Corn Production and Strip-Tillage in the Western Plains

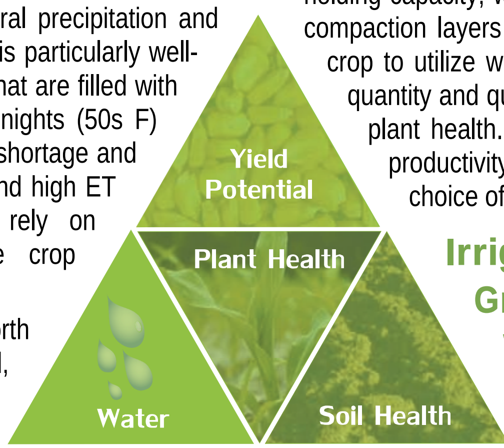
An Emphasis on Irrigation Management, Fertilizer Placement, Soil Health, and Drought Tolerance in a Challenging Environment

Corn, sorghum, soybeans, small grains, alfalfa, sunflowers, and many other crops are grown in the semi-arid environment of the central Great Plains and southern High Plains. Natural precipitation is often deficient in the Great Plains. A harsh, unpredictable, and diverse climate in these Plains areas makes the production of corn and other crops challenging and risky. Strip-tillage is a production option that can improve yield potential due to realized benefits in irrigation use efficiency and better soil and plant health.

Background

Annual rainfall from the Front Range of the Rocky Mountains in Colorado to Eastern Kansas varies from 16 inches to approximately 32 inches, respectively[1,2]. These precipitation values are less than one-half compared to annual precipitation in much of the Corn Belt. During the summer months, it is common to experience several continuous weeks of daytime temperatures in the high 90°s F and low relative humidity levels (< 20%) in parts of the region. Combined with winds in excess of 15 mph, and exposed soils, evaporative losses in the area can exceed 0.50 inch per day.

Despite the challenges of limited natural precipitation and high evapotranspiration (ET), the area is particularly well-suited for corn production. Long days that are filled with sunshine and low humidity, and cool nights (50s F) are ideal for sugar production. But the shortage and variation in year-to-year precipitation and high ET rates requires many producers to rely on irrigation to increase and stabilize crop production.



One of the highest ET rates in North America was recorded near Bushland, Texas, at 0.6 inch per day[3]. The Central High Plains (Western Kansas, Eastern Colorado, and Southwestern Nebraska) can experience 2.52 inches per week of ET for several weeks at a time with little or no rain. Corn, grain sorghum, beans, and small grains can all wilt and suffer yield loss, damage, and occasionally premature death in such growing conditions.

Synergistic interactions between improved agronomic practices, notably irrigation management, fertilizer placement, soil health, and plant breeding efforts, such as drought tolerance, may help to mitigate some of the environmental challenges and improve yield potential in the area.

Water, Soil Health, and Plant Health

The relationship between corn plants and their soil environment is critical to successful irrigation management and subsequent yield potential. Total seasonal water use, daily crop water use, the rate of plant development, and rooting depth (plant health) all affect growth and development. In turn, a healthy plant is able to extract more water from the soil and improve yield potential. Soil water holding capacity, water intake rate, and the presence of any compaction layers (soil health) also affect the ability of the crop to utilize water and can affect yield potential. Water quantity and quality are also important factors in soil and plant health. Irrigation water quantity may affect crop productivity more than any other factor, including choice of hybrid, fertility, and weed management.

Irrigated Corn, Population Growth, and Limits on Water

The Ogallala Aquifer provides water for approximately 13 million irrigated acres of farmland in the region[4]. The aquifer is the world's largest underground water system providing drinking water to parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. Initially, water supplies seemed limitless, but in the 1990s the wells began to lose output. A severe drought period from 1998 through 2007 further challenged traditional irrigation management practices, and the Ogallala

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Unconsolidated Aquifer began to run low. Limitations in the supply of precipitation and irrigation combined with other harsh environmental parameters required attentive and adaptive crop management practices.

Some of the key differences between corn production in central Great Plains and southern High Plains compared to the central and eastern Corn Belt include irrigation management, tillage, residue management, fertility, soil health, and hybrid selection. Conservation-tillage and strip-tillage have been gaining popularity in the Plains region during the past decade (Table 1) partly due to soil improvements and corn production innovation.

