

The effects of tillage upon snow cover and spring soil water

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Maulé, C. P. and Chanasyk, D. S. 1990. **The effects of tillage upon snow cover and spring soil water.** *Can. Agric. Eng.* 32: 25–31. Snow management for agricultural purposes includes trapping snow and improving infiltration into frozen soil. The infiltration capacity of both frozen and unfrozen soils is influenced by the physical state of the soil surface. The effects of after-harvest tillage upon the snow cover, and soil water from fall through spring snowmelt to seeding were examined during two overwinter periods 1 November to 31 March of 1985–1986 and 1986–1987. Four tillage treatments (summerfallow, standing stubble, disced stubble, and chiselled stubble) were established on a Black Chernozem south of Edmonton, Alberta. Snow depths on the stubble and chiselled plots were significantly greater ($P \leq 0.05$) than those on the disced and fallow plots. The chiselled and stubble treatments had significantly greater overwinter soil water gains than did the disced and fallow treatments in the top 40 cm. Stubble gained the most (or lost the least) soil water from fall to seeding, with the chiselled treatment being second. For wet fall conditions, the soil water content for fallow at spring seeding was significantly greater than those for the other treatments only below 65 cm. The stubble and chiselled treatment water contents were significantly higher or equivalent than those in the disced treatment at postmelt.

INTRODUCTION

Approximately 30% of the annual precipitation on the Canadian prairies occurs as snowfall during the winter. Conservation and management of winter precipitation has the potential to improve crop yields. Snowtrapping techniques such as standing stubble, alternate height windrows, deflector strips, etc. have proven effective in retaining more snow than fallow fields (Lal and Steppuhn 1980; Steppuhn 1980; Nicholaichuk et al. 1984). However, the water from the augmented snow does not always enter the soil root zone, contributing instead to surface runoff (Willis et al. 1969; Chanasyk 1986). The low infiltration capacity of frozen soils imposes definite limits to water intake in many locations, especially on medium-textured soils (McConkey et al. 1988).

The two controlling factors of infiltration rates in frozen soils are the frozen water content and the size and continuity of the conducting pores. Frozen soil water blocks pores and increases tortuosity. An inverse relationship between the frozen water content and infiltration rates exists with ice blockage reducing infiltration rates by 10–300 times (Hobbs and Krogman 1971; Murray and Gillies 1971; Kane and Stein 1983; Granger et al. 1984).

Fall cultivation of agricultural fields is practiced on the prairies in order to incorporate crop residues into the soil, to control weeds, to disperse fertilizers and herbicides, to prepare for the land spring seeding, and to promote the infiltration and soil storage of precipitation (Lal and Steppuhn 1980). Fall discing generally reduces overwinter storage relative to that of standing

stubble (Staple et al. 1960). A 9-yr study in southern Saskatchewan concluded that there was no significant difference in overwinter water storage between fall blade tillage and standing stubble (Staple et al. 1960). Kachanoski et al. (1985), summarizing 4 yr of measurements on different slope positions, found that fall cultivation resulted in less recharge than did standing stubble. An extensive literature review of fall tillage on the Canadian Prairies by Lal and Steppuhn (1980) indicated that tillage does not seem to increase soil water storage of overwinter precipitation as compared to stubble. Only weak trends were present with one-way disc tillage conserving slightly less water and blading slightly more than no tillage at all, especially during a heavy snow year. Chanasyk (1986) reported variable water gains from cultivated stubble as compared to standing stubble. Fall chiselling or spiking has been reported to contribute more overwinter recharge than conventional stubble (Masse and Siddoway 1969) or to have a higher recharge efficiency (Zuzel and Pikul 1987) but with less trapped snow (Patterson 1984). Subsoiling has also been reported to increase snowmelt recharge efficiency in central and southern Saskatchewan (Patterson 1984; McConkey et al. 1988).

Although some of the above studies have shown that snowmelt recharge into frozen soils may be enhanced by tillage, trends are not consistent and are likely influenced by the snow-trapping ability of the remaining stubble and the meteorological conditions of the study area during winter. This study compares the effects of four commonly used agricultural management practices on the prairies: standing stubble, disced stubble, chiselled stubble, and summerfallow upon the amount of snow accumulated and the amount of snowmelt recharge at one location in the Black soil zone of Alberta.

MATERIALS AND METHODS

Site description

The study site was located approximately 15 km south of the Edmonton city center at the Ellerslie Research Station. A fully equipped meteorological station is situated at the site. The study period extended from fall 1985 to spring 1987.

The climate of the Edmonton area is subhumid and is characterized by relatively warm summers and cold winters. The average annual temperature is 3°C, with January the coldest month at -14°C and July the warmest month at 16°C. The mean annual precipitation is 460 mm with 60% occurring during May through August, with July having the greatest amount (85 mm). The mean annual overwinter precipitation (1 November through 31 March) is 89 mm, or about 19% of the total annual precipitation.

