Technology and wheat yields in the Central Great Plains

Experiment station advances

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search Station at Akron, Colorado, with a
Sligo silt loam soil (Pachic Argiustoll); the
North Platte, Nebraska, Experiment Sta-
tion, with a Holdrege silt loam soil (Mesic
Typic Argiustoll), and the Colby, Kansas,
Experiment Station, with a Colby silt loam
soil (Mesic Ustic Torriorthent).

Summer fallow

Winter wheat in the Central Great Plains requires that fields remain fallow
because the wheat requires about 22 centi-
meters (8.7 inches) of water for evapo-
transpiration in relation to expected an-
nual precipitation for initial grain develop-
ment (4, 12, 18). Yields then increase
rapidly—105 to 185 kilograms per hectare
per centimeter of water (4 to 7 bushels/
acre/inch). Adequate soil water during fal-
low maintains wheat through winter, a pe-
riod of low water demand. The wheat then
can use late spring rainfall to meet peak
growth demands. The fallow period is 14
months, from harvest in early July until
planting in early September the next year.

Fallow research programs have two
main objectives: to increase soil water stor-
age during fallow and to decrease the soil’s
vulnerability to wind erosion. Success with
either objective can increase and/or stabil-
ize wheat yields.

Research data and experience suggest
that five requirements must be met to im-
prove water conservation and erosion con-
trol in the wheat-fallow system (2, 3, 4, 5,
6, 7, 8, 9, 10, 11, 12, 13, 19, 20, 21, 22, 23,
24, 25, 26):

- Weed control for the entire fallow
period (harvest-to-planting) is essential.
- Stubble must be left standing over-
winter.
- Straw mulches must be left on the
soil surface during the warm season.
- Hard soil clods 1 to 8 centimeters
(0.4 to 3.2 inches) in diameter must be left
on the soil surface during the warm season.
- Soil must be managed to retain
enough water in the seedbed to germinate
seeds.

Meeting these requirements maximizes
soil water storage and the retention of ni-
trate nitrogen in the soil, reduces to near
zero the potential for soil erosion, and
minimizes the energy required and other
crop production expenses.

Weed control. Unwanted vegetation in
fallow stubble includes grassy and broad-
leaf weeds, both cool and warm season
species, and some volunteer wheat. This
vegetation in undisturbed stubble produces
900 to 2,700 kilograms per hectare (800 to
2,400 pounds/acre) of dry matter and may
use 0.5 centimeters (0.2 inches) water per
day (6, 26). Dry matter production of
1,120 kilograms per hectare (1,000
pounds/acre) weeds consumes about 7.6
centimeters per hectare (3 inches) and 30
kilograms per hectare (27 pounds/acre) of
available nitrogen (6, 20).

Until recently, weed control began dur-
ing early to mid-spring, using various till-
age implements. Tillage, however, results
in a water loss, by evaporation, of 0.5 to
0.8 centimeters (0.2 to 0.3 inches) per op-
eration (4). Experimentation with herbi-
cides, particularly post-harvest treatment
in new wheat stubble, gained momentum as
broader spectrum contact and preemerg-
genence herbicides became available (4, 6,
22, 26). Weed control with herbicides does
not disturb the soil, but to be effective her-
bicides must kill unwanted vegetation ra-
pidly and completely. Stunted weeds con-
tinue to use water.

Standing stubble overwinter. Snowfall
catchment by stubble is an important wa-
ter source during the fallow season (7, 23).
North of 38.5 degrees latitude snowfall ex-
cceeds 600 millimeters (24 inches) a year
with a water equivalent of 72 millimeters
(2.8 inches). Measurements show that 35 to
55 percent of water recharge during fallow
is from snowmelt in stubble, which, to-
gether with snowfall on planted wheat the
second winter, accounts for an estimated
45 percent of the region’s wheat produc-
tion (7, 23). Storage efficiency of snowmelt
averaged 53 percent in undisturbed stubble
at Akron over a 16-year period (7). Conse-
quently, destroying fall weeds by disking is
detrimental. Water saved by controlling
weeds with a disk was more than offset by
the water loss from snow blowoff caused
by lack of stubble (6).

