducing the frequency of fallow in the Brown and Dark Brown soil zones offers the greatest potential for reducing soil degradation from declining soil organic matter, erosion, and possible salinization.

This paper will discuss the possible role of subsoiling for soil and water conservation on the prairies based on a literature review and on preliminary results of on-going subsoiling research at the Swift Current Research Station. The emphasis will be on water conservation for recropping in the Brown soil zone and drier portions of the Dark Brown soil zone. There will be no discussion of the possible use of deep tillage to produce a cloddy soil surface as a short-lived control measure against wind and water erosion.

LITERATURE REVIEW

Subsoiling Soils Without Structural Problems

Many studies have investigated the effects of subsoiling soils without obvious structural problems on soil water and crop yields. Unger et al. (1981) reviewed the literature pertaining to subsoiling and concluded that deep tillage was only beneficial when it improved water availability to the crop. Where well timed and sufficient rainfall and/or irrigation prevented water from becoming limiting to crop growth, deep tillage did not result in a yield improvement. They noted that negative yield responses to subsoiling were very rare.

After reviewing many studies of subsoiling in the semiarid great plains, Duley (1958) concluded there was no consistent or predictable increases in either crop yields or water storage due to subsoiling. On the other hand, subsoiling rarely depressed crop yields. In Kansas, Hobbs et al. (1961) believed the lack of effect of subsoiling on water conservation was because subsequent shallow plowing destroyed any vertical soil channels formed during the subsoiling operation. In most early subsoiling trials, shallow plowing with a moldboard or discs normally followed subsoiling so that the infiltration characteristics of the soil surface were essentially the same for both subsoiled and check treatments.

Working in northwestern Texas, Gerard et al. (1984) found the effect of subsoiling varied with slope position and weather. Unlike other researchers, they measured greater yield increases due to subsoiling during wet years than during dry years. The yield response of cotton and sorghum to subsoiling was greater for upper and middle slopes than for lower slopes.

Vertical mulching or slot mulch is a refinement to subsoiling where organic matter, usually straw, is incorporated into the subsoil channel to improve the effectiveness and longevity of the channel for conduction of water. In northeastern Colorado, 15 cm deep slot mulch increased water infiltration such that 41% more water was stored in the soil than in the untreated check area (Fairbourn and Gardner, 1974). Without incorporation of the straw in the channel, the infiltration improvement from slot mulching is much less than with straw incorporation (Parr, 1959; Hauser and Taylor, 1964) Subsequent shallow tillage reduces the effect of slot mulch on water infiltration and moldboard plowing can immediately erase the infiltration benefits of slot mulch (Clark and Hore, 1965). Slot mulch holds most promise for minimum and zero tillage farming systems.

Subsoiling Solonetzic Soils

For many years deep tillage has been tried as a method of physically breaking the solonetzic Bnt hardpan to increase water storage for crop use and improve soil structure. Earlier deep tillage work involved deep plowing but recently there has been great interest in less drastic subsoiling as an amelioration method for solonetzic soils. Deep plowing mixes the soil and lime and gypsum brought from the C horizon can greatly improve the physical and chemical properties of some solonetzic soils (Cairns and Bowser, 1977). Similarly, greater benefits are sometimes realized by combining subsoiling with gypsum and/or lime application (Rasmussen et al., 1972).

In northwestern South Dakota, White et al. (1981) found ripping increased water infiltration and range productivity on solonetzic soil which were ripped 50 cm deep. In some cases, the beneficial effects of subsoiling were still noticeable after 20 years. Also in northern South Dakota, Kinsley and Shubeck (1964) tried subsoiling and slot mulch as a means of increasing water infiltration into a solonetzic soil. The slot mulch treatment increased water storage by approximately 1 cm for each 30 cm layer down to 1.2 m, while the fall subsoiling operation did not improve water storage over the untilled check treatment.

Most research into deep tillage of solonetzic soils in Canada has been conducted in Alberta. The benefits of subsoiling have been mixed in the Black soil zone (Webster and Nyborg, 1986) and in the Brown soil zone (Lavado and Cairns, 1980). Chang et al. (1986) found subsoiling a Brown solonetzic soil had no significant effect on soil salinity and sodicity or on wheat yield. However, under irrigation, subsoiling did enhance the downward movement of salts but had no significant effect on wheat yields. Lickacz (1986) evaluated 105 subsoiling trials conducted in Alberta. He concluded subsoiling was less benefit in the Brown soil zone because moisture deficits are the major limitation to crop production so subsoiling to augment water storage may not be economical. The average wheat yield increases for subsoiled solonetzic soils in the Brown soil zone have been 130 kg/ha compared with 400 kg/ha in the Dark Brown, Thin Black, and Black soil zones. Adopting snow trapping techniques may improve water availability for subsoiled Brown solonetzic soils. Lickacz identified the properties of the solonetzic soils most likely to benefit from subsoiling as: i) no evidence of accumulation of salts on the soil surface, ii) at least 7.5 cm of topsoil, iii) an acidic topsoil, iv) a definite hardpan but with low levels of sodium, and v) a depth to sodic bedrock greater than the depth of subsoiling.

