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IMPACTS OF RESIDUE MANAGEMENT IN IRRIGATED PRODUCTION

J Schneekloth
Water Resources Spec
Joel.Schneekloth@Colostate.Edu

F. Calderon
Res. Soil Sci.
Francisco.Calderon@Ars.Usda.Gov

Steven Fonte
Assist. Professor
Steven.Fonte@Colostate.edu

Colorado State University
USDA-ARS
Akron, Colorado
(970) 345-2259

ABSTRACT

Irrigated corn production was compared in two tillage management practices (no-till and conventional) and two residue management practices (when residue was not removed or was harvested). Corn yields were suppressed in both 2014 and 2015. In 2014, zinc deficiencies were prevalent and most severe in no-till management and severe hail damage in 2015. Impacts to water infiltration were significant in both 2014 and 2015 due to residue and tillage management. Infiltration was not significant in 2016 but followed similar trends of 2104 and 2015. In 2014, first year in no-till, residue was the significant factor in influencing infiltration, time to runoff and steady state infiltration. In 2015, residue management impacted total infiltration and time to runoff but tillage management was significant in steady state infiltration. No-till had significantly greater infiltration rates after 30 minutes of water application. Residue management had more significant impact to total infiltration than tillage management on average while steady state infiltration tends to increase with tillage management.

INTRODUCTION

With recent droughts, forage prices have escalated and have attracted the use of corn stover as a feed source. Also, continued research could expand the use of corn stover for cellulosic ethanol production. Continual removal of corn residue can have significant impacts on soil properties as well as the potential productivity without the additional input of nutrients to offset those removed in the residue. One of the potential greatest impacts is water. Residue can reduce evaporation from the soil surface as well as increase snow retention in the field. As water supplies become limited, the impact of residue management can signficantly impact the proftablity of production. Previous work has show that the reduction in evaporation from residue can impact yields positvely in limited water situations.

With low corn prices, economics of reduced input costs (tillage) and increased income (residue sales) can have an impact on decision making. However, consideration for the long term implications must be considered.

GENERAL STUDY METHODS

The study was conducted under a linear sprinkler system at the USDA-ARS Central Great Plains Research Center at Akron, CO beginning in 2014. Corn was previously grown on this site with conventional tillage management. The predominant soil type is Weld Silt loam with a water holding capacity of 2.0 inches foot^{-1}. Average yearly precipitation is 16.8 inches with an average of 11 inches of growing season precipitation.

A corn hybrid with a relative maturity of 104 days (DeKalb 54-18: 2014 and 2015; Dekalb 54-38: 2016) was planted on May 15, 2014, May 3, 2015 and May 16, 2016. The seeding rate was 34,500 seeds acre^{-1} for all treatments. Plots were planted with a 4 row JD 1700 MaxEmerge planter with Accra-Plant Zone Till row cleaners. Irrigation was scheduled on a water balance approach with estimates of evapotranspiration based on CoAgMet estimates.

Treatments included no-till and conventional tillage (tandem disk) and where residue was harvested or remained in the field for a total of 4 treatments. Treatments were replicated 4 times in a randomized complete block design. Within each treatment, sub plots of nitrogen rates of recommended, +/- 50 lbs acre^{-1} were applied to look at nitrogen response with tillage and residue management. Residue in 2014 was harvested in early April, November of 2014 and April 2016. Tillage occurred following residue harvest.

Fertilizer was applied according to soil test results and expected yields. An application of 15 gallon acre^{-1} of 10-34-0 was applied at planting with 0, 50 and 100 lbs N additional for the fertility study. Additional N was applied through the sprinkler system during the growing season prior to tassel emergence. Water was monitored bi-weekly to a depth of 6 feet for irrigation scheduling.

Soil infiltration rates were measured using the Cornell Infiltrometer in late August to early September. Measurements were taken on when first runoff occurred as well as runoff amounts and water applications over a 30 minute period with readings every 1 minute for 6 minutes and then every 3 minutes for the next 24 minutes. Steady state infiltration was estimated with the average of the final 3 infiltration readings. Total infiltration was the difference between water applied in the 30 minute time period and runoff measured.

RESULTS AND DISCUSSION

Residue Cover

Residue was removed from 2 treatments in April 2014, November 2014 for the 2015 cropping season and April 2016 for the 2016 cropping season. Tillage plots were tilled immediately after residue removal. Tillage was done with a tandem disc. Plots with the residue removed were tilled 2 times while the plots with the residue remaining were tilled 3 times. Residue cover for the T/NR was approximately 13% while the NT/R plots had 89% cover. Both NT/NR and T/R plots had approximately 55% residue cover. Residue covers in 2015 were similar to 2014. Both NT and the T/R plots were within conservation compliance which mandates a minimum of 30% cover.