Straw mulch. Development of modern
high-clearance, V-blade “sweep” imple-
ments and rodweathers with attached sechi-
sols (tongs), in combination with greatly
increased power, has made stubble mulching a widely accepted tillage prac-
tice. By absorbing raindrop impact, mulches help prevent puddling and facili-
tate water infiltration. Mulches also re-
duce evaporation by insulating the soil
from the sun’s energy and by decreasing
wind speed at the air-soil interface (4, 8).

Studies at seven locations in the Central
Great Plains showed an average net gain of
2.6 centimeters (1.1 inches) of soil water
per season for mulched fallow compared
with bare fallow (Table 1). The quantity of
straw mulch available at the beginning of
fallow influenced water storage during
fallow (Table 2). Soil water storage in-
creased 5 centimeters (2 inches) when the
mulching rate increased from 0 to 6.6 met-
ric tons per hectare (6,000 pounds/acre).

Application rates of straw mulch needed
to cover 100 percent of the soil surface are
3.6, 2.3, 3.6, 6.8, 8.1, and 16.4 metric tons
per hectare for winter wheat, spring barley
(Hordeum vulgare L.), spring oats (Avena
sativa L.), sudangrass (Sorghum vulgare
sudanense), hay millet (Setaria italica (L)
Beauv.), and grain sorghum (Sorghum bi-
color L.), respectively (5). In the Central
Great Plains the amount of wheat stubble
available for mulching ranges from 3.4 to
4.7 metric tons per hectare (3,000 to 4,200
pounds/acre).

Straw mulches were also found to ac-
cumulate in the surface 7.6 centimeters (3
inches) of soil through at least three cycles
of wheat-fallow at three Great Plains loca-
tions (11). Straw accumulation increased
as the straw available increased, but at a
decreasing percentage, which suggests a
trend toward equilibrium. This trend in
straw accumulation was due to the gen-
ernly dry climate in the region and to tillage
practices that leave the surface soil loose
for rapid drying (11).

Although mulches increase soil water
storage in fallow, they tend to reduce the
accumulation of soil nitrate nitrogen at the
end of fallow by 5 to 15 percent, depend-
ing upon the quantity at the beginning of
fallow (19, 24). This nitrate reduction has
not influenced yields, but it has slightly re-
duced the protein content of the grain (19,
24). Results at eight Central Great Plains
locations (42 test years) showed an average
gain in net yield of 170 kilograms per hect-
are (2.5 bushels/acre) of winter wheat for
mulched fallow compared with bare fal-
low (19).

Soil clods. Only a small amount of fine,
moist soil is needed around a wheat seed
for germination. Surface clods resist wind
erosion, help anchor mulches, slow runoff
water, provide shade, and physically pro-
tect young plants. However, they do not
provide a good medium for weed seed ge-
minaion. Straw mulches assist in the for-
mation of nonerodible soil aggregates by
providing binding agents, such as fats,
waxes, and oils (21).

Seedbed water. Modern deep-furrow
planters can penetrate 12 to 14 centimeters
(4.7 to 5.5 inches) of dry soil and place
seeds in wet soil for prompt germination.
This is important in case of late summer
drought, which is common in the region.
Nevertheless, mulches maintain soil water
closer to the surface to assure good wheat
stands (20). Poor penetrations by shallow
disk drills in dry seedbeds, whether in fal-
low or continuous wheat, was a major factor in the dust bowl syndrome of the 1930s and 1940s. Over the last 30 years, improved management of seed-zone water for wheat, in combination with a capacity to plant deeper, has increased yields an estimated 8 percent in the Central Great Plains (8).