Subsoiling to Alleviate Soil Compaction

Most compaction occurs under the wheels of heavy machinery such as large tractors, combines, and loaded trucks. The zone of maximum compaction occurs at the apex of a 45° isoceles triangle whose base is the width of soil contact area of the tire (or tires in the case of dual or triple wheels). A dense layer forms immediately below the depth of tillage. This dense layer is called a plowpan, tillage pan, or traffic pan. For a fine sandy loam soil in North Dakota, Locke et al. (1960) found tillage pan formation was evident from a single spring plowing operation when the soil was moist. The tillage pan did not affect crop yields. Freezing and thawing overwinter did not destroy the tillage pan. Other researchers have also concluded that freeze-thaw cycles do not completely alleviate compaction (Blake et al., 1976; Saini, 1978; Akram and Kemper, 1979).

Compaction reduces the size of the soil pores with the greatest reduction occurring in the largest pores. In this manner, compacted soil layers reduce soil hydraulic conductivity when the soil is wet (Warketin, 1971) or frozen (Pikul et al., 1985). A severely compacted soil may prevent roots from thoroughly exploring a considerable volume of surface soil and thereby lead to inefficient use of fertilizer (Voorhees and Lindstrom, 1983). Likewise, reductions in pore size can reduce nutrient uptake by restricting nutrient movement to the roots via diffusion and mass flow (Sumner and Bowell, 1981). Compaction is not considered to be an important problem on the Canadian prairies (Cameron et al., 1981) although compaction problems in this region have not been well investigated. There is little evidence to suggest soil compaction on prairie soils is directly detrimental to crop growth. The major problem with soil compaction is probably decreased water and nutrient movement into the soil.

Under dry conditions, compaction can be beneficial by reducing water evaporation from the soil and increasing the movement of water from the subsoil during stand establishment. One can identify compaction problems by observing crop growth in wheel tracks in the seedbed. If the crop is usually poorer in the wheel tracks than the rest of the field, then a compaction problem exists. Conversely, the crop is generally better in the wheel tracks, then the soil has larger pore sizes than optimal.

Tillage is widely used to alleviate soil compaction. Generally, inversion of the soil with a moldboard plow is the most effective method of loosening the soil. Chiseling and subsoiling are less effective because the soil is broken into clods each of which retains the compaction. In Minnesota, chiseling or disking were only slightly better than natural weathering forces at reducing soil strength in the compacted layers (Voorhess, 1983). Douglas and McKyes (1983) found that subsoiling 45 cm deep was superior to chiseling 25 cm deep in alleviating the compaction caused by the passage of normal agricultural machinery.

Subsoiling to Increase Overwinter Infiltration

Snowfall represents one-quarter to one-third of the annual precipitation on the prairies. Various snow management techniques have been used to retain as much snow as possible on the field. However, the greatest frustration with snow trapping has been the poor infiltration of snowmelt into many soils. Table I summarizes the results of 14 years of snow trapping research with tall stubble at the Swift Current Research Station. The soil had a silt loam texture. Table II divides the overwinter water gain into three classes based on overwinter water gain - good (> 7.4 cm), moderate (5.0-7.4 cm), and poor (< 5.0 cm). Good overwinter water gain was associated with above-average overwinter precipitation and premelt snowpack combined with no severe limitation to infiltration. The years with moderate overwinter water gain tended to also have no important limitation to infiltration but have below-average overwinter precipitation and snowpack. Those years with poor overwinter water gain had near average overwinter precipitation and premelt snowpack but had limited infiltration. Consequently, at Swift Current, the potential benefit of snow management was restricted by the infiltration characteristics of the soil about one year out of three. The variability in the amount of snowfall had far less influence on overwinter water gain than infiltration.

Infiltration into frozen soil is a poorly understood, complex thermodynamic process involving coupled heat and mass flow. There is a well recognized inverse relationship between soil moisture at freeze-up and infiltration of snowmelt. The depth of soil whose water content is believed to control the amount of snowmelt infiltration varies from the upper 5 cm (Murray and Gillies, 1971) to the entire rooting zone (Kane and Stein, 1983).

Table I. Overwinter precipitation (OWP) from Oct. 1 to April 30, snow water equivalent (SWE) of snowpack before spring melt, and overwinter water gain (OWG) between October and April soil sampling for wheat stubble with snow trapping[1] at Swift Current

Year	OWP (cm)	SWE (cm)	OWG (cm)
1972-73	12.6	1.3	6.3
73-74	19.4	7.7	8.2
74-75	12.6	5.4	4.7
75-76	14.5	5.3	2.5
76-77	6.0	3.0	4.5
77-78	12.7	6.0	11.1
78-79	11.0	6.8	5.5
79-80	7.7	2.4	7.1
80-81	11.4	0	5.1
81-82	11.0	12.2	12.1
82-83	11.3	4.2	4.4
83-84	7.2	6.4	5.4
84-85	11.4	9.6	7.5
85-86	8.2	9.1	2.5
Mean	11.2	5.7	6.2

[1] Alternate height stubble until 1980-81 then clipper trap strips.

