Weed populations and crop yield as influenced by the temperature and soil moisture characteristics of no-till cropping practices
by Steven Arlen Dewey

A thesis submitted in partial fulfillment of the requirement for the degree of MASTER OF SCIENCE in Agronomy
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Abstract:
No-till and conventional tillage methods of small grain production were compared in a dryland annual cropping situation. Yield data were collected and the weed population in each cropping system was characterized.

Tillage and no-till yields differed significantly in winter wheat, hut not in spring wheat or barley, No-till winter wheat plots produced 875 kg/ha more grain and 1277 kg/ha more vegetative dry matter.

After one growing season, broadleaf weeds were generally more abundant in tillage plots. Some shifts in the predominent weed species were also evident. Meadow salsify and prickly lettuce were more common in no-till plots, while common lambsquarters was the predominent weed in tillage treatments. Volunteer wheat was a weed problem in winter wheat, being more abundant in the tillage plots.

Moisture and temperature characteristics of the two cropping systems were studied to evaluate their potential influence on weed populations and crop yield. Results indicate that no-till cropping is capable of greater soil water accumulation and conservation. In the spring, no-till winter wheat plots contained 5.44 cm more available soil moisture than tillage plots in the surface 1.2 meters of soil. Tilled plots actually lost moisture overwinter, due to evaporative loss from the soil surface, Temperatures measured above and below the soil surface demonstrated significant differences between the two cropping systems.

During the winter, no-till air and soil temperature fluctuations were less extreme than those in tillage plots. In the spring and summer soil temperatures in tillage plots were warmer than in the no-till treatments. This difference was as great as 4,1° C at a 2 cm depth.

Air temperatures in tillage plots were cooler in the spring and summer by as much as 4.5°C at a height of 2 cm.

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Date June 26, 1978

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BY THE TEMPERATURE AND SOIL MOISTURE CHARACTERISTICS
OF NO-TILL CROPPING PRACTICES

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ABSTRACT

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INTRODUCTION

No-till farming is rapidly gaining acceptance among farmers in many areas of the United States. It is presently being practiced successfully in corn, soybeans, cotton, rice, peanuts, wheat, barley, oats, tobacco, grain sorghum, sunflowers, forage crops, and some vegetables. In 1976 no-till methods of crop production were used on 7.3 million acres in the U.S.; a value which represents 2.6% of the total cropland that year. An additional 52.5 million acres, or 28.9% of the total, were cropped using a form of minimum tillage. By the year 2010 it is estimated by the USDA that 90% of all U.S. cropland will be in some form of minimum tillage production; and that no-till will represent over 50% of our total cropping acreage (Triplett and Van Doren 1977).

If the anticipated success of no-till is to be realized, a better understanding must be gained as to its influence on the plant growth environment. The ability of a plant to grow and reproduce is dependent upon external or environmental conditions. Soil moisture, soil temperature, and air temperature are major variables in determining the success of a crop.

The standing stubble environment created by no-till dryland wheat production methods modifies temperature and moisture conditions from those common to conventional practices. The nature and intensity of these changes will affect crops, weeds, and their competitive interaction.

In this study no-till and conventionally cropped small grain plots were established under dryland conditions. The objectives were to determine 1) weed population and crop yield characteristics of no-till and conventional methods in an annual cropping situation, 2) soil moisture, soil temperature, and air temperature conditions created in each system, and 3) whether differences in moisture and/or temperature are of sufficient magnitude to contribute significantly to crop and weed growth differences between the two systems.

LITERATURE REVIEW

Moisture

Small grain production under dryland conditions is dependent upon the available soil moisture present at planting, and the amount and distribution of precipitation received during the growing season. In the Northern Great Plains no other single factor is more critical in limiting dryland small grain yields than is moisture (Bauer 1972).

Because of their role in determining crop success, soil moisture and precipitation data are often used to project grain yields. Based on 871 trials between 1909 and 1962 (Bauer 1972), more than 9.4 cm of available soil moisture was required to obtain any yield of spring wheat in the Northern Great Plains. Each 2.5 cm of moisture in excess of that amount increased grain yields by 161 kg/ha. These data represent moisture use efficiency under conditions of generally inadequate soil fertility and weed control. More recent studies indicate that higher soil fertility levels improve water use efficiency. Bauer et al. (1965, 1966) reported an average yield increase of 403 kg/ha with each additional 2.5 cm of available soil moisture. Their work involved 31 adequately fertilized locations in North Dakota.