A large portion of the study region is under mixed grain cultivation, with barley being the common grain crop. The local

topography is gently rolling to rolling. The study site is located at the toe to mid-slope of a 1–2% west slope. Parent material consists of fine-textured glacial lacustrine over morainal material. Soils in the well-drained to moderately well-drained positions of the Ellerslie Research Station, which include the study site, have been described as Eluviated Black Chernozems. Soil textures across the study area range from clay through a clay loam to a silt loam. Total carbon of the Ap horizon has been measured at 5.2% (Crown and Greenlee 1978).

Experimental design

To account for soil variability and site characteristics that could affect snow accumulation or infiltration, a randomized complete block design was used. This consisted of four treatments (standing stubble, chiselled stubble, disced stubble, and summerfallow), replicated three times, resulting in a total of 12 plots. Each plot was 23 m × 45 m and included a 5-m buffer border, resulting in an effective plot size for sampling of 13 m × 35 m. The entire site had been in barley for at least 3 yr prior to plot establishment in the fall of 1985. All plots, except the summerfallow ones, were cultivated in mid-October 1985. The summerfallow plots were left as standing stubble for the first winter, 1985–1986, and fallow was accomplished by discing during the summer and fall of 1986. Thus, the fallow treatment could not be properly incorporated into the statistical design until the fall of 1986, the second winter.

Chiselling was accomplished with a cultivator equipped with 4–5-cm-wide shanks spaced approximately 20 cm apart and set to a 15-cm depth. The disc was a tandem double disc with 25-cm blades spaced 20 cm apart. The discs disturbed the top 8 cm of soil.

Seed bed preparation took place during early May and consisted of shallow discing. The plots were seeded during mid-May to the end of May. Spraying for Canada thistle was done with 2–4D (Gleen by Hoegrass) at midsummer. The summerfallow plots were disced three times during the growing season to control weeds. Harvest took place during the first half of September 1986 and 1987 and the plots were cultivated with the same management practices as the previous fall.

Five aluminum neutron tubes were installed at randomly chosen locations within each plot. To allow for proper field maintenance, they were installed after fall cultivation (mid to late October) and removed before seeding (mid to late May). New sites were randomly chosen for each installation. Soil water was measured at 10-cm-depth intervals from 15 to 95 cm on a monthly basis during winter and more frequently during melt periods using a Campbell Pacific Nuclear 503 Depthprobe.

Snow stakes, marked in 2-cm increments were driven into the ground 1.5 m from each neutron access tube. Readings of snow depth were obtained at the time of each soil water measurement during the winter. Snow cores for the determination of snow water equivalence (SWE) were taken four or five times each winter with a 15-cm-diameter PVC tube. Three to five cores were taken from each plot.

Soil samples, from cores obtained during the first neutron access tube installation (fall 1985), were taken at 15-cm intervals from the surface to a depth 90 cm. The soil samples were analyzed for bulk density, particle size using the hydrometer method (McKeague 1978), and water retention by pressure plate apparatus (Richards 1965).

Hypotheses tested

The following null hypotheses were tested with analysis of variance for a randomized block design with subsampling:

1. The type of fall cultivation treatment does not have an effect upon snow depth accumulation.
2. Fall cultivation does not have an effect upon the amount of snowmelt recharge.
3. Fall cultivation does not have an effect upon soil water content at time of seeding.

If the null hypothesis was rejected at the 0.05 significance level (with the *F*-test), then a multiple means test (least significant difference), was used to test for differences among treatments.

RESULTS AND DISCUSSION

Soil physical properties

Bulk density from all 60 locations ranged from 0.92 (± 0.14) Mg m^{-3} (\pm one standard deviation) for the uppermost 10 cm to 1.56 (± 0.11) Mg m^{-3} for the 0.75- to 0.90-m depth interval. Soil texture varied from clay to clay loam throughout the sampled profile (0 to 100+ cm) with clay content increasing with depth. Numerous discontinuous sand lenses, 1–4 cm thick, were observed below 60 cm. The Ah horizon had an average depth of 31 (± 7) cm. Water content at field capacity and permanent wilting point for the top 15 cm were 0.38 $\text{m}^3 \text{m}^{-3}$ and 0.22 $\text{m}^3 \text{m}^{-3}$, respectively, whereas below 15 cm, field capacity ranged from 0.40 to 0.43 $\text{m}^3 \text{m}^{-3}$ and permanent wilting point was approximately 0.27 $\text{m}^3 \text{m}^{-3}$.

Snow accumulation

After-harvest stubble heights were between 10 and 15 cm. Chiselling left a rough surface with clods 5–15 cm in diameter. Much of the stubble after chiselling remained standing, although at a variety of angles, and combined with the rough surface frequently resulted in the stubble tops being 20 cm higher than bottom of the clods. Discing resulted in a smoother surface and a smaller clod size, less than 5 cm, and with more than 50% of the straw being incorporated. The remaining stubble usually was left standing less than 5 cm above the soil surface.

