# DEEP TILLAGE OF NON-SOLENETZIC SOILS TO ENHANCE SNOW-MELT INFILTRATION

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## INTRODUCTION

Low amounts and variable distribution of precipitation represent the greatest limitation to crop production in the semiarid portion of the Canadian Prairies. Most producers in this region summerfallow the land every second year partly to conserve soil water to increase the probability of having a satisfactory crop the next year. The prevalent wheat-fallow rotation has been linked to soil degradation through erosion from wind and water, soil salinization and decreased soil organic mater (Dumanski et al. 1986). Consequently, reducing the amount of fallow by adopting annual cropping rotations is desired to minimize soil degradation. Unfortunately, the profitability of annual wheat rotations in southwestern Saskatchewan has been lower and more risky than that of a wheat-fallow rotation (Zentner et al. 1984).

De Jong and Steppuhn (1983) suggested that retaining snow on the field offers the greatest potential for increasing the amount of water available for crops on the semiarid Prairies. Snow management, by leaving tall wheat stubble strips, has typically increased soil water conservation over the winter by 1 to 2 cm (Nicholaichuk et al. 1986) and increased the yields and profitability of continuous spring wheat in southwestern Saskatchewan (Steppuhn et al. 1986; Zentner et al. 1988). The two major limitations of snow management have been the frequent occurrence of years with low snowfall and/or poor infiltration of the snowmelt (De Jong et al. 1986; McConkey 1987).

Deep tillage increased conservation of winter precipitation in the northwestern U.S. (Massee and Siddoway 1966; Lindstrom et al. 1974; Pikul et al. 1985; Papendick 1987; Zuzel and Pikul 1987); in the steppes of the U.S.S.R. (Burnatzki and Yarovenko 1961; Larin 1962; Pabat and Gninenko 1987); and in Saskatchewan (Granger and Gray 1986; Patterson et al. 1986; McConkey et al. 1988; Grevers 1988, 1989). However, many early studies showed no water conservation benefit from deep tillage on the Great Plains of the U.S.A. (Duley 19457; Power et al. 1958; Black and Power 1965; Haas et al. 1966) or on the Canadian Prairies (Wenhardt 1950-55; Paterson and Lapp 1964).

The objective of subsoiling research at Swift Current is to determine the effects of subsoiling with and without snow management on water conservation and yields primarily for continuous spring wheat (*Triticum aestivum L.*) and to a lesser extent for fallow wheat grown on an Orthic Brown Chernozemic soil in southwestern Saskatchewan. The first phase of the research has been reported by McConkey et al. (1990). The work reported here is a continuation of the research on a broader scale. Some of the field research is scheduled to continue for another season or more.

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## MATERIALS AND METHODS

Various tillage implements were used in establishing the treatments on each of the experimental sites.

All Kello-Bilt[2] (KB) treatments were placed with a three shank implement. The Kello-Bilt subsoiler (Fig.1) consists of 3.8 cm wide parabolic shanks with a 5 cm replaceable wear strip on the shin of the shank. The shank spacing was maintained at 76 cm. The implement is capable of working to a depth of 65 cm.

The chisel plow (CP) (Fig.2) treatments were placed with a chisel plow equipped with 5 cm by 35 cm chisel points mounted on spring cushioned 5 cm wide curved shanks. The shank spacing varied between 30 and 50 cm between experiments. The maximum working depth of the chisel plow is 30 cm.

The deep banding (DB) treatments were placed using an air seeder mounted on a chisel plow equipped with 5 cm wide points on shanks spaced 30 cm apart. Maximum tillage depth is 20 cm.

The Paraplow[2] (PP) (Fig. 3) treatments were placed with a three shank unit. The Paraplow has a 2.54 cm wide leg which is bent $45^0$ laterally 25.5 cm from the points. A serrated coulter cuts the soil in front of each leg. The points are 6.4 cm wide. Behind the points is an adjustable shatter plate. The leg spacing was 50 cm. The maximum working depth is 35 cm.

The Hubee[2] (HB) subsoiler (Fig.4) consists of 3 cm x 20 cm x 84 cm parabolic shanks. Shank spacing varied between 58 cm and 81 cm. The Hubee has a maximum tillage depth of 55 cm.

The disc treatment (Fig. 5) was placed with an implement designed by F.B. Dyck and constructed at the Swift Current Research Station. The implement consisted of four 81 cm diameter flat metal discs 1.27 cm in width mounted on bearings allowing the discs to turn. The discs are mounted at a 60 degree angle to the horizontal and at a 8 degree angle to the direction of travel. Discs were spaced 50 cm apart. The implement has a maximum working depth of 30 cm when equipped with 81 cm diameter discs. The objective was to design a subsoiler with minimum surface soil disturbance similar to the Paraplow but with lower energy requirements.

Soil moisture determination methods varied between experiments. For experiment #1, and sub-soiling site #2, soil moisture was measured volumetrically using a neutron depth moisture probe. Readings were taken every 10 cm between 20 and 120 cm. Soil cores from 0-10 and 10-20 cm were taken in conjunction with neutron probe readings to determine gravimetric soil moisture near the surface. These were then converted to volumetric soil moisture using soil bulk densities measured from soil samples taken on the site. The remaining experiments had soil moisture determined gravimetrically by taking soil cores to a depth of 120 cm. Soil bulk densities determined from soil cores collected on site were used to

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[2]Trade names and company names are included for the benefit of the reader and do not infer any endorsement or preferential treatment of the product listed by Agriculture Canada.

convert from gravimetric to volumetric soil moisture content. All the sites with the exception of the Willow Bunch site had water content at 40 bar measured with a pressure plate apparatus from soil samples collected on site. This was assumed to be the lower limit of water availability for wheat.

On all sites except the Willow Bunch site fertilizer N (as ammonium nitrate) was applied at recommended rates (Saskatchewan Advisory Council 1987-1990) based on levels of $NO_3$-N in the 0-60 cm depth from soil sample taken the previous fall. Fertilizer P (as monammonium phosphate) was applied at recommended rates based on levels of $P_2O_5$ in the 0-15 cm soil depth from fall soil samples. On the Willow Bunch Site fertilizer rates were based on general recommendations (Soils and Crops Branch of Saskatchewan Agriculture 1988-1990).

Precipitation between seeding and harvest dates was measured with gauges located on or near the experiment. The Leinan site (20 km north of Swift Current) was monitored with a Universal weighing bucket equipped with a pen recording drum. The Willow Bunch site was monitored using a Universal weighing bucket equipped with an automated electronic recording device. The remaining experiments were monitored with Canadian Standard rain gauges.

Snow surveys were conducted by measuring snow depths with a ruler and snow densities with a M.S.C. Type 1 snow sampler (Meteorol. Branch 1964).