Corn Production and a Strip-Tillage Approach

Strip-Tillage Defined. Strip-tillage, or strip-till, is a form of vertical zone tillage that combines the benefits of zero-tillage and conventional-tillage. Narrow row strips, usually 8 to 10 inches wide and 8 to 12 inches deep, are tilled by way of a residue cutting coulter and a soil displacing mole knife. The area between the rows is undisturbed, while the tilled strips correspond to planter rows. Fertilizer may be injected into the tilled area during the strip-tilling process. Due to the demand for grazing stalks in the fall, strip-tillage practices in the Western Plains are commonly performed in the spring.

Table 1. Increases in Irrigated Conservation and Strip-Tillage Acreage in the Great Plains from 2000 to 2011.
Personal Communication Mike Petersen.

	2000	2011
Total Conservation-Tillage Acres		
Colorado	189,600	601,250
Kansas	228,560	795,670
Nebraska	526,500	1,780,050
Strip-Tillage Acres		
Colorado	17,400	211,500
Kansas	27,900	382,250
Nebraska	55,600	702,100

Benefits of Strip-Tillage. Some of the more immediate benefits of strip-tillage include the field-wide preservation of soil colloids, soil pores, and root channels from previous crops. Strip-tillage also helps to preserve crop residue which aids in the buildup of soil organic matter. Additionally, the presence of large pores in the soil increases water percolation and improves crop rooting. Long-term research studies conducted at the Irrigation Research Foundation (IRF) in Yuma, CO, from 2003 to 2008 showed that utilization of strip-tillage and strategic fertilizer placement improves the three facets of yield potential: water, soil, and plant health. Soils that were managed under strip-tillage conditions had more beneficial worms per square foot, more frequent and larger soil pores per square inch, greater percent organic matter, faster water infiltration rates, and greater crop yields compared to soils that were managed under conventional-tillage. Strip-tillage acreage in the Great Plains has greatly increased since the year 2000.

Improvements in Fertility. Growers manage the economics of fertilizer inputs. With strip-tillage, the focus is to place it right within the root-zone for immediate uptake.

In order to grow a larger and more effective root system and healthier plant, nutrients should be readily available. Roots placed in close proximity to nutrients allow plants to thrive. Plants will expend more energy to grow and produce grain when nutrients are not available close to the plant. With the strip-tillage system, growers can place fertilizer within the tillage band, at different depths to feed the plant. By precisely placing fertilizer, the grower can take advantage of more moist conditions in order for the nutrient to go into soil solution to access it by the roots. With knowledge gained from studies conducted at the IRF, researchers were able to use less total nitrogen (N), phosphorus (P), and potassium (K) to obtain equal or better corn yields in a strip-tillage system compared to the common approach of broadcasting fertilizer. Results have been expressed in deeper roots, more total root inches and consistent higher yields. In addition to the IRF studies, research was conducted at a private farm near Mingo, KS and at the Kansas State University Northwest Research Extension Center near Colby, KS.

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Weather Patterns 2001-08. A widespread drought affected crop production across western Nebraska, Colorado, western Kansas and the Texas panhandle during the first five years of the study period. Winter moisture was generally limited and accompanied by above-normal temperatures and wind. Spring and summer rainfall was generally deficient compared to long-term averages for these periods. Summer temperatures exceeded 100° F numerous times during several growing seasons. In 2003, the day time temperature exceeded 100° F for more than sixty contiguous days. Irrigation well levels dropped and some pivots were not able to supply adequate water for crop use. In some cases, one-half of a pivot was abandoned to increase water supply to the other half.

Study Guidelines

Large plot trials were conducted during 2001 through 2008 to evaluate strip-tillage and conventional-tillage practices in the context of soil and plant health. Studies were performed in full- and limited-irrigation environments for six of the seven years. Limited irrigation water studies were conducted with Dr. Freddie Lamm of KSU Colby, KS at the Northwest Research and Extension Center and with a grower Mark Myers near Mingo, KS. A short- and long-season corn hybrid were included in some of the test years. Standard agronomic practices were followed for each tillage system. Standard corn hybrid products with a relative maturity appropriate to the area were selected for use in the studies. Conclusions should be drawn with the qualification that results are from multiple-year, non-replicated studies.

Figure 1. A soil managed with strip-tillage practices (left) has better water infiltration compared to a soil managed with conventional-tillage practices (right). Photo taken at the IRF, May of 2003; courtesy Orthman Manufacturing, Inc.

