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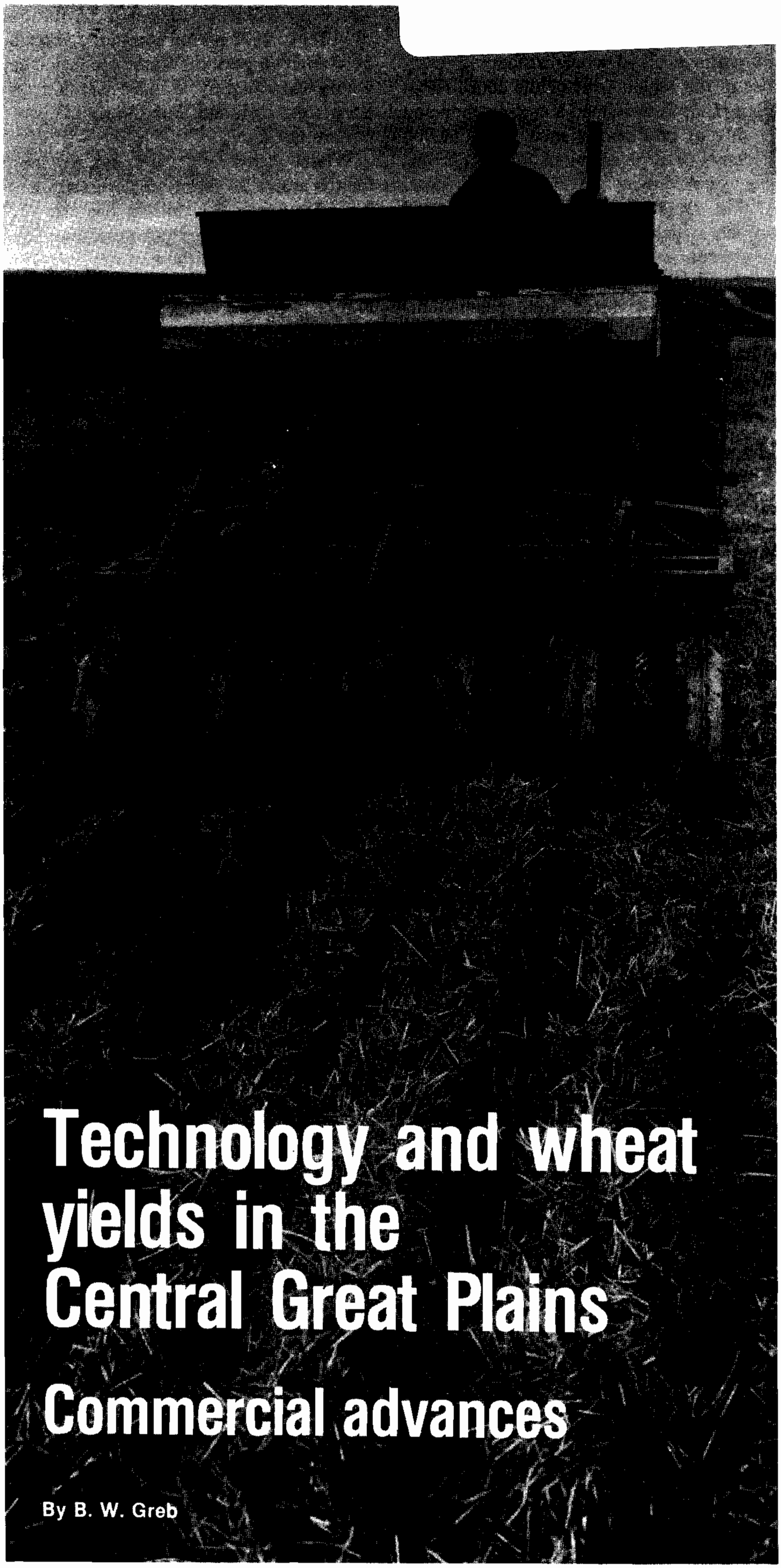

Technology and wheat yields in the Central Great Plains

Commercial advances

By B. W. Greb

ronomic practices have increased winter wheat (*Triticum aestivum* L.) yields and water-use efficiency significantly on experimental plots in the semiarid Central Great Plains (*3, 5, 8, 10*). These yield increases came about mostly because of (a) greater soil water storage during fallow through the use of straw mulches to suppress evaporation, (b) improved weed control, and (c) breeding of better wheat varieties.