During the first fall (September and October 1985) and winter (1 November 1985 to 31 March 1986) of the study, temperature and precipitation were near normal (Table I); however, the fall of 1986 had about twice the long-term precipitation (long term being 58 mm), while the winter of 1986–1987 was warmer and drier than normal. Total precipitation during the first and second winters of the study were 81 mm and 50 mm, respectively.

Major midwinter melts, in which there was substantial reductions in snow depth and in SWE, occurred twice during the first winter, 19–25 December 1985 and 28 February to 4 March 1986, but not during the second winter. Minor midwinter melts occurred during the second winter resulting in a gradual snowpack ablation and the development of an ice layer at the bottom of the snowpack. By the beginning of March for both winters there was an ice layer on the soil surface underlying the snowpack of the stubble, chiselled, and disced plots. Generally the fallow plots

Table I. Climatic summary of study period, September 1985 to May 1987

Season	1985–1986		1986–1987		Long-term mean	
	T (°C)	P (mm)	T (°C)	P (mm)	T (°C)	P (mm)
Sept. – Oct.	5.4	65.4	7.2	109.4	7.4	57.5
Nov. – Mar.	–8.6	80.8	–6.6	49.8	–9.9	89.0
Apr. – May	7.5	84.7	9.5	80.5	6.7	64.9
Jun. – Aug.	14.9	222.5	/	/	15.0	228.9

had a shallow depth of snow which was periodically removed due to melts or winds. During the first winter, snow from the disced sites had completely ablated several days before the snow from the stubble and chiselled plots had ablated (27 March 1986). During the second winter, snowmelt had begun by 23 March 1987 and by 30 March only snow on the chiselled and stubble plots and ice in tillage ruts of the disced plots remained. Snow was completely melted by 3 April 1987. Due to midwinter melts, drifting snow, and ice layers, it was difficult to quantify the total amount of snow trapped by each plot.

Snow depth and snow-water equivalent (SWE) for both winters are depicted in Fig. 1. The snow depths are the average of 15 measurements per treatment, while the SWE was measured at 3–5 locations per plot several times each winter. Snowfall during the first winter was greater than the second winter; however, midwinter melts were more extensive and the snow amounts shown in Fig. 1 are more representative of the snow falls between melt periods. As a gradual reduction of the snow depth and SWE occurred during the second winter, the final snowpack measurements do not represent the cumulative snowfall. For both winters the greatest depth of snow was present on the stubble and chiselled plots with the smallest depth on the fallow plots. In general snow depth for the treatments may be ordered from greatest to least as follows:

(stubble \approx chiselled) > (disced \geq fallow)

with the stubble and chiselled treatments significantly trapping more snow than the disced and fallow treatments.

Soil water; fall to post melt

In the fall of 1985 there was less soil water for all treatments than in the fall of 1986, which was at or above field capacity (Fig. 2). A greater overwinter increase in soil water occurred during the first winter of study (1985–1986) than during the second winter (1986–1987). This was possibly due to a higher infiltration capacity resulting from a lower frozen water content during the first winter; a greater snowfall during the first winter; and two major melt periods occurring during the first winter. As the reduced snowfall during the second winter did not result in a proportionately lesser amount of snow measured on the plots (Fig. 1), and as much of the soil water increase had occurred by midwinter for both winters (Fig. 2, Table II), the major reason for the greater increase in overwinter soil water of the first winter may have been the lower soil water contents and thus the greater infiltration capacity of the soil (Hobbs and Krogman 1971; Murray and Gillies 1971). Insufficient snow depth and SWE measurements were taken to conduct any form of water budgeting for the snowpack or the soil water.

The only significant difference in soil water in fall 1985, among treatments, occurred at 15 cm where the water content of the stubble was greater than that of the chiselled or disced treatments. This was likely due to water loss through evaporation from the tilled surfaces of the chiselled and disced treatments. On 4 December 1986, the water contents of the stubble and chiselled treatments were significantly greater than those of fallow at 15 cm. This could be due to false neutron reading at this depth due to backscatter from snow on the stubble and chiselled plots. However, readings at 20 cm in November 1986 indicated that the water contents at this depth under fallow were significantly greater than those in the stubble and chiselled treatments at this depth. At 35 cm and deeper, the fallow water content during fall 1986 was significantly greater than that in the other treatments.

For the first winter, which had relatively low fall soil water contents, the chiselled treatment had a significantly greater overwinter water increase than did the stubble treatment for the 15-cm depth and the disced treatment for the 15- to 35-cm depths (Table III). For the second winter, which had a wetter fall, overwinter water gains in the chiselled and stubble treatments were similar for the 15- to 35-cm depths and significantly greater than the disced and fallow treatments (Tables II and III).