Experiment #1 (Ken Warkentin co-operator)

The area (SE 17-15-13-W3rd) is located west of and adjacent to the Swift Current Research Station south farm. The soil is a Swinton Loam, brown chernozemic soil which has developed from a loess veneer overlying a medium-textured glacial till (Ayres et al. 1985).

The experiment covers an area of 185 m x 300 m. The experimental design is a split-split plot with four replicates. Each replicate is divided into two main plots: conventional stubble, and stubble with trap strips. The tillage sub-plots having dimensions of 18.5 m x 60 m were randomized within these main plots. The sub-plots were further split into N fertility sub-sub-plots. The normal N fertility sub-subplots received fertilizer N to recommended rates for normal moisture conditions whereas the above normal N fertility sub-subplots received fertilizer N to recommended rates for above normal moisture conditions. This paper does not contain any results or analyses of sub-sub-plots fertilized for above normal moisture conditions. The snow management main plot area had four tillage treatments placed in the fall of 1986: check, Paraplow with a shank spacing of 50 cm to a depth of 35 cm, chisel plow with a shank spacing of 30 cm to a depth of 25 cm, and deep banding treatment with a shank spacing of 30 cm to a depth of 12 cm. The conventional stubble contained two treatments: check, and chisel plow with a shank spacing of 30 cm to a depth of 25 cm. In 1987 additional tillage treatments were added. On the snow management area the following treatments were placed: Paraplow with a spacing of 50 cm to a depth of 35 cm to replace the deep banding treatment, an additional chisel plow treatment with a spacing of 30 cm to a depth of 25 cm, a Hubee treatment with a shank spacing of 58 cm to a depth of 38 cm, and a Kello-Bilt treatment with a shank spacing of 76 cm to a depth of 53 cm. On conventional stubble the following treatments were added in the fall of 1987: chisel plow with a shank spacing of 30 cm to a depth of 25 cm to replace the previous chisel plow treatment, and a Hubee treatment to a depth of 38 cm and shank spacing of 58 cm.

Seeding, fertilizing, control of weeds, and harvesting were performed by research station staff. In the spring of 1987 and 1988 the site was harrow packed with coil packers and spring tine harrows and cultivated with sweeps prior to seeding to create a suitable seed bed. Seeding was done with a conventional hoe drill. In 1990 seeding was done directly into standing stubble using a zero-till hoe drill. The area has been continuously cropped to hard red spring wheat (cv 'Leader') at a rate of 67 kg $ha^{-1}$ since 1986. On areas fertilized for above normal moisture conditions additional nitrogen was broadcast prior to seeding. Nitrogen and phosphorous fertilizer was applied with the seed with additional nitrogen broadcast after seeding on all treatments. Winter annual weeds were controlled with a late fall application of 2,4-D. Grassy and broad leaf weeds were controlled in-crop with a dicloflop-methyl/bromoxynil mixture. In the fall of 1988 chlorsulfuron was applied to control green foxtail (*Seteria viridis*). At harvest stubble treatments were placed using a straight cut header. Stubble management areas consisted of 1 m wide leave strips or tall standing stubble running north and south spaced 6 m apart.

Soil moisture was determined volumetrically using a neutron depth moisture probe. On the snow trap areas from two to four 5 cm diameter aluminum access tubes were installed per plot. On the conventional stubble one aluminum access tube was installed per plot. Soil moisture was measured in late fall, early spring, at seeding, heading, and again at harvest. Two grain samples were collected on each sub-subplot with a plot combine. The combine header cut a swath 1.37 m in width. Combine sample lengths which varied between 9 m and 12 m were measured for each sampling site. Additional harvest samples were taken with six hand samples per plot on sub-subplots fertilized for normal moisture conditions in the stubble management main plots. Each hand sample contained two 3 m long crop rows. Straw and grain samples from the hand samples were then submitted and analyzed for % nitrogen. Four soil cores per plot were taken at seeding and again at harvest to a depth of 120 cm on the same sub-subplots where hand samples were taken and analyzed for levels of $NO_3$-N and $NH_4$-N. This additional hand and soil sampling was to look at the effects of subsoiling on soil N and plant N. The results of this additional sampling is not contained in this paper. Two snow surveys were conducted between January and February.

Sub-soiling Site #2 (Research Station South Farm)

The site is located on SE 16-15-13 W3rd approximately 500 m east of the south farm meteorological site. This is on the same site as a previous 1983 subsoiling experiment (McConkey 1990). The soil is a Swinton Loam, brown chernozemic soil which has developed from a loess veneer overlying a medium-textured glacial till (Ayers et al. 1985).

Hard red spring wheat (cv 'leader') was seeded directly into standing stubble with a prototype zero-tillage disc drill (Dyck and Tessier 1986) at a rate of 67 kg $ha^{-1}$. Prior to seeding in 1988, the subsoiled plots were firmed in one operation with spring tooth harrows and spiral coil packers. Fertilizer N was broadcast immediately prior to seeding. Fertilizer P was applied with the seed. The harrow tines did not penetrate the soil more then 1 cm. Grassy and broadleaf weeds were controlled with a dicloflop-methyl/bromoxynil mixture. Occasional spot applications of glyphophate were required prior to seeding to control perennial grasses, principally crested wheatgrass (*Agropyron desertorum* [Fisch.ex Link]Schult.) and foxtail barley (*Hordeum jubatum L.*)

One 120 m x 260 m field contained all the treatments with zero and preseeding tillage along with snow management for 1988 to 1990. For statistical analyses of 1988, 1989, and 1990 data a split-block model was used to analyze the results. The plot size was 13.4 m x 30 m and the plots were randomized within six replicates on the field. From 1988 to 1990 crop years there were 90 cm wide x 40 cm high strips of tall stubble spaced 6 m apart for snow management. The strips were oriented north south; perpendicular to the predominantly westerly winds. The trap strips themselves were not subsoiled. The six treatments consisted of three tillage treatments on snow management and three treatments on conventional stubble. The three tillage treatments were: control (CK), subsoiling with the Paraplow (PP) to a depth of 35 cm and 50 cm spacing, subsoiling with the Hubee subsoiler (HB) to a depth of 40 cm with a spacing of 60 cm. The experiment was subsoiled in October, 1987 on stubble left from a hard red spring wheat crop which was grown on fallow.

Soil moisture was determined volumetrically using a neutron depth moisture probe. In snow management areas two 5 cm diameter access tube were placed in each plot. On conventional stubble one access tube was placed on each plot. Grain yields were determined with a plot combine with one sample per plot on snow management and conventional stubble areas. Yields were taken across the widths of the plots. Precipitation and air temperatures were monitored within 600 m of the experiment sites. Snow surveys were conducted in the late winter of 1987-1988 to 1989-90.