Seasonal distribution is often more crucial than the total amount of precipitation received during the growing season. Water stress on a cereal plant at a critical stage of development can result in significant and irreversible yield reduction (Dubetz 1973).

It appears that all stages of plant growth--from germination to maturity--are sensitive to moisture stress. The degree of yield reduction depends upon intensity and duration of the stress, in addition to the stage of plant growth. According to Aspinall (1965), the plant organ growing most rapidly at the time of water stress will be the one most affected. Aspinall et al. (1964) conducted both long and short duration stress experiments with barley at various growth stages. Pre-flowering moisture stress resulted in 8% yield reduction while stress at flowering reduced yields by 37%. Multiple (5-7) short-term stress periods prior to flowering reduced yields as much as 70%. The greater yield reduction observed when moisture stress occurs between heading and flowering is probably due to the water stress vulnerability of pollen formation and fertilization processes (Bauers 1972). Robins and Domingo (1962) produced moisture stress on spring wheat by omitting one scheduled irrigation during various plant growth stages. Stress while plants were in the boot to heading stage resulted in 28% yield reduction. Water stress at boot to late heading, and soft dough to maturity, resulted in yield reductions of 38% and 30%, respectively.

There are several ways, depending upon the plant development stage, in which water stress can reduce grain yields. Chinoy (1962) allowed wheat plants to wilt at one of three developmental stages and then kept them well watered to maturity. The number of kernels per spike was reduced when moisture stress occurred at jointing or at flowering. The number of spikelets per spike was also reduced when wilting occurred at jointing, but not at flowering. The number of spikes and spike length were significantly reduced only when stress occurred during the jointing stage. Of the three stages studied, tillering was the least sensitive to moisture stress. Wardlaw (1966) observed a significant reduction in seed set and larger kernels in wheat plants which were stressed for six days, beginning at anthesis. Langer and Ampong (1970) noticed a reduction in kernel weight when wheat plants were stressed at anthesis. Wells and Dubetz (1966) imposed a water stress situation under greenhouse conditions. A loam soil was allowed to dry to 8 bars atmospheric pressure at one of four plant developmental stages. The number of spikes was reduced by 14% when wheat plants were stressed at early boot stage or at the soft dough stage. Number of kernels per spike was reduced by 15% when soil moisture stress occurred at early boot stage.

No-till and tillage systems differ significantly in terms of soil moisture accumulation and moisture conservation (Jones et al. 1969, Wilson 1976). The moisture advantages offered by no-till make it especially attractive in areas where moisture is sometimes limited.

Standing stubble and surface mulch in no-till cropped cereals cause increased soil moisture accumulation. Smika and Whitfield (1966) measured the amount of total soil moisture accumulated overwinter in tillage and no-till plots. No-till plots consisted of standing stubble (46 cm), while stubble in tillage plots had been incorporated. Results demonstrate an overwinter gain of 5 cm moisture in the top 1.8 m of soil on no-till plots. Tillage plots actually showed a net overwinter loss of water. Staple et al. (1960) determined from a 20 year study the average overwinter soil moisture accumulation in tilled and undisturbed stubble fallow in Saskatchewan. They reported soil water increases of 5.1 cm in stubble and 1.1 cm in tilled fallow.

Krall (1969) and others have questioned the need for summer fallow in some areas. According to Black and Siddoway (1976), often as much soil moisture can be stored overwinter with no-till as during an entire summer fallow period using tillage. Increased soil moisture accumulation in no-till is due, in part, to snow retention differences. The standing stubble acts as a snow trap to prevent loss of snow from blowing and drifting. In many areas of the Northern Great Plains the removal of snow by wind from cropland represents a significant loss of potential moisture. Black and Siddoway (1977) recorded a four fold snow depth difference between no-till and tillage plots after just one wind-accompanied snow storm. Snow depth on tillage plots averaged 6 cm while no-till plots (38 cm stubble) accumulated 26 cm. Aase and Siddoway (1978) used stubble heights of 0, 19, and 35 cm to study snow accumulation. The tall stubble collected 3.6

times more snow and 2.5 times more water equivalent than the bare plots during one snow storm.