Results and Discussion

Soil Health

Soils that were managed under strip-tillage had reduced compaction compared to soils that were managed under conventional-tillage.

Soil pores hold the air and water necessary for plant growth. Compacted soils are dense and had smaller pores compared to healthy soils. Compacted soils have reduced infiltration rates, and resulted in ponding and crusting after moderate to heavy rainfall (Figure 1). Plants were less able to extract nutrients from compacted soils. Soil compaction was measured in units of pressure (pounds per square inch (PSI)). Root growth may become restricted at 290 PSI, and corn roots can have difficulty penetrating soils with a PSI rating greater than 400. Soil compaction levels were measured five times at soil depths of between one to six inches, seven, and 11 inches with a

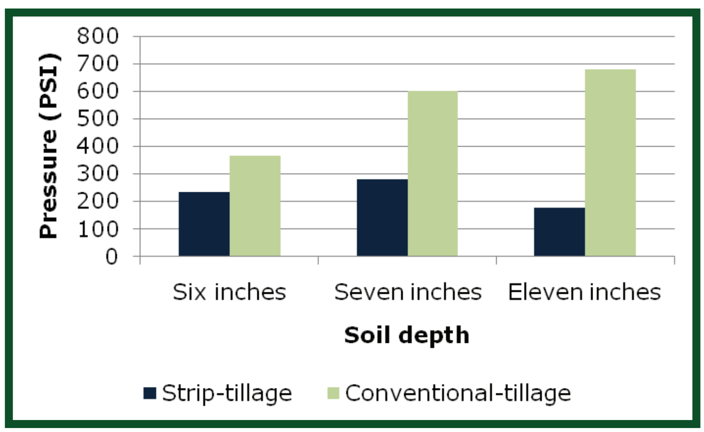

Figure 2. Soil compaction measured in pressure (pounds per square inch) for a sandy clay loam soil managed under strip-tillage and conventional-tillage systems. Data from IRF-Yuma, CO; 2004.

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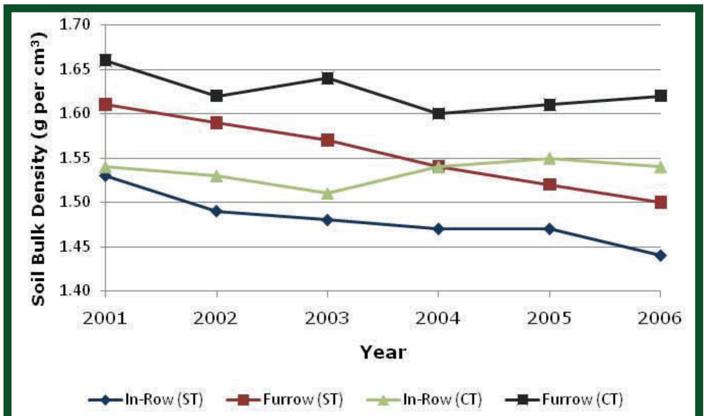

Figure 3. Changes in soil bulk density (g per cm³) measured in the crop row and in furrow over six years for a soil managed under strip-tillage and conventional-tillage systems. Up to forty minutes may elapse before water infiltrates a soil with a bulk density of 1.65 g per cm³ or greater (Mike Peterson, personal communication). IRM– Yuma, CO.

Table 2. Soil changes over seven years (2001-2007) on soils with strip-tillage and conventional-tillage management at the Irrigation Research Foundation.

	Strip-tillage	Conventional-tillage (chisel and disk)
Organic matter	2.4%	1.5%
Water intake rates (in/hour)	0.8—5	0.06—1.80
Worms/square ft	15—32	1—10
Soil pores per four square inches		
Small soil pores (< 1mm)	320—688	65—314
Medium soil pores (1-2 mm)	25—81	10—21
Large soil pores (2-5 mm)	6—18	1—6

Irrigation Research Foundation—Yuma, CO

penetrometer. Soils were 36%, 53%, and 73% less compacted at the three sampling depths, respectively, under strip-tillage management compared to conventional-tillage (Figures 2 and 3).

Soils that were managed under strip-tillage had better water percolation rates compared to soils that were managed under conventional-tillage.