Infiltration

One of the benefits of residue and reduced tillage has been the resulting increase in infiltration shown by previous research. Increasing tillage destroys macro and micro pore structure which reduced infiltration of water. Maintaining or increasing infiltration is important for irrigation sprinkler package design to reduce runoff potential without increasing system pressure to increase the wetted diameter and reduce the maximum application rate. In the fall of each year, a Cornell Infiltrometer was used to measure infiltration patterns of the treatments.

Differences were observed in the pattern of measured infiltration by residue management. Where residue was not removed, infiltration was greater than that of when residue was removed no matter what tillage system was utilized in 2014 and 2015 (Figure 1). Positive impacts when residue remained in the field were observed for the 3 major factors of infiltration. Total infiltration in 30 minutes increased in 2015 and 2016 compared to 2014 and was still the greatest when residue was not removed. Total infiltration was less than 2 inches in 30 minutes for all treatments in 2014 and 2015 but greater than 2 inches in 2016 for all treatments except for NT/NR.

When looking at what the main impact to total infiltration of tillage or residue management (Figure 1), residue was the significant impact for 2014, 2015 and average. When comparing NT vs T (average of residue and no residue), total infiltration was similar for each tillage management each of the four years. On a four year average, tillage did have a significant impact on infiltration. This was influenced by the lower total infiltration with the practice of no-till and residue removal. However, residue management (average of NT and T), residue removal significantly impacted total infiltration. On average, residue removal reduced total infiltration by approximately 0.4 inches in a 30 minute infiltration test.

Total infiltration in 2016 and 2017 was not impacted by either tillage or residue removal. In 2016, no significant intense precipitation event occurred nor was irrigation applied until near canopy development. In 2017, there was a significant precipitation event that occurred but only NT/NR had significantly lower infiltration. After further investigation, it appeared that there is a possible influence from planting impacting T/NR. Compared to the other treatments, there was a slight movement of soil to the soft row from the starter fertilizer units on the planter that left a mound of soft soil in the measurement row.

Total infiltration by treatment (Figure 2) shows that there is variability in year to year infiltration for tillage treatments. The NT/R treatment showed slight improvement in infiltration from 2014 to 2016 with a larger increase in infiltration in 2017. The NT/NR had a similar trend in 2014 to 2016 but a significant drop in 2017. In 2018, the NT/NR had an increase in infiltration which is related to a small tillage event prior to planting to remove a planter error at the first planting. This may entail changes in surface conditions with residue management. Where the residue has been removed, soil surface conditions have deteriorated while tillage potentially offsets that impact.

Total infiltration for the NT/R treatment has shown greater average infiltration over the 5 years as compared to all other treatments. Infiltration for both tilled treatments is slightly lower than NT/R at approximately 2.5 inches as compared to compared to 3 inches respectively. Yearly trends in total infiltration show that after 2015, infiltration rates have been relatively stable in all treatments other than the NT/NR. Changes to total infiltration is a slow process and highly influenced by surface conditions.

When comparing infiltration rates between 2016 to 2018, statistically, only NT/R was greater than NT/NR and all other treatments were not significantly different from another. This once again shows the variability in infiltration measurements across a small area can have significant impacts.

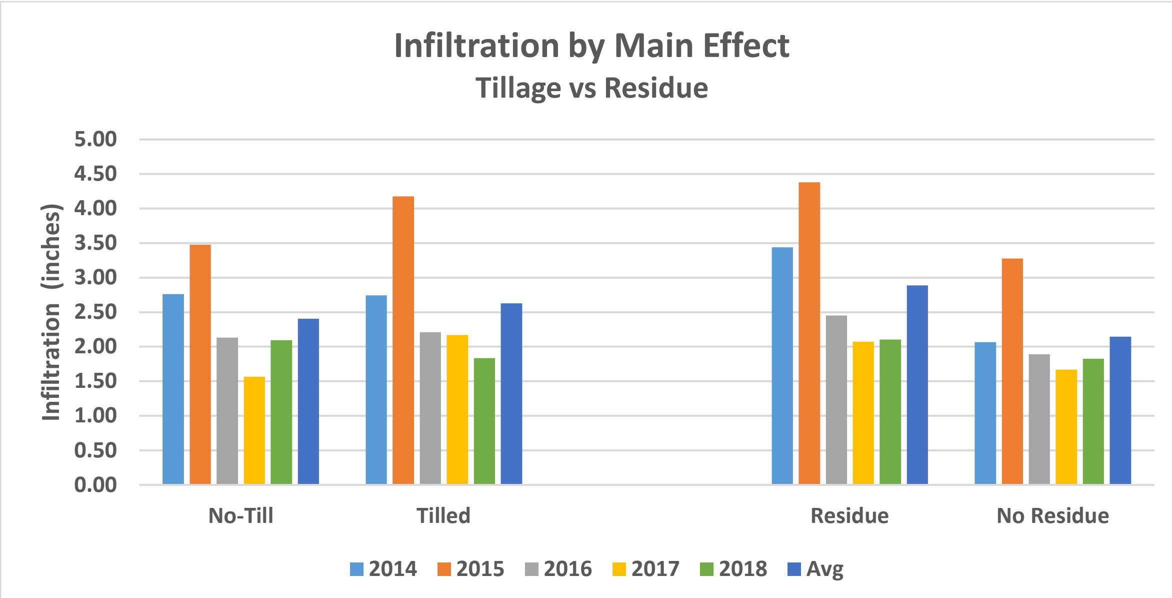

Figure 1. Impact of tillage and residue management on measured total infiltration.