Nevertheless, experimental results have their limitations. The dimensions of small plots, of course, do not compare with commercial fields. Plots also involve a fixed orientation direction that is subject to some degree of position bias, such as snow catchment; and most experimental plots have favorable topography with deep and fertile soils. Commercial data can confirm or negate experimental results.

Improvements in dryland wheat yields at experiment stations (*4*) have been paralleled by improvements in commercial dryland farming. These yield improvements represent an outstanding agricultural production achievement in a region once classified as the Great American Desert.

Periodic drought remains a reality for the region, much of which receives less than 500 millimeters of precipitation annually. The drought probability increases southward in the region because of increasing temperatures (evaporation factor) and, to a lesser extent, westward because of decreasing average precipitation (*3, 5*).

Level to gently rolling dryland cropped areas occupy uplands between drainages.

The major land resource areas in the region include the Central High Plains, Central High Tableland, and the Arkansas Valley Rolling Plains. Great Soil Groups under cultivation are Alfisols (red-brown), Aridisols (sierozen to light brown), Entisols (brown, sandy or shallow), Inceptisols, and Mollisols (brown to chestnut). Mollisols are the most prominent soils farmed.

Before World War II, annual crop farming prevailed. There was little specialized wheat-fallow in the dryland area. About 9.3 million hectares (23.0 million acres) of dryland is now cultivated. Of this, about 3.6 million hectares (9.0 million acres) is usually in winter wheat and 3.5 million hectares (8.7 million acres) in fallow (*1, 3, 6, 7*).

Data sources and methods

To ascertain the commercial agricultural advances in the Central Great Plains

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Table 1. Major winter wheat-producing counties in the Central Great Plains (*1, 6, 7*).

County	Average Hectares Planted/Year, 1946-1975 (1,000 ha)
Western Half	
Northwest Nebraska	
Banner	31
Box Butte	46
Cheyenne	89
Dawes	20
Deuel	36
Garden	25
Kimball	65
Morrill	17
Sheridan	25
Northeast Colorado	
Logan	66
Morgan	23
Phillips	54
Sedgwick	32
Weld	80
Yuma	70
East-Central Colorado	
Adams	63
Arapahoe	28
Elbert	28
Kit Carson	106
Lincoln	62
Washington	118
Southeast Colorado	
Baca	114
Cheyenne	63
Kiowa	86
Prowers	59
Eastern Half	
Southwest Nebraska	
Chase	34
Dundy	16
Frontier	28
Hayes	22
Hitchcock	34
Keith	35
Lincoln	25
Perkins	68
Red Willow	30
Northwest Kansas	
Cheyenne	61
Decator	48
Rawlins	64
Sheridan	57
Sherman	76
Thomas	94
West Central Kansas	
Finney	87
Gove	54
Greeley	68
Lane	56
Logan	55
Scott	57
Wallace	38
Wichita	55
Southwest Kansas	
Grant	41
Gray	87
Hamilton	67
Haskell	62
Kearney	47
Meade	70
Morton	42
Seward	45
Stanton	61
Stevens	44

I compiled winter wheat-yield data from the crop reporting services in Colorado, Kansas, and Nebraska. These data covered 58 major dryland wheat-producing counties in the region west of the 100th meridian (*1, 6, 7*). I defined a major producing county as one having more than 15,000 hectares (37,000 acres) of wheat planted per year during 30 consecutive years (Table 1). I did not include irrigated wheat, which is of minor importance in most counties, in my yield determinations.

My tabulated data included the hectares planted and harvested, total production, hectares abandoned, and yields per hectare planted and harvested for each county from 1936 through 1977. Because high losses of wheat plantings are not unusual, yields are reported here on a planted-hectare basis, rather than on a harvested basis, which reflects the risk factor.

