**Long-term effects of nitrogen and tillage on yields and nitrogen**

**use efficiency in irrigated corn**

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**Supplementary Information File**

**In this file:**

* Supplementary tables (Tables S1-S21)
* Supplementary figure (Figure S1)

**Table S1.** Summary of weather variables§ by growing season of each year for the no till (NT) study (planting to physiological maturity [R6]). Weather data downloaded on July 20, 2022 via CoAgMet from ARDEC station FTC03 (<http://www.coagmet.colostate.edu/station/ftc03_main.html>) and CSU station FCL01 (<http://www.coagmet.colostate.edu/station/fcl01_main.html>).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Time Period** | **Average Mean**  **Daily Max**  **Temperature (°C)** | **Average Mean**  **Daily Minimum Temperature (°C)** | **Average Mean Daily Mean Temperature (°C)** | **Mean Annual GDD (°C)** | **Mean Annual Precipitation (mm)** |
| 2001 - 2007  2006 - 2007  2006 - 2017  2001 - 2017 | 26.7  27.8  26.7  26.6 | 9.8  10.7  10.3  10.1 | 18.2  19.3  18.5  18.3 | 1293  1323  1313  1303 | 139.8  105.1  211.8  194.7 |

§Relative to NT, the R6 sampling for the conventional till (CT) study occurred 2 days earlier in 2007 and the R6 sampling for the full-plot strip till (ST) study occurred 2 days later in 2010, 3 days later in 2011, 2 days earlier in 2012, and 1 day earlier in 2015. The weather data for the CT and ST periods, although very similar, may be slightly different than the NT weather data, due to the minor differences in sampling dates in certain years as described above. For exact weather data for the CT and ST that accounts for these minor differences in sampling dates for the above years, see the accompanying datasets and metadata to adjust as necessary. Due to the large number of R6 field samples to collect during the above years, CT and ST R6 samples were collected a couple of days earlier or later than NT during these years.

**Table S2.** Nitrogen (N) fertilizer treatment details and application rates by year, ordered by treatment at N rate levels of 0, 67, 134, 202, and 246 kg N ha-1¥.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Study | Tillage | Year(s) | Fertilizer source | N rates  (kg N ha-1) | Fertilizer placement |
| CT/ST | CT | 2001 | UAN: 32% N | 0, 67, 134, 168 | Subsurface band |
| CT/ST | CT | 2002 | Blend: N-P-K-S  3 – 9 – 21 – 8%  UAN: 32% N | 3.4 (all levels) **¶**  0, 34, 67, 134, 202 | Seed trench  Subsurface band |
| CT/ST | CT | 2003-2004 | Blend: N-P-K-S  3 – 9 – 21 – 8%  UAN: 32% N | 3.4 (all levels) **¶**  0, 34, 67, 101, 134, 224 | Seed trench  Subsurface band |
| CT/ST | CT | 2005 | UAN: 32% N  ESN: 45% N | 0, 17, 34, 50, 67, 123  0, 17, 34, 50, 67, 123 | Subsurface band  Surface broadcast |
| CT/ST | CT | 2006 | Blend: N-P-K-S  1.5 – 9 – 21.5–8.5%  Urea: 46% N  ESN: 43% N | 1.5 (all levels) **¶**  0, 17, 34, 50, 67, 123  0, 17, 34, 50, 67, 123 | Seed trench  Surface band  Surface band |
| CT/ST | CT | 2007 | ESN: 44% N | 0, 67, 134, 202, 246 | Surface band |
| CT/ST | ST | 2009-2010 | ESN: 44% N | 0, 67, 134, 202, 246 | Surface band |
| CT/ST | ST | 2011 | ESN: 44% N | 0, 67, 134, 202 | Surface band |
| CT/ST | ST | 2012-2013 | SuperU: 46% N | 0, 67, 134, 202 | Surface band |
| CT/ST | ST | 2014-2017 | Urea: 46% N | 0, 67, 134, 202 | Surface band |
| NT CC | NT | 2001 | UAN: 32% N | 0, 34, 67, 101, 134, 168 | Subsurface band |
| NT CC | NT | 2002 | Blend: N-P-K-S  3 – 9 – 21 – 8%  UAN: 32% N | 3.4 (all levels)  0, 34, 67, 101, 134, 202 | Seed trench  Subsurface band |
| NT CC | NT | 2003-2004 | Blend: N-P-K-S  3 – 9 – 21 – 8%  UAN: 32% N | 3.4 (all levels)  0, 34, 67, 101, 134, 224 | Seed trench  Subsurface band |
| NT CC | NT | 2005 | UAN: 32% N  ESN: 45% N | 0, 17, 34, 50, 67, 123  0, 17, 34, 50, 67, 123 | Subsurface band  Surface broadcast |
| NT CC | NT, ST | 2006 | Urea: 46% N  ESN: 43% N | 0, 17, 34, 50, 67, 123  0, 17, 34, 50, 67, 123 | Surface band  Surface band |
| NT CC | NT, ST | 2007 | ESN: 44% N | 0, 67, 134, 202, 246 | Surface band |
| NT CC | NT | 2009 | ESN: 44% N | 0, 67, 202, 246 | Surface band |
| NT CC | ST | 2009 | ESN: 44% N | 0, 67, 134, 202, 246 | Surface band |
| NT CC | NT, ST | 2010-2011 | ESN: 44% N | 0, 67, 134, 202, 246 | Surface band |
| NT CC | NT, ST | 2012 | SuperU: 46% N | 0, 67, 134, 202, 246 | Surface band |
| NT CC | NT | 2013 | SuperU: 46% N | 0, 67, 134, 202, 246 | Surface band |
| NT CC | NT | 2014-2017 | Urea: 46% N | 0, 34, 67, 134, 202, 246 | Surface band |

¥In addition to N, P in the form of triple superphosphate (0 – 46 – 0) was applied to all experimental units as follows: 49 kg P ha-1 on 03/28/2005; and 20 kg P ha-1 on 04/29/2009. P in the form of triple superphosphate (0 – 45 – 0) was applied to all experimental units as follows: 56 kg P ha-1 on 03/30/2010; 56 kg P ha-1 on 03/18/2013; 56 kg P ha-1 on 04/14/2015; and 56 kg P ha-1 on 03/13/2018.

**¶**The values of 3.4 kg N ha-1 from 2002 to 2004 and 1.5 kg N ha-1 in 2006 were not accounted for in calculations for N balance, NUe, nor N losses from 2001 to 2007.

**Table S3.** Descriptions of the weed and pest control; nitrogen management; tillage management; plant, soil, and irrigation sampling and analysis; calibration of instruments for plant N analysis; the linear-plus-plateau model analysis; and nitrogen use efficiency (NUE) equations used.

|  |  |
| --- | --- |
| **Practice** | **Description** |
| Weed control | In general, all of the continuous corn experimental units were managed the same as far as weed control, regardless of tillage treatment or row spacing. On average, a pre-plant or pre-crop-emergence broad-spectrum herbicide like glyphosate (Roundup®) or glufosinate-ammonium (Liberty®) were applied to control emerged broadleaf and grass weeds. This herbicide was usually tank mixed with a broad-spectrum, residual herbicide (Zidua®) to suppress un-emerged weeds, followed by a post-emergence herbicide mix (Roundup® or Liberty and Status®) to control or suppress any escaped weeds just prior to crop canopy closure. Problem weeds such as Canada thistle were spot sprayed by hand as needed using clopyralid (Stinger®). Over the 20+ years of maintaining these experimental units, the chemicals have varied based on the EPA-approved products available at that time, but the intended weed management strategy has remained consistent. |
| Pest control | Slugs severely damaged the no-till continuous corn as it emerged in 2009 (8 experimental units).  For pest management, a molluscicide (DEADLINE® M-Ps™ Mini-Pellets, a dry pellet bait) was applied to the experimental units to kill slugs and snails. Spider mites have also been a significant issue with the corn crop, affecting some experimental units in 2011 (2 experimental units) and 2012 (6 experimental units). To rescue the crop those years, the field was aerial-sprayed with one of two pesticides (Onager® and Warrior®) or both, depending on timing (one targets the adult stage of the mites and the other targets the juvenile stage). Bird damage is significant at ARDEC. Sunflower experimental units in the area have attracted huge flocks of blackbirds that also damaged the corn. Several deterrent strategies have been employed including predator decoys, balloons with eyes, kites, flashing lights, banging sounds, and once a propane cannon. One practice employed was to switch to a hybrid of corn with a tighter husk to try to deter the birds. The experimental units were sufficiently large to enable us to sample corn plants that were not affected by bird damage. In cases where there was significant corn crop damage in a sample row or for a given year, another plant within the experimental units would be sampled at random from the adjacent row instead. |
| Nitrogen management | For fertilizer applications we used liquid UAN 32% (32-0-0) applied at pre-planting using liquid fertilizer applicator with coulter shanks for sub-surface bands and 13” spacing (2001 to 2005). We also used a liquid starter + KTS blend (3-9-21-8) applied at planting in the years 2002, 2003, and 2004, and a liquid starter + KTS blend (1.5-9-21.5-8.5) in 2006. This was applied using micro tubes in seed row with a corn planter and 30” spacing. Granular ESN (44-0-0 or 43-0-0; see Table S2) was applied post-emergence from 2005 to 2011. Granular SUPERU® (46-0-0) was applied post-emergence from 2012 to 2013. From 2014 to 2017, granular urea (46-0-0) was also applied post-emergence using a Barber drop spreader with surface side bands and 30” spacing. Granular triple super phosphate (0-46-0) was applied to the surface in 10’ bands at pre-planting in 2004, 2005, 2009, 2010, 2013, and 2015. |
| Tillage management | The crop tillage management for these systems was as follows. For the 2001 to 2017 CC under NT, we flail chopped corn stalks at pre-planting (2001 only) with a 15’ wide flail chopper, pulled with a 140 horsepower (hp) tractor. From 2013 to 2017, we used a 15’ wide roll chopper, mounted on the front of 165 hp tractor, on corn stalks at pre-planting for both the NT and ST plots. For the ST plots, from 2006 to 2017 during pre-planting we strip tilled to a soil depth of 9 inches with a 15’ Orthman 1tRIPr strip tiller pulled with a 140 or 165 hp tractor. For CC under CT, from 2001 to 2007 we flail chopped corn stalks during pre-planting with a 15’ flail chopper pulled with 140 hp tractor. We disced in surface residue at pre-planting from 2001 to 2006 using a 15’ disc harrow pulled with a 140 hp tractor. From 2001 to 2007, during pre-planting we plowed to a 12” plow depth using 3, 4, or 6 bottom moldboard plows that were pulled with 90, 140, or 200 hp tractors. We additionally disked at pre-planting from 2003 to 2005 with a 15’ disc pulled with a 90 hp tractor. In 2004 only, we ripped during pre-planting only to fracture a compaction layer with a 24” tillage depth using a 6-shank parabolic plow. We also rolled during pre-planting from 2001 to 2007 with a 10’ or 30’ roller pulled with 90, 140, or 210 hp tractors doing two passes over the field. In 2003 only, we spring-tooth harrowed during pre-planting to loosen up soil from hard rains prior to leveling with a 10’ harrow pulled with a 90 hp tractor. From 2001 to 2007, we leveled during pre-planting with a 10’ or 24’ leveler pulled with 90, 140, or 210 hp tractors. In 2005 only, we dragged at pre-planting only to level the field after fertilizer application with a 10’ drag pulled with a 90 hp tractor. For 2003 only, we also rotary hoed with a 10’ rotary hoe pulled with a 90 hp tractor during pre-emergence to break up hard crust on the soil surface to aid crop emergence. The flail chopper was used to chop up corn stalks to make them easier to incorporate. The disc was used to incorporate surface residue prior to plowing and again after plowing to break up soil aggregates. The moldboard plow was used to invert the top 12 inches of soil. The roller harrow was used to help break up soil aggregates. This was typically done two times. The land plane was used to level the finely tilled soil surface, done in multiple passes. |
| Plant, Soil, and Irrigation Sampling and Analysis | To assess the effects of tillage and N rate on total biomass and the potential of crop residue returned to the field under different N rates and tillage systems, plant samples were collected during two distinct field operations each year. At physiological maturity (R6), 15 randomly selected plants were cut by hand at ground level and removed from the field to assess biomass production of stalks and leaves. Sampling at physiological maturity is essential since it is impractical to harvest a large number of plots for biomass sampling after drydown at harvest due to the fragility of the dried leaves, which will easily break and fall to the ground. After the biomass samples were collected, ears were manually removed from plants, oven dried, and then shelled, while the stalks and leaves were together shredded, subsampled, and oven dried. After shelling, the cobs were also retained and oven dried. The second sampling was performed after drydown at harvest, during which ears were manually removed from all plants in two adjacent rows, each 7.6 m long, for a total sample area of 11.6 m2 from each experimental unit. The manually harvested ears were air-dried and mechanically threshed; the grain was then subsampled and oven dried. (All oven-dried samples were left in a 60 °C oven for at least 48 h.) Plant samples (2001 to 2017) were ground to pass through a 2-mm screen and were analyzed for total N using a Carlo Erba C/N analyzer (Haake Buchler Instrument) from 2001 to 2005 and Elementar Vario Macro C-N analyzer (Elementar Americas) from 2005 to 2017.  The crop residue biomass was determined by summing the dry weight of the stalks, leaves, and cobs at R6. A small plot harvester was used to remove the harvested grain alone. The leaves, stalks, and cobs (crop residue) were left at the soil surface. Crop residue biomass N was determined by summing the N content of stalks, leaves, and cobs at R6. Total N removed from the experimental units was determined from the N content of the dried down corn at harvest. Irrigation samples were monitored and with most irrigation events, water samples were collected and analyzed for N (NO3-N and NH4-N) analysis. Water NO3-N and NH4-N content were determined with the Lachat QuickChem flow injection analyzer (Table S3) and total application of N during the study period from 2001 to 2017 was estimated at 266.6kg NO3-N ha-1 (Table S3) with an average of 15.7kg NO3-N ha-1 yr-1. The average quantities of NO3-N applied per year from 2001 to 2007, 2006 to 2007, and 2006 to 2017 were 11.1, 18.4 and 18.8 kg NO3-N ha-1, respectively (Table S3). All NT, CT, and ST plots received the same amount of irrigation and NO3-N per hectare per year, except in 2005, during which the CT plots received an additional irrigation at pre-planting of 25.4 mm and 0.1 kg NO3-N ha-1. |
| Calibration of instruments for plant N analysis | Jantalia and Halvorson [23] and Follet et al. [30] conducted a calibration using different plant samples that had a wide range of carbon (C) and N content. They reported that there were no differences between the analyses conducted with the Carlo Erba and the Elementar instruments and the plant data could be merged for a continuous analysis that contains initial plant samples measured with the Carlo Erba from 2001 to 2004 and with the Elementar since 2005. Delgado et al. [2] published and released the datasets about the use of plant standards and soil standards that were run continuously from 2005 to 2018, and the long-term analysis of plant standards showed that the long-term Elementar analysis was accurate and precise during these long-term studies and repeatedly provided accurate and precise analysis of the plant samples that were run continuously during this period (Fig. S2). |
| The linear-plus-plateau model analysis | ***Model Specification***: For the estimation we used a linear-plus-plateau model (Fig. S2), defined by a classical switching regression type of function of the form:  (**Eq.** **1**)  (**Eq.** **2**)  Where *t* is year, *i* is plot, is the yield in plot *i* at year *t* (response variable), is the N level in plot *i* at year *t* (limiting input), is the intercept, is the slope, is the minimum N level to reach the plateau yield, known as the threshold point, and finally is the random error term. Moreover, the yield at the plateau can be predicted and represented by **Eq.** 3 (Fig. 1 represents this nonlinear linear-plus-plateau model):  (**Eq.** **3**)  For this study R-NLS was used to solve this nonlinear fixed-effects regression model. Results were also checked with MATLAB FITNLM for robustness. The R-NLS function uses the Gauss-Newton algorithm to determine the nonlinear (weighted) least-squares estimates of the parameters of a nonlinear model, while MATLAB FITNLM uses the Levenberg-Marquardt nonlinear least squares algorithm, also known as the damped least-squares (DLS) method. Various combinations of starting points were tried for each regression in the effort to achieve convergence, and then the best model was selected based on the values of the (1) Mean Squared Error, and (2) Log-Likelihood.  ***Empirical Test***: The likelihood ratio (LR) test (Greene 2008) was used to determine if the estimated parameters were statistically different for NT, CT, and ST treatments. The LR test requires the estimation of both the unconstrained and constrained models. The unconstrained model is a jointly estimated response function using the data for two treatments, allowing the parameter estimates to be different between the treatments, i.e.:  (**Eq.** **4**)  Where is a dummy variable used to differentiate among two treatments, i.e., is equal to 0 when there is *NT*, and equal to 1 when there is *CT*. Similarly, the constrained model was a jointly estimated response function using the data for two treatments, but it restricts the parameter estimates to be equal between the treatments. To test the statistical difference of the intercept parameters, the constrained model is estimated with the intercepts set equal such that the null hypothesis is . The constrained model for this test is expressed as:  (**Eq.** **5**)  To test the statistical difference of the slope parameters, the constrained model is estimated with the slopes set equal such that the null hypothesis is . The constrained model for this test is expressed as:  (**Eq.** **6**)  To test the statistical difference of the N at plateau parameters, the constrained model is estimated with the N at plateaus set equal such that the null hypothesis is . The constrained model for this test is expressed as:  (**Eq.** **7**)  For each case, the test statistic is then derived as:  (**Eq.** **8**)  where is the value of the log-likelihood function at the solution for the unconstrained model, and is the analogous value for the constrained model. The test decision is based on a comparison of the computed *LR* to the applicable critical value in a chi-squared table, where *J* indicates the total number of joint restrictions to be tested (in this case *J=*1)*.* The rationalefor this test is that the value of ln*L* for the constrained model should be close to that for the unconstrained model if the imposed constraint is correct. A large difference between the two values would suggest that the constraint does not hold. For reference, the chi-squared critical values at the 1% probability level are .  The linear-plus-plateau model was used to determine differences in yield or N uptake at the plateau (), the N fertilizer rate at the plateau ), and the intercept of the linear-plus-plateau () for the data covering CT and NT from 2001 to 2007; CT, NT, and ST from 2006 to 2007; and NT and ST from 2006 to 2017. Additionally, we conducted a t-test analysis by year and N rate treatments from 2001 to 2007 (CT vs. NT), 2006 to 2007 (CT vs. NT; CT vs. ST; ST vs. NT) and from 2006 to 2017 (ST vs. NT). |
| NUE equations | The harvest grain agronomic N use efficiency (ANUEHG) (Eq. 9) was calculated by dividing the harvest grain yield at the plateau (HGMg ha-1) for each tillage system (HGYts) by the fertilizer N rate for the harvested grain at the plateau () for each tillage system (kg N ha-1):  ANUEHG (Mg kg-1) = HG  --------------------------- (**Eq.** **9**)    The crop residue biomass agronomic N use efficiency (ANUECR) (Eq. 10) was calculated by dividing the crop residue yield at the plateau (CRMg ha-1) for each tillage system by the fertilizer N rate at the plateau (; kg N ha-1) for each tillage system:  ANUECR (Mg kg-1) = CR  ------------------------------- (**Eq.** **10**)    The NUE of the harvested grain at the linear-plus-plateau (NUELPPHG) (Eq. 1) was calculated by subtracting the N content in the harvested grain of the control (intercept; HGNC kg N ha-1) from the harvested grain N content at the plateau (HGNC; kg N ha-1) at the N-fertilizer rate at the plateau, and dividing the difference by the N fertilizer added to the fertilized experimental unit at the plateau (NFR kg N ha-1):  NUELPPHG (%)           =           HGNC    –    HGNC                                      ----------------------------------  \*  100                                     (**Eq. 11**)                                                             NFR  The NUE of the aboveground crop residue (stalks, leaves and cobs) N content at the linear-plus-plateau (NUELPPCR) (Eq. 2) was calculated by subtracting the N content in the crop residue of the control (intercept, CRNC; kg N ha-1) from the crop residue N content at the plateau (CRNC; kg N ha-1) at the N-fertilizer rate at the plateau, and dividing the difference by the N fertilizer added to the fertilized experimental unit at the plateau (NFR; kg N ha-1):  NUELPPCR (%)           =              CRNC    –   CRNC                                      ----------------------------------  \*  100                                 (**Eq. 12**)                                                             NFR  The NUE of the total aboveground biomass (stalks, leaves, cobs and grain) N content at the linear-plus-plateau (NUELPPTB) (Eq. 2) was calculated by subtracting the N content in the total aboveground biomass of the control (intercept, TBNC; kg N ha-1) from the total aboveground biomass N content at the plateau (TBNC; kg N ha-1) at the N-fertilizer rate at the plateau, and dividing the difference by the N fertilizer added to the fertilized experimental unit at the plateau (NFR; kg N ha-1):  NUELPPTB (%)           =              TBNC    –   TBNC                                      ----------------------------------  \*  100                                 (**Eq. 13**)                                                             NFR  If we calculate the NUELPPHG by using the non-fertilized background N and subtracting the N uptake at the intercept from the N uptake at the plateau and dividing by the N fertilizer at the plateau, this percentage is an assessment of the N recovered by the corn grain (i.e., 100 – NUELPPHG at the plateau = % of potential N losses of the N fertilized applied). |
|  | Properties of soil samples collected in the spring of 2012. Soil samples were collected from the surface soil depth (0 to 7.6 cm) in the plots that were under NT from 2000 to 2017; in the ST plots that were under CT from 2000 to 2008 and then ST from 2009 to 2017; and in the ST plots that were under NT from 2001 to 2006 and then split to NT and ST from 2006 to 2012. Collected composite samples were sent to the CSU Soil, Water, and Plant Testing Laboratory to assess the soil pH; soil electrical conductivity (EC); organic matter (OM); nitrate N (NO3-N), phosphorus, and potassium (K) concentrations; and soil texture. |
| Properties of soil samples collected in the spring of 2012 from the surface soil depth (0 to 7.6 cm) | |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **Tillage** | **N Rate** | **Depth** | **pH** | **EC** | **OM (g/kg)** | **NO3-N (mg/kg)** | **P (mg/kg)** | **K (mg/kg)** | **Soil Texture** | |  | **(kg N/ha)** |  |  | **(mS/cm)** |  |  |  |  |  | | CT: 2001-2008  ST: 2009-2017 | 0 | 0-3" | 7.56 | 900 | 20 | 2.1 | 11 | 233 | Sandy Clay Loam | | NT: 2001 – 2005  ST: 2006-2012 | 0 | 0-3" | 7.62 | 1300 | 26 | 6.2 | 9 | 238 | Sandy Clay | | NT: 2001 - 2017 | 0 | 0-3" | 7.59 | 1000 | 23 | 8.4 | 12 | 210 | Sandy Clay Loam | | average |  |  | 7.59 | 1100 | 23 | 5.6 | 11 | 227 |  | | std |  |  | 0.03 | 200 | 3 | 3.2 | 2 | 15 |  | |  |  |  |  |  |  |  |  |  |  | | CT/ST | 202 | 0-3" | 7.61 | 800 | 24 | 11.2 | 8 | 212 | Sandy Clay Loam | | NT/ST | 202 | 0-3" | 7.61 | 1000 | 31 | 18.6 | 4 | 219 | Sandy Clay Loam | | NT | 202 | 0-3" | 7.55 | 1000 | 20 | 21.5 | 16 | 217 | Sandy Clay Loam | | average |  |  | 7.59 | 900 | 25 | 17.1 | 9 | 216 |  | | std |  |  | 0.03 | 100 | 6 | 5.3 | 6 | 3 |  | |
|  | Soil pH and EC were determined by the saturated paste method; OM was determined by the loss-on-ignition method; NO3-N, P, and K were determined by AB-DTPA extraction; and soil texture was determined with the hydrometer method. |

