KANSAS STATE UNIVERSITY Agronomy

# Kansas Field Research 2017

K-STATE Research and Extension

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

# Kansas Field Research 2017

## Contents

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# East Central Kansas Experiment Field

## Introduction
The research program at the East Central Kansas Experiment Field is designed to keep area crop producers abreast of technological advances in agronomic agriculture. Specific objectives are to 1) identify top performing varieties and hybrids of wheat, corn, soybean, and grain sorghum; 2) establish the amount of tillage and crop residue cover needed for optimum crop production; 3) evaluate weed and disease control practices using chemical, no chemical, and combination methods; and 4) test fertilizer rates, timing, and application methods for agronomic proficiency and environmental stewardship.

## Soil Description
Soils on the field's 160 acres are Woodson. The terrain is upland and level to gently rolling. The surface soil is a dark gray-brown, somewhat poorly drained silt loam to silty clay loam over slowly permeable clay subsoil. The soil is derived from old alluvium. Water intake is slow, averaging less than 0.1 in./hour when saturated. This makes the soil susceptible to water runoff and sheet erosion.

## 2016 Weather Information
Precipitation during 2016 was about average, and only June was below average during the growing season (Table 1). Overall, the 2016 growing season was similar to 2015. The summer of 2016 had 39 days exceeding 90°F, but none of those days exceeding 100°F, compared to 2015, which had 37 days exceeding 90°F, but none of those days exceeding 100°F. There were only 8 days with low temperatures in the single digits, compared to 14 days in 2015. The last freezing temperature in the spring was April 12 (average, April 18), and the first killing frost in the fall was November 13 (average, October 21). There were 215 frost-free days, compared to the long-term average of 185.

With the exception of a dry June, the growing conditions were very favorable. The short-season and full-season corn hybrid trials averaged 153 and 178 bu/a, respectively. The soybean yields were very good, with the soybean variety trial averaging 79 bu/a, compared to 59 bu/a in 2015 and 41 in 2014.

**Table 1. Precipitation at the East Central Kansas Experiment Field, Ottawa**

| Month | 2016 | 35-year avg. | Month | 2016 | 35-year avg. |
|---|---|---|---|---|---|
| | ---------- | ---------- | in. | ---------- | ---------- |
| January | 0.63 | 1.03 | July | 5.64 | 3.37 |
| February | 0.62 | 1.32 | August | 6.53 | 3.59 |
| March | 1.96 | 2.49 | September | 5.81 | 3.83 |
| April | 3.91 | 3.50 | October | 1.29 | 3.43 |
| May | 6.06 | 5.23 | November | 0.26 | 2.32 |
| June | 1.87 | 5.21 | December | 0.87 | 1.45 |
| | | | Annual total | 35.45 | 36.78 |

# Kansas River Valley Experiment Field

## Introduction

The Kansas River Valley Experiment Field was established to study management and effective use of irrigation resources for crop production in the Kansas River Valley (KRV). The Paramore Unit consists of 80 acres located 3.5 miles east of Silver Lake on U.S. Highway 24, then 1 mile south of Kiro, and 1.5 miles east on 17th street. The Rossville Unit consists of 80 acres located 1 mile east of Rossville or 4 miles west of Silver Lake on U.S. Highway 24.

## Soil Description

Soils on the two fields are predominately in the Eudora series. Small areas of soils in the Sarpy, Kimo, and Wabash series also occur. Except for small areas of Kimo and Wabash soils in low areas, the soils are well drained. Soil texture varies from silt loam to sandy loam, and the soils are subject to wind erosion. Most soils are deep, but texture and surface drainage vary widely.

## 2016 Weather Information

The year was not as not as cold as previous years, but it was wetter during most of the growing season. The frost-free season was 212 days at both units (average = 173 days), with 7 and 8 days in single digits at Paramore and Rossville, respectively. This compares to 19 and 18 days in single digits in 2015 at Paramore and Rossville, respectively, compared to 30 and 31 days in 2014, respectively. The last spring freeze was April 12 (average = April 21), and the first fall freeze was November 10 (average = October 11). There were 43 and 39 days above 90°F at Paramore and Rossville, respectively, and one of those days above 100°F. Precipitation was above normal at both fields for the year (Table 1) and above average for all the months during the growing season except June. Irrigation requirements were approximately 6 inches for the corn and 1 inch for the soybeans. The corn performance trials averaged 226 bu/a for the irrigated and 180 bu/a for the dryland. The soybean performance trials averaged 57 bu/a for the irrigated and 76 bu/a for the dryland. The extremes in soil moisture from dry to saturated may have been the major yield limiting factor in the irrigated corn, and sudden death syndrome in 2016 was more severe than in 2015, but less than in 2014 in the irrigated soybeans at KRV.

**Table 1. Precipitation at the Kansas River Valley Experiment Field**

| Month | Rossville unit | | Paramore unit | |
|---|---|---|---|---|
| | 2016 | 30-year average | 2016 | 30-year average |
| | ---------- | ---------- in. ---------- | ---------- | ---------- |
| January | 0.84 | 3.18 | 0.74 | 3.08 |
| February | 0.58 | 4.88 | 0.53 | 4.45 |
| March | 1.14 | 5.46 | 1.03 | 5.54 |
| April | 10.30 | 3.67 | 6.37 | 3.59 |
| May | 6.63 | 3.44 | 5.61 | 3.89 |
| June | 2.31 | 4.64 | 2.73 | 3.81 |
| July | 4.91 | 2.97 | 5.30 | 3.06 |
| August | 7.61 | 1.90 | 4.96 | 1.93 |
| September | 9.20 | 1.24 | 10.33 | 1.43 |
| October | 1.68 | 0.95 | 1.15 | 0.95 |
| November | 0.34 | 0.89 | 0.23 | 1.04 |
| December | 0.85 | 2.42 | 0.81 | 2.46 |
| Total | 46.39 | 35.64 | 39.79 | 35.23 |

# Weather Reports for Research Field Locations

**Table 1. Precipitation at Ashland Bottoms, Belleville, and Colby**

| | Ashland Bottoms | | Belleville | | Colby | |
|---|---|---|---|---|---|---|
| Month | 2016 | 30-year average | 2016 | 30-year average | 2016 | 30-year average |
| | ------------------------------------------------- | ------------------------------------------------- | ------------------------------------------------- in. | ------------------------------------------------- | ------------------------------------------------- | ------------------------------------------------- |
| January | 0.50 | 0.65 | 0.87 | 0.61 | 0.00 | 0.41 |
| February | 0.40 | 1.07 | 0.55 | 0.87 | 0.17 | 0.48 |
| March | 0.44 | 2.20 | 0.58 | 2.12 | 0.26 | 1.12 |
| April | 8.45 | 2.80 | 4.93 | 2.87 | 5.64 | 2.03 |
| May | 6.98 | 4.48 | 9.44 | 4.35 | 1.51 | 3.29 |
| June | 1.55 | 5.09 | 1.12 | 4.37 | 1.70 | 2.54 |
| July | 6.10 | 3.97 | 4.65 | 3.97 | 2.53 | 3.77 |
| August | 7.31 | 4.28 | 7.25 | 3.68 | 1.54 | 2.78 |
| September | 4.16 | 3.17 | 2.24 | 3.25 | 0.91 | 1.45 |
| October | 2.77 | 2.22 | 1.87 | 2.37 | 0.02 | 1.58 |
| November | 0.30 | 1.60 | 0.91 | 1.19 | 0.09 | 0.72 |
| December | 0.83 | 1.02 | 1.16 | 0.95 | 0.25 | 0.48 |
| Annual | 39.79 | 32.55 | 35.57 | 30.6 | 14.62 | 20.65 |
| | | | | | | |
| Last freeze | 4/12/16 | | 4/13/16 | | 5/2/16 | |
| First freeze | 10/13/16 | | 10/13/16 | | 10/7/16 | |
| Frost free days | 184 | | 183 | | 158 | |
| Days above 90°F | 54 | | 45 | | 52 | |
| Days above 100°F | 4 | | 2 | | 3 | |
| Days below 10°F | 8 | | 12 | | 15 | |

**Table 2. Precipitation at Conway Springs, Ellsworth, and Hays**

| | Conway Springs | | Ellsworth | | Hays | |
|---|---|---|---|---|---|---|
| Month | 2016 | 30-year average | 2016 | 30-year average | 2016 | 30-year average |
| | ---- | ---- | ---- in. ---- | ---- | ---- | ---- |
| January | 0.16 | 0.82 | 0.89 | 0.62 | 0.36 | 0.51 |
| February | 0.60 | 1.37 | 1.06 | 1.06 | 0.21 | 0.67 |
| March | 1.09 | 3.06 | 0.86 | 2.35 | 0.43 | 1.74 |
| April | 5.86 | 3.08 | 6.31 | 2.43 | 6.94 | 2.21 |
| May | 6.17 | 4.51 | 7.90 | 4.50 | 2.72 | 3.19 |
| June | 2.09 | 5.17 | 2.50 | 3.93 | 3.15 | 3.38 |
| July | 3.94 | 3.55 | 6.13 | 3.63 | 3.11 | 4.34 |
| August | 6.12 | 3.51 | 8.75 | 3.94 | 4.66 | 3.08 |
| September | 12.55 | 2.69 | 1.17 | 3.05 | 1.29 | 2.10 |
| October | 1.91 | 2.88 | 0.62 | 2.20 | 0.64 | 1.61 |
| November | 0.26 | 1.79 | 0.86 | 1.11 | 1.13 | 0.90 |
| December | 0.95 | 1.14 | 1.00 | 0.93 | 0.38 | 0.61 |
| Annual | 41.7 | 33.57 | 38.05 | 29.75 | 25.02 | 24.34 |
| | | | | | | |
| Last freeze | | | 4/13/16 | | 4/13/16 | |
| First freeze | | | 10/14/16 | | 10/7/16 | |
| Frost free days | | | 184 | | 177 | |
| Days above 90°F | | | 63 | | 65 | |
| Days above 100°F | | | 4 | | 11 | |
| Days below 10°F | | | 8 | | 9 | |

**Table 3. Precipitation at Hutchinson, Manhattan, and McPherson**

| | Hutchinson | | Manhattan | | McPherson | |
|---|---|---|---|---|---|---|
| Month | 2016 | 30-year average | 2016 | 30-year average | 2016 | 30-year average |
| | ---------- in. ---------- | | | | | |
| January | 0.63 | 0.79 | 0.55 | 0.63 | 0.78 | 0.79 |
| February | 0.53 | 1.25 | 0.34 | 1.08 | 0.65 | 1.19 |
| March | 0.99 | 2.58 | 0.36 | 2.49 | 0.84 | 2.69 |
| April | 4.56 | 2.70 | 7.94 | 3.17 | 4.91 | 2.87 |
| May | 6.57 | 4.68 | 5.94 | 5.09 | 6.48 | 4.98 |
| June | 4.00 | 4.57 | 1.27 | 5.70 | 3.55 | 4.95 |
| July | 5.04 | 4.09 | 6.96 | 4.42 | 6.77 | 3.94 |
| August | 8.06 | 3.36 | 5.89 | 4.12 | 5.38 | 3.60 |
| September | 4.92 | 2.66 | 6.18 | 3.43 | 7.52 | 2.86 |
| October | 0.60 | 2.44 | 2.17 | 2.69 | 1.53 | 2.45 |
| November | 0.44 | 1.32 | 0.43 | 1.73 | 0.55 | 1.43 |
| December | 0.83 | 1.17 | 0.75 | 1.07 | 1.32 | 1.04 |
| Annual | 37.17 | 31.61 | 38.78 | 35.62 | 40.28 | 32.79 |
| | | | | | | |
| Last freeze | 4/12/16 | | 4/12/16 | | 4/13/16 | |
| First freeze | 11/12/16 | | 11/12/16 | | 11/12/16 | |
| Frost free days | 214 | | 214 | | 213 | |
| Days above 90°F | 64 | | 51 | | 51 | |
| Days above 100°F | 6 | | 5 | | 4 | |
| Days below 10°F | 7 | | 8 | | 7 | |

**Table 4. Precipitation at Perry and Scandia**

| | Perry | | Scandia | |
|---|---|---|---|---|
| Month | 2016 | 30-year average | 2016 | 30-year average |
| | ---------- in. ---------- | | | |
| January | 0.72 | 0.93 | 0.63 | 0.45 |
| February | 1.41 | 1.10 | 0.40 | 0.74 |
| March | 2.24 | 2.53 | 0.45 | 2.12 |
| April | 3.58 | 3.83 | 4.43 | 2.96 |
| May | 6.50 | 5.43 | 6.24 | 4.21 |
| June | 2.90 | 5.85 | 0.95 | 3.81 |
| July | 8.00 | 4.37 | 5.93 | 4.24 |
| August | 6.33 | 4.22 | 7.47 | 3.26 |
| September | 5.88 | 4.24 | 2.46 | 2.84 |
| October | 1.19 | 3.08 | 1.94 | 2.14 |
| November | 1.95 | 2.10 | 0.73 | 1.26 |
| December | 1.66 | 1.50 | 0.90 | 0.79 |
| Annual | 42.36 | 39.18 | 32.53 | 28.82 |
| | | | | |
| Last freeze | 4/13/16 | | 4/12/16 | |
| First freeze | 10/13/16 | | 10/12/16 | |
| Frost free days | 183 | | 183 | |
| Days above 90°F | 25 | | 40 | |
| Days above 100°F | 0 | | 3 | |
| Days below 10°F | 48 | | 16 | |

# Effect of Residue Management, Row Spacing, and Seeding Rate on Winter Canola Establishment, Winter Survival, and Yield

*B.M. Showalter, K.L. Roozeboom, M.J. Stamm, and R. Figger*[1]

## Summary
Winter survival of canola (*Brassica napus* L.) is a challenge for producers using high-residue, no-tillage, or reduced-tillage systems. An innovative residue management system being developed by AGCO Corporation was compared to cooperating canola producers' residue management and planting methods in wheat stubble. This series of on-farm experiments was conducted in 2014-2015 and 2015-2016 at ten locations in central and south-central Kansas. The AGCO treatments were 20- or 30-in. row spacing and three seeding rates (100,000, 150,000, and 200,000 seeds/a) for a total of six treatments. The producer treatment at each location included row spacing, seeding rate, and residue management practices preferred by that producer. Due to winter stand loss, only one of the six experiments planted in the fall of 2014 was harvested for yield in 2015. All four experiments planted in fall 2015 were harvested for yield in 2016. Fall stands usually differed in response to seeding rate and often were greater in 20-in. rows than in 30-in. rows. Spring stands were not as tightly correlated with seeding rate, but were consistently greater in narrow rows, regardless of seeding rate and residue management practices. Winter survival increased with reductions in seeding rate at most locations and was greater in 20-in. rows than in 30-in. rows at three of the five harvested locations. Yields were not affected by residue management, row spacing, or seeding rate at two of the five locations, including the location with yields surpassing 60 bu/a. At the other three locations, yields with the AGCO residue management system equaled or exceeded yields obtained with cooperator practices that typically included much greater seeding rates. Yields seldom responded to seeding rate, but when they did, yields tended to increase as seeding rate decreased.

## Introduction
Winter survival of canola (*Brassica napus* L.) is a challenge for producers using high-residue, no-tillage, or reduced tillage systems. If seed-to-soil contact is poor, emergence may be delayed, making the plant more susceptible to winter kill. A thick layer of plant residue above the seed row results in lengthening of the hypocotyl above the soil surface, exposing the crown to greater risk of damage from sub-freezing temperatures. The objective of this study conducted in cooperation with AGCO Corporation was to determine the effect of residue management, seeding density, and row spacing on stand establishment, winter survival, and yield.

[1] AGCO Corporation, Hesston, KS.

## Procedures

An innovative residue management system being developed by AGCO Corp. was compared to cooperating canola producers' no-tillage residue management and planting methods in wheat residue. This series of on-farm experiments was conducted in 2014-2015 and 2015-2016 at ten locations across Kansas. The AGCO treatments were 20- or 30-in. row spacing and three seeding rates (100,000, 150,000, and 200,000 seeds/a) for a total of six treatments. The producer treatment at each location included row spacing, seeding rate, and residue management practices preferred by that producer (Table 1). Plots were 30 feet in width and 550 to 626 feet in length depending on location. Fall establishment was determined by counting four sections of rows in each plot, each 3.3 to 10 feet in length. The average number of leaves per plant was determined just before winter dormancy to quantify potential differences in seedling development. The number of living plants was counted after green-up the next spring to determine spring plant density. Winter survival percent was calculated by dividing spring plant density by fall plant density and multiplying by 100. Bloom progression was estimated visually during mid bloom to determine if treatments influenced spring plant development. Cooperators' equipment was used to swath plots at 40 to 60% seed color change and to harvest for yield determination several days after swathing. Weight of canola from each plot was determined with weigh wagons or yield monitors depending on location (Table 1). Seed samples were collected from each plot and sent to the Brassica Breeding and Research program at the University of Idaho (Moscow, ID) for near-infrared spectroscopy (NIRS) oil content estimation. Due to winter stand loss, only one of the six experiments planted in the fall of 2014 was harvested for yield in 2015. All four experiments planted in fall 2015 were harvested for yield in 2016.

## Results

### *Fall Stand Establishment*

Fall plant density typically increased as seeding rates increased (Table 2). The 20-in. row spacing resulted in greater plant density than the 30-in. row spacing at a given seeding rate and averaged across seeding rates in three of five locations. Cooperator seeding rates often were substantially greater than all AGCO seeding rates and resulted in significantly greater fall stands in three of five locations. At these three locations (Kingman 2015, Conway Springs 2015, and Kiowa 2015), cooperators also planted canola in row spacings ranging from 10 to 15 inches. At one location (Stafford 2015) the AGCO treatments resulted in fall plant densities comparable to those achieved with cooperator practice. At another location (Andale 2014), AGCO seeding rates were greater than targeted and resulted in plant densities significantly greater than for the cooperator practice.

### *Spring Plant Density*

Spring plant density was not consistently related to seeding rate, indicating that plant density tended to equalize during the winter, regardless of how many seeds were planted (Table 3). Spring plant density was consistently greater in row spacings less than 30 in., regardless of seeding rate and residue management system. Reduced intra-plant competition in narrow row spacings may have allowed more plants to survive the winter.

### *Winter Survival*

Winter survival increased with decreasing seeding rates in 20-in. rows at four of the five locations (Table 4). Although winter survival followed a similar pattern in 30-in. rows only at Kiowa 2016 (winter survival increased with decreasing seeding rate), winter survival for the highest seeding rate was either equal to or less than that for the lowest seeding rate. Winter survival was greater in 20-in. vs. 30-in. rows at three of the five locations. Winter survival was negatively correlated with fall plant density at Andale 2015 (r = -0.36 and $P = 0.0590$), and Stafford 2016 (r = -0.45 and $P = 0.0178$), across all seeding rates and row spacings. These results suggest that greater intra-plant competition within the row resulting from greater seeding rates and/or wider row spacing likely increased the probability of plant death during the winter.

### *Plant Growth and Seed Oil Concentration*

Although leaf number and bloom progression differed between treatments at some locations, no consistent patterns were evident for fall or spring plant growth response to residue management, row spacing, or seeding rate (data not shown). Seed oil concentration differed between treatments only at Andale 2015, where oil concentration was greatest in the AGCO 20-in. row treatment with the lowest seeding rate. The cooperator practice treatment resulted in the lowest oil concentration. Even though treatment differences could be detected, the total range in oil concentration at this location was small, 39.5 to 41.1%. The range of plant populations and plant to plant spacings achieved in these experiments did not have a consistent effect on plant development or seed oil concentration.

### *Yield*

Yield response to management practices was not consistent at all locations. Yields were not affected by equipment, row spacing, or seeding rate at the Conway Springs 2016 and Kiowa 2016 locations, representing almost the extremes of the yield range across locations (Table 5). The relatively strong negative correlations between both fall establishment and spring stands versus yield at Kingman 2016 (r = -0.84, $P = <0.0001$, r = -0.85, and $P = <0.0001$, respectively) and at Conway Springs 2016 (r = -0.49, $P = 0.0125$, r = -0.46, and $P = 0.0188$, respectively) were likely related to plant stress resulting from periods of limited rainfall in fall and early spring at these environments. At Kiowa, where plants were under less drought stress, and yields were greater, there was a positive correlation between both fall establishment (r = 0.36 and $P = 0.0706$) and spring stands (r = 0.49 and $P = 0.0112$) and yield. These contrasting correlations at different locations reveal the influence of specific growing conditions on yield response to plant density. All AGCO treatments, including those with seeding rates substantially less than most cooperators' practice, produced yields that were either similar to or greater than those achieved using cooperator practices across a wide range of yield levels. This yield advantage was most consistent in 20-in. rows, but row spacing had a significant influence on yield only at Andale in 2015. These results indicate that seeding rates likely can be reduced from those typically used by canola producers in high residue, no-tillage or reduced tillage systems if residue can be adequately removed from the seed row. Seeding rates of 100,000 seeds/a (0.9 to 1.1 pounds per acre depending on seed size) resulting in spring plant densities as low as 50,000 plants/a (~1.1 plants/$ft^2$) supported yields ranging from 800 to 3100 lb/a.

### *Conclusions*

Cooperator practice tended to produce the greatest fall and spring plant densities, unless the AGCO seeding rate was greater than targeted (e.g. Andale 2015). Winter survival tended to increase as seeding rate decreased in 20-in. rows at four of the five locations. This could have been a result of greater intra-row plant spacing achieved with narrower rows. Yield increased as seeding rate decreased in AGCO treatments when row spacing was 20 in. at three locations. At Kingman 2016, all AGCO treatments yielded more than the cooperator practice. Reduced seeding rates in 20- and 30-in. row spacings using the AGCO residue management system produced yields similar to or superior than cooperator practice in all environments. Using the AGCO system, lower seeding rates produced superior yields regardless of row spacing in two environments, and 20-in. rows out-yielded 30-in. rows in one environment. These results indicate that seeding rates can be reduced from those typically used by canola producers in high residue, no-tillage systems if residue can be adequately removed from the seed row, and that row spacing less than 30 inches may increase establishment and winter survival.

**Table 1. Producer field operations for experiments comparing AGCO Corporation's residue management system with two different row spacings and three seeding rates with producer planting practices at five locations in Kansas in 2014-2016**

| Management factor | Andale 2014-2015 | Stafford 2015-2016 | Kingman 2015-2016 | Conway Springs 2015-2016 | Kiowa 2015-2016 |
|---|---|---|---|---|---|
| Residue management | Burned | Strip tillage | Vertical tillage | No-tillage | Vertical tillage |
| Planting equipment | John Deere 1750 row crop planter | John Deere 1790 row crop planter | John Deere 1890 air drill, disk openers | John Deere 1790 row crop planter | John Deere 1870 air hoe drill, Conservapak hoe openers |
| Row spacing (inches) | 30 | 30 | 10 | 15 | 12 |
| Cultivar | Mercedes | HyClass 115 W | DKW 44-10 | HyClass 125 W | DKW 45-25 |
| Seeds/a | 191,600 | 312,500 | 684,000 | 562,500 | 380,000 |
| Planting | September 19 | September 11 | September 14 | September 17 | September 25 |
| Fertilizer, -Fall lb/a N-$P_2O_5$-$K_2O$-S | 25-15-0-5 | 30-30-30-32 | | None | 30-40-0-10 |
| Fertilizer, -Spring lb/a N-S | 47-9 | 11-22 | | 73-8 | 30-8.5 |
| Swathing | June 21 | June 1 | June 4 | May 29 | May 30 |
| Harvest | June 25 | June 6 | June 9 | June 4 | June 7 |
| Grain weight | Weigh wagon | Green Star™ Harvest Monitor™ | Weigh wagon | Ag Leader Yield Monitoring | Grain cart with scales |

**Table 2. Fall plant establishment of canola planted with AGCO Corporation's residue management system, including two different row spacings and three seeding rates, and canola planted with cooperator practices at five Kansas locations in 2014 and 2015**

| | AGCO planter | | | | | | |
|---|---|---|---|---|---|---|---|
| | 20-in. row spacing | | | 30-in. row spacing | | | |
| | Seeding rate (seeds/a) | | | Seeding rate (seeds/a) | | | Cooperator |
| Environment | 100,000 | 150,000 | 200,000 | 100,000 | 150,000 | 200,000 | practice[‡] |
| | plants/a | | | | | | |
| Andale 2014 | 217,747 bc† | 244,965 b | 310,024 a | 154,495 d | 201,814 c | 236,335 b | 115,365 e |
| Stafford 2015 | 111,895 c | 139,501 b | 169,013 a | 107,593 cd | 81,748 d | 93,654 cd | 135,375 b |
| Kingman 2015 | 122,186 bc | 122,839 bc | 133,294 b | 70,567 e | 86,684 ed | 105,125 cd | 236,240 a |
| Conway Springs 2015 | 52,272 d | 71,003 c | 90,823 b | 51,256 d | 60,548 cd | 90,460 b | 200,046 a |
| Kiowa 2015 | 72,527 de | 91,040 cd | 93,872 c | 67,808 e | 95,542 c | 114,853 b | 190,108 a |

| | Seeding rate (seeds/a) | | | Row spacing | |
|---|---|---|---|---|---|
| | 100,000 | 150,000 | 200,000 | 20-in. | 30-in. |
| Andale 2014 | 186,103 c† | 223,390 b | 273,179 a | 257,579 a† | 197,536 b |
| Stafford 2015 | 109,982 | 123,856 | 119,205 | 140,803 a | 94,559 b |
| Kingman 2015 | 96,377 b | 104,762 b | 119,209 a | 126,106 a | 87,459 b |
| Conway Springs 2015 | 51,746 c | 65,776 b | 90,641 a | 71,366 | 67,421 |
| Kiowa 2015 | 70,168 b | 93,291 a | 104,363 a | 85,813 | 92,734 |

†Values within a row followed by the same letter are not different at $\alpha = 0.10$.

[‡]See Table 1 for details regarding producer field operations and practices at each location.

**Table 3. Spring plant density of canola planted with AGCO Corporation's residue management system, including two different row spacings and three seeding rates, and canola planted with cooperator practices at five Kansas locations in 2015 and 2016**

| | AGCO planter | | | | | | |
|---|---|---|---|---|---|---|---|
| | 20-in. row spacing | | | 30-in. row spacing | | | |
| | Seeding rate (seeds/a) | | | Seeding rate (seeds/a) | | | |
| Environment | 100,000 | 150,000 | 200,000 | 100,000 | 150,000 | 200,000 | Cooperator practice‡ |
| | plants/a | | | | | | |
| Andale 2015 | 96,260 a† | 79,000 b | 59,084 c | 29,210 d | 29,653 d | 34,078 d | 37,914 d |
| Stafford 2016 | 79,465 bc | 87,035 ab | 95,205 a | 59,197 de | 48,497 e | 56,892 e | 70,277 cd |
| Kingman 2016 | 80,368 de | 107,375 bc | 116,523 b | 59,096 f | 68,825 ef | 91,766 cd | 206,910 a |
| Conway Springs 2016 | 44,649 d | 57,717 cd | 68,825 b | 39,494 d | 47,771 cd | 58,806 bc | 150,830 a |
| Kiowa 2016 | 66,429 b | 71,656 b | 64,033 bc | 47,045 d | 53,288 cd | 64,324 bc | 140,235 a |

| | Seeding rate (seeds/a) | | | Row spacing | |
|---|---|---|---|---|---|
| | 100,000 | 150,000 | 200,000 | 20-in. | 30-in. |
| Andale 2015 | 62,735 | 54,326 | 46,581 | 78,114 a† | 30,980 b |
| Stafford 2016 | 69,288 | 66,937 | 79,479 | 88,844 a | 54,958 b |
| Kingman 2016 | 69,732 c† | 88,100 b | 104,145 a | 101,422 a | 73,229 b |
| Conway Springs 2016 | 40,072 c | 52,744 b | 63,815 a | 57,064 a | 48,690 b |
| Kiowa 2016 | 56,737 | 62,472 | 64,178 | 67,373 a | 54,886 b |

†Values within a row followed by the same letter are not different at $\alpha = 0.10$.

‡See Table 1 for details regarding producer field operations and practices at each location.

**Table 4. Winter survival of canola planted with AGCO Corporation's residue management system, including two different row spacings and three seeding rates, and canola planted with cooperator practices at five Kansas locations in 2015 and 2016**

| | AGCO planter | | | | | | |
|---|---|---|---|---|---|---|---|
| | 20-in. row spacing | | | 30-in. row spacing | | | |
| | Seeding rate (seeds/a) | | | Seeding rate (seeds/a) | | | |
| Environment | 100,000 | 150,000 | 200,000 | 100,000 | 150,000 | 200,000 | Cooperator practice‡ |
| | % | | | | | | |
| Andale 2015 | 47.9 a† | 34.7 b | 18.9 c | 21.1 c | 15.2 c | 15.5 c | 34.1 b |
| Stafford 2016 | 74.7 a | 66.6 ab | 60.6 bc | 55.1 bc | 66.8 ab | 61.2 bc | 53.9 c |
| Kingman 2016 | 69.4 c | 86.8 ab | 88.2 ab | 84.9 ab | 81.2 b | 89.2 a | 87.6 ab |
| Conway Springs 2016 | 86.4 a | 81.4 ab | 75.5 b | 77.5 b | 80.4 ab | 66.0 c | 76.5 b |
| Kiowa 2016 | 92.2 a | 80.3 b | 69.5 c | 72.9 bc | 57.4 d | 56.9 d | 75.9 bc |

| | Seeding rate (seeds/a) | | | Row spacing | |
|---|---|---|---|---|---|
| | 100,000 | 150,000 | 200,000 | 20-in. | 30-in. |
| Andale 2015 | 34.5 a† | 24.9 b | 17.2 b | 33.8 a† | 17.3 b |
| Stafford 2016 | 64.9 | 62.2 | 66.3 | 67.9 | 61.0 |
| Kingman 2016 | 77.2 b | 84.0 a | 88.7 a | 81.4 | 85.1 |
| Conway Springs 2016 | 82.0 a | 80.9 a | 70.8 b | 81.1 a | 74.7 b |
| Kiowa 2016 | 82.5 a | 68.9 b | 63.2 b | 80.6 a | 62.4 b |

†Values within a row followed by the same letter are not different at $\alpha = 0.10$.

‡See Table 1 for details regarding producer field operations and practices at each location.

**Table 5. Yield of canola planted with AGCO Corporation's residue management system, including two different row spacings and three seeding rates, and canola planted with cooperator practices at five Kansas locations in 2015 and 2016**

| | AGCO planter | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20-in. row spacing | | | | | | 30-in. row spacing | | | | | | |
| | Seeding rate (seeds/a) | | | | | | Seeding rate (seeds/a) | | | | | | |
| Environment | 100,000 | | 150,000 | | 200,000 | | 100,000 | | 150,000 | | 200,000 | | Cooperator practice‡ |
| | bu/a | | | | | | | | | | | | |
| Andale 2015 | 34.5 | a† | 33.4 | ab | 31.9 | abc | 29.9 | bc | 27.7 | c | 30.3 | abc | 32.2 abc |
| Stafford 2016 | 17.4 | a | 16.2 | ab | 16.8 | ab | 18.3 | a | 16.3 | ab | 22.3 | a | 12.5 b |
| Kingman 2016 | 24.2 | a | 21.9 | ab | 20.2 | b | 23.1 | a | 22.1 | ab | 19.9 | b | 15.7 c |
| Conway Springs 2016 | 23.5 | | 23.6 | | 23.1 | | 23.2 | | 23.7 | | 23.3 | | 21.9 |
| Kiowa 2016 | 63.5 | | 62.6 | | 61.7 | | 63.5 | | 62.6 | | 61.7 | | 65.6 |

| | Seeding rate (seeds/a) | | | | | | Row spacing | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100,000 | | 150,000 | | 200,000 | | 20-in. | | 30-in. | |
| Andale 2015 | 32.2 | a† | 30.5 | b | 31.2 | c | 33.3 | a† | 29.3 | b |
| Stafford 2016 | 17.7 | | 16.3 | | 19.8 | | 19.0 | | 16.8 | |
| Kingman 2016 | 23.6 | a | 22.0 | b | 20.1 | c | 22.1 | | 21.7 | |
| Conway Springs 2016 | 23.4 | | 23.7 | | 23.2 | | 23.4 | | 23.4 | |
| Kiowa 2016 | 63.5 | | 62.6 | | 61.7 | | 62.6 | | 62.6 | |

†Values within a row followed by the same letter are not different at $\alpha = 0.10$.

‡See Table 1 for details regarding producer field operations and practices at each location.

# Do Winter Canola Hybrids and Open-Pollinated Varieties Respond Differently to Seeding Rate?

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## Summary
Several producers have turned to planting canola in 30-in. rows as a strategy to take advantage of residue management options (e.g. planter-mounted residue managers and strip tillage) to facilitate planting canola in high-residue cropping systems. Canola hybrids are gaining acres in the southern Great Plains and may require different management than the traditional open-pollinated cultivars. The objective of this study was to determine the effect of seeding rate on winter survival and yield of hybrid and open-pollinated winter canola cultivars in 30-in. and 9-in. rows. Experiments were conducted in 2013-2014, 2014-2015, and 2015-2016 at two K-State Research and Extension facilities. Treatments were four locally adapted cultivars (two hybrids and two open-pollinated cultivars) and three or five seeding rates for a total of twelve or twenty treatments in each experiment. Due to nearly complete winter stand loss of hybrids in the experiment planted in 2013, only open-pollinated cultivars were harvested. No experiments were harvested for yield in 2015 because of nearly complete stand loss in all treatments at all locations. In both row spacings, fall stands tended to increase with increasing seeding rates, and hybrids tended to establish more plants than open-pollinated cultivars. Differences in stands due to seeding rate were somewhat less evident in the spring, but stand differences due to cultivars were more evident. Winter survival tended to increase as the number of plants present in the fall decreased, whether that was due to seeding rate or other factors. Bloom occasionally was delayed, and harvested seed moisture tended to be greater when fewer plants were present in the spring, likely due to a greater percentage of buds forming on branches. Seeding rate had a minimal impact on yields in 30-in. rows, with hybrids and open-pollinated cultivars responding similarly in most cases. In 9-in. rows, seeding rate did not affect yields in 2014. In 2016, both hybrids and open-pollinated cultivars maximized yield at 300,000 seeds per acre in 9-in. rows, but hybrids maintained greater yields than open-pollinated cultivars at sub-optimal seeding rates.

## Introduction
A successful winter canola crop is achieved through the multifaceted interaction of genetics, management, and environment. High-residue cropping systems have been particularly challenging for winter canola survival because of the winter stand loss that often accompanies no-tillage planting. Planting canola with a row-crop planter in 30-in. rows provides additional options for residue management and facilitates precise seed singulation and seed placement. One of the major differences between winter canola cultivars on the market today is whether they are open-pollinated versus hybrid cultivars. Hybrid canola cultivars typically have larger seed, making them particularly well suited for the seed singulation and precise metering facilitated by row-crop planters. We hypothesized that the more vigorous seedling growth and larger plant size often characteristic of canola hybrids may require fewer plants, and therefore reduced seeding

rates, to maximize yield compared to open-pollinated varieties. In addition, the greater intra-row competition associated with 30-in. rows compared to narrower row spacings may be more detrimental for hybrids than for open-pollinated cultivars because of this increased vigorous growth. The objective of this series of experiments was to determine the effect of seeding rate on winter survival and yield of hybrid (HYB) and open-pollinated (OP) winter canola cultivars in both 30-in. and 9-in. rows. We wanted to answer the question: "Should seeding rates differ for HYB and OP?"

## Procedures

### *30-In. Rows*

Two experiments were planted 2014-2015 and three in 2015-2016 at two K-State Research and Extension facilities. Treatments were four locally adapted cultivars, two HYB (Safran, Mercedes) and two OP (Riley, DKW44-10), and five seeding rates (100,000, 175,000, 250,000, 325,000, and 400,000 seeds per acre) for a total of twenty treatments in each experiment. Plots were planted with planters equipped with Monosem seed meters mounted with canola plates on either Monosem or John Deere row units. Row units were equipped with Yetter residue managers adjusted to remove residue from above the seed furrow. Plots consisted of 4 rows 35 feet in length with data collected from the center two rows. Four of the experiments were planted into wheat stubble without tillage, one near Manhattan, KS (Manhattan-NT), and one near Hutchinson, KS (Hutchinson-NT). The fifth experiment was planted into vertically tilled wheat stubble near Hutchinson, KS in 2015 (Hutchinson-VT). Treatments were replicated four times in each experiment in a randomized complete block design with a factorial treatment structure in the Hutchinson experiments and a split plot treatment structure in the Manhattan-NT experiment, with seeding rates as the whole plots. Fall establishment was determined by counting two sections of row in each plot, each 3.3 feet in length. The number of living plants was counted in these same sections after green-up the next spring to determine spring plant density. Winter survival percent was calculated by dividing spring plant density by fall plant density and multiplying by 100. Bloom progression was estimated visually during mid bloom to determine if treatments influenced spring plant development.

### *9-In. Rows*

One experiment was conducted in 2013-2014, two in 2014-2015, and two in 2015-2016 at two K-State Research and Extension facilities. Treatments were four locally adapted cultivars, two HYB (Hekip and Mercedes), and two OP (DKW44-10 and DKW46-15 in 2013-2014, Riley and HyCLASS115W in 2015-2016) and three or five seeding rates (500,000, 750,000, and 1,000,000 seeds per acre in 2013-2014 or 150,000, 225,000, 300,000, 375,000, and 450,000 seeds per acre in 2014-2015 and 2015-2016) for a total of twelve or twenty treatments in each experiment. Experiments were planted with a drill equipped with double-disc openers into tilled soil that had been rolled to establish a firm seedbed. Fall establishment and winter survival were estimated by visual ratings. Treatments were replicated three or four times in each experiment in a randomized complete block design with a split plot treatment structure with cultivar as the whole plots.

### *All Experiments*
Plots were swathed at 40 to 60% seed color change. Several days after swathing, weight of canola seed from each plot was determined using a plot combine capable of weighing harvested seed and capturing samples for moisture and oil concentration analysis. Seed samples were sent to the Brassica Breeding and Research program at the University of Idaho (Moscow, ID) for near-infrared spectroscopy (NIRS) oil content estimation. Analysis of variance was used to determine significance of seeding rate, cultivar type (TYPE), cultivar, and their interaction effects ($\alpha = 0.05$). Treatment and interaction means were separated using pairwise t tests when a treatment or interaction effect was deemed significant.

## Results
Fall establishment was excellent in all years. The HYB did not survive the winter in the experiment planted in 2013, and nearly complete stand loss occurred in all treatments resulting from a dramatic temperature drop in November 2014 so that no experiments were harvested in 2015. All four experiments planted in the fall of 2015 were harvested for yield in 2016.

### *Fall Stand Establishment in 30-In. Rows*
Fall stands differed depending on seeding rate and TYPE, but the responses were not consistent at all locations (Table 1). Fall stands increased with increasing seeding rate in the Manhattan-NT and Hutchinson-NT experiments. The response was not consistent for all cultivars in Manhattan-NT, and the differences in response depended on individual cultivar rather than TYPE. Fall stands were greater on average for HYB than for OP at both locations. The separation between TYPE was caused primarily by the lower stands of Riley at all seeding rates in Manhattan-NT. In the Hutchinson-VT experiment, HYB and OP responded differently to seeding rate with HYB establishing more plants at 250,000 seeds per acre and fewer plants at 100,000 seeds per acre. Most often, HYB tended to establish more plants than OP, but a greater number of fall plants was associated with greater seeding rates at only two of the three locations.

### *Spring Stands in 30-In. Rows*
Spring stands reflected trends similar to those observed for fall stands. In the Manhattan-NT experiment, all cultivars had greater spring stands as seeding rate increased (Table 2). Spring stands averaged less for OP than for HYB across seeding rates, but the difference was largely due to Riley having fewer plants than the other cultivars. Safran had fewer plants than Mercedes but was superior to Riley. In the Hutchinson-NT experiment, all cultivars had greater spring stands with increasing seeding rate, but the increase was minimal for the HYB. In the Hutchinson-VT experiment, spring stands for HYB were stable across seeding rates except for a drop off at the lowest seeding rate. The OP had greater spring stands at the lowest two seeding rates. Averaged across seeding rates, Mercedes had the most plants in the spring and Safran the fewest, with the OP cultivars falling between those two. Differences in stands due to seeding rate tended to persist throughout the winter, and differences due to cultivar were accentuated.

### *Winter Survival in 30-In. Rows*

A greater percentage of plants tended to survive when fewer plants were present the previous fall. In the Manhattan-NT and Hutchinson-NT experiments, winter survival decreased with increasing seeding rate for all four cultivars (Table 3). In the Hutchinson-NT experiment, winter survival was greater for OP than for HYB averaged across seeding rates. Inconsistent variation in winter survival values within treatments prevented detecting treatment differences in the Hutchinson-VT experiment.

### *Bloom Progression in 30-In. Rows*

Bloom rate differed depending on seeding rate or the interaction of seeding rate at all three locations (Table 4). At Manhattan-NT, a greater percentage of the plants were blooming as seeding rate increased. This reflected the expectation that reduced stands are likely to produce more branches that tend to bloom slightly later than the main stem. The pattern was almost the opposite in the Hutchinson-VT experiment with the most rapid blooming associated with the lowest seeding rate. In the Hutchinson-NT experiment, bloom response to seeding rate differed with cultivar. Bloom progression was greater with greater seeding rates for Mercedes, following the expected response. Both Safran and DKW44-10 exhibited a minimal response of bloom progression to seeding rate except for an unexplained increase at 175,000 seeds per acre. Bloom progression did not differ with seeding rate for Riley. Delayed or extended bloom associated with reduced stands may impact yield in years with a shortened seed fill period.

### *Yield and Oil Concentration in 30-In. Rows*

The only location where treatments had a significant effect on yield was at Manhattan-NT (Table 5). Yield was less for DKW44-10 and more for Riley than for the HYB regardless of seeding rate. Seeding rate did not affect yield at any of the locations except in the Manhattan-NT experiment where the OP cultivars produced four to seven fewer bushels per acre at 325,000 seeds per acre than at the other seeding rates. Seed oil concentration was influenced by treatment factors only in the Manhattan-NT experiment. Oil concentration was influenced by seeding rate, but the ranking of oil concentration did not follow the seeding rate ranking (data not shown). Oil concentration was 2 to 3% less for DKW44-10 than for the other cultivars at this location.

### *Fall Stand Establishment, Winter Survival, and Harvested Seed Moisture in 9-In. Rows*

Fall stands, winter survival, and harvested seed moisture were affected by seeding rate in at least one of the two experiments. Fall stands increased with greater seeding rates in both experiments (Tables 6 and 7). Winter survival decreased as seeding rate increased in the 2013-2014 experiment (Table 6). Harvested seed moisture increased as seeding rate decreased, but the differences were significant only in the 2015-2016 experiment (Table 7).

### *Yield in 9-In. Rows*

In 9-in. rows, seeding rate and cultivar affected yield only in 2015-2016 (Tables 6 and 7). The yield response to seeding rate differed with TYPE in this experiment (Table 7). Yield was maximized at the 300,000 seeds per acre seeding rate for both HYB and OP, but yield of HYB surpassed that of OP at the 150,000 seeds per acre seeding rate. Averaged over seeding rates, Mercedes yielded more than the other cultivars.

### *Conclusions*

These results indicate that fall stands generally reflect differences in seeding rate, but spring stands tend to differ less because fewer plants are lost during winter when fewer plants are present in the fall. In 30-in. rows, seeding rates as low as 100,000 seeds per acre supported yields from 700 to 2100 pounds per acre in high residue, no-tillage or reduced tillage systems when residue was adequately removed from the seed row. Hybrid and open-pollinated winter canola cultivars responded similarly to seeding rate in these experiments, providing a preliminary indication that similar seeding rates could be used for both types of cultivars in 30-in. rows. Experiments producing greater yields may be more likely to detect influences of seeding rate and cultivar types on seed yield. In 9-in. rows, seeding rates of 300,000 seeds per acre or more supported maximum yields, ranging from 2,000 to 3,300 pounds per acre, but hybrids maintained yield better than open-pollinated cultivars at sub-optimal seeding rates. Within the range of environmental conditions and yields produced in these experiments, similar seeding rates can be used for hybrids and open-pollinated cultivars, but seeding rates can be less with wider row spacing.

**Table 1. Fall stands of four canola cultivars planted at five seeding rates in 30-in. rows at three Kansas locations in 2015**

| Cultivar (TYPE) | 100,000 | | 175,000 | | 250,000 | | 325,000 | | 400,000 | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seeding rate (seeds per acre) | | | | | | | | | | | |
| | Plants per acre × 1,000 | | | | | | | | | | | |
| Manhattan-NT | | | | | | | | | | | | |
| HYB | 47.5 | | 64.6 | | 97.0 | | 112.1 | | 145.7 | | 93.4 | A† |
| OP | 36.2 | | 52.7 | | 91.1 | | 103.4 | | 120.1 | | 80.7 | B |
| Safran (HYB) | 42.6 | kl‡ | 73.2 | g-j | 92.3 | d-g | 95.5 | d-f | 138.0 | ab | 88.3 | B |
| Mercedes (HYB) | 52.4 | jk | 55.9 | i-k | 101.8 | c-e | 128.8 | b | 153.5 | a | 98.5 | A |
| Riley (OP) | 32.6 | l | 38.0 | kl | 75.1 | f-i | 83.9 | e-h | 100.6 | de | 66.0 | C |
| DKW44-10 (OP) | 39.8 | kl | 67.4 | h-j | 107.0 | cd | 122.9 | bc | 139.6 | ab | 95.4 | AB |
| Mean | 41.9 | D | 58.6 | C | 94.0 | B | 107.8 | B | 132.9 | A | | |
| Hutchinson-NT | | | | | | | | | | | | |
| HYB | 75.0 | | 84.0 | | 104.2 | | 126.5 | | 116.5 | | 101.2 | A |
| OP | 55.1 | | 71.7 | | 81.0 | | 113.5 | | 122.8 | | 88.8 | B |
| Safran (HYB) | 65.7 | | 79.7 | | 98.9 | | 132.1 | | 116.2 | | 98.5 | |
| Mercedes (HYB) | 84.3 | | 88.3 | | 109.5 | | 120.8 | | 116.8 | | 104.0 | |
| Riley (OP) | 61.7 | | 67.7 | | 81.7 | | 115.5 | | 124.8 | | 90.3 | |
| DKW44-10 (OP) | 48.5 | | 75.7 | | 80.3 | | 111.5 | | 120.8 | | 87.4 | |
| Mean | 65.1 | D | 77.8 | C | 92.6 | B | 120.0 | A | 120.0 | A | | |
| Hutchinson-VT | | | | | | | | | | | | |
| HYB | 75.7 | b-d | 101.9 | a | 104.6 | a | 82.0 | a-d | 87.3 | a-d | 90.2 | |
| OP | 93.6 | a-c | 97.6 | ab | 67.7 | d | 77.7 | b-d | 73.4 | cd | 82.0 | |
| Safran (HYB) | 63.7 | | 84.3 | | 104.9 | | 90.3 | | 90.9 | | 86.8 | |
| Mercedes (HYB) | 87.6 | | 119.5 | | 104.2 | | 73.7 | | 83.6 | | 93.7 | |
| Riley (OP) | 103.6 | | 98.3 | | 60.4 | | 77.7 | | 71.0 | | 82.2 | |
| DKW44-10 (OP) | 83.6 | | 96.9 | | 75.0 | | 77.7 | | 75.7 | | 81.8 | |
| Mean | 84.6 | | 99.7 | | 86.1 | | 79.8 | | 80.3 | | | |

† Values within a set of type, cultivar, or seeding rate means followed by the same upper case letter are not different at $\alpha = 0.05$.
‡ Values within a set of type or cultivar × seeding rate combinations followed by the same lower case letter are not different at $\alpha = 0.05$.