Disc Experiment (Ken Warkentin co-operator)

The area (SE 17-15-13-W3rd) is located west of and adjacent to the Swift Current Research Station south farm. The soil is a Swinton Loam, brown chernozemic soil which has developed from a loess veneer overlying a medium-textured glacial till (Ayers et al. 1985).

The experiment covers an area of 110 m x 56 m. The experimental design is a randomized complete block design with four replicates. Each plot has dimensions of 7 m x 55 m. Four treatments were placed in the fall of 1988: check, Paraplow with a shank spacing of 50 cm to a depth of 35 cm, chisel plow with a shank spacing of 50 cm to a depth of 25 cm, and a disc treatment with a shank spacing of 50 cm to a depth of 25 cm.

Seeding, fertilizing, control of weeds, and harvesting was performed by research station staff. In the spring of 1989 the site was cultivated once with sweeps prior to seeding to create a suitable seed bed. Seeding was done with a conventional hoe drill. In 1990 the area was cultivated prior to seeding and in 1990 seeding was done directly into standing stubble using a zero-till hoe drill. The area has been continuously cropped to hard red spring wheat (cv 'Leader') at a rate of 67 kg $ha^{-1}$ since 1986. Nitrogen and phosphorous fertilizer was applied with the seed with additional nitrogen broadcast after seeding. Winter annual weeds were controlled with a late fall application of 2,4-D. Grassy and broad leaf weeds were controlled in-crop with a dicloflop-methyl/bromoxynil mixture. After harvest the experiment was left to conventional stubble until the following spring.

Soil moisture was determined from two soil cores per plot taken in late fall, at seeding, and again at harvest. Two harvest grain samples per plot were obtained using a plot combine. The plot combine header cut a swath 1.37 m in width. Sample lengths were measured and varied between 8 m and 10 m.

Leinan Site (Harvey Wentland co-operator)

The experiment is located approximately 20 km north of Swift Current on S 1/2 LSD 16 of 2-18-13 W3rd. The land is gently rolling with soil developed on a glacial till soil. The soil is a loam, orthic brown chernozemic soil (Ayres et al. 1985).

The experiment is a split-split plot design with 5 replications. The experiment covers an area 174 m x 400 m. Each replication is further divided into two stubble treatments namely conventional and tall stubble. The stubble treatments are re-randomized each year. Four tillage treatments within each replication are common to each of the stubble treatments. Each tillage treatment or plot covers an area of 20 m x 87 m. The data presented in this paper represents results from four of the five replicates as one of the replicates occupying a predominantly low lying area was felt to bias the results. The four tillage treatments placed in the fall of 1988 include a check, a deep banding treatment placed with an air seeder having a shank spacing of 30 cm to a depth of 15 cm, a chisel plow treatment with a shank spacing of 50 cm to a depth of 25 cm, and a Kello-Bilt treatment with a shank spacing of 76 cm to a depth of 45 cm.

Seeding and fertilizing along with weed control with post-emergence herbicides were performed by the co-operator. The area has been continuously seeded to durum wheat (cv 'Kyle') with a discer since 1988 at a rate of 74 kg $ha^{-1}$. In 1989 the area was harrow packed once with coil packers and spring tine harrows followed by a second pass on the Kello-Bilt treatment. This in turn was followed by cultivation with sweeps and packing the area again to establish an adequate seed bed. In 1990 seeding was done directly into stubble. The bulk of the nitrogen fertilizer was broadcast prior to seeding. The remaining fertilizer requirements were added at seeding. Grassy and broad leaf weeds were controlled in-crop with a dicloflop-methyl/bromoxynil mixture. In the fall of 1988 chlorsulfuron was applied to control green foxtail (*Seteria viridis*). At harvest the co-operator, using a straight cut header, would leave as much standing stubble as possible. The short stubble treatments were then placed using a grass mower.

In 1989 monitoring sites within treatments were separated based on topography. Three positions were identified; level, sloping, and low lying. In the fall of 1989 it was decided to reduce the number of sites to two, namely level-sloping and low lying. This established a better distribution of sampling sites among the different treatments. Only the level-sloping sites were common to all plots with at least four sampling sites per plot. This paper presents analyses of only the level-sloping sites. Soil moisture was determined gravimetrically from one soil core per sampling site taken in late fall, again at seeding, and at harvest. Harvest grain samples were obtained using a plot combine. In 1989 one grain sample per sampling site was taken which was increased to two grain samples per sampling site in 1990. The plot combine had a header with a cutting width of 1.37 m. Combine sample lengths which varied from 6 m to 16 m were measured individually. Two snow surveys were conducted between January and February.

Willow Bunch Site (Andre Boivert co-operator)

The experiment is located north west of the town of Willow Bunch in southern Saskatchewan on NE 10-6-28-W2nd. The soil is a loam to clay loam, orthic brown chernozemic soil (Ellis et al. 1967).

The experiment is a randomized complete block design with three replicates. The experiment lies in an area 176 m x 800 m. Plot widths range from 6.7 m to 9 m depending on the width of the implement used to place the tillage treatment. Each plot is 800 m long running in a north south direction. Three treatments were replicated three times on summer fallow and three times on stubble, for a total of nine plots on summer fallow and nine on stubble. The tillage treatments were placed in the fall of 1988 with a chisel plow to a depth of 25 cm with a shank spacing of 41 cm, and Kello-Bilt subsoiler to a depth of 48 cm and 76 cm shank spacing.

The experiment incorporated a wheat-fallow rotation and is split into two with one half in fallow while the other half is cropped. Seeding and fertilizing along with weed control using post-emergence herbicides on the crop and cultivation with sweeps of the fallow was performed by the co-operator. The fallow half of the experiment is seeded to hard red spring wheat (cv 'Columbus') using a conventional hoe drill. All treatments are cultivated with sweeps prior to seeding to create an adequate seed bed. Fertilizer N and P were applied with the seed. Broad leaf weeds were controlled in-crop with 2,4-D. In 1990 a mixture of 2,4-D and chlorsulfuron was applied. After harvest the cropped area remains in conventional stubble until the following spring.

Each plot has three sampling sites a south sampling site, a north sampling site and middle sampling site. Soil moisture was determined from one soil core per sampling site taken in the fall of 1988 and at seeding in 1989 and 1990. In 1989 three half meter square samples were taken per sampling site at harvest to measure yields. In 1990 four half square meter hand samples were taken per sampling site and bulked to form two samples per sampling site.

## RESULTS AND OBSERVATIONS

The data and observations for the various experiments are presented in the same order as in the Materials and Methods.