**Table S4.** Summary of irrigation water applied by calendar year (2001-2017) and the respective background nitrogen content as nitrate-nitrogen (NO3-N). Although most of the irrigation was applied between planting and physiological maturity (R6), on occasion irrigation events may have occurred before planting or after R6.

|  |  |  |
| --- | --- | --- |
| Year | Irrigation Water Applied (mm) | NO3-N (kg ha-1) |
| 2001  2002  2003  2004  2005  2006  2007  2008  2009  2010  2011  2012  2013  2014  2015  2016  2017 | 509  504  411  362  388 (413) §  403  406  360  396  395  354  506  438  472  475  488  375 | N/A¥  6.9  10.8  7.5  16.0 (16.1) §  16.7  20.1  13.9  15.1  22.7  16.4  21.1  33.3  20.6  19.8  14.8  10.9 |

¥The background nitrogen content as NO3-N was not measured.

§In 2005, the CT system received an earlier irrigation application of 25 mm containing 0.1 kg NO3-N as background NO3-N. See 2015 data for total irrigation and background NO3-N for CT.

**Table S5.** Means, standard deviations, and significance (S) for harvested grain yield of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2001 to 2007 under different N rates and tillage systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | Yield  (kg ha-1) | Standard  Deviation | S£ |
| 0 | 2001 | CT | 4 | 5839.8 | 455.6 | n.s. |
| 0 | 2001 | NT | 3 | 5979.0 | 184.2 | n.s. |
| 33.6 | 2001 | NT | 3 | 7147.1 | 1174.9 | N/A |
| **67.2** | **2001** | **CT** | **4** | **9847.2** | **453.2** | **\*\*** |
| 67.2 | 2001 | NT | 3 | 7814.6 | 333.1 | \*\* |
| 101 | 2001 | NT | 3 | 9001.0 | 613.6 | N/A |
| **134** | **2001** | **CT** | **4** | **11521.6** | **393.8** | **\*\*** |
| 134 | 2001 | NT | 3 | 9173.8 | 244.4 | \*\* |
| **168** | **2001** | **CT** | **4** | **11762.5** | **130.7** | **\*\*** |
| 168 | 2001 | NT | 3 | 9768.8 | 285.0 | \*\* |
|  |  |  |  |  |  |  |
| **0** | **2002** | **CT** | **4** | **5553.0** | **606.1** | **\*\*** |
| 0 | 2002 | NT | 3 | 4611.4 | 288.4 | \*\* |
| **33.6** | **2002** | **CT** | **4** | **8256.4** | **455.6** | **\*\*** |
| 33.6 | 2002 | NT | 3 | 5772.7 | 1218.4 | \*\* |
| **67.2** | **2002** | **CT** | **4** | **9086.2** | **472.5** | **\*\*** |
| 67.2 | 2002 | NT | 3 | 6095.1 | 507.3 | \*\* |
| 101 | 2002 | NT | 3 | 6973.1 | 787.3 | N/A |
| **134** | **2002** | **CT** | **4** | **10601.8** | **355.3** | **\*\*** |
| 134 | 2002 | NT | 3 | 8042.3 | 659.2 | \*\* |
| 202 | 2002 | CT | 4 | 10455.9 | 879.3 | n.s. |
| 202 | 2002 | NT | 3 | 9431.0 | 831.5 | n.s. |
|  |  |  |  |  |  |  |
| **0** | **2003** | **CT** | **4** | **5903.6** | **739.5** | **\*\*** |
| 0 | 2003 | NT | 3 | 3966.7 | 366.5 | \*\* |
| 33.6 | 2003 | CT | 4 | 6713.2 | 532.8 | n.s. |
| 33.6 | 2003 | NT | 3 | 6044.7 | 734.9 | n.s. |
| 67.2 | 2003 | CT | 4 | 7310.4 | 405.8 | n.s. |
| 67.2 | 2003 | NT | 3 | 6874.3 | 965.4 | n.s. |
| **101** | **2003** | **CT** | **4** | **8610.5** | **376.8** | **\*\*** |
| 101 | 2003 | NT | 3 | 6985.2 | 848.3 | \*\* |
| 134 | 2003 | CT | 4 | 9169.9 | 598.9 | n.s. |
| 134 | 2003 | NT | 3 | 8358.2 | 800.0 | n.s. |
| 224 | 2003 | CT | 4 | 9859.4 | 777.7 | n.s. |
| 224 | 2003 | NT | 3 | 8982.2 | 636.2 | n.s. |
|  |  |  |  |  |  |  |
| **0** | **2004** | **CT** | **4** | **5843.8** | **1159.2** | **\*\*** |
| 0 | 2004 | NT | 3 | 3565.5 | 114.1 | \*\* |
| **33.6** | **2004** | **CT** | **4** | **8305.6** | **967.8** | **\*\*** |
| 33.6 | 2004 | NT | 3 | 5098.3 | 312.0 | \*\* |
| **67.2** | **2004** | **CT** | **4** | **8926.6** | **576.3** | **\*\*** |
| 67.2 | 2004 | NT | 3 | 6160.3 | 835.5 | \*\* |
| **101** | **2004** | **CT** | **4** | **9772.0** | **339.0** | **\*\*** |
| 101 | 2004 | NT | 3 | 7423.7 | 381.2 | \*\* |
| **134** | **2004** | **CT** | **4** | **9557.3** | **752.5** | **\*\*** |
| 134 | 2004 | NT | 3 | 7626.9 | 346.8 | \*\* |
| **224** | **2004** | **CT** | **4** | **10509.9** | **365.3** | **\*\*** |
| 224 | 2004 | NT | 3 | 9626.1 | 388.1 | \*\* |
|  |  |  |  |  |  |  |
| 0 | 2005 | CT | 4 | 4794.4 | 505.6 | n.s. |
| 0 | 2005 | NT | 3 | 4755.9 | 484.2 | n.s. |
| **33.6** | **2005** | **CT** | **4** | **7097.0** | **361.8** | **\*** |
| 33.6 | 2005 | NT | 3 | 5955.7 | 730.2 | \* |
| 67.2 | 2005 | CT | 4 | 8170.3 | **221.5** | **\*\*** |
| 67.2 | 2005 | NT | 3 | 8680.9 | 344.5 | \*\* |
| **101** | **2005** | **CT** | **4** | **9168.6** | **256.0** | **\*\*** |
| 101 | 2005 | NT | 3 | 7349.8 | 264.6 | \*\* |
| **134** | **2005** | **CT** | **4** | **9863.3** | **465.4** | **\*\*** |
| 134 | 2005 | NT | 3 | 8322.0 | 485.8 | \*\* |
| **246** | **2005** | **CT** | **4** | **10716.6** | **19.9** | **\*\*** |
| 246 | 2005 | NT | 3 | 8930.1 | 554.9 | \*\* |
|  |  |  |  |  |  |  |
| **0** | **2006** | **CT** | **4** | **5609.0** | **574.4** | **\*\*** |
| 0 | 2006 | NT | 3 | 4368.4 | 745.9 | \*\* |
| **33.6** | **2006** | **CT** | **4** | **7684.7** | **137.9** | **\*\*** |
| 33.6 | 2006 | NT | 3 | 5752.4 | 850.3 | \*\* |
| 67.2 | 2006 | CT | 4 | 7972.7 | 197.9 | n.s. |
| 67.2 | 2006 | NT | 3 | 7428.4 | 819.4 | n.s. |
| 101 | 2006 | CT | 4 | 9000.9 | 723.8 | n.s. |
| 101 | 2006 | NT | 3 | 8680.1 | 519.7 | n.s. |
| 134 | 2006 | CT | 4 | 8659.6 | 740.1 | n.s. |
| 134 | 2006 | NT | 3 | 8593.1 | 822.2 | n.s. |
| 246 | 2006 | CT | 4 | 8170.3 | 469.9 | n.s. |
| 246 | 2006 | NT | 3 | 8680.9 | 1122.6 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2007 | CT | 4 | 5469.7 | 814.9 | n.s. |
| 0 | 2007 | NT | 3 | 5225.8 | 308.7 | n.s. |
| **67.2** | **2007** | **CT** | **4** | **9609.1** | **416.8** | **\*\*** |
| 67.2 | 2007 | NT | 3 | 8255.7 | 229.8 | \*\* |
| **134** | **2007** | **CT** | **4** | **10211.6** | **320.5** | \*\* |
| 134 | 2007 | NT | 3 | 9630.9 | 360.2 | \*\* |
| 202 | 2007 | CT | 4 | 9612.2 | 226.5 | n.s. |
| 202 | 2007 | NT | 3 | 9552.7 | 343.3 | n.s. |
| 246 | 2007 | CT | 4 | 9963.9 | 311.3 | \*\* |
| **246** | **2007** | **NT** | **3** | **10591.2** | **177.4** | **\*\*** |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ \*\*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.05; \*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate, N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test for difference among tillage systems within a year and N rate.

**Table S6.** Means, standard deviations, and significance (S) for harvested grain yield of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2006 to 2007 under different N rates and tillage systems.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | Yield  (kg ha-1) | Standard Deviation | S£ | S£ |
| **0** | **2006** | **CT** | **4** | **5609.0** | **574.4** | **a** | **AB** |
| **0** | **2006** | **NT** | **3** | **4368.4** | **745.9** | **b** | **C** |
| 0 | 2006 | ST | 3 | 5196.5 | 1040.5 | ab | BC |
| **33.6** | **2006** | **CT** | **4** | **7684.7** | **137.9** | **a** | **A** |
| **33.6** | **2006** | **NT** | **3** | **5752.4** | **850.3** | **b** | **B** |
| **33.6** | **2006** | **ST** | **3** | **6536.5** | **1159.9** | **b** | **B** |
| 67.2 | 2006 | CT | 4 | 7972.7 | 197.9 | n.s. | n.s. |
| 67.2 | 2006 | NT | 3 | 7428.4 | 819.4 | n.s. | n.s. |
| 67.2 | 2006 | ST | 3 | 8033.1 | 742.3 | n.s. | n.s. |
| 101 | 2006 | CT | 4 | 9000.9 | 723.8 | n.s. | n.s. |
| 101 | 2006 | NT | 3 | 8680.1 | 519.7 | n.s. | n.s. |
| 101 | 2006 | ST | 3 | 9086.0 | 1196.1 | n.s. | n.s. |
| 134 | 2006 | CT | 4 | 8659.6 | 740.1 | n.s. | n.s. |
| 134 | 2006 | NT | 3 | 8593.1 | 822.2 | n.s. | n.s. |
| 134 | 2006 | ST | 3 | 9297.4 | 1870.9 | n.s. | n.s. |
| **246** | **2006** | **CT** | **4** | **8170.3** | **469.9** | **b** | **B** |
| 246 | 2006 | NT | 3 | 8680.9 | 1122.6 | ab | AB |
| **246** | **2006** | **ST** | **3** | **10025.3** | **1339.0** | **a** | **A** |
|  |  |  |  |  |  |  |  |
| 0 | 2007 | CT | 4 | 5469.7 | 814.9 | n.s. | n.s. |
| 0 | 2007 | NT | 3 | 5225.8 | 308.7 | n.s. | n.s. |
| 0 | 2007 | ST | 3 | 5987.3 | 618.8 | n.s. | n.s. |
| **67.2** | **2007** | **CT** | 4 | **9609.1** | **416.8** | **a** | **A** |
| **67.2** | **2007** | **NT** | 3 | **8255.7** | **229.8** | **b** | **B** |
| 67.2 | 2007 | ST | 3 | 8929.7 | 581.8 | ab | AB |
| **134** | **2007** | **CT** | **4** | **10211.6** | **320.5** | **a** | **A** |
| **134** | **2007** | **NT** | **3** | **9630.9** | **360.2** | **b** | **B** |
| 134 | 2007 | ST | 3 | 9902.9 | 502.2 | ab | AB |
| 202 | 2007 | CT | 4 | 9612.2 | 226.5 | n.s. | n.s. |
| 202 | 2007 | NT | 3 | 9552.7 | 343.3 | n.s. | n.s. |
| 202 | 2007 | ST | 3 | 10131.5 | 480.8 | n.s. | n.s. |
| **246** | **2007** | **CT** | **4** | **9963.9** | **311.3** | **b** | **B** |
| **246** | **2007** | **NT** | **3** | **10591.2** | **177.4** | **a** | **A** |
| **246** | **2007** | **ST** | **3** | **10131.4** | **237.0** | **b** | AB |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ Tillage systems within a year and N rate with different uppercase letters are significantly different at P<0.05; Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate; N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

**Table S7.** Means, standard deviations, and significance (S) for harvested grain yield of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2006 to 2017 under different N rates and tillage systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | Yield  (kg ha-1) | Standard Deviation | S£ |
| 0 | 2006 | NT | 3 | 4368.4 | 745.9 | n.s. |
| 0 | 2006 | ST | 3 | 5196.5 | 1040.5 | n.s. |
| 33.6 | 2006 | NT | 3 | 5752.4 | 850.3 | n.s. |
| 33.6 | 2006 | ST | 3 | 6536.5 | 1159.9 | n.s. |
| 67.2 | 2006 | NT | 3 | 7428.4 | 819.4 | n.s. |
| 67.2 | 2006 | ST | 3 | 8033.1 | 742.3 | n.s. |
| 101 | 2006 | NT | 3 | 8680.1 | 519.7 | n.s. |
| 101 | 2006 | ST | 3 | 9086.0 | 1196.1 | n.s. |
| 134 | 2006 | NT | 3 | 8593.1 | 822.2 | n.s. |
| 134 | 2006 | ST | 3 | 9297.4 | 1870.9 | n.s. |
| 246 | 2006 | NT | 3 | 8680.9 | 1122.6 | n.s. |
| 246 | 2006 | ST | 3 | 10025.3 | 1339.0 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2007 | NT | 3 | 5225.8 | 308.7 | n.s. |
| 0 | 2007 | ST | 3 | 5987.3 | 618.8 | n.s. |
| 67.2 | 2007 | NT | 3 | 8255.7 | 229.8 | n.s. |
| 67.2 | 2007 | ST | 3 | 8929.7 | 581.8 | n.s. |
| 134 | 2007 | NT | 3 | 9630.9 | 360.2 | n.s. |
| 134 | 2007 | ST | 3 | 9902.9 | 502.2 | n.s. |
| 202 | 2007 | NT | 3 | 9552.7 | 343.3 | n.s. |
| 202 | 2007 | ST | 3 | 10131.5 | 480.8 | n.s. |
| **246** | **2007** | **NT** | **3** | **10591.2** | **177.4** | **\*** |
| 246 | 2007 | ST | 3 | 10131.4 | 237.0 | \* |
|  |  |  |  |  |  |  |
| 0 | 2009 | NT | 3 | 5185.4 | 475.0 | n.s. |
| 0 | 2009 | ST | 7 | 5423.7 | 764.5 | n.s. |
| 67.2 | 2009 | NT | 2 | 7271.8 | 40.3 | \*\* |
| **67.2** | **2009** | **ST** | **7** | **9320.4** | **499.6** | **\*\*** |
| 134 | 2009 | ST | 7 | 10183.9 | 321.5 | N/A |
| 202 | 2009 | NT | 1€ | 8815.1 |  | N/A |
| 202 | 2009 | ST | 7 | 10051.2 | 280.9 | N/A |
| 246 | 2009 | NT | 1€ | 10393.0 |  | N/A |
| 246 | 2009 | ST | 7 | 10775.9 | 722.2 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2010 | NT | 3 | 5375.5 | 397.0 | n.s. |
| 0 | 2010 | ST | 7 | 5538.0 | 719.9 | n.s. |
| **67.2** | **2010** | **NT** | **3** | **8641.4** | **158.7** | **\*** |
| 67.2 | 2010 | ST | 7 | 8272.1 | 305.5 | \* |
| 134 | 2010 | NT | 3 | 11552.0 | 1184.2 | n.s. |
| 134 | 2010 | ST | 7 | 10821.9 | 403.7 | n.s. |
| 202 | 2010 | NT | 3 | 11072.7 | 490.8 | n.s. |
| 202 | 2010 | ST | 7 | 11119.9 | 684.9 | n.s. |
| 246 | 2010 | NT | 3 | 10774.7 | 189.5 | n.s. |
| 246 | 2010 | ST | 7 | 10980.6 | 776.2 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2011 | NT | 3 | 4927.6 | 137.1 | n.s. |
| 0 | 2011 | ST | 7 | 5432.6 | 614.0 | n.s. |
| 67.2 | 2011 | NT | 3 | 6825.5 | 511.0 | \*\* |
| **67.2** | **2011** | **ST** | **7** | **8163.6** | **809.0** | **\*\*** |
| 134 | 2011 | NT | 3 | 8790.9 | 254.5 | n.s. |
| 134 | 2011 | ST | 7 | 9874.3 | 989.2 | n.s. |
| 202 | 2011 | NT | 2 | 9645.9 | 12.0 | n.s. |
| 202 | 2011 | ST | 5 | 10969.0 | 1001.1 | n.s. |
| 246 | 2011 | NT | 2 | 10645.1 | 1920.2 | n.s. |
| 246 | 2011 | ST | 2 | 10849.3 | 218.1 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2012 | NT | 3 | 4789.5 | 367.1 | n.s. |
| 0 | 2012 | ST | 7 | 4365.8 | 423.4 | n.s. |
| 67.2 | 2012 | NT | 2 | 7698.7 | 1031.0 | n.s. |
| 67.2 | 2012 | ST | 6 | 7227.8 | 524.9 | n.s. |
| 134 | 2012 | NT | 1€ | 10056.0 |  | N/A |
| 134 | 2012 | ST | 3 | 9304.6 | 514.0 | N/A |
| 202 | 2012 | NT | 2 | 9261.5 | 1015.3 | n.s. |
| 202 | 2012 | ST | 4 | 9720.3 | 585.4 | n.s. |
| 246 | 2012 | NT | 1€ | 10372.0 |  | N/A |
| 246 | 2012 | ST | 2 | 10139.0 | 624.8 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2013 | NT | 3 | 5694.6 | 859.4 | n.s. |
| 0 | 2013 | ST | 4 | 5851.4 | 614.7 | n.s. |
| 67.2 | 2013 | NT | 3 | 8969.1 | 1101.3 | n.s. |
| 67.2 | 2013 | ST | 3 | 8604.6 | 661.1 | n.s. |
| 134 | 2013 | NT | 3 | 11155.5 | 183.7 | n.s. |
| 134 | 2013 | ST | 4 | 10852.4 | 457.7 | n.s. |
| 202 | 2013 | NT | 3 | 11218.3 | 246.7 | n.s. |
| 202 | 2013 | ST | 4 | 10550.7 | 1200.1 | n.s. |
| 246 | 2013 | NT | 3 | 11023.0 | 378.7 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2014 | NT | 3 | 4952.0 | 549.6 | n.s. |
| 0 | 2014 | ST | 3 | 5057.0 | 526.6 | n.s. |
| 33.6 | 2014 | NT | 3 | 7312.3 | 576.4 | N/A |
| 67.2 | 2014 | NT | 3 | 8001.3 | 662.6 | n.s. |
| 67.2 | 2014 | ST | 3 | 8520.0 | 87.2 | n.s. |
| 134 | 2014 | NT | 3 | 9699.0 | 424.7 | n.s. |
| 134 | 2014 | ST | 3 | 10086.2 | 364.8 | n.s. |
| 202 | 2014 | NT | 3 | 9890.3 | 553.0 | n.s. |
| 202 | 2014 | ST | 3 | 9993.6 | 382.1 | n.s. |
| 246 | 2014 | NT | 3 | 9834.0 | 788.1 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2015 | NT | 3 | 5989.6 | 596.7 | n.s. |
| 0 | 2015 | ST | 3 | 5668.9 | 650.3 | n.s. |
| 33.6 | 2015 | NT | 3 | 7395.2 | 561.4 | N/A |
| **67.2** | **2015** | **NT** | **3** | **8139.3** | **373.3** | **\*** |
| 67.2 | 2015 | ST | 3 | 7553.3 | 244.9 | \* |
| 134 | 2015 | NT | 3 | 9672.9 | 1025.4 | n.s. |
| 134 | 2015 | ST | 3 | 9781.3 | 985.9 | n.s. |
| 202 | 2015 | NT | 3 | 10398.0 | 446.1 | n.s. |
| 202 | 2015 | ST | 3 | 10902.9 | 256.9 | n.s. |
| 246 | 2015 | NT | 3 | 10490.1 | 442.1 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2016 | NT | 3 | 4906.9 | 504.8 | \*\* |
| **0** | **2016** | **ST** | **3** | **5815.2** | **331.2** | **\*\*** |
| 33.6 | 2016 | NT | 3 | 6462.3 | 127.8 | N/A |
| 67.2 | 2016 | NT | 3 | 7971.9 | 820.6 | n.s. |
| 67.2 | 2016 | ST | 3 | 8249.2 | 235.5 | n.s. |
| 134 | 2016 | NT | 3 | 9530.4 | 696.5 | n.s. |
| 134 | 2016 | ST | 3 | 9644.7 | 1224.9 | n.s. |
| 202 | 2016 | NT | 3 | 9830.3 | 758.5 | \*\* |
| **202** | **2016** | **ST** | **3** | **10814.3** | **87.2** | **\*\*** |
| 246 | 2016 | NT | 3 | 10283.7 | 538.6 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2017 | NT | 3 | 5360.0 | 593.7 | n.s. |
| 0 | 2017 | ST | 3 | 5965.2 | 332.5 | n.s. |
| 33.6 | 2017 | NT | 3 | 6518.4 | 323.1 | N/A |
| 67.2 | 2017 | NT | 3 | 8223.4 | 647.8 | n.s. |
| 67.2 | 2017 | ST | 3 | 8603.2 | 551.4 | n.s. |
| 134 | 2017 | NT | 3 | 9513.2 | 761.9 | n.s. |
| 134 | 2017 | ST | 3 | 9450.4 | 578.9 | n.s. |
| 202 | 2017 | NT | 3 | 10029.7 | 369.2 | n.s. |
| 202 | 2017 | ST | 3 | 10122.1 | 225.2 | n.s. |
| 246 | 2017 | NT | 3 | 10437.1 | 535.5 | N/A |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ \*\*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.05; \*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate, N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