**Table 2. Spring stands of four canola cultivars planted at five seeding rates in 30-in. rows at three Kansas locations in 2015**

| Cultivar (TYPE) | Seeding rate (seeds per acre) | | | | | |
|---|---|---|---|---|---|---|
| | 100,000 | 175,000 | 250,000 | 325,000 | 400,000 | Mean |
| | Plants per acre × 1,000 | | | | | |
| Manhattan-NT | | | | | | |
| HYB | 36.5 | 46.8 | 71.0 | 70.8 | 86.0 | 62.2 A† |
| OP | 31.8 | 40.5 | 66.4 | 66.1 | 73.0 | 55.5 B |
| Safran (HYB) | 33.9 | 47.8 | 66.4 | 61.9 | 85.0 | 59.0 B |
| Mercedes (HYB) | 39.2 | 45.8 | 75.7 | 79.7 | 87.0 | 65.5 A |
| Riley (OP) | 28.3 | 32.5 | 58.4 | 59.7 | 65.7 | 49.0 C |
| DKW44-10 (OP) | 35.2 | 48.5 | 74.4 | 72.4 | 80.3 | 62.1 AB |
| Mean | 34.1 D | 43.6 C | 68.7 B | 68.4 B | 79.5 A | |
| Hutchinson-NT | | | | | | |
| HYB | 53.4 cd‡ | 53.4 cd | 58.4 a-c | 56.1 bc | 68.7 a | 58.0 |
| OP | 43.8 d | 53.1 cd | 48.1 cd | 67.4 a | 66.7 ab | 55.8 |
| Safran (HYB) | 57.8 | 51.8 | 52.4 | 61.7 | 71.7 | 59.1 |
| Mercedes (HYB) | 49.1 | 55.1 | 64.4 | 50.4 | 65.7 | 57.0 |
| Riley (OP) | 50.5 | 51.8 | 51.8 | 69.7 | 63.7 | 57.5 |
| DKW44-10 (OP) | 31.2 | 54.4 | 44.5 | 65.1 | 69.7 | 54.2 |
| Mean | 48.6 B | 53.3 B | 53.3 B | 61.7 A | 67.7 A | |
| Hutchinson-VT | | | | | | |
| HYB | 48.5 de | 62.7 a-c | 60.7 a-d | 59.4 a-e | 62.1 a-d | 58.7 |
| OP | 70.7 a | 67.6 ab | 51.3 c-e | 46.8 e | 56.8 b-e | 58.6 |
| Safran (HYB) | 39.3 | 58.4 | 51.8 | 63.7 | 53.8 | 53.4 B |
| Mercedes (HYB) | 57.8 | 67.1 | 69.7 | 55.1 | 70.4 | 64.0 A |
| Riley (OP) | 79.0 | 63.8 | 44.9 | 46.5 | 61.1 | 59.1 AB |
| DKW44-10 (OP) | 62.4 | 71.4 | 57.8 | 47.1 | 52.4 | 58.2 AB |
| Mean | 59.6 | 66.2 | 56.0 | 53.1 | 59.4 | |

† Values within a set of type, cultivar, or seeding rate means followed by the same upper case letter are not different at $\alpha = 0.05$.
‡ Values within a set of type or cultivar × seeding rate combinations followed by the same lower case letter are not different at $\alpha = 0.05$.

**Table 3. Winter survival of four canola cultivars planted at five seeding rates in 30-in. rows at three Kansas locations in 2015**

| | Seeding rate (seeds per acre) | | | | | |
|---|---|---|---|---|---|---|
| Cultivar (TYPE) | 100,000 | 175,000 | 250,000 | 325,000 | 400,000 | Mean |
| | % | | | | | |
| Manhattan-NT | | | | | | |
| HYB | 81 | 75 | 74 | 65 | 60 | 71 |
| OP | 81 | 82 | 75 | 67 | 63 | 74 |
| Safran (HYB) | 81 | 66 | 73 | 67 | 62 | 70 |
| Mercedes (HYB) | 81 | 84 | 74 | 62 | 58 | 72 |
| Riley (OP) | 75 | 88 | 79 | 72 | 67 | 76 |
| DKW44-10 (OP) | 87 | 76 | 71 | 62 | 60 | 71 |
| Mean | 81 A† | 79 A | 74 A | 66 B | 61 B | |
| Hutchinson-NT | | | | | | |
| HYB | 74 | 66 | 56 | 47 | 60 | 61 B |
| OP | 79 | 78 | 61 | 63 | 56 | 67 A |
| Safran (HYB) | 88 | 65 | 55 | 58 | 64 | 64 |
| Mercedes (HYB) | 59 | 67 | 57 | 46 | 57 | 57 |
| Riley (OP) | 82 | 78 | 64 | 66 | 51 | 68 |
| DKW44-10 (OP) | 76 | 78 | 59 | 60 | 60 | 67 |
| Mean | 76 A | 72 A | 59 B | 55 B | 58 B | |
| Hutchinson-VT | | | | | | |
| HYB | 78 | 65 | 63 | 74 | 78 | 71 |
| OP | 77 | 70 | 76 | 67 | 79 | 74 |
| Safran (HYB) | 75 | 67 | 53 | 71 | 71 | 67 |
| Mercedes (HYB) | 81 | 62 | 73 | 77 | 84 | 76 |
| Riley (OP) | 78 | 68 | 75 | 82 | 86 | 74 |
| DKW44-10 (OP) | 77 | 72 | 77 | 71 | 72 | 74 |
| Mean | 78 | 67 | 70 | 70 | 78 | |

†Values within a set of type, cultivar, or seeding rate means followed by the same upper case letter are not different at $\alpha = 0.05$.

**Table 4. Bloom progression of four canola cultivars planted at five seeding rates in 30-in. rows at three Kansas locations in 2015**

| | Seeding rate (seeds per acre) | | | | | |
|---|---|---|---|---|---|---|
| Cultivar (TYPE) | 100,000 | 175,000 | 250,000 | 325,000 | 400,000 | Mean |
| | Progression of bloom (%) | | | | | |
| Manhattan-NT | | | | | | |
| HYB | 43 | 43 | 47 | 47 | 47 | 45 |
| OP | 42 | 43 | 47 | 45 | 47 | 45 |
| Safran (HYB) | 43 | 41 | 48 | 48 | 46 | 45 |
| Mercedes (HYB) | 43 | 44 | 46 | 46 | 48 | 45 |
| Riley (OP) | 41 | 43 | 46 | 45 | 45 | 44 |
| DKW44-10 (OP) | 43 | 43 | 48 | 45 | 49 | 45 |
| Mean | 42 C† | 43 BC | 47A | 46 AB | 47 A | |
| Hutchinson-NT | | | | | | |
| HYB | 48 | 52 | 43 | 49 | 53 | 49 |
| OP | 48 | 53 | 58 | 47 | 45 | 48 |
| Safran (HYB) | 48 cd‡ | 59 ab | 43 d | 45 cd | 48 cd | 48 |
| Mercedes (HYB) | 49 b-d | 45 cd | 44 cd | 54 a-c | 59 ab | 50 |
| Riley (OP) | 49 b-d | 46 cd | 50 a-d | 48 cd | 46 cd | 48 |
| DKW44-10 (OP) | 48 cd | 60 a | 45 cd | 46 cd | 44 cd | 49 |
| Mean | 48 | 53 | 45 | 48 | 49 | |
| Hutchinson-VT | | | | | | |
| HYB | 53 | 49 | 56 | 48 | 51 | 51 |
| OP | 55 | 51 | 49 | 48 | 51 | 51 |
| Safran (HYB) | 56 | 48 | 56 | 50 | 50 | 52 |
| Mercedes (HYB) | 49 | 51 | 56 | 45 | 53 | 51 |
| Riley (OP) | 51 | 48 | 49 | 50 | 51 | 50 |
| DKW44-10 (OP) | 59 | 55 | 50 | 46 | 50 | 52 |
| Mean | 54 A | 50 AB | 53 A | 48 B | 51 AB | |

† Values within a set of type, cultivar, or seeding rate means followed by the same upper case letter are not different at $\alpha = 0.05$.
‡Values within a set of type or cultivar × seeding rate combinations followed by the same lower case letter are not different at $\alpha = 0.05$.

**Table 5. Yield of four canola cultivars planted at five seeding rates in 30-in. rows at three Kansas locations in 2015**

| Cultivar (TYPE) | Seeding rate (seeds per acre) 100,000 | 175,000 | 250,000 | 325,000 | 400,000 | Mean |
|---|---|---|---|---|---|---|
| | Bushels per acre | | | | | |
| Manhattan-NT | | | | | | |
| HYB | 23 a[†] | 20 ab | 20 ab | 22 a | 22 ab | 22 |
| OP | 23 a | 21 ab | 23 a | 16 b | 20 ab | 21 |
| Safran (HYB) | 21 | 20 | 20 | 25 | 21 | 21 B[‡] |
| Mercedes (HYB) | 26 | 19 | 21 | 20 | 22 | 22 B |
| Riley (OP) | 26 | 23 | 26 | 19 | 27 | 24 A |
| DKW44-10 (OP) | 20 | 19 | 19 | 13 | 14 | 17 C |
| Mean | 23 | 20 | 21 | 19 | 21 | |
| Hutchinson-NT | | | | | | |
| HYB | 23 | 27 | 21 | 24 | 26 | 24 |
| OP | 24 | 21 | 23 | 23 | 22 | 23 |
| Safran (HYB) | 20 | 28 | 22 | 21 | 27 | 24 |
| Mercedes (HYB) | 26 | 26 | 19 | 27 | 24 | 24 |
| Riley (OP) | 23 | 21 | 21 | 22 | 23 | 22 |
| DKW44-10 (OP) | 25 | 21 | 24 | 25 | 21 | 23 |
| Mean | 24 | 24 | 22 | 24 | 24 | |
| Hutchinson-VT | | | | | | |
| HYB | 37 | 28 | 32 | 32 | 31 | 32 |
| OP | 34 | 35 | 30 | 31 | 33 | 33 |
| Safran (HYB) | 38 | 30 | 34 | 37 | 32 | 34 |
| Mercedes (HYB) | 35 | 26 | 30 | 27 | 30 | 30 |
| Riley (OP) | 32 | 37 | 34 | 37 | 32 | 34 |
| DKW44-10 (OP) | 35 | 33 | 27 | 25 | 34 | 31 |
| Mean | 35 | 32 | 31 | 32 | 32 | |

[†]Values within a set of type or cultivar × seeding rate combinations followed by the same lower case letter are not different at $\alpha = 0.05$.
[‡]Values within a set of type, cultivar, or seeding rate means followed by the same upper case letter are not different at $\alpha = 0.05$.

**Table 6. Fall stand ratings, winter survival ratings, harvested seed moisture, and yield of four canola cultivars planted at five seeding rates in 9-in. rows at Hutchinson, KS, in 2013**

| Response parameter | Seeding rate (seeds per acre) | | | |
|---|---|---|---|---|
| Cultivar (TYPE) | 500,000 | 750,000 | 1,000,000 | Mean |
| | ------------ Rating[†] ------------ | | | |
| Fall stand | | | | |
| DKW44-10 (OP) | 8.3 | 9.0 | 9.5 | 8.9 |
| DKW46-15 (OP) | 8.3 | 8.8 | 9.3 | 8.8 |
| Mean | 8.3 B[‡] | 8.9 A | 9.4 A | |
| Winter survival | ------------ Percent ------------ | | | |
| DKW44-10 (OP) | 83 | 93 | 78 | 84 |
| DKW46-15 (OP) | 78 | 80 | 68 | 75 |
| Mean | 80 A | 86 AB | 73 B | |
| Harvested seed moisture | ------------ Percent ------------ | | | |
| DKW44-10 (OP) | 7.2 | 7.6 | 7.3 | 7.4 |
| DKW46-15 (OP) | 7.6 | 6.6 | 7.0 | 7.0 |
| Mean | 7.4 | 7.1 | 7.1 | |
| Yield | ------------ Bushels per acre ------------ | | | |
| DKW44-10 (OP) | 40 | 38 | 35 | 38 |
| DKW46-15 (OP) | 35 | 37 | 34 | 35 |
| Mean | 37 | 38 | 35 | |

[†] Rated 0 to 9 where 0 = no plants, 9 = full stand, no gaps.

[‡]Values within a set of cultivar, or seeding rate means followed by the same upper case letter are not different at $\alpha$ = 0.06.

**Table 7. Fall stand ratings, harvested seed moisture, and yield of four canola cultivars planted at five seeding rates in 9-in. rows at Hutchinson, KS, in 2015**

| Response parameter | Seeding rate (seeds per acre) | | | | | |
|---|---|---|---|---|---|---|
| Cultivar (TYPE) | 150,000 | 225,000 | 300,000 | 375,000 | 450,000 | Mean |
| | ---------- Rating† ---------- | | | | | |
| Fall stand | | | | | | |
| HYB | 7.5 | 7.3 | 8.2 | 8.5 | 8.2 | 7.9 A‡ |
| OP | 6.5 | 7.4 | 7.3 | 7.8 | 7.8 | 7.4 B |
| | | | | | | |
| Hekip (HYB) | 8.0 | 7.7 | 8.0 | 8.3 | 8.3 | 8.1 A |
| Mercedes (HYB) | 7.0 | 7.0 | 8.3 | 8.7 | 8.0 | 7.8 A |
| Riley (OP) | 5.7 | 7.0 | 6.3 | 7.0 | 7.0 | 6.6 B |
| HyCLASS 115W (OP) | 7.3 | 7.9 | 8.3 | 8.7 | 8.7 | 8.2 A |
| | | | | | | |
| Mean | 7.0 D | 7.4 CD | 7.8 BC | 8.2 A | 8.0 AB | |
| | | | | | | |
| Harvested seed moisture | ---------- Percent ---------- | | | | | |
| HYB | 6.7 | 6.6 | 6.5 | 6.4 | 6.5 | 6.5 A |
| OP | 6.2 | 6.0 | 5.9 | 5.7 | 5.8 | 5.9 B |
| | | | | | | |
| Hekip (HYB) | 6.5 | 6.4 | 6.5 | 6.4 | 6.4 | 6.4 |
| Mercedes (HYB) | 6.8 | 6.8 | 6.5 | 6.5 | 6.6 | 6.7 |
| Riley (OP) | 6.3 | 6.3 | 6.0 | 5.8 | 6.2 | 5.8 |
| HyCLASS 115W (OP) | 6.0 | 5.8 | 5.8 | 5.7 | 5.5 | 6.1 |
| | | | | | | |
| Mean | 6.4 A | 6.3 AB | 6.2 BC | 6.1 C | 6.2 BC | |
| | | | | | | |
| Yield | ---------- Bushels per acre ---------- | | | | | |
| HYB | 61 a-c§ | 57 bc | 66 a | 63 a-c | 60 a-c | 61 |
| OP | 49 d | 56 c | 64 ab | 61 a-c | 62 a-c | 58 |
| | | | | | | |
| Hekip (HYB) | 58 | 48 | 57 | 54 | 53 | 54 B‡ |
| Mercedes (HYB) | 64 | 66 | 74 | 71 | 67 | 68 A |
| Riley (OP) | 49 | 54 | 68 | 63 | 66 | 60 B |
| HyCLASS 115W (OP) | 48 | 58 | 60 | 59 | 57 | 56 B |
| | | | | | | |
| Mean | 55 C | 56 BC | 65 A | 62 A | 61 AB | |

† Rated 0 to 9 where 0 = no plants, 9 = full stand, no gaps.
‡ Values within a set of type or cultivar × seeding rate combinations followed by the same upper case letter are not different at $\alpha = 0.06$.
§ Values within a set of type, cultivar, or seeding rate means followed by the same lower case letter are not different at $\alpha = 0.06$.

# Timing of Strobilurin Fungicide for Control of Top Dieback in Corn

*E.A. Adee and S. Duncan*

## Summary
Significant yield losses can result from top dieback (TDB) in dent corn, which is caused by infection by the fungus, *Colletotrichum graminicola*, causing anthracnose. Research is limited on the effectiveness of fungicide application because of the unpredictable nature of the disease. Three field studies were established to assess the timing of fungicide application on foliar diseases that developed TDB, one in Illinois (2010) and the other two in Kansas (2015 and 2016). Fungicide applications at tasseling and later were effective in reducing the incidence of TDB by greater than 20% and increasing yield greater than 14 bu/a, or greater than 7%, while earlier applications (V5 to V8) did not reduce TDB or increase yield compared to the untreated check.

## Introduction
Top dieback (TDB) of dent corn *(Zea mays*) is caused by an infection of the upper part of the corn plant by the fungus causing anthracnose (*Colletotrichum graminicola).* Anthracnose can infect the corn plant early in the season, causing foliar lesions, and/or stay dormant in the plant until stress conditions cause the infection to result in stalk rot and/or TDB symptoms. Infections later in the season, under the right environmental conditions, have been reported when the infection occurs in the pre-tassel whorl or on the leaf sheaths. Spores of the pathogen are dispersed by wind and rain, and infection is favored by warm, humid, and overcast conditions. The symptoms of TDB can be diagnosed when leaves in the top part of the plant, primarily the flag leaf, start to become reddish/purple, then yellow and then necrotic, while the lower leaves around the ear remain green. The formation of black lesions and fungal fruiting bodies on the stalk near and under the leaf sheath confirm the diagnosis and distinguish TDB from other causes of the top of the corn plant dying prematurely.

Management practices to reduce losses to anthracnose in corn include hybrid selection, crop rotation, controlling insect damage, and reducing stress from low fertility and moisture as much as possible. Strobilurin fungicides are effective at controlling the leaf blight phase of anthracnose, primarily in the early growth stages. However, there is little information on the effectiveness of strobilurins against the TDB phase of anthracnose. Strobilurins applied at tasseling or later reduced TDB, but did not affect yield in a one-year fungicide study in Iowa (Robertson, et al., 2010). Furthermore, reproducing the conditions that result in TDB is difficult, hindering experimentation. Similarly, repeating the same study for controlling TDB at multiple locations or years has not been very effective. The authors have observed TDB in only 3 of 9 corn fungicide studies. The results presented in this paper are from these three fungicide-timing studies that became infected with anthracnose causing the TDB symptoms on corn.

## Procedures

Fungicide timing application studies on corn that developed TDB symptoms were conducted in 2010 at the University of Illinois' Northwestern Illinois Agricultural Research and Demonstration Center (NWRC), near Monmouth, IL, and in 2015 and 2016 at Kansas State University's Kansas River Valley experiment fields (KRV), near Topeka, KS (Table 1). The dryland study at NWRC was in corn following soybeans, while the studies at KRV were under sprinkler irrigation in second-year corn. Nitrogen fertilizer was applied at recommended levels at all locations (Table 1). Due to the sandy soils and 10.31 inches of rain in May 2015 at KRV, an additional 130 lb/a of nitrogen (N) was sidedressed at V5 (five leaves with collars visible), which alleviated some of the N deficiency symptoms. In all studies, the corn was planted in 30-inch rows. The hybrid DeKalb 61-69 was planted at NWRC. Golden Harvest 11U58-3111 and Golden Harvest G12J11-3111 were planted at KRV in 2015 and 2016, respectively. The plots were 10 ft wide (4 rows) by 100 ft long at NWRC and 40 ft long at KRV. The experimental design was a randomized complete block with 4 replications for all studies. Additional crop management details are listed in Table 1. The irrigation scheduling at KRV was assisted by the KanSched2 K-State Research and Extension Mobile Irrigation Lab scheduling program (www.bae.ksu.edu/mobileirrigationlab/kansched2).

The fungicide treatments were applied with a $CO_2$ backpack sprayer equipped with Spraying Systems TJ 8002VS nozzles, 30 psi, 19 gal/a, to the middle two rows of a 4-row plot. The fungicide applied at NWRC was Headline SC at 6 oz/a. At KRV, several different fungicides with strobilurin as the active ingredient, along with some strobilurin and conazole were included as well. At KRV, multiple fungicide treatments applied at the same time were grouped for analysis because there were no significant differences in TDB, foliar disease, and yield between strobilurin treatments that were applied at the same time. The growth stages of the corn at treatment applications were: V5-8 (five to eight leaves with collars emerged), tasseling (VT), seven days after tasseling (VT+7 days), and 14 days after tasseling (VT+14 days).

### *Data Collection and Analysis*

Foliar disease severity was quantified at R5 (dent), evaluating the severity of foliar disease from the ear leaf and above as a percent of the leaf area with symptoms in the middle two rows of each plot. Gray leaf spot (GLS), *Cercospora zeae-maydis* (Tehon and W.Y. Daniels), was the predominant leaf disease at NWRC. Gray leaf spot and common rust, *Puccinia sorghi* (Schwein.), were present at KRV. Plants with the top two to four leaves with purple or yellow coloration or necrotic, while the lower leaves remained green, occurred in the studies (Figure 1). Observations of black lesions and fungal fruiting bodies on the stalk near and under the leaf sheath below the lowest leaf that expressed symptoms confirmed that the TDB symptoms were caused by *C. graminicola*. Additionally, the absence of any insect feeding into the stalk, such as European corn borer, showed there was not an additional factor causing TDB. The number of plants exhibiting TDB symptoms were counted in the middle two rows of each plot and converted to a percentage of all plants. The middle two rows of the plots were harvested for yield, and yields were calculated from plot weights adjusted to 15.5% grain moisture. Return on fungicide investment for an application at different growth stages was calculated by multiplying the yield increase over the check treatment by corn price, then subtracting an estimated cost of foliar fungicide and application. A range of corn prices and costs of fungicide application were used to include possible value/cost ratios a grower might encounter.

### *Effect of Fungicide Application on Top Dieback in Corn*

The early season fungicide application at the V5 to V8 growth stages did not reduce foliar disease, TDB, or increase yield when compared with the untreated check (Tables 2, 3, 4, and 5). As a result, fungicide application did not result in a positive economic return (Table 6). The lack of effectiveness of fungicides against TDB indicates the infection occurred after the V5 to V8 application, and near VT when the environmental conditions were very favorable for the disease.

The foliar application of fungicides to corn at VT or up to 14 days after VT reduced the incidence of TDB to less than half of the incidence in the untreated checks, and resulted in increased grain yield up to 10% (Tables 2, 3, 4, and 5). The reduction in TDB and foliar leaf disease by the fungicide applications were very similar at all locations (Table 2, 3, and 4), with greater reduction in the diseases with the VT and later timing of fungicide application. Due to the variability within the experiment at KRV in 2015, the effect of timing of fungicide application was not significant for yield (Table 3), but the relationships between treatments were similar to those at NWRC (Table 2). The lower incidence of TDB in 2016 resulted in no difference between yields as well (Table 4). The combined analysis showed differences between timing of fungicide application in yield, with the application at VT or later resulting in greater yields than with the untreated check (Table 5).

Foliar disease level, due to GLS and common rust, was reduced from 5% in the untreated checks, to 3% or less (Tables 2, 3, 4, and 5), but at a level of severity that had little impact on yield, as demonstrated by previous research. Applying a strobilurin fungicide up to 2 weeks after VT also resulted in a positive return on investment of the foliar fungicide application (Table 6). The rate of return for the investment in fungicide application can be influenced by ratio between the value of corn and the cost of the fungicide application. The effect of the timing of strobilurin fungicides on TDB agrees with the results from a study conducted in Iowa, where TDB was reduced by the VT or later application of fungicides.

The yield potential was much lower at KRV in 2015, averaging 131 bu/a, compared to 237 and 195 bu/a, respectively, at NWRC and KRV in 2016. Excessive rainfall in May caused a loss of N in the KRV soil for which sidedressed N could not fully compensate. Additionally, the incidence of TDB in the check treatment was 65% at NWRC compared to 37% at KRV in 2015 and 8.9% at KRV in 2016. However, the response of TDB to the fungicide applications was very similar at all locations (Tables 2 and 3). While there were many differences between the three locations, the period of several days of rain and overcast conditions just prior to or at VT was a common factor (Figures 1 and 2) linking the occurrence of TDB.

Anthracnose is favored by warm, wet, and overcast conditions (Figures 1 and 2). The onset of TDB in these studies is probably attributed to several days of rain and overcast conditions around tasseling. In 2012 through 2014, the solar radiation was relatively high and rainfall low in the days just prior to and after VT at KRV (Figure 3), resulting in no observable TDB. Irrigation was probably not a very significant factor since most irrigation occurs when the solar radiation is relatively high (Figures 2 and 3). At KRV in 2015, corn reached VT in the period of July 6 to 10 under overcast conditions which resulted in below average solar radiation recorded (Figure 2), resulting significant incidence of TDB. For the week around VT for 2015 and 2016, the average solar radiation was 15.8 and 17.6 mJ/m$^2$, respectively, compared to the VT week average of 26.4, 23.7, 22.5 mJ/m$^2$ for 2012, 2013, and 2014, respectively, with several days greater than 30 mJ/m$^2$. No TDB was observed in the corn fungicide trials at KRV in 2012, 2013, and 2014. No anthracnose lesions were observed at any location at the V5 to V8 growth stages.

Additional factors that favored TDB development at KRV were crop rotation, tillage, and possible N stress. The studies at KRV were planted into cornstalks that had been vertical tilled in the fall, leaving ample corn residue on the soil surface to serve as an inoculum source. Additionally, the N deficiency experienced early in the 2015 season and into the growing season could have been an additional stress factor that could have made the corn more susceptible to TDB. The conditions at NWRC were favorable for high yield potential, and there were no other factors other than the warm and humid weather conditions that increased the risk of TDB.

### *Practical Applications*

Relative to TDB, the positive benefit to fungicide application for up to two weeks after VT demonstrates a relatively wide window of application time that will still result in a positive return on investment for fungicide application. Delays to fungicide application at VT could be attributed to weather or scheduling a commercial applicator. A two-week window gives growers some flexibility when faced with potential delays. With foliar fungal diseases, such as GLS and rust, the observation of the symptoms on the lower leaves can be an early indicator that a fungicide could be warranted if the environmental conditions are favorable for foliar disease to progress up through the crop canopy. However, with TDB, there may be no early symptoms to alert a grower to a potential problem. A key factor in determining if TDB will be an issue is periods of rainy/overcast conditions just prior to and at VT.

Confirming that fungicides containing strobilurin are effective in reducing TDB and increasing yield of corn could be a significant factor in reducing yield losses to TDB. The difficulty will be in predicting when the environmental conditions are most conducive for TDB. If other foliar fungal diseases are at the threshold to apply a fungicide at VT, then there could be the added benefit of control of TDB. However, if the foliar disease level is below the threshold at VT, it may be more difficult to guarantee a positive return for the investment in the fungicide application. Much more attention should be paid to the timing of overcast periods and rainfall/irrigation events in coordination with VT. Additionally, better understanding of the hybrid, crop rotation, and/or tillage interaction with rainfall at VT will help improve the success rate of a fungicide application in improving yield in the event that TDB is expressed.

## Results

These data have demonstrated the effectiveness of strobilurin fungicides in reducing the severity and yield loss to TDB in corn. Additionally, there is a relatively wide window, up to two weeks after VT, for fungicide application that can result in an increase in corn yield and a positive return on investment for the fungicide application if the conditions warrant the application of a fungicide. It appears TDB is favored by periods of rainy/overcast conditions for several days right around VT.

## Reference

Robertson, A.E., Peckinovsky, K., and Liu, L. 2010. Effect of foliar fungicides on anthracnose top dieback, and frost injury of corn in Iowa, 2009. Plant Disease Management Report, 4:FC087.

**Table 1. Study details for corn fungicide studies on top dieback (TDB)**

| | NWRC 2010 | KRV 2015 | KRV 2016 |
|---|---|---|---|
| Soil type | Muscatune silt loam | Eudora sandy loam | Eudora sandy loam |
| Previous crop | Soybeans | Corn | Corn |
| Tillage | Chisel in fall, field cultivate in spring | Vertical tillage in fall | Vertical tillage in fall |
| Nitrogen fertilizer | 160 lb | 200 lb followed by 130 lb side-dressed | 200 lb |
| Planting date | April 20 | April 16 | April 16 |
| Hybrid | DK 61-69 | GH 11U-58-3111 | GH G12J-11-3111 |
| Seeding rate | 37,800 | 32,000 | 32,000 |
| V5-8 application | June 1 | June 8 | May 31 |
| VT application | July 8 | July 8 | July 1 |
| VT+1 application | July 15 | July 15 | July 8 |
| VT+2 application | July 22 | July 22 | July 15 |
| Plant disease rating | August 23 | August 6 | August 1 |
| TDB rating | August 23 | August 14 | August 1 |
| Harvested | September 8 | September 14 | September 20 |

Corn growth stages: V5-8 = 5 to 8 leaf collar visible, VT = tasseling.
University of Illinois' Northwestern Illinois Agricultural Research and Demonstration Center (NWRC), near Monmouth, IL, and the Kansas State University's Kansas River Valley experiment fields (KRV), near Topeka, KS.

**Table 2. Effect of timing of fungicide application to corn on top dieback (TDB) at Northwestern Research Center, Monmouth, IL, in 2010**

| | Yield | | Top dieback | | Foliar disease severity | |
|---|---|---|---|---|---|---|
| Timing of fungicide application | bu/a[z] | | Percentage of plants[z] | | Percentage ear leaf and above[z] | |
| Check | 228 | b | 65.5 | a | 4.5 | a |
| V5-8 [y] | 233 | b | 64.3 | a | 4.5 | a |
| VT | 252 | a | 32.1 | b | 1.3 | b |
| VT+7 days | 251 | a | 25.5 | b | 1.5 | b |
| VT+14 days | 246 | a | 33 | b | 3.8 | a |
| Pr>F* | <0.0001 | | <0.0001 | | <0.0001 | |

[y] Corn growth stages: V5-8 = 5 to 8 leaf collar visible, VT = tasseling.
[z] Means followed by the same letter within a column are not significantly different at Pr>0.05.
*The lower the Pr>F value, the greater probability that there is a significant difference between yields.

**Table 3. Effect of timing of fungicide application to corn on top dieback (TDB) at Kansas River Valley, Topeka, KS, in 2015**

| | Yield | Top dieback | | Foliar disease severity | |
|---|---|---|---|---|---|
| Timing of fungicide application | bu/a | Percentage of plants[z] | | Percentage ear leaf and above[z] | |
| Check | 128 | 37.0 | a | 6.2 | a |
| V5-8 [y] | 128 | 33.1 | a | 3.3 | b |
| VT | 143 | 12.6 | b | 2.3 | b |
| VT+7 days | 140 | 14.9 | b | 2.3 | b |
| VT+14 days | 144 | 18.4 | b | 1.7 | b |
| Pr>F* | 0.50 | <0.0001 | | <0.0001 | |

[y] Corn growth stages: V5-8 = 5 to 8 leaf collar visible, VT = tasseling.
[z] Means followed by the same letter within a column are not significantly different at Pr>0.05.
*The lower the Pr>F value, the greater probability that there is a significant difference between yields.

**Table 4. Effect of timing of fungicide application to corn on top dieback (TDB) at Kansas River Valley, Topeka, KS, in 2016**

| | Yield | Top dieback | | Foliar disease severity | |
|---|---|---|---|---|---|
| Timing of fungicide application | bu/a | Percentage of plants[z] | | Percentage ear leaf and above[z] | |
| Check | 192 | 8.9 | a | 3.4 | a |
| V5-8 [y] | 188 | 5.6 | b | 2.2 | b |
| VT | 194 | 4.1 | bc | 0.9 | c |
| VT+7 days | 199 | 1.1 | c | 0.7 | c |
| VT+14 days | 203 | 1.9 | c | 1.0 | c |
| Pr>F* | 0.27 | <0.0001 | | <0.0001 | |

Corn growth stages: V5-8 = 5 to 8 leaf collar visible, VT = tasseling.
[z] Means followed by the same letter within a column are not significantly different at Pr>0.05.
*The lower the Pr>F value, the greater probability that there is a significant difference between yields.

**Table 5. Combined data on effect of timing of fungicide application to corn on top dieback (TDB) at Northwestern Research Center (NWRC), Illinois, in 2010, and Kansas River Valley (KRV), KS, in 2015 and 2016**

| Timing of fungicide application | Yield | | Top dieback | | Foliar disease severity | |
|---|---|---|---|---|---|---|
| | bu/a[z] | | Percentage of plants[z] | | Percentage ear leaf and above[z] | |
| Check | 183 | b | 37.1 | a | 4.5 | a |
| V5-8 [y] | 184 | b | 34.6 | a | 3.2 | b |
| VT | 196 | a | 16.4 | b | 1.6 | c |
| VT+7 days | 197 | a | 13.8 | b | 1.4 | c |
| VT+14 days | 197 | a | 17.8 | b | 2.0 | c |
| Pr>F* | 0.008 | | <0.0001 | | <0.0001 | |

[y] Corn growth stages: V5-8 = 5 to 8 leaf collar visible, VT = tasseling.
[z] Means followed by the same letter within a column are not significantly different at Pr>0.05.
*The lower the Pr>F value, the greater probability that there is a significant difference between yields.

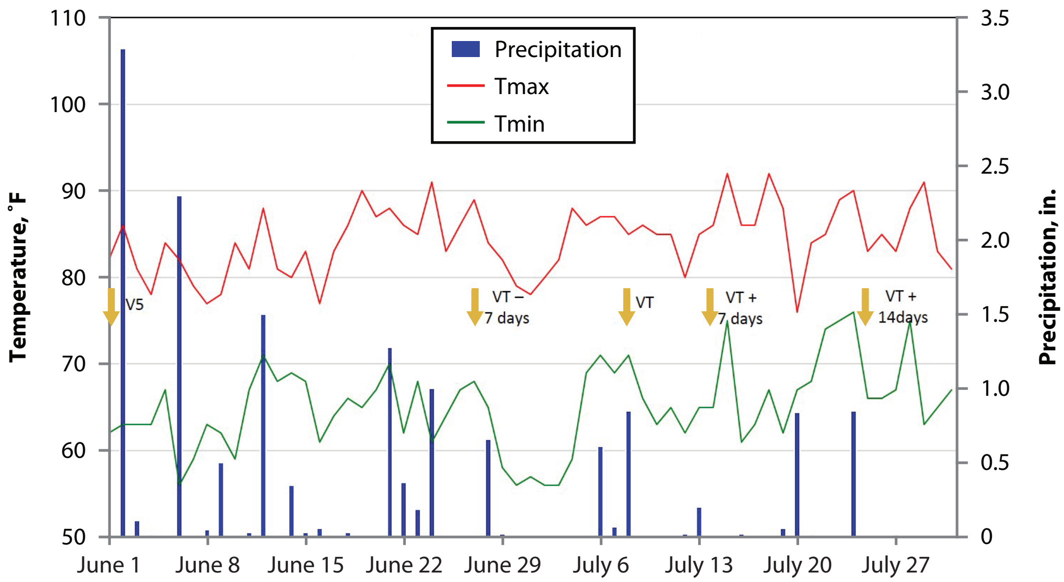


**Figure 1. Rainfall and temperature from University of Illinois' Northwestern Illinois Agricultural Research and Demonstration Research Center, Monmouth, IL, for June and July 2010. National Climate Data Center (2016).**

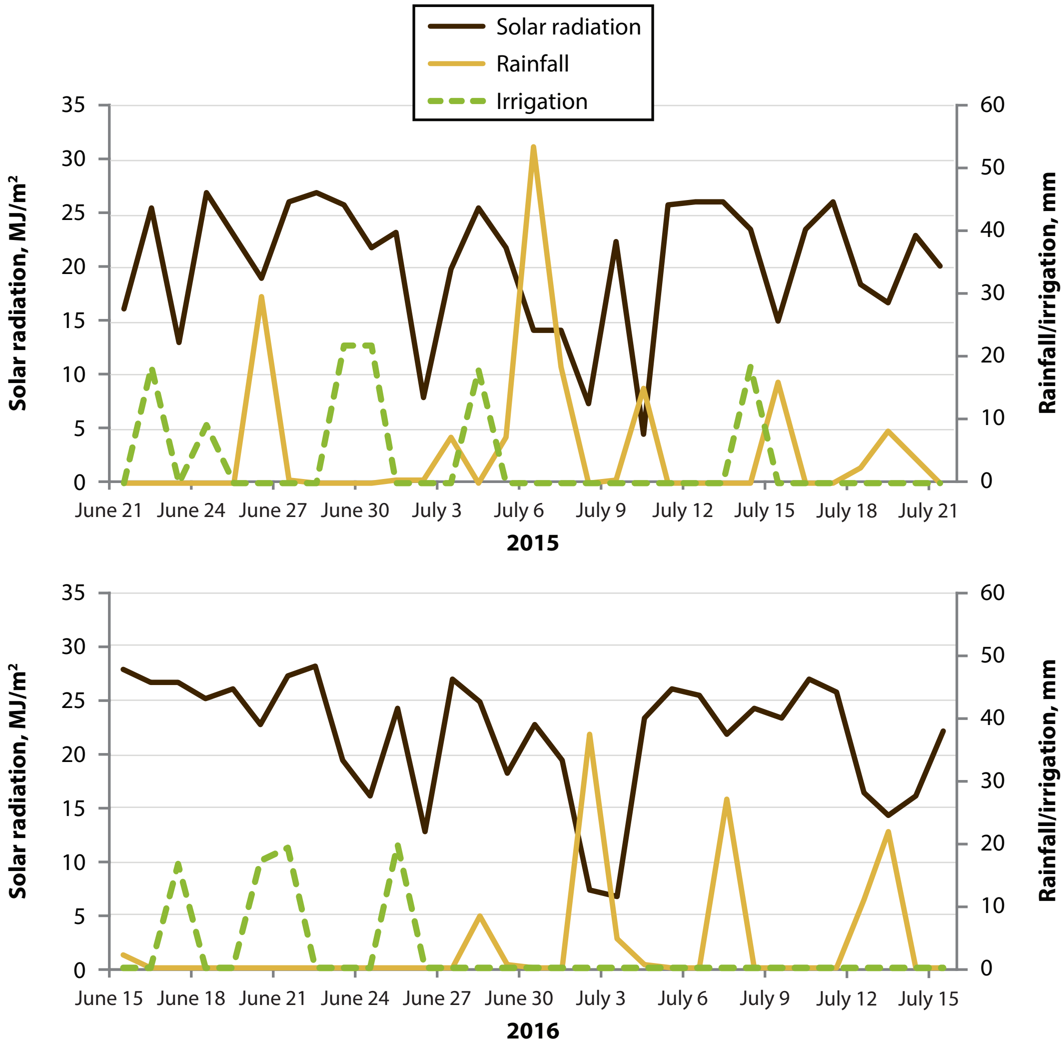


**Figure 2. Solar radiation, rainfall, and irrigation of VT fungicide applied July 1 for the Kansas State University Kansas River Valley experimental fields, Topeka, KS, for two weeks before and after tasseling of corn (VT) in 2015 and 2016, corresponding to development of top dieback. Weather Data Library, Kansas State University, 2016.**

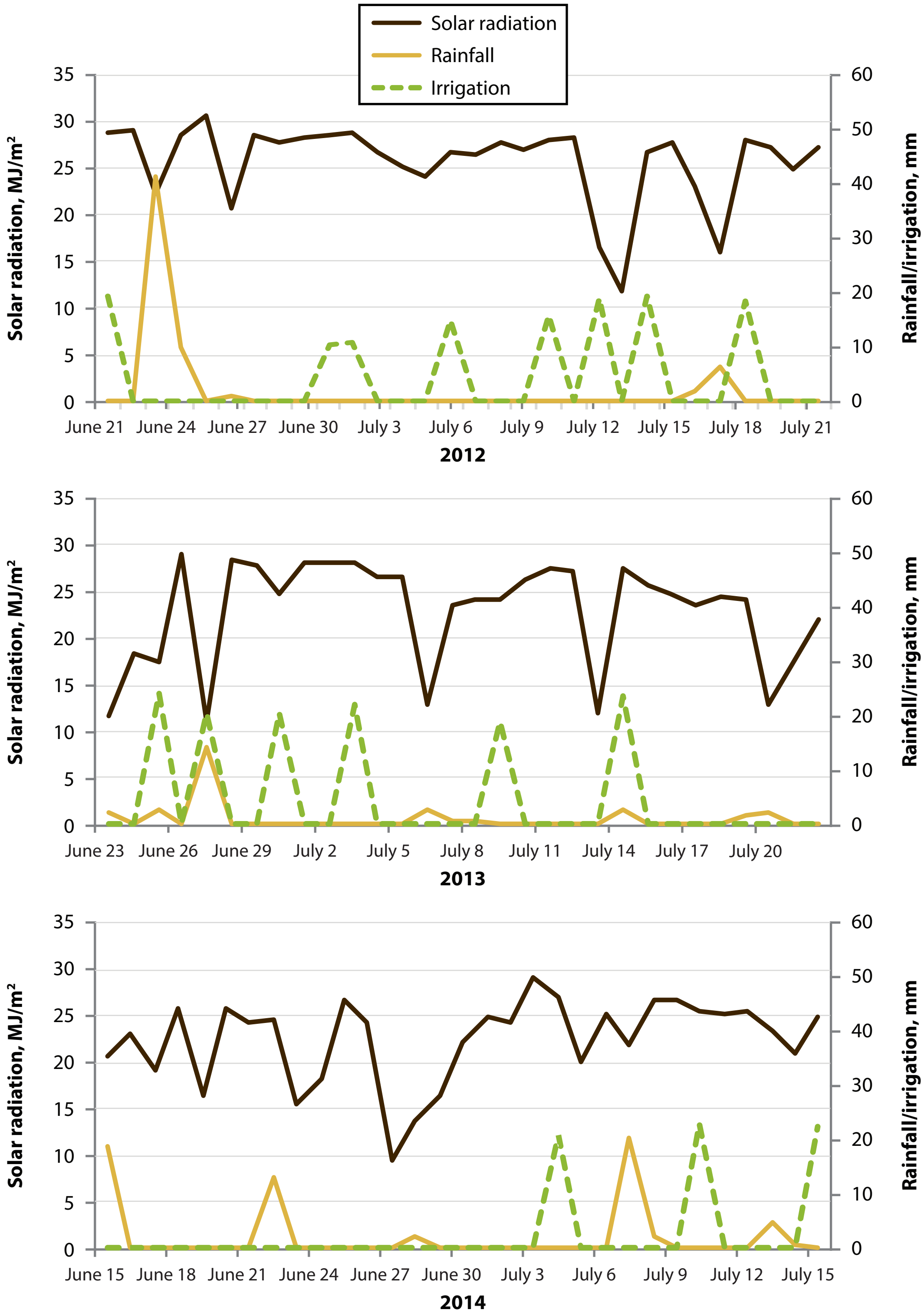


**Figure 3. Solar radiation, rainfall and irrigation of VT fungicide applied July 3, July 8, and July 1 for the Kansas State University Kansas River Valley experimental fields, Topeka, KS, for two weeks before and after tasseling of corn in 2012, 2013, and 2014, corresponding to no observed top dieback. Weather Data Library, Kansas State University, 2016.**

# Closing Corn Yield Gaps via Improved Management: A Systems Approach

*G.R. Balboa and I.A. Ciampitti*

## Summary

Three corn research trials were conducted during the 2016 growing season. Two studies were conducted at Scandia, KS, (dryland and irrigated) and one at Topeka, KS (dryland). The objective of these trials was to investigate the contribution of different farming systems for closing corn yield gaps. Each experiment consisted of five treatments: common practices (CP), comprehensive fertilization (CF), production intensity (PI), ecological intensification (CF + PI), and advanced plus (AD). Across all three experiments and under dryland and irrigation scenarios, CP presented the lowest yield. In environments with yield response, intensifying production without a balanced nutrition program did not increase yields. A balanced nutrition program substantially increased yields in corn with more relative impact in dryland environments. The absolute yield gap was 86 bu/a for dryland and 75 bu/a for irrigated condition.

## Introduction

Crop management practices (such as row spacing, planting date, and nutrient application) and their interactions with the environment (soil + weather) have a direct impact on closing yield gaps. By choosing different combinations of practices, farmers can modify the growing conditions. Thus, after considering the contribution from the genetics and the environment, on-farm yield is primarily influenced by farmers' decisions, the main components of which are agronomic practices. Crop management practices are often specific to the environment, hybrid/variety, and/or yield level. Each farmer needs to find the appropriate management practices that can help them increase yields and profits. Increasing seeding rates and narrowing rows are two common intensification practices in high-yielding corn systems.

## Procedures

Three corn research trials were conducted during the 2016 growing season. Two studies were located at the North Central Kansas (NCK) experiment fields (Scandia, KS), and one at the Kansas River Valley (KRV) experimental fields (Topeka, KS). At Scandia, one experiment was conducted under dryland and one under irrigated conditions. The corn was planted on May 6 at both locations. Each experiment consists of 5 treatments with five replications in a completely randomized block design: 1) common practices (CP), (30,000 seeds/a + no-nutrient application + 30-in. row spacing); 2) comprehensive fertilization (CF), (30,000 seeds/a + balanced nutrient application + 30-in. row spacing); 3) production intensity (PI), (36,000 seeds/a + no-nutrient application + 15-in. row spacing); 4) ecological intensification (CF + PI; 36,000 seeds/a + balanced nutrient application + 15-in. row spacing + fungicides and micronutrients); and 5) advanced plus (AD), or increasing input applications (36,000 seeds/a + balanced nutrient application + 15-in. row spacing + double application of fungicides and micronutrients). Mes SZ and Aspire (Mosaic company) rates in lb N-$P_2O_5$-$K_2O$-S/a for irrigated were 141 and 133 lb/a, while for dryland fertilizer P and K rates were 105 and 99 lb/a, respectively. Nitrogen rate for the treatments of CF, ecological intensification (EI ) (CF+PI), and AD was 175 lb/a of UAN (28%). The EI and AD treatments received an extra 175 lb/a of UAN at flowering. The rates per nutrients in lb/A (N-$P_2O_5$-$K_2O$-S-Zn-B) were 73-56-80-14-1.4Zn-0.65B and 68-42-105-11-1Zn-0.85B for irrigated and dryland scenario.

# Results

### *Weather Conditions*

Weather conditions for the growing season and historical values are shown in Figure 1 for the NCK site and Figure 2 for the KRV location (Mesonet, Kansas State University). The total amount of precipitation received during the growing season was 17 inches at both locations.

The total amount of water provided to the irrigated condition at NCK site was 6.3 inches (6/23, 7/15, 7/21, 7/29, and 8/10). Temperatures ranged in normal values for the crop, registering only a few days of heat stress.

### *Soil Test and Phenological Information*

Soil samples were collected before planting to characterize each experimental site. Soil test results are shown in Table 1. The previous crop was soybean at all locations. The corn hybrid planted, the date for phenological stages, and the harvest date are shown in Table 2.

### *North Central Kansas, Scandia, Yields*

At the NCK Scandia field experiment, average yield for dryland corn was 159 bu/a; while irrigation yielded on average 190 bu/a (+19%). In both water scenarios there were statistical differences ($P < 0.05$) between treatments, CP and PI recorded the lowest corn yields, and CF the highest values, 199 bu/a for dryland and 226 bu/a for irrigated (Figure 3). Common practices (CP) and intensification without balanced nutrition (PI) treatments obtained the lowest yields under both water scenarios (CP vs. PI, 113 < 122 bu/a for dryland and 164 > 151 bu/a for irrigated). Intensifying management practices with balanced nutrition (EI) treatment yielded more than CP and PI but less than CF (Figure 3). The absolute yield gap was 86 bu/a for dryland and 75 bu/a for irrigated condition (calculated as the maximum yield value, CF treatment, minus lowest yield value, CP treatment for dryland, and PI for irrigation) (Figure 3).

### *Kansas River Valley, Topeka, Yields*

At the KRV Topeka field experiment, average corn yield was 156 bu/a ranging from 150 to 163 bu/a (Figure 4). There were no statistically significant differences between all the treatments ($P > 0.05$) evaluated in this location during the 2016 growing season.

# Acknowledgments

Thanks to the Kansas State University Crops Production Team for the valuable help in collecting and processing all the field data during 2016 growing season. This study was supported by the International Plant Nutrition Institute (IPNI, Project GBL 62), K-State Research and Extension and the Fulbright Program (partially covering G.R. Balboa's stipend).

**Table 1. Soil characterization before planting time**

| Corn studies | Organic matter | pH | Phosphorus |
|---|---|---|---|
| | % | | ppm |
| NCK Scandia irrigated | 2.1 | 5.8 | 6.3 |
| NCK Scandia dryland | 2.1 | 5.3 | 8.3 |
| KRV Topeka dryland | 2.5 | 6.1 | 12.3 |

NCK = North Central Kansas.
KRV = Kansas River Valley.