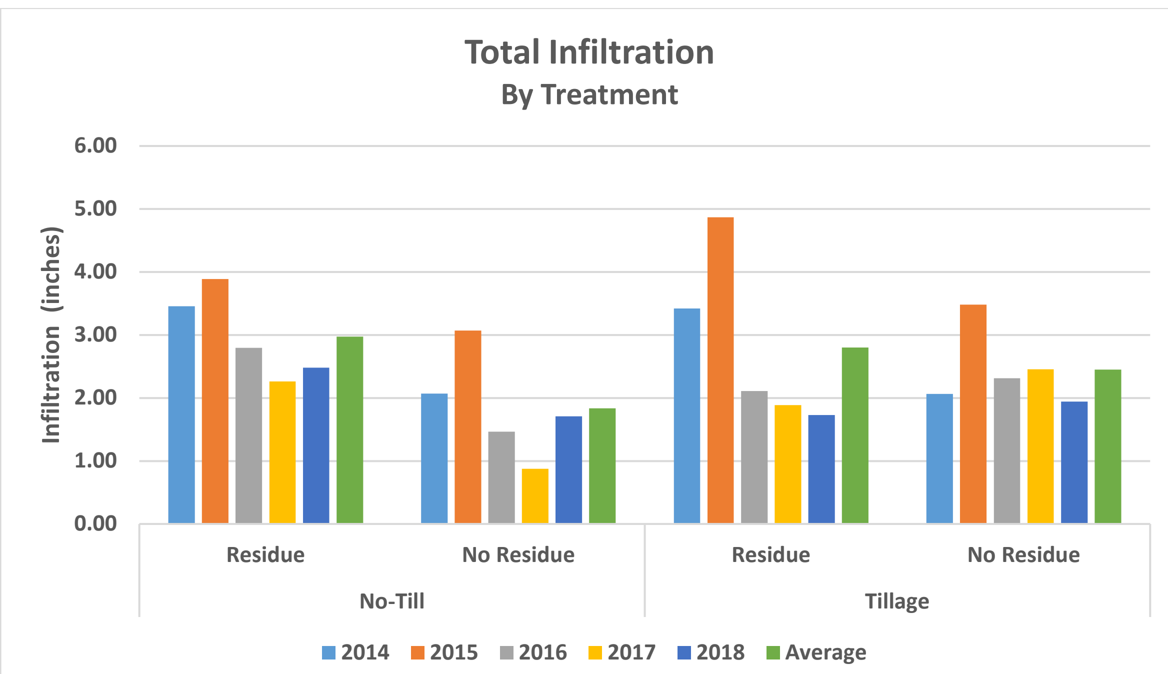

Figure 2. Measured infiltration over 30 minutes for tillage and residue management.