€Only one observation for the NT tillage treatment this year

**Table S8.** Means, standard deviations, and significance (S) for crop residue (CR) yield of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2001 to 2007 under different N rates and tillage systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | CR Yield  (kg ha-1) | Standard Deviation | S£ |
| 0 | 2001 | CT | 4 | 7495.8 | 587.1 | \*\* |
| **0** | **2001** | **NT** | **3** | **9071.4** | **792.3** | **\*\*** |
| 33.6 | 2001 | NT | 3 | 10007.7 | 131.3 | N/A |
| 67.2 | 2001 | CT | 4 | 9585.8 | 781.7 | n.s. |
| 67.2 | 2001 | NT | 3 | 10648.8 | 727.4 | n.s. |
| 101 | 2001 | NT | 3 | 11435.6 | 979.7 | N/A |
| 134 | 2001 | CT | 4 | 10309.3 | 351.8 | \*\* |
| **134** | **2001** | **NT** | **3** | **11640.9** | **1179.9** | **\*\*** |
| 168 | 2001 | CT | 4 | 11343.1 | 768.0 | n.s. |
| 168 | 2001 | NT | 3 | 11688.5 | 913.6 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2002 | CT | 4 | 6333.5 | 679.2 | n.s. |
| 0 | 2002 | NT | 3 | 6119.3 | 307.9 | n.s. |
| **33.6** | **2002** | **CT** | **4** | **8397.0** | **514.6** | **\*\*** |
| 33.6 | 2002 | NT | 3 | 6905.0 | 1229.5 | \*\* |
| 67.2 | 2002 | CT | 4 | 8705.1 | 1001.4 | n.s. |
| 67.2 | 2002 | NT | 3 | 7885.9 | 1199.8 | n.s. |
| 101 | 2002 | NT | 3 | 8438.2 | 1933.2 | N/A |
| 134 | 2002 | CT | 4 | 9301.9 | 393.8 | n.s. |
| 134 | 2002 | NT | 3 | 8626.8 | 1373.7 | n.s. |
| 202 | 2002 | CT | 4 | 9032.0 | 992.9 | n.s. |
| 202 | 2002 | NT | 3 | 9366.4 | 602.5 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2003 | CT | 4 | 5653.6 | 773.9 | n.s. |
| 0 | 2003 | NT | 3 | 5100.6 | 933.2 | n.s. |
| 33.6 | 2003 | CT | 4 | 6323.3 | 707.4 | n.s. |
| 33.6 | 2003 | NT | 3 | 5708.6 | 390.8 | n.s. |
| 67.2 | 2003 | CT | 4 | 5633.1 | 1540.5 | n.s. |
| 67.2 | 2003 | NT | 3 | 5426.9 | 700.2 | n.s. |
| 101 | 2003 | CT | 4 | 6321.5 | 624.7 | n.s. |
| 101 | 2003 | NT | 3 | 6641.3 | 1120.7 | n.s. |
| 134 | 2003 | CT | 4 | 7248.7 | 290.2 | n.s. |
| 134 | 2003 | NT | 3 | 6617.8 | 1007.0 | n.s. |
| 224 | 2003 | CT | 4 | 7366.7 | 1124.0 | n.s. |
| 224 | 2003 | NT | 3 | 8393.8 | 621.0 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2004 | CT | 4 | 5884.1 | 668.5 | n.s. |
| 0 | 2004 | NT | 3 | 5109.5 | 416.4 | n.s. |
| **33.6** | **2004** | **CT** | **4** | **7311.0** | **392.8** | **\*\*** |
| 33.6 | 2004 | NT | 3 | 6255.3 | 834.1 | \*\* |
| 67.2 | 2004 | CT | 4 | 7676.8 | 793.6 | n.s. |
| 67.2 | 2004 | NT | 3 | 7109.6 | 145.8 | n.s. |
| 101 | 2004 | CT | 4 | 7026.0 | 537.8 | n.s. |
| 101 | 2004 | NT | 3 | 6742.0 | 941.9 | n.s. |
| 134 | 2004 | CT | 4 | 8190.6 | 513.9 | n.s. |
| 134 | 2004 | NT | 3 | 7677.1 | 99.8 | n.s. |
| 224 | 2004 | CT | 4 | 8955.1 | 332.8 | n.s. |
| 224 | 2004 | NT | 3 | 8792.1 | 143.3 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2005 | CT | 4 | 4640.2 | 926.5 | n.s. |
| 0 | 2005 | NT | 3 | 5335.1 | 563.7 | n.s. |
| 33.6 | 2005 | CT | 4 | 6502.2 | 695.4 | n.s. |
| 33.6 | 2005 | NT | 3 | 6171.7 | 1109.9 | n.s. |
| **67.2** | **2005** | **CT** | **4** | **6867.0** | **338.2** | **\*\*** |
| 67.2 | 2005 | NT | 3 | 6016.4 | 700.0 | \*\* |
| 101 | 2005 | CT | 4 | 7049.4 | 321.5 | n.s. |
| 101 | 2005 | NT | 3 | 6427.5 | 718.2 | n.s. |
| 134 | 2005 | CT | 4 | 8007.1 | 512.5 | n.s. |
| 134 | 2005 | NT | 3 | 7724.2 | 964.2 | n.s. |
| 246 | 2005 | CT | 4 | 8915.9 | 218.5 | n.s. |
| 246 | 2005 | NT | 3 | 7562.0 | 1483.8 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2006 | CT | 4 | 4917.9 | 718.4 | n.s. |
| 0 | 2006 | NT | 3 | 5496.2 | 373.7 | n.s. |
| 33.6 | 2006 | CT | 4 | 6589.5 | 501.4 | n.s. |
| 33.6 | 2006 | NT | 3 | 7157.0 | 634.9 | n.s. |
| 67.2 | 2006 | CT | 4 | 6309.1 | 921.4 | n.s. |
| 67.2 | 2006 | NT | 3 | 7312.3 | 707.1 | n.s. |
| 101 | 2006 | CT | 4 | 7037.6 | 119.8 | n.s. |
| 101 | 2006 | NT | 3 | 7279.6 | 828.8 | n.s. |
| 134 | 2006 | CT | 4 | 6993.4 | 863.4 | \*\* |
| **134** | **2006** | **NT** | **3** | **8778.5** | **458.7** | **\*\*** |
| 246 | 2006 | CT | 4 | 6419.6 | 336.9 | \*\* |
| **246** | **2006** | **NT** | **3** | **9195.898** | **944.2** | **\*\*** |
|  |  |  |  |  |  |  |
| 0 | 2007 | CT | 4 | 5730.059 | 670.4 | n.s. |
| 0 | 2007 | NT | 3 | 6175.575 | 947.4 | n.s. |
| **67.2** | **2007** | **CT** | **4** | **8161.414** | **541.4** | **\*\*** |
| 67.2 | 2007 | NT | 3 | 7262.628 | 182.8 | \*\* |
| 134 | 2007 | CT | 4 | 8438.309 | 959.1 | n.s. |
| 134 | 2007 | NT | 3 | 8157.434 | 292.3 | n.s. |
| 202 | 2007 | CT | 4 | 8400.892 | 988.2 | n.s. |
| 202 | 2007 | NT | 3 | 9050.574 | 186.0 | n.s. |
| 246 | 2007 | CT | 4 | 10678.438 | 967.8 | n.s. |
| 246 | 2007 | NT | 3 | 10691.777 | 800.4 | n.s. |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ \*\*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.05; \*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate; N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

**Table S9.** Means, standard deviations, and significance (S) for crop residue (CR) yield of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2006 to 2007 under different N rates and tillage systems.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | CR Yield  (kg ha-1) | Standard Deviation | S£ | S£ |
| 0 | 2006 | CT | 4 | 4917.9 | 718.4 | n.s. | n.s. |
| 0 | 2006 | NT | 3 | 5496.2 | 373.7 | n.s. | n.s. | |
| 0 | 2006 | ST | 3 | 5617.5 | 108.1 | n.s. | n.s. | |
| 33.6 | 2006 | CT | 4 | 6589.5 | 501.4 | n.s. | n.s. | |
| 33.6 | 2006 | NT | 3 | 7157.0 | 634.9 | n.s. | n.s. | |
| 33.6 | 2006 | ST | 3 | 6275.6 | 1199.7 | n.s. | n.s. | |
| 67.2 | 2006 | CT | 4 | 6309.1 | 921.4 | n.s. | n.s. | |
| 67.2 | 2006 | NT | 3 | 7312.3 | 707.1 | n.s. | n.s. | |
| 67.2 | 2006 | ST | 3 | 7154.6 | 808.9 | n.s. | n.s. | |
| **101** | **2006** | **CT** | **4** | **7037.6** | **119.8** | **b** | **C** | |
| 101 | 2006 | NT | 3 | 7279.6 | 828.8 | ab | BC | |
| **101** | **2006** | **ST** | **3** | **8174.8** | **577.1** | **a** | **AB** | |
| **134** | **2006** | **CT** | **4** | **6993.4** | **863.4** | **b** | **CB** | |
| **134** | **2006** | **NT** | **3** | **8778.5** | **458.7** | **a** | **A** | |
| 134 | 2006 | ST | 3 | 8092.2 | 465.2 | ab | AB | |
| **246** | **2006** | **CT** | **4** | **6419.6** | **336.9** | **c** | **C** | |
| **246** | **2006** | **NT** | **3** | **9195.9** | **944.2** | **a** | **A** | |
| **246** | **2006** | **ST** | **3** | **7611.3** | **182.9** | **b** | **B** | |
|  |  |  |  |  |  |  |  | |
| **0** | **2007** | **CT** | **4** | **5730.1** | **670.4** | **b** | n.s. | |
| 0 | 2007 | NT | 3 | 6175.6 | 947.4 | ab | n.s. | |
| **0** | **2007** | **ST** | **3** | **7348.0** | **882.7** | **a** | n.s. | |
| **67.2** | **2007** | **CT** | **4** | **8161.4** | **541.4** | **a** | AB | |
| **67.2** | **2007** | **NT** | **3** | **7262.6** | **182.8** | **b** | C | |
| 67.2 | 2007 | ST | 3 | 7904.3 | 781.5 | ab | CB | |
| 134 | 2007 | CT | 4 | 8438.3 | 959.1 | n.s. | n.s. | |
| 134 | 2007 | NT | 3 | 8157.4 | 292.3 | n.s. | n.s. | |
| 134 | 2007 | ST | 3 | 8531.5 | 578.8 | n.s. | n.s. | |
| 202 | 2007 | CT | 4 | 8400.9 | 988.2 | n.s. | n.s. | |
| 202 | 2007 | NT | 3 | 9050.6 | 186.0 | n.s. | n.s. | |
| 202 | 2007 | ST | 3 | 8415.2 | 1443.6 | n.s. | n.s. | |
| **246** | **2007** | **CT** | **4** | **10678.4** | **967.8** | **a** | **A** | |
| **246** | **2007** | **NT** | **3** | **10691.8** | **800.4** | **a** | **B** | |
| **246** | **2007** | **ST** | **3** | **8631.3** | **690.9** | **b** | **B** | |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ Tillage systems within a year and N rate with different uppercase letters are significantly different at P<0.05; Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate, N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