**Table 2. Phenological data for the 2016 growing season for corn**

| Phenological data | North Central Kansas, Scandia | Kansas River Valley, Topeka |
|---|---|---|
| Corn hybrid | DKc64-69rib | DKc64-69rib |
| Planting date | 05/05/2016 | 05/05/2016 |
| Emergence date (VE) | 05/13/2016 | 05/11/2016 |
| Flowering (R1) | 07/21/2016 | 07/18/2016 |
| Maturity | 09/07/2016 | 08/26/2016 |
| Harvest time | 11/04/2016 | 09/23/2016 |

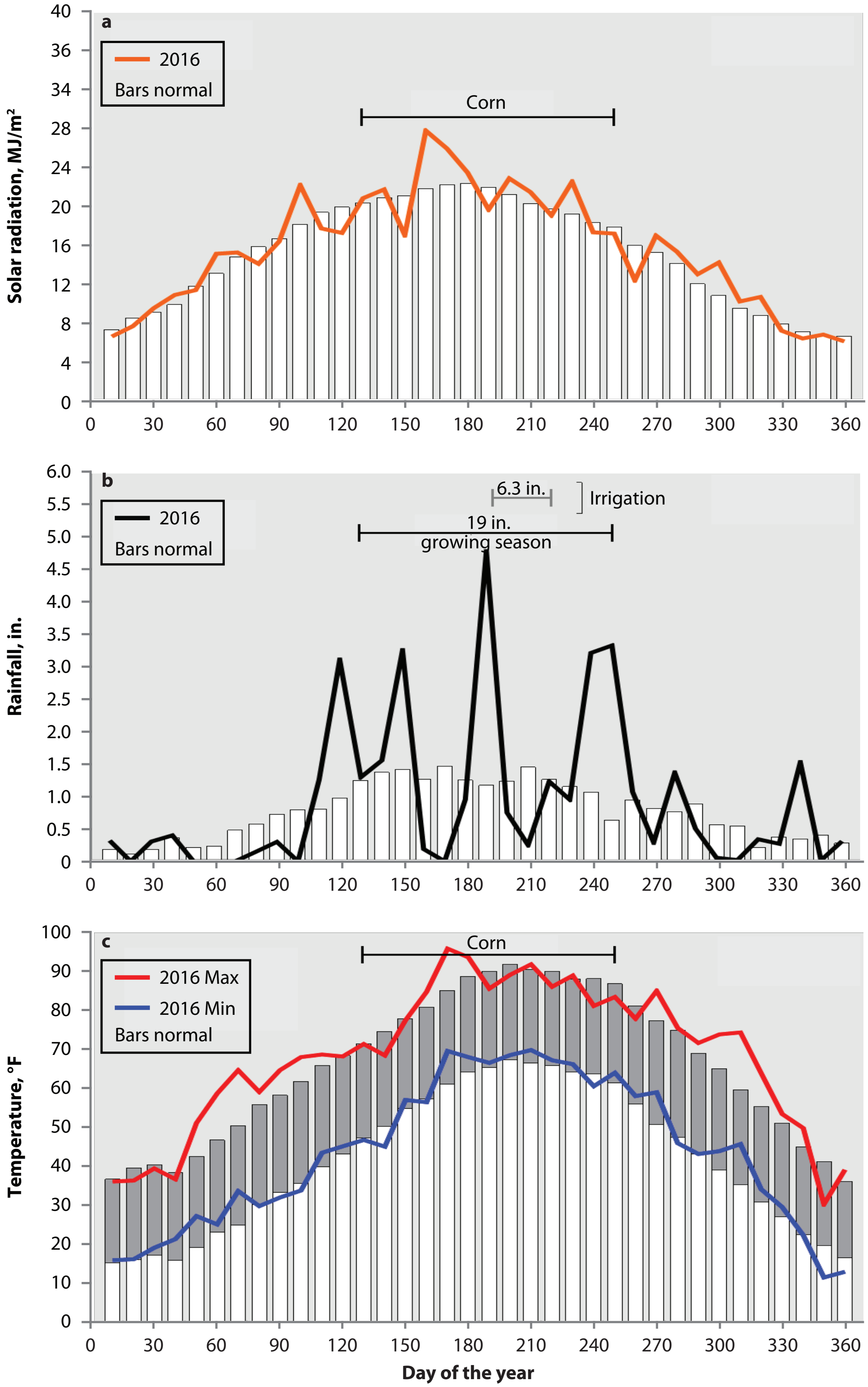


**Figure 1. a) Daily solar radiation; b) Daily precipitation; and c) Daily maximum and minimum temperatures all for 2016 season and historical. North Central Kansas, Scandia.**

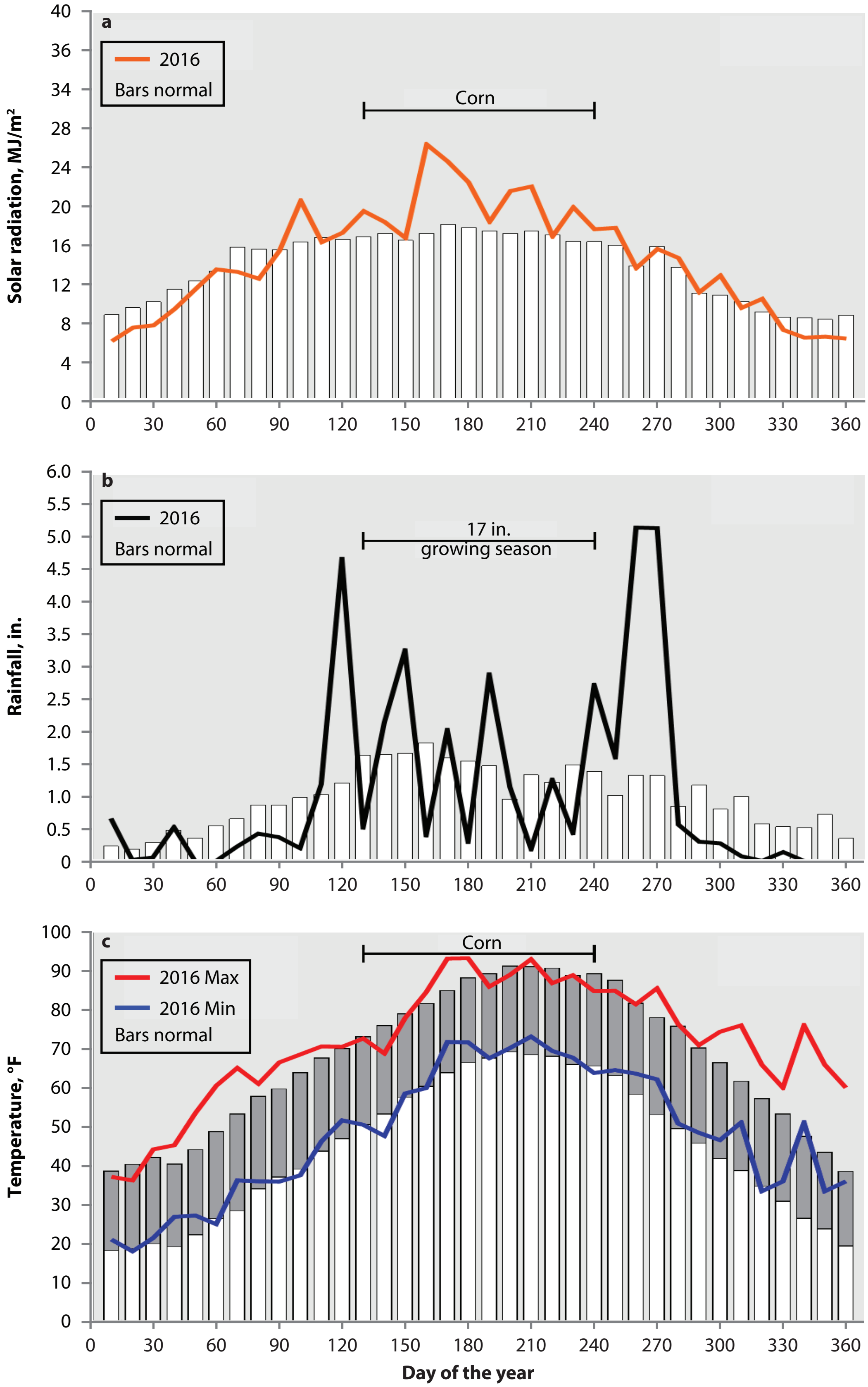


**Figure 2. a) Daily solar radiation; b) Daily precipitation; and c) Daily maximum and minimum temperatures all for 2016 season and historical. Kansas River Valley, Topeka.**

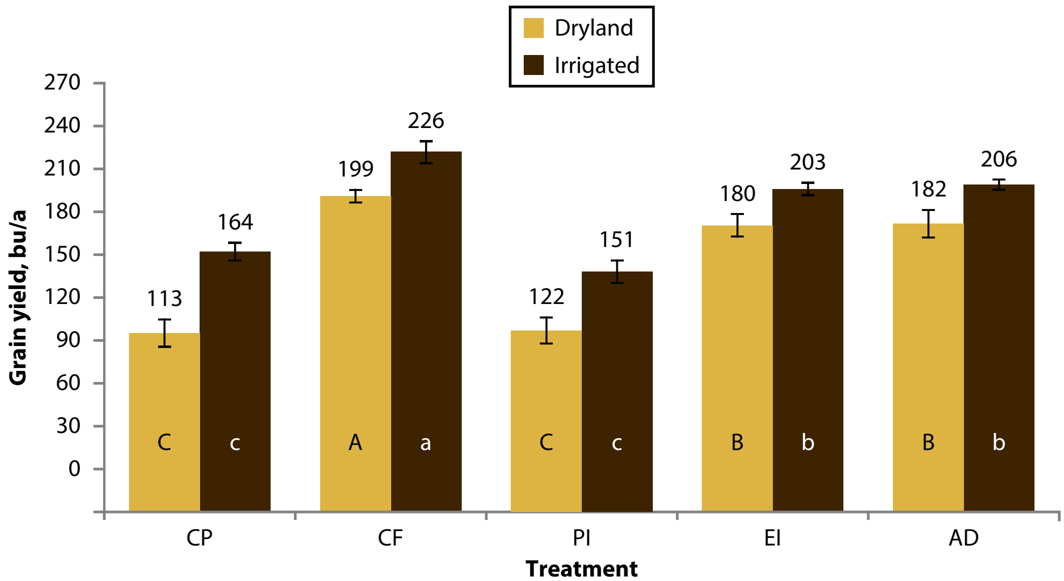


**Figure 3. Corn grain yield by treatment for dryland and irrigated conditions during the 2016 growing season, North Central Kansas, Scandia. Different letter shows statistical differences ($P < 0.05$). CP = Common practices, CF = comprehensive fertilization, PI = production intensification, EI = ecological intensification (CF+PI), AD = advanced plus. Lines in bars indicate standard deviation.**

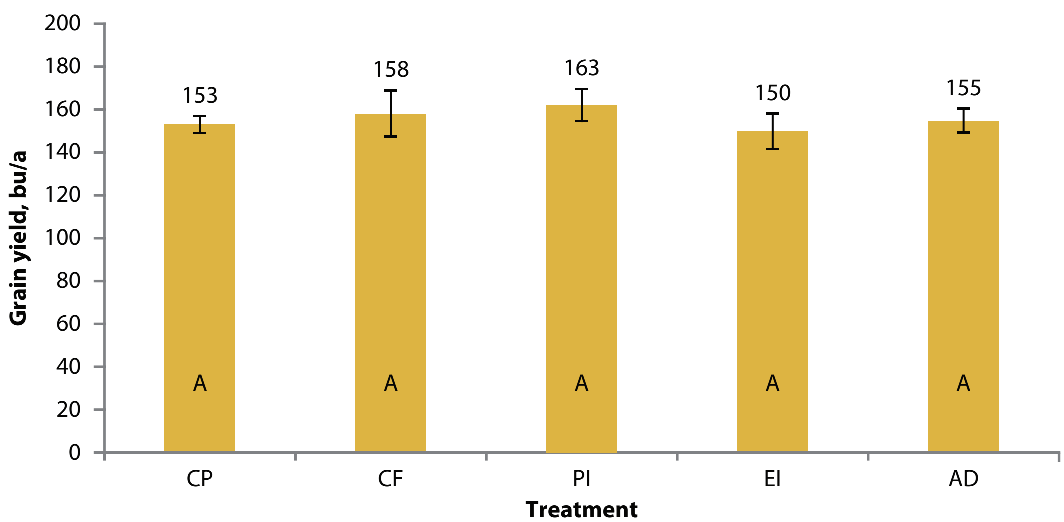


**Figure 4. Corn grain yield by treatment during the 2016 growing season, Kansas River Valley, Topeka. Different letter shows statistical differences ($P < 0.05$). CP = Common practices, CF = comprehensive fertilization, PI = production intensification, EI = ecological intensification (CF+PI), AD = advanced plus. Lines in bars indicate standard deviation.**

# Irrigation and Tillage Management Effects on Canopy Formation in Corn

*R.M. Aiken, F.R. Lamm, and A.A. AbouKheira*


## Summary
Effects of canopy formation and function are frequently represented in irrigation management models by crop coefficients, which can be used to calculate expected crop water requirements. Soil tillage alters the micro-environment of a developing corn canopy. The objective of this study was to evaluate irrigation capacity and tillage effects on seasonal changes in maize canopy and above-ground biomass productivity. Leaf area index (LAI) and above-ground biomass (AGB) were quantified by non-destructive methods during four growing seasons for corn under two irrigation capacities (1 in./4 days or 1 in./8 days) and three tillage regimes (no-tillage (NT), strip tillage (ST), or conventional tillage (CT)). Irrigation capacity and tillage effects were evaluated for each sampling period; seasonal trends were evaluated for year and treatment effects. Conventional tillage management resulted in earlier canopy formation and greater AGB accumulation during early vegetative growth in three of four years. No-tillage management resulted in extended canopy duration and greater AGB at tassel stage in two of four years; ST management resulted in greatest canopy duration in one year. Evaluated during four years, seasonal trends in LAI indicated earliest development under CT and delayed canopy development under NT management. The intermediate rate of canopy development of corn under ST management, and favorable yield and water productivity, indicates utility of ST management for irrigated corn production.


## Introduction
The canopy of maize crops generates the structural biomass and carbohydrates which support grain yield formation. Stomata embedded in leaves mediate the atmospheric demand, which results in the transpiration component of evapotranspiration (ET). Effects of canopy formation are frequently represented in irrigation management models by crop coefficients, which can be combined with reference or potential ET to calculate expected crop water requirements (Allen et al., 1998). The relationship of crop canopy formation and function to crop water requirements suggests the question: Can crop management alter canopy formation and subsequent productivity?

Soil tillage alters the micro-environment of a developing corn canopy, affecting crop residue distribution and soil physical properties in the tillage zone. Full surface coverage by residue was required to reduce energy-limited evaporation by 50% or more, relative to bare soil with no shading by crop canopy; partial residue coverage (25 to 75%) resulted in limited evaporation suppression relative to that of bare soil with no shading (Klocke et al., 2009). Corn grown under NT management required five to seven days longer to reach V6 development stage than corn under CT management in Ontario (Fortin, 1993). Corn yields were numerically greater under ST and NT management, relative to CT management (Lamm et al., 2009). The objective of this study was to evaluate irrigation capacity and tillage effects on seasonal changes in maize canopy and above-ground biomass productivity.

## Procedures

A corn hybrid of approximately 110-day relative maturity (Dekalb DCK60-19 in 2004 and DCK60-18 in 2005 through 2007) was planted in 30-inch spaced circular rows on May 8, 2004; April 27, 2005; April 20, 2006; and May 8, 2007. The two hybrids differ only slightly, with the latter hybrid having an additional genetic modification of corn rootworm control. Three target seeding rates (27,000; 30,000; and 33,000 seeds/a) were superimposed onto each tillage treatment in a complete randomized block design. Irrigation was scheduled with a weather-based water budget but was limited to the three treatment capacities of 1 in. every 4, 6, or 8 days (IC-4, IC-6, and IC-8, respectively). This results in typical seasonal irrigation amounts of 12-20, 11-15, and 8-12 in., respectively. The weather-based water budget was constructed using data collected from a National Oceanic and Atmospheric Administration (NOAA) weather station located approximately 600 yd. northeast of the study site. The reference evapotranspiration (ETr) was calculated using a modified Penman combination equation similar to the procedures outlined by Kincaid and Heermann (1974). The specifics of the ETr calculations used in this study are fully described by Lamm et al. (1987). The basal crop coefficients were calculated for the area by assuming 70 days from emergence to full canopy for corn with physiological maturity at 130 days.

Leaf area index (LAI) was quantified, approximately bi-weekly, by a non-destructive light transmission technique (Welles and Norman, 1991; LAI-2000 Plant Canopy Analyzer (Li-Cor, Lincoln, NE). Three sets of four below-canopy measurements were each referenced to an above-canopy measurement, minimizing sensor exposure to direct (beam) irradiance. Readings were screened against apparent transmittance ratios exceeding 1 using the manufacturer's software, FV2000 (Li-Cor, Lincoln, NE). An inverse solution to a model of light transmission through a vegetative canopy, provided by the manufacturer, was used to quantify apparent LAI.

Above-ground biomass (AGB) was quantified by non-destructive allometric measurements from V6 through early grain fill stages. Three representative plants in each experimental unit were identified for repeated measure, commencing from V6 stage. Stem measurements included diameter of the second internode and at the upper sheath of the youngest fully expanded leaf, distance from the ground to the base of the youngest fully expanded leaf, and number of fully expanded leaves. For each sampling period, identical measurements were made for similar plants, outside the plot area but receiving similar management. These plants were cut at ground level and dried, to determine above-ground biomass. An allometric model was developed by regressing AGB against stem volume (calculated using cylindrical geometry) and cumulative growing degree days (cGDD). Coefficients of this model were then applied to in-plot measurements to calculate apparent above-ground biomass.
Growing degree days (GDD) were calculated from daily temperature extremes (Equation 1) recorded at the Kansas State University Northwest Research and Extension Center weather station, using a mercury thermometer.

$$GDD = \frac{T_{max} - T_{min}}{2} - T_b \qquad \textit{Equation 1}$$

Upper and lower limits to temperature extremes were 86 and 50°F, respectively. Cumulative GDD was computed by summation of GDD, commencing from planting date.

Experimental design was randomized complete block, with some restrictions based on distance from the center pivot point. Treatment design was split-plot with irrigation capacity (1 in./4 days or 1 in./8 days) as whole-plot treatment and tillage method (NT, ST, or CT) as split plot treatment. Population treatments were sampled for LAI and AGB at the mid-level (30,000 seeds/a) only.

Statistical analysis included analysis of variance (ANOVA), analysis of covariance (ANCOVA), and regression techniques (linear and non-linear). Repeated measure of LAI and maximum LAI observed in a year were analyzed by ANOVA, using Proc GLM from SAS 9.4 (SAS Institute Inc., Cary, NC). Seasonal trends in LAI and AGB were analyzed by ANCOVA using third order linear terms of cGDD or days after planting (DAP) as covariates. A logistic model was also used to quantify changes in LAI through pollen shed stage, when all leaves were fully expanded. A three-parameter form of the logistic equation (equation 2) was fit to each set of LAI measurements from V6 through R1, for each set of treatment combinations of each year, using the non-linear feature of Statistix v9.1 (Analytical Software, Tallahassee, FL). Coefficients for 'a', 'b', and 'c' terms were subjected to univariate analysis of variance, with year as a sampling environment.

$$LAI = \frac{a}{1 + e^{b - c * cGDD}} \qquad \textit{Equation 2}$$

A linearized form of the logistic equation (Equation 3) was also evaluated.

$$LAI = \frac{L_o * L_m}{L_o + (L_m - L_o)e^{-kL_m t}} \qquad \textit{Equation 3}$$

Here, $L_o$ and $L_m$ are initial and maximum leaf area, t represents days following emergence and k is a logistic coefficient for this linearized form (Aiken, 2005).

# Results

## *Canopy Formation*

Early season canopy formation occurred more rapidly under CT management in 2005, 2006 and 2007, as indicated by greater leaf area index (LAI, Table 1). End of season canopy persistence was favored by NT management in 2005 and 2006, and by ST management in 2007, as indicated by larger LAI values for later samplings. Irrigation capacity affected LAI mid-season (97 DAP, 1976 °Fd) in 2004 and late-season in 2006 (132 DAP, 2615 °Fd). Maximum canopy formation, averaged among tillage treatments was greatest in 2007 (4.80), least in 2005 (3.35), and intermediate in 2004 (4.12) and 2006 (4.30) (Table and Figure 1).

Seasonal trends in LAI, averaged over tillage and irrigation capacity effects, indicate delayed LAI development in 2006, relative to the other years (Figure 1). Tillage effects were detected in the 'b' term of the three-term logistic model (Equation 2), when combined for the four years. This term affects the rate of increase in the LAI function, indicating earliest canopy formation for CT (b = 6.25)[1], intermediate rate of canopy formation for ST (b = 5.61) and latest canopy formation for NT (b = 4.96). No significant differences were detected for 'a' (4.16) or 'c' (0.0094) terms, which scale final and initial LAI values, respectively. The linearized form of the logistic equation indicated

[1] Note that 'a', 'b', and 'c' terms were fit in relation to Celsius units for thermal time.

a negative linear relationship between maximum LAI and the logistic coefficient 'k' (Equation 3 and Figure 3). This 'k' term affects the rate of increase in the LAI function of Equation 3, similar to the 'b' term of Equation 2. A smaller 'k' coefficient indicates a slower rate of canopy formation.

### *Above-Ground Biomass*

Increased irrigation capacity (1 in./4 days) resulted in greater early vegetative growth in 2004 and 2005, greater mid-vegetative growth in all years, and greater biomass accumulation at maturity in all years but 2007, as indicated by larger values for AGB (Table 2). Early vegetative AGB accumulation was favored by CT management in 2005, 2006, and 2007, relative to NT management; ST management resulted in similar AGB values to CT management in 2006 and 2007. By tassel formation, AGB was greater under NT management than for CT management in 2004 and 2007; at maturity, in 2004, AGB was greater under ST management than that under CT management. Seasonal trends for AGB accumulation (Figure 4) indicate slightly greater AGB under CT but similar or greater AGB for NT and ST corn by early grain fill stage.

Early canopy formation and senescence for CT is evident (Figure 5c), with delayed canopy formation for NT; maximum canopy occurred with ST management. Similarly, more AGB accumulated during early vegetative growth under CT management (Figure 5b) with similar AGB for ST by tassel and maximum AGB at maturity for NT. Vegetative crop water use was similar among tillage treatments (Figure 6a), but greater for NT and ST than for CT by maturity, reflecting differences in canopy senescence.

### *Discussion*

Earlier canopy formation and AGB accumulation under CT, detected in three of four years, is consistent with a report of more rapid corn development under CT management in Ontario (Fortin, 1993). This likely results from warmer soil conditions, early emergence, and more vigorous seedling growth under CT management. Earlier canopy senescence and maturity also resulted from CT management in the same three growing seasons, indicating tillage management can cause a shift in canopy formation and senescence.

The delayed canopy formation and extended canopy duration for NT and, to a lesser extent, ST appears to be related to increased grain yield and increased water use. This could result in extended water use during the late grain fill period, which may not be sufficiently represented in standard crop coefficients used in irrigation scheduling.

Vegetative water use was similar among tillage treatments (an exception: water use was least for NT in 2006, 1 in./8 days irrigation capacity). Klocke et al. (2009) reported that virtually 100% residue cover was required to achieve evaporation suppression with incomplete canopy closure. Field observations on April 17, 2007, indicated 80%, 91%, and 99% residue cover for CT, ST, and NT, respectively. However, greater seasonal water use for ST and NT treatments appears to be associated with delayed canopy senescence and with greater grain yields.

The two forms of the logistic equation (three-term and linearized) provide scaling tools with applications to functional representation of corn canopy formation. In this regard, the tillage effect on the three-term model provides a useful basis for simulating tillage effects. Similarly, the linearized scaling relationship between LAI max and the 'k' coefficient could be useful for adjusting seasonal LAI values for remote sensing and geographic information system (GIS) applications (Maas, 1988; Coyne et al., 2009).

### *Conclusions*

Reduced tillage delayed corn canopy formation and AGB accumulation during early- to mid-vegetative growth, relative to conventional tillage management, in three of four growing seasons. Delayed canopy senescence was also detected in the same three growing seasons. Greater grain yield and crop water use was associated with this shift in canopy formation. Two forms of the logistic equation provide opportunities to functionally represent tillage effects on corn canopy formation and for use in remote sensing/GIS applications.

## Acknowledgments

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**Table 1. Leaf area index (yd² yd⁻²) of corn grown in no-tillage, strip tillage, or conventional tillage management in 2004–2007 growing seasons**

| Crop year, 2004 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Days after planting | 37 | 51 | 65 | 86 | 97 | 110 | 121 | |
| Cumulative growing degree days (°F d) | 711 | 911 | 1,231 | 1,739 | 1,976 | 2,228 | 2,455 | |
| | Leaf area index (yd² yd⁻²) | | | | | | | |
| IC 1 in./4 days | 0.60a | 1.41a | 3.25a | 3.58a | 4.49a | 4.12a | 2.97a | |
| IC 1 in./8 days | 0.55a | 1.31a | 3.17a | 3.58a | 3.75b | 3.81b | 2.64b | |
| NT | 0.56a | 1.32a | 3.41a | 3.51a | 4.00a | 4.04a | 2.79a | |
| ST | 0.62a | 1.36a | 3.08a | 3.63a | 4.18a | 3.95a | 2.90a | |
| CT | 0.55a | 1.39a | 3.14a | 3.62a | 4.18a | 3.91a | 2.74a | |

| Crop year, 2005 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Days after planting | 50 | 55 | 70 | 83 | 96 | 112 | 126 | 138 |
| Cumulative growing degree days (°F d) | 679 | 803 | 1,154 | 1,472 | 1,773 | 2,117 | 2,428 | 2,689 |
| | Leaf area index (yd² yd⁻²) | | | | | | | |
| IC 1 in./4 days | 0.71a | 0.97a | 2.23b | 3.18a | 3.20a | 3.38a | 2.82a | 2.08a |
| IC 1 in./8 days | 0.77a | 1.12a | 2.66a | 3.28a | 3.25a | 3.31a | 2.74a | 2.09a |
| NT | 0.65b | 0.89b | 2.41a | 3.24a | 3.18a | 3.41a | 2.82a | 2.20a |
| ST | 0.58b | 0.96b | 2.32a | 3.28a | 3.23a | 3.34a | 2.82a | 2.16ab |
| CT | 1.00a | 1.28a | 2.60a | 3.17a | 3.26a | 3.29a | 2.70a | 1.91b |

| Crop year, 2006 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Days after planting | 47 | 61 | 76 | 90 | 104 | 118 | 132 | 147 |
| Cumulative growing degree days (°F d) | 677 | 1,004 | 1,336 | 1,685 | 1,996 | 2,336 | 2,615 | 2,840 |
| | Leaf area index (yd² yd⁻²) | | | | | | | |
| IC 1 in./4 days | 0.63a | 1.29a | 2.37a | 4.05a | 3.73a | 4.40a | 3.72a | 3.88a |
| IC 1 in./8 days | 0.59a | 1.17a | 2.39a | 3.96a | 3.57a | 4.20a | 3.25b | 3.60a |
| NT | 0.53a | 1.04b | 2.27a | 4.00a | 3.87a | 4.46a | 3.66a | 3.64a |
| ST | 0.60a | 1.29ab | 2.26a | 4.08a | 3.55a | 4.41a | 3.54ab | 4.00a |
| CT | 0.70a | 1.35a | 2.61a | 3.94a | 3.52a | 4.04a | 3.26b | 3.58a |

| Crop year, 2007 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Days after planting | 30 | 44 | 58 | 73 | 87 | 100 | 114 | 132 |
| Cumulative growing degree days (°F d) | 468 | 761 | 1,073 | 1,422 | 1,780 | 2,117 | 2,453 | 2,761 |
| | Leaf area index (yd² yd⁻²) | | | | | | | |
| IC 1 in./4 days | 0.30a | 1.38a | 3.52a | 4.65a | 4.92a | 4.00a | 3.32a | 2.71a |
| IC 1 in./8 days | 0.31a | 1.39a | 3.28a | 4.65a | 4.82a | 3.80a | 3.13b | 2.58a |
| NT | 0.25b | 1.16b | 3.30a | 4.51a | 4.75a | 3.77b | 3.20b | 2.49b |
| ST | 0.27b | 1.35b | 3.39a | 4.61a | 4.91a | 4.14a | 3.44a | 2.83a |
| CT | 0.40a | 1.64a | 3.51a | 4.83a | 4.96a | 3.80b | 3.04b | 2.62b |

Shaded items within a column are significantly different at $P < 0.05$ when followed by a different lower case letter. No-tillage (NT), strip tillage (ST), conventional tillage (CT). IC refers to Irrigation Capacity; either 1 in./4 days or 1 in./8 days.

**Table 2. Irrigation and tillage effects on above-ground corn biomass (lb/a), determined by a non-destructive allometric method, is shown for the 2004–2007 growing seasons**

| Crop year, 2004 | | | | | | |
|---|---|---|---|---|---|---|
| Days after planting | 36 | 50 | 64 | 82 | 95 | 148 |
| Cumulative growing degree days (°F d) | 661 | 882 | 1,174 | 1,622 | 1,933 | 2,957 |
| | Irrigation and tillage effects | | | | | |
| IC 1 in. /4 days | 350a | 4,160a | 8,600a | 11,890a | 12,570a | 31,310a |
| IC 1 in. /8 days | 280b | 3,520b | 7,780b | 10,730b | 11,590a | 27,540b |
| NT | 300a | 3,810a | 8,120a | 12,160a | 12,550a | 29,380ab |
| ST | 290a | 3,980a | 8,540a | 11,400ab | 12,380a | 31,690a |
| CT | 350a | 3,690a | 7,890a | 10,400b | 11,330a | 27,270b |

| Crop year, 2005 | | | | | | |
|---|---|---|---|---|---|---|
| Days after planting | 40 | 54 | 68 | 82 | 95 | 153 |
| Cumulative growing degree days (°F d) | 508 | 778 | 1,118 | 1,447 | 1,750 | 2,713 |
| | Irrigation and tillage effects | | | | | |
| IC 1 in. /4 days | 1,210a | 4,520a | | | 14,460a | 36,520a |
| IC 1 in. /8 days | 1,300b | 4,720a | | | 13,540a | 31,350b |
| NT | 1,170b | 4,160b | | | 14,340a | 35,370a |
| ST | 1,180b | 4,560ab | | | 13,810a | 32,610a |
| CT | 1,430a | 5,190a | | | 13,840a | 34,210a |

| Crop year, 2006 | | | | | | |
|---|---|---|---|---|---|---|
| Days after planting | 46 | 60 | 75 | 89 | 102 | 151 |
| Cumulative growing degree days (°F d) | 655 | 979 | 1,314 | 1,658 | 1,942 | 2,920 |
| | Irrigation and tillage effects | | | | | |
| IC 1 in./4 days | 2,910a | 5,930a | 12,700a | 13,620a | 14,510a | 30,400a |
| IC 1 in./8 days | 2,900a | 5,640a | 12,160a | 12,710b | 13,450b | 25,500b |
| NT | 2,800b | 5,210c | 11,360b | 12,910a | 14,170a | 27,760a |
| ST | 2,850b | 5,780b | 12,750a | 13,320a | 14,100a | 29,390a |
| CT | 3,070a | 6,420a | 13,250a | 13,250a | 13,660a | 26,500a |

| Crop year, 2007 | | | | | | |
|---|---|---|---|---|---|---|
| Days after planting | 29 | 43 | 57 | 75 | 85 | 132 |
| Cumulative growing degree days (°F d) | 450 | 725 | 1,028 | 1,433 | 1,670 | 2,707 |
| | Irrigation and tillage effects | | | | | |
| IC 1 in./4 days | 140a | 1,940a | 9,830a | 19,580a | 19,090a | 31,230a |
| IC 1 in./8 days | 140a | 1,910a | 11,070a | 16,320a | 17,850a | 31,790a |
| NT | 90b | 1,400c | 10,270a | 19,870a | 20,600a | 31,620a |
| ST | 160a | 1,840b | 10,830a | 16,590a | 18,990a | 32,260a |
| CT | 190a | 2,770a | 10,200a | 17,330a | 16,080b | 30,670a |

Shaded items within a column are significantly different at $P < 0.05$ when followed by a different lower case letter. No-tillage (NT), strip tillage (ST), conventional tillage (CT). IC refers to Irrigation Capacity; either 1 in./4 days or 1 in./8 days.

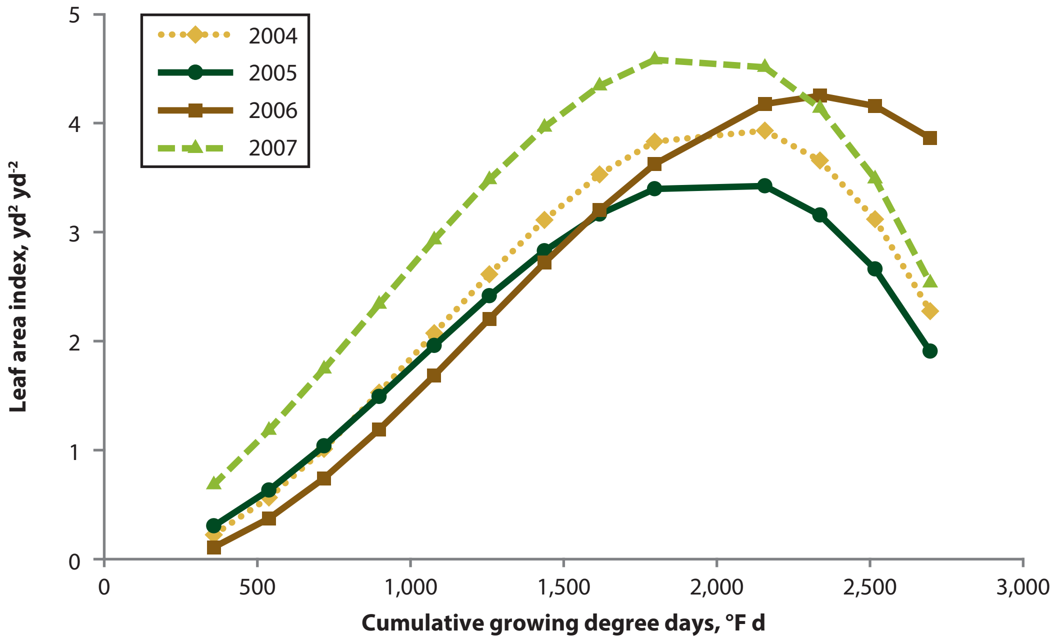


**Figure 1. Seasonal trends in leaf area index are shown in relation to cumulative growing degree days after planting, for corn grown in 2004–2007 seasons.**

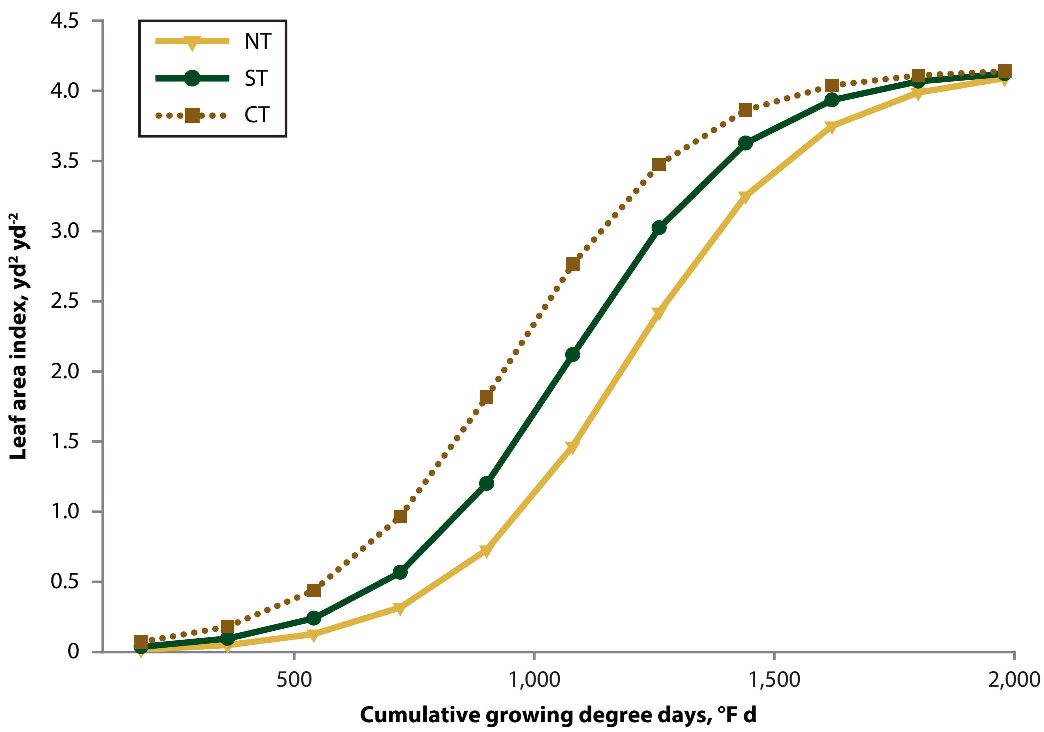


**Figure 2. Effects of tillage on seasonal trends in leaf area index are shown in relation to cumulative growing degree days after planting; results are a composite of 2004–2007 growing seasons.**

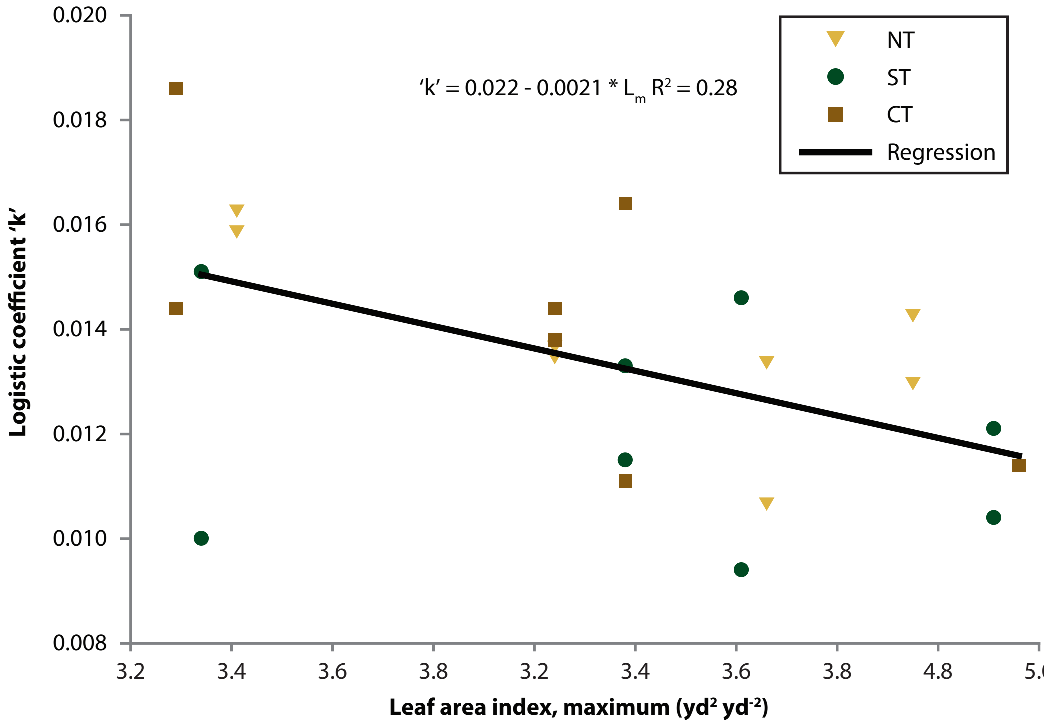


**Figure 3. A linear relationship between the linearized logistic coefficient ('k,' Equation 3) and maximum leaf area index is shown for corn canopies observed in 2004–2007 growing seasons.**

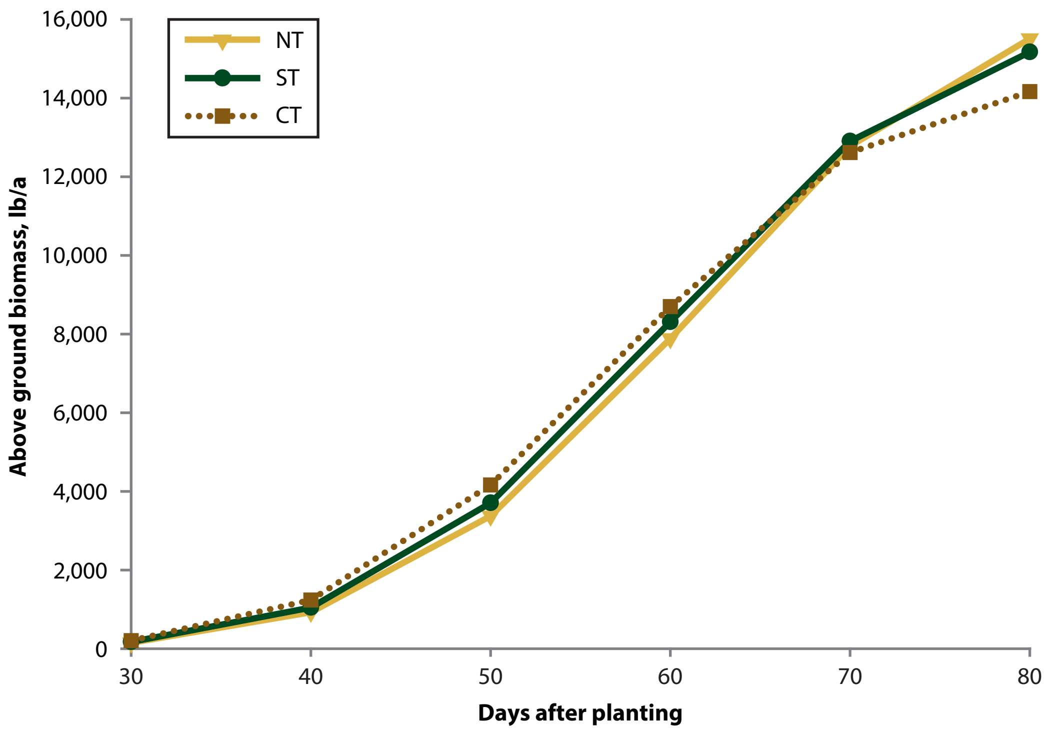


**Figure 4. Tillage effects on seasonal trends in apparent above-ground biomass of corn are shown in relation to cumulative growing degree days after planting for corn grown under no-tillage (NT), strip tillage (ST) or conventional tillage (CT) management, derived from the 2004–2007 growing seasons.**

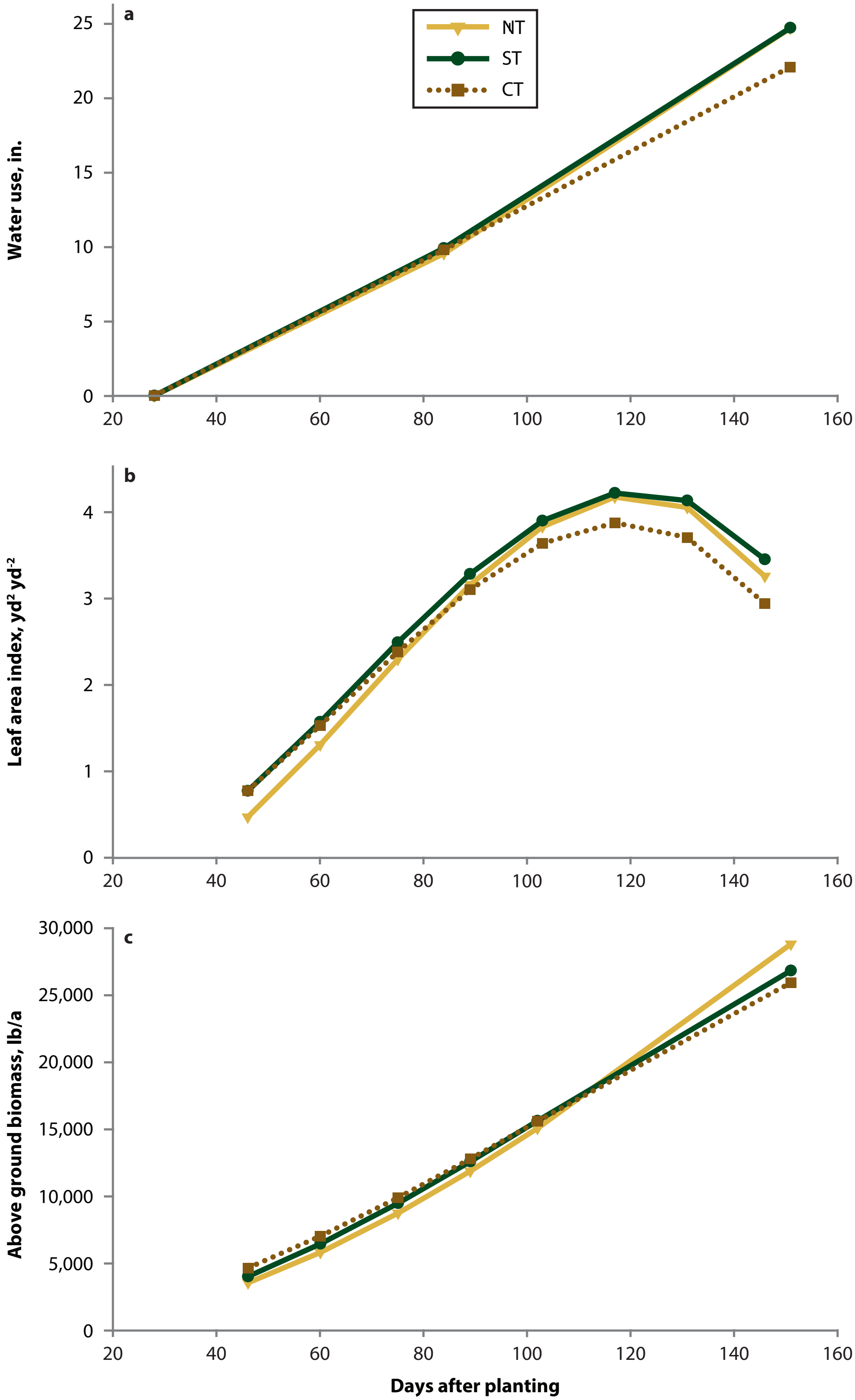


**Figure 5. Tillage effects on seasonal trends in crop water use (a), above-ground biomass accumulation (b), and canopy formation (c), are shown in relation to days after planting for corn grown under no-tillage (NT), strip tillage (ST), or conventional tillage (CT) management in the 2006 growing season; data are taken from the lowest irrigation capacity (1 in./8 d).**

# Cover Crop Effects on Soybean in a Soybean/Corn Rotation

*D.E. Shoup, I.A. Ciampitti, J. Kimball, and G.F. Sassenrath*

## Summary

A research study was established in 2011 in a soybean and corn rotation with cover crops planted soon after each crop harvest in the fall. A variety of complex cover crop mixtures were evaluated ranging from single specie to 7 specie mixtures. Cover crops were terminated in the spring soon after anthesis of the cool season cereal in the cover crop. Soybean yield responded differently among the four years of the study. In an extreme drought year of 2012, the unplanted check yielded 29.4 bu/a. Soybean yield was significantly reduced by 4.2 and 3.4 bu/a in treatments with wheat or turnip cover crop, respectively. In 2014, the unplanted check yielded 33.9 bu/a and cover crop treatments rye, rye + radish, and >6-species mix had significantly greater soybean yield at 3.7, 3.4, and 3.3 bu/a, respectively. In 2015, only the rye cover crop treatment significantly reduced soybean yield compared to the unplanted check at a 4.2 bu/a yield loss. No significant yield differences were observed in any cover crop treatment in 2016.

## Introduction

Cover crops are being used by more producers throughout Kansas. Reasons for the adoption of cover crops include reduced soil erosion, nutrient cycling, weed suppression, compaction alleviation, increased soil organic matter, and biological activity. Kansas State University has evaluated cover crops extensively for the last two decades in various crop rotations; however, few studies have evaluated the effect of cover crops in a soybean/corn rotation.

Kansas has a diverse geography, with many of the soybean/corn crop rotations occurring in the eastern third of the state. There can be quite a range in growing season from south to north, with an average of 25-days difference from the last freeze in the spring to the first frost in the fall. These 25 days can impact the amount of fall growth a cover crop can establish before winter sets in. While it is a challenge to establish cover crops after soybean harvest, it is more likely to be successful following corn harvest prior to soybean planting the following spring. Regardless of the planting challenges, soybean's response to cover crops established immediately after corn harvest in a soybean/corn rotation needs to be evaluated.

## Procedures

This trial was initiated in 2011 after corn harvest at the K-State East Central experiment field near Ottawa. Fall plantings were established on September 13, 2011; September 27, 2013; September 23, 2014; and September 11, 2015.

Five cover crop mixtures and one unplanted check were established, ranging in species complexity (Table 1). In the first year of the study, mostly single species were used, but in subsequent years, more complex mixtures replaced the original treatment structure.