The soil water content immediately following springmelt was tested for significant differences ($P \leq 0.05$) among treatments. The only significant difference occurred at the 15-cm depth for both winters where chiselled and stubble treatments had significantly greater water contents than did disced (for both winters) and fallow (only the second winter could be appropriately tested) treatments.

About half to two-thirds of the fall to springmelt soil water increase had occurred by the end of February (Table II and Fig. 2), yet much of the snow still remained (Fig. 1). Much of this midwinter increase occurred in the top 20–40 cm. The large proportion of soil water increase that occurred by midwinter indicates the importance of midwinter melt, but can also result in reduction of infiltration during springmelt due to increased blockage of pores by frozen soil water.

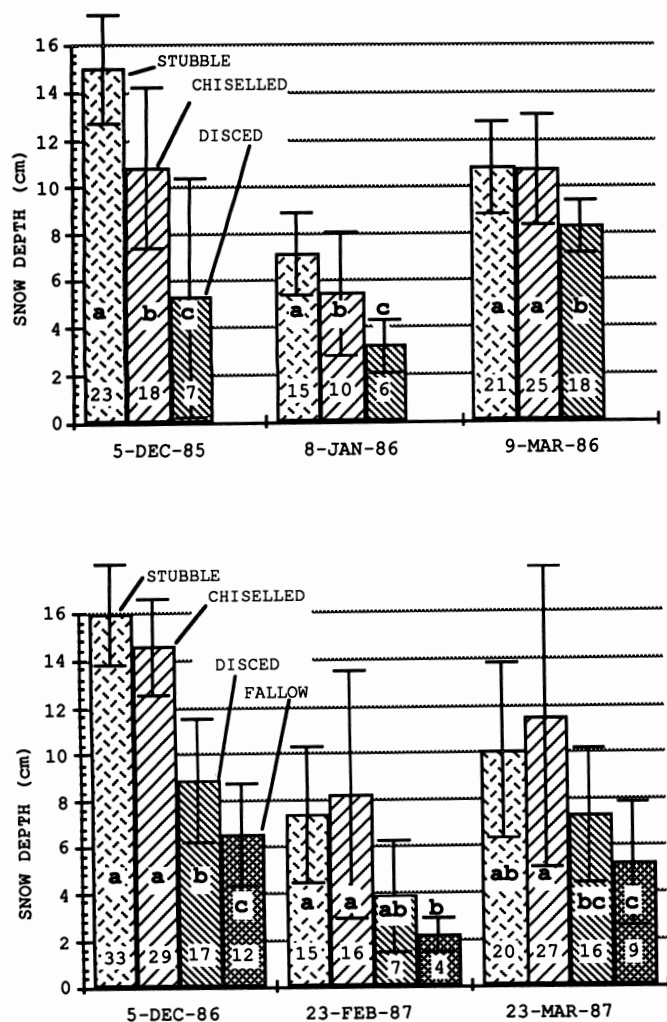


Figure 1. Average depth and water equivalent of snow by plot treatments for the two winters of study. Vertical bars indicate \pm one standard deviation. a-c: same letters for same date, no significant difference at 95% level, according to least significant differences test. Numbers at bottom of columns indicate snow water equivalent in mm.