**Table S10.** Means, standard deviations, and significance (S) for crop residue (CR) yield of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2006 to 2017 under different N rates and tillage systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | CR Yield  (kg ha-1) | Standard Deviation | S£ |
| 0 | 2006 | NT | 3 | 5496.2 | 373.7 | n.s. |
| 0 | 2006 | ST | 3 | 5617.5 | 108.1 | n.s. |
| 33.6 | 2006 | NT | 3 | 7157.0 | 634.9 | n.s. |
| 33.6 | 2006 | ST | 3 | 6275.6 | 1199.7 | n.s. |
| 67.2 | 2006 | NT | 3 | 7312.3 | 707.1 | n.s. |
| 67.2 | 2006 | ST | 3 | 7154.6 | 808.9 | n.s. |
| 101 | 2006 | NT | 3 | 7279.6 | 828.8 | n.s. |
| 101 | 2006 | ST | 3 | 8174.8 | 577.1 | n.s. |
| 134 | 2006 | NT | 3 | 8778.5 | 458.7 | n.s. |
| 134 | 2006 | ST | 3 | 8092.2 | 465.2 | n.s. |
| **246** | **2006** | **NT** | **3** | **9195.9** | **944.2** | **\*\*** |
| 246 | 2006 | ST | 3 | 7611.3 | 182.9 | \*\* |
|  |  |  |  |  |  |  |
| 0 | 2007 | NT | 3 | 6175.6 | 947.4 | n.s. |
| 0 | 2007 | ST | 3 | 7348.0 | 882.7 | n.s. |
| 67.2 | 2007 | NT | 3 | 7262.6 | 182.8 | n.s. |
| 67.2 | 2007 | ST | 3 | 7904.3 | 781.5 | n.s. |
| 134 | 2007 | NT | 3 | 8157.4 | 292.3 | n.s. |
| 134 | 2007 | ST | 3 | 8531.5 | 578.8 | n.s. |
| 202 | 2007 | NT | 3 | 9050.6 | 186.0 | n.s. |
| 202 | 2007 | ST | 3 | 8415.2 | 1443.6 | n.s. |
| **246** | **2007** | **NT** | **3** | **10691.8** | **800.4** | **\*\*** |
| 246 | 2007 | ST | 3 | 8631.3 | 690.9 | \*\* |
|  |  |  |  |  |  |  |
| 0 | 2009 | NT | 3 | 7005.1 | 925.2 | n.s. |
| 0 | 2009 | ST | 7 | 6022.3 | 747.9 | n.s. |
| 67.2 | 2009 | NT | 2 | 8706.1 | 276.0 | n.s. |
| 67.2 | 2009 | ST | 7 | 8018.1 | 877.4 | n.s. |
| 134 | 2009 | ST | 7 | 8601.0 | 735.5 | N/A |
| 202 | 2009 | NT | 1€ | 8634.5 |  | N/A |
| 202 | 2009 | ST | 7 | 9002.3 | 680.0 | N/A |
| 246 | 2009 | NT | 1€ | 9114.6 |  | N/A |
| 246 | 2009 | ST | 7 | 9450.3 | 693.6 | N/A. |
|  |  |  |  |  |  |  |
| **0** | **2010** | **NT** | **3** | **5969.8** | **755.4** | **\*\*** |
| 0 | 2010 | ST | 7 | 4403.1 | 664.5 | \*\* |
| 67.2 | 2010 | NT | 3 | 7032.3 | 733.1 | n.s. |
| 67.2 | 2010 | ST | 7 | 6522.6 | 541.3 | n.s. |
| 134 | 2010 | NT | 3 | 8454.6 | 682.5 | n.s. |
| 134 | 2010 | ST | 7 | 8600.9 | 980.0 | n.s. |
| 202 | 2010 | NT | 3 | 7723.0 | 206.2 | n.s. |
| 202 | 2010 | ST | 7 | 8127.8 | 1046.1 | n.s. |
| 246 | 2010 | NT | 3 | 7946.9 | 571.9 | n.s. |
| 246 | 2010 | ST | 7 | 8181.6 | 1191.3 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2011 | NT | 3 | 6460.3 | 442.0 | n.s. |
| 0 | 2011 | ST | 7 | 6374.6 | 1941.2 | n.s. |
| 67.2 | 2011 | NT | 3 | 8399.3 | 678.7 | n.s. |
| 67.2 | 2011 | ST | 7 | 8551.6 | 826.9 | n.s. |
| 134 | 2011 | NT | 3 | 8915.3 | 712.7 | n.s. |
| 134 | 2011 | ST | 7 | 8877.7 | 1725.4 | n.s. |
| 202 | 2011 | NT | 2 | 9624.1 | 41.6 | n.s. |
| 202 | 2011 | ST | 5 | 9720.7 | 1427.4 | n.s. |
| 246 | 2011 | NT | 2 | 10515.9 | 2038.6 | n.s. |
| 246 | 2011 | ST | 2 | 10272.2 | 1393.9 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2012 | NT | 3 | 7062.3 | 698.0 | n.s. |
| 0 | 2012 | ST | 7 | 5833.8 | 1051.5 | n.s. |
| 67.2 | 2012 | NT | 2 | 10092.5 | 1529.8 | n.s. |
| 67.2 | 2012 | ST | 6 | 9035.2 | 1078.5 | n.s. |
| 134 | 2012 | NT | 1€ | 11973.8 |  | N/A |
| 134 | 2012 | ST | 3 | 10415.1 | 333.2 | N/A |
| 202 | 2012 | NT | 2 | 10583.1 | 970.3 | n.s. |
| 202 | 2012 | ST | 4 | 10344.8 | 1956.4 | n.s. |
| 246 | 2012 | NT | 1€ | 10770.0 |  | N/A |
| 246 | 2012 | ST | 2 | 9753.6 | 10.2 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2013 | NT | 3 | 7287.8 | 1982.6 | n.s. |
| 0 | 2013 | ST | 4 | 6613.7 | 580.8 | n.s. |
| 67.2 | 2013 | NT | 3 | 9682.1 | 826.0 | n.s. |
| 67.2 | 2013 | ST | 3 | 9756.7 | 864.0 | n.s. |
| 134 | 2013 | NT | 3 | 10487.5 | 411.3 | n.s. |
| 134 | 2013 | ST | 4 | 10406.4 | 377.2 | n.s. |
| 202 | 2013 | NT | 3 | 10828.8 | 958.8 | n.s. |
| 202 | 2013 | ST | 4 | 10400.8 | 974.5 | n.s. |
| 246 | 2013 | NT | 3 | 10805.9 | 1341.2 | N/A |
|  |  |  |  |  |  |  |
| **0** | **2014** | **NT** | **3** | **6922.3** | **438.8** | **\*\*** |
| 0 | 2014 | ST | 3 | 5809.4 | 361.9 | \*\* |
| 33.6 | 2014 | NT | 3 | 9211.0 | 1143.3 | N/A |
| 67.2 | 2014 | NT | 3 | 9510.3 | 243.8 | n.s. |
| 67.2 | 2014 | ST | 3 | 9875.3 | 1526.9 | n.s. |
| 134 | 2014 | NT | 3 | 10488.7 | 781.1 | n.s. |
| 134 | 2014 | ST | 3 | 10233.3 | 928.2 | n.s. |
| 202 | 2014 | NT | 3 | 10296.3 | 254.8 | n.s. |
| 202 | 2014 | ST | 3 | 10155.5 | 559.9 | n.s. |
| 246 | 2014 | NT | 3 | 9930.7 | 590.0 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2015 | NT | 3 | 7995.4 | 522.6 | n.s. |
| 0 | 2015 | ST | 3 | 7522.2 | 1421.8 | n.s. |
| 33.6 | 2015 | NT | 3 | 9645.8 | 695.0 | N/A |
| 67.2 | 2015 | NT | 3 | 10354.2 | 1083.6 | n.s. |
| 67.2 | 2015 | ST | 3 | 9433.0 | 296.6 | n.s. |
| 134 | 2015 | NT | 3 | 10901.0 | 738.4 | n.s. |
| 134 | 2015 | ST | 3 | 10247.8 | 602.8 | n.s. |
| 202 | 2015 | NT | 3 | 10905.3 | 350.4 | n.s. |
| 202 | 2015 | ST | 3 | 11319.2 | 1140.8 | n.s. |
| 246 | 2015 | NT | 3 | 11000.1 | 969.1 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2016 | NT | 3 | 6900.1 | 751.1 | n.s. |
| 0 | 2016 | ST | 3 | 7272.8 | 1119.4 | n.s. |
| 33.6 | 2016 | NT | 3 | 10350.6 | 646.4 | N/A |
| 67.2 | 2016 | NT | 3 | 11640.1 | 1806.4 | n.s. |
| 67.2 | 2016 | ST | 3 | 12002.4 | 1174.7 | n.s. |
| 134 | 2016 | NT | 3 | 11626.5 | 723.0 | n.s. |
| 134 | 2016 | ST | 3 | 11686.9 | 682.3 | n.s. |
| 202 | 2016 | NT | 3 | 9955.1 | 523.3 | n.s. |
| 202 | 2016 | ST | 3 | 11178.5 | 920.5 | n.s. |
| 246 | 2016 | NT | 3 | 11196.7 | 1679.7 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2017 | NT | 3 | 12064.5 | 1569.4 | n.s. |
| 0 | 2017 | ST | 3 | 8054.6 | 3196.3 | n.s. |
| 33.6 | 2017 | NT | 3 | 13421.0 | 1548.0 | N/A |
| 67.2 | 2017 | NT | 3 | 13740.5 | 992.0 | n.s. |
| 67.2 | 2017 | ST | 3 | 11385.3 | 3514.4 | n.s. |
| **134** | **2017** | **NT** | **3** | **13614.2** | **2063.9** | **\*\*** |
| 134 | 2017 | ST | 3 | 9828.4 | 332.1 | \*\* |
| 202 | 2017 | NT | 3 | 13920.8 | 3342.1 | n.s. |
| 202 | 2017 | ST | 3 | 11949.2 | 3698.5 | n.s. |
| 246 | 2017 | NT | 3 | 13797.0 | 2321.9 | N/A |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ \*\*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.05; \*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate; N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

€Only one observation for the NT tillage treatment this year

**Table S11.** Means, standard deviations, and significance for harvested grain nitrogen (N) content of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2001 to 2007 under different N rates and tillage systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | Grain  (kg N ha-1) | Standard  Deviation | S£ |
| 0 | 2001 | CT | 4 | 45.7 | 5.2 | n.s. |
| 0 | 2001 | NT | 3 | 52.1 | 5.3 | n.s. |
| 33.6 | 2001 | NT | 3 | 63.0 | 13.7 | N/A |
| **67.2** | **2001** | **CT** | **4** | **83.9** | **5.3** | **\*** |
| 67.2 | 2001 | NT | 3 | 74.5 | 4.8 | \* |
| 101 | 2001 | NT | 3 | 94.3 | 6.1 | N/A |
| 134 | 2001 | CT | 4 | 110.5 | 9.2 | n.s. |
| 134 | 2001 | NT | 3 | 109.3 | 10.0 | n.s. |
| 168 | 2001 | CT | 4 | 121.6 | 2.3 | n.s. |
| 168 | 2001 | NT | 3 | 119.2 | 5.7 | n.s. |
|  |  |  |  |  |  |  |
| **0** | **2002** | **CT** | **4** | **52.6** | **7.6** | **\*** |
| 0 | 2002 | NT | 3 | 43.2 | 2.7 | \* |
| **33.6** | **2002** | **CT** | **4** | **93.8** | **7.9** | **\*** |
| 33.6 | 2002 | NT | 3 | 56.3 | 12.0 | \* |
| **67.2** | **2002** | **CT** | **4** | **96.6** | **11.2** | **\*\*** |
| 67.2 | 2002 | NT | 3 | 59.0 | 4.7 | \*\* |
| 101 | 2002 | NT | 3 | 73.1 | 9.2 | N/A |
| **134** | **2002** | **CT** | **4** | **126.4** | **5.8** | **\*\*** |
| 134 | 2002 | NT | 3 | 91.4 | 6.8 | \*\* |
| **202** | **2002** | **CT** | **4** | **134.0** | **11.3** | **\*\*** |
| 202 | 2002 | NT | 3 | 116.6 | 9.4 | **\*\*** |
|  |  |  |  |  |  |  |
| **0** | **2003** | **CT** | **4** | **54.2** | **8.2** | **\*\*** |
| 0 | 2003 | NT | 3 | 33.7 | 2.6 | \*\* |
| **33.6** | **2003** | **CT** | **4** | **66.5** | **6.4** | **\*** |
| 33.6 | 2003 | NT | 3 | 53.1 | 7.3 | \* |
| 67.2 | 2003 | CT | 4 | 69.5 | 0.8 | n.s. |
| 67.2 | 2003 | NT | 3 | 60.3 | 9.7 | n.s. |
| **101** | **2003** | **CT** | **4** | **85.8** | **4.6** | **\*\*** |
| 101 | 2003 | NT | 3 | 65.8 | 9.5 | \*\* |
| **134** | **2003** | **CT** | **4** | **99.8** | **10.8** | **\*\*** |
| 134 | 2003 | NT | 3 | 83.2 | 10.5 | **\*\***. |
| **224** | **2003** | **CT** | **4** | **117.9** | **15.0** | **\*\*** |
| 224 | 2003 | NT | 3 | 98.1 | 8.2 | **\*\*** |
|  |  |  |  |  |  |  |
| **0** | **2004** | **CT** | **4** | **62.6** | **14.1** | **\*\*** |
| 0 | 2004 | NT | 3 | 35.0 | 4.0 | \*\* |
| **33.6** | **2004** | **CT** | **4** | **98.4** | **13.4** | **\*\*** |
| 33.6 | 2004 | NT | 3 | 56.0 | 5.8 | \*\* |
| **67.2** | **2004** | **CT** | **4** | **109.5** | **8.1** | **\*\*** |
| 67.2 | 2004 | NT | 3 | 72.3 | 5.4 | \*\* |
| **101** | **2004** | **CT** | **4** | **125.7** | **8.3** | **\*\*** |
| 101 | 2004 | NT | 3 | 90.1 | 9.8 | \*\* |
| **134** | **2004** | **CT** | **4** | **131.0** | **8.9** | **\*\*** |
| 134 | 2004 | NT | 3 | 102.2 | 8.1 | \*\* |
| 224 | 2004 | CT | 4 | 142.5 | 10.9 | n.s. |
| 224 | 2004 | NT | 3 | 148.6 | 3.6 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2005 | CT | 4 | 44.6 | 4.9 | n.s. |
| 0 | 2005 | NT | 3 | 50.6 | 8.7 | n.s. |
| 33.6 | 2005 | CT | 4 | 70.4 | 3.2 | n.s. |
| 33.6 | 2005 | NT | 3 | 68.9 | 11.2 | n.s. |
| 67.2 | 2005 | CT | 4 | 83.2 | 4.1 | n.s. |
| 67.2 | 2005 | NT | 3 | 85.9 | 11.4 | n.s. |
| 101 | 2005 | CT | 4 | 101.6 | 6.0 | n.s. |
| 101 | 2005 | NT | 3 | 98.5 | 5.3 | n.s. |
| 134 | 2005 | CT | 4 | 126.6 | 15.2 | n.s. |
| 134 | 2005 | NT | 3 | 116.5 | 11.9 | n.s. |
| 246 | 2005 | CT | 4 | 149.0 | 11.6 | n.s. |
| 246 | 2005 | NT | 3 | 134.0 | 12.6 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2006 | CT | 4 | 56.1 | 8.9 | n.s. |
| 0 | 2006 | NT | 3 | 45.2 | 7.8 | n.s. |
| **33.6** | **2006** | **CT** | **4** | **92.1** | **4.3** | **\*\*** |
| 33.6 | 2006 | NT | 3 | 59.9 | 7.9 | \*\* |
| 67.2 | 2006 | CT | 4 | 92.7 | 3.9 | n.s. |
| 67.2 | 2006 | NT | 3 | 85.4 | 4.5 | n.s. |
| 101 | 2006 | CT | 4 | 105.1 | 16.4 | n.s. |
| 101 | 2006 | NT | 3 | 106.2 | 8.8 | n.s. |
| 134 | 2006 | CT | 4 | 112.2 | 12.0 | n.s. |
| 134 | 2006 | NT | 3 | 106.9 | 18.2 | n.s. |
| 246 | 2006 | CT | 4 | 109.2 | 10.0 | n.s. |
| 246 | 2006 | NT | 3 | 119.3 | 17.6 | n.s. |
|  |  |  |  |  |  |  |
| **0** | **2007** | **CT** | **4** | **40.8** | **6.3** | **\*** |
| 0 | 2007 | NT | 3 | 31.6 | 1.6 | \* |
| **67.2** | **2007** | **CT** | **4** | **109.9** | **7.8** | **\*\*** |
| 67.2 | 2007 | NT | 3 | 57.5 | 5.6 | \*\* |
| **134** | **2007** | **CT** | **4** | **137.7** | **8.2** | **\*\*** |
| 134 | 2007 | NT | 3 | 76.5 | 5.4 | \*\* |
| **202** | **2007** | **CT** | **4** | **127.2** | **2.8** | **\*\*** |
| 202 | 2007 | NT | 3 | 87.5 | 1.7 | \*\* |
| **246** | **2007** | **CT** | **4** | **139.1** | **4.0** | **\*\*** |
| 246 | 2007 | NT | 3 | 99.2 | 7.1 | \*\* |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ \*\*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.05; \*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate, N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

**Table S12.** Means, standard deviations, and significance (S) for harvested grain nitrogen (N) content of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2006 to 2007 under different N rates and tillage systems.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | Grain  (kg N ha-1) | Standard Deviation | S£ | S£ |
| 0 | 2006 | CT | 4 | 56.1 | 8.9 | ab | AB |
| **0** | **2006** | **NT** | **3** | **45.2** | **7.8** | **b** | **B** |
| **0** | **2006** | **ST** | **3** | **58.8** | **3.8** | **a** | **A** |
| **33.6** | **2006** | **CT** | **4** | **92.1** | **4.3** | **a** | **AB** |
| **33.6** | **2006** | **NT** | **3** | **59.9** | **7.9** | **b** | **B** |
| **33.6** | **2006** | **ST** | **3** | **72.0** | **12.0** | **b** | **B** |
| **67.2** | **2006** | **CT** | **4** | **92.7** | **3.9** | **a** | n.s. |
| **67.2** | **2006** | **NT** | **3** | **85.4** | **4.5** | **b** | n.s. |
| 67.2 | 2006 | ST | 3 | 93.4 | 10.4 | ab | n.s. |
| 101 | 2006 | CT | 4 | 105.1 | 16.4 | n.s. | n.s. |
| 101 | 2006 | NT | 3 | 106.2 | 8.8 | n.s. | n.s. |
| 101 | 2006 | ST | 3 | 112.8 | 12.3 | n.s. | n.s. |
| 134 | 2006 | CT | 4 | 112.2 | 12.0 | n.s. | n.s. |
| 134 | 2006 | NT | 3 | 106.9 | 18.2 | n.s. | n.s. |
| 134 | 2006 | ST | 3 | 119.8 | 22.2 | n.s. | n.s. |
| 246 | 2006 | CT | 4 | 109.2 | 10.0 | n.s. | n.s. |
| 246 | 2006 | NT | 3 | 119.3 | 17.6 | n.s. | n.s. |
| 246 | 2006 | ST | 3 | 128.1 | 36.3 | n.s. | n.s. |
|  |  |  |  |  |  |  |  |
| **0** | **2007** | **CT** | **4** | **40.8** | **6.3** | **a** | **A** |
| **0** | **2007** | **NT** | **3** | **31.6** | **1.6** | **b** | **B** |
| **0** | **2007** | **ST** | **3** | **53.0** | **11.3** | **a** | **A** |
| **67.2** | **2007** | **CT** | **4** | **109.9** | **7.8** | **a** | **A** |
| **67.2** | **2007** | **NT** | **3** | **57.5** | **5.6** | **b** | **B** |
| **67.2** | **2007** | **ST** | **3** | **96.6** | **15.0** | **a** | **A** |
| **134** | **2007** | **CT** | **4** | **137.7** | **8.2** | **a** | **A** |
| **134** | **2007** | **NT** | **3** | **76.5** | **5.4** | **b** | **B** |
| **134** | **2007** | **ST** | **3** | **128.7** | **6.7** | **a** | **A** |
| **202** | **2007** | **CT** | **4** | **127.2** | **2.8** | **b** | **B** |
| **202** | **2007** | **NT** | **3** | **87.5** | **1.7** | **c** | **C** |
| **202** | **2007** | **ST** | **3** | **135.5** | **7.5** | **a** | **A** |
| **246** | **2007** | **CT** | **4** | **139.1** | **4.0** | **a** | **A** |
| **246** | **2007** | **NT** | **3** | **99.2** | **7.1** | **b** | **B** |
| **246** | **2007** | **ST** | **3** | **142.9** | **1.4** | **a** | **A** |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ Tillage systems within a year and N rate with different uppercase letters are significantly different at P<0.05; Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate; N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t- test to test for difference among tillage systems within a year and N rate.