Macropores are small, open channels in the soil created by earthworm activity, soil cracking, and old root growth (Figure 4). Tillage destroys macropores by mixing or disturbing the upper soil profile. The preservation of root channels, soils pores, and other holes in the soil profile leads to better water infiltration (Table 2). As water percolation improves, surface runoff decreases, leading to gains in irrigation and rainfall water management and efficiency. Improvements in water management can help to maintain the optimum soil moisture for growth, reproductive development and yield potential.

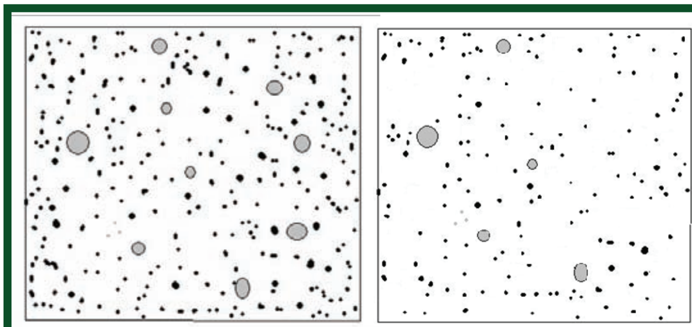

Figure 4 (above left). A soil managed under strip-tillage can have more, large sized pores (2 to 5 mm diameter) and fewer small sized pores for faster water infiltration rates in dry and wet soils. (above right) Conventional-tilled soils typically have fewer pores of smaller size.
Figure courtesy of Orthman Manufacturing, Inc.

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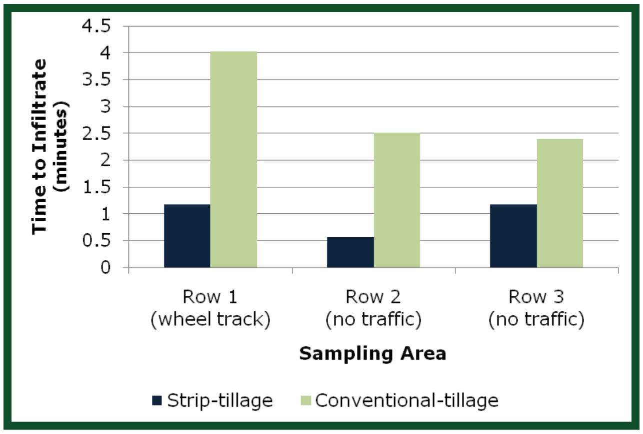

Figure 4. Time in minutes for one inch of water to infiltrate a dry soil managed under strip-tillage or conventional-tillage systems. IRF– Yuma, CO; 2005.

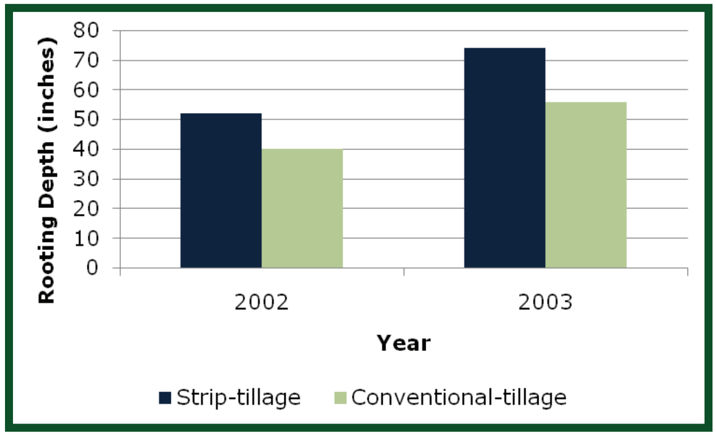

Figure 6. Total rooting depth per corn plant for plants grown in a soil managed under strip-tillage and conventional-tillage systems in the driest years (2002 and 2003) of the drought period. IRF– Yuma, CO.

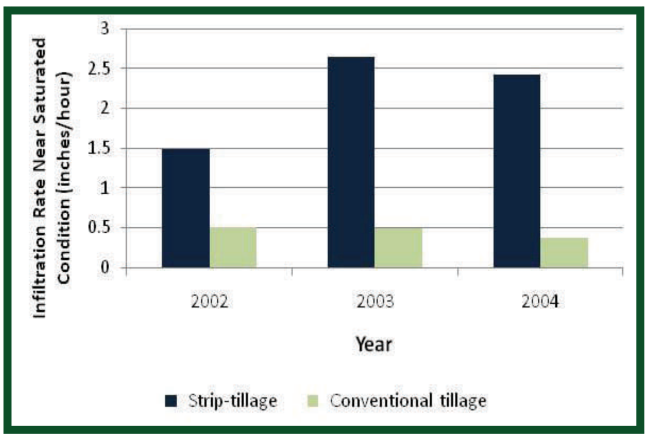

Figure 5. Water infiltration in inches per hour into a wet soil managed under strip-tillage or conventional-tillage systems. IRF– Yuma, CO.