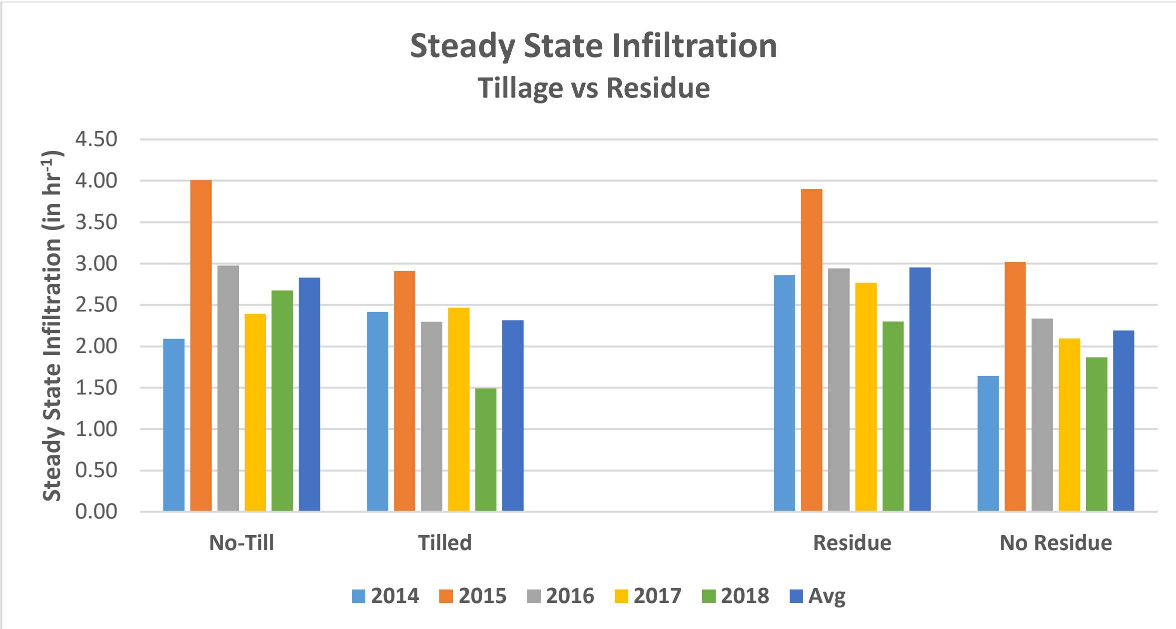

Figure 3. Impact of tillage and residue management on steady state infiltration.

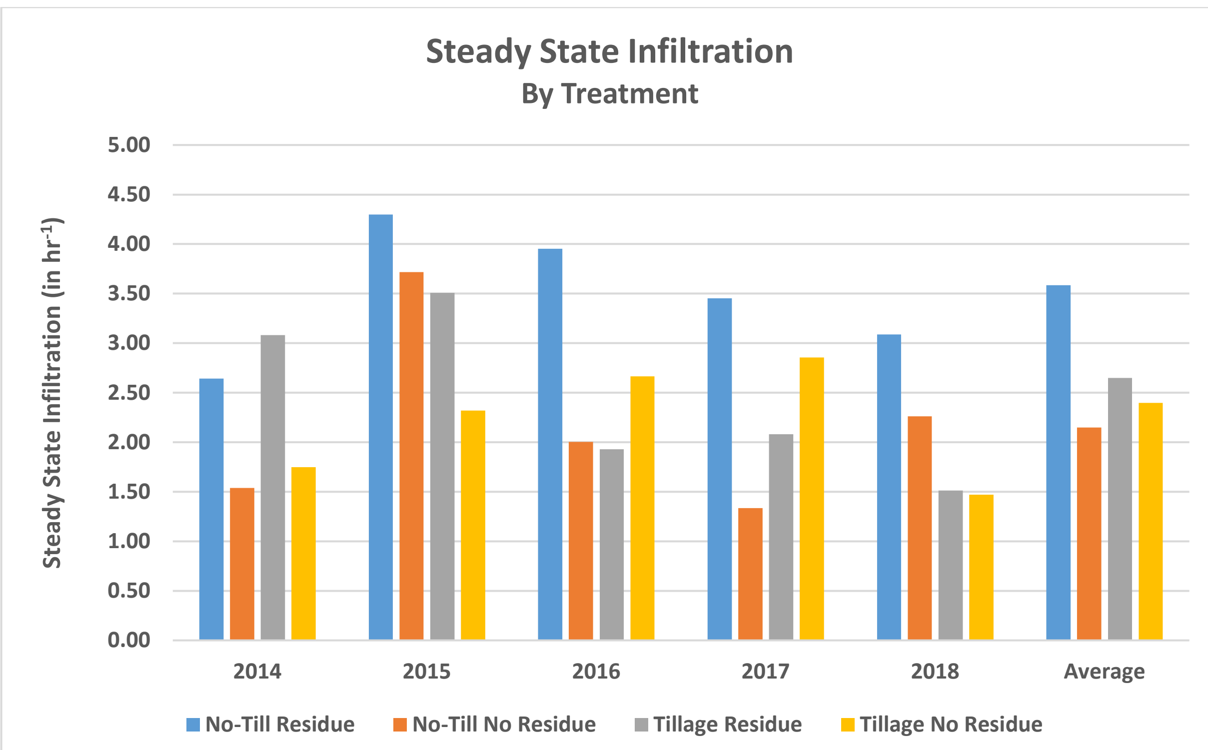

Figure 4. Steady state infiltration averaged over the last 4 measurements.

Steady state infiltration (Figure 3) over the 5 years shows that tillage and residue had no significant impact on steady state infiltration although there was a tendency for greater infiltration with residue remaining in the field compared to residue harvested. In 2017, there was a residue by tillage interaction. This impact was with no-till management (Figure 4). When residue was harvested, steady state infiltration was significantly less than NT/R. Both tilled treatments were not statistically different from any other treatment.

However, changing infiltration parameters is a long term change. When looking at 2016 to 2018 infiltration parameters, significant differences occur. For steady state infiltration, NT/R is significantly greater than either NT/NR and T/R. It is unknown why T/NR steady state infiltration rates have remained as high as they were when residue has been removed.