I compiled annual precipitation and temperature data from one to three reporting weather stations per county for analysis of yield trends within the region. The year 1946 was a base for this analysis, which featured a grouping of eight districts based on climatic differences and geographic location.

Wheat yield trends

Yield data for the 58-county area varied widely among individual years in response to climatic conditions (Figure 1). Generally, however, yields increased from 1936 to 1977 at an average rate of 33 kilograms per hectare (0.5 bushels/acre) per year.

There were three distinct low yield cycles and three distinct high yield cycles of varying duration (Figure 1, Table 2). The low cycles correlated well with extensive drought in the 1930s, early 1950s, and middle 1960s. Average yields, nevertheless, showed that, with time, each successive low yield cycle was greater than the previous low yield cycle. Likewise, each successive high yield cycle was greater than the previous high cycle. Despite periodic drought from 1969 to 1977, yields stabilized at a high level.

Table 3 shows gross regional yields and water use efficiency of wheat in a different time scale analysis. Wheat yields during the 1971 to 1977 period averaged 2.35 times greater than during the 1936 to 1945 period.

Varying precipitation patterns did not seem to influence wheat yields or water-use efficiency. Mean precipitation values for seven widely scattered weather stations were quite consistent for three decades and decreased 10 percent in the 1966 to 1975 period. In spite of this, yields increased 30 percent and water use efficiency increased 44 percent over the previous decade. Also, water use efficiency increased 2.6-fold for the 1971 to 1977 period compared with the 1936 to 1945 period. Water use efficiency would vary slightly if more weather stations were included, but the trend would remain the same.

Wheat yields and water use efficiency for the entire 58-county region, representing an average 3.1 million hectares (7.7 million acres) planted per year, increased but at a lower level than on the long-term test plots at Akron, Colorado, North Platte, Nebraska, and Colby, Kansas (*4*). Obviously technology had a dramatic impact on yield and water use efficiency, both experimentally and commercially—independent of shifts in precipitation patterns (*3, 5*).

Projected increases in commercial use of stubble mulching, minimum tillage, and no-till fallow could push wheat yields by 1990 to 2,015 kilograms per hectare (30 bushels/acre), assuming weather similar to that in the past 30 years.

Yield trends by climatic districts

For all climatic districts combined, wheat yields increased an average of 29 kilograms per hectare per year (0.43 bushels/acre) for the 1956 to 1965 period compared with the 1946 to 1955 decade (Table

Table 2. Cycles of wheat yield trends in the semiarid Central Great Plains (*1, 6, 7*).

Years	Wheat Yield Trends: Low Cycle	High Cycle
	kg/ha	
1931*-40	455	
1941-48		955
1949-56	745	
1957-62		1,540
1963-68	935	
1969-77		1,800

*Beginning of 1930s general drought.

Table 3. Progress of winter wheat yields and water use efficiency in the semiarid Central Great Plains by decades (*1, 2, 6, 7, 9*).

Time Period	Average Precipitation* (mm/yr)	Wheat Yield (kg/ha)	Water Use Efficiency† (kg/ha-cm)
1936-45	443	775	8.7
1946-55	436	925	10.7
1956-65	445	1,215	13.7
1966-75	398	1,580	19.6
1971-77	405	1,820	22.5

*Combined average precipitation for weather stations at Sidney and North Platte, Nebraska; Akron, Burlington and Springfield, Colorado; and Colby and Tribune, Kansas.

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

Table 4. Winter wheat yields in eight climatic districts over three decades, planted-area basis (*1, 2, 6, 7, 9*).