Table II. Number of years with good, moderate and poor overwinter water gain for wheat stubble with snow trapping

OWG class	Number of years	Mean OWG (cm)	Mean OWP (cm)	Mean SWE (cm)	OWG/ OWP (%)	OWG/ SWE (%)
good (> 7.4 cm)	4	9.7	13.6	8.9	71	110
moderate (5.0-7.4 cm)	5	5.9	10.0	3.4	59	174
poor (< 5.0 cm)	5	3.7	10.5	5.4	35	69

Komarov and Makorova (1973) stated that water infiltration into frozen soil takes place through noncapillary macropores. Infiltration decreases as the water content of the frozen soil increases because the ice reduces the effective pore size. In southwestern Saskatchewan, Granger et al. (1984) determined infiltration into well cracked heavy clay soils was limited only by the amount of water in the snowpack, whereas infiltration into uncracked soils was dependent on both the air filled pore volume in the upper 30 cm of the soil at the initiation of the melt and the water in the snowpack.

After reviewing numerous published experiments, Lal and Steppuhn (1980) concluded that shallow fall tillage did not generally increase overwinter water gain on the prairies. Tests during 9 years at Swift Current indicated that overwinter soil water gain following fall blading was 0.5 cm more than untilled stubble and 1.5 cm greater than after a fall one-way disc operation (Staple et al., 1960).

Deep fall tillage can influence snowmelt infiltration. Larin (1962) measured ponded infiltration into a frozen loam soil. The total infiltration over one hour was 97, 144, and 167 mm for undisturbed cereal stubble, stubble plowed 25 cm deep, and tilled 40 cm deep, respectively. He concluded the infiltration into frozen soil was proportional to the depth of tillage.

Considerable research has been conducted into the effect of deep tillage for improving overwinter water gain in the semiarid Columbia plateau in the states of Washington, Oregon, and Idaho. Lindstrom et al. (1974) found fall chiseling a silt loam soil to 25 cm on a 30 cm spacing increased the overwinter water gain by 8.7 cm compared with no fall tillage in a winter when the soil was frozen 30 cm deep. In a mild winter without soil freezing, fall chiseling had no influence on overwinter water gain. By chiseling a silt loam soil 30 cm deep on a 90 cm spacing in the fall, Massee and Siddoway (1969) were able to add 6 cm more available soil water in the spring over non-chiseled soil resulting in average yield increases of 285 kg/ha for continuous spring wheat. Allmaras et al. (1977) determined that chiseling at least 25 cm deep in the fall would bring about deeper penetration of winter precipitation and thereby increase moisture storage during the following fallow year. Saxton et al. (1981) measured a 10 fold increase in infiltration into a frozen soil with a 25 cm deep slot mulch treatment. They concluded slot mulch had greatest potential for increasing overwinter water conservation in semiarid regions with frozen soils when combined with conservation tillage practices.

For a heavy clay soil in central Manitoba, Paterson and Lapp (1964) determined that fall subsoiling to 40 or 60 cm deep did not affect overwinter water conservation for either stubble or fallow land. In eastern Montana, Black and Power (1965) found that chiseling 30 cm deep during the first fall of the fallow period did not increase water conservation or subsequent fallow spring wheat yields. Chiseling during the second fall of the fallow period also had no effect on water conservation (Power et al., 1958). However, chiseling during the second fall worsened water erosion from snowmelt because water concentrated in the chisel furrow. This effect was noticed on soils with slopes of 1% or more. Rasmussen et al. (1986) did not find that fall subsoiling improved the infiltration of snowmelt in northern Utah. However, water erosion from intense summer rainstorms was approximately 10 times greater off chemical fallow subsoiled in the fall than off untilled chemical fallow.

Haas et al. (1966) tried fall chiseling on level benches in central

North Dakota. The level benches capture both snow and runoff. Fall chiseling increased overwinter water gain by 1 cm but did not increase continuous spring wheat yields.

With 60 cm deep subsoiling on a 185 cm spacing, Granger and Gray (1986) measured increases in snowmelt infiltration of 6 to 8 times that of undisturbed soils in west central Saskatchewan. Lateral movement of water was detected as far as 1 m from the subsoiler furrows. Dessication cracks tended to reform in the subsoiler furrows during the second year following subsoiling. Use of the paraplow to 35 cm was not as effective as deeper ripping. They recommended subsoiling be performed to a 40 to 50 cm depth on a 1.0 to 1.5 m spacing for purposes of increasing snowmelt infiltration. Over two years, spring wheat yields were increased by approximately 200 kg/ha. They believed larger yield increases were possible if snow management had been used along with more optimal soil fertility.