**Table S13.** Means, standard deviations, and significance (S) for harvested grain nitrogen (N) content of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2006 to 2017 under different N rates and tillage systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | Grain  (kg N ha-1) | Standard Deviation | S£ |
| 0 | 2006 | NT | 3 | 45.2 | 7.8 | \*\* |
| **0** | **2006** | **ST** | **3** | **58.8** | **3.8** | **\*\*** |
| 33.6 | 2006 | NT | 3 | 59.9 | 7.9 | n.s. |
| 33.6 | 2006 | ST | 3 | 72.0 | 12.0 | n.s. |
| 67.2 | 2006 | NT | 3 | 85.4 | 4.5 | n.s. |
| 67.2 | 2006 | ST | 3 | 93.4 | 10.4 | n.s. |
| 101 | 2006 | NT | 3 | 106.2 | 8.8 | n.s. |
| 101 | 2006 | ST | 3 | 112.8 | 12.3 | n.s. |
| 134 | 2006 | NT | 3 | 106.9 | 18.2 | n.s. |
| 134 | 2006 | ST | 3 | 119.8 | 22.2 | n.s. |
| 246 | 2006 | NT | 3 | 119.3 | 17.6 | n.s. |
| 246 | 2006 | ST | 3 | 128.1 | 36.3 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2007 | NT | 3 | 31.6 | 1.6 | \*\* |
| **0** | **2007** | **ST** | **3** | **53.0** | **11.3** | **\*\*** |
| 67.2 | 2007 | NT | 3 | 57.5 | 5.6 | \*\* |
| **67.2** | **2007** | **ST** | **3** | **96.6** | **15.0** | **\*\*** |
| 134 | 2007 | NT | 3 | 76.5 | 5.4 | \* |
| **134** | **2007** | **ST** | **3** | **128.7** | **6.7** | **\*** |
| 202 | 2007 | NT | 3 | 87.5 | 1.7 | \*\* |
| **202** | **2007** | **ST** | **3** | **135.5** | **7.5** | **\*\*** |
| 246 | 2007 | NT | 3 | 99.2 | 7.1 | \*\* |
| **246** | **2007** | **ST** | **3** | **142.9** | **1.4** | **\*\*** |
|  |  |  |  |  |  |  |
| 0 | 2009 | NT | 3 | 46.0 | 3.2 | n.s. |
| 0 | 2009 | ST | 7 | 44.4 | 8.4 | n.s. |
| 67.2 | 2009 | NT | 2 | 72.9 | 10.6 | \* |
| **67.2** | **2009** | **ST** | **7** | **95.3** | **11.6** | **\*** |
| 134 | 2009 | ST | 7 | 122.4 | 12.6 | N/A |
| 202 | 2009 | NT | 1 | 110.8 |  | N/A |
| 202 | 2009 | ST | 7 | 130.6 | 4.2 | N/A |
| 246 | 2009 | NT | 1 | 135.4 |  | N/A |
| 246 | 2009 | ST | 7 | 142.1 | 9.2 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2010 | NT | 3 | 49.8 | 3.8 | n.s. |
| 0 | 2010 | ST | 7 | 52.7 | 7.5 | n.s. |
| 67.2 | 2010 | NT | 3 | 85.7 | 4.0 | n.s. |
| 67.2 | 2010 | ST | 7 | 80.4 | 6.3 | n.s. |
| 134 | 2010 | NT | 3 | 131.3 | 15.7 | n.s. |
| 134 | 2010 | ST | 7 | 121.6 | 4.9 | n.s. |
| 202 | 2010 | NT | 3 | 128.0 | 2.2 | n.s. |
| 202 | 2010 | ST | 7 | 129.8 | 7.1 | n.s. |
| 246 | 2010 | NT | 3 | 127.3 | 3.8 | n.s. |
| 246 | 2010 | ST | 7 | 132.4 | 8.4 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2011 | NT | 3 | 47.8 | 3.7 | n.s. |
| 0 | 2011 | ST | 7 | 45.2 | 9.8 | n.s. |
| 67.2 | 2011 | NT | 3 | 72.5 | 4.1 | \*\* |
| **67.2** | **2011** | **ST** | **7** | **83.4** | **10.0** | **\*\*** |
| 134 | 2011 | NT | 3 | 109.0 | 4.0 | n.s. |
| 134 | 2011 | ST | 7 | 113.8 | 8.6 | n.s. |
| 202 | 2011 | NT | 2 | 122.1 | 0.0 | \*\* |
| **202** | **2011** | **ST** | **5** | **130.4** | **9.7** | **\*\*** |
| 246 | 2011 | NT | 2 | 134.4 | 21.3 | n.s. |
| 246 | 2011 | ST | 2 | 130.6 | 5.0 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2012 | NT | 3 | 44.9 | 8.1 | n.s. |
| 0 | 2012 | ST | 7 | 42.2 | 10.0 | n.s. |
| 67.2 | 2012 | NT | 2 | 86.8 | 16.9 | n.s. |
| 67.2 | 2012 | ST | 6 | 73.8 | 11.1 | n.s. |
| 134 | 2012 | NT | 1 | 124.7 |  | N/A |
| 134 | 2012 | ST | 3 | 114.2 | 5.5 | N/A |
| 202 | 2012 | NT | 2 | 124.7 | 13.6 | n.s. |
| 202 | 2012 | ST | 4 | 125.6 | 6.0 | n.s. |
| 246 | 2012 | NT | 1 | 130.1 |  | N/A |
| 246 | 2012 | ST | 2 | 134.4 | 3.5 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2013 | NT | 3 | 49.5 | 9.0 | n.s. |
| 0 | 2013 | ST | 4 | 45.0 | 3.9 | n.s. |
| 67.2 | 2013 | NT | 3 | 91.5 | 14.6 | n.s. |
| 67.2 | 2013 | ST | 3 | 84.5 | 10.7 | n.s. |
| 134 | 2013 | NT | 3 | 138.6 | 3.2 | n.s. |
| 134 | 2013 | ST | 4 | 137.6 | 9.9 | n.s. |
| 202 | 2013 | NT | 3 | 139.1 | 2.0 | n.s. |
| 202 | 2013 | ST | 4 | 135.6 | 12.1 | n.s. |
| 246 | 2013 | NT | 3 | 140.7 | 7.6 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2014 | NT | 3 | 44.6 | 9.6 | n.s. |
| 0 | 2014 | ST | 3 | 39.7 | 5.4 | n.s. |
| 33.6 | 2014 | NT | 3 | 60.1 | 7.7 | N/A |
| 67.2 | 2014 | NT | 3 | 72.4 | 9.2 | n.s. |
| 67.2 | 2014 | ST | 3 | 72.1 | 2.4 | n.s. |
| 134 | 2014 | NT | 3 | 121.7 | 10.8 | n.s. |
| 134 | 2014 | ST | 3 | 105.6 | 19.8 | n.s. |
| **202** | **2014** | **NT** | **3** | **130.6** | **0.9** | **\*** |
| 202 | 2014 | ST | 3 | 118.2 | 12.0 | \* |
| 246 | 2014 | NT | 3 | 127.5 | 10.2 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2015 | NT | 3 | 50.5 | 8.5 | n.s. |
| 0 | 2015 | ST | 3 | 56.7 | 16.0 | n.s. |
| 33.6 | 2015 | NT | 3 | 55.2 | 4.5 | N/A |
| 67.2 | 2015 | NT | 3 | 79.6 | 5.0 | n.s. |
| 67.2 | 2015 | ST | 3 | 76.6 | 12.7 | n.s. |
| 134 | 2015 | NT | 3 | 107.8 | 14.6 | n.s. |
| 134 | 2015 | ST | 3 | 96.4 | 19.3 | n.s. |
| 202 | 2015 | NT | 3 | 130.6 | 6.1 | n.s. |
| 202 | 2015 | ST | 3 | 115.2 | 23.5 | n.s. |
| 246 | 2015 | NT | 3 | 136.0 | 6.3 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2016 | NT | 3 | 53.0 | 3.9 | n.s. |
| 0 | 2016 | ST | 3 | 53.2 | 3.3 | n.s. |
| 33.6 | 2016 | NT | 3 | 68.4 | 12.4 | N/A |
| 67.2 | 2016 | NT | 3 | 94.2 | 28.0 | n.s. |
| 67.2 | 2016 | ST | 3 | 84.3 | 4.5 | n.s. |
| 134 | 2016 | NT | 3 | 97.8 | 15.7 | n.s. |
| 134 | 2016 | ST | 3 | 111.9 | 18.4 | n.s. |
| 202 | 2016 | NT | 3 | 105.9 | 23.1 | n.s. |
| 202 | 2016 | ST | 3 | 133.9 | 6.7 | n.s. |
| 246 | 2016 | NT | 3 | 107.3 | 28.6 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2017 | NT | 3 | 40.9 | 9.2 | n.s. |
| 0 | 2017 | ST | 3 | 41.8 | 1.8 | n.s. |
| 33.6 | 2017 | NT | 3 | 55.5 | 8.0 | N/A |
| 67.2 | 2017 | NT | 3 | 78.1 | 9.2 | n.s. |
| 67.2 | 2017 | ST | 3 | 78.4 | 14.8 | n.s. |
| 134 | 2017 | NT | 3 | 110.5 | 6.5 | n.s. |
| 134 | 2017 | ST | 3 | 101.0 | 6.1 | n.s. |
| **202** | **2017** | **NT** | **3** | **126.2** | **5.2** | **\*\*** |
| 202 | 2017 | ST | 3 | 107.9 | 10.1 | \*\* |
| 246 | 2017 | NT | 3 | 131.5 | 4.6 | N/A |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ \*\*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.05; \*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate, N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

**Table S14.** Means, standard deviations, and significance (S) for total aboveground N uptake (grain, stalks, leaves, and cobs) of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2001 to 2007 under different N rates and tillage systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | Mean  (kg N ha-1) | Standard  Deviation | S£ |
| 0 | 2001 | CT | 4 | 77.1 | 6.7 | \*\* |
| **0** | **2001** | **NT** | **3** | **99.0** | **11.8** | **\*\*** |
| 33.6 | 2001 | NT | 3 | 115.0 | 19.6 | N/A |
| 67.2 | 2001 | CT | 4 | 134.0 | 11.0 | n.s. |
| 67.2 | 2001 | NT | 3 | 134.9 | 2.4 | n.s. |
| 101 | 2001 | NT | 3 | 161.5 | 15.1 | N/A |
| 134 | 2001 | CT | 4 | 183.4 | 16.9 | n.s. |
| 134 | 2001 | NT | 3 | 192.5 | 5.2 | n.s. |
| 168 | 2001 | CT | 4 | 210.1 | 14.3 | n.s. |
| 168 | 2001 | NT | 3 | 212.9 | 4.1 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2002 | CT | 4 | 76.5 | 7.3 | n.s. |
| 0 | 2002 | NT | 3 | 69.6 | 2.3 | n.s. |
| **33.6** | **2002** | **CT** | **4** | **131.5** | **10.0** | **\*\*** |
| 33.6 | 2002 | NT | 3 | 84.6 | 17.6 | \*\* |
| **67.2** | **2002** | **CT** | **4** | **136.9** | **10.0** | **\*\*** |
| 67.2 | 2002 | NT | 3 | 95.1 | 12.1 | \*\* |
| 101 | 2002 | NT | 3 | 112.3 | 18.9 | N/A |
| **134** | **2002** | **CT** | **4** | **178.5** | **10.7** | **\*\*** |
| 134 | 2002 | NT | 3 | 139.3 | 18.4 | \*\* |
| 202 | 2002 | CT | 4 | 197.5 | 24.7 | n.s. |
| 202 | 2002 | NT | 3 | 175.4 | 11.7 | n.s. |
|  |  |  |  |  |  |  |
| **0** | **2003** | **CT** | **4** | **78.4** | **10.2** | **\*\*** |
| 0 | 2003 | NT | 3 | 50.5 | 1.3 | \*\* |
| **33.6** | **2003** | **CT** | **4** | **97.4** | **8.4** | **\*\*** |
| 33.6 | 2003 | NT | 3 | 72.6 | 8.8 | \*\* |
| 67.2 | 2003 | CT | 4 | 94.8 | 8.5 | n.s. |
| 67.2 | 2003 | NT | 3 | 81.5 | 13.8 | n.s. |
| **101** | **2003** | **CT** | **4** | **117.7** | **8.3** | **\*\*** |
| 101 | 2003 | NT | 3 | 89.8 | 12.7 | \*\* |
| **134** | **2003** | **CT** | **4** | **139.7** | **9.2** | **\*\*** |
| 134 | 2003 | NT | 3 | 111.4 | 14.7 | \*\* |
| 224 | 2003 | CT | 4 | 170.6 | 27.7 | n.s. |
| 224 | 2003 | NT | 3 | 139.5 | 11.6 | n.s. |
|  |  |  |  |  |  |  |
| **0** | **2004** | **CT** | **4** | **82.5** | **16.0** | **\*\*** |
| 0 | 2004 | NT | 3 | 55.5 | 4.2 | \*\* |
| **33.6** | **2004** | **CT** | **4** | **130.5** | **14.9** | **\*\*** |
| 33.6 | 2004 | NT | 3 | 78.3 | 8.1 | \*\* |
| **67.2** | **2004** | **CT** | **4** | **141.9** | **10.4** | **\*\*** |
| 67.2 | 2004 | NT | 3 | 100.9 | 7.0 | \*\* |
| **101** | **2004** | **CT** | **4** | **161.0** | **13.0** | **\*\*** |
| 101 | 2004 | NT | 3 | 118.4 | 10.7 | \*\* |
| **134** | **2004** | **CT** | **4** | **174.6** | **6.9** | **\*\*** |
| 134 | 2004 | NT | 3 | 138.7 | 6.6 | \*\* |
| 224 | 2004 | CT | 4 | 200.9 | 17.1 | n.s. |
| 224 | 2004 | NT | 3 | 210.3 | 4.4 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2005 | CT | 4 | 65.7 | 9.6 | n.s. |
| 0 | 2005 | NT | 3 | 77.5 | 6.3 | n.s. |
| 33.6 | 2005 | CT | 4 | 106.2 | 10.0 | n.s. |
| 33.6 | 2005 | NT | 3 | 109.1 | 26.2 | n.s. |
| 67.2 | 2005 | CT | 4 | 117.5 | 6.9 | n.s. |
| 67.2 | 2005 | NT | 3 | 126.2 | 17.0 | n.s. |
| 101 | 2005 | CT | 4 | 145.2 | 9.4 | n.s. |
| 101 | 2005 | NT | 3 | 142.4 | 10.1 | n.s. |
| 134 | 2005 | CT | 4 | 183.2 | 16.0 | n.s. |
| 134 | 2005 | NT | 3 | 180.0 | 28.4 | n.s. |
| 246 | 2005 | CT | 4 | 222.3 | 16.8 | n.s. |
| 246 | 2005 | NT | 3 | 199.9 | 27.4 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2006 | CT | 4 | 76.7 | 8.6 | n.s. |
| 0 | 2006 | NT | 3 | 69.8 | 6.9 | n.s. |
| **33.6** | **2006** | **CT** | **4** | **123.6** | **6.9** | **\*\*** |
| 33.6 | 2006 | NT | 3 | 95.8 | 2.4 | \*\* |
| 67.2 | 2006 | CT | 4 | 123.4 | 8.4 | n.s. |
| 67.2 | 2006 | NT | 3 | 124.0 | 10.3 | n.s. |
| 101 | 2006 | CT | 4 | 144.2 | 17.0 | n.s. |
| 101 | 2006 | NT | 3 | 150.1 | 9.7 | n.s. |
| 134 | 2006 | CT | 4 | 156.0 | 15.3 | n.s. |
| 134 | 2006 | NT | 3 | 163.8 | 20.6 | n.s. |
| 246 | 2006 | CT | 4 | 171.3 | 15.8 | n.s. |
| 246 | 2006 | NT | 3 | 195.5 | 21.7 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2007 | CT | 4 | 66.0 | 10.5 | n.s. |
| 0 | 2007 | NT | 3 | 62.2 | 6.6 | n.s. |
| **67.2** | **2007** | **CT** | **4** | **152.9** | **7.5** | **\*\*** |
| 67.2 | 2007 | NT | 3 | 97.2 | 7.3 | \*\* |
| **134** | **2007** | **CT** | **4** | **188.8** | **21.8** | **\*\*** |
| 134 | 2007 | NT | 3 | 126.5 | 3.4 | \*\* |
| **202** | **2007** | **CT** | **4** | **178.6** | **8.9** | **\*\*** |
| 202 | 2007 | NT | 3 | 151.9 | 3.0 | \*\* |
| **246** | **2007** | **CT** | **4** | **226.4** | **18.7** | **\*\*** |
| 246 | 2007 | NT | 3 | 177.9 | 10.8 | \*\* |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ \*\*Significant difference between tillage systems by year and N rate at P<0.05; \*Significant difference between tillage systems by year and N rate at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate; N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

**Table S15.** Means, standard deviations, and significance (S) for total aboveground N uptake (grain, stalks, leaves, and cobs) of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2001 to 2007 under different N rates and tillage systems.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | Mean  (kg N ha-1) | Standard  Deviation | S£ | S£ |
| 0 | 2006 | CT | 4 | 76.7 | 8.6 | ab | AB |
| **0** | **2006** | **NT** | **3** | **69.8** | **6.9** | **b** | **B** |
| **0** | **2006** | **ST** | **3** | **83.3** | **4.3** | **a** | **A** |
| **33.6** | **2006** | **CT** | **4** | **123.6** | **6.9** | **a** | **A** |
| **33.6** | **2006** | **NT** | **3** | **95.8** | **2.4** | **b** | **B** |
| **33.6** | **2006** | **ST** | **3** | **96.9** | **14.5** | **b** | **B** |
| 67.2 | 2006 | CT | 4 | 123.4 | 8.4 | n.s. | n.s. |
| 67.2 | 2006 | NT | 3 | 124.0 | 10.3 | n.s. | n.s. |
| 67.2 | 2006 | ST | 3 | 127.1 | 14.6 | n.s. | n.s. |
| 101 | 2006 | CT | 4 | 144.2 | 17.0 | n.s. | n.s. |
| 101 | 2006 | NT | 3 | 150.1 | 9.7 | n.s. | n.s. |
| 101 | 2006 | ST | 3 | 156.8 | 12.6 | n.s. | n.s. |
| 134 | 2006 | CT | 4 | 156.0 | 15.3 | n.s. | n.s. |
| 134 | 2006 | NT | 3 | 163.8 | 20.6 | n.s. | n.s. |
| 134 | 2006 | ST | 3 | 176.9 | 25.0 | n.s. | n.s. |
| 246 | 2006 | CT | 4 | 171.3 | 15.8 | n.s. | n.s. |
| 246 | 2006 | NT | 3 | 195.5 | 21.7 | n.s. | n.s. |
| 246 | 2006 | ST | 3 | 185.2 | 38.1 | n.s. | n.s. |
|  |  |  |  |  |  |  |  |
| 0 | 2007 | CT | 4 | 66.0 | 10.5 | ab | n.s. |
| **0** | **2007** | **NT** | **3** | **62.2** | **6.6** | **b** | n.s. |
| **0** | **2007** | **ST** | **3** | **86.1** | **16.9** | **a** | n.s. |
| **67.2** | **2007** | **CT** | **4** | **152.9** | **7.5** | **a** | **A** |
| **67.2** | **2007** | **NT** | **3** | **97.2** | **7.3** | **b** | **B** |
| **67.2** | **2007** | **ST** | **3** | **132.0** | **20.6** | **a** | **A** |
| 134 | 2007 | CT | 4 | 188.8 | 21.8 | n.s. | n.s. |
| 134 | 2007 | NT | 3 | 126.5 | 3.4 | n.s. | n.s. |
| 134 | 2007 | ST | 3 | 180.6 | 17.5 | n.s. | n.s. |
| **202** | **2007** | **CT** | **4** | **178.6** | **8.9** | **a** | **A** |
| **202** | **2007** | **NT** | **3** | **151.9** | **3.0** | **b** | **B** |
| **202** | **2007** | **ST** | **3** | **195.0** | **20.5** | **a** | **A** |
| **246** | **2007** | **CT** | **4** | **226.4** | **18.7** | **a** | **A** |
| **246** | **2007** | **NT** | **3** | **177.9** | **10.8** | **c** | **C** |
| **246** | **2007** | **ST** | **3** | **203.6** | **2.9** | **b** | **B** |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.05; Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate; N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t- test to test for difference among tillage systems within a year and N rate.