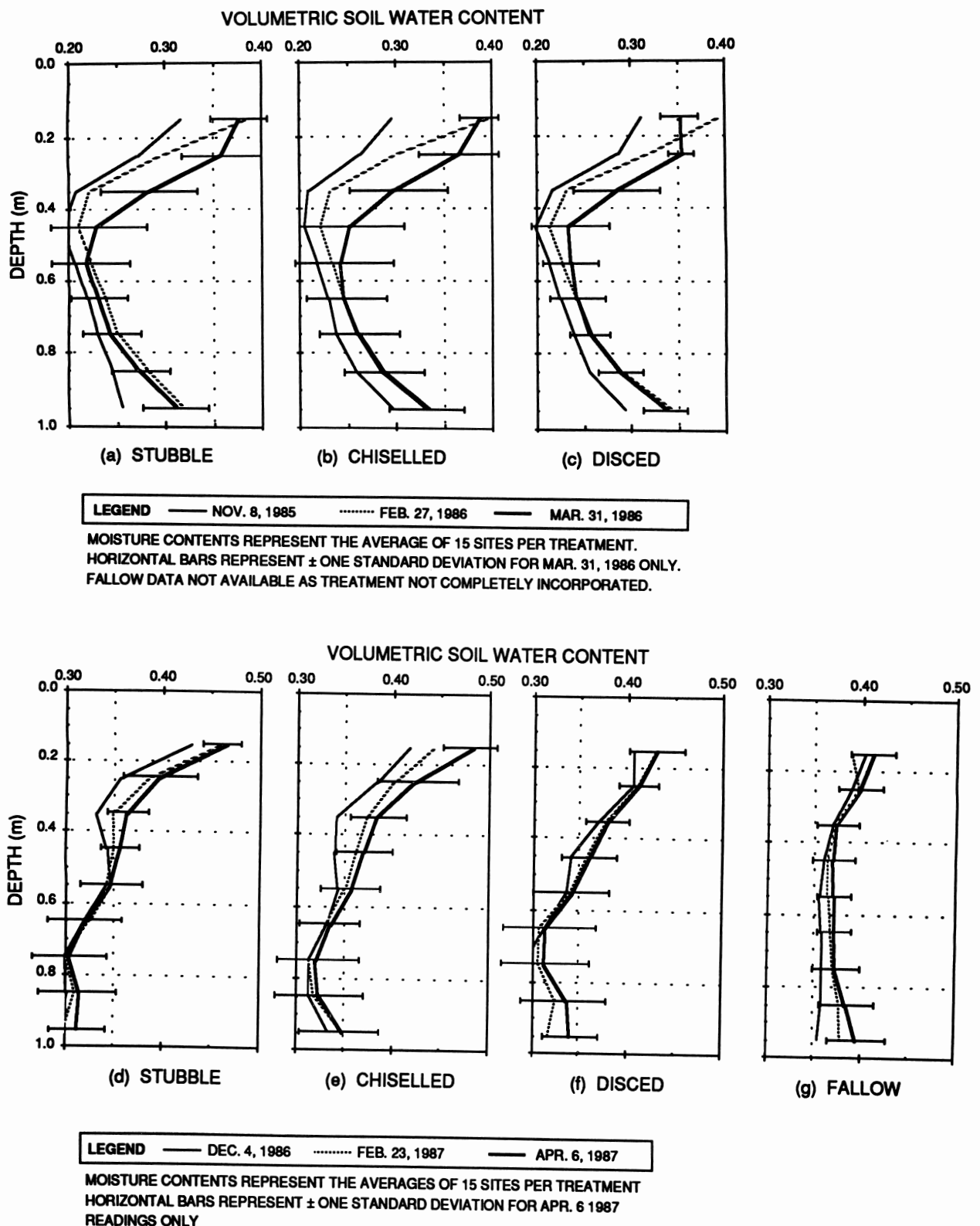


Figure 2. Fall to spring soil water content for tillage treatments during two winters, 1985–1986 (a–c) and 1986–1987 (d–g).

Soil water; postmelt to seeding

During the period between spring snowmelt and seeding, redistribution of the soil water in the profile and water gains through precipitation events, or losses due to evaporation may occur. Large changes in soil water content occurred for some of the treatments in the period between melt and seeding (Table II and Fig. 3). Between 31 March and 29 May 1986 there

was a slight net loss from the 0- to 20-cm-depth interval for the stubble treatment but below this depth there was a large gain. Between 6 April and 9 May 1987 there was a decrease in soil water from the surface to about 50 cm for all treatments (Fig. 3), likely due to evaporative losses. April 1987 was drier (11 mm of precipitation compared to 45 mm) and warmer (7.0°C as compared to 3.6 °C) than April 1986.

Table II. Overwinter and spring changes in soil water storage (mm) for winters 1985–1986 and 1986–1987

Depth	Stubble			Chiselled			Disced			Fallow		
	Change in soil moisture storage (mm) from 4 Nov. 1985 to:											
(m)	27/2	31/3	29/5	27/2	31/3	29/5	27/2	31/3	29/5			
0 – 0.2	13.5	12.0	7.1	20.5	18.5	12.2	16.6	8.4	6.9			
0.2 – 0.4	3.8	16.0	21.2	6.0	19.0	20.9	4.9	13.9	14.5			
0.4 – 0.6	3.3	4.8	18.1	3.4	7.1	12.1	2.9	6.0	7.7	Not available		
0.6 – 0.8	3.9	2.4	4.7	4.0	3.9	5.4	3.7	3.6	5.2			
0.8 – 1.0	9.9	8.3	8.3	6.8	6.2	4.0	8.5	7.7	5.4			
Total	34.5	43.5	59.4	40.7	54.7	54.6	36.6	39.6	39.6			
	Change in soil moisture storage (mm) from 4 Dec. 1986 to:											
	23/2	6/4	9/5	23/2	6/4	9/5	23/2	6/4	9/5	23/2	6/4	9/5
0 – 0.2	6.3	7.3	–12.6	5.7	13.3	–14.8	4.7	4.9	–12.8	2.8	4.4	–13.6
0.2 – 0.4	4.7	7.0	3.3	5.7	8.0	0.5	1.2	1.5	–6.5	–1.2	0.0	–6.8
0.4 – 0.6	0.2	1.0	1.5	3.3	4.4	3.4	2.0	2.6	2.3	1.3	2.5	–0.6
0.6 – 0.8	–0.6	–0.4	3.5	0.0	1.0	3.8	1.1	2.3	2.5	2.1	2.6	1.8
0.8 – 1.0	1.1	2.9	2.8	1.9	2.3	0.8	5.3	8.7	4.6	4.4	6.6	3.6
Total	11.6	17.8	–1.5	16.7	29.1	–6.3	14.3	20.2	–9.8	9.4	16.0	–15.6

All storage numbers represent the average of measurements from 15 sites.