SUBSOILING RESEARCH AT SWIFT CURRENT RESEARCH STATION

Subsoiling was first investigated at the Swift Current Research Station during the 1950's (Wenhardt, 1950-55). The soils at the Research Station do not have any obvious structural problems. In one experiment, deep tillage was part of summerfallow tillage. There was no clear benefit for deep tillage either in terms of water conservation or yields of spring or winter wheat. In another experiment, subsoiling was performed in the fall and before seeding in the spring. Again, subsoiling in either the spring or fall did not significantly affect water conservation or spring wheat yields. As with other deep tillage experiments of the era, intensive shallow tillage by present day standards during seedbed preparation no doubt influenced the results.

1983 Subsoiling Experiment

In the fall of 1983, Dr. W. Nicholaichuk set out a preliminary experiment to investigate the effect of subsoiling on the infiltration of snowmelt. Two subsoiling methods were used - the paraplow and the "DUAL" subsoiler. The paraplow has an almost vertical standard which bends laterally near the bottom. The purpose of this design is to lift the soil over the bend to increase soil fracturing. The paraplow was operated at the manufacturers recommended depth and spacing of 35 cm and 50 cm, respectively. The "DUAL" subsoiler has nearly rigid shanks which are highly curved in the direction of travel. A 5 cm wide chisel point is welded onto the end of the shank. Subsoiling with this implement was also done at a 35 cm depth on a 50 cm shank spacing. Both subsoiling operations were performed once in the fall of 1983 on wheat stubble. Also included in the experiment was an untilled, check treatment.

The 1983 subsoiling experiment had one block with and one block without snow trapping. Within each block were two replicates containing the tillage treatments. Each tillage plot was 10 x 122 m. In the winter of 1983-84 snow trapping was accomplished with clipper and deflector trap strips formed at harvest with a suitably equipped swather. In 1984-85, 60 cm tall snow fencing on a 11 m spacing provided snow trapping. The entire experimental area was standard height stubble in the winter of 1985-86.

In 1984, the "DUAL" subsoiler plots had to be packed before seeding to crush clods which had been produced during subsoiling. Otherwise, all plots were zero till seeded to hard red spring wheat each year. Nitrogen and phosphorus were applied according to soil-test recommendations from soil samples taken in October.

Table III summarizes the results for this experiment. There was no significant difference between the two subsoilers.

In 1984, wheat yields were disastrous on all plots without snow trapping. Subsoiling without snow trapping probably aggravated soil water losses due to evaporation. Less available water on the latter plots no doubt contributed to the lower yields from the subsoiled land than the check treatment without snow trapping.

Mean wheat yields in 1984 of all tillage plots with snow trapping were approximately four times that of the plots with standard height stubble. With snow trapping the mean overwinter water gain was 75% larger for the subsoiled treatments than the check. This additional water resulted in an 88% greater wheat yield than the check. Figure 1 shows the distribution of soil water in the plots with snow trapping in early spring of 1984. Subsoiling increased both infiltration and downward movement of water. The greatest proportion of the additional water found in the subsoiled treatments over the check was below 30 cm.

In the spring of 1985, natural soil infiltration permitted a high proportion of snowmelt to enter the soil. Therefore, there was no infiltration benefit from subsoiling. Despite this, the subsoiled plots had greater yields than the check plots. Figures 2 and 3 show the soil water distribution with depth for the tillage treatments for situations with snow trapping and with standard stubble, respectively. Both indicate that subsoiling increased the amount of water found below 30 cm. The water located deeper in the rooting zone would be available for crop use later in the growing season and less subject to evaporative losses than water near the soil surface. Therefore, the deeper distribution of soil water with subsoiling was likely particularly beneficial during a drought year such as 1985. In addition, the subsoiling may have produced a better soil structure for wheat growth permitting more efficient use of water for producing seed. Figure 3 shows that the 0-15 cm layer was drier in the spring for the subsoiled treatments than the check. This again indicated that subsoiling can aggravate soil drying.

In 1985-86 there was no detectable influence from subsoiling on either soil water or wheat yields. This may indicate that the soil structure of the subsoiled land had returned to its original condition. Alternatively, generally excellent moisture conditions during 1986 may have prevented any yield effect of subsoiling from manifesting itself.

1985 Paraplow Experiment

In the fall of 1985, Dr. H. Steppuhn set out an experiment to further evaluate the effect of the paraplow on overwinter water gain. Paraplowing was performed October, 1985 on wheat stubble.