Results for Experiment #1

Table 1. Snow Water Equivalent (SWE:mm), Grain Yield (kg $ha^{-1}$), Over Winter Soil Water Gain (OWG:mm), Available Soil Water at Seeding (SDSW:mm), Water Use between Seeding and Harvest(WU:mm) for experiment #1.

| | Treatment | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Snowtrap | | | | | | | Non-Snowtrap | | |
| Year | CK | CP86 | PP86 | DB86 PP87 | CP87 | HB87 | KB87 | CK | CP86 CP87 | HB87 |
| 1987 | | | | | | | | | | |
| OWG | 32 | 16 | 31 | 27 | - | - | - | 13 | 19 | - |
| SDSW | 92 | 86 | 85 | 93 | - | - | - | 93 | 78 | - |
| WU | 209 | 212 | 214 | 208 | - | - | - | 209 | 211 | - |
| YIELD | 1622ab | 1725ab | 1781a | 1611ab | - | - | - | 1566 | 1693 | - |
| 1988 | | | | | | | | | | |
| SWE | 40 | 38 | 41 | 20 | 21 | 17 | 21 | 17 | 4 | 10 |
| OWG | 18a | 21a | 26a | 4b | 7b | 4b | 5b | 10 | 10 | 5 |
| SDSW | 55a | 50abc | 50ab | 29bcd | 18d | 29cd | 23cd | 46 | 30 | 37 |
| WU | 197a | 197a | 189a | 165b | 166b | 169b | 163b | 183a | 169b | 169b |
| YIELD | 412a | 362a | 392a | 287b | 246b | 207b | 225b | 378a | 251b | 273b |
| | | | | **** | **** | **** | **** | | | |
| 1989 | | | | | | | | | | |
| SWE | 53 | 47 | 47 | 39 | 39 | 37 | 40 | 25 | 18 | 22 |
| OWG | 41 | 41 | 41 | 51 | 57 | 51 | 52 | 46 | 35 | 28 |
| SDSW | 85 | 83 | 90 | 93 | 96 | 87 | 91 | 94a | 83ab | 76b |
| WU | 285 | 286 | 291 | 286 | 302 | 290 | 294 | 288 | 283 | 278 |
| YIELD | 2129 | 2082 | 2206 | 2187 | 2181 | 2260 | 2068 | 2022b | 2259a | 2154ab |
| 1990 | | | | | | | | | | |
| SWE | 48 | 59 | 63 | 57 | 56 | 52 | 53 | 36 | 37 | 38 |
| OWG | 34 | 32 | 35 | 33 | 37 | 36 | 42 | 37 | 36 | 32 |
| SDSW | 96 | 103 | 105 | 108 | 98 | 109 | 100 | 90 | 95 | 93 |
| WU | 233 | 236 | 231 | 235 | 235 | 238 | 233 | 215b | 233a | 227a |
| YIELD | 2347 | 2375 | 2323 | 2352 | 2415 | 2411 | 2413 | 2198 | 2437 | 2432 |

Means within rows followed by letters with different letters are significant different (P<0.05).
Underlined means within rows averaged together by line type were found to significantly different in orthogonal contrast statements (P<0.05).

## Observations

### 1987

Weather Conditions:
- Below normal snow accumulations and above -normal temperatures in winter of 1986-87
- Snow surveys: conventional stubble - 0 cm
  stubble with trap strips - 0 cm
- Precipitation and temperatures during growing season were normal
- Growing season precipitation: 16.7 cm ( May 15- Aug 28)

Soil Water and Yield Observations:
- Because of the poor snow accumulations and warm temperatures the modest gains in soil water during the winter were lost to evaporation in the spring.
- No significant differences in soil water between treatments
- Orthogonal contrasts showed the chisel plow and Paraplow significantly outyielded the check and deep banding treatment by an average of 135 kg/ha on snowtrapping. This cannot be explained by differences in soil water.

### 1988

Weather Conditions:
- Below normal snow accumulations and above -normal temperatures in winter of 1987-88
- Snow surveys: conventional stubble - 1 cm water equiv.
  stubble with trap strips - 2.8 cm water equiv.
- April to May was very dry followed by above normal temperatures in June
- Growing season precipitation: 17.8 cm (May 7 - Aug 22)

Soil Water and Yield:
- 1987 subsoiling treatments had lower overwinter gains then the 1986 treatments by an average of 19 mm and lower available soil water at seeding by an average of 34 mm. Attributed to higher evaporation losses on 1987 tilled treatments.
- On snow management: The check had significantly higher yields then the 1987 treatments by an average of 170 kg/ha while the 1986 treatments had significantly higher yields then those of the 1987 treatments by an average of 136 kg/ha. These yield differences are a result of differences in available soil water at spring
- There were no differences between subsoiling treatments of the same year

### 1989

Weather Conditions:
- Normal Precipitation and normal temperatures for winter of 1988-89 (unfortunately with very short stubble could not take advantage of snow)
- Snow surveys: conventional stubble - 2.2 cm water equiv.
  stubble with trap strips - 4.3 cm water equiv.
- Excellent conditions for infiltration (slow melt, dry soil)
- Precipitation in May and June was above normal
- Growing season precipitation: 26 cm (May 23- Sept 11)

Soil Water and Yield:
- Snowtrapping: 1987 tilled treatments had higher overwinter gains then those of the check and 1986 tilled treatments. However this merely compensated for earlier soil drying as by seeding time there were no

differences.
- No significant differences in yield between treatments

1990

Weather Conditions:
- Below normal precipitation and normal temperatures for winter of 1989-90
- Snow surveys: conventional stubble - 3.7 cm water equiv.
  stubble with trap strips - 5.5 cm water equiv.
- Above normal precipitation May and July
- Growing season precipitation: 13 cm (June 1- Aug 22)

Soil Water and Yield:
- No differences in soil water between treatments under snow management or conventional stubble
- Orthogonal contrasts showed the yields of the tilled treatments on conventional stubble significantly outyielded the check by an average of 237 kg/ha.

Results for Subsoiling Site # 2

Table 2. Snow Water Equivalent (SWE:mm), Grain Yield (kg $ha^{-1}$) Over Winter Soil Water Gain (OWG:mm), Avaliable Soil Water at Seeding (SDSW:mm), for preseeding tillage on Subsoiling Site #2.