Steady state infiltration was extremely variable within a year which shows the variability in soil characteristics that impact infiltration. However, looking at year to year changes within a treatment (figure 4), steady state infiltration for NT/R was relatively stable in 2014 to 2016 with a large increase in 2017. Steady state infiltration rates for T/R have been relatively steady from 2016 to 2018. Steady state infiltration rates for T/NR have increased in 2016 and 2017 compared to 2014 and 2015 with a significant drop in 2018. However, this may have been influenced by the planter moving soil into the soft row.

Samples collected in 2016 show that NT/R had significantly greater earthworm populations compared to all other treatments. Over time, this difference in earthworm activity may have an influence on soil characteristics. In 2017, this difference may be occurring in between the no-till treatments where the residue had significantly greater infiltration than the no residue.

Time to first runoff was greatest for NT/R followed by T/R (data not shown). Both treatments where residue was removed had faster times to runoff. Steady state infiltration was the average of the last 4 infiltration readings. Treatments with the residue removed have had significantly shorter time measurements to first observed runoff compared to the treatments where residue remained. Only in 2017 did the NT/R have a greater observed time to runoff compared to T/R. Over the 4 years, time to first runoff was greatest in NT/R followed by T/R followed by both NT/NR and T/NR which had similar times. Residue management was the significant factor each of the 4 years while tillage was only a significant factor in year 4.

Precipitation Storage and Evapotranspiration

In dryland systems, precipitation storage during the non-growing season is an important component to grain yield. When residue is harvested in the fall, there is no standing residue to capture snow that occurs during wind events. Long term precipitation from October 1 to May 1 is approximately 5 inches. Precipitation prior to the 2015 and 2016 growing seasons were 85 and 150% above average. This resulted in similar beginning stored soil moisture and no difference in storage efficiency. However, in winter prior to 2017, winter precipitation was only 17% above average. Precipitation storage efficiency when residue remained in the field was 15 to 23% greater than when residue was harvested. This difference resulted in storing 1.3 to nearly 2 inches more precipitation. Spring tillage had a small impact on beginning soil moisture which was equivalent to approximately 0.5 inches difference between NT and T.

Precipitation storage efficiency for 2017 to 2019 (Figure 5) shows that standing residue is an important factor in beginning soil moisture. Precipitation was near average in 2017 and 2018 and standing residue increase storage efficiency by 17 to 20%. That increase in storage efficiency results in an increase in precipitation storage by approximately 1 inch each season. In 2019, precipitation was 88% of average. Standing residue increased storage efficiency by nearly 40% as compared to no residue. This difference resulted in a 1.8" increase of stored soil moisture with standing residue.

Research has shown the value of residue on reducing evaporation losses. The major time period in irrigated corn production to reduce evaporative losses would be from planting to full canopy development. Using a water balance approach with a neutron probe, we can calculate the consumptive water use between when tubes are installed (generally early June) to beginning reproductive growth stages (VT) (Figure 6).