**Table S16.** Means, standard deviations, and significance for total aboveground nitrogen (N) uptake (grain, stalks, leaves, and cobs) of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2006 to 2017 under different N rates and tillage systems.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | N Rate |  |  |  | N Means  kg N ha-1 | Standar  Deviation | Confident  Interval | §\* | | |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Year |  |  | n | N Means  kg N ha-1 | Standar  Deviation | Confident  Interval | §\* | | Tillage¥ | |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | n¶ |  | Tillage | n | N Means  kg N ha-1 | Standar  Deviation | Confident  Interval | §\* | | Mean  (kg N ha-1) | |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Standard  Deviation |  | Tillage | n | N Means  kg N ha-1 | Standar  Deviation | Confident  Interval | §\* | | |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | S£ |  | Tillage | n | N Means  kg N ha-1 | Standar  Deviation | Confident  Interval | §\* | |
| 0 | 2006 | NT | 3 | 69.8 | 6.9 | \*\* |
| **0** | **2006** | **ST** | **3** | **83.3** | **4.3** | **\*\*** |
| 33.6 | 2006 | NT | 3 | 95.8 | 2.4 | n.s. |
| 33.6 | 2006 | ST | 3 | 96.9 | 14.5 | n.s. |
| 67.2 | 2006 | NT | 3 | 124.0 | 10.3 | n.s. |
| 67.2 | 2006 | ST | 3 | 127.1 | 14.6 | n.s. |
| 101 | 2006 | NT | 3 | 150.1 | 9.7 | n.s. |
| 101 | 2006 | ST | 3 | 156.8 | 12.6 | n.s. |
| 134 | 2006 | NT | 3 | 163.8 | 20.6 | n.s. |
| 134 | 2006 | ST | 3 | 176.9 | 25.0 | n.s. |
| 246 | 2006 | NT | 3 | 195.5 | 21.7 | n.s. |
| 246 | 2006 | ST | 3 | 185.2 | 38.1 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2007 | NT | 3 | 62.2 | 6.6 | \* |
| **0** | **2007** | **ST** | **3** | **86.1** | **16.9** | **\*** |
| 67.2 | 2007 | NT | 3 | 97.2 | 7.3 | \*\* |
| **67.2** | **2007** | **ST** | **3** | **132.0** | **20.6** | **\*\*** |
| 134 | 2007 | NT | 3 | 126.5 | 3.4 | \*\* |
| **134** | **2007** | **ST** | **3** | **180.6** | **17.5** | **\*\*** |
| 202 | 2007 | NT | 3 | 151.9 | 3.0 | \*\* |
| **202** | **2007** | **ST** | **3** | **195.0** | **20.5** | **\*\*** |
| 246 | 2007 | NT | 3 | 177.9 | 10.8 | \*\* |
| **246** | **2007** | **ST** | **3** | **203.6** | **2.9** | **\*\*** |
|  |  |  |  |  |  |  |
| 0 | 2009 | NT | 3 | 70.4 | 7.4 | n.s. |
| 0 | 2009 | ST | 7 | 67.9 | 13.1 | n.s. |
| 67.2 | 2009 | NT | 2 | 104.8 | 13.3 | \* |
| **67.2** | **2009** | **ST** | **7** | **134.1** | **16.3** | **\*** |
| 134 | 2009 | ST | 7 | 171.4 | 25.3 | N/A |
| 202 | 2009 | NT | 1€ | 166.7 |  | N/A |
| 202 | 2009 | ST | 7 | 195.8 | 13.0 | N/A |
| 246 | 2009 | NT | 1€ | 183.9 |  | N/A |
| 246 | 2009 | ST | 7 | 205.6 | 18.1 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2010 | NT | 3 | 86.0 | 9.7 | n.s. |
| 0 | 2010 | ST | 7 | 74.9 | 11.3 | n.s. |
| 67.2 | 2010 | NT | 3 | 114.0 | 9.8 | n.s. |
| 67.2 | 2010 | ST | 7 | 118.4 | 11.7 | n.s. |
| 134 | 2010 | NT | 3 | 175.1 | 26.2 | n.s. |
| 134 | 2010 | ST | 7 | 184.5 | 17.3 | n.s. |
| 202 | 2010 | NT | 3 | 172.3 | 10.9 | n.s. |
| 202 | 2010 | ST | 7 | 193.1 | 21.9 | n.s. |
| 246 | 2010 | NT | 3 | 181.6 | 1.8 | n.s. |
| 246 | 2010 | ST | 7 | 191.9 | 19.4 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2011 | NT | 3 | 86.0 | 17.2 | n.s. |
| 0 | 2011 | ST | 7 | 73.7 | 25.6 | n.s. |
| 67.2 | 2011 | NT | 3 | 120.6 | 4.7 | n.s. |
| 67.2 | 2011 | ST | 7 | 129.9 | 16.8 | n.s. |
| 134 | 2011 | NT | 3 | 182.2 | 2.1 | n.s. |
| 134 | 2011 | ST | 7 | 171.1 | 13.4 | n.s. |
| 202 | 2011 | NT | 2 | 208.4 | 24.4 | n.s. |
| 202 | 2011 | ST | 5 | 194.6 | 19.3 | n.s. |
| 246 | 2011 | NT | 2 | 228.3 | 53.1 | n.s. |
| 246 | 2011 | ST | 2 | 207.6 | 21.9 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2012 | NT | 3 | 78.4 | 19.0 | n.s. |
| 0 | 2012 | ST | 7 | 81.5 | 27.9 | n.s. |
| **67.2** | **2012** | **NT** | **2** | **165.5** | **38.1** | **\*\*** |
| 67.2 | 2012 | ST | 6 | 125.6 | 19.6 | \*\* |
| 134 | 2012 | NT | 1€ | 253.8 |  | N/A |
| 134 | 2012 | ST | 3 | 175.1 | 14.9 | N/A |
| **202** | **2012** | **NT** | **2** | **264.3** | **8.1** | **\*\*** |
| 202 | 2012 | ST | 4 | 198.8 | 8.8 | \*\* |
| 246 | 2012 | NT | 1€ | 258.8 |  | N/A |
| 246 | 2012 | ST | 2 | 199.9 | 34.1 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2013 | NT | 3 | 79.7 | 21.2 | n.s. |
| 0 | 2013 | ST | 4 | 67.7 | 6.2 | n.s. |
| 67.2 | 2013 | NT | 3 | 138.6 | 12.4 | n.s. |
| 67.2 | 2013 | ST | 3 | 123.0 | 15.8 | n.s. |
| 134 | 2013 | NT | 3 | 198.4 | 5.7 | n.s. |
| 134 | 2013 | ST | 4 | 193.3 | 9.7 | n.s. |
| 202 | 2013 | NT | 3 | 207.9 | 14.9 | n.s. |
| 202 | 2013 | ST | 4 | 195.2 | 15.1 | n.s. |
| 246 | 2013 | NT | 3 | 199.5 | 3.1 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2014 | NT | 3 | 73.3 | 11.1 | n.s. |
| 0 | 2014 | ST | 3 | 63.8 | 6.6 | n.s. |
| 33.6 | 2014 | NT | 3 | 109.7 | 18.2 | N/A |
| 67.2 | 2014 | NT | 3 | 118.3 | 8.7 | n.s. |
| 67.2 | 2014 | ST | 3 | 118.8 | 14.5 | n.s. |
| 134 | 2014 | NT | 3 | 194.8 | 26.9 | n.s. |
| 134 | 2014 | ST | 3 | 162.3 | 20.5 | n.s. |
| **202** | **2014** | **NT** | **3** | **205.2** | **5.4** | **\*\*** |
| 202 | 2014 | ST | 3 | 184.8 | 8.6 | \*\* |
| 246 | 2014 | NT | 3 | 198.3 | 10.5 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2015 | NT | 3 | 78.2 | 7.9 | n.s. |
| 0 | 2015 | ST | 3 | 83.2 | 21.5 | n.s. |
| 33.6 | 2015 | NT | 3 | 88.7 | 6.1 | N/A |
| 67.2 | 2015 | NT | 3 | 120.0 | 3.3 | n.s. |
| 67.2 | 2015 | ST | 3 | 116.7 | 16.1 | n.s. |
| 134 | 2015 | NT | 3 | 153.1 | 15.7 | n.s. |
| 134 | 2015 | ST | 3 | 143.9 | 23.0 | n.s. |
| 202 | 2015 | NT | 3 | 189.3 | 12.6 | n.s. |
| 202 | 2015 | ST | 3 | 184.5 | 31.3 | n.s. |
| 246 | 2015 | NT | 3 | 196.1 | 15.0 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2016 | NT | 3 | 79.1 | 9.0 | n.s. |
| 0 | 2016 | ST | 3 | 78.1 | 7.1 | n.s. |
| 33.6 | 2016 | NT | 3 | 104.8 | 13.7 | N/A |
| 67.2 | 2016 | NT | 3 | 140.7 | 36.0 | n.s. |
| 67.2 | 2016 | ST | 3 | 133.5 | 4.5 | n.s. |
| 134 | 2016 | NT | 3 | 150.7 | 11.1 | n.s. |
| 134 | 2016 | ST | 3 | 164.7 | 26.9 | n.s. |
| 202 | 2016 | NT | 3 | 163.1 | 19.7 | \*\* |
| **202** | **2016** | **ST** | **3** | **196.3** | **11.6** | **\*\*** |
| 246 | 2016 | NT | 3 | 168.4 | 35.0 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2017 | NT | 3 | 89.8 | 15.2 | n.s. |
| 0 | 2017 | ST | 3 | 75.8 | 15.3 | n.s. |
| 33.6 | 2017 | NT | 3 | 114.9 | 7.1 | N/A |
| 67.2 | 2017 | NT | 3 | 140.0 | 5.2 | n.s. |
| 67.2 | 2017 | ST | 3 | 131.6 | 15.3 | n.s. |
| **134** | **2017** | **NT** | **3** | **204.8** | **9.2** | **\*\*** |
| 134 | 2017 | ST | 3 | 153.2 | 6.4 | \*\* |
| 202 | 2017 | NT | 3 | 229.4 | 44.3 | n.s. |
| 202 | 2017 | ST | 3 | 195.0 | 21.7 | n.s. |
| 246 | 2017 | NT | 3 | 238.1 | 2.2 | N/A |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ \*\*Significant difference between tillage systems by year and N rate at P<0.05; \*Significant difference between tillage systems by year and N rate at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate; N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

€Only one observation for the NT tillage treatment this year

**Table S17.** Means, standard deviations, and significance (S) for crop residue N content of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2001 to 2007 under different N rates and tillage systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | CR N Content (kg N ha-1) | Standard Deviation | S£ |
| 0 | 2001 | CT | 4 | 31.477 | 3.474 | \*\* |
| **0** | **2001** | **NT** | **3** | **46.928** | **6.714** | **\*\*** |
| 33.6 | 2001 | NT | 3 | 52.044 | 5.917 | N/A |
| 67.2 | 2001 | CT | 4 | 50.098 | 6.463 | \*\* |
| **67.2** | **2001** | **NT** | **3** | **60.406** | **2.406** | **\*\*** |
| 101 | 2001 | NT | 3 | 67.150 | 10.085 | N/A |
| 134 | 2001 | CT | 4 | 72.919 | 7.888 | n.s. |
| 134 | 2001 | NT | 3 | 83.193 | 5.496 | n.s. |
| 168 | 2001 | CT | 4 | 88.483 | 13.484 | n.s. |
| 168 | 2001 | NT | 3 | 93.761 | 3.098 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2002 | CT | 4 | 23.840 | 3.102 | n.s. |
| 0 | 2002 | NT | 3 | 26.411 | 0.654 | n.s. |
| **33.6** | **2002** | **CT** | **4** | **37.632** | **3.184** | **\*\*** |
| 33.6 | 2002 | NT | 3 | 28.365 | 5.690 | \*\* |
| 67.2 | 2002 | CT | 4 | 40.297 | 5.652 | n.s. |
| 67.2 | 2002 | NT | 3 | 36.080 | 8.424 | n.s. |
| 101 | 2002 | NT | 3 | 39.242 | 10.943 | N/A |
| 134 | 2002 | CT | 4 | 52.123 | 6.268 | n.s. |
| 134 | 2002 | NT | 3 | 47.921 | 11.740 | n.s. |
| 202 | 2002 | CT | 4 | 63.505 | 14.296 | n.s. |
| 202 | 2002 | NT | 3 | 58.823 | 7.309 | n.s. |
|  |  |  |  |  |  |  |
| **0** | **2003** | **CT** | **4** | **24.125** | **4.668** | **\*** |
| 0 | 2003 | NT | 3 | 16.847 | 2.678 | \* |
| **33.6** | **2003** | **CT** | **4** | **30.890** | **3.705** | **\*\*** |
| 33.6 | 2003 | NT | 3 | 19.440 | 2.880 | \*\* |
| 67.2 | 2003 | CT | 4 | 25.306 | 8.934 | n.s. |
| 67.2 | 2003 | NT | 3 | 21.156 | 4.070 | n.s. |
| **101** | **2003** | **CT** | **4** | **31.887** | **4.007** | **\*\*** |
| 101 | 2003 | NT | 3 | 23.998 | 5.230 | \*\* |
| **134** | **2003** | **CT** | **4** | **39.891** | **3.103** | **\*\*** |
| 134 | 2003 | NT | 3 | 28.195 | 4.154 | \*\* |
| 224 | 2003 | CT | 4 | 52.622 | 14.297 | n.s. |
| 224 | 2003 | NT | 3 | 41.349 | 4.969 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2004 | CT | 4 | 19.841 | 1.934 | n.s. |
| 0 | 2004 | NT | 3 | 20.450 | 3.101 | n.s. |
| **33.6** | **2004** | **CT** | **4** | **32.133** | **1.994** | **\*\*** |
| 33.6 | 2004 | NT | 3 | 22.280 | 4.757 | \*\* |
| 67.2 | 2004 | CT | 4 | 32.338 | 2.400 | n.s. |
| 67.2 | 2004 | NT | 3 | 28.543 | 3.462 | n.s. |
| **101** | **2004** | **CT** | **4** | **35.312** | **5.579** | **\*\*** |
| 101 | 2004 | NT | 3 | 28.325 | 1.108 | \*\* |
| 134 | 2004 | CT | 4 | 43.595 | 6.577 | n.s. |
| 134 | 2004 | NT | 3 | 36.543 | 6.095 | n.s. |
| 224 | 2004 | CT | 4 | 58.409 | 6.976 | n.s. |
| 224 | 2004 | NT | 3 | 61.744 | 1.890 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2005 | CT | 4 | 21.101 | 5.054 | n.s. |
| 0 | 2005 | NT | 3 | 26.889 | 2.660 | n.s. |
| 33.6 | 2005 | CT | 4 | 35.757 | 7.065 | n.s. |
| 33.6 | 2005 | NT | 3 | 40.258 | 14.977 | n.s. |
| 67.2 | 2005 | CT | 4 | 34.244 | 4.116 | n.s. |
| 67.2 | 2005 | NT | 3 | 40.322 | 5.705 | n.s. |
| 101 | 2005 | CT | 4 | 43.613 | 3.612 | n.s. |
| 101 | 2005 | NT | 3 | 43.938 | 7.410 | n.s. |
| 134 | 2005 | CT | 4 | 56.663 | 4.286 | n.s. |
| 134 | 2005 | NT | 3 | 63.554 | 16.838 | n.s. |
| 246 | 2005 | CT | 4 | 73.247 | 7.018 | n.s. |
| 246 | 2005 | NT | 3 | 65.951 | 16.434 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2006 | CT | 4 | 20.614 | 3.301 | n.s. |
| 0 | 2006 | NT | 3 | 24.602 | 5.505 | n.s. |
| 33.6 | 2006 | CT | 4 | 31.494 | 5.873 | n.s. |
| 33.6 | 2006 | NT | 3 | 35.906 | 9.845 | n.s. |
| 67.2 | 2006 | CT | 4 | 30.767 | 6.632 | n.s. |
| 67.2 | 2006 | NT | 3 | 38.553 | 6.840 | n.s. |
| 101 | 2006 | CT | 4 | 39.118 | 5.459 | n.s. |
| 101 | 2006 | NT | 3 | 43.827 | 2.108 | n.s. |
| 134 | 2006 | CT | 4 | 43.765 | 3.913 | \*\* |
| **134** | **2006** | **NT** | **3** | **56.862** | **2.427** | **\*\*** |
| 246 | 2006 | CT | 4 | 62.156 | 7.163 | \*\* |
| **246** | **2006** | **NT** | **3** | **76.211** | **7.156** | **\*\*** |
|  |  |  |  |  |  |  |
| 0 | 2007 | CT | 4 | 25.172 | 7.749 | n.s. |
| 0 | 2007 | NT | 3 | 30.635 | 7.093 | n.s. |
| 67.2 | 2007 | CT | 4 | 42.997 | 5.719 | n.s. |
| 67.2 | 2007 | NT | 3 | 39.661 | 1.731 | n.s. |
| 134 | 2007 | CT | 4 | 51.148 | 14.078 | n.s. |
| 134 | 2007 | NT | 3 | 50.018 | 5.708 | n.s. |
| 202 | 2007 | CT | 4 | 51.461 | 9.141 | \*\* |
| **202** | **2007** | **NT** | **3** | **64.434** | **2.608** | **\*\*** |
| **246** | **2007** | **CT** | **4** | **87.287** | **15.298** | **\*\*** |
| 246 | 2007 | NT | 3 | 78.681 | 8.200 | \*\* |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ \*\*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.05; \*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate; N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

**Table S18.** Means, standard deviations, and significance (S) for crop residue nitrogen (N) content of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2006 to 2007 under different N rates and tillage systems.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | CR N Content  (kg N ha-1) | Standard Deviation | S£ | S£ |
| **0** | **2006** | **CT** | **4** | **20.6** | **3.3** | **c** | n.s. |
| 0 | 2006 | NT | 3 | 24.6 | 5.5 | cb | n.s. |
| **0** | **2006** | **ST** | **3** | **24.5** | **0.8** | **ab** | n.s. |
| 33.6 | 2006 | CT | 4 | 31.5 | 5.9 | n.s. | n.s. |
| 33.6 | 2006 | NT | 3 | 35.9 | 9.8 | n.s. | n.s. |
| 33.6 | 2006 | ST | 3 | 25.0 | 3.1 | n.s. | n.s. |
| 67.2 | 2006 | CT | 4 | 30.8 | 6.6 | n.s. | n.s. |
| 67.2 | 2006 | NT | 3 | 38.6 | 6.8 | n.s. | n.s. |
| 67.2 | 2006 | ST | 3 | 33.7 | 6.8 | n.s. | n.s. |
| 101 | 2006 | CT | 4 | 39.1 | 5.5 | n.s. | n.s. |
| 101 | 2006 | NT | 3 | 43.8 | 2.1 | n.s. | n.s. |
| 101 | 2006 | ST | 3 | 44.1 | 2.0 | n.s. | n.s. |
| **134** | **2006** | **CT** | **4** | **43.8** | **3.9** | **b** | **B** |
| **134** | **2006** | **NT** | **3** | **56.9** | **2.4** | **a** | **A** |
| **134** | **2006** | **ST** | **3** | **57.1** | **2.8** | **a** | **A** |
| **246** | **2006** | **CT** | **4** | **62.2** | **7.2** | **b** | **B** |
| **246** | **2006** | **NT** | **3** | **76.2** | **7.2** | **a** | **A** |
| **246** | **2006** | **ST** | **3** | **57.0** | **2.5** | **b** | **B** |
|  |  |  |  |  |  |  |  |
| 0 | 2007 | CT | 4 | 25.2 | 7.7 | n.s. | n.s. |
| 0 | 2007 | NT | 3 | 30.6 | 7.1 | n.s. | n.s. |
| 0 | 2007 | ST | 3 | 33.1 | 9.0 | n.s. | n.s. |
| 67.2 | 2007 | CT | 4 | 43.0 | 5.7 | n.s. | n.s. |
| 67.2 | 2007 | NT | 3 | 39.7 | 1.7 | n.s. | n.s. |
| 67.2 | 2007 | ST | 3 | 35.5 | 5.7 | n.s. | n.s. |
| 134 | 2007 | CT | 4 | 51.1 | 14.1 | n.s. | n.s. |
| 134 | 2007 | NT | 3 | 50.0 | 5.7 | n.s. | n.s. |
| 134 | 2007 | ST | 3 | 51.8 | 11.2 | n.s. | n.s. |
| **202** | **2007** | **CT** | **4** | **51.5** | **9.1** | **b** | **B** |
| **202** | **2007** | **NT** | **3** | **64.4** | **2.6** | **a** | **A** |
| 202 | 2007 | ST | 3 | 59.4 | 15.1 | ab | AB |
| **246** | **2007** | **CT** | **4** | **87.3** | **15.3** | **a** | **A** |
| **246** | **2007** | **NT** | **3** | **78.7** | **8.2** | **a** | **A** |
| **246** | **2007** | **ST** | **3** | **60.7** | **3.9** | **b** | **B** |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ Tillage systems within a year and N rate with different uppercase letters are significantly different at P<0.05; Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate, N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t- test to test for difference among tillage systems within a year and N rate.