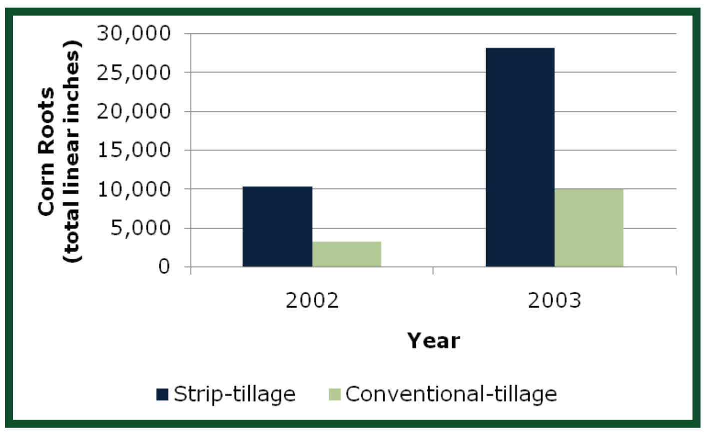

Figure 7. Total length of corn roots per plant for plants grown in a soil managed under strip-tillage and conventional-tillage systems in the driest years (2002 and 2003) of the drought period. IRF– Yuma, CO.

The average time for one inch of water to infiltrate a dry soil managed by strip-tillage was 1.1 minutes compared to 3.5 minutes for a soil managed under conventional tillage (Figure 4). A similar trend was observed for water infiltration into a soil at field capacity (Figure 5).

Plant Health

Corn plants that were managed under strip-tillage had more roots and rooted to greater depths compared to plants that were grown in soils managed under conventional-tillage.

Improved soil quality allows for better root growth. A large root system results in greater root-soil contact for improved water

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and nutrient absorption. This is especially true for immobile nutrients such as phosphorus and potassium. Furthermore, a large and deep root system may be the mechanism by which corn plants grown in strip-tillage environments have greater rooting depths compared to plants grown under conventional tillage (Figure 6). Large root systems are able to acquire nutrients and water while supporting above-ground growth. The extended drought which lasted from 1999 through 2006, had extremely limited moisture during 2002 and 2003 growing seasons. Corn plants that were grown in soils managed with strip-tillage practices produced between 10,000 and 28,000 total linear inches of roots per plant compared to 3,200 and 10,000 total linear inches in conventional tillage, in 2002 and 2003, respectively (Figure 7).

Corn plants that were managed under strip-tillage along with a small amount of starter fertilizer and deep placement of phosphorus (P) with a strip-tillage mole knife had greater yields than corn plants that were grown under conventional-tillage with broadcast fertilizer.

Starter fertilizers can help to mitigate the conditions of reduced growth rates, lack of nutrient mobility, and decreased nutrient mineralization that may occur in cool, wet soils. Starter fertilizer, especially in cool soils, tends to support early-season growth and vigor in corn. The fertilizer meets early demands of the seedling until the root system develops, and its placement is important to avoid injury to germinating seedlings.

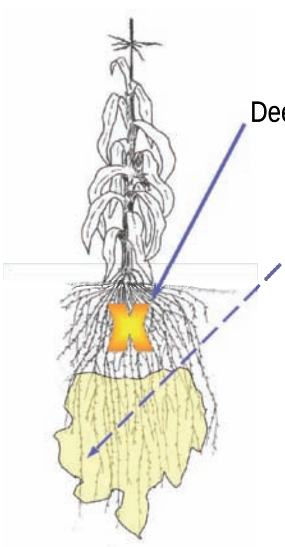

Figure 8. Fertilizer placed in a deeper location can stimulate an explosion of corn roots at the time roots are ready to extend vertically.
Figure courtesy Orthman Manufacturing, Inc.