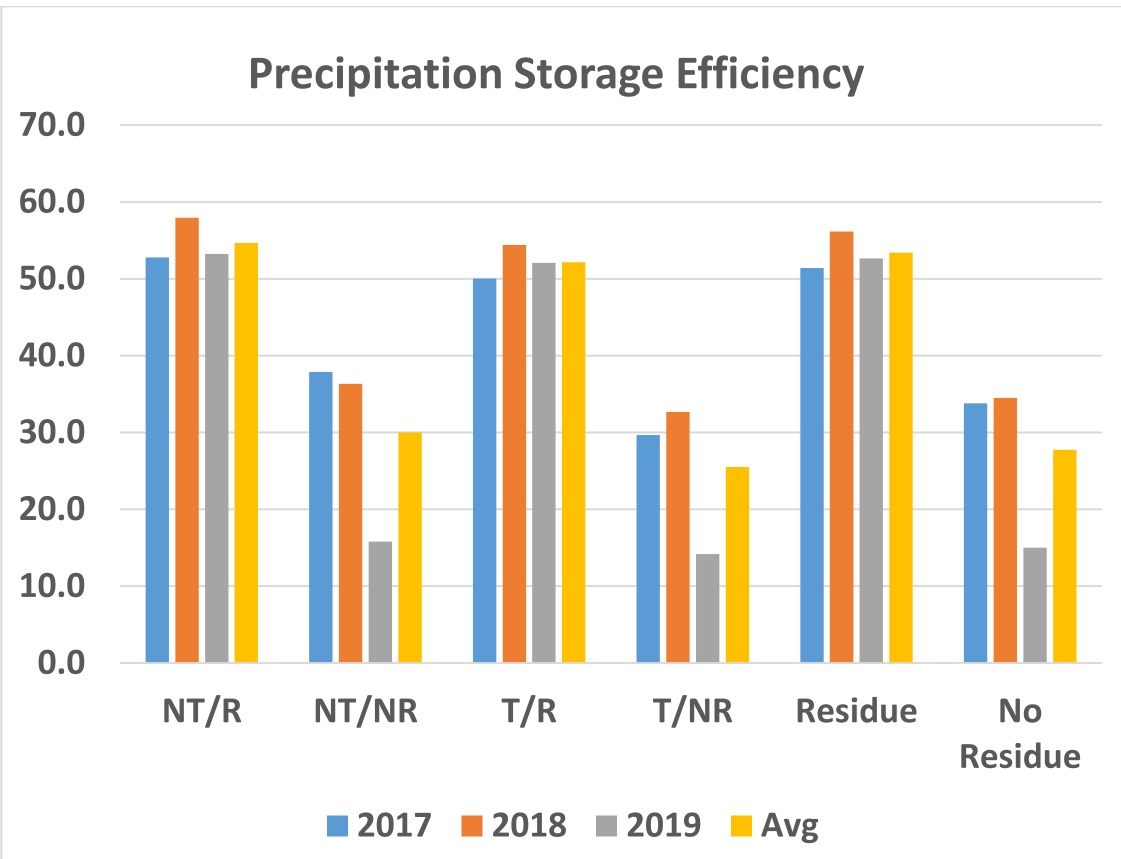

Figure 5. Precipitation storage efficiency from Oct 1 to May 30.

Vegetative water use ranged from 7.6 to 12.4 inches. The lowest ET was in 2016 and 2018 when the tubes were installed in mid-June compared to early June in 2015 and the end of May in 2017. There were no statistical differences in vegetative ET in 2015. In 2016, vegetative ET was the lowest in the NT/R treatment when ET was approximately 0.8" lower as compared to all other treatments. In 2017, the only significant difference in vegetative ET was between NT/R and NT/NR with a lower ET of 2.8". Over the four years, NT/R had a significantly lower vegetative ET by nearly 0.8" compared to all other treatments.

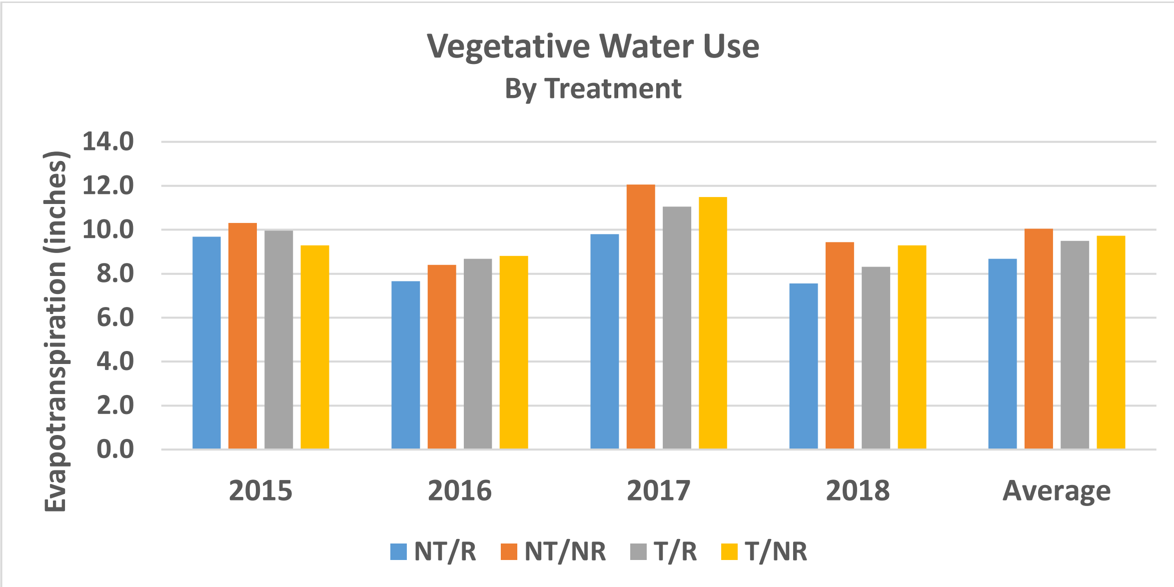

Figure 6. Vegetative water use by treatments for 2015 to 2018 and average.

Reducing evaporation during that time period in water limited situation would lead to either reduced irrigation needs or more water available during the reproductive stages where water stress has a greater impact to yield potential.

Agronomics and Grain Yield

Plant stands were measured at V5 with multiple 30 ft measurements within the plots. Final plant stands ranged from 33,800 to 31,100 plants acre^{-1}. The stand counts for NT/NR, T/R and T/NR were equal with stands from 32,900 to 33,800 plants acre^{-1} and less than 3% difference. NT/R had a significantly lower plant stand and was 7% less than the average of the other tillage/residue treatments.

Grain yields in 2014 were impacted by zinc deficiencies which impacted the NT/R treatments more significantly than the other treatments. In 2015, grain yields (Figure 7) were significantly reduced for all treatments by a significant hail storm that occurred on August 1 with estimates of 75 to 80% leaf area loss for all treatments. Grain yields averaged from 84 bu acre^{-1} to 99 bu acre^{-1} for NT/R to T/R. Grain yields for NT/R were significantly lower than all other treatments.