Snow moisture accumulation in no-till is also enhanced by increased water infiltration. Early work done by Barnes et al. (1955) compared infiltration rates on bare and straw mulch covered soils. In the first hour the water infiltration rate on mulch covered soil was 3.82 cm/hr while that for bare soil was 2.49 cm/hr. Some researchers attribute increased infiltration rates in no-till to improved soil macrostructure (Black 1973, Blevins et al. 1977). Russel et al. (1975) observed an increase in soil surface aggregates, extensive root channel networks created by previous crops, vertical planes of weakness remaining from drying or shrinking soil, and an increase in earthworm channels in the soil of no-till plots. He considered the changes in macrostructure to be responsible for the increased infiltration rates.

No-till cropping practices not only accumulate more soil moisture, but are also more efficient at conserving existing levels of water in the soil. The surface mulch serves to greatly reduce evaporative loss from the soil surface. Russel (1940) compared evaporative water loss on bare soil and soils covered with various amounts of straw mulch, and found that bare soil lost the greatest amount of moisture. Evaporative water loss was reduced 55% by 2250 kg/ha of mulch, and 4500 kg/ha of straw reduced the loss from bare soil in the first 24 hours following irrigation by 62%. Bond and Sillis (1969) noted that, because of decreased evaporation, mulch covered soils remained moist much longer in no-till plots following precipitation.

Standing stubble, grass barriers, or any other form of windbreak also serve to reduce evaporation from the soil surface. Aase and Siddoway (1976) showed bare soils exposed to reduced wind movement remained wet three days longer than check plots.

Temperature

Temperature is important in determining cereal growth and grain yield. However, it is difficult to quantify its individual contribution to yield in relation to that of moisture. Hopkins (1935), in Canada, concluded that ambient temperature conditions during the growing season were secondary to precipitation in determining grain yield. Blair (1918) found that in South Dakota ambient temperatures during May and June were often of greater importance than precipitation in determining wheat yields. Army and Hanson (1960) found that spring wheat yields in Montana were more closely correlated to temperature than to precipitation after heading.

The effect of temperature stress on plant growth depends on the stage of plant growth. Above average temperatures may be detrimental at some stages and beneficial at others. Hopkins (1935) reported above average air temperatures in western Canada to be detrimental during mid-season, and beneficial at emergence and prior to ripening.

Walster and Nystuen (1948) compiled spring wheat yield and air temperature data from 1911 to 1945 in North Dakota. They demonstrate significant negative correlations between yield and temperature during June and July. Thompson (1962), using data from the Dakotas from 1935 to 1961, determined that air temperatures one degree (°C) above average during April and May increased yields from 12.1 to 22.9 kg/ha. The same temperature increase in June reduced yields by 61.9 to 63.2 kg/ha. In July the warmer temperature resulted in yield reductions of 15.5 to 57.8 kg/ha. Brengle and Whitfield (1969) noted significant positive correlations between increasing soil temperature and grain yield when temperature treatments were applied at the three-leaf stage. Treatment at heading resulted in a significant negative correlation.

Wardlaw (1970), in determining the effect of air temperature on wheat yield, established three temperature regimes. Day/night temperatures were 27/22, 21/16, and 15/10° C during the first ten days after anthesis. Air temperatures before and after the ten day treatment period were 21° during the day and 16° during the night. The highest temperature treatment resulted in larger kernels but fewer kernels per spike. Total grain yield was highest and vegetative yield lowest at 27/22. Asana (1964), using somewhat higher temperatures, found total grain weight per spike to decrease as air temperatures increased from 20° to 31° C. By exposing 23-day-old wheat plants to an air temperature of 42° C for 36 hours, Sojka et al. (1972) were able to significantly reduce tillering. Total dry weight at maturity had also been significantly reduced.

Fischer (1976) modified air temperatures in the field by covering plants with a transparent ventilated chamber that could be heated or cooled to differ by as much as 10° C from the ambient temperature. He noted the greatest temperature effect between the time from jointing to anthesis. A grain yield reduction of 4% was associated with each 1° C increase above ambient temperature during that period.