Application below the soil places P in the soil volume where it can be easily accessed by corn roots (Figure 8). Furthermore, concentrated zones of P can decrease P fixation, making it more readily available for plant uptake.

It is estimated that approximately 50% of yield gains observed with the adoption of strip-tillage can be attributed to the efficient banded placement of fertilizer. The other 50% of yield gain can be attributed to overall improved soil health and water holding capacity.

Strip-tillage – Yield Summary

FULL IRRIGATION STUDIES:

The objective of this study was to determine whether strip-tillage could equal or improve upon conventional-tillage yields. Dry land corn growers often employ a no-tillage system to maximize soil moisture storage for corn growth and minimize moisture loss as an effect of tillage. Corn under irrigation is typically a good producer of grain yield and residue. Strip-tillage practices are an option to take advantage of minimum tillage practices while planting corn in heavy residue conditions. Several advantages to strip tillage compared with conventional-tillage were observed including fewer tillage passes, improved soil quality characteristics, and reduced operator and equipment time. Yield increases were also observed when fertilizer was applied below the plant and under the planted row. Later measurements demonstrated that corn roots under strip-tillage grow faster and deeper, compared to roots searching for nutrients placed adjacent but not in the row. Growing seasons varied from 2001 to 2006 with continued drought and high summer temperatures. Hail damage prior to pollination in 2004 reduced leaf area and decreased yields. Lack of nitrogen and Goss's wilt disease pressure during 2006 and 2007,

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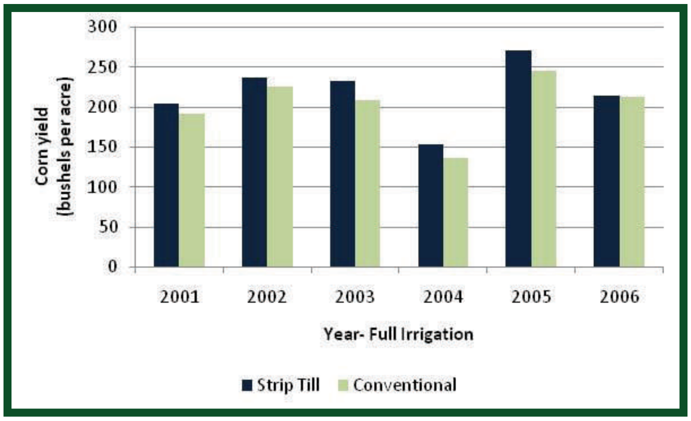

Figure 9. Corn yields from 2001 to 2006 in a soil managed under strip-tillage and conventional-tillage with full irrigation. IRF– Yuma, CO.

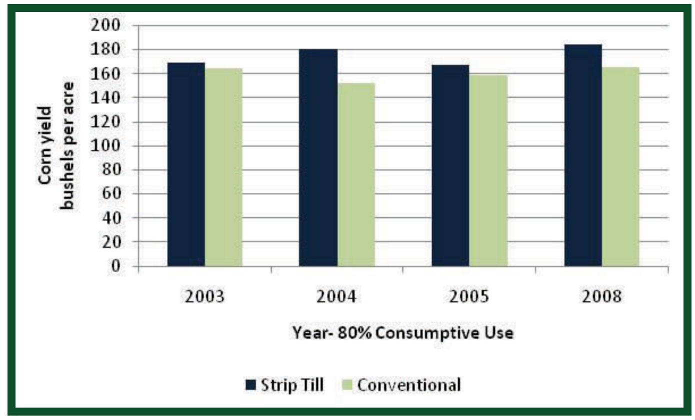

Figure 10. Yields averaged from plots during the period 2003 to 2008 with corn plots at application rates of 80% of consumptive use. IRF– Yuma, CO.

respectively, compromised data and results are not included for those years.

Corn yields (Figure 9) showed a positive response to strip -tillage and were greater than conventional-tilled plots in all years except 2006 when nitrogen was limited to 0.50 lb/bushel of grain and less available under strip-tillage due to organic matter decomposition. Strip-tillage yields were measured and found to often surpass conventional-tillage yields. Additional benefits of strip-tillage systems included improved soil quality and plant health, reduced soil erosion, and reduced operator and equipment costs.