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | Non Snowtrap | | | Snowtrap | | |
| Year | CK | PP87 | HB87 | CK | PP87 | HB87 |
| 1988 | | | | | | |
| SWE | 21b | 16b | 13b | 40a | 38a | 33a |
| OWG | 21 | 14 | 26 | 28 | 15 | 28 |
| SDSW | 11ab | -8b | 5ab | 20a | 1ab | 16ab |
| YIELD | 286b | 236b | 262b | 416a | 285b | 334ab |
| 1989 | | | | | | |
| SWE | 39c | 42bc | 36c | 55ab | 58a | 47abc |
| OWG | 98 | 97 | 89 | 108 | 99 | 93 |
| SDSW | 85 | 75 | 73 | 97 | 80 | 77 |
| YIELD | 2158 | 2115 | 2196 | 2297 | 2004 | 2138 |
| 1990 | | | | | | |
| SWE | 43b | 44b | 42b | 61a | 61a | 58a |
| OWG | 57 | 53 | 69 | 71 | 56 | 52 |
| SDSW | 114 | 104 | 123 | 120 | 109 | 105 |
| YIELD | 2382 | 2438 | 2467 | 2562 | 2556 | 2464 |

Means within rows followed by letters with different letters are significantly different (P<0.05).

Table 3. Snow Water Equivalent (SWE:mm), Grain Yield (kg $ha^{-1}$) Over Winter Soil Water Gain (OWG:mm), Avaliable Soil Water at Seeding (SDSW:mm), for zero tillage on Subsoiling Site # 2.

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | Non Snowtrap | | | Snowtrap | | |
| Year | CK | PP87 | HB87 | CK | PP87 | HB87 |
| 1988 | | | | | | |
| SWE | 21b | 16b | 13b | 40a | 38a | 33a |
| OWG | 21 | 14 | 26 | 28 | 15 | 28 |
| SDSW | 11ab | -8b | 5ab | 20a | 1ab | 16ab |
| YIELD | 285ab | 233b | 230b | 376a | 293ab | 275ab |
| 1989 | | | | | | |
| SWE | 39c | 42bc | 36c | 55ab | 58a | 47abc |
| OWG | 110 | 136 | 115 | 112 | 144 | 117 |
| SDSW | 97 | 114 | 98 | 101 | 124 | 101 |
| YIELD | 2150 | 2184 | 2115 | 2231 | 2264 | 2248 |
| 1990 | | | | | | |
| SWE | 43b | 44b | 42b | 61a | 61a | 58a |
| OWG | 49 | 55 | 31 | 48 | 59 | 73 |
| SDSW | 105 | 102 | 90 | 109 | 121 | 131 |
| YIELD | 2462 | 2427 | 2307 | 2558 | 2528 | 2345 |

Means within rows followed by letters with different letters are significantly different ($P<0.05$).

Observations

Weather data is the same as reported for experiment #1.

For 1988 SWE, OWG, and SDSW common data was used for both zero and preseeding tillage. The SWE shows that all snow trapping treatments were better then the standard stubble. There was no significant differences in OWG in snow trapping vs standard stubble, but SDSW snow trapping control had the most moisture in the soil profile. Both zero and preseeding tillage gained more grain yield in snow trapping control then all the other treatments. The preseeding tillage yields were a little better then zero-tillage but was not significant.

In 1989, SWE was significantly better for snow trapping for both zero and preseeding tillage plots. However OWG and SDSW were better for zero tillage but at harvest there was no significant difference in yields of all treatments. The above average growing season precipitation tended to even out all treatment effects.

In 1990 zero and preseeding tillage SWE data was the same with snow trapping gaining 17 mm more water then the standard stubble. However, this did not result in significant differences in OWG, SDSW and yield for all treatments. Above normal early season precipitation appeared to even out all treatment effects.

Results of the Disc Experiment

Table 4. Grain Yield (kg $ha^{-1}$), Over Winter Soil Water Gain (OWG:mm), Avaliable Soil Water at Seeding (SDSW:mm), Water Use between Seeding and Harvest (WU:mm) for the Disc experiment.

| | -----------Treatment----------- | | | |
|---|---|---|---|---|
| Year | CK | PP88 | CP88 | DISC88 |
| 1989 | | | | |
| OWG | 39c | 118a | 109a | 92ab |
| SDSW | 54b | 127a | 122a | 110a |
| WU | 249b | 329a | 306a | 299ab |
| YIELD | 2279 | 2292 | 2363 | 2211 |
| 1990 | | | | |
| OWG | 51 | 54 | 40 | 58 |
| SDSW | 103 | 99 | 103 | 116 |
| WU | 242 | 245 | 245 | 264 |
| YIELD | 2032 | 2185 | 2109 | 2184 |

Means within rows followed by letters with different letters are significantly different (P<0.05). Underlined means within rows averaged together by line type were found to be significantly different in orthogonal contrast statements (P<0.05).

Observations

The same weather conditions were encountered as in Experiment #1.

1989

Soil Water and Yield Observations:
- All three tillage treatments had significantly higher over winter soil water gains then the check
- The paraplow had a higher over winter soil gain, higher levels of available soil water at seeding, a higher water use during the growing season and the greatest yield.
- Water use of the Paraplow and chisel plow were found to be significantly higher then those of the disc or check plots

1990

Soil Water and Yield Observations:
- No significant differences in over winter soil water gain, available soil water at seeding, or water use could be established between treatments in the anova test.
- Orthogonal contrasts showed that the disc treatment had a significantly higher level of water use compared to the other treatments by an average of 20 mm.
- No significant differences in yield between treatments could be established. The Paraplow and disc outyielded the check by an average of 153 kg/ha.

## Results for the Leinan Experiment

Table 5. Snow Water Equivalent (SWE:mm), Grain Yield (kg $ha^{-1}$) Over Winter Soil Water Gain (OWG:mm), Avaliable Soil Water at Seeding (SDSW:mm), Water Use between Seeding and Harvest (WU:mm) for the Leinan Site.

| | Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Snowtrap | | | | Non Snowtrap | | | |
| Year | CK | DB88 | CP88 | KB88 | CK | DB88 | CP88 | KB88 |
| 1989 | | | | | | | | |
| SWE | 80 | 80 | 80 | 80 | 55 | 55 | 55 | 55 |
| OWG | 59 | 47 | 61 | 77 | 38 | 42 | 42 | 57 |
| SDSW | 45 | 39 | 51 | 47 | 51 | 48 | 33 | 43 |
| WU | 302 | 331 | 326 | 338 | 298 | 299 | 303 | 320 |
| YIELD | 1767 | 1984 | 2136 | 2229 | 1746 | 1768 | 2135 | 2065 |
| 1990 | | | | | | | | |
| SWE | 53 | 53 | 53 | 53 | 28 | 28 | 28 | 28 |
| OWG | 33 | 25 | 27 | 53 | 27 | 6 | 22 | -5 |
| SDSW | 78 | 66 | 76 | 88 | 78 | 52 | 58 | 50 |
| WU | 374 | 405 | 386 | 398 | 402 | 385 | 400 | 368 |
| YIELD | 2401 | 2480 | 2321 | 2625 | 2285 | 1937 | 2014 | 2058 |

Means within rows followed by letters with different letters are significantly different ($P<0.05$).
Underlined means within rows averaged together by line type were found to be significantly different in orthogonal contrast statements ($P<0.05$).