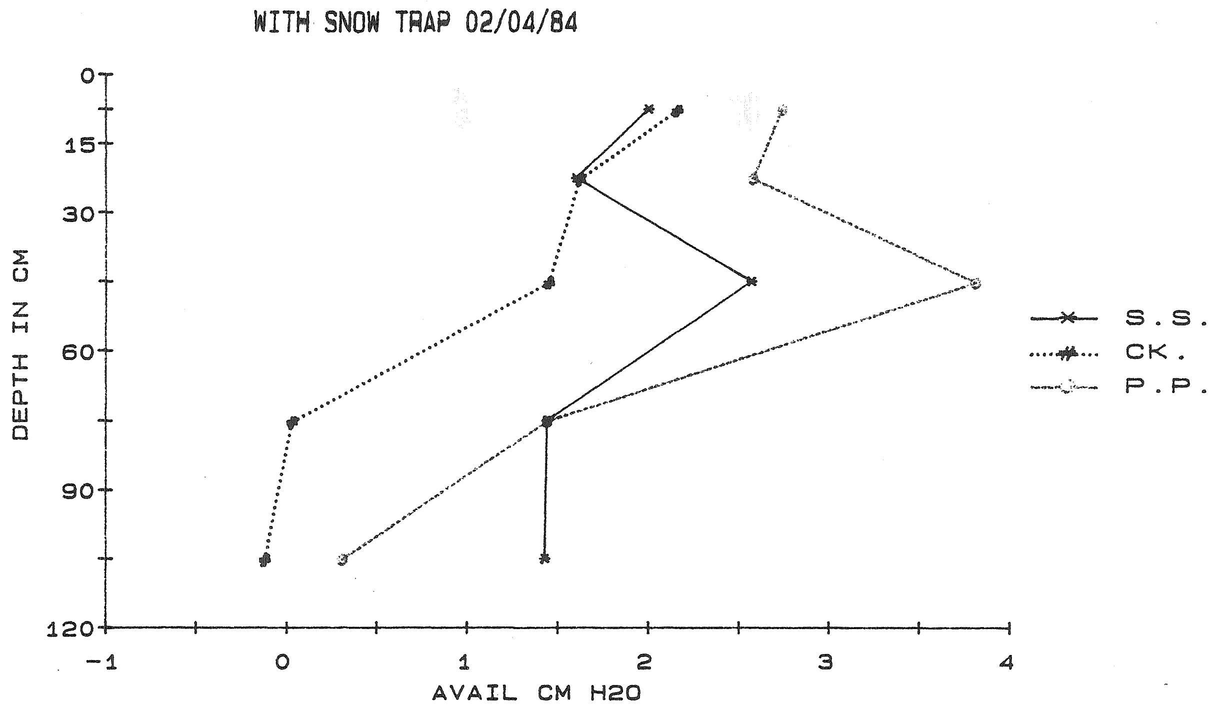

Figure 1. Soil water distribution in spring, 1984 for DUAL subsoiler (S.S.), paraplow (P.P.), and check (CK.) after snow trapping.

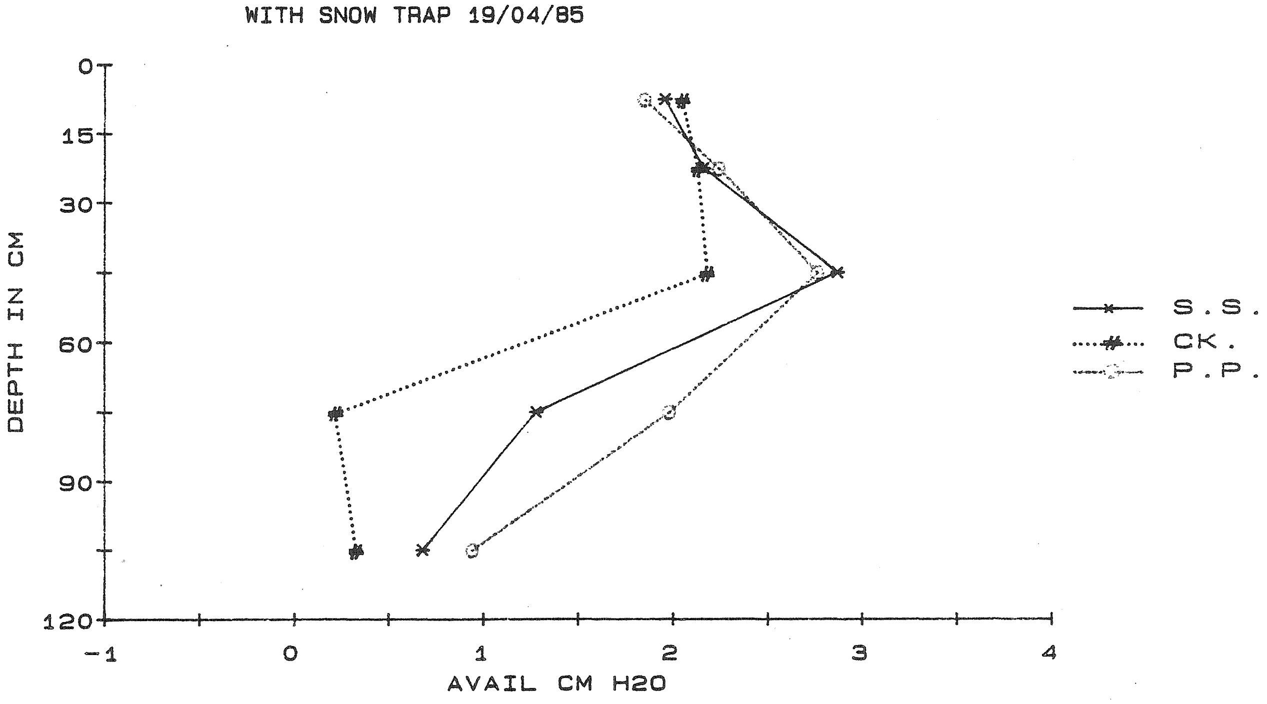

Figure 2. Soil water distribution in spring, 1985 for DUAL subsoiler (S.S.), paraplow (P.P.), and check (CK.) after snow trapping.