LIMITED IRRIGATION STUDIES:

These data are an average of limited water yields over locations (IRF, KSU-Colby, KS and Mark Myers, Colby, KS). Data were averaged across the short- and long-season hybrids when available. Limited irrigation level was designed to supply approximately 80 percent of the consumptive water need of a full-watered corn crop (Figures 10 and 11) placing the corn under drought stress, but allowed corn production even under drought and heat environments. While yields varied across years and locations, generally strip-tillage management had greater yields compared with conventional-tillage management. The increased yield under strip tillage was

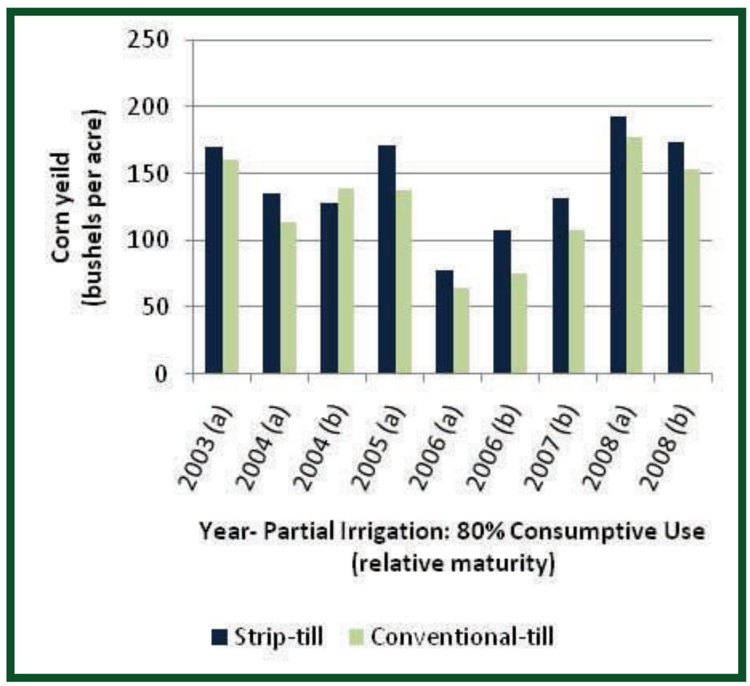

Figure 11. Corn yield over eight years in soils with strip-till and conventional-till management with irrigation at 80% consumptive use. In years 2004-06 and 2008, the relative maturities of two corn products were compared: (a)=longer (110-day RM) versus (b) =shorter (100-day RM). IRF– Yuma, CO and Colby, KS.

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likely attributed to improvements in soil quality, deeper rooting, improving plant health and increasing water infiltration rates. Strip-tillage management allowed more water storage for corn growth under arid conditions.

Irrigation was reduced to 66% of consumptive use at the IRF during test years 2003 through 2008 (Figure 12). A portion of these trials incorporated a short and long-season hybrid component, thus the yield data were averaged across hybrids when available. Corn yields were decreased when irrigation was limited to only 66% compared to fully irrigated practices at the IRF. The soil quality, plant health and soil water storage advantages of strip-tillage were significant as heat and drought deteriorated growing conditions compared to conventional-tillage plots. Yields decreased as irrigation levels dropped, and strip-tillage produced more bushels of corn per inch of water compared to conventional-tillage management.

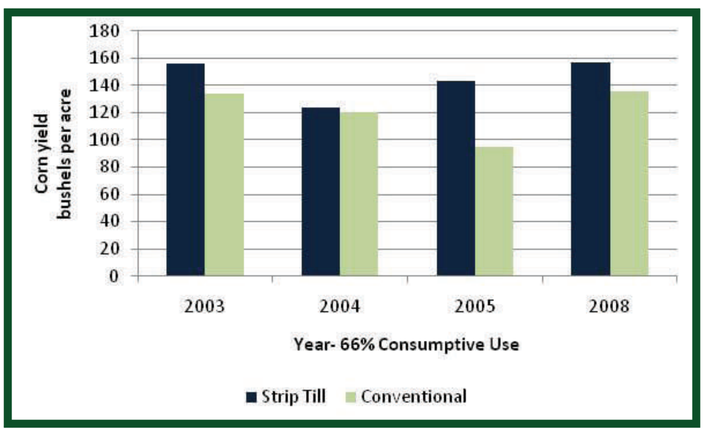

Figure 12. Yields averaged from plots during the period 2003 to 2008 with corn plots at low application rates of 66% of consumptive use. IRF– Yuma, CO.

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Acknowledgements

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