Warrington et al. (1977) demonstrated direct effects of air temperature on cereals. Spring wheat plants were grown in liquid growth medium in chambers of controlled vapor pressure deficit. Plants were subjected to day/night temperatures of 25/20, 20/15, or 15/10 during one of three growth stages for approximately a 30-day period. The plants were grown at 20/15 during the other two growth stages. Growth stages were: 1) germination to pre-boot; 2) boot to anthesis; and 3) anthesis to maturity. Total grain weight per spike was most affected in stage 2, but was also influenced in stages 1 and 3. Grain weight per spike was largest at the lowest temperature treatment. Only the most distal kernels on the spike were affected in stages 1 and 2 while all were influenced by temperature in period 3. The number of kernels per spike was least affected by temperature in stage 1, but at stage 2 there were 3.5 more kernels per head at 15/10 than at 25/20. More fertile tillers per plant resulted from high temperatures in stage 1 and low temperatures in stage 2. Total vegetative dry matter yields followed this same pattern. Plant height was only affected in stage 2, where low temperatures gave the shortest plants. The authors feel that temperature can influence yield at any stage of plant development and that this influence upon yield is growth stage dependent. Total yield was greatest when air temperatures were high in stage 1 and low in stages 2 and 3.

Peters et al. (1971) found that night air temperatures of 8.9, 15.3, and 26.5° C corresponded to wheat yields of 2556, 2421, and 1345 kg/ha, respectively. High night temperatures reduced yields by 47.4%. Kerby (1973) observed spike deformation from high air temperatures to be very similar to that caused by 2,4-D.

Many other researchers have done work to determine the influence of air temperature on cereals; all showed significant responses. Contradictions in response trends may be due to varietal differences (as demonstrated by Varade et al. 1970), plant growth stage, or from inability to separate influence of temperature interactions with the water balance of the plant.

Soil temperature has been studied by researchers in an effort to determine its effect upon wheat and barley. Sojka et al. (1975), in studying a semi-dwarf spring wheat variety, observed the effect of three soil temperatures. Treatments of 9, 15, or 21° C were initiated at the three leaf stage and continued for 25 days. Plants were then harvested, and vegetative yields determined. Fifteen degrees was the optimum temperature for shoot dry weight, root dry weight, tillers per plant, and leaves per plant. Brengle and Whitfield (1969) found decreasing soil temperatures from 18° to 12° at this growth stage to cause reduced tillering of spring wheat. Labanauskas et al. (1975) recorded nearly a 50% reduction in total grain yield when soil temperatures during grain filling were increased from 15° to 25° C. Individual kernel weight was much reduced. Luxmoore et al. (1973), using soil temperature treatments of 5, 15, and 25° C during grain filling, observed similar trends in grain yields. The lowest soil temperature during the 30-day treatment resulted in the highest total dry weight per plant, largest spike size, most kernels per spike, and the largest total grain yield. Individual grain weight was greatest at 15° C. Of the soil temperatures 8, 12, 19, and 26° C compared in a study by Boatwright et al. (1976), the greatest total dry weight per plant was obtained at 19°. Plants in this study were treated for 11 days, beginning seven days after emergence, and soil temperatures were varied only in the top 2.5 cm of soil. Soil below that point was held constant at 18° C.

Whitfield and Smika (1971) in Colorado noted extreme variability in varietal response to soil temperature. Wheat plants were subjected to soil temperatures of 7, 13, and 18° C from seeding until plants were 3/4 headed. Of the four varieties tested, two were winter wheats (Witchita and Lancer), and two were spring wheats (Lee and Crim). Winter wheat varieties produced more spikes per plant at 13° (after vernalization) than at 7° or 18°. Spring wheats, on the other hand, produced most spikes at 18° and fewest at 7°. Root weight increased with increasing soil temperature for all varieties, but response of top growth to temperature was again dependent on variety. Both winter wheat top growth yields were highest at 13°. Lee and Crim vegetative yields were lowest at that temperature, and yielded best at 18°. Tillering was greatest at 18° for all varieties. Spikelets per spike increased with increasing temperature in the winter wheats and Crim spring wheat. Lee wheat produced most spikelets per spike at 7°. The number of tillers producing spikes was also temperature dependent. The number decreased with increasing temperature in Lancer and Witchita, remained unchanged in Crim, and increased in Lee. Wall and Cartwright (1974) observed similar varietal differences in response to air temperature.

The crown node was tested by Boatwright et al. (1976) for its role in plant response to soil temperature. It was concluded that the crown node is the seedling part most sensitive to temperature; and therefore, temperatures in the top 3 cm are the most critical in determining plant growth response. Smika (1974) attempted to determine the optimum crown depth temperatures from planting to heading.

For winter wheat varieties the greatest number of spikelets per spike were formed at 15° C, and the most spikes per plant resulted from the 13° treatment. For spring wheat varieties, spikes per plant and spikelets per spike were greatest at 18° and 13.5° C, respectively.