In general, rye and/or radish were the base species for each treatment, but other species were interchanged depending on seed availability in that given year. Seeding rates of individual species were adjusted as the number of species in the mixture increased to avoid extremely high plant populations. Plots were 10-ft wide by 90-ft long and drilled on 7-inch spacings with a cone drill for uniform seed distribution throughout the plot.

Cover crops were terminated just after anthesis of the cool season cereal in late April with glyphosate plus additional soybean burndown herbicides. Soybean was no-tilled into the standing residue on May 29, 2012; May 22, 2014; June 10, 2015; and June 6, 2016.

Experiments were arranged in a randomized complete block design with 4 replications. Soybean plots were harvested, and plot weights, moisture, and test weights were determined. Bartlett's homogeneity of variance was tested and data were analyzed using analysis of variance (ANOVA). Means were separated by using a *P* value of 0.10.

## Results

### *2012 Yields*

During the first year of the study, soybean yields were below average due to extremely dry conditions in June, July, and August; only 1.78 inches of rain fell across those three months (Table 2). The unplanted check yielded the highest across all cover crop treatments, with an average of 29.4 bu/a (Table 3). The two cover crop treatments that had significantly lower yield than the check were the wheat and the turnip treatments, which reduced yield by 4.2 and 3.4 bu/a, respectively. Reduction in yield was likely due to the cover crop using soil moisture that could have maintained the soybean plant later in the growing season.

### *2014 Yields*

Opposite to the previous year, several cover crop treatments significantly increased yield when compared to the unplanted check. The highest soybean yields were observed after rye, rye + radish, and the >6-specie mix treatment, with 37.6, 37.3, and 37.2 bu/a, respectively (Table 3). Two treatments that yielded significantly lower than the top yielding cover crop treatments were the unplanted check and the radish, at 33.9 and 31.7 bu/a, respectively.

### *2015 Yields*

Excellent yields were observed in 2015, with 2.3 to 4.4 inches of precipitation falling each month from June to September (Table 2). Only one cover crop treatment significantly reduced yield, with the soybean planted after rye yielding 49.4 bu/a compared to the unplanted check at 53.6 bu/a (Table 3).

### *2016 Yields*

Record soybean yields were achieved in Kansas in 2016. The unplanted check yielded 60.2 bu/a (Table 3). No significant differences among all cover crop treatments were observed.

**Table 1. Cover crop treatments and seeding rate at the Kansas State University East Central experiment fields near Ottawa**

| Cover crop | Seeding rate (lb/a) |
|---|---|
| Unplanted check | --- |
| | |
| Wheat (2012) | 100 |
| Cereal rye (2014-2016) | 75 |
| | |
| Radish (2012, 2014-2016) | 6 |
| | |
| Turnip (2012) | 4 |
| Rye + radish (2014-2016) | 60 + 4 |
| | |
| Canola (2012) | 5 |
| Rye + radish + buckwheat (2014) | 50 + 3 + 3 |
| Rye + radish + alfalfa (2015) | 50 + 3 + 3 |
| Rye + radish + winter pea (2016) | 50 + 3 + 20 |
| | |
| Wheat + radish + winter pea (2012) | 20 + 1 + 20 |
| Rye + radish + turnip + buckwheat + rapeseed + sorghum (2014) | 50 + 3 + 3 + 1 + 1 + 1 |
| Rye + radish + turnip + alfalfa + rapeseed + wheat + sorghum (2015) | 50 + 3 + 1 + 3 + 1 + 20 + 1 |
| Rye + radish + turnip + winter pea + oat + crimson clover + sorghum (2016) | 50 + 3 + 1 + 20 + 20 + 3 + 1 |

**Table 2. Total monthly rainfall at the Kansas State University East Central experiment fields near Ottawa from 2012 and 2014-2016**

| Year | March | April | May | June | July | August | September |
|---|---|---|---|---|---|---|---|
| | precipitation (in.) | | | | | | |
| 30-year average | 2.67 | 3.84 | 5.41 | 5.63 | 4.09 | 4.04 | 4.12 |
| 2012 | 4.7 | 1.6 | 3.8 | 0.0 | 1.2 | 0.6 | 3.4 |
| 2014 | 0.6 | 3.5 | 1.2 | 7.1 | 0.9 | 2.9 | 3.4 |
| 2015 | 0.6 | 3.5 | 10.7 | 4.4 | 3.3 | 2.3 | 2.8 |
| 2016 | 2.0 | 3.9 | 6.1 | 1.9 | 5.6 | 6.5 | 5.8 |

**Table 3. Soybean yield as affected by cover crop treatment at the Kansas State University East Central experiment fields near Ottawa**

| | Soybean yield (bu/a) | | | |
|---|---|---|---|---|
| Cover crop | 2012* | 2014 | 2015 | 2016 |
| Check | 29.4 a | 33.9 b | 53.6 a | 60.2 a |
| Radish | --- --- | 31.7 b | 54.3 a | 59.4 a |
| Rye | 25.2 b | 37.6 a | 49.4 b | 60.3 a |
| Rye + radish | 26.0 b | 37.3 a | 52.3 a | 59.6 a |
| 3-specie mix | 27.6 ab | 35.7 ab | 51.8 ab | 59.3 a |
| >6-specie mix | 27.4 ab | 37.2 a | 51.6 ab | 59.0 a |

*Means followed by the same letter are not significantly different at $P = 0.10$.

# Cover Crop Effects on Corn in a Corn/Soybean Rotation

*D.E. Shoup, I.A. Ciampitti, J. Kimball, and G.F. Sassenrath*

## Summary
A research study was established in 2013 in a corn and soybean rotation with cover crops planted soon after each crop harvest. A variety of complex cover crop mixtures were evaluated ranging from single-specie to 7-specie mixtures. Cover crops were terminated in the spring prior to corn planting. Corn yield responded differently among the three years of the study. In general, 2014 and 2016 showed a similar trend of decreased corn yield as the complexity of cover crop specie mixtures increased. Significant corn yield losses ranged from 8.6 to 15.1 bu/a across all cover crop treatments in 2014. In 2016, corn yield loss was 8.1, 9.7, and 12.0 bu/a for the 3-specie mix, rye, and 7-specie mix, respectively. In 2015, however, an opposite trend was observed in the trial with increasing corn yield across all cover crop treatments. A dry fall following soybean harvest resulted in poor germination of all cover crops, so no biomass accumulated prior to corn planting. Corn yield increases ranged from 10.5 to 16.4 bu/a in 2015.

## Introduction
Cover crops are being utilized by more producers throughout Kansas. Reasons for the adoption of cover crops include reduced erosion, nutrient cycling, weed suppression, compaction alleviation, increased soil organic matter, and biological activity. Kansas State University has evaluated cover crops extensively for the last two decades in various crop rotations; however, few have evaluated the effect of cover crops in a corn/soybean rotation.

The challenge with establishing cover crops in a corn/soybean rotation is the shortened window of cover crop growing season following harvest. If cover crops are planted soon after corn harvest, there usually are one to two months of growing season in southern Kansas before the first killing freeze. However, the length of frost free days following soybean harvest is much shorter in Kansas, resulting in an even more suppressed cover crop growth. Regardless of the planting challenges, corn's response to cover crops established immediately after harvest in a corn/soybean rotation needs to be evaluated.

## Procedures
The trial was initiated in 2013 at the K-State East Central experiment fields near Ottawa. In the first year of the trial, cover crops were planted after corn, but a corn/soybean rotation was implemented for future rotation. Fall plantings were established on September 27, 2013; November 3, 2014; and October 30, 2015.

Five cover crop mixtures and one unplanted check were established, ranging in species complexity (Table 1). Base species included rye and radish, but other species were interchanged depending on seed availability in that given year. Seeding rates of individual species were adjusted as the number of species in the mixture increased to avoid extremely high plant populations. Plots were 10-ft wide by 90-ft long and drilled on 7-inch spacings with a cone drill for uniform seed distribution throughout the plot.

Cover crops were terminated in late March with glyphosate plus additional corn preemergence residual herbicides. Corn was no-tilled into the standing residue on April 9, 2014; April 2, 2015; and April 7, 2016. Liquid fertilizer at a rate of 120-40-13 nitrogen-phosphorus-potassium (N-P-K) were applied with the planter as a 2 × 2 application.

Experiments were arranged in a randomized complete block design with 4 replications. Corn plots were harvested, and plot weights, moisture, and test weights were determined. Bartlett's homogeneity of variance was tested and data were analyzed using ANOVA. Means were separated by using a *P* value of 0.10.

# Results

## *2014 Yields*

During the first year of the study, corn yields were relatively lower, likely due to corn being the previous crop and depressed yields from lack of crop rotation. In addition, a light freeze occurred on May 16, resulting in damaged corn leaves only in the cover crop treatments. Damage was likely due to cover crop residue preventing soil heat from buffering against the cold air temperature. Corn did recover; however, below-normal precipitation fell during the months of May and July, critical periods for corn yield determination (Table 2). All cover crop treatments significantly reduced corn yield when compared to the check (Table 3). Yield losses in 2014 ranged from 8.6 to 15.1 bu/a.

## *2015 Yields*

Cover crops were planted after the 2014 soybean harvest; however, an extremely cold and dry winter prevented any of the cover crop species from emerging. Consequently, corn was planted into bare soybean residue in 2015.

Opposite to the previous year, several cover crop treatments significantly increased yield when compared to the check. The highest yield was in the 3-specie cover crop at 136.1 bu/a, which yielded significantly greater than the rye, and check treatments at 130.1 and 119.7 bu/a, respectively (Table 3).

An extremely wet May resulted in significant denitrification as indicated by results in other nitrogen-application timing studies in southeast Kansas (Sweeney and Shoup, 2016) (Table 2). This may explain the cover crop effects in 2015 if additional organic matter from previous cover crops had mineralized later in the growing season, supplying additional nitrogen.

### *2016 Yields*

Although cover crops had limited growth prior to termination in the spring, biomass did accumulate approximately 6 inches of growth. Favorable moisture throughout the growing season resulted in greater than average yields exceeding 145 bu/a (Table 3). Corn yields responded to cover crops in a similar way as in 2014, with decreasing yields as the species complexity increased. The check and radish treatments yielded significantly greater than the rye, 3-specie mix, and 7-specie mix. Yield losses ranged from 8.1 to 12.0 bu/a.

**Table 1. Cover crop treatments and seeding rate at the Kansas State University East Central experiment fields near Ottawa, KS**

| Cover crop | Seeding rate (lb/a) |
|---|---|
| Unplanted check | |
| Cereal rye | 75 |
| Tillage radish | 6 |
| Rye + radish | 60 + 4 |
| Rye + radish + buckwheat (2014)<br>Rye + radish + alfalfa (2015)<br>Rye + radish + winter pea (2016) | 50 + 3 + 3<br>50 + 3 + 3<br>50 + 3 + 20 |
| Rye + radish + turnip + buckwheat + rapeseed + sorghum (2014)<br>Rye + radish + turnip + alfalfa + rapeseed + wheat + sorghum (2015)<br>Rye + radish + turnip + winter pea + oat + crimson clover + sorghum (2016) | 50 + 3 + 3 + 1 + 1 + 1<br>50 + 3 + 1 + 3 + 1 + 20 + 1<br>50 + 3 + 1 + 20 + 20 + 3 + 1 |

**Table 2. Total monthly rainfall at the Kansas State University East Central experiment fields near Ottawa, KS, from 2014-2016**

| Year | March | April | May | June | July | August | September |
|---|---|---|---|---|---|---|---|
| | ------------ | ------------ | ------------ | precipitation (in.) | ------------ | ------------ | ------------ |
| 30-yr average | 2.67 | 3.84 | 5.41 | 5.63 | 4.09 | 4.04 | 4.12 |
| 2014 | 0.57 | 3.49 | 1.18 | 7.1 | 0.85 | 2.88 | 3.39 |
| 2015 | 0.58 | 3.45 | 10.65 | 4.37 | 3.27 | 2.33 | 2.83 |
| 2016 | 1.96 | 3.91 | 6.06 | 1.87 | 5.64 | 6.53 | 5.81 |

**Table 3. Corn yield as affected by cover crop treatment at the Kansas State University East Central experiment fields near Ottawa, KS**

| | Corn yield (bu/a) | | |
|---|---|---|---|
| Cover crop | 2014* | 2015 | 2016 |
| Check | 108.2 a | 119.7 c | 157.3 a |
| Radish | 99.6 b | 131.1 ab | 158.3 a |
| Rye | 93.1 c | 130.1 b | 147.5 b |
| Rye + radish | 95.3 bc | 134.7 ab | 151.0 ab |
| 3-specie mix | 96.2 bc | 136.1 a | 149.1 b |
| >6-specie mix | 94.9 bc | 134.3 ab | 145.3 b |

*Means followed by the same letter are not significantly different at $P = 0.10$.

# Tillage Study for Corn and Soybean: Comparing Vertical, Deep, and No-Tillage

*E.A. Adee*

## Summary
A tillage study comparing no-tillage, shallow tillage, and deep tillage in alternate or every year for corn and soybeans in annual rotation was conducted at Kansas River Valley Experiment Field for five years. The influence of tillage system on corn yield appears to be increasing with time, soybean yields appear to perform equally well with any of the systems. As the study progresses, the corn yields were increased with deep tillage occurring sometime in the cropping rotation.

## Introduction
The need for tillage in corn and soybean production in the Kansas River Valley continues to be debated. The soils of the Kansas River Valley are highly variable, with much of the soil sandy to silty loam in texture. These soils tend to be relatively low in organic matter (< 2%) and susceptible to wind erosion. Although typically well drained, these soils can develop compaction layers under certain conditions. A tillage study was initiated in the fall of 2011 at the Kansas River Valley Experiment Field near Topeka to compare deep vs. shallow vs. no-tillage vs. deep tillage in alternate years. Corn and soybean crops will be rotated annually. This is intended to be a long-term study to determine if soil characteristics and yields change in response to a history of each tillage system.

## Procedures
A tillage study was laid out in the fall of 2011 in a field that had been planted with soybean. The tillage treatments were (1) no-tillage, (2) deep tillage in the fall and shallow tillage in the spring every year, (3) shallow tillage in the fall following both crops, and (4) deep tillage followed by a shallow tillage in the spring only after soybean, and shallow tillage in the fall after corn. The fall of 2010, prior to the soybean crop, the entire field was subsoiled with a John Deere V-ripper. After soybean harvest, 30 ft × 100 ft individual plots were tilled with a Great Plains TurboMax vertical tillage tool at 3 in. deep or a John Deere V-ripper at 14 in. deep. Spring tillage was done with a field cultivator. Starting in the fall of 2012, the treatments were tilled with the TurboMax vertical tillage tool or a Great Plains Sub-soiler Inline Ripper SS0300. Spring tillage in 2013-2015 was done with the TurboMax on the required treatments. Each tillage treatment had 4 replications.

Dry fertilizer (11-52-60 nitrogen (N), phosphorus (P), and potassium (K)) was applied to the entire field prior to fall tillage in 2012 and to the soybean stubble in 2013 and 2014. In fall of 2015 and 2016, 14-52-40-10 (N, P, K, and sulfur (S)) was applied to the soybean stubble prior to fall tillage. Nitrogen (150 lb in 2012 and 2013; and 185 lb in 2014, 2015, and 2016) was applied in March prior to corn planting. Corn hybrid Pioneer 1395 was planted at 30,600 seeds/a on April 12, 2012; P1498HR at 30,600 seeds/a on April 30, 2013; P1105 at 32,000 seeds/a on April 21, 2014, and April 14, 2015; and P1257 at 32,000 seeds/a on April 12, 2016. Soybean variety Pioneer 93Y92 was planted at 155,000 seeds/a on May 14, 2012; P94Y01 140,000 seeds/a on May 15, 2013; Asgrow 3833 at 140,000 seeds/a on May 21, 2014; Midland 3884NR2 with ILeVO seed treatment at 144,000 seeds/a on June 1, 2015; and Stine 42RE02 with ILeVO seed treatment at 140,000 seeds/a on May 31, 2016. Soybeans were planted after soybeans in the setup year.

Irrigation to meet evapotranspiration (ET) rates was started May 26 and concluded August 1 for corn, and started July 5 and concluded August 23 for soybean in 2012. Irrigation for corn started June 24, 2013, and concluded August 1. Irrigation for soybeans in 2013 started June 30 and concluded September 8. Irrigation in 2014 started July 1 and ended August 16 for corn, and started July 22 and ended August 22 for soybeans. In 2015, the first irrigation for both crops was June 23, and the last on August 24. The first irrigation on corn in 2016 was on June 20, and the last on August 4, while the only irrigation for soybean was on August 18. Two yields were taken from each plot from the middle 2 rows of planter passes. Corn was harvested on August 31, 2012; September 25, 2013; September 11, 2014; September 10, 2015; and September 16, 2016. Soybeans were harvested on October 5, 2012; October 10, 2013; October 9, 2014; October 3, 2015; and October 17, 2016.

A preliminary comparison of the different tillage systems across both crops of the rotation was made by calculating gross income per acre. The gross income per acre was calculated by multiplying the average yield for each crop by the closing market price on January 3, 2016, \$3.51 and \$9.11/bu for corn and soybean, respectively, then dividing by 2 to get the average gross income per acre. Differences between cost of tillage operations and herbicide weed control were not factored in this preliminary comparison.

## Results

Yields of corn or soybeans did not differ due to tillage in the setup year of the study (Table 1). The yields were respectable considering the extreme heat and drought experienced this growing season. The growing conditions were better in 2013, resulting in higher yields in both corn and soybeans, but no significant differences between tillage treatments (Tables 2 and 3). In 2014, the corn yields were very good, and Sudden Death Syndrome lowered soybean yields, but there were no differences between tillage treatments (Tables 2 and 3). The cool and rainy start to the season in 2015 slowed corn growth and lowered yields, while the soybeans had very good yields (Tables 2 and 3). In 2016, the deep tillage treatments yielded higher than the shallow tillage in the corn, but not in the soybeans. In the corn, there had been a trend with the yield data that was becoming closer to being significantly different as the years progressed, as indicated by the Pr>F value that was decreasing. Combining data from 2013 - 2016 for analysis showed corn yields are favored by deep tillage, but soybean yields are not affected by tillage system (Tables 2 and 3). Averages of stand counts taken at the V5 stage in the corn for 2014 -2016 did not show any differences (Table 2). We anticipate that it will take several years for any characteristics of a given tillage system to build up to the point of influencing yields.

Comparing the average gross income per acre across both crops showed that different systems had the higher income within a given year. This varying response is probably due to the environmental conditions experienced prior to or during each growing season. However, when averaged across the four years, there was up to $20/a advantage of the systems that included deep tillage vs. the no-tillage or shallow-tillage-only systems.

## Conclusions

While the influence of tillage system on corn yield appears to be increasing with time, soybean yields appear to perform equally well with any of the systems. Numerous other factors need to be considered when comparing tillage systems, such as soil erosion, water conservation, weed control options (becoming more challenging with herbicide-resistant weeds), labor, and equipment costs, and time available to conduct field work. Identifying the yield limiting conditions may vary between fields based on soil type and environmental conditions during a season and over the long term.

**Table 1. Effects of tillage treatments on corn and soybean yields in 2012 at Kansas River Valley experiment fields**

| Tillage treatment | Corn yield | Soybean yield |
|---|---|---|
| | bu/a | bu/a |
| No-tillage | 196 | 59.9 |
| Fall subsoil/spring field cultivate | 202 | 55.5 |
| Fall vertical tillage | 198 | 57.9 |
| Pr>F * | 0.64 | 0.14 |

*The lower the Pr>F value, the greater probability that there is a significant difference between yields.

**Table 2. Effects of tillage treatments on corn yields and plant stands in 2013-2016 at Kansas River Valley experiment fields**

| Tillage treatment | Corn yield | | | | | Average stand |
|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2015 | 2016 | Average corn yield | 2014 - 2016 |
| | bu/a | | | | | Plants/a |
| No-tillage | 221 | 243 | 205 | 183 b* | 213 | 33,000 |
| Fall subsoil/spring field cultivate | 217 | 259 | 213 | 202 a | 223 | 32,500 |
| Fall vertical tillage | 196 | 259 | 207 | 189 b | 213 | 32,479 |
| Fall subsoil after sb/vertical tillage after corn | 219 | 256 | 214 | 195 a | 221 | 32,125 |
| Pr>F# | 0.48 | 0.27 | 0.10 | 0.005 | 0.063 | 0.26 |

*Values followed by the same letter are not significantly different at Pr = 0.05.
#The lower the Pr>F value, the greater probability that there is a significant difference between yields.

**Table 3. Effects of tillage treatments on soybean yields in 2013-2016 at Kansas River Valley experiment fields**

| Tillage treatment | Soybean yield 2013 | 2014 | 2015 | 2016 | Average soybean yield |
|---|---|---|---|---|---|
| | ------------------- | ------------------- | bu/a | ------------------- | ------------------- |
| No-tillage | 62.4 | 52.8 | 69.7 | 80.2 | 66.3 |
| Fall subsoil/spring field cultivate | 64.3 | 54.6 | 73.1 | 76.1 | 67.0 |
| Fall vertical tillage | 64.4 | 55.5 | 72.8 | 78.6 | 67.8 |
| Fall subsoil after sb/vertical tillage after corn | 66.3 | 53.4 | 70.9 | 75.7 | 66.6 |
| Pr>F | 0.52 | 0.59 | 0.23 | 0.11 | 0.50 |

The lower the Pr>F value, the greater probability that there is a significant difference between yields.

**Table 4. Income return comparison of tillage systems for corn/soybean rotation at Kansas River Valley experiment fields**

| Tillage treatment | Average gross income from corn and soybean crops* 2013 | 2014 | 2015 | 2016 | Average gross income |
|---|---|---|---|---|---|
| | ------------------- | ------------------- | $/a | ------------------- | ------------------- |
| No-tillage | 672 | 667 | 677 | 686 | 676 |
| Fall subsoil/spring field cultivate | 674 | 703 | 707 | 701 | 697 |
| Fall vertical tillage | 637 | 709 | 695 | 690 | 686 |
| Fall subsoil after sb/vertical tillage after corn | 686 | 693 | 699 | 687 | 691 |

*Gross income = ((average corn yield × $.3.51 + average soybean yield × $9.11)/2) (Closing grain price January 3, 2016, Cargill, Topeka, KS).

# Cropping Sequence Influenced Crop Yield, Soil Water Content, Residue Return, and $CO_2$ Efflux in Wheat-Camelina Cropping System

*E. Obeng, A.K. Obour, N.O. Nelson, I.A. Ciampitti, D. Wang, and E.A. Santos*

## Summary
Camelina (*Camelina sativa* L. Crantz) is a short-seasoned oilseed crop with potential as a fallow replacement crop in dryland wheat *(Triticum aestivum)* - based cropping systems. Crop rotation management can affect the quality and quantity of crop residue return to the system. In addition, residue has the ability to sequester carbon and can affect plant available water. This study was conducted to investigate the effect of replacing fallow with camelina on crop yield, soil water at wheat planting, soil carbon dioxide ($CO_2$) efflux from treatments, and residue return. Treatments were four rotation schemes, and included wheat-fallow (W-F), wheat-sorghum-fallow (W-S-F), wheat-spring camelina (W-SC), and wheat-sorghum-spring camelina (W-S-SC). Our findings showed an increase in crop residue with increasing cropping intensity. Ground cover in W-S-SC, W-S-F, and W-SC were similar, but greater than that with W-F. Soil $CO_2$ efflux in W-SC was greatest among the crop rotations regardless of sampling time. Average $CO_2$ efflux in W-SC was 11.3, 26.5, and 7.6 pounds of $CO_2$ per acre per hour in the spring, summer, and fall, respectively. Soil water content at 0-24 in. was greater in W-S-F (7.2 in.) compared to W-SC (6.0 in.), and W-S-SC (6.0 in.). However, W-S-F and W-F (6.6 in.) were not different. Wheat and sorghum yields were not affected by crop rotation. However, camelina yields were greater in W-SC (754 lb/a) compared to W-S-SC (339 lb/a) rotation.

## Introduction
In decades past, wheat-fallow (W-F) was the predominant wheat production system in the Central Great Plains. The wheat-fallow system is characterized by wheat planting in September and wheat harvesting in June of the following year, followed by a 14-month fallow period. Studies have shown inefficiencies in moisture storage during the fallow period. For example, precipitation storage efficiency has been reported to be less than 30% of total precipitation received during the fallow phase of the rotation system. In addition to this, the use of conventional tillage operations for weed control leads to less residue return, soil organic matter depletion, soil erosion, and inefficiency in moisture storage. In recent years, there has been a shift from W-F to wheat-summer crop-fallow, due to the introduction and adoption of conservation tillage practices during the fallow period. Typical 3-yr rotations in the semi-arid Great Plains are wheat-corn-fallow and wheat-sorghum-fallow cropping systems. Cropping intensification can make use of the soil moisture that is lost during the fallow period, reduce soil erosion by providing ground cover, potentially improve soil quality through residue return and nutrient cycling, and increase farmer revenue. Under the 3-yr rotation systems, there is a

10- to 12-month fallow period, which makes the introduction of a third crop to replace portions of the fallow period a possibility.

Camelina *(Camelina sativa L.* Crantz*)* is an oilseed crop that has the potential to fit in the wheat-summer crop-fallow cropping system. Camelina is cold tolerant, and is well adapted to water-limited environments. In addition, it uses less resources like fertilizer and matures early, i.e., requires 85 to 90 days to mature. The short life cycle can allow enough time for soil moisture recharge for wheat planting in fall, since camelina is harvested in June. Some of the uses of camelina include biodiesel, adhesives, varnishes, animal feed, and an ingredient in food processing. The objective of this study was to investigate the impact of replacing fallow with camelina on crop yield, soil water content at wheat planting, soil carbon dioxide ($CO_2$) efflux, and residue return.

## Procedures

This study was established in the fall of 2013 at the Kansas State University Western Kansas Agriculture Research Center, near Hays, KS. The study comprised of four rotation schemes: wheat-fallow (W-F), wheat-sorghum-fallow (W-S-F), wheat-spring camelina (W-SC), and wheat-sorghum-spring camelina (W-S-SC). The treatments were arranged in a randomized complete block design with four replicates. All phases of the crop rotations were present in each block during each year of the study. Plot size was 35 × 20 ft. Winter wheat was planted in October of each year. Spring camelina was planted in mid-April and sorghum was planted in early June. Before initiating the study, 60 lb $P_2O_5$/a was applied to the entire study area. During each growing season, nitrogen (N) fertilizer in the form of urea was applied at 60 lb/a to winter wheat and sorghum, and 40 lb/a to camelina.

Yields were determined by harvesting 5 × 36 ft from the middle section of each plot using a plot combine. After harvesting camelina, oil and protein content were determined using the Antaris II FT-NIR Spectrophotometer Analyzer. Soil $CO_2$ efflux was measured at regular intervals using LI-8100 automated $CO_2$ efflux system (LI-COR Biosciences, Lincoln, NE, US). Around the same time, soil moisture at 0-10 in. was collected using a neutron moisture probe. Profile soil moisture at wheat planting was measured at 0-24 in. using a soil auger. During summer, i.e. at the end of camelina harvesting, two quadrats of crop residue were collected from each plot in the rotation scheme, and oven-dried at 149°F. In addition, three ground cover assessments were done on each plot using the stick method.

All data were analyzed using Proc GLM procedure in the SAS 9.3 software package (SAS Institute Inc., Cary, NC). Means were separated using least significant difference (LSD). Data from the two years were analyzed together, with rotation scheme as fixed effects in the model.

## Results

### *Crop Residue and Soil Moisture*

Increase in ground cover was documented with increasing cropping intensity (Table 1). The 3-yr rotations (W-S-F and W-S-SC) had more crop residue than the 2-yr rotations (W-F and W-SC) (Table 1). Soil moisture at wheat planting was greater in W-S-F relative to the W-SC and W-S-SC rotations. Soil moisture measurements taken in

November show that volumetric water content was greater in W-F than W-SC (Figure 2). Volumetric water content in W-S-F and W-F was similar and was not different from W-F and W-SC. In March, soil volumetric water content reduced with increasing cropping intensity, i.e., water content in W-F and W-S-F was greater than W-SC and W-S-SC (Figure 2).

### *Soil $CO_2$ Efflux*

During wheat harvest in July, more $CO_2$ efflux was recorded in W-SC than W-F, but $CO_2$ efflux in W-F was not different from W-S-F and W-S-SC (Figure 1). High $CO_2$ efflux recorded at this time of the year could be ascribed to high summer temperatures (Figure 3), which accelerates microbial activity. After wheat planting in November, very low $CO_2$ efflux was recorded across all rotation schemes. This could be as a result of low temperatures (Figure 3). Notwithstanding, more $CO_2$ efflux was recorded in W-SC compared to the other crop rotations (Figure 1). This could be due to greater decomposition of camelina residue compared to wheat and sorghum. Soil $CO_2$ efflux at camelina planting in March was greater in W-F compared to W-S-F and W-S-SC, but $CO_2$ efflux in W-F and W-SC were not different (Figure 1). Residue decomposition and $CO_2$ efflux may have accelerated in the 2-yr rotation systems due to the presence of moisture in W-F (Figure 2) and the quality of residue produced in W-SC rotation.

### *Camelina, Sorghum, and Wheat Yields*

Spring camelina grain yield was 754 lb/a when planted after wheat (W-SC), but camelina yield was reduced to 339 lb/a when it was planted after sorghum in a 3-yr rotation (W-S-SC) (Table 2). The yield decline could be attributed to more residue in W-S-SC rotation, and lack of moisture to support camelina establishment. Wheat yields reduced with increasing cropping intensity, but statistically there were no differences in yield among the rotation schemes. This could be attributed to less moisture availability for wheat growth. Average wheat yield across the rotation systems was 1884 lb/a (Table 2). Sorghum yields were unaffected by rotation scheme. Average sorghum yield was 3316 lb/a.

**Table 1. Effect of crop rotation on residue return and soil water content**

| Crop rotation | Residue biomass | Ground cover | Soil moisture at 0-24-in. depth at wheat planting |
|---|---|---|---|
| | lb/a | % | in. |
| Wheat fallow | 1342 c | 67.1 b | 6.6 ab |
| Wheat-sorghum-fallow | 3379 a | 82.5 ab | 7.2 a |
| Wheat-spring camelina | 1959 b | 82.5 ab | 6.0 b |
| Wheat-sorghum-spring camelina | 2961 a | 92.3 a | 6.0 b |
| LSD | 527.7 | 15.5 | 0.96 |

Means within column followed by same letter(s) are significantly different ($P < 0.05$).
Residue and ground cover data were collected after camelina harvest in July 2015.
LSD = least significant difference.

**Table 2. Camelina, winter wheat, and grain sorghum yields averaged across two growing seasons (2015 and 2016) at Hays, KS**

| Crop rotation | Winter wheat | Grain sorghum | Camelina yield | Camelina protein content | Camelina oil content |
|---|---|---|---|---|---|
| | ------------------ lb/a | ------------------ | | ------------ % | ------------ |
| Wheat-fallow | 2016 a | - | - | - | - |
| Wheat-sorghum-fallow | 2066 a | 3334 a | - | - | - |
| Wheat-spring camelina | 1744 a | - | 754 a | 29.6 a | 28.0 a |
| Wheat-sorghum-spring camelina | 1710 a | 3298 a | 339 b | 29.5 a | 28.3 a |
| Mean | 1884 | 3316 | 546 | 29.55 | 28.15 |
| LSD | 361 | 1630 | 201 | 1.5 | 1.3 |

Means within column followed by same letter(s) are significantly different ($P < 0.05$).
LSD = least significant difference.

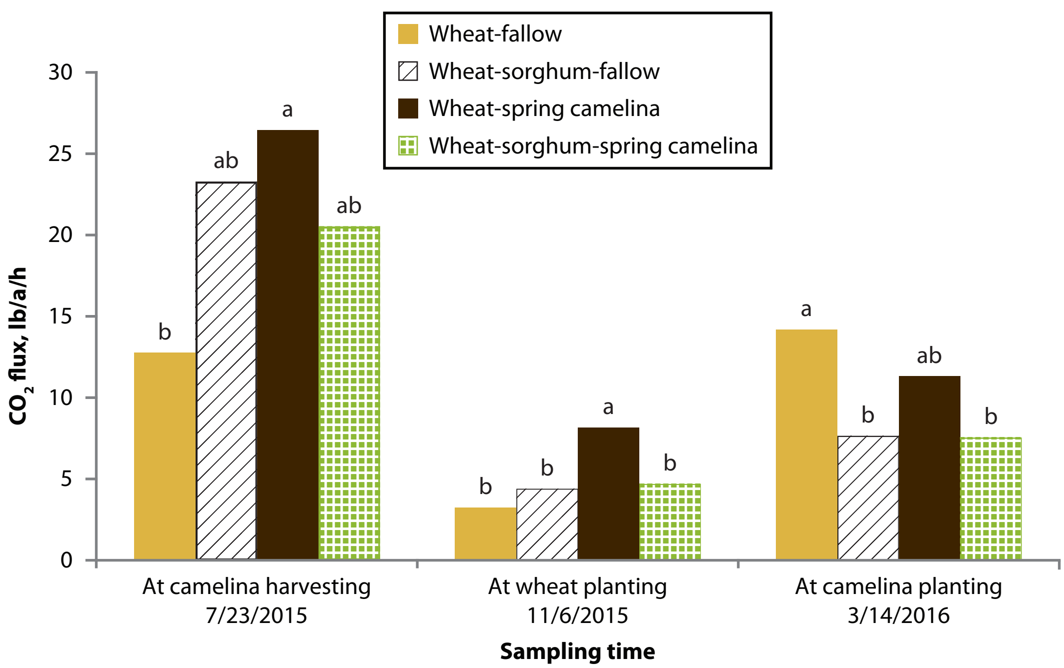


**Figure 1. Effect of crop rotation on soil $CO_2$ efflux from July 2015 to March 2016. (Means within sampling time followed by the same letter(s) are not significantly different at P > 0.05).**

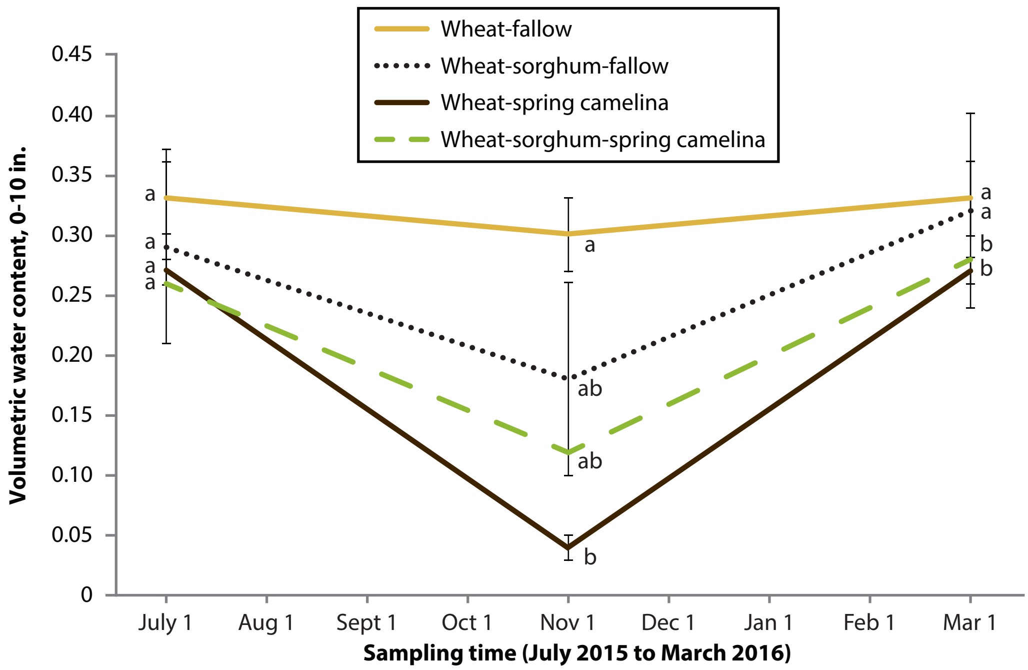


**Figure 2. Soil volumetric water content from July 2015 to March 2016. (Means within sampling time followed by the same letter(s) are not significantly different at P > 0.05).**

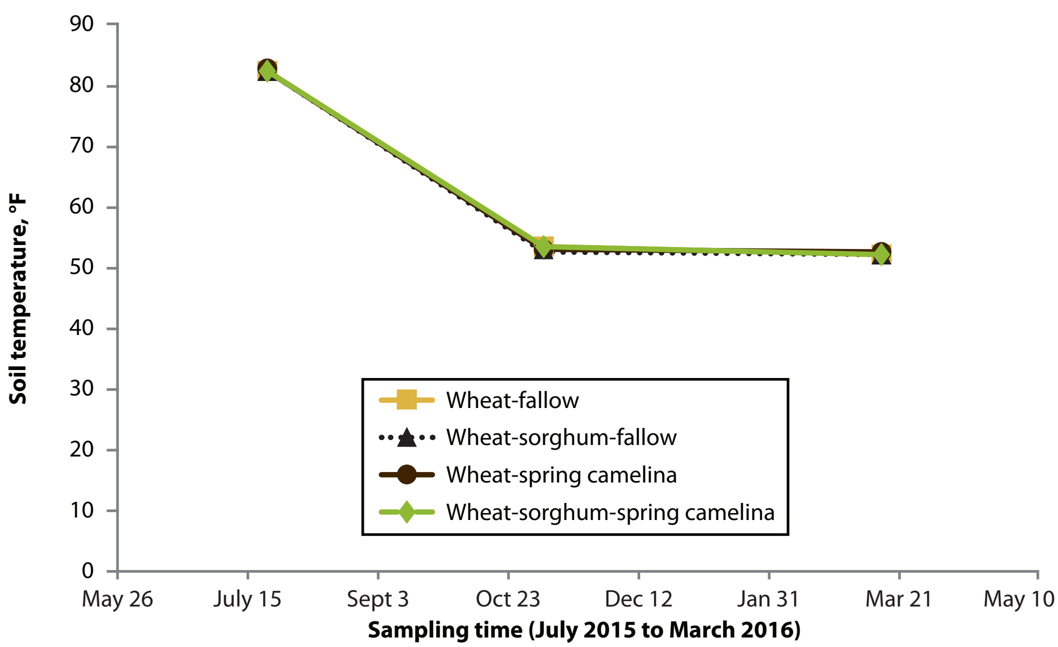


**Figure 3. Soil temperature from July 2015 to March 2016. There were no differences in soil temperature within sampling time.**

# Double Crop Soybean After Wheat

*D.S.S. Hansel, J. Kimball, D.E. Shoup, and I.A. Ciampitti*

## Summary
Two double crop (DC) soybean studies were conducted at Ottawa, KS, during the 2016 growing season. Soybean cultivar Asgrow 4232 (MG 4.2) was planted immediately after two different wheat harvest timings (Study 1: early-wheat harvest 18-20% seed moisture content, and Study 2: conventional-harvest, 13-14% seed moisture content). Seven treatments were evaluated in each of the soybean planting dates: 1) common practice, 2) no seed treatment (without seed fungicide + insecticide treatment), 3) non-stay green (without foliar fungicide + insecticide application), 4) high seeding rate (180,000 seeds per acre), 5) wide rows (30-inch row spacing), 6) nitrogen (N) fixation (without late fertilizer N application), and 7) kitchen sink (includes all management practices). Aboveground biomass, seed harvest index (HI) and yield were evaluated. For the early-planted study, a trade-off was documented between biomass and seed HI, presenting maximum yield also for values with lower HIs. Yield was greatest when planting in wide rows (64.5 bu/a) for the late-planted timing, and for the N-fixation treatment (64.0 bu/a) for the early-planted study. For the early-planted, yield gap (calculated as maximum minus minimum yield) was 6 bu/a, while for late-planted, yield gap was 7.5 bu/a. Best management practices for DC soybean can improve overall productivity via increasing yield with modifications in biomass and HI, and overall yield efficiency. Further testing on the effect of multiple management practices on DC soybean will be performed during the upcoming growing season.

## Introduction
Double crop (DC) soybean is cultivated in many regions of the United States. In most double crop systems, soybean is planted immediately after wheat harvest, which increases potential profit where there would otherwise be fallow or a non-cash cover crop. Also, soybean can be managed in no-tillage (NT) systems, reducing costs with less machinery expense after the wheat harvest. Furthermore, NT maintains wheat residue on soil surface, enhancing good soil properties. However, there are many challenges that discourage farmers from planting double crop soybean. The yield gap between full-season and double-crop soybeans is large, with the high risk of crop failure due to heat and drought during the late summer. To improve yields for DC soybean there are some management practices that may increase yield: 1) fertilizer application, promoting stronger plant growth and earlier canopy closure to overcome stresses due to a late planting season; 2) ideal row spacing and seeding rate, allowing more plants in the same unit area, potentially suppressing weed establishment and increasing yield; 3) integrated pest management (due to the late planting, the risk of late summer soil and foliar disease and insects could decrease yield); and 4) earlier planting time to lengthen growing season and allow more time for soybean plants to set pods and seed before the first killing frost.

The main objective of this study was to quantify the yield gap in double crop soybean after wheat harvest and identify the main yield-limiting factors affecting crop productivity from a perspective of environment and management practices.

# Procedures

### *Site Characteristics*

Soil type at the Ottawa location was a Woodson silt loam (Mollisols). Soil samples were taken before planting to a total depth of 6 and 12 inches. Soil chemical parameters analyzed were pH, Mehlich P, cation exchange capacity (CEC), organic matter (OM), calcium (Ca), magnesium (Mg), and potassium (K) availability (Table 1).

The studies were arranged in a randomized complete block design with 4 replications. Plot size was 10-ft wide by 60-ft long. The soybean variety used was Asgrow 4232, maturity group 4.2. Soybean was planted immediately after wheat harvest of the cultivar WB Cedar. Study 1 (early wheat harvest) was planted on June 10 and Study 2 (conventional wheat harvest), on June 23. Seven treatments were evaluated: 1) common practice - CP, 2) no seed treatment - NST, 3) non-stay green - NSG, 4) high population (180,000) - HP, 5) wide rows - WR, 6) N fixation - NF, and 7) kitchen sink - KS. The specific management practice included for each treatment is given in Table 2.

The seed treatment was Acceleron Standard® (Monsanto Company), which contains a fungicide + insecticide. For the foliar fungicide + insecticide application, the chemicals used were Aproach Prima + Prevathon (6 + 17 fl oz/a) and applied to soybean at the R3-R4 growth stage. Herbicides and hand weeding were used to maintain no weed interference for the entire season. Fertilizer application was performed on treatments 2 to 7 using the formulation 7-7-7-7S-7Cl. The application rate was 10.93 lb/a of N, phosphorus (P), K, sulfur (S), and chlorine (Cl). In treatments 2 to 6, late N was applied at a rate of 51 lb/a, in the formulation of 32-0-0 (N-P-K). Biomass was collected in a 12.5 $ft^2$ area, sampled outside the area collected for yield. Dates, degree-days and phenology at sampling were compiled in Table 3.

# Results

Despite DC soybean usually yielding significantly less than full-season soybean, the 2016 season was a very good year for summer crops, with weather conditions that created a high-yielding environment.

Precipitation was relatively high after emergence and during the entire growing season. The accumulated seasonal precipitation was 17.6 inches, which was 4 inches greater than the 2015 summer growing season, and was well distributed throughout the growing season (Figure 1).

### *Biomass, Harvest Index, and Grain Yield*

In studies 1 and 2, plant biomass was greater for the wide rows, while lower values were recorded for the non-stay green treatment. Conversely, seed harvest index was greatest for the kitchen sink treatment and least for the wide rows treatment (Figure 2). For seed yield, in Study 1, the N fixation treatment had the greatest yield at 64 bu/a, while the common practice had the lowest level at 58 bu/a (Figure 2). The yield gap between maximum and minimum yield values in this study was approximately 6 bu/a (Figure 2). In Study 2, the common practice yielded the least again, in addition to the no seed treatment, at 57 bu/a. The yield gap from maximum (wide rows treatment) and minimum yielding treatments was 7.5 bu/a (Figure 2).

### *Conclusions*

When planted earlier (Study 1), yield was higher when all inputs were utilized but without the extra late-season N. In the late-planted study (Study 2), yield was maximized also when all inputs were added but with the use of 30-in. rows instead of 15-in. rows.

Size of yield gap, measured in bu/a, was comparable for both planting times but larger for the late-planted situation (25% higher, 7.5 vs. 6.0 bu/a). Best management practices for DC soybean can improve overall productivity, increasing yield via modifications in biomass and HI. Further evaluation and testing should be performed to better understand and predict the effect of management practices on DC soybean systems.

**Table 1. Pre-plant soil characterization at 0- to 6-inch depth at Ottawa, KS, location**

| Soil parameters | Value |
|---|---|
| pH | 5.8 |
| Mehlich P (ppm) | 14.5 |
| Cation exchange capacity (meq/100 g) | 15.4 |
| Organic matter (%) | 2.8 |
| Potassium (ppm) | 79.3 |
| Calcium (ppm) | 2248.7 |
| Magnesium (ppm) | 303.5 |

**Table 2. Management practices for treatments imposed on double crop soybean planted after wheat for the early- and late-planting studies at Ottawa, KS, in 2016**

| Treatment | Description | Seed treatment | Foliar fung/ins | Fertility | Population | Rows, in. | Late N |
|---|---|---|---|---|---|---|---|
| 1 | Common practice (CP) | No | No | No | 140,000 | 30 | No |
| 2 | No seed TRT (NST) | No | Yes | Yes | 140,000 | 15 | Yes |
| 3 | Non-stay green (NSG) | Yes | No | Yes | 140,000 | 15 | Yes |
| 4 | High population (180,000) (HP) | Yes | Yes | Yes | 180,000 | 15 | Yes |
| 5 | Wide rows (WR) | Yes | Yes | Yes | 140,000 | 30 | Yes |
| 6 | N fixation (NF) | Yes | Yes | Yes | 140,000 | 15 | No |
| 7 | Kitchen sink (KS) | Yes | Yes | Yes | 140,000 | 15 | Yes |

Fung = Fungicide.
Ins = insecticide.
N = nitrogen.
TRT = treatment.