Table III. Significant differences among treatments for overwinter soil water gains

Depth (m)	Nov 4/85 – Mar 31/86				Dec 4/86 – Apr 6/87			
	S†	C	D	F	S	C	D	F
0.15	<i>b</i>	<i>a</i>	<i>c</i>	/	<i>ab</i>	<i>a</i>	<i>b</i>	<i>b</i>
0.25	<i>ab</i>	<i>a</i>	<i>b</i>	/	<i>a</i>	<i>a</i>	<i>b</i>	<i>b</i>
0.35	<i>ab</i>	<i>a</i>	<i>b</i>	/	<i>a</i>	<i>a</i>	<i>b</i>	<i>b</i>
0.45	<i>a</i>	<i>a</i>	<i>a</i>	/	<i>c</i>	<i>a</i>	<i>b</i>	<i>c</i>
0.55	<i>a</i>	<i>a</i>	<i>a</i>	/	<i>b</i>	<i>a</i>	<i>ab</i>	<i>a</i>
0.65	<i>a</i>	<i>a</i>	<i>a</i>	/	<i>c</i>	<i>b</i>	<i>b</i>	<i>a</i>
0.75	<i>a</i>	<i>a</i>	<i>a</i>	/	<i>c</i>	<i>c</i>	<i>a</i>	<i>b</i>
0.85	<i>a</i>	<i>a</i>	<i>a</i>	/	<i>c</i>	<i>c</i>	<i>a</i>	<i>b</i>

†Treatments: S = stubble, C = chiselled, D = disced, F = tilled summerfallow.

Different letters (lowercase) designate significantly different water gains for similar depths at $P \leq 0.05$, where:

a indicates greatest water gain, *b* second greatest, etc.

/data not available.

The amount of water gain or loss from fall to seeding (Table II) may be ordered as follows from the greatest gain (or least loss) to the smallest gain (or greatest loss):

Stubble > chiselled > disced for the winter of 1985–1986
Stubble > chiselled > disced > fallow for the winter of 1986–1987

The stubble and chiselled treatments either gained the greatest amount of soil water since fall (29 May 1986) or lost the least (9 May 1987) with the chiselled treatment being slightly better at soil water conservation than was stubble (Table II). The 1986 stubble water contents in May were significantly greater than those in other treatments at 15 cm (Table IV), although the chiselled soil water contents were similar to those of stubble and significantly greater than those of disced. Soil water in fallow in May 1987 was significantly greater than soil water in the other treatments only from 65 cm and deeper (Table IV). The similar soil water contents in all treatments at shallower depths could be in part related to high soil water contents for all treatments during the previous fall.

SUMMARY AND CONCLUSIONS

Four common agricultural cultivation techniques were tested to evaluate snow trapping, increases in soil water from snowmelt,

and its retention until spring seeding. The techniques evaluated were three types of stubble tillage (disced, chiselled, and standing stubble) and summerfallow. The field project in two winters of study covered dry and wet fall soil conditions enabling the potential of these cultivation methods for increasing the infiltration capacity of frozen soils to be evaluated fully. The results of the study may be summarized as follows:

1. Snow depth, from greatest to least:

(stubble \approx chiselled) > (disced \geq fallow)

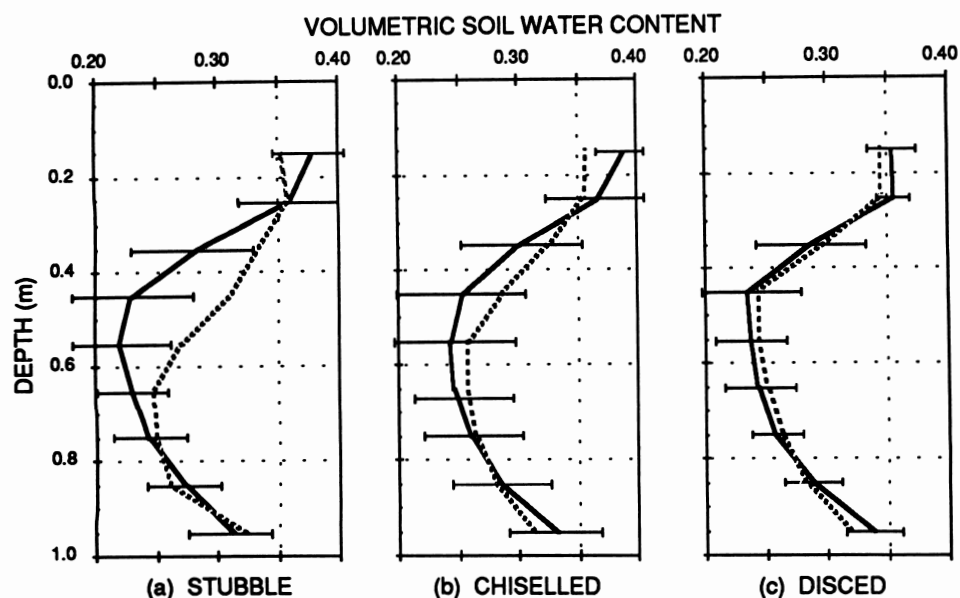
Generally the stubble and chiselled treatments were not significantly different and both trapped significantly more snow than did the disced and fallow treatments ($P \leq 0.05$). Although mid-winter melts frequently reduced the snowpack throughout the winter, the relative ranking among treatments remained the same after these melts.