### Observations

#### 1989

Weather Conditions:
- Results of snow survey (level sloping sites):
  - snow management: 8.0 cm water equiv.
  - conventional: 5.5 cm water equiv.
- Growing season precipitation: 30.2 cm (May 1- Sept 12)

Soil Water and Yield:
- On short and tall stubble the Kello-Bilt had 20 mm more over winter soil water gain then the check. The difference was found significant in orthogonal contrast statements only on the short stubble.
- On tall stubble the tilled treatments averaged 30 mm more in water use then the check. This difference was not found significant however.
- Orthogonal contrast statements showed the deeper tilled treatments of the chisel plow and Kello-Bilt significantly outyielded those of the deep banding and check treatments by an average of 322 kg/ha on both short and tall stubble.
- The Kello-Bilt outyielded the check on short stubble by an average of 319 kg/ha and on tall stubble by an average of 462 kg/ha.

1990

Weather conditions:
- Results of snow survey (level sloping sites):
  snow management: 5.3 cm water equiv.
  conventional: 2.8 cm water equiv.
- Precipitation levels were high in May and July
  growing season precipitation: 34.3 cm (May 10 - Sept 3)

Soil Water and Yield:
- No consistent trends in soil water differences among the treatments could be established. The fact that the experiment lies on a rolling landscape does complicate matters.
- No significant differences in yield could be established in anova or orthoganol contrast statements.
- Yields on tall stubble were on average 383 kg/ha higher then on short.
- The Kello-Bilt outyielded check on tall stubble by an average of 221 kg/ha
- On short stubble the check averaged 282 kg/ha more then the other tilled treatments combined.

Results for the Willow Bunch Site

Table 6. Grain Yield (kg $ha^{-1}$), Over Winter Soil Water Gain (OWG:mm), Total Soil Water at Seeding (SDSW:mm) for the Willow Bunch Site.

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | Stubble | | | Fallow | | |
| Year | CK | CP88 | KB88 | CK | CP88 | KB88 |
| 1989 | | | | | | |
| OWG | 38 | 97 | 70 | 5 | 43 | 5 |
| SDSW | 247 | 294 | 269 | 278 | 309 | 283 |
| YIELD | | | | 2156b | 2107b | 2351a |
| 1990 | | | | | | |
| SDSW | 236b | 272a | 251ab | 318 | 300 | 274 |
| YIELD | | | | 2323 | 2526 | 2361 |

Means within rows followed by letters with different letters are significantly different (P<0.05).
Underlined means within rows averaged together by line type were found to be significantly different in orthogonal contrast statements (P<0.05).

Observations

1989

Weather:
- May and June very wet while July and August were dry
- Growing season precipitation: 22.1 cm (May 2 - Aug 14)

Soil Water and Yield:
- Results indicate that the Kello-Bilt lost more water to evaporation then the chisel plow.
- Subsoiling on stubble resulted in higher over winter gains and higher levels of soil water at seeding compared to the check
- The chisel plow had consistently higher over winter gains and soil water levels at seeding on both the fallow and stubble.
- The Kello-Bilt had significantly higher yields then either the check or the chisel plow by an average of 197 kg/ha.

1990

Weather:
- Precipitation was evenly distributed throughout the growing season
- Growing season precipitation: 19.3 cm (May 3- Aug 14)

Soil and Water Yield:
- Orthogonal contrast statements showed the tilled treatments on stubble had significantly more soil water then the check at seeding by an average of 26 mm.
- As in 1989 the chisel plow had the highest level of soil water at seeding on stubble
- The chisel plow averaged 203 kg/ha more then the check and 165 kg/ha more then the Kello-Bilt. These differences were not found significant however.

General Discussions of Results

Benefits of subsoiling for the Swift Current sites (Research Station south farm and Warkentins) for the years 1987-1990 have not been as great as for the 1983 and 1985 experiments reported by McConkey (1990) previously. This may be due to the weather experienced during these years. It is also speculated that it may also be due to the fact that the sites with a history of continuous wheat cropping going into the fourth and fifth year do not respond to subsoiling as readily as fields coming out of a wheat fallow rotation as was the previous case. It is also frustrating to note that gains in OWG (i.e., Disc experiment) do not always result in significant yield gains. However, it is encouraging to note the benefits of snow trapping (Table 1 1987, Table 2 1988, Table 5 1990).

## ECONOMICS OF SUBSOILING

Table 7 is a summary of costs based on a study of ASEA Standards (1990), our own field experience on a Brown Chernozemic soil and an analysis of operating and overhead costs.

Table 7. Subsoiling Costs

| Implement | Depth | Work Rate | Tractor Costs | | | | Implement Cost | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | | Fuel | Lub | Rep | Dep | Rep | Ovrhd | |
| | (cm) | (ha/hr) | | $/ha | | | $/ha | | $/ha |
| Kello-Bilt ($10,000) | 46 | 0.6 | 11.99 | 1.80 | 4.30 | 8.98 | 3.00 | 9.80 | 39.87 |
| Paraplow ($8000) | 35 | 0.6 | 12.99 | 1.95 | 3.61 | 7.58 | 5.00 | 9.30 | 40.43 |
| Chisel Plow ($5000) | 30 | 1.0 | 5.88 | 0.88 | 2.40 | 4.52 | 2.26 | 5.39 | 21.73 |

Fuel: a value of $0.37/L was used for diesel fuel
Lub: lubrication set at 15% of fuel costs
Rep: repairs
Dep: depreciation
Ovrhd: over head
Work rate and subsequent costs are based on a field efficiency rate of 80 %.

A comparison of the significant yield benefits listed in Results and Observations with the above costs indicate that the economics are generally negative. If all the yield differences shown were real, the economics would look more promising.

## CONCLUSIONS

The conclusions listed are based on the previous study reported by McConkey (1990) and this study.

1. Subsoiling may result in a moisture and yield loss during the year following subsoiling if the winter has very little snow and the season is dry.
2. The benefits of subsoiling are greater if snow trapping is practiced.
3. Significant yield increases from subsoiling do not extend beyond three years.
4. The economics of subsoiling is generally negative and therefore is not recommended.
5. Intermediate tillage depths of approximately 25 cm merit further research. The benefits shown (chisel plow and disc treatments) appear to be equal and the costs are significantly lower.