Table III. Spring snowpack water (SWE), overwinter water gains (OWG) and wheat yields for 1983 subsoiler experiment

	1983-84			1984-85			1985-86		
Treatment	SWE (cm)	OWG (cm)	Yield (kg/ha)	SWE (cm)	OWG (cm)	Yield (kg/ha)	SWE (cm)	OWG (cm)	Yield (kg/ha)
Standard stubble									
check	4.5a	5.9a	161a	5.0a	4.8a	511a	-	1.8a	2320a
paraplow	4.0a	4.3a	114a	6.3a	5.4a	955a	-	2.8a	2266a
subsoiler	3.5a	3.9a	94a	4.0a	5.3a	827a	-	1.5a	2300a
Snow trapping									
check	5.8a	6.6a	316a	11.4b	12.9b	767a	-	-	-
paraplow	7.4a	12.4a	619a	10.8b	16.0b	1190b	-	-	-
subsoiler	7.1a	10.8a	572a	13.2b	10.7b	1291b	-	-	-

Means within columns not followed by the same letter are significantly different (5% level).

The four treatments were check (untilled) with standard stubble, check with 60 cm tall snow fencing, paraplowed with standard stubble, and paraplowed with 60 cm tall snow fencing. The snow fencing was arranged in a 9 x 15 m rectangle and a 10 to 20 cm tall earthen dike was constructed around each snow fence enclosure. Each treatment was located on 60 x 45 m plots to minimize snow trapping interference between treatments. The experiment was a randomized complete block with three replicates.

At the centre of each plot were two parallel 1.5 m long aluminum access tubes installed 30 cm apart. The access tubes were used to measure soil bulk density using the twin probe gamma attenuation method and soil water using a neutron probe. For the treatments with snow fence enclosures, the access tubes were located near the centre of the enclosure. On the paraplowed plots, the tubes straddled the paraplow furrow. Wheat yield samples were taken within 9 m of the access tubes on all plots. Nitrogen and phosphorus were applied according to soil test recommendations and all plots were zero till seeded to Leader hard red spring wheat.

Table IV summarizes the effect of each treatment on soil water and March snowpack. Natural infiltration of snowmelt was restricted so that the check plots with snow trapping gained no more water than the plots with standard height stubble. Snowmelt remained ponded in the diked snow fence enclosures for more than a week after snow had disappeared from standard height stubble. The paraplowing allowed a substantial proportion of the snowmelt to infiltrate. There was no noticeable difference in the rate of disappearance of water and snow between the paraplowed and check treatments.

Fall paraplowing with snow trapping resulted in more available water than the other treatments throughout the growing season. By contrast, the paraplowed treatment without snow trapping had less available water than the other treatments. During June, the wheat grown on the paraplowed soils with snow trapping was shorter and a paler green color than any of the other treatments. This probably indicated the wetter soil conditions created a nitrogen deficiency via nitrate leaching below the rooting zone and/or greater denitrification. These visual differences had disappeared by July. Crop maturity was three or four days later on the paraplowed land with snow trapping.

Table V lists the wheat yields for this experiment. The method of contrasts was used to compare treatment yields (SAS, 1985). The paraplowed plots yielded significantly more than the check plots. Among individual treatments, the only significant difference was between the paraplowed with snow trapping and the check with snow trapping. One possible explanation for the yield response to paraplowing was improved soil structure for growth.

Figure 4 is a plot of soil bulk density versus depth for the paraplowed and the untilled soils as determined by the twin probe gamma attenuation method. The tillage pan at the 15 cm depth is very distinct. Paraplowing had no effect on soil bulk density. Any vertical macropores produced by subsoiling would have to have been at the expense of lateral compaction of the soil between macropores. The apparent difference in bulk density between tillage treatments below 60 cm was attributed to variations in the amount of small stones at those depths.