The effect of a mulch on the soil surface, such as occurs in no-till, is to lower temperatures of the soil, especially near the surface. Being a poor conductor, a straw mulch absorbs radiant energy from the sun but transmits little to the soil in the form of heat. It also acts as an insulator to reduce transfer of heat from warmer air to cooler soil.

Work done in corn (Lemon 1956, Moch and Erbach 1977) shows that a straw mulch on the soil surface results in reduced soil temperatures. Van Wijk (1959) recorded average weekly soil temperatures to be as much as 5.6° C lower under mulch in corn. Early vegetative growth was significantly reduced by this temperature depression in Minnesota and Ohio; but not in South Carolina where normal soil temperatures are significantly higher. The same trend appears true for wheat and barley.

Black and Siddoway (1977) in Montana measured soil temperature in spring wheat at the 5 cm depth from the middle of May to June 10. Maximum soil temperatures in no-till plots (stubble heights of 28 and 38 cm) averaged 18.3 and 17.1° C, respectively, while those in tillage plots averaged 20.2° C. Black (1970) planted winter wheat by conventional methods and then covered the plots with straw. Residue rates of 0, 1680, and 3360 kg/ha produced average midday May temperatures of 17.1, 12.0, and 8.1° C at the 5 cm depth.

Aase and Siddoway (1978) planted winter wheat using no-till methods into stubble heights of 0 (burned), 17, and 33 cm. Much of the loose straw was removed. Readings taken every half hour from late September to early April showed soil temperatures at the surface to differ significantly. During the fall and spring, stubble-plot daytime soil surface temperatures were as much as 5° C cooler. Winter temperature data showed the daily range of temperatures in stubble plots to be less extreme than those in bare plots. That is, the highest and lowest soil temperatures recorded overwinter were in bare plots. Under certain conditions bare-soil winter temperatures fluctuated as much as 15° C daily while temperatures under tall stubble varied only 1°. This pattern is principally due to snow insulation. Stubble plots in this example had approximately 11 cm of snow while bare plots had snow only in the drill furrows.

Aase and Siddoway et al. (1977) suggested that under extreme cold conditions the added snow in no-till plots could insulate sufficiently to prevent or reduce winter kill. Their studies showed the minimum winter soil temperature at a 5 cm depth that year to be -19° in stubble-free tillage plots. The minimum temperature at that depth in no-till plots (35 cm stubble) was -15° C. If the threshold for winter kill of winter wheat is -16° C at the crown depth (Ulanova 1975), no-till would have been beneficial in reducing wheat loss.

Air temperatures are also affected by no-till. In the absence of snow, daytime temperatures in the stubble are higher and night temperatures lower than those over bare soil. Aase and Siddoway (1978) observed higher fall and spring midday temperatures in stubble. At a 5 cm height these differences were as great as 3° C.

Weeds

Weed population changes have always accompanied changes in agricultural practices (Thurston 1971). The interaction between weeds and their environment is delicate; and even a slight change in the timing of events or conditions of the environment may have a great effect on weed growth. Weed responses to environmental changes include changes in 1) the size, vigor, or competitiveness of a weed, 2) the number of individual weed plants, and 3) the number of weed species.

The moisture characteristics of a soil are influencial in determining the weed population density and species composition. This is demonstrated by an experiment conducted under greenhouse conditions by Weise and Vandiver (1970). Corn, sorghum and eight weeds were subjected to three levels of soil moisture. Common cocklebur (<u>Xanthium</u>

strumarium), common crabgrass (Digitaria sanguinalis), and barnyard-grass (Echinochloa crusgalli) grew best and were most competitive under moist soil conditions. Kochia and Russian thistle plants were comparatively large and competitive at very low soil moisture levels. Palmer amaranth was most suited to a moderate soil moisture content. The authors suggest that the moisture characteristics of an area determine, in part, the weeds which will be present in agronomic crops. They also demonstrated that the soil moisture level affects the ability of a weed to compete with a crop.

Weeds respond to temperature much as do crop plants (McWhorter and Jordon 1976). Weed species differ in their temperature requirements; and thus temperature change could be expected to produce some change in the weed population (Hallgren 1976, Harris 1972, Potter 1976).