**Table S19.** Means, standard deviations, and significance (S) for crop residue nitrogen (N) content of irrigated corn grown on a clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) with a 1 to 2% slope at the Agricultural Research, Development, and Education Center (ARDEC) from 2006 to 2017 under different N rates and tillage systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| N Rate | Year | Tillage¥ | n¶ | CR N Content  (kg N ha-1) | Standard Deviation | S£ |
| 0 | 2006 | NT | 3 | 24.6 | 5.5 | n.s. |
| 0 | 2006 | ST | 3 | 24.5 | 0.8 | n.s. |
| 33.6 | 2006 | NT | 3 | 35.9 | 9.8 | n.s. |
| 33.6 | 2006 | ST | 3 | 25.0 | 3.1 | n.s. |
| 67.2 | 2006 | NT | 3 | 38.6 | 6.8 | n.s. |
| 67.2 | 2006 | ST | 3 | 33.7 | 6.8 | n.s. |
| 101 | 2006 | NT | 3 | 43.8 | 2.1 | n.s. |
| 101 | 2006 | ST | 3 | 44.1 | 2.0 | n.s. |
| 134 | 2006 | NT | 3 | 56.9 | 2.4 | n.s. |
| 134 | 2006 | ST | 3 | 57.1 | 2.8 | n.s. |
| **246** | **2006** | **NT** | **3** | **76.2** | **7.2** | **\*\*** |
| 246 | 2006 | ST | 3 | 57.0 | 2.5 | \*\* |
|  |  |  |  |  |  |  |
| 0 | 2007 | NT | 3 | 30.6 | 7.1 | n.s. |
| 0 | 2007 | ST | 3 | 33.1 | 9.0 | n.s. |
| 67.2 | 2007 | NT | 3 | 39.7 | 1.7 | n.s. |
| 67.2 | 2007 | ST | 3 | 35.5 | 5.7 | n.s. |
| 134 | 2007 | NT | 3 | 50.0 | 5.7 | n.s. |
| 134 | 2007 | ST | 3 | 51.8 | 11.2 | n.s. |
| 202 | 2007 | NT | 3 | 64.4 | 2.6 | n.s. |
| 202 | 2007 | ST | 3 | 59.4 | 15.1 | n.s. |
| **246** | **2007** | **NT** | **3** | **78.7** | **8.2** | **\*\*** |
| 246 | 2007 | ST | 3 | 60.7 | 3.9 | \*\* |
|  |  |  |  |  |  |  |
| 0 | 2009 | NT | 3 | 24.4 | 4.3 | n.s. |
| 0 | 2009 | ST | 7 | 23.5 | 5.7 | n.s. |
| 67.2 | 2009 | NT | 2 | 31.9 | 2.7 | n.s. |
| 67.2 | 2009 | ST | 7 | 38.7 | 7.3 | n.s. |
| 134 | 2009 | ST | 7 | 49.0 | 14.2 | N/A |
| 202 | 2009 | NT | 1€ | 55.9 |  | N/A |
| 202 | 2009 | ST | 7 | 65.2 | 9.5 | N/A |
| 246 | 2009 | NT | 1€ | 48.6 |  | N/A |
| 246 | 2009 | ST | 7 | 63.5 | 11.1 | N/A |
|  |  |  |  |  |  |  |
| **0** | **2010** | **NT** | **3** | **36.2** | **6.2** | **\*\*** |
| 0 | 2010 | ST | 7 | 22.2 | 6.4 | \*\* |
| 67.2 | 2010 | NT | 3 | 28.3 | 6.0 | \*\* |
| **67.2** | **2010** | **ST** | **7** | **37.9** | **7.6** | **\*\*** |
| 134 | 2010 | NT | 3 | 43.8 | 10.5 | n.s. |
| 134 | 2010 | ST | 7 | 63.0 | 16.7 | n.s. |
| 202 | 2010 | NT | 3 | 44.3 | 10.5 | n.s. |
| 202 | 2010 | ST | 7 | 63.3 | 19.0 | n.s. |
| 246 | 2010 | NT | 3 | 54.2 | 2.6 | n.s. |
| 246 | 2010 | ST | 7 | 59.5 | 12.3 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2011 | NT | 3 | 38.2 | 13.8 | n.s. |
| 0 | 2011 | ST | 7 | 28.5 | 16.9 | n.s. |
| 67.2 | 2011 | NT | 3 | 48.1 | 1.8 | n.s. |
| 67.2 | 2011 | ST | 7 | 46.4 | 16.4 | n.s. |
| 134 | 2011 | NT | 3 | 73.2 | 6.0 | n.s. |
| 134 | 2011 | ST | 7 | 57.3 | 15.3 | n.s. |
| 202 | 2011 | NT | 2 | 86.3 | 24.4 | n.s. |
| 202 | 2011 | ST | 5 | 64.2 | 26.3 | n.s. |
| 246 | 2011 | NT | 2 | 93.9 | 31.8 | n.s. |
| 246 | 2011 | ST | 2 | 77.0 | 16.9 | n.s. |
|  |  |  |  |  |  |  |
| 0 | 2012 | NT | 3 | 33.5 | 11.5 | n.s. |
| 0 | 2012 | ST | 7 | 39.3 | 20.7 | n.s. |
| **67.2** | **2012** | **NT** | **2** | **78.8** | **21.2** | **\*\*** |
| 67.2 | 2012 | ST | 6 | 51.7 | 9.5 | \*\* |
| 134 | 2012 | NT | 1€ | 129.2 |  | N/A |
| 134 | 2012 | ST | 3 | 60.9 | 9.7 | N/A |
| **202** | **2012** | **NT** | **2** | **139.6** | **21.7** | **\*\*** |
| 202 | 2012 | ST | 4 | 73.2 | 8.0 | \*\* |
| 246 | 2012 | NT | 1€ | 128.6 |  | N/A |
| 246 | 2012 | ST | 2 | 65.5 | 37.7 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2013 | NT | 3 | 30.1 | 12.2 | n.s. |
| 0 | 2013 | ST | 4 | 22.7 | 3.3 | n.s. |
| **67.2** | **2013** | **NT** | **3** | **47.1** | **3.5** | **\*\*** |
| 67.2 | 2013 | ST | 3 | 38.5 | 5.7 | \*\* |
| 134 | 2013 | NT | 3 | 59.8 | 5.0 | n.s. |
| 134 | 2013 | ST | 4 | 55.7 | 6.6 | n.s. |
| 202 | 2013 | NT | 3 | 68.8 | 13.1 | n.s. |
| 202 | 2013 | ST | 4 | 59.6 | 9.3 | n.s. |
| 246 | 2013 | NT | 3 | 58.8 | 9.5 | N/A |
|  |  |  |  |  |  |  |
| **0** | **2014** | **NT** | **3** | **28.7** | **2.5** | **\*\*** |
| 0 | 2014 | ST | 3 | 24.1 | 1.4 | \*\* |
| 33.6 | 2014 | NT | 3 | 49.6 | 10.9 | N/A |
| 67.2 | 2014 | NT | 3 | 45.9 | 4.8 | n.s. |
| 67.2 | 2014 | ST | 3 | 46.7 | 12.5 | n.s. |
| 134 | 2014 | NT | 3 | 73.1 | 18.3 | n.s. |
| 134 | 2014 | ST | 3 | 56.7 | 1.9 | n.s. |
| 202 | 2014 | NT | 3 | 74.6 | 6.1 | n.s. |
| 202 | 2014 | ST | 3 | 66.6 | 7.4 | n.s. |
| 246 | 2014 | NT | 3 | 70.8 | 4.3 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2015 | NT | 3 | 27.7 | 3.2 | n.s. |
| 0 | 2015 | ST | 3 | 26.5 | 5.6 | n.s. |
| 33.6 | 2015 | NT | 3 | 33.5 | 4.4 | N/A |
| 67.2 | 2015 | NT | 3 | 40.4 | 4.9 | n.s. |
| 67.2 | 2015 | ST | 3 | 40.1 | 4.4 | n.s. |
| 134 | 2015 | NT | 3 | 45.3 | 5.4 | n.s. |
| 134 | 2015 | ST | 3 | 47.5 | 4.9 | n.s. |
| 202 | 2015 | NT | 3 | 58.6 | 7.5 | n.s. |
| 202 | 2015 | ST | 3 | 69.2 | 13.8 | n.s. |
| 246 | 2015 | NT | 3 | 60.1 | 8.7 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2016 | NT | 3 | 26.1 | 5.1 | n.s. |
| 0 | 2016 | ST | 3 | 24.9 | 3.9 | n.s. |
| 33.6 | 2016 | NT | 3 | 36.4 | 1.4 | N/A |
| 67.2 | 2016 | NT | 3 | 46.5 | 10.2 | n.s. |
| 67.2 | 2016 | ST | 3 | 49.3 | 2.8 | n.s. |
| 134 | 2016 | NT | 3 | 52.9 | 4.7 | n.s. |
| 134 | 2016 | ST | 3 | 52.8 | 9.0 | n.s. |
| 202 | 2016 | NT | 3 | 57.2 | 3.6 | n.s. |
| 202 | 2016 | ST | 3 | 62.4 | 8.8 | n.s. |
| 246 | 2016 | NT | 3 | 61.1 | 8.3 | N/A |
|  |  |  |  |  |  |  |
| 0 | 2017 | NT | 3 | 48.9 | 10.1 | n.s. |
| 0 | 2017 | ST | 3 | 34.0 | 14.4 | n.s. |
| 33.6 | 2017 | NT | 3 | 59.4 | 15.0 | N/A |
| 67.2 | 2017 | NT | 3 | 61.9 | 8.7 | n.s. |
| 67.2 | 2017 | ST | 3 | 53.2 | 16.4 | n.s. |
| **134** | **2017** | **NT** | **3** | **94.3** | **15.7** | **\*\*** |
| 134 | 2017 | ST | 3 | 52.2 | 4.6 | \*\* |
| 202 | 2017 | NT | 3 | 103.2 | 39.2 | n.s. |
| 202 | 2017 | ST | 3 | 87.1 | 24.9 | n.s. |
| 246 | 2017 | NT | 3 | 106.5 | 6.6 | N/A |

¥ Cultivated system (CT) and no till (NT);

¶ Number of observations (n);

S£ \*\*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.05; \*Tillage systems within a year and N rate with different lowercase letters are significantly different at P<0.10; n.s. = not significantly different between tillage systems within a year and N rate; N/A = tillage treatments missing for this year and N rate. Significance (S) determined using t-test to test for difference among tillage systems within a year and N rate.

€Only one observation for the NT tillage treatment this year

**Table S20.** Further discussion of the grain yield and crop residue findings for the 2001 to 2007 (NT and CT); 2006 and 2007 ( NT, ST and CT) and 2006 to 2017 (NT and ST) time periods.

|  |  |
| --- | --- |
| Time Period and Tillage System | Additional Details from Discussion Section |
| 2001 to 2007:  NT vs. CT | For the initial period of 2001 to 2007, the higher HGNC of 130 kg N ha-1 with CT was achieved at a lower NFR (150 kg N ha-1) than the NFRof the NT (169 kg N ha-1; P<0.10; Fig. 1; Tables 1 and 2). The higher HGNC of the non-fertilized CT treatment during this period than the HGNCof the NT suggests increased N cycling from background N sources other than N fertilizer due to tillage effects with cultivation when CT is compared to NT (P<0.01; Fig. 1; Tables 1 and 2). For CT, the NUELPPHG was 48.6%, which was higher than the NUELPPHG of the NT of 42.6%. In other words, close to 50% of the N fertilizer applied to the CT plots was taken up and removed with the harvested grain at the plateau, exceeding the 42.6% taken up and removed with the harvested grain of the NT during the 2001 to 2007 period at the plateau. The potential for N losses from N fertilizer applied was therefore higher with the NT (57.4%) than the potential for N losses with the CT plots (51.4%) at the NFR of the grain. These findings with respect to NUE agree with the NUE values reported by Halvorson et al., which covered the preliminary results for NUE of the CT and NT treatments in the early years (2001 to 2005) of the study [22]. Using a quadratic approach, Halvorson et al. reported an NUE of 43% of N fertilizer rates over years for CT and NT [22]. This is comparable to the average NUELPPHG found in the present work of 45.6% for NT and CT for the 2001 to 2007 period, which was obtained using a linear-plus-plateau model approach.  When we look at the 2001 to 2007 total aboveground N uptake, the NFR values with the CT and NT were similar for both treatments and averaged 170 kg N ha-1 (Fig. 4; Tables 1 and 2). However, the TBNC with the CT was significantly higher than the TBNC with the NT during this period (P<0.01; Fig. 4; Tables 1 and 2), which contributed to a higher TBNCwith the CT than the NT. The NUELPPTB with the CT of 68.3% was higher than the NUELPPTB with the NT of 64.2% during this 2001 to 2007 period. When we used the linear-plus-plateau model to do an N balance during the 2001 to 2007 period, we found that although a similar amount of N was left in the field with the crop residue for CT and NT systems that received the same N rates, there was greater TBNC for CT, as well as greater TBNCwith the CT plots. This resulted in greater movement of N to the grain compartment and larger removal of N from the field with the harvested CT grain, which was removing about 15 kg N ha-1 yr-1 more N than the grain harvested under NT. These results are in sync with the total N uptake found with the CT, which was about 17 kg N ha-1 more than the NT.  The NFRfor crop residue was much larger than the NFR for harvested grain. The NFR for the 2001 to 2007 period for crop residue was not significantly different between the CT and NT treatments and averaged 182 kg N ha-1 (Fig. 7; Tables 1 and 2). There were no significant differences in CRNC for CT and NT systems. The NUELPPCR averaged for both treatments was only 22.0%, indicating that most of the N fertilizer is recovered and removed from the field with the harvested grain, leaving a lower amount of N fertilizer in the crop residue since 66.4 and 64.2% of the total N fertilizer uptake in corn was in the corn grain compartment for the CT and NT treatments, respectively. However, these much larger NFRvalues for crop residue for harvested grain suggest that if we want to continue having N cycling that supplies N to the soil system, we may have to apply N in a greater quantity than needed for achieving grain production at the linear plateau N rate; otherwise, the N cycling with the crop residue may be reduced. |
| 2006 to 2007:  NT vs. CT vs. ST | The NFR for grain production with NT of 101 kg N ha-1 was not significantly different from the NFR of 114.2 kg N ha-1 with CT, but both were significantly lower than the NFRof 151 kg N ha-1 with ST (P<0.05 ST vs. NT; P<0.10 CT vs. ST; Fig. 1; Tables 1 and 3). The HGNCof NT of 98 kg N ha-1 was significantly lower than the HGNCof CT and ST of 125 and 136 kg N ha-1, respectively (P<0.05 ST vs. NT; P<0.10 CT vs. ST; Fig. 4; Tables 1 and 3). The HGNC values for the CT and ST were 125 and 136 kg N ha-1, respectively, and were not significantly different (Table 1). The HGNC for the CT and ST were 56 and 57 kg N ha-1, respectively, and were not significantly different. However, both HGNC values were higher than the HGNC of 37 kg N ha-1 with the NT (P<0.01 Fig. 4; Tables 1 and 3). These differences in N uptake of the HGNC suggest that there was still a cultivation effect with the CT and ST that contributed to increasing the N cycling compared to the N cycling with the NT during this period. The NUELPPHG values at the plateau for the grain N uptake were 61 and 60.1% for the CT and NT, which were higher than the average NUELPPHG with the ST (52%). This response in NUELPPHG also suggests that the higher N cycling with the fertilized crop residue of the NT may have also started to contribute to greater N cycling from the crop residue left at the surface soil after harvest with NT during the 2006 to 2007 period.  The NFRvalues for TBNCwere not significantly different for the NT, CT, and ST, and averaged 162 kg N ha-1 during the 2006 to 2007 period. The TBNC of the ST of 82 kg N ha-1 was significantly higher than the TBNC of 70 kg N ha-1 with the NT (P<0.10; Fig. 5; Tables 1 and 3), but it was not significantly different from the TBNC of the CT of 82 kg N ha-1. The 2006 to 2007 TBNC values of the CT and NT were not significantly different. The NUELPPTB values of the CT (70.3%) and ST (70.1%) from 2006 to 2007 were higher on average than the NUELPPTB of the NT (61.3%).  We were not able to use the linear-plus-plateau model as a response function for describing crop residue N uptake versus N, and due to this we had to use a linear regression model that was able to describe the crop residue data response during 2006 to 2007 (Fig. 5b; Tables 1 and 5). There was no difference in the maximum N uptake of the crop residue between the NT (76 kg N ha-1) and CT (69 kg N ha-1). However, the maximum N uptake of the crop residue for NT and CT was significantly higher than the crop residue N uptake of the ST (62 kg N ha-1). These maximum crop residue N uptake values during 2006 to 2007 were obtained with an N fertilizer rate of 246 kg N ha-1. The CRNCvalues of the non-fertilized plots for the NT, CT, and ST were not significantly different and averaged 26 kg N ha-1. |
| 2006 to 2017:  NT vs. ST | The corn grain N uptake with ST (HGNC of 131 kg N ha-1) was not different with NT (HGNC of 123 kg N ha-1), though both were achieved at the same NFRof 157 kg N ha-1. The HGNC values were similar for the NT and ST and averaged 48 kg N ha-1. Thus, the NUELPPHG of the ST of 51.7% was higher than the NUELPPHG of 47.1% with the NT.  The NFR for the total aboveground biomass N uptake was similar for the NT and ST treatments and averaged 165 kg N ha-1. The average N uptake by the (non-fertilized) control plots were similar and averaged 78 kg N ha-1 (Fig. 4c, Table 1 and 4). The average NUELPPTB at the plateau for NT and ST was 71.3% during the 2006 to 2017 period.  The 2006 to 2017 CRNCwith the NT of the non-fertilized plots of 32 kg N ha-1 was higher than the CRNC of 28 kg N ha-1 with the ST (P<0.10; Fig. 4c, Table 1 and 4). The NFR values at the plateau for the crop residue of the NT and ST treatments were similar and averaged 182 kg N ha-1. The NUELPPCR of NT (22.7%) was thus higher than the NUELPPCR with ST (21.1%). |

**Table S21.** Analysis of the yields and N uptake t-test results by year and N rate were in sync with the findings for the linear-plus-plateau model for 2001 to 2007 (NT and CT); 2006 and 2007 ( NT, ST, and CT) and 2006 to 2017 (NT and ST) time periods.