These five requirements for improving water conservation and erosion control in the winter wheat-fallow system have gradually been integrated into new fallow systems. There is now less reliance upon mechanical tillage during the spring and summer months. The fallow system now extends the full 14 months from harvest to planting, when using minimum tillage and no-till fallow systems.

### Fall weed control and minimum tillage

Data previously were published on the effects of mulching rates during fallow on soil water storage at Akron (9, 10). Not reported were the results of fall-spring initial tillage with V-blade sweeps. Fall tillage and fall weed control refer here to suppressing weed growth in wheat stubble, usually within 5 to 35 days after harvest.

Results showed that, compared with spring initial tillage, a single fall sweep operation within 10 days after harvest, which reduced potential fall weed growth by 40 percent, stored 1.3 centimeters (0.5 inches) more soil water and accumulated 19 kilograms per hectare (17 pounds/acre) more nitrate nitrogen in the soil by the end of fallow. These extra growth inputs, in turn, increased wheat yields an average of 200 kilograms per hectare (3 bushels/acre) over four seasons. Similar results were obtained at North Platte (22).

These results led to expanded experimentation on fall weed control using tillage and/or herbicides (6, 26). Suppressing fall weed growth increased soil water storage in fallow, which increased wheat yields (Table 3).

Minimum tillage implies the application of contact and preemergence herbicides shortly after wheat harvest to kill all weeds and to inhibit any weeds or volunteer wheat from germinating until late in the following spring. One sweep operation and one to two rowdeddings (semi-chisel attached) usually are required until planting in early September. A variation of minimum tillage involves a single fall sweep plus a preemergence herbicide, usually atrazine.

### No-till fallow

A no-till fallow system relies entirely on herbicides throughout the fallow season. Experimentation with no-till systems is currently underway at Akron; Sidney, Nebraska; and North Platte. Minimum disturbance of stubble and maximum control of weeds offers the ultimate in water storage, double that of conventional spring mechanical fallow (4). Wind erosion threats are nearly eliminated. No-till could conceivably be used for fallow for two consecutive seasons in regions severely affected by prolonged drought. Also, wheat yields increase with a significant reduction in energy expenditure.

Some limitations of the no-till system include the high cost of some contact herbicides, possible residual carryover of preemergence herbicides in sandy and high lime surface soils, and difficulties of planting wheat in heavy undisturbed stubble.

### Progress with fallow systems

Table 4 summarizes tests with various fallow systems between 1915 and the present at Akron and North Platte. Trends show a gradual change in mechanical implementations used, from soil inverting by plowing to soil cutting with disks to soil undercutting with duckfoots, sweeps, and rowdeddings. This evolution in tillage systems is also being adapted by farmers in the region, but at a slower rate.

The number of operations used during fallow dropped sharply as herbicides be-

### Table 1. Soil water increase at the end of fallow for bare soil versus straw mulches in seven Great Plains locations (19).

<table>
<thead>
<tr>
<th>Location</th>
<th>Years Tested (no.)</th>
<th>Soil Water Increase (cm)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Bare</td>
</tr>
<tr>
<td>Akron, Colorado</td>
<td>6</td>
<td>14.2</td>
</tr>
<tr>
<td>Alliance, Nebraska</td>
<td>6</td>
<td>2.9</td>
</tr>
<tr>
<td>Archer, Wyoming</td>
<td>2</td>
<td>2.8</td>
</tr>
<tr>
<td>Colby, Kansas</td>
<td>4</td>
<td>11.5</td>
</tr>
<tr>
<td>Garden City, Kansas</td>
<td>6</td>
<td>8.6</td>
</tr>
<tr>
<td>North Platte, Nebraska</td>
<td>6</td>
<td>14.6</td>
</tr>
<tr>
<td>Oakley, Kansas</td>
<td>4</td>
<td>8.2</td>
</tr>
<tr>
<td>Total or average</td>
<td>38</td>
<td>9.0</td>
</tr>
</tbody>
</table>

*Soil water sampled to depths of 120 to 180 centimeters per location.  
†Sampled spring to fall (4 months), other locations from harvest to planting (14 months).