Weeds are a major variable in determining the success of no-till yields. This is especially true in areas where the soil moisture advantage of no-till is of primary importance. It has been shown that weed populations can be changed by variations in temperature and soil moisture, and that temperature and moisture conditions in no-till can differ significantly from those of tillage methods. On the basis of those facts alone, it might be expected that weed populations in no-till will differ from those in tilled systems. However, there are other, and possible more important, reasons why no-till weed problems should be different.

Tillage in itself significantly affects weeds. Stobbe (1977) categorized weeds under major headings according to germination response to tillage. Arable response weeds exhibit increased germination in response to increased tillage. Germination of inverse response weeds decreases with increasing tillage. He found a shift from tillage to no-till resulted in a shift towards less arable response weeds and more inverse response weeds.

The increased dependence upon herbicides in no-till allows for additional weed population changes. Weed population shifts in response to herbicides are often rapid and dramatic (Fryer and Chacelle 1970, Shuck 1975). Weeds controlled by a herbicide decline in number while resistant weeds become more numerous. Weeds not presently controlled by available herbicides should become more prevalent in non-tilled crops if they are suited to the no-till environment. Further restrictions are made on "available" herbicides because, without tillage, only those herbicides requiring no incorporation can be used.

Interception of herbicide spray by straw residue results in less herbicide reaching the smaller weeds, thus, less effective weed control (Erbach 1975).

Actual reports of weed population changes in no-till are common, and follow a general pattern. Bachthaler (1975) compared weed infestations in wheat for six years. Broadleaf weeds decreased in no-till plots while perennial grasses (especially _Agropyron repens_) increased.

The perennial grasses became such a problem that plots at some locations were discontinued after five years. From his own work and that of others in Great Britain and Europe, Cussans (1975) concluded that, in general, annual broadleaf weeds are greatly reduced in no-till systems. Annual grasses as a group follow no pattern. Some such as Setaria sp., Avena fatua, and Bromus sp. have been reported to increase significantly. Volunteer grain, often considered an annual grassy weed, is usually less of a problem in no-till. Perennials, especially grasses, increase in no-till cereals. Researchers in the U.S. and Canada generally agree with the pattern outlined by Cussans (Stobbe and Taylor 1977, Triplett and Lytle 1972, Kapastra and Strieka 1976, Larson 1970).

Additional research is needed to determine effective means of no-till weed control if the projected success of this cropping method is to be achieved. Proper timing of herbicides and use of crop rotations will be of primary importance in adequately controlling weeds in no-till systems.

MATERIALS & METHODS

Two small grain cropping methods were initiated on a Manhattan very fine sandy loam soil September 7, 1976 in a dryland agricultural area of southwestern Montana. A description of these two methods is presented in Table 1. This study was designed to compare yield and weed population characteristics of no-till and conventional small grain cropping practices. Temperature and moisture conditions throughout the year were recorded in an effort to determine their relationship to the weed problem and crop yield of each cropping system.

Plots were established 15 km north of Belgrade, Montana in the Horseshoe Hills. This area receives an average annual precipitation of 35.3 cm (Appendix, Table 1). The study site is an area 91.4 x 100.6 meters, located on a northeast facing slope. Plots were arranged in a randomized complete block design with nine replications. Individual plot dimensions were 6.1 x 9.1 meters. The entire plot area had been cropped to winter wheat during the previous season (1975-76). Straw residue remaining after that harvest averaged 4770 kg/ha with an average stubble height of 31.9 cm.

The two cropping methods (treatments) were designated tillage and no-till (Table 1). Both treatments were established for winter wheat, spring wheat, and barley. Cheyenne winter wheat was seeded at a rate of 87 seeds per meter Sept. 28, 1976. Newana spring wheat (87 seeds per meter) and Shabet barley (54 kernels per meter) were

Table 1: Treatment description for tillage and no-till on winter wheat, spring wheat, and barley plots from Sept. 1976 to Aug. 1977.

Crop & Date	Tillage treatment	No-till treatment
Winter Wheat		
Sept. 25	Seedbed preparation	-------
Sept. 27	Fertilizer application	Fertilizer application
Sept. 28	Seeding	Seeding
Oct. 6	-------	.56 kg glyphosate
May 12	.28 kg/ha 2,4-D .02 kg/ha picloram	.28 kg/ha 2,4-D .02 kg/ha picloram
Aug. 4	Harvest	Harvest
Spring Wheat and Barley		
April 19	Seedbed preparation	-------
April 20	Fertilizer application	Fertilizer application
April 21	Seeding	Seeding
April 28	-------	.56 kg glyphosate
Aug. 12	Harvest	Harvest

seeded April 23, 1977. Seeding depth was approximately 5 cm, and row spacing was 35.6 cm in all plots. Both no-till and tillage plots were seeded with a no-till press drill with double-disc openers.