2. Snowmelt recharge (fall to post-melt spring water gain):

0–0.4 m chiselled \geq stubble \geq [disced \approx fallow],
0.4–0.9 m chiselled \approx stubble \approx disced for dry fall conditions,
fallow \approx disced \geq chiselled \geq stubble for wet fall conditions.

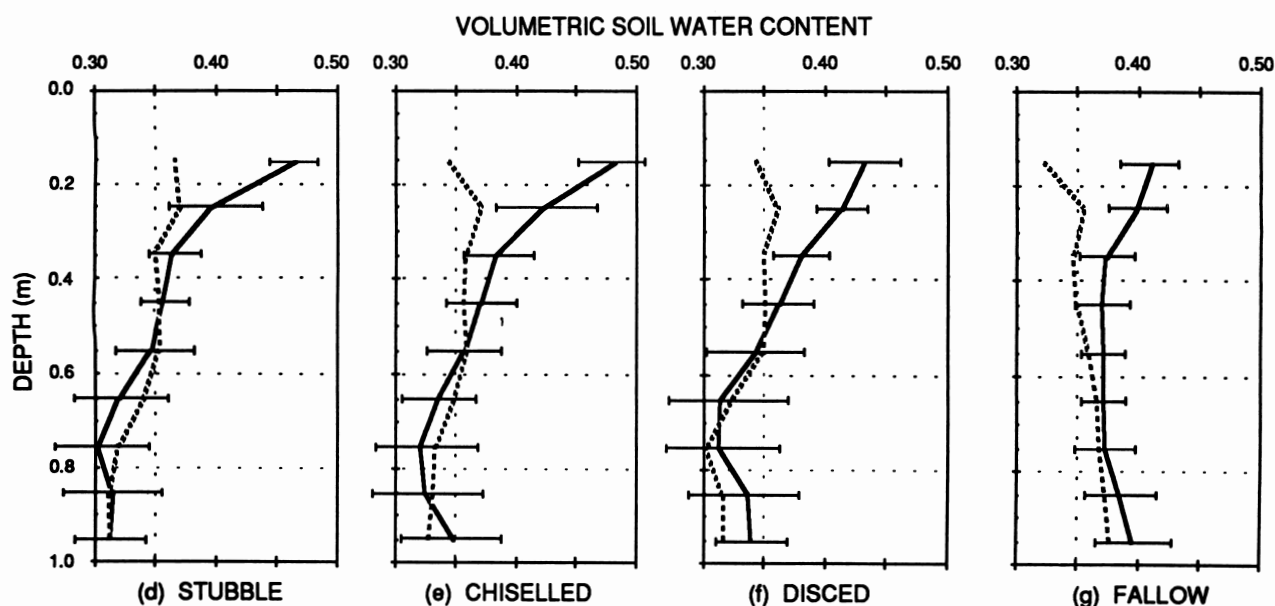
For dry fall conditions, the chiselled treatment resulted in a significantly greater gain in soil water content due to snowmelt recharge at the 15-cm depth than the other treatments. For all other depths and for wet fall conditions, the chiselled and stubble treatments had similar gains. Generally the chiselled treatment always had a greater increase in soil moisture than did the disced treatment for top 40–50 cm, whereas the stubble moisture increase was sometimes not significantly different from either the disced or the chiselled treatments. In terms of total over-winter (November–March) water gain, the chiselled treatment gained the most for both years (55 mm and 29 mm for dry and wet years, respectively), whereas gains in the stubble (44 and 18 mm) and the disced treatment (40 and 20 mm) were similar.

The fallow treatment during the second winter had a slightly greater, though not significant, spring water content only below 45 cm than the other treatments. The only significant difference in spring soil water content among treatments, occurred at 15 cm where the stubble and chiselled soil water contents were greater than those for disced and fallow under wet fall conditions.