**Table 3. Date, degree-days, and phenology at planting date, biomass samplings and harvest for both studies at Ottawa, KS, 2016**

| | Study 1 (early-planted) | | | Study 2 (late-planted) | | |
|---|---|---|---|---|---|---|
| | Date | Degree days (°F) | Phenology | Date | Degree days (°F) | Phenology |
| Planting | June 16 | 35 | | June 23 | 33 | |
| Biomass 1 | July 27 | 1,369 | R2 | August 8 | 1,442 | R2 |
| Biomass 2 | August 23 | 2,179 | R3 | September 13 | 2,455 | R3 |
| Biomass 3 | October 18 | 3,383 | R7 | October 18 | 3,080 | R7 |
| Harvest | November 3 | 3,623 | R8 | November 3 | 3,321 | R8 |

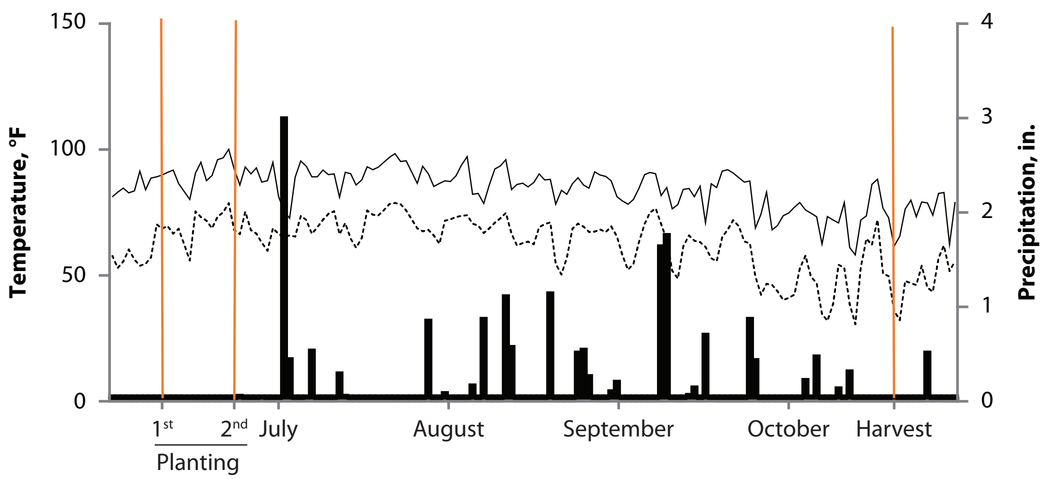


**Figure 1. Precipitation and temperature during the growing season at Ottawa, KS, in 2016. Columns correspond to precipitation; continuous horizontal line corresponds to maximum temperature; dash horizontal line corresponds to minimum temperature; and vertical lines represent planting and harvest dates.**

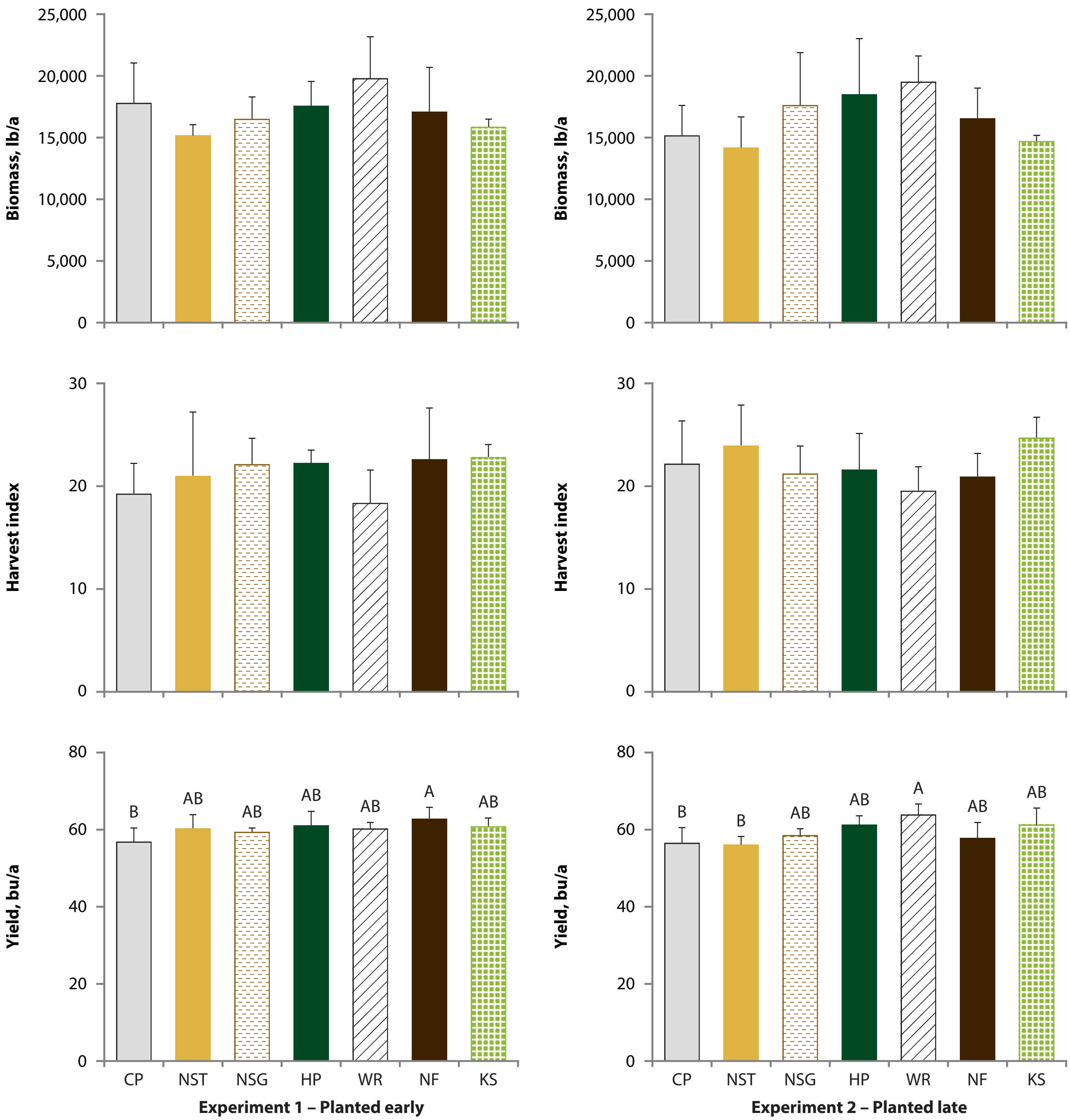


**Figure 2. Biomass, harvest index, and yield in experiments 1 and 2. Common practice, CP; no seed treatment, NST; non-stay green, NSG; high population, HP; wide rows, WR; nitrogen fixation, NF; kitchen sink, KS (Table 2), Ottawa, KS, 2016.**

# Soybean Sudden Death Syndrome Influenced by Macronutrient Fertility on Irrigated Soybeans in a Corn/Soybean Rotation

*E.A. Adee, D. Ruiz Diaz, and C.R. Little*

## Summary
The effects of nitrogen (N), phosphorus (P), and potassium (K) fertilization on a corn/soybean cropping sequence were evaluated from 1983 to 2016, with corn planted in odd years. There was a negative relationship between the P rate applied during the corn years and the severity of sudden death syndrome (SDS) in 2014 and 2016 soybean.

## Introduction
Sudden death syndrome (SDS) of soybean [*Glycine max* (L.) Merr], caused by *Fusarium virguliforme*, can cause significant yield loss in soybean, and has been associated with wet soils. Management practices to reduce yield losses have been to select tolerant varieties that are resistant to soybean cyst nematode (SCN), alleviate soil compaction, and delay planting to avoid wet soils. While these practices can reduce yield loss to SDS, significant losses can still occur.

A study was initiated in 1972 at the Topeka unit of the Kansas River Valley experiment field to evaluate the effects of N, P, and K on furrow-irrigated soybean. In 1983, the study was changed to a corn/soybean rotation with corn planted and fertilizer treatments applied in odd years. Study objectives were to evaluate the effects of N, P, and K applications on a corn crop on grain yield of corn, yield of the following soybean crop, and soil test values.

## Procedures
The initial soil test in March 1972 on the silt loam soil was 47 lb/a available P and 312 lb/a exchangeable K in the top 6 in. of the soil profile. Rates of P were 50 and 100 lb/a $P_2O_5$ (1972–1975), and 30 and 60 lb/a $P_2O_5$ (1976–2011); except in 1997 and 1998, when a starter of 120 lb/a of 10-34-0 (12 lb/a N + 41 lb/a $P_2O_5$) was applied to all plots of corn and soybean. Rates of K were 100 lb/a $K_2O$ (1972–1975), 60 lb/a $K_2O$ (1976–1995), and 150 lb/a $K_2O$ (1997–2011). Nitrogen rates included a factorial arrangement of 0, 40, and 160 lb/a of preplant N (with single treatments of 80 and 240 lb/a N). The 40 lb/a N rate was changed to 120 lb/a N in 1997. Treatments of N, P, and K were applied every year to continuous soybean (1972–1982) and every other year (odd years) to corn (1983–1995, 1999–2013). Soil cores were pulled from each plot in the spring of 2014, prior to planting. Analyses for macronutrients were performed from soil for each one-foot increment to a depth of four feet.

Soybean varieties planted in even years were: Douglas (1984); Sherman (1986, 1988, 1990, 1992, 1996, 1998); Edison (1994); IA 3010 (2000); Garst 399RR (2002); Stine 3982-4 (2004); Stine 4302-4 (2006); Midland 9A385 (2008); Asgrow 4005 (2010); Asgrow 3832 (2012); Asgrow 3833 (2014); and Asgrow 3731 (2016). Soybean was planted in early to mid-May. Herbicides were applied preplant each year, and postemergent herbicides were applied as needed. Plots were cultivated, furrowed, and furrow-irrigated through 2001 and sprinkler-irrigated with a linear move irrigation system from 2002 to 2016. In 2014, soil cores were collected from each plot at the 0-12-in. sampling depth prior to planting. The cores were then analyzed for soil test P, and the uppermost trifoliate leaflets were collected at R6 and analyzed for total P. Population densities (CFUs) of *F. virguliforme* were measured from post-harvest soil samples in 2014. The deep soil samples and trifoliate samples were only collected in 2014, while the disease ratings, normalized difference vegetation index (NDVI) , and yields were measured both years. In both years, percentage of leaf area infested by SDS was rated visually, and NDVI ratings were measured with a GreenSeeker meter (Trimble Navigation, Ag Division, Westminster, CO) at growth stage R6. Height to the top node with pods was measured at maturity (R8). A plot combine was used to harvest grain.

## Results

The severity of foliar SDS symptoms in soybean was related to the rate of P applied to the corn in the corn/soybean rotation during previous years (Tables 1 and 2). The SDS was more severe, and the NDVI (measure of greenness), heights, and yields decreased as the rate of P decreased. The level of P in the soil was different at the different rates in a soil sample taken in the spring of 2014 (Table 3). The largest difference between P rates was in samples collected from the top foot of soil. There was no effect of N, K, nor any interactions of the three macronutrients with these four measurements (data not shown) in 2014. The level of P in leaf tissue decreased as the rate of P applied decreased. In 2016, the higher rates of N had less SDS and higher NDVI, but no difference in height or yield (data not shown). The average yield for the study in 2016 was greater than in 2014, 43.9 vs. 58.7 bu/a, respectively for 2014 and 2016.

Sudden death syndrome had not been observed to this degree in these plots in previous years. In addition, the effect of P on yield has not been this high. From 1984 to 2012, the average yield response from the check to the 60-lb rate was less than 6 bu/a. For 2014 and 2016, the average yield response to the 60-lb rate was 29 bu/a. Population densities (CFUs) of *F. virguliforme* were not significantly different between P levels, but tended to be greater with the decreasing levels of P (Table 1). The development of SDS in 2014 was probably related to the above-average rainfall in June of 8.26 in., which is 3.62 in. more than the 30-year average. The severity of SDS in 2016 was not as great as in 2014, with the average severity of 15% leaf area for 2016 compared 41% in 2014. The reduced severity of SDS may be related to the rainfall for June 2016, 2.73 inches, more than one inch below normal.

There was a very strong negative correlation between the foliar symptoms of SDS and NDVI for both years of the study (-0.79, <0.0001; Figure 1). The NDVI measurements are an objective measurement based on near-infrared light reflectance off the crop canopy, which can be affected by the greenness of leaves and density of the canopy, both of which can be influenced by multiple factors. Height of plants, development of branches, number and size of leaves, and amount of chlorophyll in leaves are some of the factors that can affect NDVI readings. The visual ratings of foliar symptoms tend to be more subjective but can focus on a single aspect of the crop health, in this case foliar symptoms of SDS. The strength of this correlation indicates that SDS was a primary factor affecting the health of this crop, even though height differences were related to P rates.

Yield of soybean correlated well with both the visual rating for SDS (-0.70, <0.0001) and NDVI (0.83, <0.0001) (Figures 2 and 3). This result suggests that SDS was a major factor affecting yield of soybean in this study. Combined with the strong relationship between the rate of P applied during the corn year of the rotation with yield and NDVI, the negative relationship with foliar symptoms of SDS indicates that P had a significant role in the severity of SDS and subsequent yield loss. To our knowledge, this relationship between P applied as a fertilizer and SDS has not been previously reported.

The consistency of the results from these two years further confirms the role P is having on the severity of SDS in this long-term fertility study. Even though the environments of both years were different, as well as the severity of disease and levels of yield, the relationships between P, SDS, and soybean productivity were very strong. These results enforce the importance of monitoring soil P levels in fields and increasing the soil P levels in fields with a history of SDS.

**Table 1. Effects of phosphorus (P) applied to corn on sudden death syndrome (SDS) and yield of soybean, Kansas River Valley experiment fields, 2014**

| P rate on corn | *F. virguliforme* | Leaf phosphorus | SDS severity | NDVI[1] | Height | Yield |
|---|---|---|---|---|---|---|
| lb/a | CFU $g^{-1}$ soil | parts per million | % foliage affected | | in. | bu/a |
| 0 | 70.8 | 0.15 | 58 | 0.758 | 29.8 | 34.0 |
| 30 | 62.5 | 0.18 | 43 | 0.777 | 36.0 | 44.8 |
| 60 | 41.7 | 0.26 | 23 | 0.799 | 37.0 | 52.9 |
| LSD (0.05) | NS | 0.01 | 16 | 0.018 | 2.2 | 4.3 |

[1]Normalized difference vegetation index.
LSD = least significant difference.
NS = not significant.

**Table 2. Effects of phosphorus (P) applied to corn on sudden death syndrome (SDS) and yield of soybean, Kansas River Valley experiment fields, 2016**

| P rate on corn | SDS severity | NDVI[1] | Height | Yield |
|---|---|---|---|---|
| lb/a | % Foliage affected | | in. | bu/a |
| 0 | 20 | 0.796 | 34.6 | 46.4 |
| 30 | 17 | 0.803 | 39.5 | 60.1 |
| 60 | 8 | 0.810 | 41.6 | 69.5 |
| LSD (0.05) | 9 | 0.011 | 2.0 | 4.5 |

[1]Normalized difference vegetation index.
LSD = least significant difference.
NS = not significant.

**Table 3. Soil test values for phosphorus (P) in macro-fertility study at Kansas River Valley experiment fields, 2014**

| P rate | 1st Foot | 2nd Foot | 3rd Foot | 4th Foot |
|---|---|---|---|---|
| | | lb/a | | |
| 0 | 13 | 15 | 22 | 16.6 |
| 30 | 30 | 17.4 | 24.2 | 17.2 |
| 60 | 92 | 27.2 | 30.6 | 18.4 |
| LSD (0.05) | 8.8 | 1.9 | 2.7 | NS |

LSD = least significant difference.
NS = not significant.

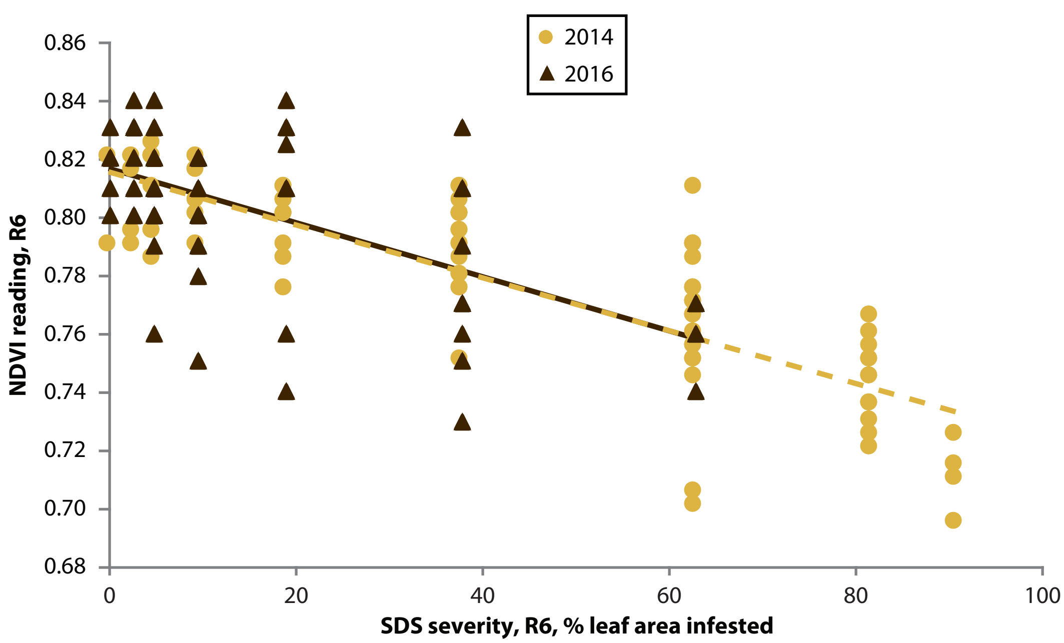


**Figure 1. Relationship between visual ratings for severity of foliar symptoms of sudden death syndrome (SDS) and normalized difference vegetation index (NDVI) measurements with a GreenSeeker meter in a long-term macronutrient fertility study at the Kansas River Valley experiment fields, 2014 and 2016.**

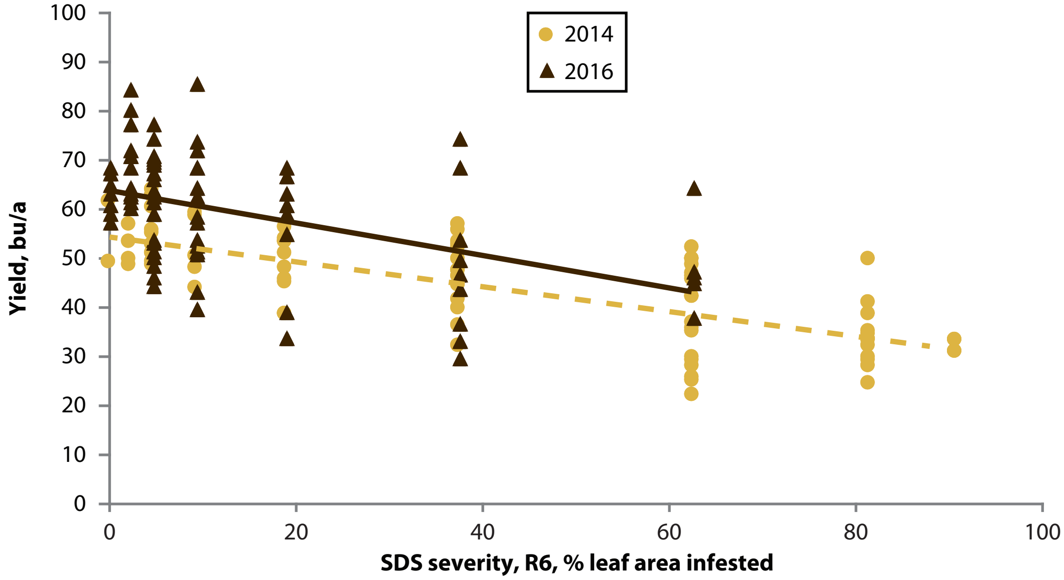


**Figure 2. Relationship between foliar symptoms of sudden death syndrome (SDS) and yield of soybean at the Kansas River Valley experiment fields, 2014 and 2016.**

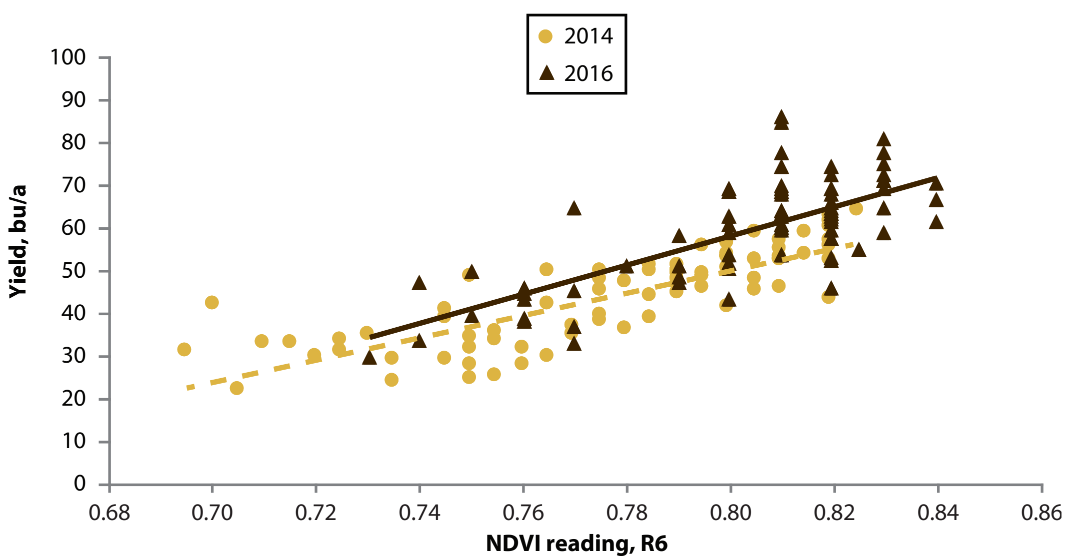


**Figure 3. Relationship between normalized difference vegetation index (NDVI) and yield of soybean at the Kansas River Valley experiment fields, 2014 and 2016.**

# Sudden Death Syndrome and Soybean Planting Date

*E.A. Adee, C.R. Little, and I.A. Ciampitti*

## Summary
The effect of planting date on severity of sudden death syndrome (SDS) and yield was evaluated for the second year in two studies at the Kansas River Valley experiment fields in 2016. One study was established to promote SDS and the other to minimize SDS. In both studies the severity of SDS was greatest with the earlier planting dates. The yield was greatest with the earlier planting date, except for the most susceptible variety. The severity of SDS was not as great as had been observed in previous years. There is a very positive benefit to planting in early May when measures are taken to reduce the severity of SDS, such as variety selection.

## Introduction
Soybean planting dates have been moving increasingly earlier in much of the soybean growing region, including Kansas. Yield increases due to earlier planting dates of soybeans have been shown in many soybean growing regions. However, in the Kansas River Valley, many of the soybeans have been planted after mid-May because of the perennial problem with SDS on soybeans. Later planting has been prescribed to help avoid the cooler/wetter soils that can favor infection by the fungus *Fusarium virguliforme*, the causal agent of SDS. Two soybean planting date studies were conducted at the Kansas River Valley experiment fields at Topeka in 2016. One was specifically looking at SDS infection, and the other was targeting best management practices for soybean production. Both had foliar symptoms of SDS develop during the growing season.

## Procedures
### *Sudden Death Syndrome Planting Date Study*
Management practices to promote SDS, such as early and greater volume of irrigation, were used in this study. Soybean were planted on four different dates into a field with a history of SDS at Rossville and Topeka units of the Kansas River Valley experiment fields in 2015 and 2016, respectively. Two soybean varieties, SDS-susceptible KS 3406 RR and SDS-tolerant Pioneer P35T58 were planted on average planting dates of May 3 and 18, June 9 and 22 at 140,000 seeds/a into 10- by 30-ft plots, with four replications in a randomized complete block design. The soil was Eudora silt loam, and the previous crop was corn. Irrigation with a linear-move sprinkler irrigation system was started on June 24, 2015, and June 25, 2016. Total irrigation was 2.8 in. during 2015 and 5.5 in. for 2016. There were 33.9 and 35.3 in. of rain received during the 2015 and 2016 growing seasons, respectively. Preemergent herbicide applied at planting was Authority Maxx (FMC Corporation Agricultural Products Group, Philadelphia, PA) (5 oz), Dual II Mag (Syngenta Crop Protection, LLC, Greensboro, NC) (1.5 pt) and Liberty (Bayer CropScience, Research Park Triangle, NC) (32 oz). Postemergent herbicides were Roundup PowerMax (Monsanto Company, St. Louis, MO) (32 oz) and Outlook (BASF, Research Park Triangle, NC) (12 oz) (2015), or Zidua (BASF) (2 oz) (2016).

Foliar symptoms of SDS were rated weekly starting July 29, 2015 at R3 (beginning pods) and August 8, 2016, when the soybean were at the R4 (full length pods) until R6 (full seed) for all planting dates. Ratings were based on incidence and severity of the symptoms resulting in percent defoliation. An area under the disease progress curve (AUDPC), a unitless number describing the development of defoliation effects over time, was derived by plotting periodic measurements of disease over time and integrating the area under the disease curve. The harvest of the two middle rows of all planting dates was completed by October 12, 2015 and October 13, 2016.

### *Best Management Practice Study*

Management practices to reduce or avoid SDS were implemented in this study. These include treating the seed with ILeVO (Bayer) (35 ml/unit of seed) to protect against SDS, and withholding irrigation until the crop was getting close to moisture stress (September 1, 2015 and August 10, 2016). Three soybean varieties of differing maturities were planted on three different dates. The varieties were Asgrow (Monsanto) AG 3034 (MG 3.0) (2015 and 2016), AG 4534 (2015), AG 4531 (MG 4.5) (2016), and Pioneer 39T67R (MG 3.9) (2016). The average planting dates for both years were May 3 and 18, and June 8 at 140,000 seeds/a into 10- by 30-ft plots, with four replications in a randomized complete block design. Soil type, rainfall and herbicide programs were the same as with the SDS Planting Date Study mentioned previously. SDS ratings began on July 29, 2015 (beginning pods) and August 19, 2016 (R5, beginning seed fill). Harvest completed on October 12, 2015 and October 17, 2016.

## Results

The severity of SDS was greatest with the early planting dates in both studies (Figures 1 and 3), decreasing to very little SDS with the June planting dates with the varieties having average or below average tolerance to SDS. Overall, SDS foliar symptoms developed later in 2016 than in 2015, resulting in a lower severity of SDS. However, the effect of planting date on SDS was consistent with all studies, confirming that earlier planting dates can result in more severe symptoms of SDS.

Compared to research conducted in previous years, the SDS was not as severe for both 2015 and 2016. For example, the P35T58 averaged less than 5% and 12% of the leaf area with symptoms on August 27 and 30 (R6) for 2015 and 2016, respectively; while in 2014 at a similar planting date averaged nearly 60% on August 25. Similarly, the very susceptible variety, KS 3406, averaged under 75% and 56%, for 2015 and 2016, respectively, compared to greater than 90% in 2014. It is not clear why the SDS was not as severe as in previous years, though the June rainfall was almost double the 30-year average in 2014, while 2015 was 50% above average and 2016 was 30% below the 30-year average.

The yields were also the greatest with the earlier planting dates in both studies (Figures 2 and 4) except for the earliest maturing variety (Figure 4). Generally, there is a negative relationship between SDS and yield at each planting date (i.e. the greater the SDS the lower the yield). However, in these experiments, the increased yield potential with the earlier planting dates may have helped counteract some of the yield loss due to SDS, especially when the SDS severity was reduced.

The greatest benefit to early planting was with the SDS-tolerant MG 3.5 variety in the SDS Planting Date Study, showing a 0.48 bu/day yield increase for planting dates before late June. The SDS susceptible variety of similar maturity responded with 0.30 bu/day yield increase over the late June planting date. The greater severity of SDS at the earlier planting dates probably contributed to some of the difference between the varieties.

Based on two years' data from two experiments, it appears that SDS and yield are favored by earlier planting. It will be interesting to see in a year when the SDS is more severe whether the yield potential for early planting date is greatly reduced or if a yield benefit is still realized. It could be that with more severe SDS the yield response to earlier planting date may look more like that of the very susceptible variety in Figure 2: fairly flat until the planting date is very late.

These studies show that when choosing the more SDS-tolerant varieties and taking measures to reduce SDS, there is a very positive benefit for earlier planting dates of soybeans in the Kansas River Valley.

This research was funded in part by the Kansas Soybean Commission.

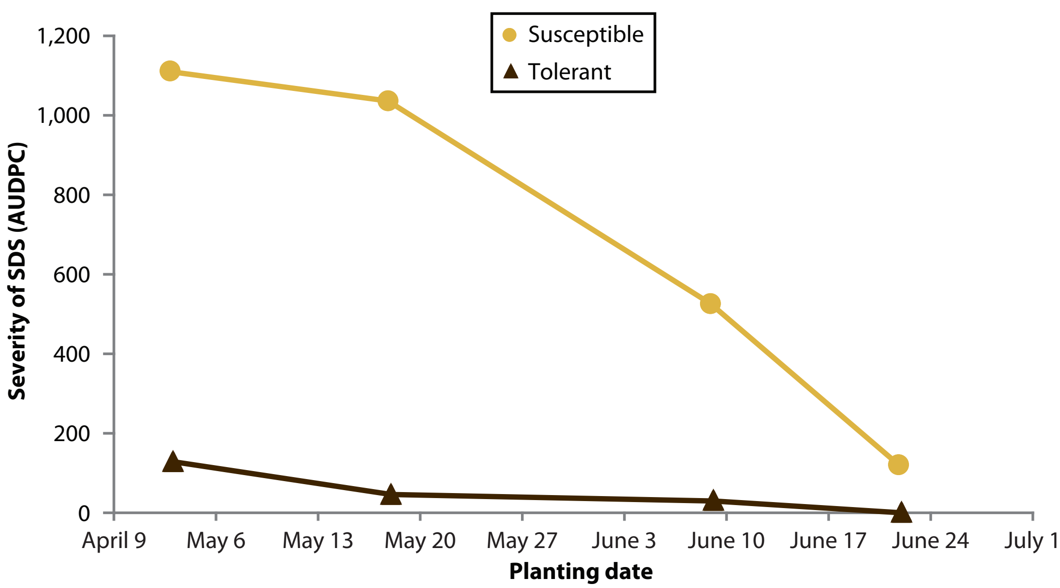


**Figure 1. Effect of planting date for two soybean varieties on severity of sudden death syndrome (SDS) measured as area under disease progress curve (AUDPC), Kansas River Valley experiment fields, 2015 and 2016 averages.**

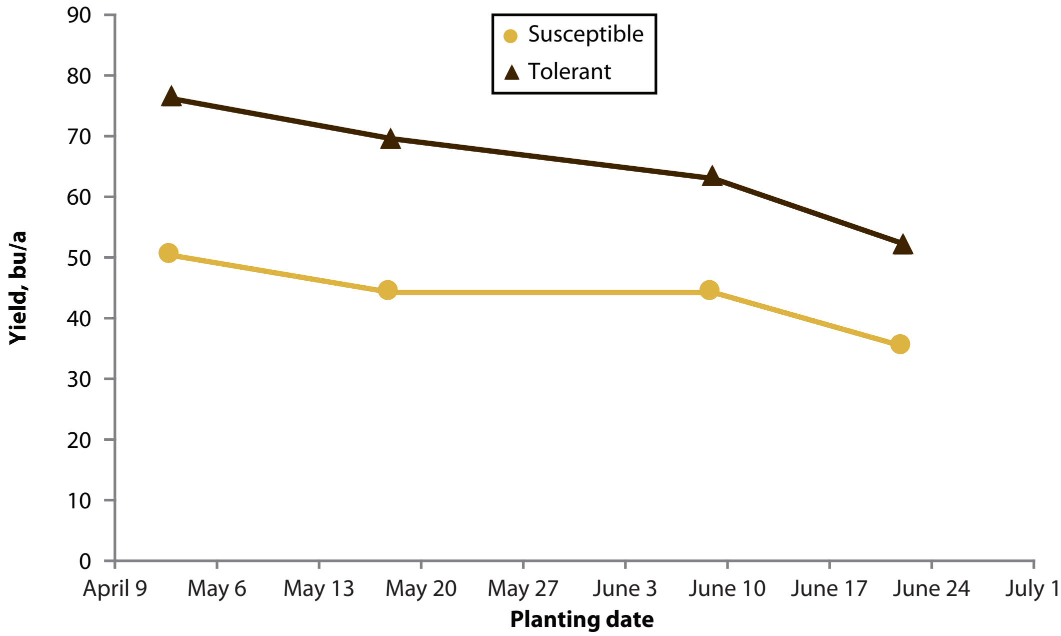


**Figure 2. Effect of planting date on yield for two soybean varieties with different levels of susceptibility to sudden death syndrome (SDS), Kansas River Valley experiment fields, 2015 and 2016 averages.**

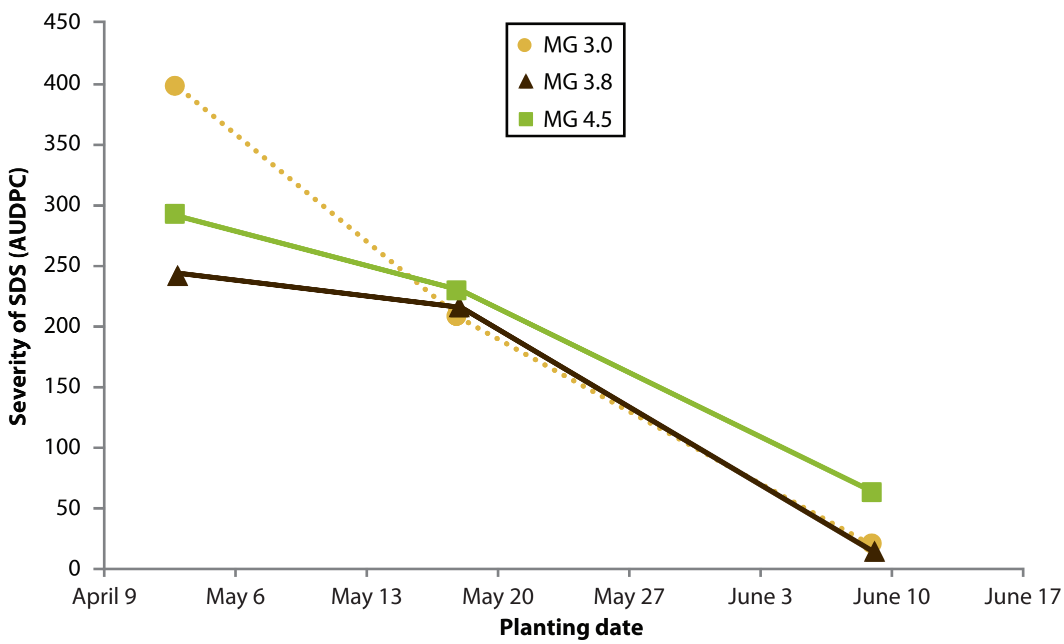


**Figure 3. Effect of planting date on severity of sudden death syndrome (SDS) measured as area under disease progress curve (AUDPC) in soybean varieties of different maturity groups (MG) treated with ILeVO, Kansas River Valley experiment fields, 2015 and 2016 averages.**

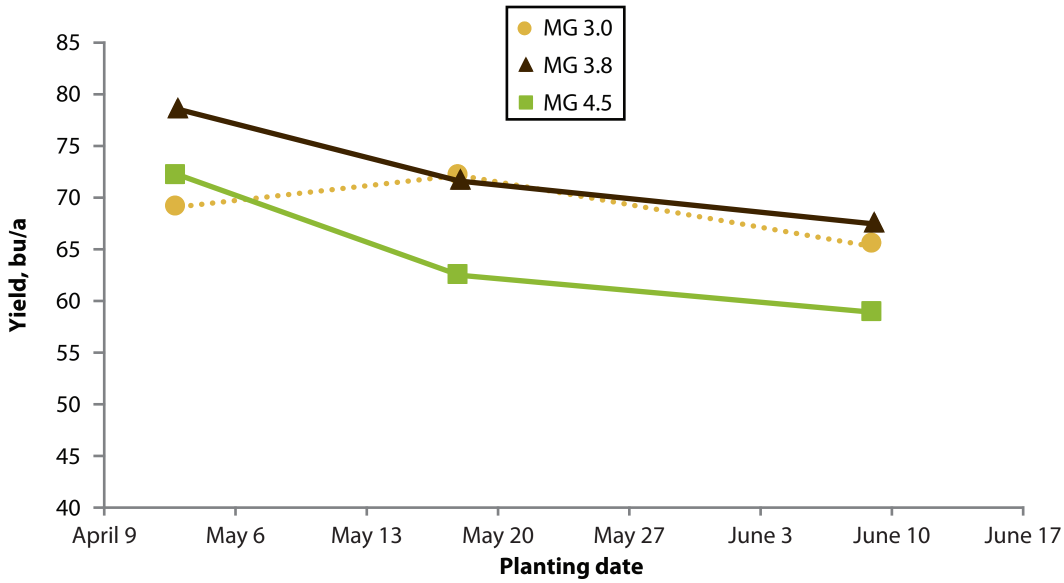


**Figure 4. Effect of planting date on yield of soybean varieties of different maturity groups (MG), Kansas River Valley experiment fields, 2015 and 2016 averages.**

# Closing Soybean Yield Gaps via Improved Management: A Systems Approach

*G.R. Balboa and I.A. Ciampitti*


## Summary

Three soybean research trials were conducted during the 2016 growing season. Two studies were conducted at Scandia, KS, (dryland and irrigated) and one at Topeka, KS (dryland). The objective of this study was to investigate the contribution of different farming systems for closing soybean yield gaps. Each experiment consisted of five treatments: common practices (CP), comprehensive fertilization (CF), production intensity (PI), ecological intensification (CF + PI), and advanced plus (AD). The EI and AD treatments presented the maximum yields at both locations. Under irrigation conditions, yield gap was larger at Scandia relative to Topeka site. Across all three soybean experiments, CP presented the lowest yield. EI yielded 79 bu/a at Topeka, and 83 and 86 bu/a at Scandia dryland and irrigated scenarios, respectively.


## Introduction

Crop management practices (such as row spacing, planting date, and nutrient application) and their interactions with the environment (soil + weather) have a direct impact in closing yield gaps. By choosing different combinations of practices, farmers can modify the growing conditions. Thus, after considering the contribution from the genetics and the environment, on-farm yield is primarily influenced by farmers' decisions, the main components of which are agronomic practices. Crop management practices are often specific to the environment, hybrid/variety, and/or yield level. Each farmer needs to find the appropriate management practices that can help them to increase yields and profits. Increasing seeding rates and narrowing rows are two common intensification practices in high-yielding soybean systems.

## Procedures

Three soybean research trials were conducted during the 2016 growing season. Two studies were located at the North Central Kansas (NCK) experiment fields (Scandia, KS), and one at the Kansas River Valley (KRV) experimental fields (Topeka, KS). At Scandia, one experiment was conducted under dryland and one under irrigated conditions. Soybean from maturity group 4 (MG 4) was planted on May 6 at Scandia and June 1 at Topeka. Each experiment consisted of 5 treatments with five replications in a completely randomized block design: 1) common practices (CP), (110,000 seeds/a + no-inoculation + no-nutrient application + 30-in. row spacing); 2) comprehensive fertilization (CF), (110,000 seeds/a + inoculation + nutrient application + 30-in. row spacing); 3) production intensity (PI), increasing productivity via narrowing rows and increasing seeding rate (174,000 seeds/a + inoculation + no-nutrient application + 15-in. row spacing); 4) ecological intensification (CF + PI; 174,000 seeds/a + inoculation + nutrient application + 15-in. row spacing + micronutrients + fungicides); and 5) advanced plus (AD), or increasing input applications (174,000 seeds/a + inoculation + nutrient application + 15-in. row spacing + double application of micronutrients and fungicides). Mes SZ and Aspire (Mosaic company) product rates for an irrigated environment were 108 and 300 lb/a, with 77 and 215 lb/a for dryland scenario, respectively. The rates per nutrients in lb/a (N-$P_2O_5$-$K_2O$-S-Zn-B) were 13-43-180-11-1Zn-1.5B and 9-31-129-8-0.75Zn-1B for irrigated and dryland.

# Results

## *Weather Conditions*

Weather conditions for the growing season and historical information are shown in Figure 1 for NCK Scandia site and Figure 2 for KRV Topeka location (Mesonet, Kansas State University). The total amount of precipitation received during the growing season was 23 inches for the Scandia site and 24 inches for Topeka.

The total amount of water provided to the irrigated condition at NCK Scandia was 6.3 inches (6/23, 7/15, 7/21, 7/29, and 8/10). Temperatures ranged in normal values except for a few days that could present some heat stress for the soybeans.

## *Soil Test and Phenological Information*

Soil samples were collected before planting to characterize each experimental site. Soil test results are shown in Table 1. The previous crop was corn at all locations. The soybean variety planted (MG 4), the date for phenological stages, and the harvest date are shown in Table 2.

## *North Central Kansas, Scandia Yields*

At the NCK Scandia fields, average yield for the dryland condition was 75 bu/a, ranging from 63 to 85 bu/a (Figure 3). The irrigated condition yielded on average 73 bu/a. The total in-season precipitation can largely explain the lack of yield differential between dryland and irrigated conditions. Under dryland and irrigated conditions differences in yield were statistically significant ($P < 0.05$). For the dryland environment, the CF treatment yielded 7 bu/a more than the CP, but yields did not statistically differ. A balanced nutrition program and intensifying production (EI) in dryland allowed increasing yield 28% over the CP treatment (Figure 3). Treatments EI and AD showed the highest yields under both water environments. Maximum yield was recorded for the AD treatment under irrigation, averaging 90 bu/a. Yield gaps were 34 bu/a under irrigation and 22 bu/a under dryland (calculated as AD minus CP) (Figure 3). The PI treatment presented comparable soybean yields relative to the CF combination.

## *Kansas River Valley, Topeka Yields*

At KRV Topeka site, average yield was 74 bu/a (Figure 4). Common practices (CP) and intensifying production without a balanced nutrition (PI) presented the lowest yield, averaging 72 bu/a. Soybean yields for CF, EI, and AD did not statistically differ, presenting an average of 76 bu/a. The yield gap in this environment was only 9 bu/a (calculated as the difference between EI—79 bu/a—minus PI—70 bu/a—maximum and minimum soybean yields for this site, respectively).

## Acknowledgments

Thanks to the Kansas State University Crops Production Team for the valuable help in collecting and processing all the field data during 2016 growing season. This study was supported by the International Plant Nutrition Institute (IPNI, Project GBL 62), K-State Research and Extension and the Fulbright Program (partially covering G.R. Balboa's stipend).

**Table 1. Soil characterization before planting time**

| Soybean studies | Organic matter | pH | Phosphorus |
|---|---|---|---|
| | % | | ppm |
| NCK Scandia irrigated | 2.2 | 6.2 | 11 |
| NCK Scandia dryland | 2.3 | 5.4 | 7.4 |
| KRV Topeka dryland | 2.3 | 5.8 | 11.3 |

NCK = North Central Kansas.
KRV = Kansas River Valley.

**Table 2. Phenological data for the 2016 growing season for soybean**

| Phenological data | North Central Kansas, Scandia | Kansas River Valley, Topeka |
|---|---|---|
| Soybean variety | P39T67R (MG 4.0) | P39T67R (MG 4.0) |
| Planting date | 05/06/2016 | 06/01/2016 |
| Emergence date (VE) | 05/12/2016 | 06/07/2016 |
| Flowering (R1) | 07/12/2016 | 07/20/2016 |
| Maturity | 09/26/2016 | 10/3/2016 |
| Harvest date | 10/18/2016 | 10/18/2016 |

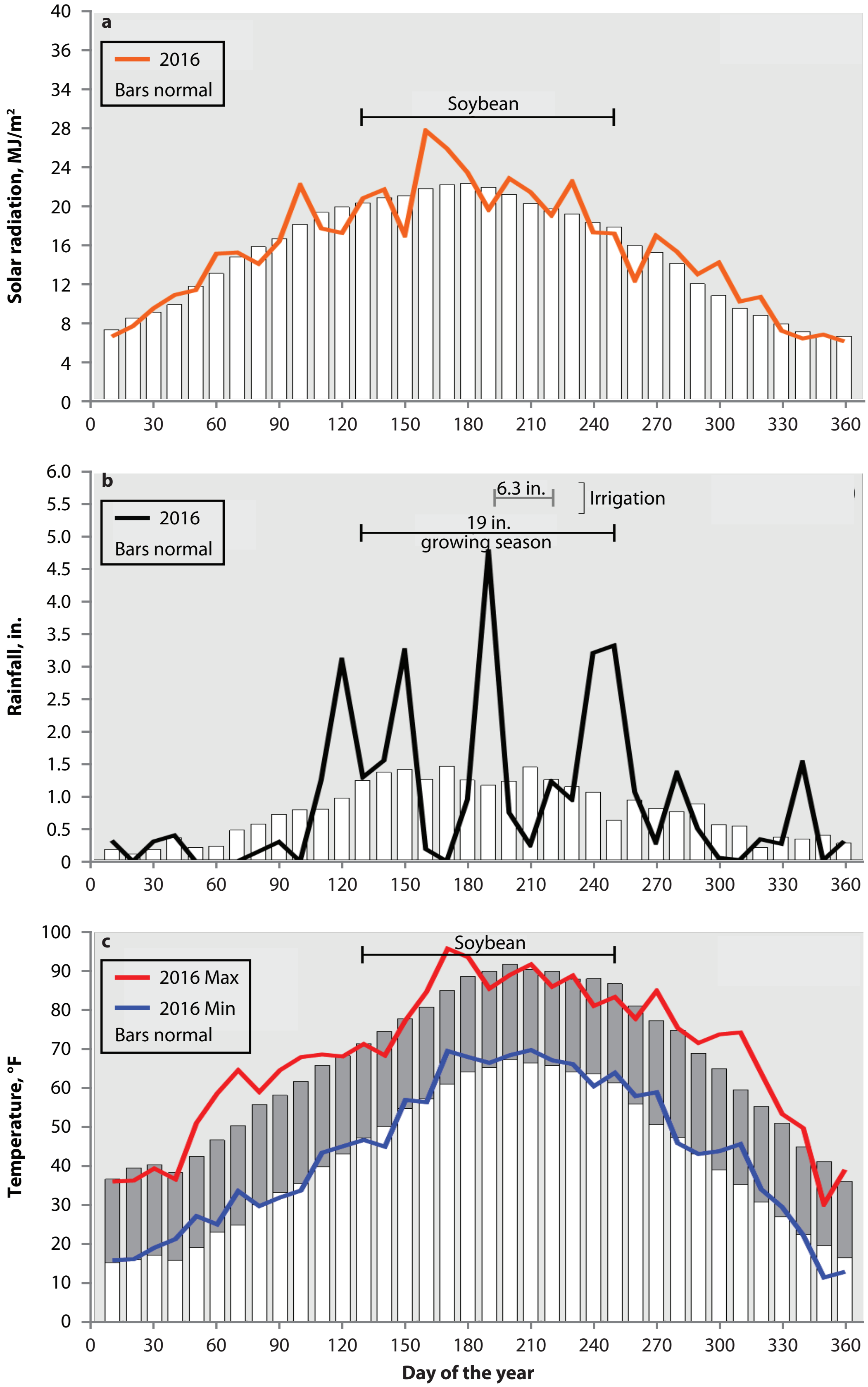


**Figure 1. a) Daily solar radiation; b) Daily precipitation; and c) Daily maximum and minimum temperatures all for 2016 season and historical; North Central Kansas, Scandia.**

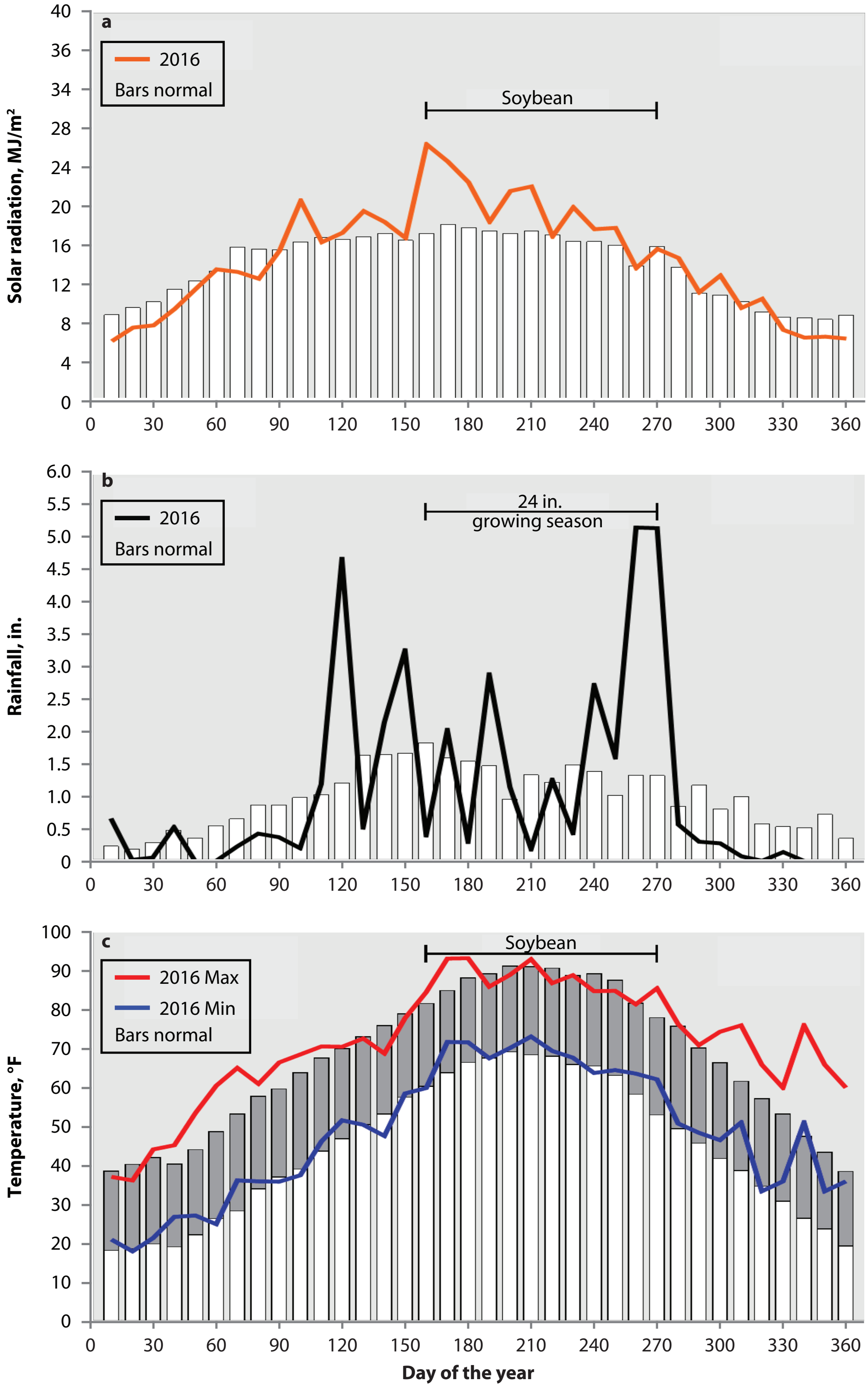


**Figure 2. a) Daily solar radiation; b) Daily precipitation; and c) Daily maximum and minimum temperatures all for 2016 season and historical; Kansas River Valley, Topeka.**

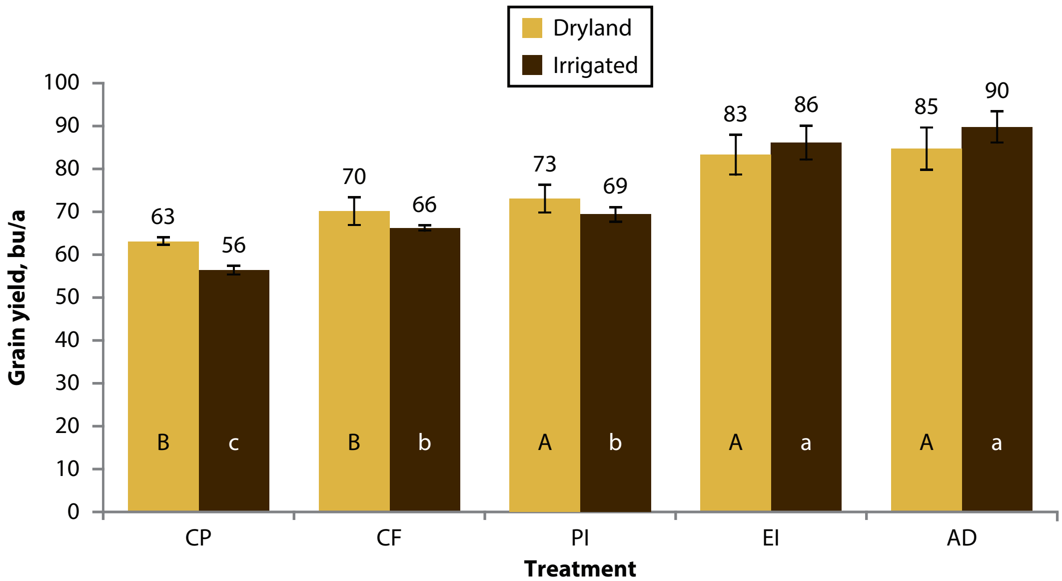


**Figure 3. Soybean yield by treatment for dryland and irrigated conditions during the 2016 growing season, North Central Kansas, Scandia. Different letter shows statistical differences ($P < 0.05$). CP = Common practices, CF = comprehensive fertilization, PI = production intensification, EI = ecological intensification (CF+PI), AD = advanced plus. Lines in bars indicate standard deviation.**

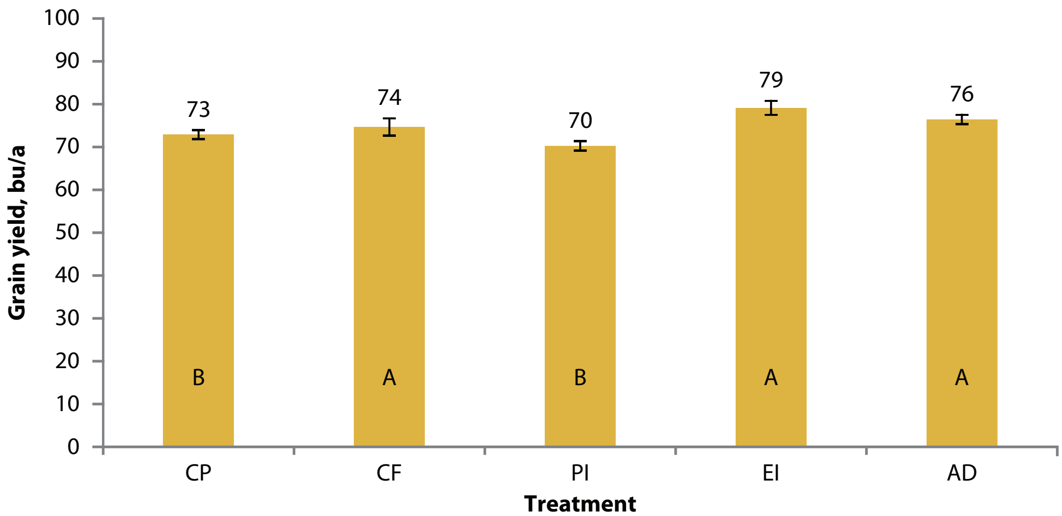


**Figure 4. Soybean yield by treatment during the 2016 growing season, Kansas River Valley, Topeka. Different letter shows statistical differences ($P < 0.05$). CP = Common practices, CF = comprehensive fertilization, PI = production intensification, EI = ecological intensification (CF+PI), AD = advanced plus. Lines in bars indicate standard deviation.**

# Planting Date by Maturity Group in Kansas: 2016 Season and Three-Year Summary

*I.A. Ciampitti, O.A. Ortez, D.E. Shoup, E.A. Adee, J. Kimball, G.F. Sassenrath, and G.L. Cramer*

## Summary
Optimal planting should be timed to capture a favorable environment (e.g., fall rains and cooler temperatures during grain filling). Five field studies were conducted during the 2014 growing season (Manhattan, Topeka, Ottawa, Parsons, and Hutchinson); five in 2015 (Manhattan, Rossville, Ottawa, Parsons, and Hutchinson); and three in 2016 (Manhattan, Topeka, and Ottawa). This study explores the impact of planting date (early-, mid-, and late-planted) on yield for soybean cultivars from a range of maturity groups (early, medium, and late groups). For 2016, the overall main factor impacting yield across sites was planting date, which increased yields with early-planted soybeans. Based on all 13 sites (2014, 2015, and 2016), maximum soybean yield potential decreased by 0.5 bushels per day of delay on planting date when soybean is planted after April 15. Comparable yield penalties have been documented for other main production regions. In summary, weather patterns dictate soybean yields, especially under dryland conditions. There is no guarantee that any certain planting date will always work out the best when it comes to soybean yields in Kansas.