Climatic Districts	*Average Precipitation (mm/yr)*	*Average Temperature (°C/yr)*	*Wheat Planted (1,000 ha/yr)*	*Average Wheat Yield (kg/ha)**			
				1946-1955	*1956-1965*	*1966-1975*	*30-Year Average*
Western Half							
Northwestern Nebraska	444	9.2	354	1,330	1,460	1,955	1,580
Northeastern Colorado	432	9.6	325	1,100	1,215	1,555	1,290
East Central Colorado	401	9.8	405	845	990	1,215	1,015
Southeastern Colorado	391	11.7	322	495	665	895	685
Total or average	416	10.1	1,406	935	1,090	1,415	1,145
Eastern Half							
Southwestern Nebraska	498	11.6	292	1,275	1,465	2,135	1,605
Northwestern Kansas	488	11.9	400	1,075	1,410	1,895	1,430
West Central Kansas	495	12.8	470	825	1,330	1,620	1,235
Southwestern Kansas	480	13.5	566	720	1,180	1,430	1,075
Total or average	490	12.5	1,728	920	1,325	1,705	1,290
Total or average of all districts	453	11.3	3,134	925	1,215	1,580	1,215

*Based on total production divided by total area planted.

4). Yields increased 36 kilograms per hectare per year (0.54 bushels/acre) for the 1966 to 1975 period compared with the 1956 to 1965 period.

Over three decades, each county experienced progressively greater yields. For the 1956 to 1965 period, 57 counties recorded yield increases compared with the 1946 to 1955 period; 56 counties experienced higher yields during the 1966 to 1975 period compared with the 1956 to 1965 period.

Following are some key trends for the 1966 to 1975 period compared with the 1946 to 1955 period, by climatic districts (Table 4):

- During the three decades, yield differences among climatic districts persisted regardless of variation in yield increases.
- Yields increased 305 kilograms per hectare (4.6 bushels/acre) more in the wetter, eastern half of the climatic districts than in the drier, western half.
- Yields increased 125 kilograms per hectare (1.8 bushels/acre) more in the cooler, northern climatic districts than in the warmer, southern districts.
- The yield increase differential was greatest for the northeastern quarter of southwest Nebraska and northwest Kansas, 495 kilograms per hectare (6.8 bushels/acre), compared with that for the southwest quarter of east-central and southeastern Colorado.

County performance further dramatized the effect of greater precipitation and cooler temperatures on yield increases. For example, Red Willow, Frontier, and Hitchcock Counties in southwestern Nebraska recorded yield increases of 1,115, 1,095, and 1,060 kilograms per hectare, respectively, compared with yield increases of 220, 235, and 230 kilograms per hectare for Morton and Stanton Counties in southwestern Kansas and Baca County in southeastern Colorado, respectively (*1, 6, 7*).

Table 5 shows another example of long-term climatic effects on yields in four counties, each with extensive yearly wheat plantings, going north to south from Cheyenne County, Nebraska to Sherman and Greeley Counties, Kansas, and Baca County, Colorado. A shift of only 50 millimeters (2 inches) in annual precipitation and 3 degrees C (5.4°F) resulted in a 2.8-fold average yield difference between Cheyenne and Baca Counties.

The yield decrease with warmer annual temperature, despite nearly equal annual precipitation, is shown by the comparison of yields and the percentage of abandoned wheat plantings in three of these counties. A change of 1°C (1.8°F) in the annual temperature resulted in an average yield differential of 250 kilograms per hectare (2.0 bushels/acre 1°F).

Table 4 shows a similar yield decrease with increased annual temperatures between climatic districts. The data in tables 4 and 5 also suggest an average wheat yield decline of about 135 kilograms per hectare for each 25-millimeter drop (2.0 bushels/acre-inch) in annual precipitation.

Abandoned wheat plantings

Wheat plantings are often abandoned because of such disasters as hail, late frost, winterkill, disease, and insects. Most important, farmers abandon planted wheat because of water shortages in the soil profile, especially the seedbed, in combination with periodic drought over wide areas.