### Table 2. Influence of straw mulch rates on soil water storage at the end of fallow at four Great Plains locations (data interpolated from 9, 10, 25).

<table>
<thead>
<tr>
<th>Location</th>
<th>Years Tested (no.)</th>
<th>0 Metric Tons Straw/Hectare</th>
<th>2.2 Metric Tons Straw/Hectare</th>
<th>4.4 Metric Tons Straw/Hectare</th>
<th>6.6 Metric Tons Straw/Hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akron, Colorado</td>
<td>6</td>
<td>13.4</td>
<td>15.0</td>
<td>16.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Bushland, Texas</td>
<td>3</td>
<td>7.1</td>
<td>9.9</td>
<td>9.9</td>
<td>10.7</td>
</tr>
<tr>
<td>North Platte, Nebraska</td>
<td>7</td>
<td>16.5</td>
<td>19.3</td>
<td>21.6</td>
<td>23.4</td>
</tr>
<tr>
<td>Sidney, Montana</td>
<td>4</td>
<td>5.3</td>
<td>6.9</td>
<td>9.4</td>
<td>10.2</td>
</tr>
<tr>
<td>Total or average</td>
<td>20</td>
<td>10.7</td>
<td>12.7</td>
<td>14.5</td>
<td>15.7</td>
</tr>
</tbody>
</table>

*Soil water sampled to depths of 150 to 180 centimeters per location.

### Table 3. Effect of fall weed control treatments in new wheat stubble on soil water storage during fallow at two Central Great Plains locations for two time periods (6, 26).

<table>
<thead>
<tr>
<th>Fall Weed Control Treatments</th>
<th>Fall Weed Growth (kg/ha)</th>
<th>Fall Dormancy†</th>
<th>End of Fallow‡</th>
<th>Wheat Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Platte, Nebraska (1963-1969)</td>
<td>1,800</td>
<td>- 4.4</td>
<td>14.6</td>
<td>2,690</td>
</tr>
<tr>
<td>Fall sweep, single</td>
<td>1,480</td>
<td>0.5</td>
<td>20.3</td>
<td>2,880</td>
</tr>
<tr>
<td>Fall sweep + atrazine</td>
<td>400</td>
<td>1.2</td>
<td>21.5</td>
<td>2,910</td>
</tr>
<tr>
<td>Contact herbicide + atrazine + fall sweep</td>
<td>350</td>
<td>3.4</td>
<td>23.7</td>
<td>3,040</td>
</tr>
<tr>
<td>Akron, Colorado (1969-1972)</td>
<td>1,140</td>
<td>2.8</td>
<td>8.9</td>
<td>2,420</td>
</tr>
<tr>
<td>Check, spring disk</td>
<td>650</td>
<td>5.3</td>
<td>11.2</td>
<td>2,690</td>
</tr>
<tr>
<td>Fall sweep, single</td>
<td>370</td>
<td>6.4</td>
<td>12.7</td>
<td>2,940</td>
</tr>
<tr>
<td>Contact herbicide + atrazine</td>
<td>325</td>
<td>6.4</td>
<td>12.7</td>
<td>2,940</td>
</tr>
</tbody>
</table>

*Soil water sampled to 180-centimeter depth.  
†October 25 to November 10.  
‡August 27 to September 10.
gan to replace mechanical tillage. Currently, fallow efficiency with no-till averages about 50 percent, compared with about 20 percent for the original dust mulch system and 24 percent for conventional black fallow, which is still used on about a third of commercial fallow fields today.

**Breeding Improved wheat varieties**

Mennonite immigrants introduced hard red winter wheat varieties to the Great Plains in the late 1800s. The original genetic material was based on the well-adapted Turkey types, which were generally tall and winterhardy. Breeding and improvement programs were established later to improve yield potential and other wheat characteristics.