At the time of the hail event, the NT/R was slightly behind the other treatments in growth stage. NT/R was slightly past silking while the other treatments were closer to silks brown. Estimates of yield loss with similar hail damage show 60% for silks brown and 65% for silked. Similar hail damage at an earlier growth stage for NT/R would have brought yields closer to that of all other treatments if the hail had not occurred. Yield estimates for NT/R adjusted for hail damage would have averaged 240 bu acre^{-1} with no statistical difference between treatments.

Grain yields in 2016 where greater for NT than T by 6 to 9 bu ac^{-1}. This increase could be attributed to less evaporative losses by tillage. Residue management did not impact grain yields as compared to tillage management. In limited water situations as in 2016, tillage was the main factor in decreased yields.

Grain yields in 2017 were greatest for T/R by approximately 10 bu ac^{-1} compared to NT/R. However, irrigation applied was 2 inches less for NT/R than all other treatments (1 inch in vegetative and 1 inch in reproductive). An addition of 1 inch of irrigation may have offset that yield difference. Yields for T/NR were 15 and 24 bu ac^{-1} greater than T/NR and NT/NR respectively. With the same amount of irrigation applied to all treatments, this differences shows the value of residue retention in the field with an economic loss of $47 to $75 ac^{-1} that must be recuperated by the value of the residue.

Grain yields in 2019 were lower than the previous 4 years. Significantly lower than average temperatures from planting to July 1 slowed growth. Colder soil temperatures also increased the level of chlorosis observed in each of the treatments but more so in the NR/R treatment.

The 5 year average yields show that T/R yields were 2, 13 and 17 bu ac^{-1} greater than NT/R, T/NR and NT/NR. The long term value of residue removal is between 4 and 13 bu ac^{-1}. Estimates of additional water needed to increase the yields to that of T/R would require 0.5 to 1 inch more irrigation applied.

In years with near average precipitation for the growing season such as 2017 and 2018, the value of leaving the residue was nearly 20 to 35 bu ac^{-1}. In terms of potentially increasing grain yields by additional irrigation, it would require at least 1.5 to 3" more ET to equal those yields and a greater amount of irrigation to due to irrigation efficiency and declining yield response as you approach maximum grain yield.

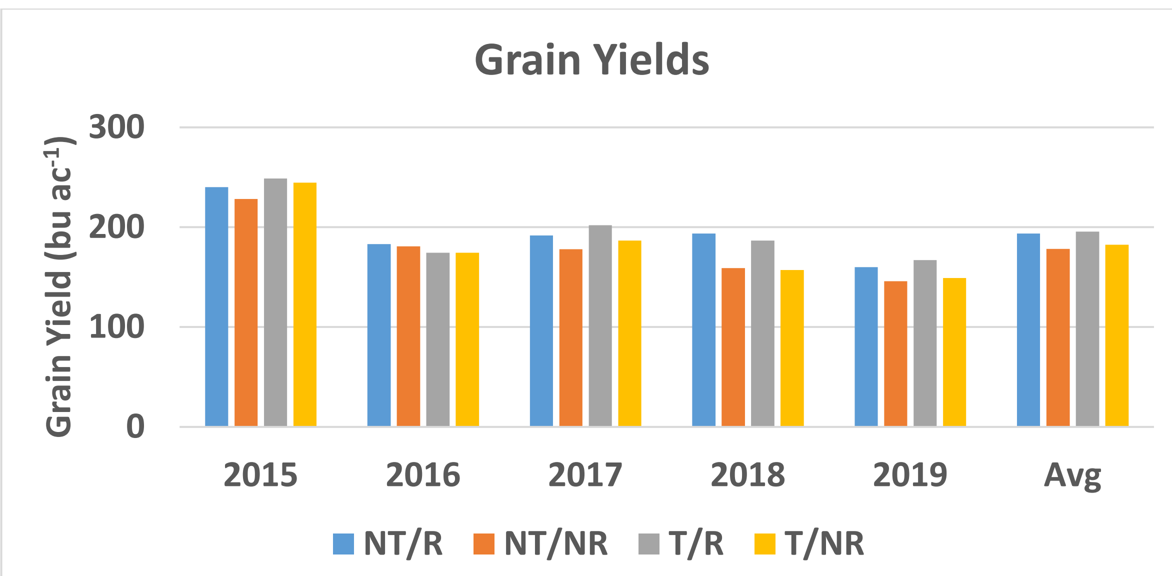

Figure 7. Grain yields for 2015, 2016, 2017, 2018 and 2019 by tillage and residue management. Average of nitrogen applications.