Abandonment percentages in table 6, exclusive of conservation reserve or set-aside hectares, are an index of crop production stability. Abandoned wheat fields in this high risk area significantly decreased from an average of 28 percent during the 1936 to 1945 period to 16 percent during the 1966 to 1975 period. The aban-

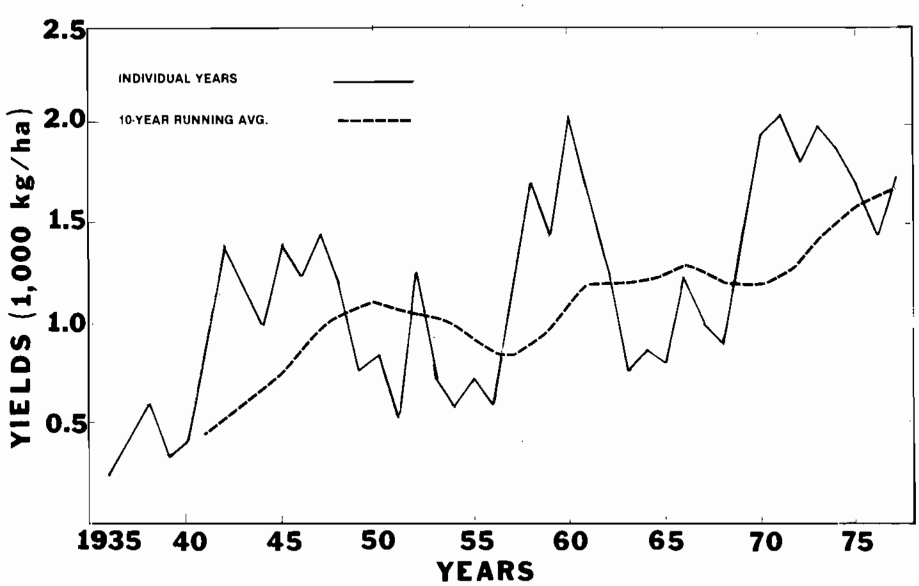

Figure 1. Winter wheat yields in the Central Great Plains, planted area basis, of 58 major wheat producing counties (*1, 6, 7*).

Table 5. Influence of climate on wheat yields and abandoned wheat area plantings in four selected counties in the semiarid Central Great Plains (*1, 2, 6, 7, 9*).

County	Average Precipitation (mm/yr)	Average Temperature (°C/yr)	1946-1955 Yield (kg/ha)	1946-1955 Planted Hectares Abandoned (%)	1956-1965 Yield (kg/ha)	1956-1965 Planted Hectares Abandoned (%)	1966-1975 Yield (kg/ha)	1966-1975 Planted Hectares Abandoned (%)	30-Year Average Yield (kg/ha)	30-Year Average Planted Hectares Abandoned (%)
Cheyenne, Nebraska	445	9.1	1,460	8	1,545	10	2,095	6	1,700	8
Sherman, Kansas	445	10.5	1,015	18	1,255	21	1,775	15	1,350	18
Greeley, Kansas	440	11.6	740	26	955	34	1,290	27	995	29
Baca, Colorado	395	12.1	490	49	610	48	720	40	610	46

donment percentage dropped even further during the 1971 to 1977 period, to only 10 percent (*1, 6, 7*).

Economic impacts

With wheat plantings equated to 3.1 million hectares (7.65 million acres) a year, gross production for the 58 major counties totaled 499 million quintals (1.83 billion bushels) in the 1969 to 1977 period, compared with 321 million quintals (1.18 billion bushels) in the 1960 to 1968 period, and 260 million quintals (0.95 billion bushels) in the 1951 to 1959 period (*1, 5, 6*).

Wheat prices, exclusive of government price supports, averaged $7.16 per quintal ($1.95 per bushel) from 1951 to 1977 in Colorado, Kansas, and Nebraska (*1, 6, 7*). This value is used for comparisons among time periods.

On this basis, the gross value of wheat in these counties during the 1969 to 1977 period exceeded that of the 1960 to 1968 period by $1.28 billion. Likewise, the value of wheat produced during the 1960 to 1968 period exceeded that of the 1951 to 1959 period by $436 million. Assuming 40 percent monetary devaluation, the combined extra real income was still $1.03 billion.

Of unknown value, but certainly measured in millions of dollars, were such factors as less emergency tillage because of fewer abandoned wheat hectares (Table 6), reduced soil erosion, and fewer government disaster payments. Obviously the impact of technology has been substantial in economic terms.