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Figure 1. The Kello-Bilt Subsoiler

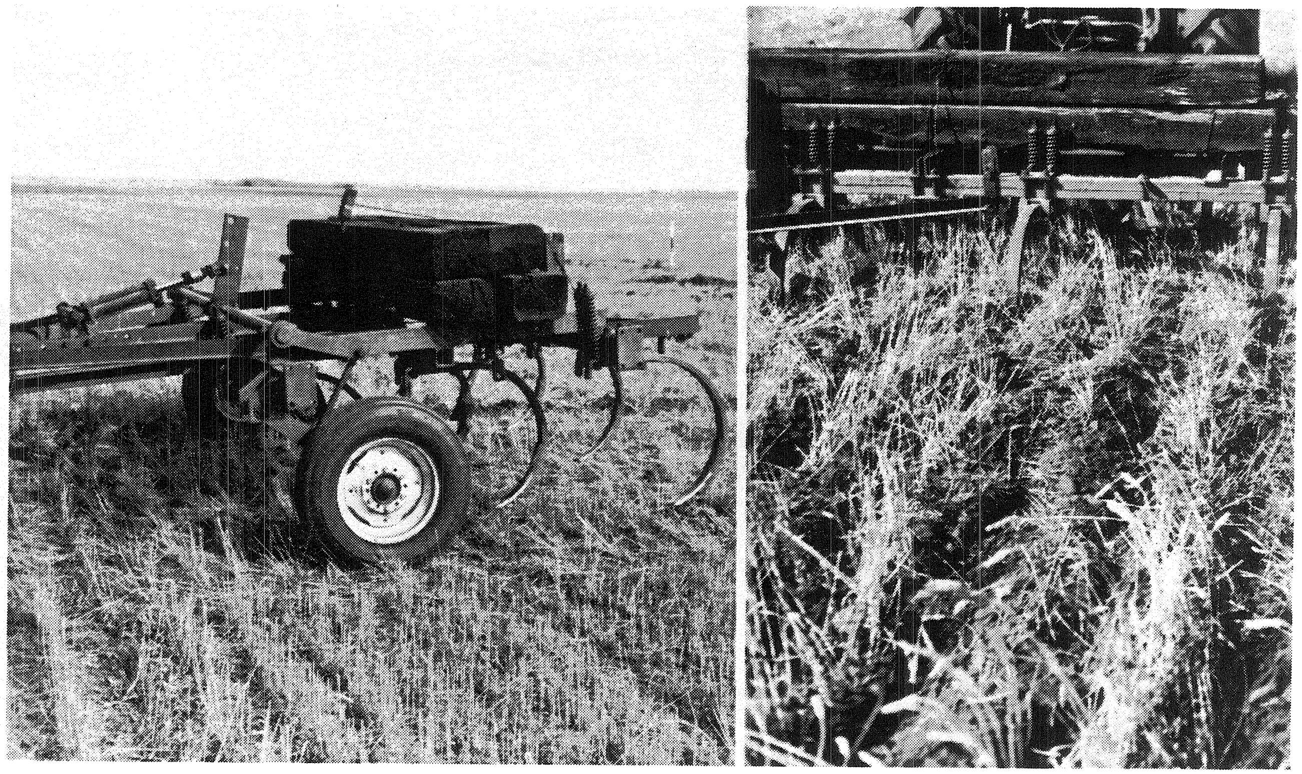

Figure 2. The Chisel Plow

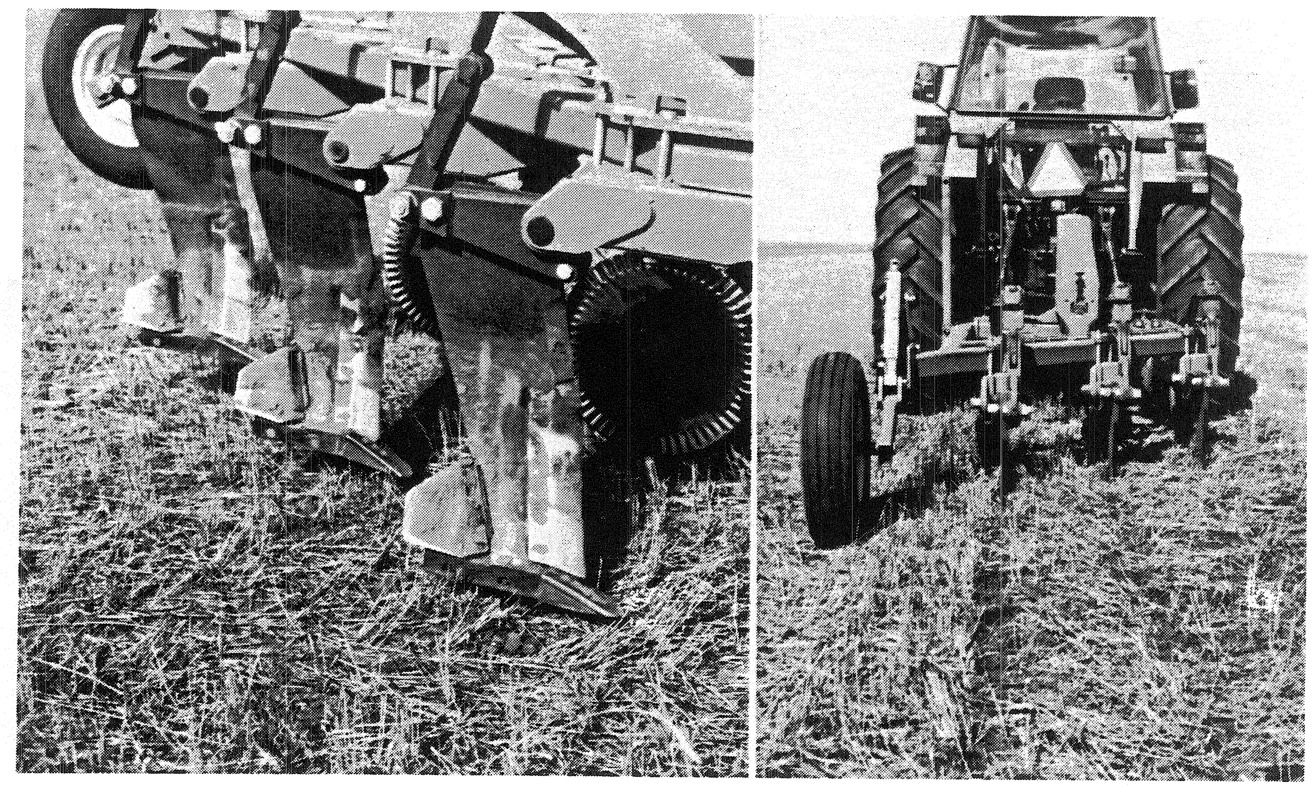