The tillage treatment consisted of planting into a prepared seedbed. Seedbed preparation was accomplished by discing each tillage plot twice prior to seeding. Seed in no-till plots were sown directly into undisturbed stubble. A post-plant pre-emergence application of glyphosate (N-phosphonomethyl glycine) at a rate of .56 kg/ha followed. Fertilizer (11-55-0) at a rate of 225 kg/ha (25 kg/ha nitrogen) was surface broadcast to all tillage and no-till plots immediately prior to planting. Tillage plots were disced before the application.

Post-emergence weed control was accomplished in both treatments by the use of herbicides. A late spring tank mix application of .28 kg/ha 2,4-D (2,4-dichlorophenoxy acetic acid) and .02 kg/ha picloram (4-amino-3,5,6-trichloropicolinic acid) was made on no-till and tillage winter wheat plots, but was not considered necessary on spring wheat or barley. All herbicides were applied in water at a rate of 190 L/ha. All herbicides were applied with a CO_2 pressurized backpack sprayer.

Moisture

Soil moisture measurements were taken in the fall of 1976, spring of 1977, and again in the fall of 1977. A "King Tube" was used to collect soil samples in 30.5 cm increments to a depth of 1.83 meters. Due to possible horizontal subsurface water movement below 1.2 meters, only soil moisture data to that depth are reported. Soil samples were weighed, dried at 60° C for 48 hours, and weighed again to determine moisture content on a percentage basis. Water content was then calculated by volume. Soil bulk density was estimated to be 1.4 g/cm^3 (Ferguson 1978).

Three permanently fixed meter sticks in each of six plots were used to measure snow accumulation throughout the winter in the winter wheat plots.

Temperature

Temperatures were recorded with YSI #44005 thermistors. Five thermistors were positioned on a partially buried, white, wooden dowel in such a manner that temperatures could be measured at depths of 2 and 8 cm below, and heights of 2, 8, and 16 cm above the soil surface. The thermistors were positioned on the north side of the dowel in an effort to reduce the effect of solar radiation on the thermistors. Because of the expense involved, only enough thermistors were acquired to monitor temperatures in six plots. Three no-till and three tillage winter wheat plots were selected randomly, and the thermistors were placed in them December 16, 1976. An equilibrating period of 21 days was allowed before the first readings were taken.

Air and soil temperatures were recorded in tillage and no-till winter wheat plots from January 1 to August 20, 1977. Readings were taken near midday at approximately weekly intervals throughout the eight month time period. Weekly temperature readings were then classified into one of three seasonal categories, according to reading date. Winter temperatures were designated as those taken between January 1 and April 1. Spring temperatures were those recorded between April 1 and June 15, while the summer category included temperatures recorded between June 15 and Aug. 20. Temperature data from each season were then used to compute average seasonal midday temperatures.

Only temperatures on clear, non-stormy days were used in calculating summer and spring average temperatures. Data from both clear and stormy days were used to determine average midday winter temperatures. However, to compensate for the extreme weather variability, three sub-classifications of winter temperature conditions were created. Average temperatures were computed for each sub-category. Daily maximum air temperatures were the basis for categorizing temperature reading dates into these three sub-classifications. Maximum air temperatures recorded at Belgrade were used to represent the approximate maximum temperature at the plot location on each recording date (Appendix, Table 3). Winter-subzero was the designation given to days with a maximum air temperature below 0° C. Maximum air temperatures between 0 and 5^{o} C were considered winter-moderate conditions; and winter-melt was the term applied to winter days with a maximum temperature above 5^{o} C. Snow was present in at least some of the plots during all temperature readings classified in winter categories.

Weeds

Weed stand densities in both winter wheat and spring grains were determined by actual counts at planting and at harvest. Weeds were also counted on four additional dates between planting and harvest in winter wheat plots, but not in spring wheat or barley. Weeds were counted at harvest over the entire 55.5 m^2 area of each plot in all nine replications of each treatment. Counts prior to that date were made on two .5 m^2 subplots in three replications of each treatment.