Technological inputs

Wheat yield increases must be credited to periodic adaptation of improved agronomic practices. Research data (*3, 4, 5, 8, 10*) suggest the following percentage credits of specific inputs to these yield increases:

- Improved stored soil water in fallow, 45 percent from increased use of better mechanical and herbicide weed control systems in terms of speed, timing, and quality, and greater use of stubble mulch in reducing water losses by evaporation and runoff.
- Improved wheat varieties, 30 percent from using efficient genetic stock by reducing straw length, better tillering capacity, more winter-hardiness, earlier ripening to escape heat and hail damage, and more resistance to disease and insect pests.
- Improved planting equipment, 8 percent from increased use of the deep furrow planter that can penetrate 12 to 14 centimeters (4.7 to 5.5 inches) in moist soil and from much wider planting units pulled by huge tractors that permit more timely planting.
- Improved harvesting equipment, 12 percent from using faster, cleaner combines with less grain over-throw and operating in fleets and from harvesting shorter, earlier-maturing wheat varieties with lower losses due to shattering and lodging.
- Improved fertilizer practices, 5 percent from application of low rates of nitrogen (30 to 40 kilograms/hectare) alone, or in combination with phosphorus, on selected nutrient-deficient soils to meet crop demands and maintain production levels.

Shifts in technological inputs by the above, or with new concepts, can be expected in the future, based on the evolution of technology.

Projected technology

Experience and research suggest there will be expanded use of fertilizers and herbicide weed control for wheat production in this region (*3, 5, 8, 10*).

About 65 percent of the wheatlands are composed of loams, silt loams, and clay loams containing a moderate to high reservoir of native, organically bound nitrogen plus mineral phosphorus and potassium. However, continued soil erosion and crop consumption have reduced these nutrient reserves, especially nitrogen, to near deficiency levels for the higher yields now obtainable. The 35 percent of less fertile, sandy, and eroded hillsides of heavier textured soils have been deficient in nitrogen and phosphorus for many years, but these soils have also been under-fertilized in the past (*5*). With continued improvement in water conservation practices and new wheat varieties to boost potential yields, fertilization of nearly all wheat plantings will be necessary within one or two decades.

Use of herbicide weed control (chemical fallow) in both minimum and no-till systems is gaining momentum commercially each year. Minimum tillage implies the use of herbicides in fallow from wheat harvest until late the succeeding spring, followed by two or three mechanical tillage opera-

Table 6. Planted wheat area abandoned in eight climatic districts (*1, 6, 7*).

Climatic Districts*	Average Planted Wheat Area Abandoned During Years 1936-1945	1946-1955	1956-1965	1966-1975	1971-1977
			%		
Western Half					
Northwestern Nebraska	20	13	12	6	5
Northeastern Colorado	21	16	16	13	9
East Central Colorado	28	22	25	19	11
Southeastern Colorado	50	45	47	34	22
Average	30	24	25	18	12
Eastern Half					
Southwestern Nebraska	16	10	9	6	5
Northwestern Kansas	20	17	13	8	5
West Central Kansas	30	23	17	15	9
Southwestern Kansas	38	26	19	18	14
Average	26	19	15	12	8
Average for all districts	28	22	20	16	10

*See table 4 for weather data.

tions to the end of fallow in early September. No-till fallow uses herbicides only throughout the entire fallow season.

Some of the present use limitations on herbicides, such as the types available, where and when they can be applied, the costs, and the systems of application, should be worked out gradually within environmental protection guidelines and regulations. Interest is high in this form of technology because of the potential for reducing tillage and soil erosion, saving energy, and increasing crop yields substantially.

Conclusion

Over the past several decades, commercial wheat yields and water use efficiency in the semiarid Central Great Plains have increased percentage-wise as much as yields of crops in more favorable climatic areas of the United States. In this region yields have fluctuated greatly in the past but have stabilized at remarkably high levels during the past decade. These yield increases have been credited to several innovations, including better mechanization, improved genotypes, and more efficient water conservation systems. Additional technical improvements can be expected with chemical fallow, use of fertilizers, and improved wheat varieties.

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