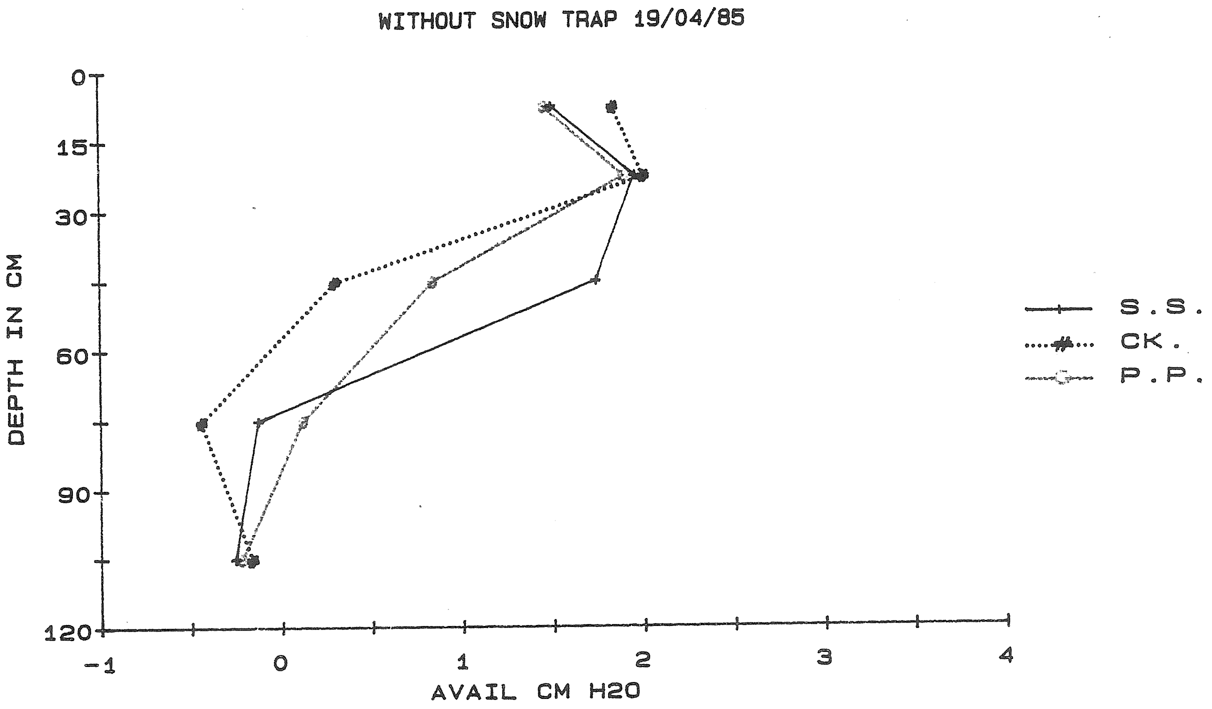

Figure 3. Soil water distribution in spring, 1985 for DUAL subsoiler (S.S.), paraplow (P.P.), and check (CK.) without snow trapping.

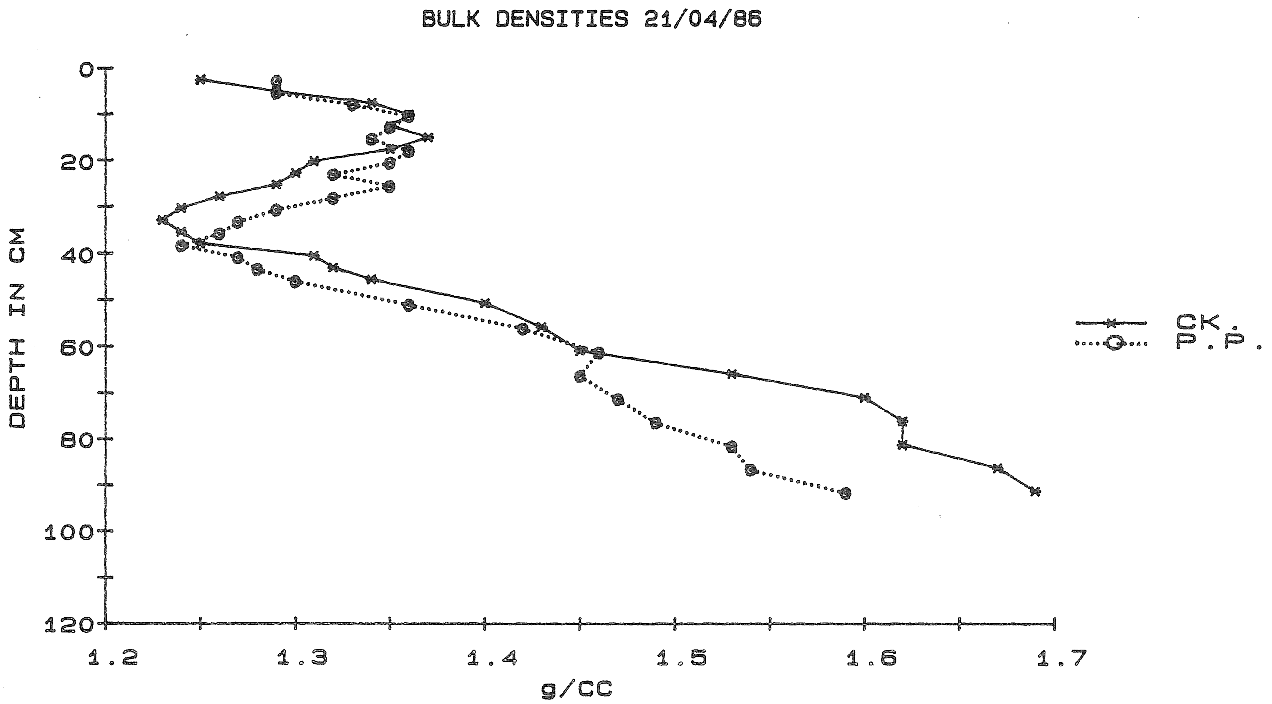

Figure 4. Soil bulk densities versus depth for paraplowed (P.P.) and check (CK.) plots.