LEGEND — MARCH 31, 1986 MAY 29, 1986

MOISTURE CONTENTS REPRESENT THE AVERAGE OF 15 SITES PER TREATMENT.
HORIZONTAL BARS REPRESENT \pm ONE STANDARD DEVIATION FOR MAR. 31, 1986 ONLY.
FALLOW DATA NOT AVAILABLE AS TREATMENT NOT COMPLETELY INCORPORATED.



LEGEND — APRIL 6, 1987 MAY 9, 1987

MOISTURE CONTENTS REPRESENT THE AVERAGE OF 15 SITES PER TREATMENT.
HORIZONTAL BARS REPRESENT \pm ONE STANDARD DEVIATION FOR APRIL 6, 1987 ONLY.

Figure 3. Soil water content for tillage treatments at snowmelt and seeding for two springs, 1986 (a-c) and 1987 (d-g).

3. Water content at seeding time

0–0.35 m stubble \approx chiselled \geq disced for dry fall conditions,
stubble \geq chiselled \geq disced $>$ fallow for wet fall conditions,
0.35–0.90 m fallow \geq (stubble \approx chiselled \approx disced).

In terms of greatest water gain (or least lost) from fall to seeding, stubble gained the most (1985–1986) or lost the least

(1986–1987), with chiselling ranking second. Soil water contents, however, were not significantly different among treatments, with the exception of fallow being significantly lower than stubble and chiselled for the top 30–40 cm and being significantly greater than all the other treatments below 60 cm.

Overall, soil water contents of the chiselled and stubble treatments were not different from each other except in the surface 20 cm. This difference could be due to the rough surface of the chiselled treatment which was observed to hold small pockets

Table IV. Before seeding soil water contents: significant differences

Depth (m)	May 29 1986				May 9 1987			
	S†	C	D	F	S	C	D	F
0.15	<i>a</i>	<i>a</i>	<i>a</i>	/	<i>a</i>	<i>b</i>	<i>b</i>	<i>c</i>
0.25	<i>a</i>	<i>a</i>	<i>a</i>	/	<i>a</i>	<i>a</i>	<i>ab</i>	<i>b</i>
0.35	<i>a</i>	<i>a</i>	<i>b</i>	/	<i>ab</i>	<i>a</i>	<i>ab</i>	<i>b</i>
0.45	<i>a</i>	<i>b</i>	<i>c</i>	/	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>
0.55	<i>a</i>	<i>ab</i>	<i>b</i>	/	<i>a</i>	<i>a</i>	<i>a</i>	<i>a</i>
0.65	<i>a</i>	<i>a</i>	<i>a</i>	/	<i>bc</i>	<i>b</i>	<i>c</i>	<i>a</i>
0.75	<i>a</i>	<i>a</i>	<i>a</i>	/	<i>bc</i>	<i>b</i>	<i>b</i>	<i>a</i>
0.85	<i>b</i>	<i>a</i>	<i>a</i>	/	<i>b</i>	<i>bc</i>	<i>b</i>	<i>a</i>

†Treatments: S = stubble, C = chiselled, D = disced, F = tilled summer-fallow.

Fallow plots for first winter had standing stubble.

Different letters (lowercase) designate significantly different moisture gains for similar depths at $P \leq 0.05$, where:

a indicates greatest moisture gain, *b* second greatest, etc.

/Data not available.

of meltwater and ice. On sloped conditions, it is likely that less runoff would occur from the chiselled treatment than from the stubble or disced treatments. Also because the soil is exposed by chiselling, runoff that would occur would likely have a higher sediment load than under a stubble treatment. The chiselled treatment also seemed more susceptible to water loss by evaporation before spring seeding, with the end result of slightly lower to equivalent surface water contents by the time of seeding compared to the stubble treatment. The chiselled treatment or a treatment that leaves a rough surface with some stubble still standing needs to be investigated further under different climatic conditions. Perhaps the chiselled treatment is more effective than a standing stubble treatment if greater amounts of snow can be retained by the chiselled stubble or in case of high post-melt precipitation. The effect of tillage upon snowmelt recharge should be investigated more closely by quantifying the effect of tillage upon straw incorporation, clod size, depth of disturbance, and surface roughness.

The disking treatment appeared to offer no advantage in comparison to the stubble or chiselled treatments; it resulted in significantly less snow trapped and significantly lower soil water contents at seeding. This is due to the lack of standing stubble, which might have caught snow and protected the soil from evaporation, and the smaller depth of disturbance and clod size as created by the disking. However, despite the fact that the disced treatment trapped less snow than did the stubble treatment, its overwinter moisture gain was not much less than the stubble treatment. This could be in part due to the tilled surface having a slightly better infiltration capacity. Although stubble displayed a tendency to conserve more soil water between the end of springmelt and seeding, more weed problems occurred during the ensuing growing season.

As the fallow treatment was only established for 1 year, it could not be evaluated for the range of climatic and soil water conditions. For the 1986–1987 year of measurement, wet fall conditions resulted in the spring soil water content of the fallow treatment being similar to the other treatments for the top 60 cm.

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