Yield

Plant heights were measured, and vegetative samples were collected throughout the growing season in order to estimate vegetative yield in winter and spring wheat. Sixteen representative plants in each of three tillage and no-till plots were marked and their height measured weekly. Marking was accomplished by placing a flagged nail in the ground near each plant. Plants in a 2.44 meter length of row were harvested from each of these plots every two weeks, by clipping to ground level. Vegetative matter was then oven dried at 60^{o} C for

48 hours and weighed to calculate vegetative yields. The final height and vegetative yield measurements at harvest were recorded from all nine replications of each treatment.

Grain yield was obtained by hand harvesting plants from a 1.73 m^2 area in each plot. Bundles were tied and placed in bags to prevent grain loss in handling. Samples were threshed with a gravity "Vogel" thresher. Spikes in a representative 2.44 meter length of row in each plot were counted prior to harvest. The number of seeds per spike was determined by harvesting 20 average mature spikes in each plot on Aug. 3.

When an effort was made to differentiate between volunteer and non-volunteer wheat plants, an arbitrary decision was made to classify as volunteer plants any which did not appear to originate near the bottom of the seed furrow. This included plants between rows and those growing on or near the crest of a seed furrow.

Treatment means were statistically compared by means of a simple analysis of variance.

RESULTS & DISCUSSION

Moisture

A base-line value representing the fall soil moisture levels in both no-till and tillage plots was obtained on Oct. 15, 1976 by sampling four non-tilled plots in the study area. The average amount of stored moisture in the surface 1.2 meters of soil was determined to be 18.74 cm on that date. Six months later, on April 15, a noticeable moisture difference had developed between treatments in the winter wheat plots. No-till plots had gained 3.69 cm of moisture, while tillage plots had lost 1.75 cm. This constitutes a difference of 5.44 cm (Table 2). The total precipitation received at the nearest weather station (16 km south) over the six month time period was 7.32 cm.

Table 2: The effect of cropping method on overwinter soil moisture storage in winter wheat to a depth of 1.2 meters.

	Soil moisture in cm 1/		
	Oct. 15, 1976	Apr. 15, 1977	Accumulated
No-till	18.74	22.43	3.69
Tillage	18.74	16.99	-1.75
Difference			5.44*

1/ Average from one 1.2 meter soil sample in each of 3 plots
* Significant at the P=.06 level

The overwinter moisture accumulation capabilities of tillage and no-till cropping methods can be attributed to differences in snow retention and evaporative water loss. No-till plots accumulated more snow over the winter than did tillage plots, due to the ability of standing stubble to retain or even accumulate snow under windy conditions. The first two major snow storms during the 1976-77 winter (January 3 and January 15) were both followed by strong northerly winds. Snow depth measurements on January 18 demonstrate the effect of stubble on wind blown snow (Table 3). On that date 5.9 and 16.8 cm of snow were recorded in tillage and no-till plots, respectively. Greater snow depth was recorded in no-till plots following each wind-accompanied snow storm during the remainder of the year.

The significant over-winter loss of soil moisture from tilled plots was probably due to evaporation rather than percolation. The only significant loss of soil moisture in tillage plots occurred in the first sampling depth (shaded area on Figure 1) with no significant overwinter change in moisture below that depth, indicating no movement of moisture down through the soil profile. Although some evaporative loss appeared to have occurred on the surface of no-till plots, there was a six-fold greater loss in tillage plots. Soil moisture values in tillage plots were significantly different from those of no-till in all but the last depth increment (.9-1.2 m) (Figure 1).

Table 3: The effect of cropping method on snow depth in winter wheat from Jan. 1 to April 7, 1977.

Date	Cropping method and snow depth[1/]		
	No-till cm	Tillage cm	Difference cm
Jan. 6	19.8	15.8	4.0**
Jan. 11	15.8	5.7	10.1*
Jan. 18	16.8	5.9	10.9**
Feb. 1	11.6	.3	11.3**
Feb. 7	12.5	.3	12.2**
Feb. 15	8.7	0	8.7**
Feb. 17	7.2	0	7.2**
Feb. 19	4.8	0	4.8*
Feb. 22	1.7	.7	1.0
Mar. 1	.2	0	.2
Mar. 31	8.0	1.8	6.2*
Apr. 4	1.1	0	1.1
Apr. 7	0	0	0

1/ Average of 3 measurements in each of 3 plots
* Significant at the P=.05 level
** Significant at the P=.01 level