## Introduction
Planting date is a valuable management practice for achieving maximum yield potential in a specific environment. For the last 30 years, at the state level, planting date has been earlier at a rate of half of one day per year. While early planting dates help maximize soybean growth in a season and potentially increase yield, early plantings may also shift reproductive stages in a hotter and drier environment, negatively impacting yields in some years in Kansas. Correct selection of both planting date and maturity group (MG) are critical for maximizing yield potential. Following this rationale, the main objective of this study was to quantify the effect from a range of planting dates and MGs on the final soybean yields at different sites in Kansas.

## Procedures
A total of thirteen field studies were conducted in Kansas during the 2014, 2015, and 2016 growing seasons. Sites evaluated in 2014 were: Manhattan, Topeka, Ottawa, Parsons, and Hutchinson; in 2015: Manhattan, Rossville, Ottawa, Parsons, and Hutchinson; and in 2016: Manhattan, Topeka, and Ottawa. All sites evaluated were under dryland conditions with the exception of Topeka (2014 and 2016) and Rossville (2015) that were irrigated. At all sites, the experimental layout was a split-split plot design with planting date as main plot and MG as a sub-plot factor. Three planting dates and three MGs were planted for a total of nine combinations per site. In 2016, early-, medium-, and late-planting dates were implemented, and varied from April 14 (earliest) to July 15 (latest) across all sites (Table 1). For the MG selection, an optimal MG was considered to be the medium MG for a particular location (environment), and shorter and longer varieties were used to characterize MGs with differential duration of

the growth cycle for soybean. For the irrigated Topeka site, total irrigation during the crop season was 1.8 inches (started from August 10). At all sites, soybean was planted at 30-inch row spacing. Final yield was obtained by harvesting the center two rows in each plot. For the purpose of uniform reporting, all yields were adjusted to 13.5% moisture content. Weather information was downloaded from the Kansas Mesonet website (http://mesonet.k-state.edu/weather/historical/).

## Results

### *Weather: 2016*

Cumulative precipitation at the Manhattan site favored early season growth for the early-planted time with small differences for the medium- and late-planted scenarios (Figure 1). At the Topeka and Ottawa sites, cumulative precipitation was similar across all planting dates, with a larger separation between medium- and late-planted time for Topeka in comparison to the Ottawa site (Figure 1).

### *Yields: 2016*

Planting date significantly influenced yields at the Manhattan and Ottawa sites. For the Manhattan site, early planting time (April 14) showed a yield advantage when compared with the late planting (June 2) scenario, with the latter resulting in a 12 bu/a reduction (Figure 2). At the Ottawa site, yield trends from high to low were: early- (63 bu/a) > medium- (57 bu/a) > late-planted (45 bu/a) (Figure 2). For Manhattan and Ottawa sites, MG factor did not present a significant influence in yields, meaning that regardless of the MG selected yields did not differ. For the Topeka site (irrigated), planting date significantly influenced yields, with comparable yields for the early- and medium-planted treatments, averaging 67 bu/a (Figure 2). The late-planted time resulted in a 6 bu/a reduction (average 61 bu/a) as compared with both early- and medium-planted scenarios. In the same location the MG factor significantly affected yields, with early and medium MGs (63 bu/a) outyielding the late variety (54 bu/a).

In summary for 2016, the main factor influencing yield for Manhattan and Ottawa was planting date; increasing yields with earlier planting dates. Later planting time reduced the overall length of the season, which diminished maximum yield potential in addition to other factors that could have limited yields (i.e. insects, disease, etc.). The MG factor reduced yields when the longest MG was used in the irrigated site, with a 15% yield reduction (across all planting times).

### *Previous Growing Seasons: Yields for 2014 and 2015*

For a complete analysis on each individual year, please visit the following resource: https://webapp.agron.ksu.edu/agr_social/eu_article.throck?article_id=900

From our planting date × maturity group study in 2014 and 2015, late planting did not clearly result in a yield reduction at the dryland sites, and caused only a minimal yield reduction at the irrigated site. Medium maturity groups (ranging from 3.8 to 4.8) yielded better, depending on the site and growing season evaluated (Figures 3 and 5).

### *Frontier Analysis: All Sites*

Based on 13 sites (2014, 2015, and 2016), maximum soybean yield potential decreased by 0.5 bushels per day of delay on planting date when soybean is planted after April 15

(Figure 7). Comparable yield penalties for soybean have been documented for other regions across the primary corn and soybean production areas. Thus, "theoretically," when soybean is planted 10 days earlier this could provide a benefit on yield potential close to 5 bushels per acre.

In summary, ultimately, weather patterns dictate soybean yields, especially under dryland conditions. There is no guarantee that any certain planting date will always work out the best when it comes to soybean yields in Kansas. In fact, the distribution and amount of rainfall and the day/night temperature variations around flowering and during the grain-filling periods have large impacts in defining soybean yield potential. Thus, when the risk of drought/heat stresses during the growing season is high, diversifying planting dates may be a good approach to consider.

## Acknowledgments
Thanks to the Kansas State University Crop Production Team (KSUCROPS) for preparing and synthesizing the database analyzed in this report, and to all K-State Research Experimental Stations that contributed with the conduction of this research.

**Table 1. Location, soil type, planting date, soybean maturity group, and variety, 2016**

| Location | Soil series | Planting date | Maturity group | Variety | Water condition |
|---|---|---|---|---|---|
| Manhattan | Reading silt loam | April 14, May 5, and June 2 | 3.0 | Asgrow 3040 | Dryland |
| | | | 3.7 | Asgrow 3731 | |
| | | | 4.5 | Asgrow 4531 | |
| Ottawa | Woodson silt loam | June 3, June 23, and July 15 | 3.8 | Pioneer 38T42R | Dryland |
| | | | 4.2 | Pioneer 42T91SR | |
| | | | 4.9 | Pioneer 49T80R | |
| Topeka | Eudora silt loam | May 5, May 23, and June 8 | 3.0 | Asgrow 3034 | Irrigated |
| | | | 3.9 | Pioneer 39T67R | |
| | | | 4.5 | Asgrow 4531 | |

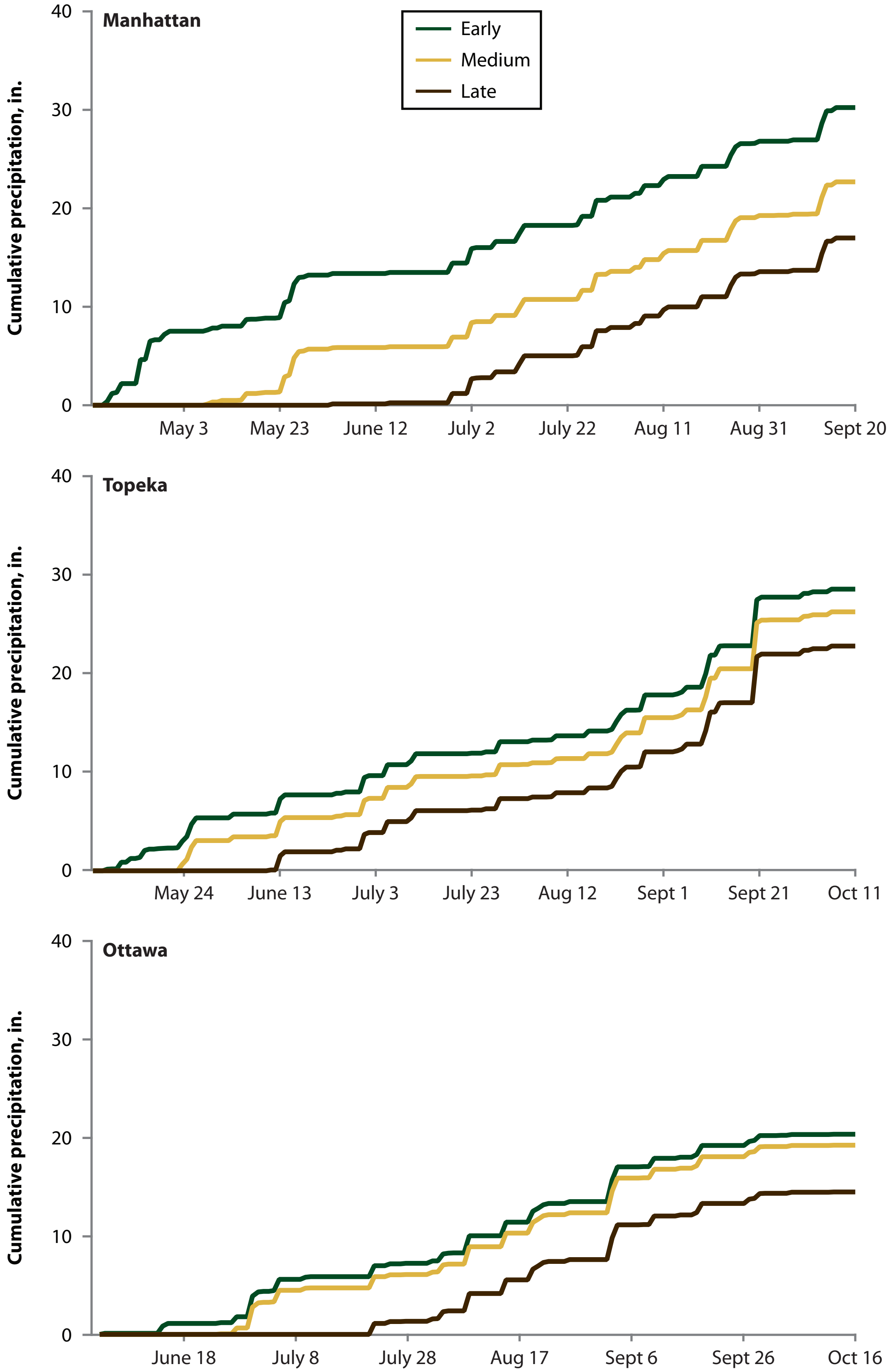


**Figure 1. Cumulative precipitation (inches) for all soybean studies with different planting dates (early, mid, and late) at three locations across Kansas during the 2016 growing season. Information related to planting dates per site is presented in Table 1.**

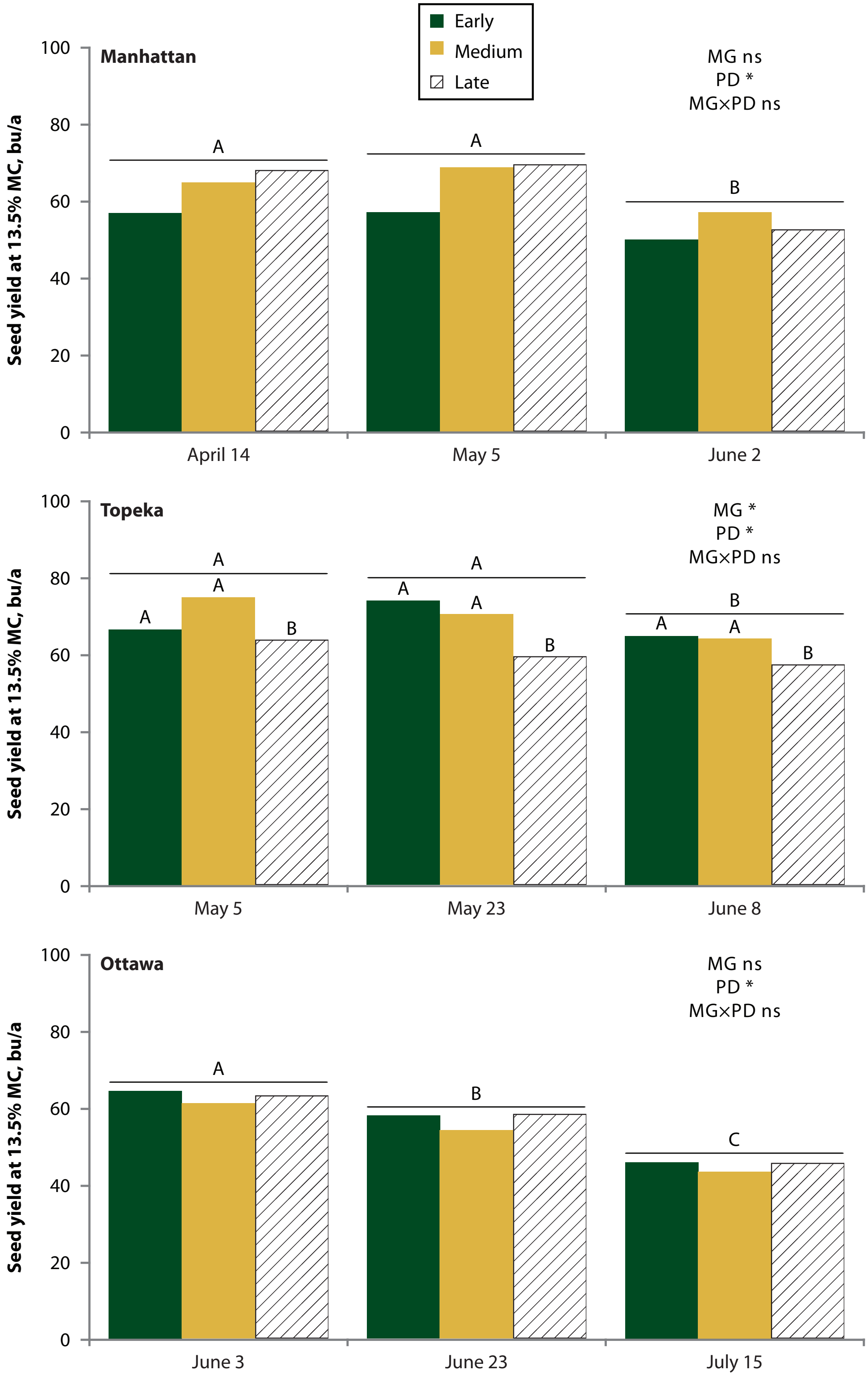


**Figure 2. Soybean yields with different planting dates (PD) (early, mid, and late) and maturity groups (MG) at three locations across the state of Kansas for 2016 growing season. MC = moisture content; NS = no significance; * = significance < 0.05.**

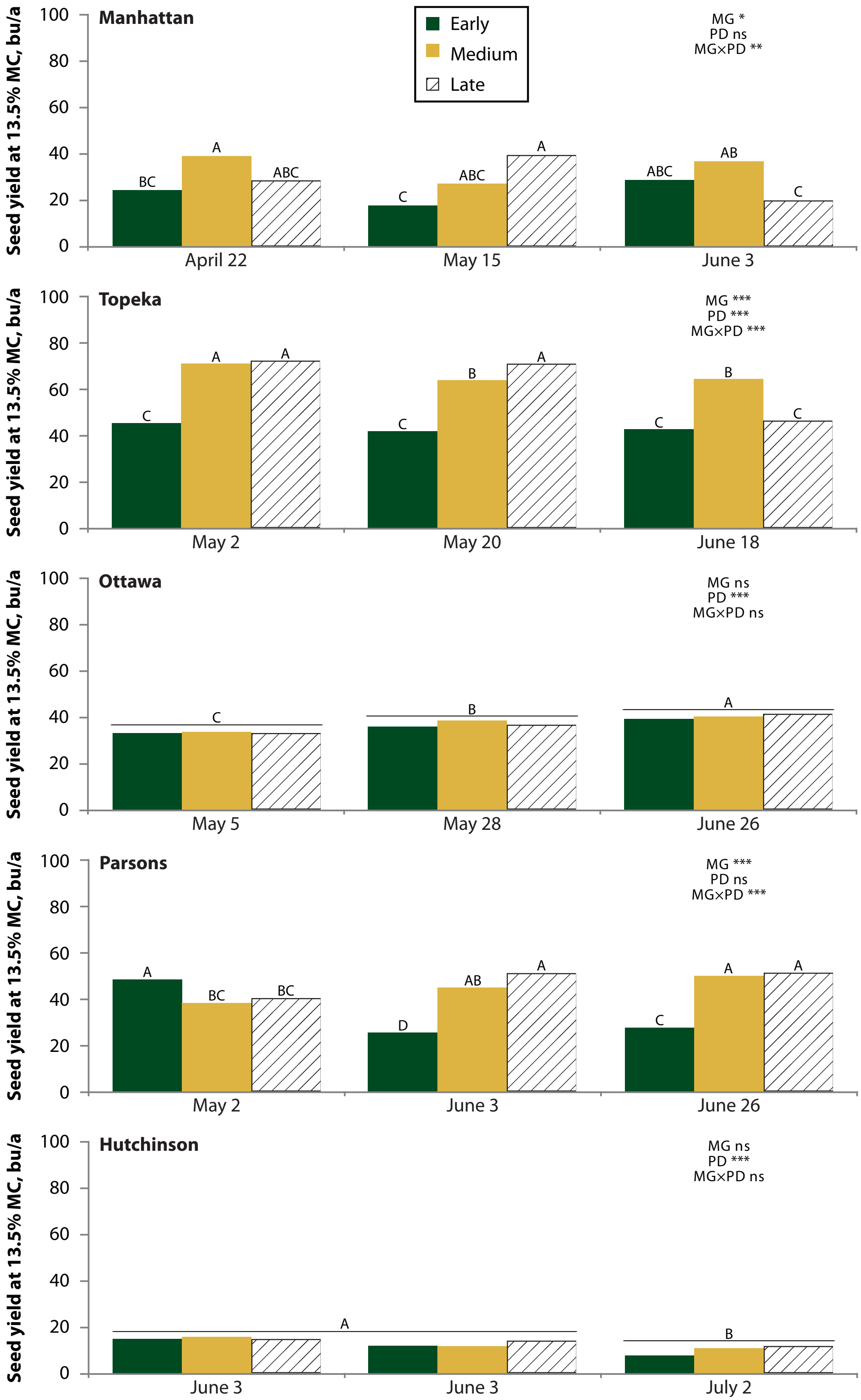


**Figure 3. Soybean yields with different planting dates (PD) (early, mid, and late) and maturity groups (MG) at five locations across the state of Kansas for 2014 growing season. MC = moisture content; NS = no significance; * = significance < 0.05; ** = significance < 0.01; *** = significance < 0.001.**

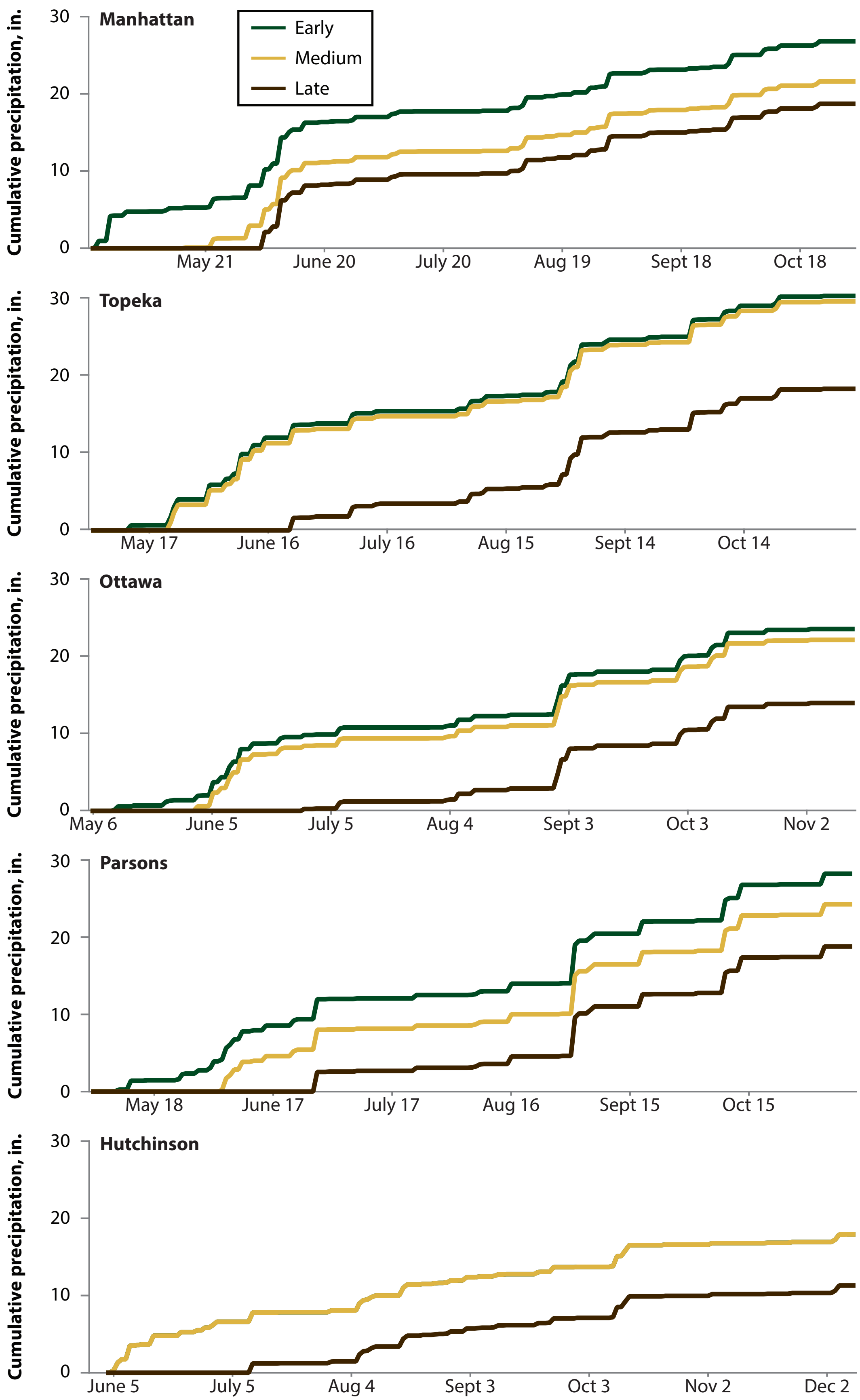


**Figure 4. Cumulative precipitation (inches) for all soybean studies with different planting dates (early, mid, and late) at five locations across Kansas during the 2014 growing season.**

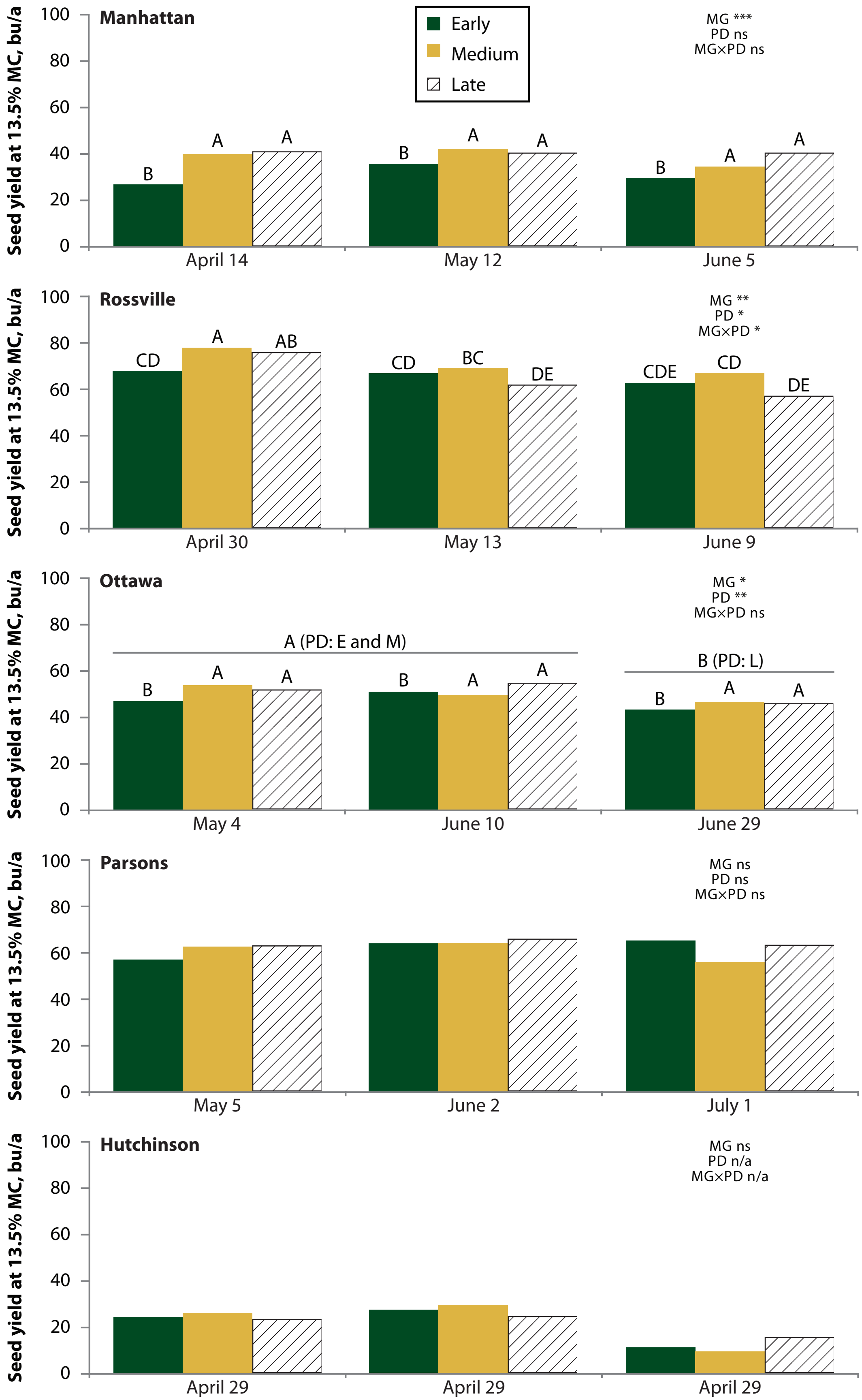


**Figure 5. Soybean yields with different planting dates (PD; early, mid, and late) and maturity groups (MG) at five locations across the state of Kansas for the 2015 growing season. MC = moisture content; NS = no significance; n/a = no available; * = < 0.05; and ** = significance < 0.01.**

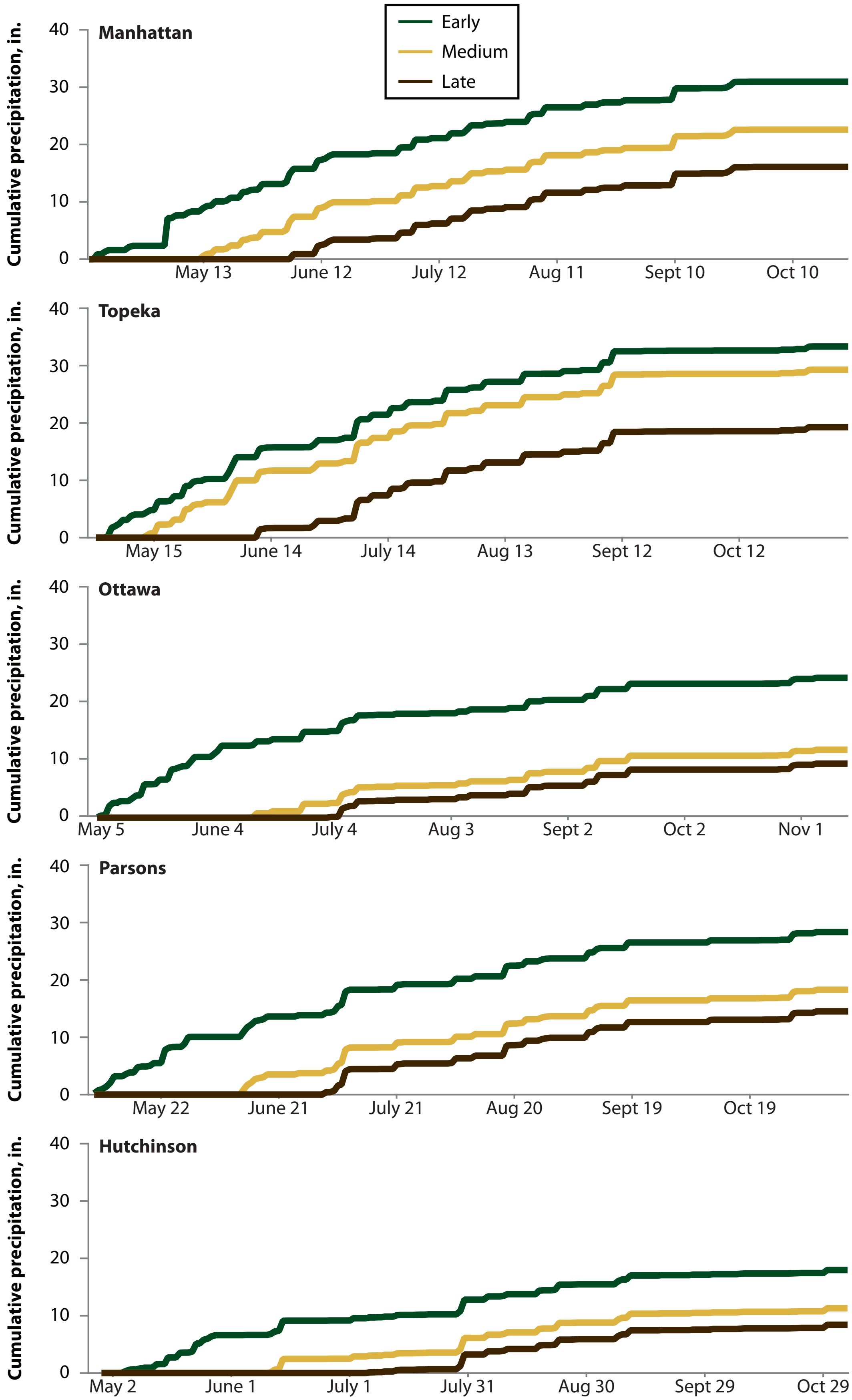


**Figure 6. Cumulative precipitation (inches) for all soybean studies with different planting dates (early, mid, and late) at three locations across Kansas during the 2015 growing season.**

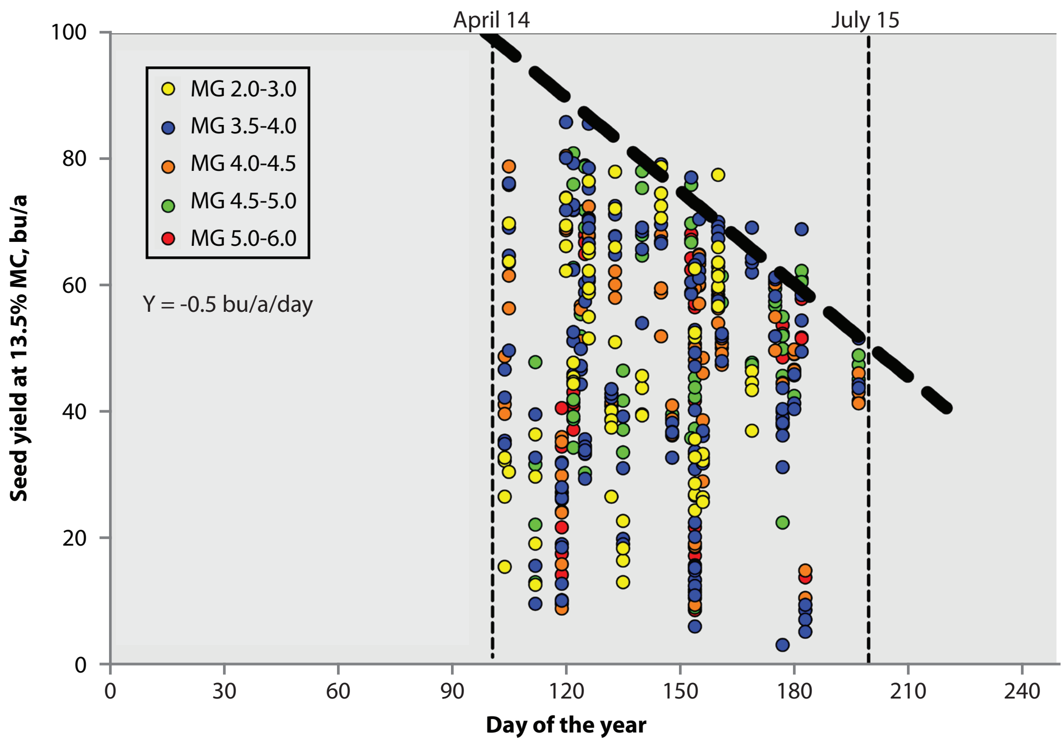


**Figure 7. Soybean yield (bushels per acre) for all soybean studies with different planting dates (early, mid, and late) and maturity groups (MG) at 13 sites across Kansas during the 2014, 2015, and 2016 growing seasons. A frontier line was determined for the points with high yield. MC = moisture content.**

# On-Farm Research: Use of Satellite Imagery Data on Soybean Production

*M. Gutierrez, S. Varela, N. Peralta, and I.A. Ciampitti*

## Summary
Nowadays, good agronomical practices demand the adoption of new technologies that deliver better resource efficiency. The objective of this study was to identify and work closely with high-yielding soybean farmers in order to implement precision agriculture tools, in this case, satellite imagery. A field of 150 acres located in Perry, KS, was evaluated in the 2016 season. The study is based on working with the field variation and the selection of three productivity zones outlined according to normalized difference vegetation index (NDVI) values. *In situ* methods of data collection were performed across the entire field and data from vegetation indices (VIs) were extracted from Landsat 8 satellite (American Earth observation satellite) imagery. Results demonstrated a strong relationship between soybean dry weight (plant biomass) and NDVI. Satellite imagery proved to be a useful tool for delineating productivity zones. A precise and adequate management per zone can be planned via the use of satellite imagery.

## Introduction
Vast information about crop health and development can be obtained via characterization of the temporal and spatial variability in the field; for example, with the use of satellite imagery. Satellite imagery may provide crucial information that could potentially influence the decision-making process related to all farming inputs, such as fertilizer, seeding rate, genotype selection, pesticide application, and others. Biomass data have proven to be a useful indicator of crop growth. Nevertheless, methodology of biomass collection can be time-consuming, labor-intensive, and destructive. Past research has demonstrated that remote-sensed crop characterization via collection of vegetation indices (VIs) presented a strong relationship with biomass, leaf area index, and yield. One of the most commonly used VIs is the normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI). The NDVI is an index that reflects the greenness of plant canopy at a specific growth stage. The EVI is basically an improved NDVI index, which is more sensitive to differences in vegetation.

The main objectives of this study were to: 1) explore the potential use of satellite imagery to identify productivity zones and evaluate soybean development across the growing season at the on-farm scale, and 2) explore relationships between satellite imagery data and ground-truth-based plant traits, such as plant growth and final yield.

## Procedures
### *Sites Description*
The evaluated sites were located in Muscotah, Perry, Morganville, and Gypsum, KS. For the purpose of this report, the focus will be on Perry, KS (39°3’23.544’ N95°23’18.5244”W). The size of the field at the Perry location was approximately 150 acres. For this observational experiment, no treatments were established. Agronomical practices were those suitable per site according to the cooperating producer.

### *Determination of Productivity Zones*

A map defining three productivity zones was elaborated with 2015 NDVI data obtained from satellite imagery of the previous crop (corn-soybean rotation). The zones were classified as high productivity (HP), medium productivity (MP), and low productivity (LP) (Figure 1). The HP, MP, and LP zones contained 40, 60, and 50 acres, respectively.

### *In Situ Data Collection*

Measurements were conducted by weekly intervals, allowing three sampling times for each site. During the growing season, measurements were done at multiple phenological stages – five-leaf (V5), full-bloom (R2), and beginning of maturity (R7). At each phenological stage, sampling was performed following the geo-located points in the field assigned to each productivity zone before the planting time. A total of three representative geo-referenced sampling points were established per productivity zone. Measurements were done on a plot (size, 50 ft long by 10 ft wide) per each productivity zone; the plot was divided into three equal parts to obtain replications within each zone. A total of 9 plots per productivity zone were sampled throughout the growing season. GPS coordinates were collected from each corner of the plot to identify the location and exact size of the sampling area. Seasonal measurements performed were plant biomass, light interception (LI-COR LI-1500), leaf area index (LI-COR LAI-2200CC), stand count on 5 ft, nodule count of 5 roots, SPAD chlorophyll readings, and soil samples. Biomass sampling was collected from an area close to 500 sq. ft. All plants located in that zone were cut at the stem base and weighed for fresh weight determination. A subsample of 5 plants was collected for dry weight purposes, dried until constant weight.

### *Satellite Data and Analysis*

For the map with NDVI of 2015, VI values and amplitude were classified by equal area quantiles using the Geostatistical Analyst in ArcGIS 9.3.1. Imagery and VI data were downloaded from Landsat 8 satellite. A quadratic non-linear regression was tested and fitted to analyze the relationship between NDVI obtained from satellite imagery versus in-situ plant biomass trait.

## Results

The comparison between the past-season productivity map and mid-season NDVI calculated from the satellite imagery shows that the MP and HP zones are similar, but a more visible difference was noticed relative to the LP zone (Figure 1). The LP zone reflects a lower NDVI at the full-bloom stage for the soybean crop.

Cumulative precipitation during growing season was approximately 30 inches, which is below the average annual precipitation for the region, ranging from 36 to 38 inches (Figure 2). Precipitation was scattered through the growing season with a lapse of 12 days of no rain when soybean was starting to flower (R1), which can be crucial for soybean development. Seasonal EVI curve reached not only higher values for the HP zone but also attained the peak earlier than the LP zone (Figure 2). Differences among productivity zones can be attributed to the topography and soil characteristics of the field.

The soil texture per zone was analyzed in the beginning of the growing season; data indicate that HP was silt loam and LP and MP were loam. Organic matter ranged from 1.1 to 2.3% across the whole field; LP zone had lower values than MP and HP zones across the three samplings. The main difference encountered per productivity zone was pH. Low productivity zones' pH ranged from 7.6 to 8 (Table 1), which is an alkaline pH and can compromise nutrient availability to the plant. The critical level for soil phosphorus (P) in Kansas is 20 ppm. The zone with the lowest soil P values during the three conducted samplings was HP; 24.7 ppm on soybean vegetative stage, 16 ppm at R2 stage of soybean, and 24.3 ppm during R7 (Table 1). The maximum availability of P is between pH 6 to 7; at pH above 7.5, phosphate ions tend to react with calcium (Ca) and magnesium (Mg) and form less-soluble compounds. Soil P values on HP productivity zone ranged from 16 to 24.3 ppm in comparison to LP zone, which ranged 38.7 to 42.3. These results may indicate that in the high-productivity environment, plants have depleted the soil P, but in the low-productivity environment, there has probably been less P absorption due to the diminished availability in relation to the high soil pH. Soil potassium (K) in the field was close to the minimum threshold assessed for Kansas (130 ppm) but none was below.

An apparent difference was not evidenced on the early vegetative stage. A trend was observed at the full bloom (R2) and beginning of senescence (R7) phenological stages; where HP zone tended to be higher than the LP zone (Figure 3). A difference of 9,464 lb/a existed between HP and LP zones at R2 stage and 5,268 lb/a at R7 stage. High productivity zone was 38% and 17% above the MP zone at R2 and R7 stage, respectively.

A strong relationship was found between NDVI calculated from the mid-season satellite imagery and measured biomass, plant dry weight. The coefficient of determination ($R^2$) for this relationship shows that the NDVI accounts for 86% of the variability on the plant biomass variation. Larger differences were documented between HP and LP zones (Figure 3).

### *Conclusion*

A strong relationship was found between NDVI calculated from a satellite imagery and soybean plant biomass, portraying satellite imagery as a useful element for plant growth; nevertheless, yield data should analyzed in the future for decision making. Satellite imagery is a promising technology that can help producers characterize on-farm variability, define management zones and improve site-specific management, optimizing resources and lowering costs. Soil characteristics were an important aspect to verify for understanding the different environments within the field. After management zones are clearly defined, on-farm seeding rate and fertilization studies must be conducted to determine optimum inputs.

**Table 1. Soil chemical analysis per productivity on each sampling time at Perry, KS, during the 2016 growing season**

| Stage | Zone | Organic matter | pH | Phosphorus | Potassium |
|---|---|---|---|---|---|
| | | % | | ---------------- ppm | ---------------- |
| V5 | LP | 1.3 | 8.0 | 38.7 | 145 |
| | MP | 1.4 | 6.8 | 35.3 | 151 |
| | HP | 2.0 | 5.8 | 24.7 | 191 |
| R2 | LP | 1.1 | 7.9 | 28.7 | 133 |
| | MP | 1.8 | 7.0 | 46.7 | 214 |
| | HP | 1.7 | 6.5 | 16.0 | 153 |
| R7 | LP | 1.1 | 7.6 | 42.3 | 130 |
| | MP | 2.3 | 7.2 | 48.0 | 200 |
| | HP | 2.2 | 6.9 | 24.3 | 154 |

Soil sampling was done at different stages on different spots of each productivity zone.
Five-leaf (V5), full-bloom (R2), and beginning of maturity (R7).
High productivity (HP), medium productivity (MP), and low productivity (LP).