Table 5 provides some examples of the yield improvement through breeding programs in the Central Great Plains. Kharkof is a typical Turkey-type wheat with average to poor yield potential and excellent winterhardiness. Using this well-adapted type as a genetic base, breeders introduced genetic variability from many sources (17).

Johnson (14) suggested that several yield thresholds have been reached through breeding. In recent years Scout and its derivatives have increased yields over a large area of the Great Plains. Centurk provided another yield step during years and at locations where moisture was adequate.

Recent variety development has concentrated on the use of exotic germ plasm from such sources as spring wheat semidwarfs. This effort has resulted in semidwarf varieties, such as Vona, which represents an additional yield increase. Vona is now rated 30 percent better than Kharkof in terms of yield potential.

These newer semidwarf varieties perform most satisfactorily under optimum environmental conditions. They may be more limited in general adaptation than Scout types. Plant heights can be reduced by the accumulation of dwarfing genes. Recently released semidwarf hard red winter varieties have generally used one dwarfing gene to reduce height by one increment. It is unlikely that plant height will be reduced more in variety development, especially in semiarid areas, because certain levels of plant residue are needed in cultural practices. Extreme shortness of straw also is detrimental to harvesting. In addition, problems associated with plant emergence and development are difficult to overcome with shorter genotypes.

While yield has been the major objective in all breeding programs, breeding has improved other specific plant characteristics, such as protein content, milling and baking properties, winterhardiness, and disease and insect resistance. Farmers can now use varieties with better characteristics, along with improved cultural practices, to convert natural resources, such as water and nutrients, efficiently and economically into consumer products with desirable properties.

**Long-term wheat yields**

Table 6 presents wheat yield data for the Akron, North Platte, and Colby stations. Between 1926 and 1975, average annual precipitation varied from 415 millimeters (16.3 inches) at Akron to 456 millimeters (18.0 inches) at Colby and 485 millimeters (19.2 inches) at North Platte.

Increases in winter wheat yields and water use efficiencies were remarkably similar at all locations, regardless of precipita-
experiment stations in the Central Great Plains between 1926 to 1975 equaled that achieved for other crops in other regions of the United States where the climate is much less extreme. This progress cannot be credited to any single phase of technology, but improved fallow systems and better wheat varieties deserve most of the credit (8). Improved planting and harvesting equipment have also contributed significantly (8, 12).

REFERENCES CITED


Table 5. Dryland yield relationships of several hard red winter wheat varieties compared with Kharkof.*

<table>
<thead>
<tr>
<th>Variety</th>
<th>Year Released</th>
<th>(% of Kharkof)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheyenne</td>
<td>1931</td>
<td>113</td>
</tr>
<tr>
<td>Pawnee</td>
<td>1943</td>
<td>108</td>
</tr>
<tr>
<td>Scout</td>
<td>1965</td>
<td>127</td>
</tr>
<tr>
<td>Ganturk</td>
<td>1973</td>
<td>125</td>
</tr>
<tr>
<td>Vona</td>
<td>1977</td>
<td>130</td>
</tr>
</tbody>
</table>

Table 6. Increase in winter wheat yields grown under fallow systems and water use efficiency during five decades at three Central Great Plains locations.

<table>
<thead>
<tr>
<th>Decades</th>
<th>Average Wheat Water Use Precipitation Yield Efficiency* (mm/yr) (kg/ha) (kg/ha-cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Platte, Nebraska</td>
<td>1926-35 467 1,675 20 1936-45 483 1,955 20 1946-55 500 2,390 24 1956-65 531 2,830 25 1966-75 457 3,090 34</td>
</tr>
<tr>
<td>Colby, Kansas</td>
<td>1926-35 396 1,060 13 1936-45 467 1,250 13 1946-55 472 1,915 21 1956-65 508 2,145 21 1966-75 446 2,980 30 1926-75 427 2,730 32</td>
</tr>
</tbody>
</table>

*Based on wheat yield divided by two years annual precipitation (fallow + crop year).