Figure 3. The Howard Paraplow

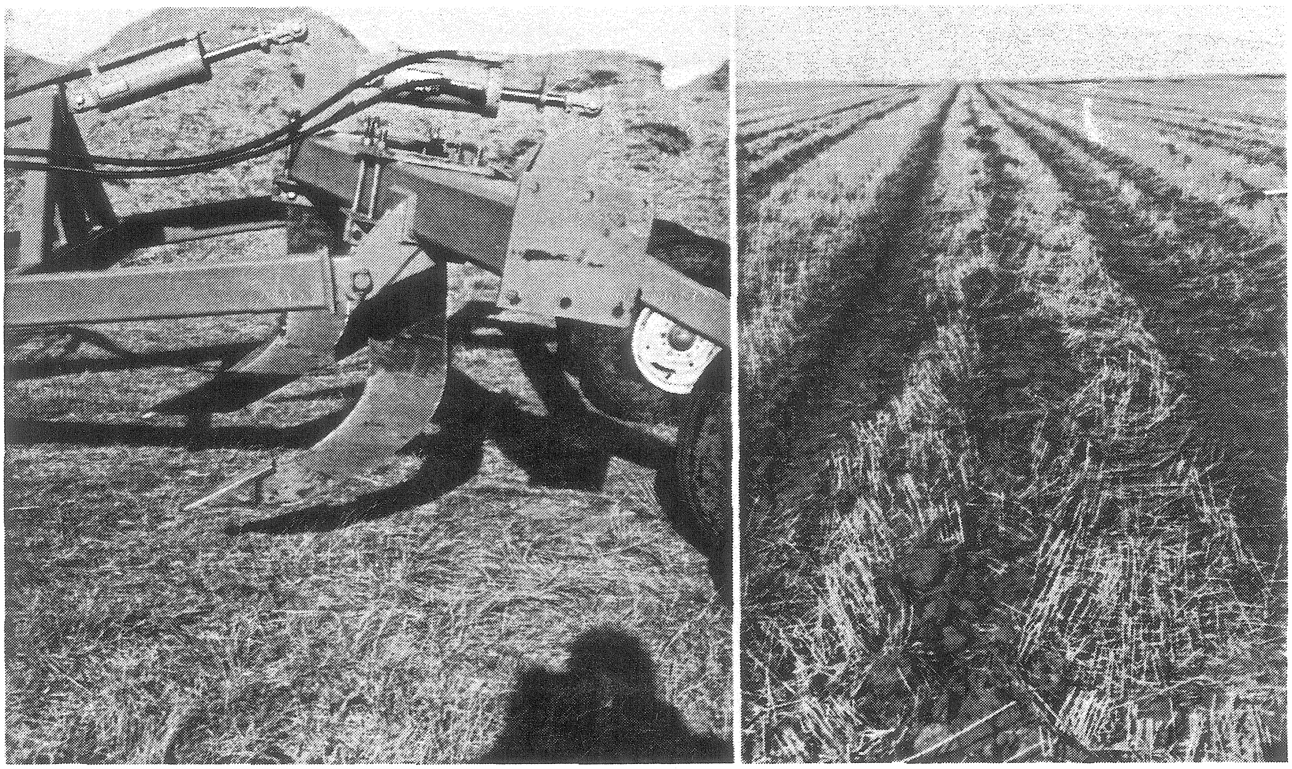

Figure 4. The Hubee Subsoiler

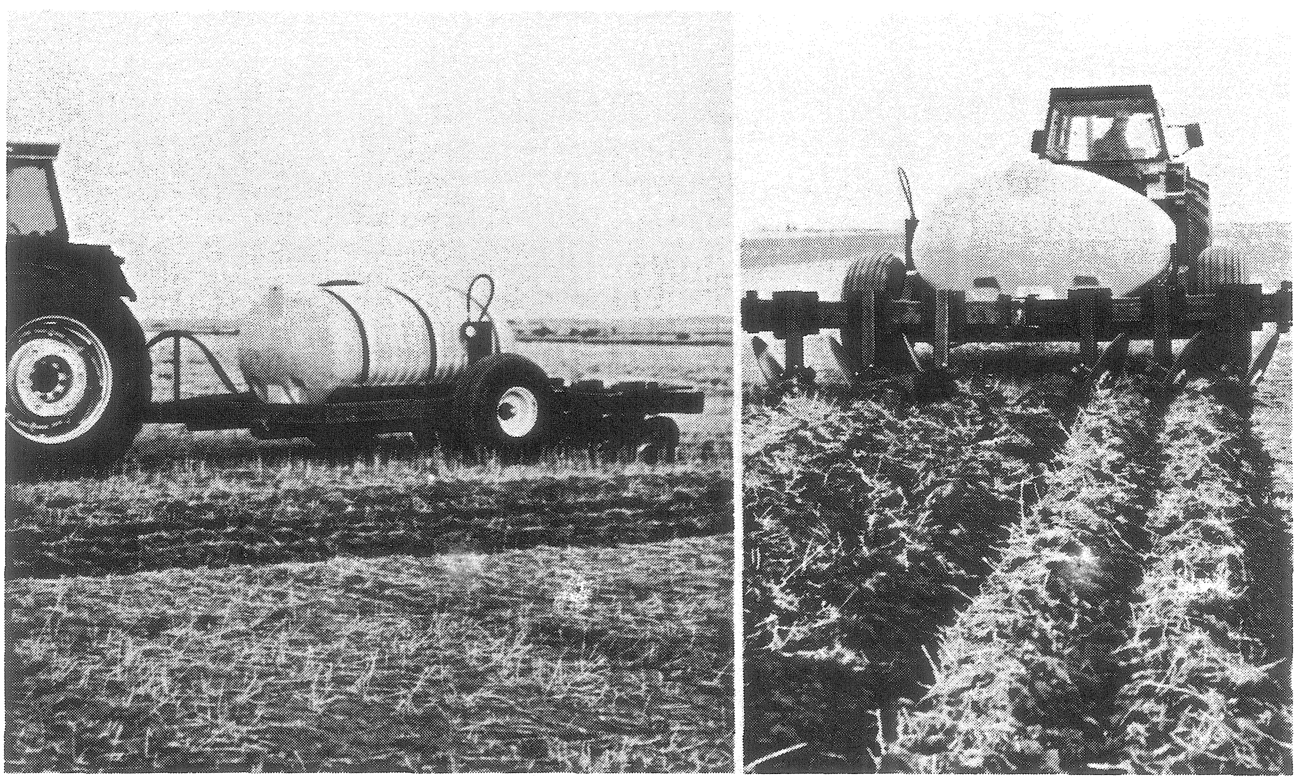

Figure 5. The Swift Current Disc Subsoiler