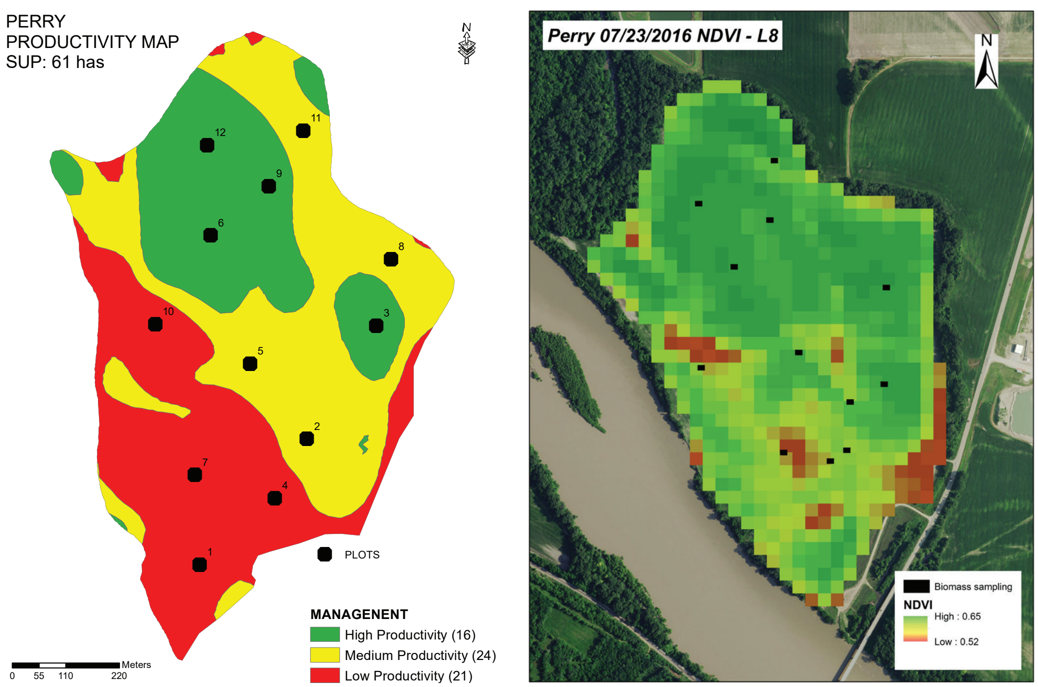


**Figure 1. Productivity zone map of 2015 data (left) and mid-season (R2 phenological stage) normalized difference vegetation index (NDVI) map of 2016 (right) soybean growing season at Perry, KS, site. Black spot indicates the sampled plots.**

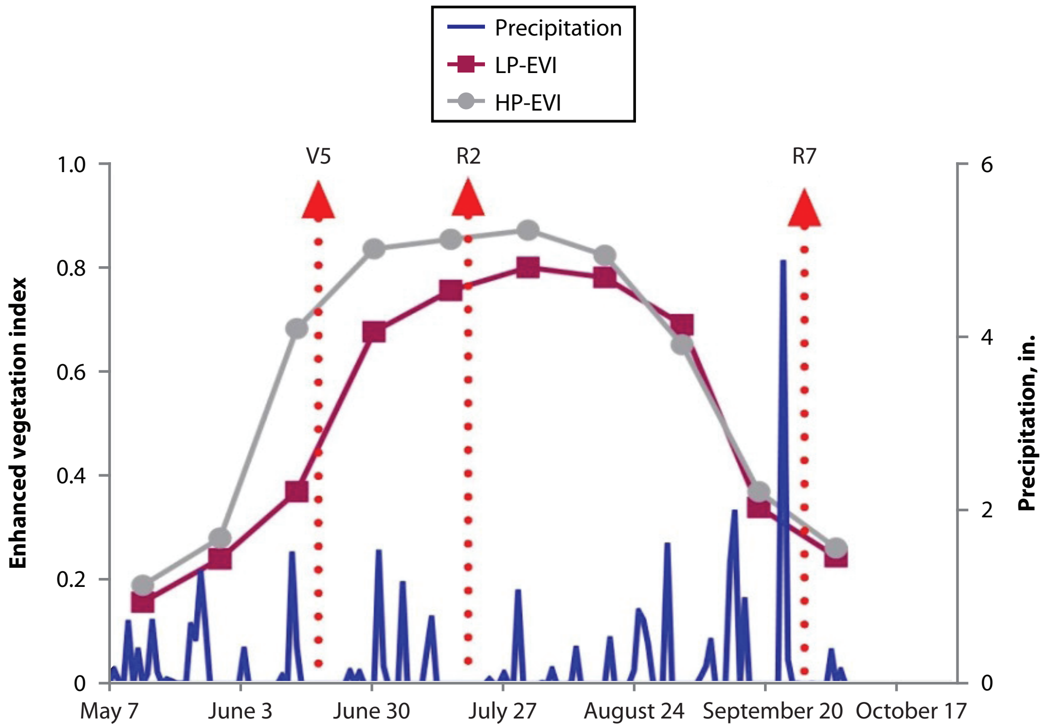


**Figure 2. Enhanced vegetation index (EVI) for high productivity (HP) and low productivity (LP) zones along with precipitation data for the Perry, KS, site during the 2016 soybean growing season.**

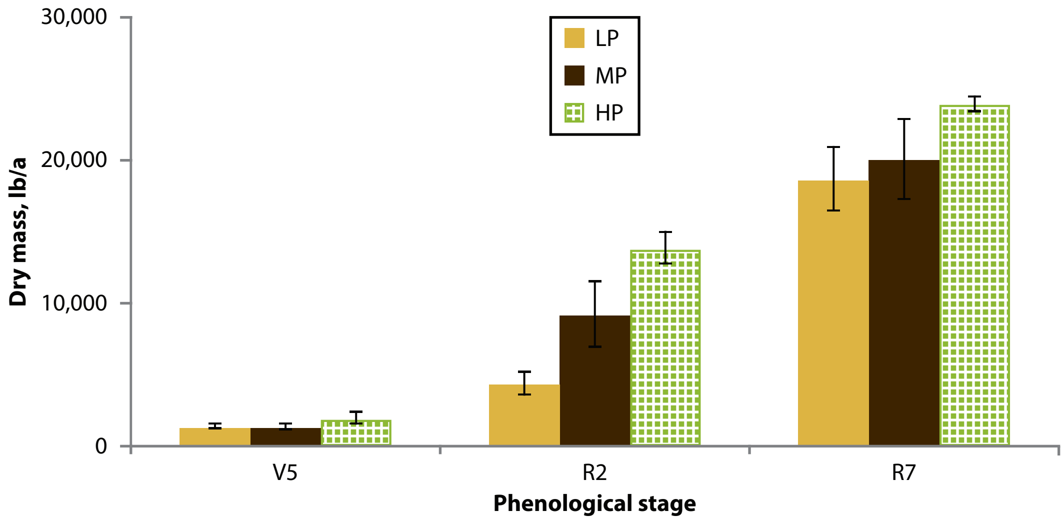


**Figure 3. Dry biomass categorized by productivity zones, high productivity (HP), medium productivity (MP), and low productivity (LP), for three sampling times during soybean five-leaf (V5), full-bloom (R2), and beginning of maturity (R7) phenological stages.**

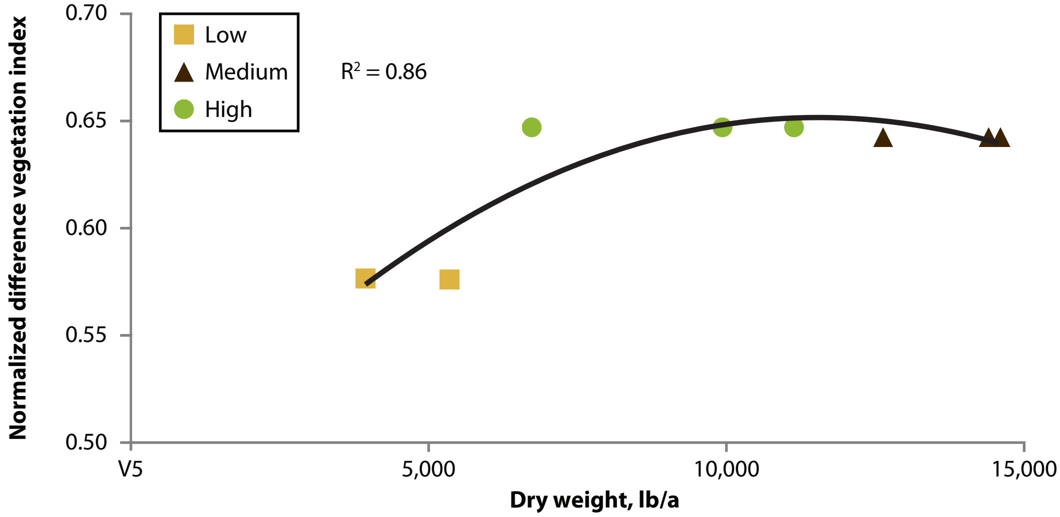


**Figure 4. Relationship between normalized difference vegetation index (NDVI) and the soybean plant dry weight. Observations performed at R2 (full bloom) phenological stage sampling were used to illustrate the relationship.**

# Seed Yield and Biological Nitrogen Fixation for Historical Soybean Genotypes

*S. Tamagno and I.A. Ciampitti*


## Summary

Seed yield formation and biological nitrogen (N) fixation (BNF) were evaluated during the seed filling period (SFP) for historical soybean genotypes under contrasting N strategies. Overall, seed yield increased with the year of release, primarily associated with increments in the seed number component. The study showed that seed weight factor was maintained across decades regardless of the improvement in seed number. Nitrogen factor, evaluated as zero-N application via inorganic fertilizers versus high-N added, influenced seed yield via impacting seed weight factor. The latter plant trait improved with the high-N treatment, which was related to changes in the duration of the SFP rather than in the rate (seed biomass accumulation per day). The BNF parameter also reflected changes during the SFP related to the N treatment implemented, with high BNF (c.a. peak around 70-90%) under zero-N treatment, but still providing N via BNF at a lower rate (c.a. peak around 40-50%) for the high-N treatment. The latter demonstrated that the N fertilization reduced BNF by nearly 50% but did not completely inhibit this process. Thus, the zero-N plants counted on three sources of N to satisfy seed N demand: N-BNF, N-soil, and N-fertilizer. Lastly, the high-N treatment also positively impacted yields (+7 bu/a), which could potentially demonstrate a nitrogen limitation toward the end of the SFP for soybeans. Further testing will be performed during the next growing season to provide an improved yield and BNF characterization under different growing seasons (weather).


## Introduction

Seed yield in crops is defined by two main numerical components: seed number and weight. For many crops such as corn and sorghum, most of the variation in seed yield is explained through changes in the final seed number. However, variations in the final seed weight can be responsible for large changes in yield (Borrás et al., 2004; Sadras, 2007).

Changes in seed weight can be characterized by the amount of dry mass deposited per unit of time (rate) and the duration of this process from beginning of seed formation to physiological maturity, herein termed as seed filling period (SFP). In soybean (*Glycine max* L. Merrill), genetic variation has been reported for rate and duration of the SFP (Egli et al., 1987; Swank et al., 1987) but also largely influenced by the environmental factors such as water, heat, or nutrient stresses (Egli, 1997; Egli et al., 1978; Saini and Westgate, 1999). During the SFP, parallel to the seed changes, production translocation of assimilates and nutrients takes place from different plant organs to the seed in order to provide sufficient supply for the seed storage components (i.e., starch, oil, and protein). Specifically for soybeans, an additional process occurs during the SFP (as a continuation of its onset during the early crop-growing season), the biological nitrogen (N) fixation (BNF), presenting the higher rates during this period and supplying a large quantity of the N available in seeds.

Hence, during the soybean SFP several processes are intertwined. Attaining a high-yield crop is not only related to the environmental conditions but also the plant physiological status during the SFP. The primary objective of this study was to investigate if N is limiting potential seed weight (via studying both rate and duration of SFP) and, in consequence, final seed yield, and to provide a better understanding of the role of BNF process during the SFP for soybean crop.

## Procedures

A field study was conducted at the Kansas River Valley research station (Rossville, KS) during the 2016 growing season. Experimental layout was a complete randomized block design with seven genotypes and two fertilizer N rates all replicated three times. For the genotype factor, seven soybean varieties with different years of release were tested: P3981 (1980), 9391 (1987), 9392 (1991), 93B82 (1997), 93B67 (2001), 93M90 (2003), and P35T58R (2013) (Pioneer®). Application treatments for the fertilizer N factor, zero-N and high-N with 500 lb N/a applied in three timings (i.e., V1, R1, and R3 growth stages). The study was planted May 12 and plot size was 10-ft wide by 50-ft long. For all treatments, seeds were inoculated and plots were maintained weed- and pest-free during the growing season. In-season cumulative precipitation was 31 inches, with an average seasonal temperature of 73°F. Prior to planting, a soil test was conducted to characterize initial soil conditions; overall, the study presented 21 ppm of P (Mehlich), 153 ppm of potassium (K) at 6-inch soil depth, and a total N of 3 ppm at 24-inch soil depth.

Seeds were sampled in all plots at R5 weekly in order to characterize the seed filling curve and estimate rate, duration, and seed weight. In each sampling time, plants were removed to use the stem fraction to measure ureides and nitrates concentration using the hot water extraction method, following Hungria and Araujo (1994). Both concentrations were used to calculate the relative abundance of ureides (%RAU) as a parameter to characterize BNF throughout the SFP.

An analysis of variance was performed to test the effect of genotype, N level, and their interaction in all traits measured. Seed growth rate and duration were determined for each combination of genotype × replication by fitting a bi-linear model (Equations [1] and [2]) as in (Gambín and Borrás, 2011) together with knowledge on heritability estimates and possible trade-off relations among traits. Sixty-five sorghum inbred lines were evaluated for grain filling and other agronomic traits during 2008 and 29 re-evaluated in 2009. Time to anthesis, final grain weight (GW):

$$\text{Seed weight (mg seed}^{-1}) = a + b * d \text{ for } d < \text{c linear function)} \quad [1]$$
$$\text{Seed weight (mg seed}^{-1}) = a + b * c \text{ for } d > \text{c plateau function)} \quad [2]$$

where $d$ are the days after R5, $a$ is the y-intercept (mg seed$^{-1}$), $b$ is the linear rate of dry mass accumulation (mg seed$^{-1}$ d$^{-1}$), and $c$ is the duration of the SFP (days).

## Results

### *Seed Yield and Numerical Components*

Differences for seed yield were significant between genotypes and N levels ($P < 0.01$ and $P < 0.05$, respectively; Table 1). There was a positive trend between year of release and seed yield, with higher yield for modern genotypes (i.e., 64.5 bu/a for 2013). This trend was also observed for the seed number component, but presented only significant differences for the genotype effect ($P < 0.001$), with greater seed number for modern soybean varieties. Furthermore, the treatment depending solely on the fertilizer N source produced an increase in overall yields relative to only the inoculated scenario ($P < 0.01$).

Differences between genotypes and N levels were highly significant for the final seed weight ($P < 0.001$; Table 1). However, for this plant trait, a different trend was documented as related to the release year of the genotypes (e.g., 1997 > 2003 > 1980 > 2013) when compared with yield and seed number factors. Nitrogen application increased seed weight as a result of an increase in the duration of the SFP, but without altering the seed growth rate (Figure 1A). Changes in seed filling duration were also previously documented in the scientific literature, and were also in agreement that the seed filling rate was less sensitive to environmental changes.

### *Biological Nitrogen Fixation During Seed Filling Period*

Regardless of the genotype evaluated, superior %RAU was observed for the zero-N treatment and with low %RAU values for the high-N scenario (Figure 1B). As expected, application of exogenous N during the growing season partially inhibited the BNF process, depicting a fairly constant value of %RAU during the seed filling period (ca. 40-50%; Figure 1B). Meanwhile, the %RAU evolution during the SFP for the zero-N application depicts superior BNF values for the first 20 days (ca. 70-90%) and then consequently dropping until a final N fixation value was attained 50 days after the onset of the SFP (ca. 50%; Figure 1B).

Even though the BNF process was partially inhibited or reduced, the high-N treatment supplied sufficient N in order to achieve larger seed weight and higher seed yield.

Key conclusions from this study are:

- Even though the response was relatively low (7 bu/a) for the environment tested, there was a positive and significant response in seed yield to N applications in soybean. This study does not warrant application of N to soybeans, but demonstrates that the crop can be limited for this nutrient at the end of the growing season.
- Seed weight was the main yield component affected by N treatments. Larger seed weight was primarily explained by changes in duration, rather than on the rate of the SFP.
- Biological nitrogen fixation activity was affected by the fertilizer N application, showing an overall reduction close to 50% at the onset of the SFP when zero-N was compared to the high-N treatment.

The results presented in this study include soil-environment conditions experienced in one growing season. Further studies are needed to explore a wider range of environmental conditions in order to provide a large dataset of the overall effect of N in limiting maximum seed weight, and thus, potentially impacting seed yields.

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**Table 1. Analysis of variance and means for seed yield (13.5% moisture), seed number, final seed weight, seed filling rate, and duration for all genotypes and nitrogen (N) levels**

| Genotype | Release year | N level | Seed yield | | Seed number | | Seed weight | | SFP rate | | SFP duration |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | bu/a | | seed $m^{-2}$ | | mg $seed^{-1}$ | | mg $d^{-1}$ | | days |
| P3981 | 1980 | | 42.7 | d | 2080 | c | 148 | b | 3.81 | b | 41 |
| 9391 | 1987 | | 51.2 | bcd | 2636 | b | 134 | c | 4.08 | ab | 35 |
| 9392 | 1991 | | 44.6 | cd | 2214 | bc | 133 | c | 4.34 | a | 32 |
| 93B82 | 1997 | | 56.2 | ab | 2583 | bc | 166 | a | 4.31 | a | 40 |
| 93B67 | 2001 | | 44.2 | cd | 2054 | bc | 135 | c | 3.86 | b | 36 |
| 93M90 | 2003 | | 53.4 | bc | 2453 | bc | 151 | ab | 4.08 | ab | 39 |
| P35T58R | 2013 | | 64.5 | a | 2664 | a | 137 | c | 4.01 | b | 36 |
| | | Zero-N | 47.5 | b | 2270 | | 133 | b | 4.06 | | 34 |
| | | High-N | 54.5 | a | 2469 | | 154 | a | 4.08 | | 40 |
| Genotype | | | ** | | *** | | *** | | * | | *** |
| N Level | | | * | | ns | | *** | | ns | | *** |
| Genotype × N level | | | ns | | ns | | ns | | ns | | * |

Different letters indicate significant differences at $P \leq 0.05$
* Significant at $P \leq 0.05$; ** significant at $P \leq 0.01$; *** significant at $P \leq 0.001$.
Ns: non-significant.
SFP = seed filling period.

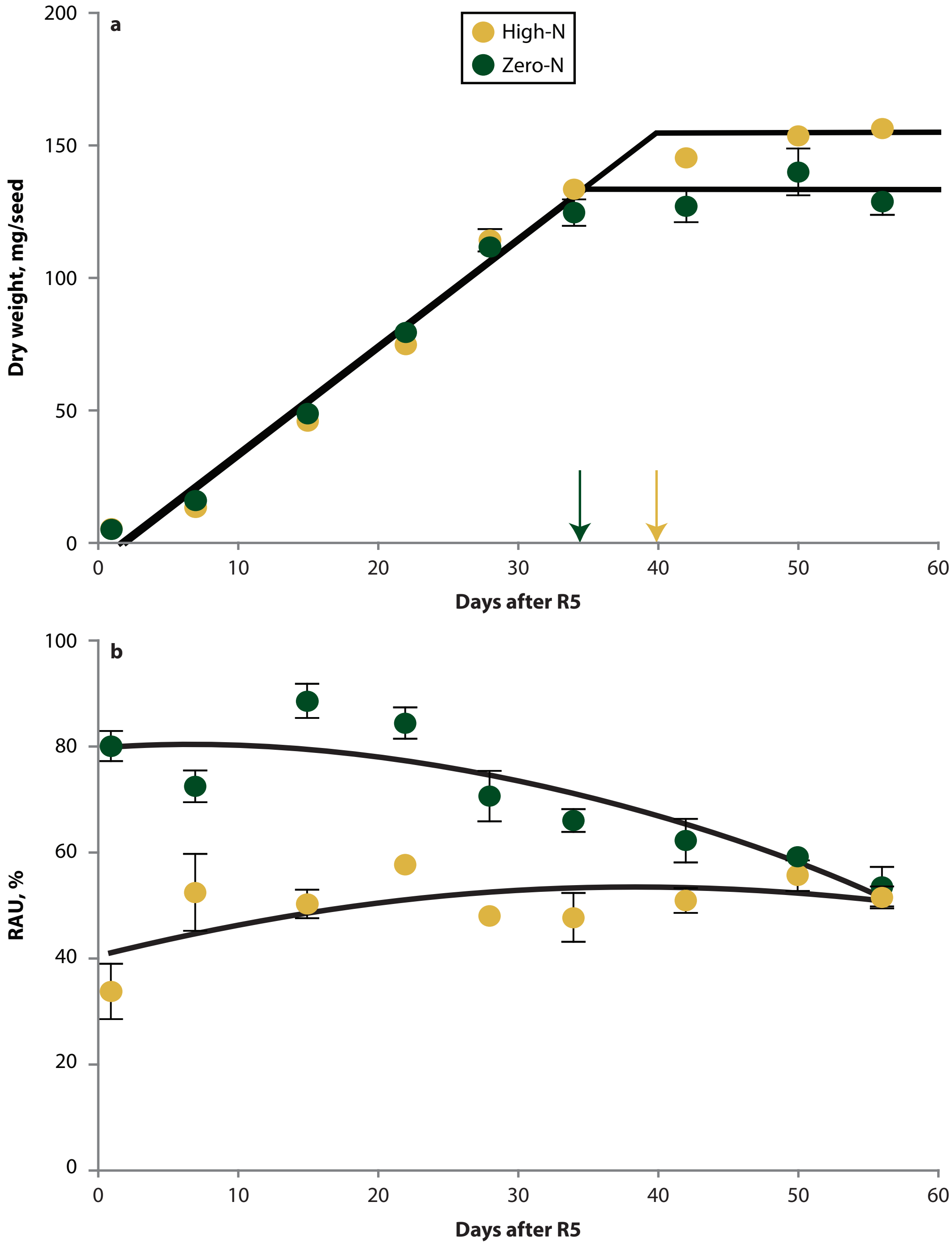


**Figure 1. Evolution of the seed dry weight, a, and percentage of relative abundance of ureides (%RAU; b) after R5 growth stage (onset of seed filling) for two different N levels. The arrows in Figure 1a portray the duration of the seed filling period for zero- (green symbols (dark)) and high-nitrogen (N) (yellow symbols (light)) treatments, respectively.**

# Soybean: Evaluation of Inoculation

*T.M. Albuquerque, O.A. Ortez, G.I. Carmona, and I.A. Ciampitti*

## Summary

Most of the nitrogen (N) required by a soybean plant is supplied via biological nitrogen fixation (BNF). When BNF is adequately established in the soil, soybean can obtain up to 50 to 75% of its N from the air. This project aims to quantify the response to inoculation for soybean in its second year in a field without previous history of this crop. Due to this objective, a field study was conducted during the 2015 and 2016 growing seasons at Ottawa, KS (East Central experiment field location). The treatments consisted of five different N-management approaches: non-inoculated (NI), inoculated ×1 (I×1), inoculated ×2 (I×2), inoculated ×3 (I×3), and non-inoculated but fertilized with 300 lb N/a (NF) as the main N source. In 2015, yields among treatments did not differ significantly from one another. In 2016, yields ranged from 36 to 59 bushels per acre. Greater yields were recorded when fertilized with 300 lb N/a, while lowest yield was related to the non-inoculated scenario. Treatments presented significant yield difference; however, the scenario with 300 lb N/a did not differ from the inoculated ×3; while the inoculated treatments were not different for the yield factor. In summary, further research should be pursued to be more conclusive as to the best management approach for N in soybeans in an area without history of this crop.

## Introduction

Soybean crop, as a legume species, has the characteristic of N fixation or can convert from the atmosphere when the proper symbiotic relationship with specific bacteria is established. The success of an effective symbiotic process depends on the existence of the bacteria in the soil. Thus, if the bacteria are not present in the soil, the "inoculation" practice can establish the specific rhizobia in the field, providing a successful N fixation. Based on previous information, inoculation is usually effective when: 1) soybean was never planted before or in the past 3 to 5 years; 2) soil pH is below 6.0 units; 3) soil has a high sand content; 4) in anaerobic conditions, field has been flooded for more than a week when nodulation was supposed to become established; and 5) early-season stress conditions (e.g. heat) affects plant-bacteria establishment. The inoculation has become a standard practice in soybean fields due to the critical supply of N coming from BNF and the high soybean N demand. Additionally, inoculation practice is relatively inexpensive as compared with other input costs. Nonetheless, it is still valid to properly assess agronomic yield advantage of the inoculation practice in fields where soybean was never grown before. The main objective of this study was to quantify the response to inoculation for soybean in a second year in a field without previous history of this crop.

### *Site Characteristics*

Soil type at the Ottawa location was a Woodson silt loam (Mollisols). Soil samples were taken before planting to a total depth of 6 inches. Soil chemical parameters analyzed were pH, Mehlich P, cation exchange capacity (CEC), organic matter (OM), calcium (Ca), magnesium (Mg), and potassium (K) availability (Table 1).

## Procedures

The study was arranged in a randomized complete block design with six replications. Plot size was 10-ft wide by 50-ft long. The soybean variety utilized was soybean P34T43R2 (RR-2 released 2014 yr; maturity group (MG) = 3.4). Five treatment combinations were evaluated for the same genotype by N management approaches: 1) non-inoculated (NI), 2) inoculated ×1 (I×1, single-rate), 3) inoculated ×2 (I×2, double-rate), 4) inoculated ×3 (I×3, triple-rate), and 5) non-inoculated but fertilized with 300 lb N/a (NF, liquid UAN, 32-0-0 split in three equal applications at planting, flowering, and pod formation) as the main N source. The inoculant used was VAULT® HP plus integral® (BASF company). Herbicides and hand weeding were used to maintain no weed interference for the entire season, and soil nutrient concentrations (other than N) were maintained above the recommended critical levels (through inorganic P/K applications). Seeding rate target was 110,000 seeds/a (see Table 2 for final stand counts).

Stand counts were performed (measuring two 17.5-ft sections per plot) immediately after emergence (VE), in the six replications. Yield information is expressed in bushels per acre adjusted to 13.5% moisture content. Yield was collected from the central two rows (5 × 50 ft). Seed harvest index was estimated as the ratio between the grain yield and the whole-plant biomass collected at R5 stage.

### *Weather Information*

Temperature maximum and minimum normal (30 years) variations followed a similar trend as the seasonal temperature for 2016 growing season. Seasonal precipitation distribution, expressed in inches, was documented throughout the entire growing season (Figure 2). For 2016, seasonal precipitation was higher relative to the historical average, with exception of the month of June.

## Results

### *Yields*

Overall yields for this site averaged 47 bu/a (ranging from 36 to 60 bu/a). Statistically, soybean yields differed among all evaluated treatments (Figure 3). High yields were recorded when 300 lb of N were added to soybeans, while lowest yield was found when no inoculant was applied.

### *Seed Harvest Index*

Seed harvest index (HI) is the ratio between seed biomass and the whole plant biomass (including seeds), expressed in relative terms. Seed HI was comparable across all treatments, averaging 29%. Highest yielding treatment, 300 lb N/a, presented the lowest seed HI, 27%; while the treatment that did not receive any inoculant achieved the maximum seed HI, 31% (Figure 4).

### *Total Biomass*

Plant biomass was also determined at the end of the season, reaching overall values for this site higher than 10,000 lb/a (Figure 4). Lowest biomass value was recorded in the non-inoculated treatment, while maximum biomass was obtained when 300 lb N/a were applied to soybeans. In this study, superior biomass was not related to high seed

HI, but these plant traits presented an opposite direction (Figure 4). Therefore, maximum yields were attained with biomass playing a major role.

### *Conclusions*

Maximum agronomical yield was documented for the soybean variety when 300 lb of N/a were applied. Conversely, the lowest yield was recorded for the variety that did not receive inoculation.

For the yield factor, treatments differed statistically, with yield ranging from 36 to 59 bushels per acre. Final soybean yields presented the following trend from high to low: 300 lb N/a > inoculated 3× > inoculated 2× = inoculated 1× = non-inoculated treatments.

In summary, further evaluation and research is needed in order to properly inform our farmers about the best nitrogen management approach in soybeans grown in an area without history of this crop.

**Table 1. Pre-plant soil characterization at 0- 6-inch depth at Ottawa location**

| Soil parameters, units | Ottawa |
|---|---|
| pH | 5.8 |
| Mehlich P (ppm) | 16.3 |
| Cation exchange capacity (meq/100 g) | 18.7 |
| Organic matter (%) | 4.3 |
| Potassium (ppm) | 83.7 |
| Calcium (ppm) | 2716 |
| Magnesium (ppm) | 379 |

**Table 2. Final stand counts per treatment at Ottawa location, 2016 growing season**

| | Treatments (× 1,000 plants/a) | | | | |
|---|---|---|---|---|---|
| Field sites | Non-Inoc | Inoc × 1 | Inoc × 2 | Inoc × 3 | Fertilizer-N |
| Ottawa | 98 | 100 | 98 | 104 | 103 |

Inoc = inoculation.
N = nitrogen.

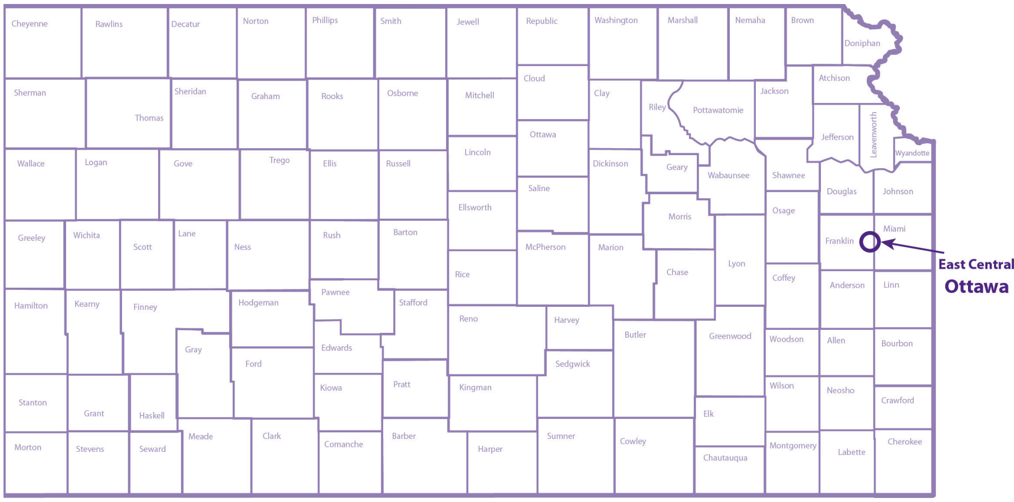


**Figure 1. Field location for the soybean inoculation project during the 2015 and 2016 growing seasons (Ottawa, KS).**

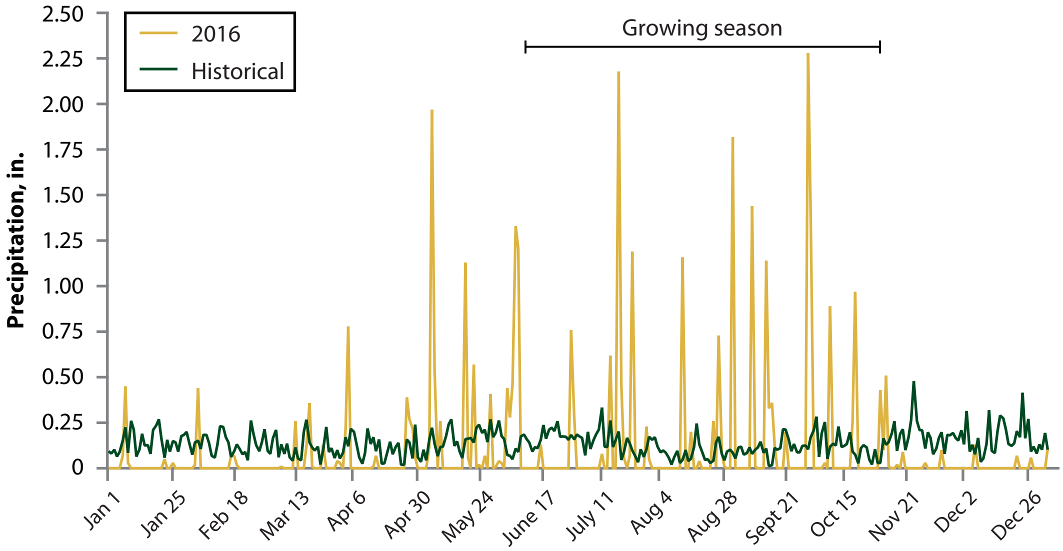


**Figure 2. Monthly precipitation (green line, darker) for the historical average (1985-2016 period) and 2016 growing season (yellow line, lighter) at Ottawa, KS. Data from Kansas Mesonet (Historical Weather, http://mesonet.k-state.edu/).**

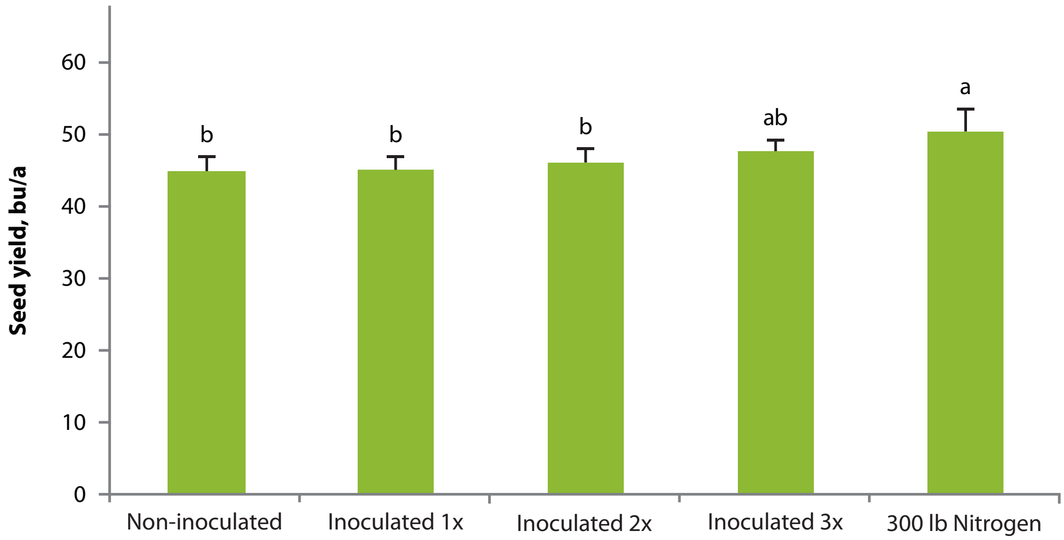


**Figure 3. Soybean yield (13.5% moisture) at Ottawa, KS, during the 2016 season. Error bars represent the standard error for each treatment.**

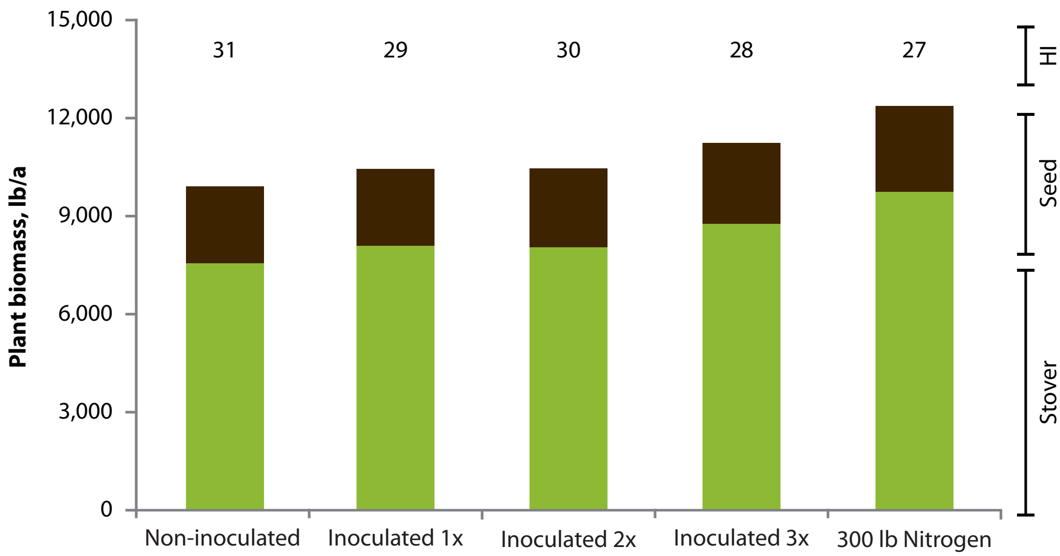


**Figure 4. Seed harvest index, at the Ottawa, KS, site during the 2016 season. HI = harvest index.**

# Soybean: Genetic Gain × Fertilizer Nitrogen Interaction

*O.A. Ortez, F. Salvagiotti, E.A. Adee, J. Enrico, and I.A. Ciampitti*

## Summary
The United States (US) and Argentina (ARG) account for more than 50% of the global soybean production. Soybean yields are determined by the genotype, environment, and management practices (G × E × M) interaction. Overall, 50-60% of soybean nitrogen (N) demand is usually met by the biological nitrogen fixation (BNF) process. An unanswered scientific question concerns the ability of BNF process to satisfy soybean N demand at varying yield levels. The overall objective of this project was to study the contribution of N via utilization of different N strategies, evaluating soybean genotypes released in different eras. Four field experiments were conducted during the 2016 season: Ottawa (east central Kansas, US), Ashland Bottoms (central Kansas, US), Rossville (central Kansas, US), and Oliveros (Santa Fe province, Argentina). A wide variety of historical and modern soybean genotypes were used (from the 1980s, 1990s, 2000s and 2010s release decades) in the US and ARG, all tested under three N management strategies (S1: non-N applied but inoculated, S2: all N provided by fertilizer, and S3: late-N applied) and all seeds inoculated. At Ottawa, the study was planted in an area without previous soybean history with yields ranging from 21 to 30 bu/a. Modern genotype (2010) increased yields by 15% relative to the other varieties. As related to the N management approach, higher yields occurred when the N nutrition was based on S2 (overall 10% increase). At Ashland Bottoms, yields ranged from 47 to 65 bu/a, and the 1990s variety out-yielded the rest of the varieties by 13%. There was not statistical significance for N management at this location. At Rossville, yields ranged from 37 to 85 bu/a, with higher yields observed for the modern genotype (released after 2010). Regarding N strategies, S2 increased yields by 18% compared to S1. At ARG, yield ranged from 40 to 74 bu/a, with modern soybean varieties (released after 2010) yielding 34% greater than the rest of the varieties. Nitrogen application S2 increased yields by 5% when compared to the S1 strategy. Relative to yield potential, yield levels in Argentina were similar to those in central Kansas (Ashland Bottoms and Rossville).

## Introduction
The United States (US) and Argentina (ARG) account for more than 50% of the global soybean production (USDA, 2016). In the US, more than 85% of the soybean land area is located in the Corn Belt region, where two-year corn-soybean rotation (>60%) is the main system. In Argentina, soybeans are planted in the Pampas and Chaco regions, under rainfed conditions, as monoculture or in rotations with corn and wheat.

Soybean yield potential is genetically determined. Yield potential ($Y_P$) can be attained under "ideal" conditions (genotype (G) × environment (E) × management practices (M)), assuming no limitations of water and nutrient supply and absence of biotic and abiotic yield-limiting factors (e.g., insects, diseases, etc.). Yield gaps between $Y_P$ and actual on-farm yield ($Y_A$) are primarily defined by crop management practices (e.g., row spacing, planting date, fungicide and nutrient application, among others) and the interactions of those with the E (weather factor). Maximum soybean yields are dependent on a balanced nutrition, with N nutrition as the main nutrient limiting soybean yields and seed quality (Ciampitti et al., 2016).

Interaction between soybean genotypes and fertilizer N response is not well understood. Rowntree et al. (2013) documented an annual genetic US soybean yield gain of approximately 0.37 bu/a for maturity group (MG) III released from 1920s to 2000s when planted around May. Yield gain for high yielding soybean was achieved in detriment to the protein concentration (Rowntree et al., 2013). Thus, it is valid to hypothesize that high-yielding soybean will have higher nutrient demand to sustain protein levels, which represents the bio fortification issue.

Soybean plants have the capacity to fix nitrogen (N) from the atmosphere through the symbiosis process of the plant with the bacteria *Bradyrhizobium* that needs to be present in the soil or added as inoculant. Nitrogen fixation is the result of the conversion of atmospheric $N_2$ into ammonia ($NH_3$), and later on into N-containing organic components that become available to the plant (Wright & Lenssen, 2013). However, it had been documented that the biological nitrogen fixation (BNF) process is not able to supply the total requirement of the plant. Overall, only 50-60% of soybean nitrogen (N) demand is usually met by the BNF process (Salvagiotti et al., 2008). An unanswered scientific question is, "How well does the BNF process satisfy soybean N demand at varying yield levels?"

In summary, for the genotype × N interaction, the main question is, "Do high yielding soybeans need to be fertilized with nitrogen?" The understanding of genetic gain × N in conditions for expressing high yield potential is a critical factor for advancing soybean yield improvement. For instance, is genetic improvement (genetic gain) accompanied by changes in N uptake (and partition) in soybean?

The objectives of this study were to 1) study the contribution of N in soybean under different N nutrition scenarios: i) soybean planted under normal production conditions, ii) all N requirement met by N fertilizer, and iii) under normal production conditions + late additional N on soybean yields and plant N content; and to 2) Evaluate the yield performance of historical and modern soybean genotypes released from the 1980s to the 2010s.

## Procedures

Four locations were evaluated, three of them located in Kansas, US (Ottawa, Ashland Bottoms, and Rossville) and one in Santa Fe, Argentina (Oliveros) (Figure 1).

### *Experimental Design*

The study was conducted in experimental plots that measured 10-ft wide by 50-ft long at Ottawa and Ashland Bottoms (US); and 10-ft wide by 30-ft long at Rossville (US). Target seeding rate was 140,000 seeds per acre at Ottawa, 180,000 seeds per acre at Ashland Bottoms, and 103,000 seeds per acre at Rossville. Row spacing of 30 inches was used at the three US locations. At Ottawa and Ashland Bottoms each treatment was replicated 6 times in a split-plot layout with a complete block arrangement (soybean variety as the main plot). Nine treatment combinations were evaluated for the genotype by N approach interaction at Ottawa and Ashland Bottoms (Table 1). Nitrogen fertilizer application (expressed in lb N/a) per treatment is also presented in Table 1. Rossville experiment had 3 replications. At this location, the experiment was structured for 13 genotypes and 3 N strategies for a total of 39 treatment combinations.

At Argentina, experimental plots were 8.5-ft wide by 23-ft long. Each treatment was replicated 4 times. Eight varieties and 3 N strategies were evaluated for a total of 24 treatment combinations.

Herbicides and hand weeding were implemented to minimize weed interference for the entire growing season, and soil nutrient concentrations (other than N) were maintained above the recommended critical levels (through inorganic P/K applications).

### *Fertilizer Applications*

The fertilizer N applications were performed using liquid urea-ammonium-nitrate (UAN at 32-0-0) as needed per each treatment combination. The three N strategies were the same at all 4 locations. Strategy 1 (S1) was a control with no N applied but seeds were inoculated. Strategy 2 (S2) was all N provided by fertilizer at a rate of 600 lb/a which was split in 3 timings: planting, R1, and R3. Strategy 3 (S3) has a late season application (at R3) of 50 lb N/a. Nitrogen applications at planting and R1 were performed using an all-terrain vehicle (ATV) equipped with spraying technology. The last N applications (at R3) were performed using a $CO_2$ backpack sprayer with drop tubes attached to the spraying boom in order to place the liquid fertilizer directly into the soil.

### *Site Characteristics*

Soil samples were taken before planting at 6 and 24 inches depth for US locations (Ottawa, Ashland Bottoms, and Rossville). Parameters analyzed from these samples were pH; Mehlich P; cation exchange capacity (CEC); organic matter (OM); Ca, Mg, and K availability; and nitrate concentration (N-$NO_3$) (Table 2).

At the Argentina site, soil samples were taken at 8 inches depth. Parameters analyzed were pH; Bray 1 P; OM; and N-$NO_3$ (Table 2).

### *In-Season Measurements*

A variety of in-season measurements were performed at the US locations. Main in-season activities are listed below:

- Stand counts (early in the season).
- Plant height (ground to the last developed leaf): At V4, R2, and R5 stages.
- Light bar interception (above and below canopy): At V4, R2, and R5 stages.
- Leaf area index (above and below canopy): At V4, R2, and R5 stages.
- Biomass sampling at V4, R2, R5, and R8 stages.

At the Argentina location, the same measurements were collected at the R2, R5, and R7 stages. Biomass determination was performed from a sample of five linear feet per plot. Each individual plant was cut at the stem base out in the field. Total fresh weight of the sample was taken and then it was sub-sampled to ten plants per plot. These 10-plant sub-samples were separated into different fractions: 1) leaves and stem (vegetative phase); and 2) pods, grain, leaves, and stems (reproductive phase). Each independent fraction was separately chopped and dried to constant weight at 140°F. When samples were dry, they were ground to fine particles that later were sent to a laboratory for analysis of nutrient concentrations.

At Ottawa and Ashland Bottoms, 2016, root samples were collected at the V4 stage. Ten roots per plot were sampled for root scanning and nodules count at three repetitions for each treatment. In addition, five ground pictures per plot were taken with a professional camera for future software analysis of canopy cover. As a complement, at Ashland Bottoms and Rossville (US) imagery analysis was performed, collecting information from different parameters using drones. The main focus was canopy cover and normalized difference vegetation index (NDVI) at different growth stages during the season.

## Results

### *Weather Information*

Seasonal precipitation, maximum (max) and minimum (min) temperatures, and solar radiation values were documented throughout the entire 2016 growing season at all sites. In the US, similar mean temperatures were observed with max of 91, 87, and 89°F and min of 46, 47, and 44°F for Ashland, Ottawa, and Rossville, respectively. Cumulative precipitation was higher in the high yielding environments (Ashland and Rossville) with 28- and 32-inch relative to the low yielding environment (Ottawa) with 21-inches (Figure 2). In Oliveros, max temperatures were close to those in the US with 90°F, although min temperatures were higher with 63°F. Cumulative precipitation was similar to the US high yield environments, totaling 27 inches. Solar radiation indexes were similar across locations with 82, 76, and 83 × 1000 cumulative Langleys (Ly), except at Ottawa, with 58,000 Ly.

### *Stand Counts*

Early-season stand counts were collected in two 5-ft sections per plot at the V4 stage (Table 3). Stand count efficiency, when compared to seeding rate at Ottawa, ranged from 39% to 89% with an average of 64%. At Ashland Bottoms, stand count efficiency ranged from 30 to 86%, and its average was 60%. Average stand count efficiency at Rossville was 66%. Efficiency in stand count at all US locations was between 60 and 66% overall. In Oliveros, stand count efficiency averaged 84%.

### *Nodules Information*

Nodules information was compiled for Ottawa and Ashland Bottoms (US) during the 2016 growing season, and expressed in nodules per plant at the V4 stage. Nitrogen strategies showed statistical effects ($P < 0.05$) while genotypes did not present differences in final nodules number. Overall, Ashland Bottoms presented a higher number of nodules per plant (Figure 3) than Ottawa (no soybean history for the last 20 years). As expected, S2 resulted in the lowest number of nodules per plant at both locations (5 nodules per plant at Ottawa and 6 nodules per plant at Ashland Bottoms) when compared to S1 and S3 treatments.

### *Genetic Gain*

Twenty-one soybean genotypes from different releases were used in this experiment. At Rossville, 13 genotypes released in the decades of the 1980s, 1990s, 2000s, and 2010s were tested. At Oliveros, 8 genotypes (two from each of the previously listed decades) were used. At both locations, maximum yield was recorded for the modern variety (2010s), with relative yields improving with the year of release of the commercial material (Figure 4).

### *Yields*

Yield information, expressed in bu/a, was adjusted to 13.5% of moisture content. Yields were recorded with a plot combine and from the two central rows in all plots.

*Soybean Genotypes by Nitrogen Fertilization Strategies*

Yields for 13 genotypes are presented for Rossville (US) and 8 genotypes for Oliveros (ARG), all considering the three N strategies. Yields were similar for both locations, ranging between 37 and 87 bu/a. Nitrogen strategy and genotypes presented statistical significance ($P < 0.05$), but there was not interaction. Greater yields, 18% increase at Rossville and 21% increase at Oliveros, were obtained with modern soybean genotypes (release year > 2000s). On the N applications, S2 (600 lb N/a) increased 18% yields at Rossville and 5% at Oliveros compared to S1 (non-N applied but inoculated) (Figure 5).

At Ottawa, yields were lower (ranging from 21 to 30 bu/a) when compared to Ashland Bottoms (47 to 65 bu/a) (Figure 6). At Ottawa and Ashland Bottoms, genotypes had statistical effect ($P < 0.05$) on soybean yields, and N application was also significant but just for Ottawa. At Ottawa, higher yields were observed for modern soybean genotypes (2010s decade) and for the S2 and S3 N-management approaches relative to past varieties and the S1 treatment.