Long Term Soil Moisture

When irrigation is limited to below that of full irrigation, management changes can have long term impacts on the beginning soil moisture available for the growing season. Year to year changes in stored soil moisture are important in meeting water needs early in the growing season so the irrigation is not needed. Figure 8 shows the changes in beginning soil moisture by management practice. The major factor impacting beginning soil moisture is residue management. Although beginning soil moisture has declined in each of the two years compared to 2016, the greatest declines have occurred when residue was harvested. Plant available soil moisture is approximately 11.8 inches for the entire 6 ft profile. All treatments were below that capacity at May 1.

By 2018, residue harvested plots had approximately 2.5 inches drier that those when residue remained in the field. Eventually, these reductions in plant available stored soil moisture will have an impact on grain yields. This was evident in 2018 when yields of both the tilled and no-till residue removed plots were 30+ bu ac^{-1} less than those when the residue remained. These impacts are a cumulative impact over time. However, future years will show if this is the maximum impact or if the difference will continue to increase.

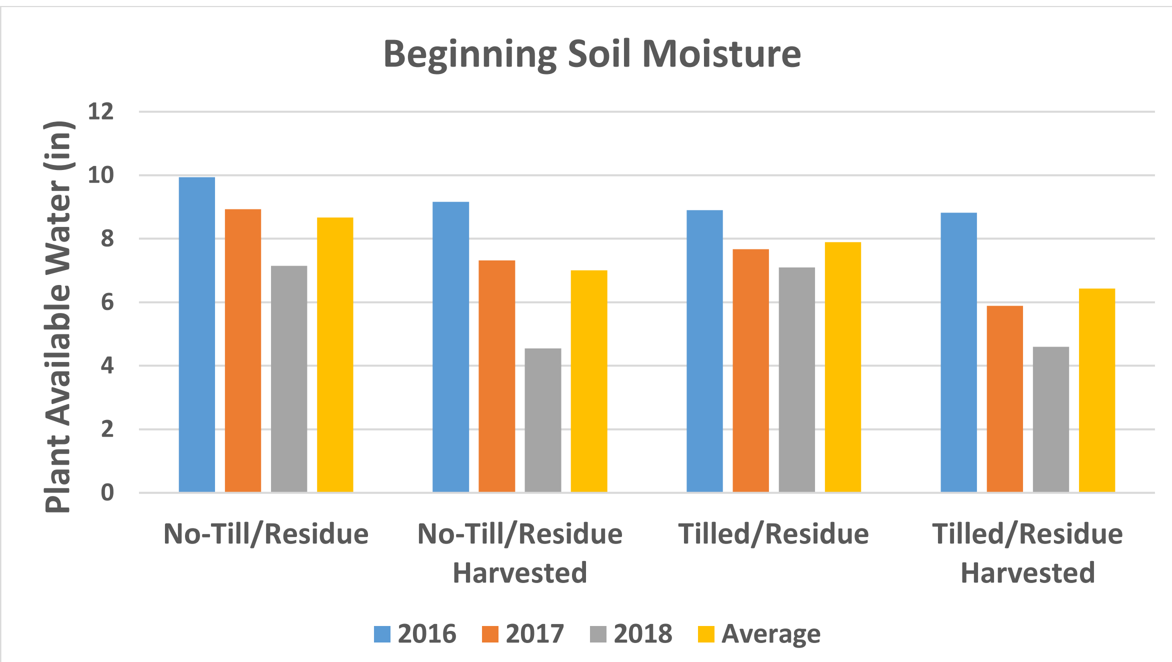

Figure 8. Plant available water as affected by tillage and residue management, 2016, 2017, 2018.

CONCLUSIONS

Changes in infiltration by residue management are significant in a short duration application of either irrigation or precipitation. Leaving residue in the field significantly increased total infiltration in 30 minutes compared to where residue was harvested irrespective of tillage in all years. Tillage had no impact on total infiltration in 30 minutes of water application. Leaving residue in the field was the significant factor for total infiltration. Changes in steady state infiltration occurred due to tillage and residue management for three years. However, no-till and leaving residue in the field had the greatest impact on steady state infiltration as compared to all other treatments.

Residue management can have a significant impact on water dynamics in irrigation management. Removal such as either baling the corn stalks for bedding or forage or harvesting for silage will change the infiltration patterns for the next year of crop production. When moisture or irrigation availability is limited, increasing moisture capture is important to maximize crop production and water availability such as in 2017. When moisture or irrigation is not limited, removal of residue had little impact on grain yields (2015).

Leaving residue intact on the surface can reduce evaporative losses compared to incorporating them with tillage or removal with baling. The reduction in evaporative losses averaged nearly 10% for a 45 to 60 day period before tassel emergence. This would lead to either less irrigation during the vegetative growth stage or more water available during the reproductive growth stages.

Long term impacts to water are important. Residue harvest can have an annual impact on water need by approximately 2 to 3 inches per year. Tillage can have an annual impact on water needs of approximately 1 inch per year when residue remains standing during the winter.