|  |  |
| --- | --- |
| Analysis | Additional Details from Discussion Section |
| Effect of Long-term Tillage on Grain Yield | Analysis of the t-test results by year and N rate from 2001 to 2007 shows that across many different year-and-N-rate combinations, there were higher harvested grain yields (HGY) with CT than with NT. Specifically, there were higher HGY with CT than NT in 2001 at 67.2, 134, and 168 kg N ha-1 (P<0.05; Table S5), in 2002 at 0, 33.6, 67.2, and 134 kg N ha-1 (P<0.05; Table S5), in 2003 at 0 and 101 kg N ha-1 (P<0.05; Table S5), in 2004 at 0, 33.6, 67.2, 101, 134, and 224 kg N ha-1 (P<0.05; Table S5), in 2005 at 33.6, 67.2, 101, 134, and 246 kg N ha-1 (P<0.05; Table S5), in 2006 at 0 and 33.6 kg N ha-1 (P<0.05; Table S5), and 2007 at 67.2 and 134 kg N ha-1 (P<0.05; Table S5). From 2001 to 2007, the significant differences detected with the t-test showed higher HGY with CT than NT, except in 2007 when the HGY with NT at 246 kg N ha-1 (P<0.05; Table S5), was higher than with CT.  From 2001 to 2007, all the CT N rates above 134 kg N ha-1 had, on average, higher or significantly higher HGY at P<0.05, except in 2006 when the average HGY of NT exceeded that of CT at the 246 kg N ha-1 rate, and in 2007, when NT at the 246 kg N ha-1 rate had significantly (P<0.05; Table S5) higher HGY than CT (P<0.05; Table S5). The analysis showed that at the zero N fertilizer rate, in four of the seven years the HGY of the CT was significantly higher than that of NT (P<0.10; Table S5). This year-by-year analysis of HGY for the CT and NT treatments from 2001 to 2007 was in sync with the HGandanalysis conducted using the linear-plus-plateau model for the 2001 to 2007 period. These year-to-year results show that immediately after conversion to NT, the HGY from NT were significantly lower than the yields from CT (P<0.1; Table S5).  The t-test results by year and N rate from 2006 to 2007 found that although during the 2006 to 2007 period the 2006 HGY with CT for the 0 and 33.6 kg N ha-1 rates and the 2007 HGY with CT for the 67.2 and 134 kg N ha-1 rates were significantly higher than that of NT (P<0.05; Table S6), in 2007 the HGY with NT at the 246 kg N ha-1 rate was higher than that of CT (P<0.05; Table S6). Additionally, in 2007 the HGY with NT at the 246 kg N ha-1 rate was also significantly higher than that of ST (P<0.05; Table S6). Although in 2006 the HGY of CT at the 33.6 kg N ha-1 rate was higher than that of ST (P<0.05), the HGY of ST at the 246 kg N ha-1 rate was higher than that of CT (P<0.05; Table S6).The year-by-year analysis of HGY with the 0 kg N ha-1 fertilizer rate for 2006 and 2007 found that although there were no differences in HGY between NT, CT, and ST at 0 kg N ha-1 in 2007, in 2006 the HGY with CT at 0 kg N ha-1 was higher than that of NT at 0 kg N ha-1, while the HGY of ST at 0 kg N ha-1 was not different from that of NT or CT at 0 kg N ha-1 (P<0.05; Table S6).  These year-by-year analyses of HGY for 2006 and 2007 for the NT, ST, and CT systems were consistent with the assessment of HGand conducted using the linear-plus-plateau model for the 2006 to 2007 period. These year-to-year results show that the average yields with the highest N rate of 246 kg N ha-1 were higher with NT. (P<0.1; Table S6), in agreement with the results obtained with the linear-plus-plateau model, which shows higher yields with no till during 2006 and 2007 compared to CT.  Analysis of t-test results by year and N rate for the 2006 to 2017 period found higher HGY with NT than ST for 2007 at the 246 kg N ha-1 rate (P<0.05; Table S7), 2010 at the 67.2 kg N ha-1 rate (P<0.05; Table S7), and 2015 at the 67.2 kg N ha-1 rate (P<0.05; Table S7). In contrast, higher HGY was achieved with ST than NT for 2009 at the 67.2 kg N ha-1 rate (P<0.05; Table S7), 2011 at the 67.2 kg N ha-1 rate (P<0.05; Table S7), and 2016 at the 0 and 202 kg N ha-1 rates (P<0.05; Table S7). The average HGY by year and treatment for the 2006 to 2017 period at N fertilizer rates equal to or greater than 134 kg N ha-1 were 9,976 and 9,863 kg ha-1 for the NT and ST systems, respectively. Most of the differences in HGY were observed at N rates lower than 134 kg N ha-1; the HGY of NT at N rates above 134 kg N ha-1 were greater than those of ST only in 2007, and the HGY of ST were higher than those of NT in 2009 and 2016, essentially showing that NT and ST were mostly equal after 2007. Out of 11 years, in only one year the HGY with ST was greater than that of NT at 0 kg N ha-1 (2016). These year-by-year analyses of HGY for the ST and NT systems from 2006 to 2017 were in sync with the assessment of HGand conducted with the linear-plus-plateau model for the 2006 to 2017 period.  In summary, our analysis of these t-test results for HGY by year and N rate are in sync with the determination of HG and HGY made with the linear-plus-plateau model for the 2001 to 2007, 2006 to 2007, and 2006 to 2017 periods (Tables 1, S5, S6, and S7). These analyses basically show a predominantly higher HGY with CT than NT for the 2001 to 2007 period, including a higher HGY with CT than with NT with the zero N fertilizer treatment. However, the year-by-year analysis shows that by the last two years of this period (2006 and 2007), there was greater HGY with NT than CT, which is also in agreement with the analysis conducted with the linear-plus-plateau model for the 2006 to 2007 period. The HGY of ST during 2006 to 2007 was higher than that of CT and ST, with NT resulting in lower HGY with zero N fertilizer. These findings suggest that the HGY of NT increased with time with respect to CT.  Our findings also indicate there were practically no differences in HGY between NT and ST during the 2006 to 2017 period with the higher N rates. These year-by-year analyses suggest that the NT yields were also improving with respect to ST with time, with yields becoming similar. The HGY with NT was higher than 10,000 kg ha-1 in 8 of the 9 years from 2009 to 2017 (Table S7); similarly, HGY of ST exceeded 10,000 kg ha-1 in 8 of 9 years (Table S7). In contrast, the HGY with NT was greater than 10,000 kg ha-1 in only 1 of the 7 years from 2001 to 2007, while the HGY with CT was higher than 10,000 kg ha-1 in 5 of 7 years during 2001 to 2007 (Table S5). During 2006 to 2007 the HGY exceeded 10,000 kg ha-1 once with CT, once with NT, and in both years with ST (Table S6). These year-by-year analyses of HGY are in sync with the determination of CRB and CRB made with the linear-plus-plateau model for the 2001 to 2007, 2006 to 2007, and 2006 to 2017 periods. In summary, these year-by-year analyses suggest improvements in HGY of NT with time with respect to other tillage systems (i.e., higher than CT after five years, and comparable to ST after seven years), which is in agreement with analysis conducted with the linear-plus-plateau model for the different periods (Tables 1, S5, S6, and S7). |
| Effect of Long-term Tillage on Crop Residue | Analysis of the t-test results by year and N rate from 2001 to 2007 found that CRB of CT was greater than that of NT during 2002 at the 33.6 kg N ha-1 rate (P<0.05; Table S8), 2004 at the 33.6 kg N ha-1 rate (P<0.05; Table S8), 2005 at the 67.2 kg N ha-1 rate (P<0.05; Table S8), and 2007 at the 67.2 kg N ha-1 rate (P<0.05; Table S8). In contrast, the CRB of NT was higher than that of CT in 2001 at the 0 and 134 kg N ha-1 rates (P<0.05; Table S8), and 2006 at the 134 and 246 kg N ha-1 rates (P<0.05; Table S8). This non-significant difference found with the CRBand analysis conducted with the linear-plus-plateau model for the 2001 to 2007 period is partially in sync with the t-test results. Although there were instances where the CT had higher CRB than the NT, it was at the lower N rates. NT had higher CRB than CT at the zero N fertilizer rate and at the higher N rates. However, on average, in six of the seven years there were no differences at high N rates or with zero N fertilizer application, which agrees with the CRBand analysis conducted with the linear-plus-plateau model for the 2001 to 2007 period.  Analysis of the t-test results by year and N rate from 2006 to 2007 found that the CRB of CT was higher than that of NT in 2007 at 67.2 kg N ha-1 (P<0.05; Table S9), and the CRB of NT was higher than that of CT in 2006 at 134 and 246 kg N ha-1 (P<0.05; Table S9). The CRB of NT was higher than that of ST in 2006 and 2007 at the 246 kg N ha-1 rate (P<0.05; Table S9). The CRB of ST was higher than that of CT in 2006 at the 101 and 246 kg N ha-1 rates and in 2007 at the 0 kg N ha-1 rate (P<0.05; Table S9). The CRB of the CT was higher than that of the ST during this period only at the 246 kg N ha-1 rate. The year-by-year analysis from 2006 and 2007, including with the zero N fertilizer, were in sync with the CRBand analysis conducted with linear-plus-plateau model for the 2006 to 2007 period.  Analysis of the t-test results by year and N rate from 2006 to 2017 found higher CRB with NT than ST in 2006 at 246 kg N ha-1 (P<0.05; Table S10), 2007 at 246 kg N ha-1 (P<0.05; Table S10), 2010 at 0 kg N ha-1 (P<0.05; Table S10), 2014 at 0 kg N ha-1; P<0.05; Table S10), and 2017 at 134 kg N ha-1 (P<0.05; Table S10). None of the t-tests by year and N rate from 2006 to 2017 found a higher CRB with ST than NT for 2006. These findings of higher CRB with NT than ST treatments from 2006 to 2017, including with the zero N fertilizer, are in sync with the CRBand analysis conducted with the linear-plus-plateau model for the 2006 to 2017 period.  In summary, the year-to-year analysis showed that from 2001 to 2007 there were four significant year-treatment combinations where the CRB with CT was higher than that of NT, and four times where the CRB with NT was greater than with CT; however, all of these significant differences were observed at N fertilizer rates of 67.2 kg N ha-1 or lower, except in 2006 when CRB with NT exceeded that of CT at N fertilizer rates of 134 and 246 kg N ha-1. These results show practically no difference in CRB from 2001 to 2007 between CT and NT at higher production levels of CRB (Table S8).  Looking at the last two years (the 2006 to 2007 period), we found that CRB with NT at rates of 134 and 246 kg N ha-1 was greater with NT than CT in 2006. Additionally, CRB with ST was greater than that of CT at rates of 101 and 246 kg N ha-1 in 2006, but in 2007 CRB with CT exceeded that of ST at the 246 kg N ha-1 rate. The CRB of ST was greater than that of NT at the zero N fertilizer rate in 2007 (Table S9).  From 2006 to 2017, there were five instances where more CRB was produced with NT than ST, including three times at N rates greater than 134 kg N ha-1 and two times at 0 kg N ha-1. At no time did the CRB from ST surpass that of NT. Additionally, from 2006 to 2017 CRB with NT was greater than 10,000 kg ha-1 in 8 of the 11 years (Table S10), while from 2001 to 2007 NT CRB exceeded 10,000 kg ha-1 in only 2 of the 7 years (Table S8). The year-to-year analysis suggests that the CRB with NT was increasing with time with respect to other tillage systems, in agreement with the analysis conducted with the linear-plus-plateau.  In summary, our analysis of the t-test results for CRB by year and N rate are in sync with the determination of CRB, and CRB made with the linear-plus-plateau model for the 2001 to 2007, 2006 to 2007, and 2006 to 2017 periods (Tables 1, S8, S9, and S10). The analysis basically shows a predominantly non-significant difference in CRB between the CT and NT for the 2001 to 2007 period, including no difference with the zero N fertilizer treatment in measured CRB between the two tillage systems during this period. At the same time, they show that among the three tillage systems, there was greater CRB with NT than ST in the last two years (2006 to 2007); however, there was greater CRB with zero N fertilizer with ST than with CT during this period (Fig. 2b).  It also shows greater CRB with NT than ST during the 2006 to 2017 period. There was also higher CRB with NT at the zero N fertilizer rate than ST during the 2006 to 2017 period. Our year-by-year analysis of CRB agrees with the determination of the CRB and CRB made with the linear-plus-plateau model for the 2001 to 2007, 2006 to 2007, and 2006 to 2017 periods. |
| Effect of Long-Term Tillage on Grain N Uptake | An analysis of t-test results by year and N rate for the 2001 to 2007 period found that across many combinations of year and N rate, there was significantly higher measured harvested grain N content (HGNC) with CT than NT. Specifically, HGNC was higher with CT than NT in 2001 at the 67.2 kg N ha-1 rate (P<0.05; Table S11), in 2002 at the 0, 33.6, 67.2, 134, and 202 kg N ha-1 rates (P<0.05; Table S11), in 2003 at the 0, 33.6, 101, 134, and 224 kg N ha-1 rates (P<0.05; Table S11), in 2004 at the 0, 33.6, 67.2, 101, and 134 kg N ha-1 rates (P<0.05; Table S11), in 2006 at the 33.6 kg N ha-1rate (P<0.05; Table S11), and in 2007 at the 0, 67.2, 134, 202, and 246 kg N ha-1 rates (P<0.05; Table S11). The HGNC with CT at 0 kg N ha-1 of fertilizer was also significantly higher than the HGNC with NT during 2002 (P<0.05), 2003 (P<0.05), 2004 (P<0.05), and 2007 (P<0.05; Table S11). These year-by-year HGNC analyses were in sync with the HGNCand HGNCanalyses conducted for 2001 to 2007 with the linear-plus-plateau model.  Analysis of the t-test results by year and N rate from 2006 to 2007 found that during the 2006 to 2007 period, the 2006 HGNC values were higher with CT than NT for the 33.6 and 67.2 kg N ha-1 rates (P<0.05; Table S12). In 2007, the HGNC was higher with CT than NT for the 67.2, 134, 202, and 246 kg N ha-1 rates (P<0.05; Table S12). Additionally, the 2007 HGNC with ST was higher than with NT for the 67.2, 134, 202 and 246 kg N ha-1 rates (P<0.05; Table S12). The 2006 HGNC with CT was higher than with the ST for the 33.6 kg N ha-1 rate (P<0.05; Table S12), while in 2007 the HGNC of the ST under the 202 kg N ha-1 application rate (P<0.05; Table S12), was higher than with CT (Table S12). Additionally, in 2007 the HGNC values of the ST under the 202 and 246 kg N ha-1 rates (P<0.05; Table S12), were higher than with NT (Table S12). The HGNC with the ST under zero N fertilizer was also significantly higher than the HGNC with NT during 2006 and 2007 (P<0.05; Table S12). The HGNC with the CT under zero N fertilizer was also significantly higher than the HGNC with NT during 2007 (P<0.05; Table S12). These year-by-year analyses of HGNC were in sync with the HGNCand HGNCanalyses for 2006 to 2007 conducted with the linear-plus-plateau model.  The analysis of t-test results by year and N rate from 2006 to 2017 found that while the HGNC with ST was higher than with NT under zero N fertilizer in 2006 and 2007, after 2007 the HGNC values of the NT and ST under zero N fertilizer were similar (Table S13). The 2006 to 2017 HGNC was higher in 2007 with the ST than NT for the 67.2, 134, 202, and 246 kg N ha-1 rates (P<0.05; Table S13). Additionally, HGNC of the ST was higher than with NT in 2011 with the 67.2 and 202 kg N ha-1 rates (P<0.05; Table S13). The HGNC of the NT was higher than with ST in 2017 under the 202 kg N ha-1 rate (P<0.05; Table S13). The average HGNC values by year and treatment from 2006 to 2017 at N fertilizer rates greater than 200 kg N ha-1 were 115 and 122 kg N ha-1 for the NT and ST systems, respectively. These analyses were in sync with the HGNCand HGNCanalyses conducted for 2006 to 2007 with the linear-plus-plateau model.  These analyses of HGNC by year and N rate treatments are in sync with the HGNC and HGNC values determined with the linear-plus-plateau model for the 2001 to 2007, 2006 to 2007, and 2006 to 2017 periods (Tables 1, S11, S12, and S13). They show a predominantly higher HGNC with CT than NT and higher N cycling and uptake with CT than NT. They also show a higher HGNC with the ST than the NT; however, the difference is much smaller than for the 2006 to 2007 period. Although initially there was higher N uptake by ST than NT, after seven years of NT, the HGNC of the ST and NT are close to similar, with no differences in the ST and NT under zero N fertilizer. |
| Effect of Long-Term Tillage on Total N Uptake | The analysis of the t-test results by year and N rate from 2001 to 2007 showed significantly higher total aboveground N content (TBNC) with CT for different N rate treatments during 2002 (33.6, 67.2, and 134 kg N ha-1; P<0.05; Table S14), 2003 (33.6, 101, and 134 kg N ha-1; P<0.05; Table S14), 2004 (33.6, 67.2, 101, and 134 kg N ha-1 P<0.05; Table S14), 2006 (33.6 kg N ha-1; P<0.05; Table S14), and 2007 (67.2, 134, 202, and 246 kg N ha-1; P<0.05; Table S14), than the TBNC with NT (Table S14). In the 2001 to 2007 period, the TBNC with the NT under zero N fertilizer during 2001 was higher than with CT (P<0.05; Table S14). Additionally, the TBNC with the CT under zero N fertilizer during 2003 (P<0.05; Table S14), and 2004 (P<0.05; Table S14), was higher than the TBNC with NT (Table S14). The average TBNC for CT under zero N fertilizer from 2001 to 2007 was 75 kg N ha-1, which was a higher average than the TBNC of 69 kg N ha-1 with NT (P<0.05; Table S14).  During the 2006 to 2007 period, in 2007 the TBNC values were higher with CT than NT for the 67.2, 202, and 246 kg N ha-1 treatments (P<0.05; Table S15). Additionally, in 2006 the TBNC with the 33.6 kg N ha-1 rate was higher with CT than NT (P<0.05; Table S15). In 2007 the TBNC was higher with CT than ST for the 246 kg N ha-1 rate (P<0.05; Table S15). However, the TBNC was higher with ST than with NT for the 202 and 246 kg N ha-1 rates in 2007 (P<0.05; Table S15). The TBNC values with ST under zero N fertilizer in 2006 and 2007 were higher than with NT (P<0.05; Table S15).  During the 2006 to 2017 period, although the TBNC with ST was higher than with NT under zero N fertilizer in 2006 and 2007, after 2007 the TBNC of the NT and ST under zero N fertilizer were similar (P<0.05; Table S16). For the 2006 to 2017 period, the TBNC was higher in 2007 with ST than NT for the 67.2, 134, 202, and 246 kg N ha-1 rates (P<0.05; Table S16). Additionally, the TBNC of ST was higher than the TBNC with NT in 2009 with the 67.2 kg N ha-1, and in 2016 with the 202 kg N ha-1 (P<0.05; Table S16), The TBNC of the NT was higher than the TBNC with ST in 2014 for the 202 kg N ha-1 and in 2017 for the 134 kg N ha-1 (P<0.05; Table S16).  These analyses of measured TBNC by year and N rate are in sync with the TBNC, NFR, and TBNC found with the linear-plus-plateau model for the 2001 to 2007, 2006 to 2007, and 2006 to 2017 periods (Tables 1, S14, S15, and S16). They show predominantly higher TBNC with the CT than NT and higher N cycling and uptake by CT than NT. They also show TBNC was initially higher with the ST than NT (2006 to 2007), but over time there was a much smaller relative difference due to tillage (2006 to 2017). Initially there was higher N uptake by ST than NT, but after seven years the difference in TBNC between ST and NT became smaller. |
| Effect of Long-Term Tillage on Crop Residue N Uptake | Analysis of the t-test results by year and N rate from 2001 to 2007 found that measured crop residue N content (CRNC) with NT was initially higher in 2001 (at 0 and 67.2 kg N ha-1;P<0.05; Table S17), and later on in 2006 (at 134 and 246 kg N ha-1) and 2007 (at 202 kg N ha-1;P<0.5; Table S17). However, the CRNC of the CT during this period essentially “compensated” for this by being higher than that of NT in 2002 (at 33.6 kg N ha-1), 2003 (at 0, 33.6, 101 and 134 kg N ha-1), and 2004 (at 33.6 and 101 kg N ha-1). In other words, the initially higher CRNC with NT in 2001, 2006, and 2007 balanced out the three years that CRNC was significant during the middle of this period, which agrees with the findings from the analysis with the linear-plus-plateau model that there were no significant differences for the 2001 to 2007 period. A similar phenomenon was observed where CRNC was higher with NT in 2001 under zero N fertilizer, but higher with CT in 2003 under zero N fertilizer, which agrees with the findings from our analysis using the linear-plus-plateau model at the intercept that there were no significant differences for the 2001 to 2007 period.  Analysis of the t-test results by year and N rate from 2006 and 2007 found that CRNC with NT was greater during these two years than with CT in 2006 (at 134 and 246 kg N ha-1) and 2007 (at 202 kg N ha-1;P<0.05; Table S18). Additionally, during these two years the CRNC with NT was greater than with ST at the highest N rate of 246 kg N ha-1 in 2006 and 2007 (P<0.05; Table S18 at 202 kg N ha-1).  The CRNC of CT with an application rate of 246 kg N ha-1 in 2007 was greater than that with ST (at 202 kg N ha-1; P<0.05; Table S18). The CRNC values with the zero N fertilizer plots during 2006 to 2007 were not significantly different (Table S18). This finding of no difference in CRNC under zero N fertilizer while having higher CRNC with NT and CT than ST during 2006 to 2007 agrees with the results of our analysis for the 2006 to 2007 period using the linear-plus-plateau model.  Analysis of the t-test results by year and N rate from 2006 and 2017 found that the CRNC with NT was greater than that with ST in 2006 (at 246 kg N ha-1), 2007 (at 246 kg N ha-1), 2010 (at 0 kg N ha-1), 2012 (at 67 and 202 kg N ha-1), 2013 (at 67 kg N ha-1), 2014 (at 0 kg N ha-1), and 2017 (at 134 kg N ha-1) (P<0.5; Table S19). The CRNC with ST was greater than that with NT only in 2010 at the 67.2 kg N ha-1 rate (P<0.5; Table S19). Analysis of the t-test results by year and N rate from 2006 and 2017 found that CRNC with NT was greater than that of ST for several year-and-N-rate combinations during this time period, which agrees with the TBNC, and TBNC modeled by the linear-plus-plateau model for the 2006 to 2017 period. |

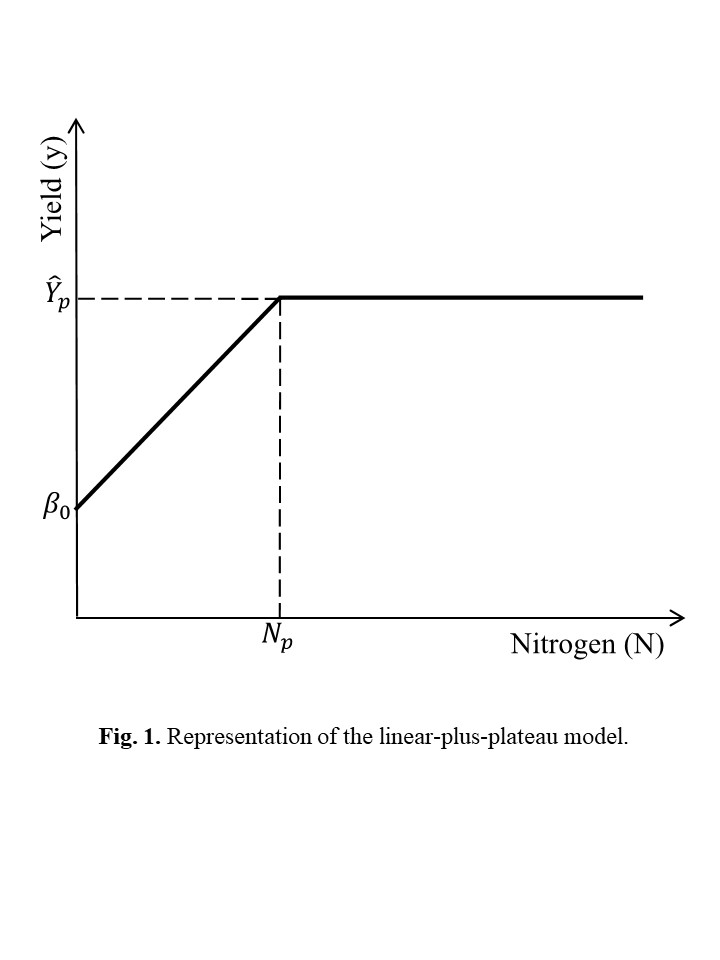
**Table S22.** List of abbreviations used in this work.

|  |  |
| --- | --- |
| ARDEC  CoAgMet  CSU  CC  CRY  CR  CR  CT  GDD  HP  HGY  HG  HGY  NFR  NH3-N  NT  NO3-N  NH4-N  NUE  N  R6  ST | Agricultural Research, Development and Education Center  COlorado AGricultural Meteorological nETwork  Colorado State University  continuous corn  Measured crop residue yield  Modeled crop residue yield at the plateau determined with the linear- plus-plateau model  Modeled crop residue yield at the intercept (zero N fertilizer) determined with the linear-plus-plateau model  conventional till  Growing degree days  horsepower  Measured harvested grain yield  Modeled harvested grain yield at the plateau determined with the linear-plus-plateau model  Modeled harvested grain yield at the intercept (zero N fertilizer) determined with the linear-plus-plateau model  Modeled nitrogen fertilizer rate at a given plateau determined with the linear-plus-plateau model  Ammonia nitrogen  no till  nitrate nitrogen  ammonium nitrogen  nitrogen use efficiency  nitrogen  physiological maturity (black layer)  strip till |

Graphical user interface, application

Description automatically generated

**Figure S1.** Standards run as samples in the Elementar C and N analyzer during this long-term study from 2005 to 2018, where the same sample was run on multiple occasions during the same year and for a large number of years. Soil, corn leaf, and corn stalk standards were run. Note that since on occasion, more than one run was done on the same day, the timescale of the regression equations in the graph of Figure S1 are in seconds (y = % N; x = seconds). However, the timescale of the graph’s x-axis is shown in years (y = % N; x = year).



**Figure S2.** Representation of the linear-plus-plateau model.