Table IV. Spring snowpack water (SWE), overwinter water gain (OWG) and available soil water at approximate wheat growth stage for 1985 paraplow experiment

			0-1.2 m available soil water above 40b (cm)				
Treatment	SWE (cm)	OWG (cm)	Fall 85/10/28	Spring 86/04/21	Seeding 86/05/18	Heading 85/07/08	Harvest 86/08/19
Standard stubble							
check	4.3a	3.2a	3.6a	6.8a	14.1a	5.6b	0.9a
paraplow	4.5a	5.9a	1.5a	7.4a	13.3a	1.4a	-2.5a
Snow trapping							
check	19.0b	4.4a	2.7a	7.1a	12.2a	5.3b	-0.4a
paraplow	18.7b	12.9b	2.4a	15.3b	20.0b	11.2c	1.6a

Means within columns not followed by the same letter are significantly different (5% level).

Table V. Wheat yields for 1985 paraplow experiment

	Standard stubble		Snow trapping	
	check	paraplow	check	paraplow
Yield (kg/ha)	2643	2966	2744	2925

Contrast	Significance
paraplow vs check	2.3%
(paraplow with snow trapping) vs (check with snow trapping)	4.1%

DISCUSSION

The possible role for subsoiling on the prairies for increasing water conservation and crop yields is limited. Some solonetzic soils may be improved by subsoiling. Subsoiling chernozemic soils is probably only justified as a practice to enhance snowmelt infiltration in combination with snow management. This use will be of most benefit in the Brown and Dark Brown soil zones where yield responses to stored soil water at seeding are most pronounced. In the wetter Black and Gray soil zones subsoiling to enhance snowmelt infiltration would be less valuable.

A literature review has revealed no consistent improvement in water conservation from subsoiling at any time during the summerfallow period. In fact, subsoiling land to be fallowed may be detrimental because subsoiling increases downward movement of soil water. Subsoiling fallow land may accentuate the leaching of nitrates and aggravate downslope salinity problems.

Traditionally, producers in the Brown and Dark Brown soil zones have adopted rotations with frequent fallow to assure themselves of a satisfactory crop yield. Water conserving practices such as snow management are needed to increase stubble yields to make extended rotations more practical. Initial test results indicate that subsoiling can enhance the value of snow management by increasing the amount and consistency of yield improvements due to snow trapping. In this manner, subsoiling can increase the feasibility of using extended crop rotations and thereby enlargen the potential for improved soil conservation.

Preliminary results from research at Swift Current indicate there is some positive yield response to subsoiling a soil without an obvious structural problem. This response may be a result of physically breaking the tillage pan. However, without snow trapping subsoiling can also accelerate soil drying and thereby reduce yields. Therefore, there is no economic justification for subsoiling in semiarid regions unless snow management is also practiced.

The economic feasibility of subsoiling depends on the costs of subsoiling and the size and longevity of the benefits of subsoiling. More research is needed into these areas to determine if subsoiling is economically justified. Clearly, the shallowest working depth and the widest shank spacing consistent with good infiltration enhancement are optimal. Possibly, subsoiling needs only to break through the tillage pan to bring about significant increases in snowmelt infiltration. Minimal surface soil disturbance is preferred both to reduce the requirement for shallow tillage to prepare a seedbed and to reduce the risk of water erosion on sloping land. Slot mulch deserves further investigation on the prairies. The effect of shallow tillage on subsoiling also requires more research.

CONCLUSIONS

The following conclusions were drawn after review of the literature and of preliminary results from subsoiling research at Swift Current:

1) Subsoiling is only justified as a method of increasing infiltration of

snowmelt when used in combination with snow management practices within extended crop rotations. Potential advantages to subsoiling are greatest in the Brown and Dark Brown soil zones. Subsoiling in combination with snow management can improve soil conservation by improving the feasibility of adopting extended crop rotations.

2) The benefits of subsoiling solonetzic soils are variable. Further research on solonetzic soils is required into combining subsoiling with snow management and using slot mulch.

3) There can be some minor crop yield benefits from subsoiling chernozemic soils which are not due to increased water conservation.

4) More research is required into subsoiling on the prairies with particular reference to i) subsoiling equipment, working depth and furrow spacing, and slot mulch; ii) nature and longevity of the benefits from subsoiling and associated economic analysis; iii) groundwater recharge and nitrate leaching as affected by deep tillage; and iv) effect of subsoiling on the productivity of knoll tops and upper slopes. (All these research topics are presently under investigation at the Swift Current Research Station).

5) At present, subsoiling any soil type can only be recommended on a field test strip basis.

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