*Historical Genotypes by Nitrogen Strategies Interaction*

At Oliveros, genotype by N strategy presented a significant ($P < 0.05$) interaction (Figure 7). Highest yield (74 bu/a) was observed with the modern soybean genotype (2010s release decade) and the S2 N-management approach. On the other hand, lower yields were documented for the 1990s variety regardless of the N-management approach.

## Acknowledgments

Thanks to the Kansas State University CROPS Crop Production Team; the National Agricultural Technology Institute (INTA), Argentina; Pioneer; and the Fluid Fertilizer Foundation.

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**Table 1. Treatment description for Ottawa and Ashland sites (US), 2016 growing season**

| Treatment | Release decades | Varieties | Nitrogen (N) application |
|---|---|---|---|
| 1 | 1990s | non-RR | Non-N applied |
| 2 | | | All N provided by fertilizer (600 lb/a) |
| 3 | | | Late-season N (50 lb/a) |
| 4 | 2000s | RR-1 | Non-N applied |
| 5 | | | All N provided by fertilizer (600 lb/a) |
| 6 | | | Late-season N (50 lb/a) |
| 7 | 2010s | RR-2 | Non-N applied |
| 8 | | | All N provided by fertilizer (600 lb/a) |
| 9 | | | Late-season N (50 lb/a) |

**Table 2. Pre-plant soil characterization at 6- and 24-inch depth for Ottawa, Ashland Bottoms, and Rossville, US sites; and 8-inch depth for Oliveros, ARG**

| | Location and soil depth | | | |
|---|---|---|---|---|
| Soil parameters | Ashland Bottoms 6 in. | Ottawa 6 in. | Rossville 6 in. | Argentina 8 in. |
| pH | 6.7 | 5.7 | 6.9 | 5.55 |
| Mehlich P (ppm) | 22 | 14 | 21 | 12 |
| CEC (meq/100g) | 9 | 18.5 | 11 | - |
| Organic matter (%) | 1.5 | 4.3 | 2.17 | 2.14 |
| Potassium (ppm) | 181 | 80 | 153 | - |
| Calcium (ppm) | 1599 | 2665 | 2074 | - |
| Magnesium (ppm) | 179 | 393 | 202 | - |
| $N\text{-}NO_3$ (ppm)* | 2.5 | 5 | 3 | 6.3 |

* Nitrate concentration ($N\text{-}NO_3$ ppm): all 3 US locations samples were taken at 24-inch depth.

**Table 3. Final stand counts per repetition block and seeding rate for Ottawa, Ashland Bottoms, and Rossville, US sites, and Oliveros, ARG, during the 2016 growing season**

| | Repetitions (× 1,000 plants/a) | | | | | | Seeding rate |
|---|---|---|---|---|---|---|---|
| Field sites | 1 | 2 | 3 | 4 | 5 | 6 | (× 1,000 plants/a) |
| Ottawa | 94 | 94 | 93 | 97 | 82 | 81 | 140 |
| Ashland Bottoms | 104 | 112 | 97 | 111 | 88 | 119 | 180 |
| Rossville | 67 | | 72 | | 68 | | 103 |
| Oliveros | 120 | | 126 | | 120 | | 146 |

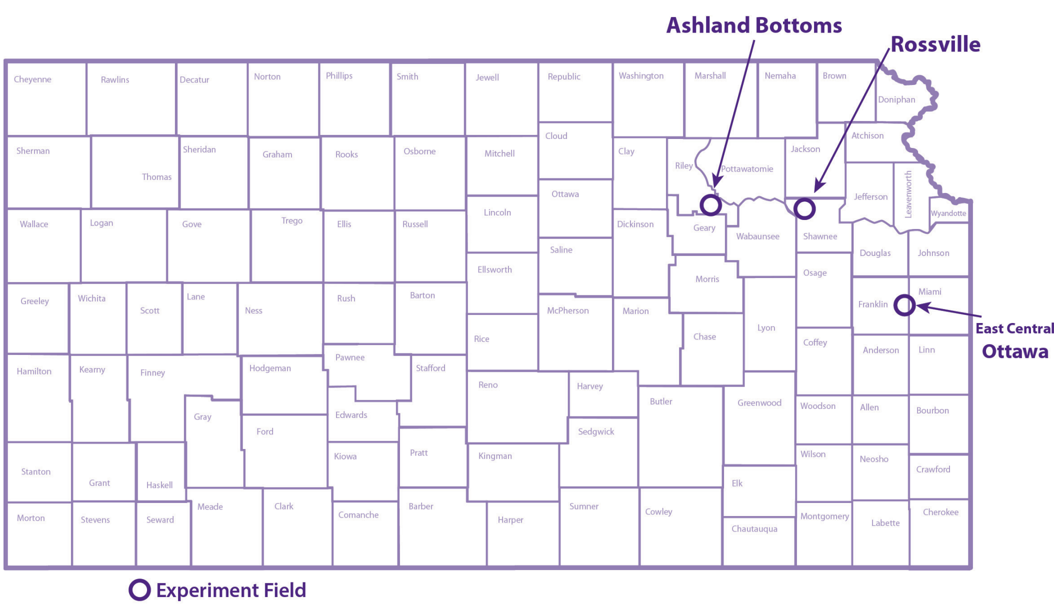


**Figure 1. Map of the state of Kansas and Argentina identifying the four studies conducted during the 2016 season: Ottawa, Ashland, Rossville (US), and Oliveros (ARG).**

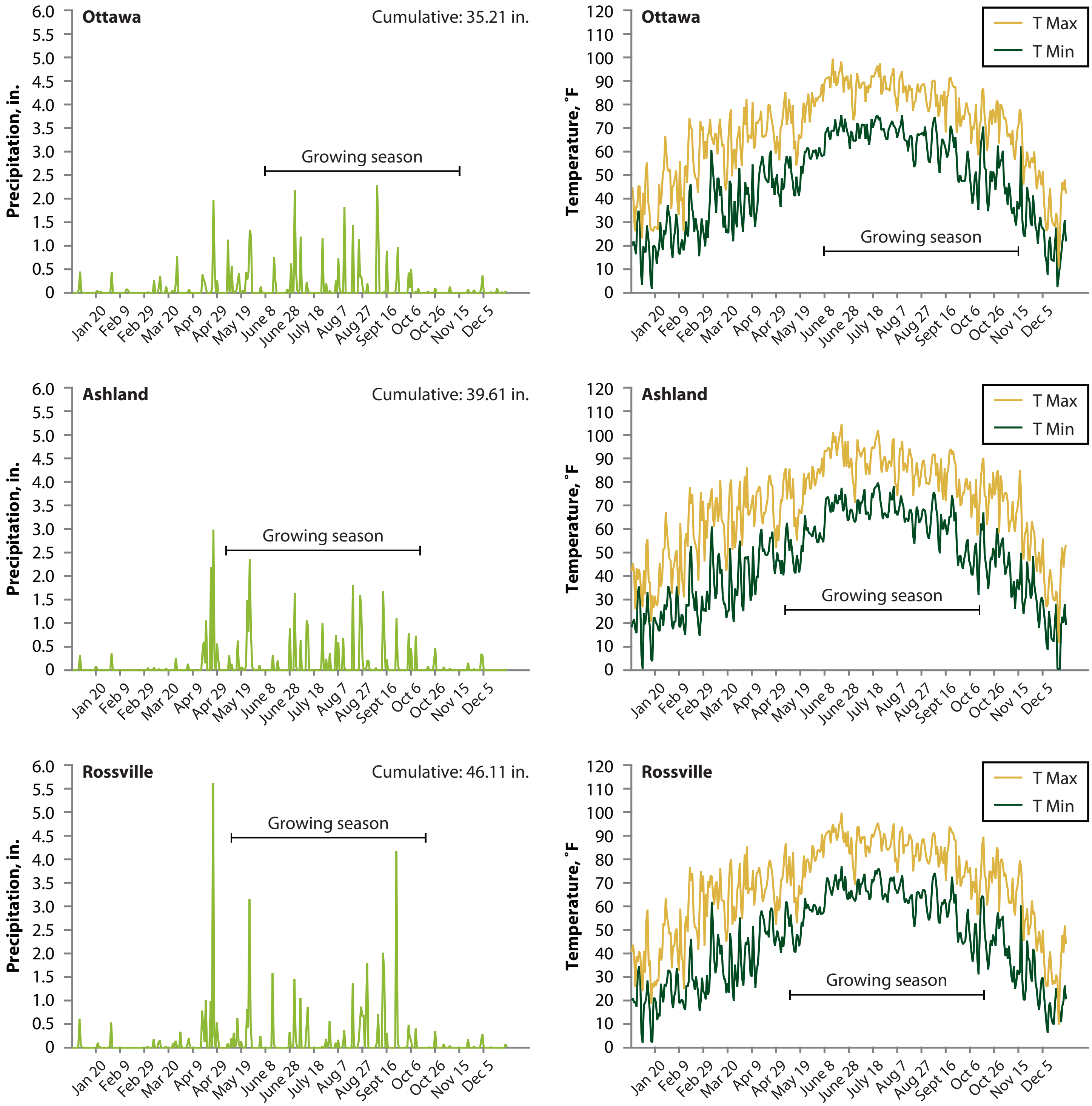


**Figure 2. Daily precipitation, from January to December, (left panels) and seasonal minimum and maximum temperatures (right panels) for the 2016 growing season at Ottawa, Ashland Bottoms, and Rossville (US locations).**

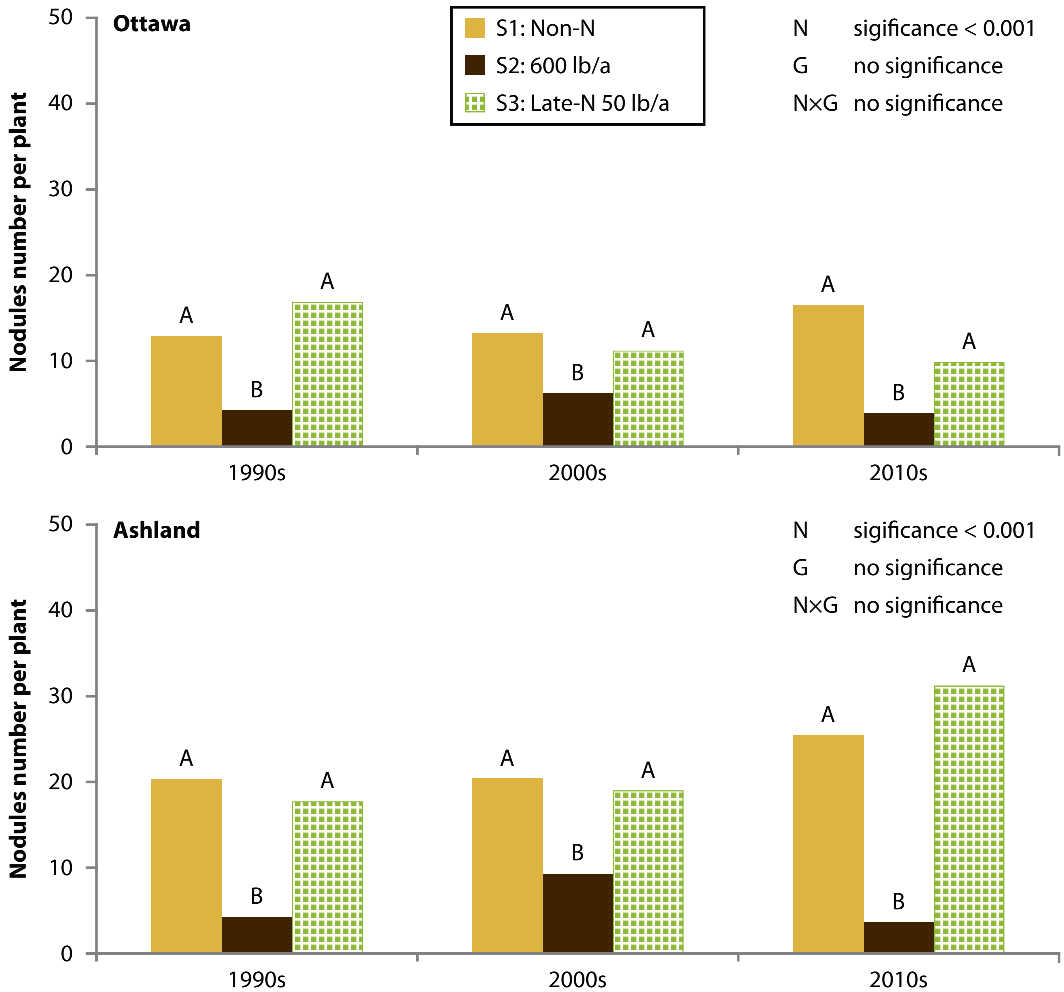


**Figure 3. Per-plant nodule number affected by soybean genotype and nitrogen interaction at Ottawa (top) and Ashland Bottoms (bottom) sites, US, at V4 stage during the 2016 growing season.**

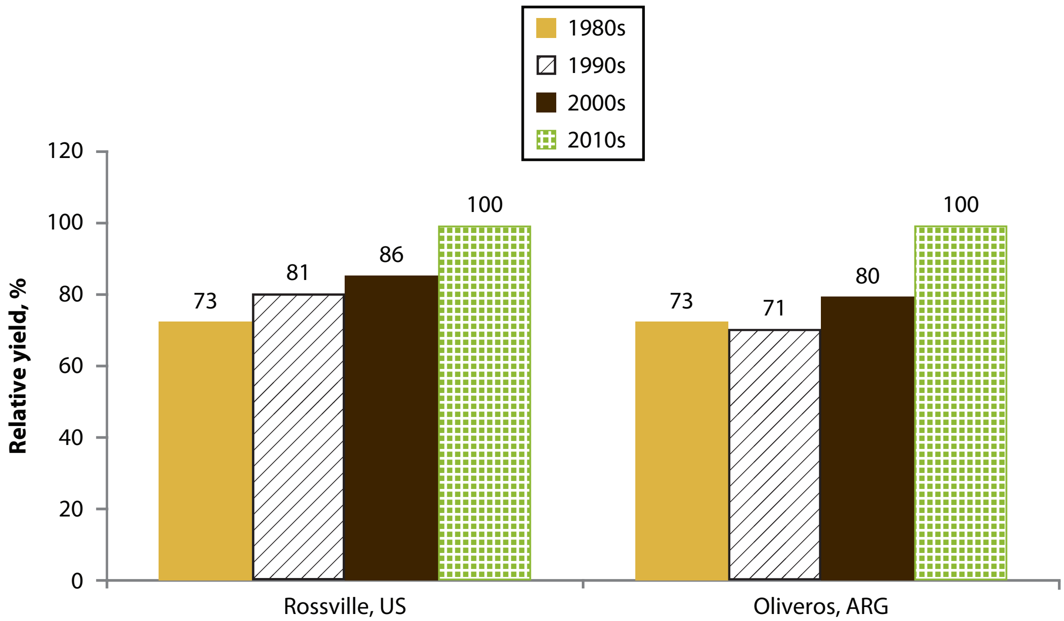


**Figure 4. Genetic improvement for soybean genotypes presented in relative yields (%) for four release decades at Rossville, US, and Oliveros, ARG, during the 2016 growing season.**

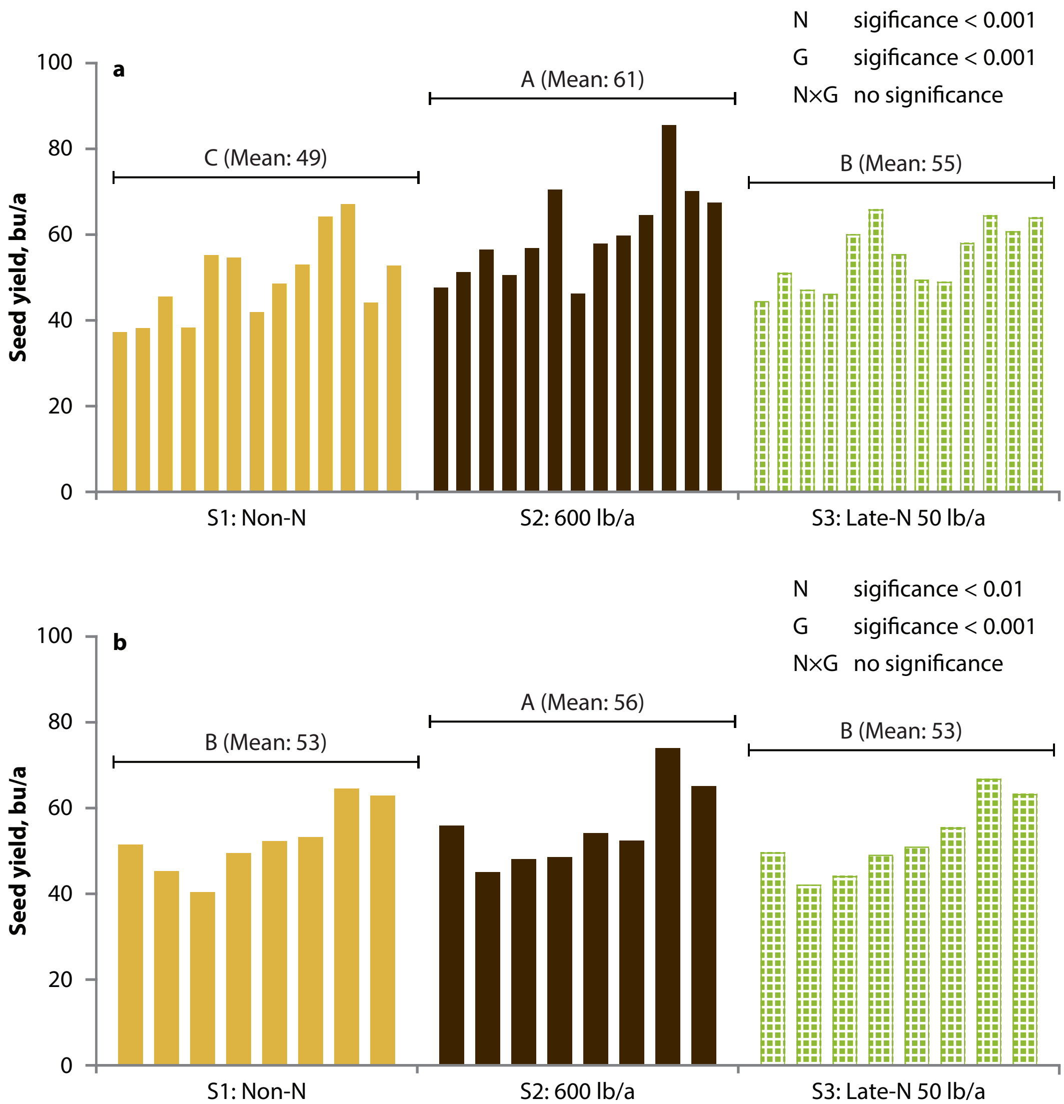


**Figure 5. Seed yield for soybean genotypes with different nitrogen fertilization strategies at Rossville, US (top), and Oliveros, ARG (bottom), during the 2016 growing season.**

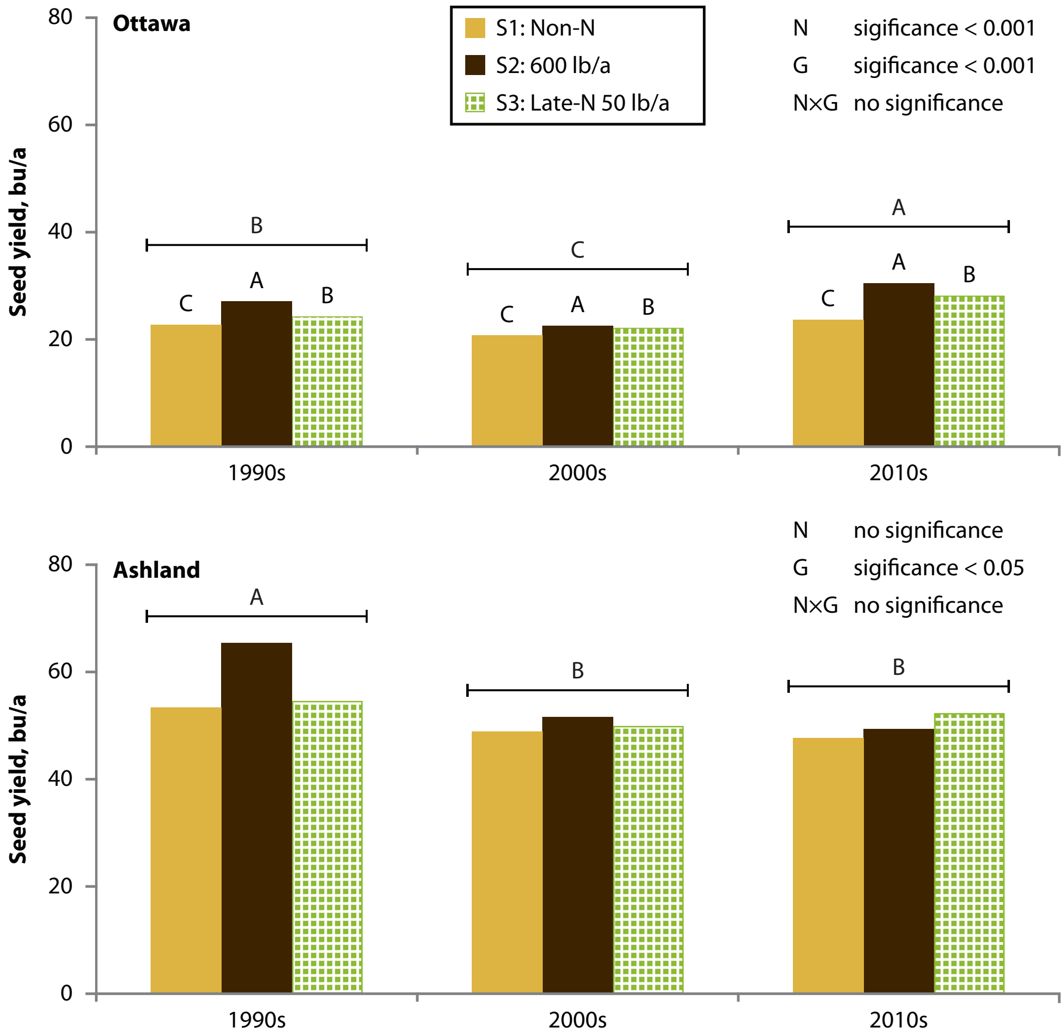


**Figure 6. Seed yield for soybean genotypes with different nitrogen fertilization strategies at Ottawa (top) and Ashland Bottoms (bottom), US, during the 2016 growing season.**

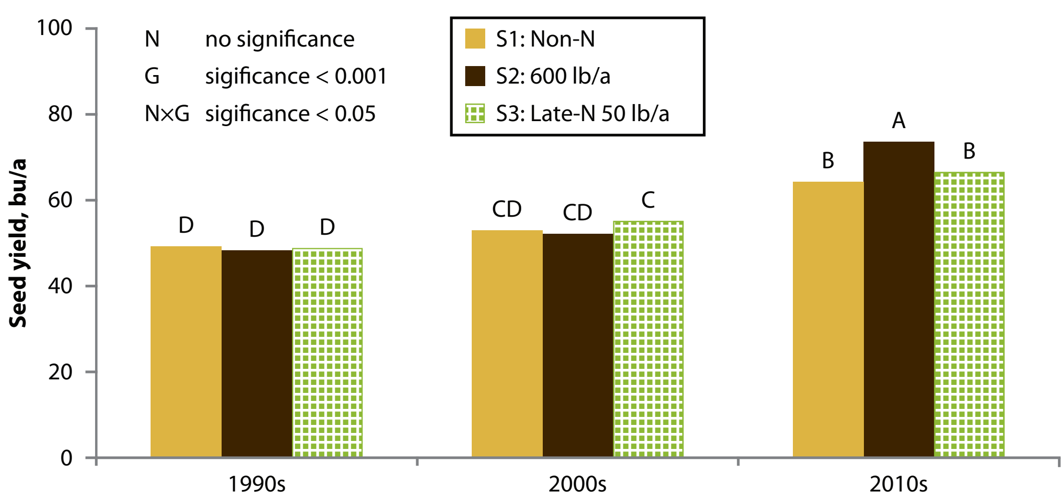


**Figure 7. Seed yield for soybean genotypes with different nitrogen fertilization strategies at Oliveros, ARG, during the 2016 growing season.**

# Irrigated Sunflowers in Northwest Kansas: Productivity and Canopy Formation

*F.R. Lamm, R.M. Aiken, A.A. AbouKheira, and G.J. Seiler*

## Summary
Sunflower was grown in a three-year study (2009, 2010, and 2012) at the Kansas State University Northwest Research-Extension Center at Colby, KS, under a lateral move sprinkler irrigation system. Irrigation capacities were limited to no more than 1 inch every 4, 8, or 12 days but were scheduled only as needed as determined with a weather-based water budget. Achene (sunflower seed) yields and oil yield generally plateaued at the medium irrigation level. Dormant preseason irrigation increased achene yield and oil yield by 2% with most of this increase occurring in the extreme drought year, 2012. The optimum harvest plant population for sunflower in this study in terms of achene yield and oil yield was approximately 19,000 to 20,000 plants/a.

## Introduction
Sunflower is a crop of interest in the Ogallala Aquifer region because of its shorter growing season and thus lower overall irrigation needs. Sunflowers are thought to better withstand short periods of crop water stress than corn and soybeans, and the timing of critical sunflower water needs is also displaced from those of corn and soybeans. Thus, sunflowers might be a good choice for marginal sprinkler systems and for situations where the crop types are split within the center pivot sprinkler land area.

Center pivot sprinkler irrigation (CP), the predominant irrigation method in the Ogallala region, presents unique challenges when used for deficit irrigation. Center pivot sprinkler irrigation cannot be effectively used to apply large amounts of water timed to a critical growth stage as can be done with surface irrigation methods. The CP systems also cannot efficiently use small, frequent events to alleviate water stress as is the case with subsurface drip irrigation (SDI). Thus, with CP systems, it is important that available soil water in storage be correctly managed temporally in terms of additions and withdrawals so that best crop production can be achieved both economically and water-wise. Three easy ways to control irrigation water additions are irrigation capacity, preseason management, and the season initiation date. Withdrawals can be partially managed by plant population. This study examined sunflower production using the three methods of controlling irrigation additions for three different targeted plant populations.

## Procedures
The study was conducted from 2009 through 2012 at the Kansas State University Northwest Research-Extension Center (NWREC) at Colby, KS, under a lateral move sprinkler irrigation system. However, data from 2011 are excluded due to a devastating hail storm that destroyed the crop. Key agronomic characteristics of the annual tests are shown in Table 1.

Whole-plot treatments were sprinkler irrigation capacities of 1 inch every 4, 8, or 12 days as limited by evapotranspiration (ET)-based water budget irrigation scheduling. An additional whole-plot irrigation factor was the addition, or no addition, of dormant preseason irrigation, resulting in a total of 6 different irrigation treatments. The target preseason irrigation amount for those plots receiving this treatment was 5 inches, but in 2012 a total of 9.2 inches of preseason irrigation was applied due to an application error. Three targeted plant populations 18,000, 23,000, or 28,000 plants/a were superimposed on the whole plots for a grand total of 108 subplots. Irrigation amounts were 1 inch applied as needed, but limited by the imposed capacity and the water budget irrigation schedule. The whole plots (6 repetitions) were in a randomized complete block design.

Soil water was measured periodically in each plot each crop season with a neutron probe to a depth of 8 feet in one foot increments. Crop water use was calculated as the sum of changes in soil water between emergence and physiological maturity, precipitation and irrigation amount. Crop water productivity (WP, also known as water use efficiency) was calculated as the achene yield in lb/a divided by the total crop water use in inches.

At R6 development stage and to maturity (R9 development stage), sunflower achene moisture content, dry mass, and oil content were measured by collecting six achenes from each of five representative plants, semi-weekly. At maturity, sunflower heads were hand harvested from a representative sample area and threshed for yield and yield component.

Leaf area index (LAI) was quantified, approximately bi-weekly, by a non-destructive light transmission technique (Welles, 1991; LAI-2000 Plant Canopy Analyzer; Li-Cor, Lincoln, NE). Three sets of four below-canopy measurements were each referenced to an above-canopy measurement, minimizing sensor exposure to direct (beam) irradiance. Readings were screened against apparent transmittance ratios exceeding 1 using the manufacturer's software, FV2000 (Li-Cor, Lincoln, NE). An inverse solution to a model of light transmission through a vegetative canopy, provided by the manufacturer, was used to quantify apparent LAI.

Growing degree days (GDD) were calculated from daily temperature extremes (Equation 1) recorded at the NWREC weather station, using a mercury thermometer.

$$GDD = \frac{T_{max} - T_{min}}{2} - T_b \qquad \textit{Equation 1}$$

Upper and lower limits to temperature extremes were 34°C and 4°C (93°F and 39°F), respectively. Cumulative GDD (cGDD) was computed by summation of GDD, commencing from planting date.

Statistical analysis used analysis of variance (ANOVA) and analysis of covariance (ANCOVA). Repeated measure of LAI and maximum LAI observed in a year were analyzed by ANOVA, using Proc GLM from SAS 9.4 (SAS Institute Inc., Cary, NC). Seasonal trends in LAI were analyzed by ANCOVA using third-order linear terms of cGDD or days after planting (DAP) as covariates.

# Results

## *Weather Conditions*

The crop year 2009 was very cool and wet and irrigation needs were low. In-season irrigation amounts for the 1 inch every 4, 8, and 12 days' treatments were 7.68, 6.72, and 4.80 inches, respectively. During the period April through October, every month had above-normal precipitation and between crop emergence and crop maturity the total precipitation was 9.89 inches.

The early portion of the crop year 2010 was wet, and irrigation needs were lower than normal. However, later in season, it was extremely dry, with only 1.08 inches of precipitation occurring between August 4 and crop maturity on October 11. Precipitation during the sunflower growing period totaled 7.32 inches. In-season irrigation amounts were 11.52, 6.72, and 4.8 inches for the irrigation capacities limited to 1 in./4 d, 1 in./8 d, and 1 in./12 d, respectively. The 2010 sunflower irrigation amounts appear to be approximately 1 inch less than normal as estimated from long term (1972-2005) irrigation scheduling simulations conducted at Colby, KS.

Extreme drought conditions existed for all of 2012, and only 5.25 inches of precipitation occurred during the sunflower growing period. Additionally, temperatures of 100°F or greater occurred on 20 days between June 26 and August 15. Crop establishment may have been negatively affected by excessively hot temperatures (99 to 104°F) that occurred for the entire period between planting and emergence even though small amounts of irrigation kept sufficient amounts of water in the seed zone. Sunflower plant populations at harvest in 2012 averaged approximately 75% of levels that occurred in 2009 and 2010. In-season irrigation amounts were 13.94, 8.18, and 6.26 inches for the irrigation capacities limited to 1 in./4 d, 1 in./8 d, and 1 in./12 d, respectively.

Summarizing the weather conditions, the crop year 2009 was cooler and wetter than normal, the crop year 2010 was approximately normal, though a severe drought began in early August, and the crop year 2012 was extremely hot and dry.

## *Crop Yields and Yield Components*

The addition of dormant preseason irrigation did not significantly increase yields in any of the three years (Tables 2, 3, and 4), but it did increase achene yield and oil yield by 2%, when all years were analyzed together. Most of the increase in yield for preseason irrigation occurred in the extreme drought year, 2012. Preseason irrigation did significantly increase heads per plant in 2009 and harvest plant population in 2010, but these differences were only about 3% greater. There were no statistically significant differences in yield attributable to irrigation capacity in 2009 and 2012, but increased irrigation capacity did increase achene yield in 2010. Increased irrigation capacity tended to numerically increase achene and oil yield in all three years up through the 1 in./8 d irrigation capacity but tended to have less or no response above that level (Figure 1). Achene yields were lower in 2010 than in 2009 and 2012, but still were towards the upper range of yields for the region.

There were no plant population effects on achene yield in 2009, but increased plant population decreased achene yield in 2010 and increased achene yield in 2012 (Tables 2, 3, and 4). The difference between 2010 and 2012 responses is probably related to the differences in harvest plant populations between the two years. As indicated in earlier section, crop establishment was poor in 2012. Harvest plant populations in 2010 averaged 19,263, 23,426, and 26,257 plants/a for the three respective targets as compared to the much lower 2012 values of 14,452, 17,530, and 19,781 plants/a. Increasing plant population significantly decreased achenes/head in both 2009 and 2010 but had no consistent effect in 2012, once again probably because harvest plant populations were so low (Tables 2, 3, and 4). Increasing plant population significantly decreased achene mass and significantly increased achene oil content (percentage) in all three years. Within a given year average differences in oil content ranged from 1 to 2% as affected by plant population. Harvest plant populations above 19,000 to 20,000 plants/a resulted in reduced achene yields and oil yields, but oil content was greatest at the greatest plant population in all three years (Figure 2).

### *Crop Water Use and Water Productivity*

In-season crop water use was significantly greater due to increased irrigation in all three years (Tables 2, 3, and 4, and Figure 1). However, crop water productivity (WP) was significantly reduced by increased irrigation in all three years. Irrigation amounts ranged from 4.80 to 7.68 inches in 2009, 4.80 to 11.52 inches in 2010, and 6.26 to 13.94 inches in 2012. Soil water depletion decreased with irrigation capacity (data not shown).

### *Canopy Formation*

Seasonal changes in sunflower canopy are shown in Figure 3. Preseason irrigation amounts of 9 inches resulted in greater leaf area from mid-vegetative growth through mid-seed fill in 2012. Canopy formation and senescence occurred relatively earlier in 2010 than 2009 and 2012, which were similar. Canopy formation was greatest in 2010 and least in 2012.

### *Yield Formation*

Achene water content, oil content, and dry mass changes during the season are shown in Figure 4. Achene water contents were greatest for the initial sampling dates and declined throughout the seed fill period. In 2010, achene water content was slightly greater for the largest irrigation capacity. Oil content of achenes increased from the R6 to R8 development stage, remaining consistent through maturity; slightly greater oil contents were observed for the smallest irrigation capacity in 2010. Oil contents from late-season samples appeared similar, though the harvest samples from a larger sampling area (Tables 2, 3, and 4) indicate greatest oil content in 2009 (46.0%) and smallest oil content in 2012 (39.9%). The change in achene mass in 2012, relative to the initial sampling date, was approximately twice the amount than what was observed in 2009 and 2010; this likely reflected effects of the reduced stands discussed earlier. Preseason irrigation resulted in larger achenes in 2009, but smaller achenes in 2012, likely reflecting differences in achenes per head. Cumulative growing degree days appear to provide an inconsistent measure of time relative to onset and completion of the yield formation periods, as indicated by the staggered onset and duration of sampling intervals over the three growing seasons (Figure 4).

### *Conclusion*

Sunflower was grown under sprinkler irrigation in Colby, KS, for three very different crop years (2009, cool and wet year; 2010, near normal overall but very dry after flowering; and 2012, severe drought year with high temperatures). Irrigation capacities were limited to not more than 1 inch every 4, 8, or 12 days, but irrigation events were scheduled only as needed as determined with a weather-based water budget. Seasonal trends indicated earlier canopy formation, greatest canopy extent, and earliest senescence in 2010; least canopy extent developed in 2012. Seasonal trends were similar for achene water content (decreasing through maturity), oil content, and achene mass (increasing through R8 development stage). Achene yield was only statistically increased by irrigation in 2010, but tended to increase numerically up through the medium irrigation level (1 in./8 d) in all three years. Similarly, oil yield plateaued at the medium irrigation level. Dormant preseason irrigation increased achene yield and oil yield by 2%. The optimum harvest plant population for sunflower in this study in terms of achene yield and oil yield was approximately 19,000 to 20,000 plants/a.

## Acknowledgements

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## Reference

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**Table 1. Agronomic characteristics of an irrigated sunflower study conducted at the Kansas State University Northwest Research-Extension Center, Colby, KS, 2009-2012[1]**

| Characteristic | 2009 | 2010 | 2012 |
|---|---|---|---|
| Hybrid | Triumph S671 | Triumph S671 | Triumph S671 |
| Planting date | June 18 | June 16 | June 13 |
| Emergence date | June 25 | June 24 | June 26 |
| Harvest date | October 16 | October 13 | October 8 |
| Rainfall, emergence to maturity (inches) | 9.89 | 7.32 | 5.25 |
| Preseason irrigation (inches) | 5.0 | 5.0 | 9.2 |
| First seasonal irrigation | July 27 | July 25 | July 25 |
| Last seasonal irrigation | September 15 | September 15 | September 23 |

[1]Data from 2011 are excluded due to devastating hail storm.

**Table 2. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2009, Kansas State University Northwest Research-Extension Center, Colby, KS**

| Irrigation capacity | Preseason irrigation | Targeted plant population | Yield | Harvest plant population | Heads /plant | Achenes /head | Achene mass | Achene oil | Water use | Water productivity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1,000 p/a | lb/a | p/a | | | mg | % | in. | lb/a, in. |
| 1 in/4 d (7.68 in.) | None | 18 | 3,266 | 16,262 | 0.94 | 2,114 | 46.6 | 45.6 | 21.94 | 149 |
| | | 23 | 3,324 | 20,183 | 0.92 | 2,043 | 40.2 | 46.2 | 22.49 | 148 |
| | | 23 | 3,109 | 23,813 | 0.93 | 1,720 | 37.2 | 46.6 | 22.10 | 141 |
| | | Mean | 3,233 | 20,086 | 0.93 | 1,959 | 41.3 | 46.2 | 22.18 | 146 |
| | 5 inches | 18 | 3,229 | 16,553 | 0.94 | 2,155 | 44.3 | 45.7 | 22.06 | 146 |
| | | 23 | 3,326 | 20,328 | 0.93 | 1,919 | 42.0 | 46.3 | 22.24 | 150 |
| | | 28 | 3,246 | 22,942 | 0.99 | 1,728 | 39.3 | 46.8 | 22.96 | 141 |
| | | Mean | 3,267 | 19,941 | 0.95 | 1,934 | 41.9 | 46.2 | 22.42 | 146 |
| Mean 1 inch/4 days | | | 3,250 | 20,013 | 0.94 | 1,947 | 41.6 | 46.2 | 22.30 c | 146 b |
| 1 in/8 d (6.72 in.) | None | 18 | 3,376 | 16,698 | 0.95 | 2,259 | 43.4 | 45.7 | 21.08 | 161 |
| | | 23 | 3,189 | 20,183 | 0.95 | 1,893 | 40.4 | 46.0 | 21.29 | 150 |
| | | 23 | 3,081 | 22,506 | 0.96 | 1,790 | 37.5 | 46.5 | 21.89 | 141 |
| | | Mean | 3,215 | 19,796 | 0.95 | 1,981 | 40.4 | 46.1 | 21.42 | 151 |
| | 5 inches | 18 | 3,427 | 16,553 | 0.99 | 2,214 | 42.8 | 45.0 | 21.56 | 159 |
| | | 23 | 3,208 | 19,312 | 0.96 | 1,934 | 40.6 | 46.1 | 21.21 | 151 |
| | | 28 | 3,332 | 22,506 | 1.01 | 1,766 | 38.4 | 46.6 | 22.01 | 152 |
| | | Mean | 3,322 | 19,457 | 0.99 | 1,971 | 40.6 | 45.9 | 21.60 | 154 |
| Mean 1 inch/8 days | | | 3,269 | 19,626 | 0.97 | 1,976 | 40.5 | 46.0 | 21.51 b | 152 a |
| 1 in/12 d (4.80 in.) | None | 18 | 3,158 | 16,408 | 0.93 | 2,198 | 42.8 | 45.7 | 20.38 | 155 |
| | | 23 | 3,186 | 19,457 | 0.96 | 1,923 | 40.3 | 45.9 | 20.75 | 154 |
| | | 23 | 3,168 | 24,103 | 0.91 | 1,728 | 38.3 | 46.5 | 20.75 | 153 |
| | | Mean | 3,171 | 19,989 | 0.93 | 1,950 | 40.5 | 46.0 | 20.63 | 154 |
| | 5 inches | 18 | 3,100 | 16,117 | 0.97 | 2,127 | 42.3 | 46.1 | 20.36 | 152 |
| | | 23 | 3,345 | 19,166 | 0.96 | 1,985 | 41.9 | 45.6 | 20.41 | 164 |
| | | 28 | 3,279 | 23,522 | 0.94 | 1,758 | 38.4 | 46.2 | 20.68 | 159 |
| | | Mean | 3,241 | 19,602 | 0.96 | 1,957 | 40.8 | 45.9 | 20.48 | 158 |
| Mean 1 inch/12 days | | | 3,206 | 19,796 | 0.95 | 1,953 | 40.7 | 46.0 | 20.56 a | 156 a |
| Study-wide mean | | | 3,242 | 19,812 | 0.95 | 1,959 | 40.9 | 46.0 | 21.45 | 151 |
| Preseason irrigation | None | | 3,206 | 19,957 | 0.94 a | 1,963 | 40.7 | 46.1 | 21.41 | 150 |
| | 5 inches | | 3,277 | 19,667 | 0.97 b | 1,954 | 41.1 | 46.0 | 21.50 | 153 |
| Target plant population (1000 p/a) | | 18 | 3,260 | 16,432 a | 0.95 | 2,178 a | 43.7 a | 45.6 c | 21.23 a | 154 a |
| | | 23 | 3,263 | 19,771 b | 0.95 | 1,950 b | 40.9 b | 46.0 b | 21.40 a | 153 a |
| | | 28 | 3,203 | 23,232 c | 0.96 | 1,748 c | 38.2 c | 46.5 a | 21.73 b | 148 b |

Shaded items within a column are significantly different at $P < 0.05$ when followed by a different lower-cased letter.

**Table 3. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2010, Kansas State University Northwest Research-Extension Center, Colby, KS**

| Irrigation capacity | Preseason irrigation | Targeted plant population | Yield | Harvest plant population | Heads /plant | Achenes /head | Achene mass | Achene oil | Water use | Water productivity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1,000 p/a | lb/a | p/a | | | mg | % | in. | lb/a, in. |
| 1 in/4 d (11.52 in) | None | 18 | 3,172 | 20,038 | 0.94 | 1,916 | 40.4 | 44.2 | 22.69 | 141 |
| | | 23 | 2,919 | 23,668 | 0.89 | 1,631 | 38.6 | 44.7 | 22.74 | 128 |
| | | 28 | 2,946 | 27,007 | 0.85 | 1,570 | 37.4 | 45.0 | 23.32 | 127 |
| | | Mean | 3,012 | 23,571 | 0.90 | 1,706 | 38.8 | 44.6 | 22.92 | 132 |
| | 5 inches | 18 | 3,000 | 19,166 | 0.93 | 1,845 | 42.3 | 43.8 | 20.99 | 143 |
| | | 23 | 3,062 | 23,958 | 0.95 | 1,646 | 37.3 | 44.7 | 21.15 | 146 |
| | | 28 | 2,987 | 25,265 | 0.95 | 1,597 | 36.1 | 45.3 | 20.72 | 145 |
| | | Mean | 3,172 | 20,038 | 0.94 | 1,916 | 40.4 | 44.2 | 22.69 | 141 |
| Mean 1 inch/4 days | | | 3,014 a | 23,184 | 0.92 | 1,701 | 38.7 | 44.6 a | 21.93 a | 138 c |
| 1 in/8 d (6.72 in) | None | 18 | 3,043 | 19,602 | 0.92 | 1,893 | 41.0 | 44.5 | 19.63 | 157 |
| | | | 2,989 | 23,377 | 0.98 | 1,668 | 36.1 | 44.6 | 20.01 | 150 |
| | | | 3,004 | 25,700 | 0.97 | 1,563 | 35.7 | 45.3 | 19.36 | 156 |
| | | | 3,012 | 22,893 | 0.96 | 1,708 | 37.6 | 44.8 | 19.66 | 154 |
| | 5 inches | 18 | 3,091 | 18,440 | 0.98 | 1,912 | 40.6 | 44.3 | 19.01 | 164 |
| | | | 2,892 | 23,087 | 0.93 | 1,647 | 37.2 | 44.7 | 19.31 | 151 |
| | | | 2,951 | 25,410 | 0.98 | 1,506 | 36.3 | 45.3 | 19.58 | 152 |
| | | | 3,043 | 19,602 | 0.92 | 1,893 | 41.0 | 44.5 | 19.63 | 157 |
| Mean 1 inch/8 days | | | 2,995 a | 22,603 | 0.96 | 1,698 | 37.8 | 44.8 a | 19.48 b | 155 b |
| 1 in/12 d (4.80 in) | None | 18 | 2,983 | 19,312 | 0.96 | 1,868 | 39.4 | 43.2 | 17.25 | 175 |
| | | | 2,886 | 23,522 | 0.96 | 1,715 | 34.4 | 43.6 | 16.85 | 175 |
| | | | 2,705 | 27,588 | 0.88 | 1,480 | 34.4 | 44.0 | 17.10 | 159 |
| | | | 2,858 | 23,474 | 0.93 | 1,688 | 36.1 | 43.6 | 17.07 | 170 |
| | 5 inches | 18 | 3,059 | 19,021 | 0.95 | 1,983 | 39.0 | 43.7 | 18.12 | 170 |
| | | | 2,831 | 22,942 | 0.94 | 1,613 | 37.0 | 43.6 | 17.99 | 158 |
| | | | 2,833 | 26,572 | 0.91 | 1,511 | 35.5 | 44.1 | 17.67 | 162 |
| | | | 2,908 | 22,845 | 0.93 | 1,702 | 37.2 | 43.8 | 17.93 | 163 |
| Mean 1 inch/12 days | | | 2883 b | 23,159 | 0.93 | 1,695 | 36.6 | 43.7 b | 17.50 c | 167 a |
| Study-wide mean | | | 2,964 | 22,982 | 0.94 | 1,698 | 37.7 | 44.4 | 19.64 | 153 |
| Preseason irrigation | None | | 2,961 | 23,313 a | 0.93 | 1,700 | 37.5 | 44.3 | 19.88 | 152 |
| | 5 inches | | 2,967 | 22,651 b | 0.95 | 1,695 | 37.9 | 44.4 | 19.39 | 155 |
| Target plant population (1000 p/a) | | 18 | 3,058 a | 19,263 c | 0.94 | 1,903 a | 40.5 a | 43.9 c | 19.61 | 158 a |
| | | 23 | 2,930 b | 23,426 b | 0.94 | 1,653 b | 36.8 b | 44.3 b | 19.67 | 151 b |
| | | 28 | 2,904 b | 26,257 a | 0.92 | 1,538 c | 35.9 b | 44.8 a | 19.62 | 150 b |

Shaded items within a column are significantly different at $P < 0.05$ when followed by a different lower-cased letter.

**Table 4. Summary of sunflower yield components and water use parameters for a sprinkler irrigated study, 2012, Kansas State University Northwest Research-Extension Center, Colby, KS**

| Irrigation capacity | Preseason irrigation | Targeted plant population | Yield | Harvest plant population | Heads /plant | Achenes /head | Achene mass | Achene oil | Water use | Water productivity |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1,000 p/a | lb/a | p/a | | | mg | % | in. | lb/a, in. |
| 1 in/4 d (13.94 in.) | None | 18 | 3,145 | 14,956 | 1.00 | 1,555 | 61.6 | 39.4 | 24.82 | 126 |
| | | | 3,265 | 16,988 | 0.99 | 1,497 | 59.6 | 39.8 | 25.89 | 126 |
| | | | 3,315 | 21,635 | 0.87 | 1,750 | 52.9 | 41.6 | 24.86 | 133 |
| | | | 3,242 | 17,860 | 0.95 | 1,601 | 58.0 | 40.3 | 25.19 | 129 |
| | 9.2 inches | 18 | 3,183 | 14,985 | 1.00 | 1,666 | 58.1 | 39.1 | 25.33 | 126 |
| | | | 3,448 | 17,424 | 0.99 | 1,572 | 58.2 | 40.3 | 25.64 | 134 |
| | | | 3,662 | 19,689 | 0.99 | 1,599 | 53.7 | 40.3 | 26.79 | 137 |
| | | | 3,431 | 17,366 | 0.99 | 1,612 | 56.6 | 39.9 | 25.92 | 132 |
| Mean 1 inch/4 days | | | 3,328 | 17,635 | 0.97 | 1,606 | 57.4 | 40.1 | 25.52 a | 130 c |
| 1 in/8 d (8.18 in.) | None | 18 | 3,191 | 13,939 | 1.00 | 1,717 | 62.6 | 38.9 | 20.45 | 157 |
| | | | 3,160 | 16,698 | 0.99 | 1,494 | 58.8 | 39.6 | 20.23 | 156 |
| | | | 3,423 | 19,747 | 1.00 | 1,439 | 55.3 | 40.8 | 20.80 | 165 |
| | | | 3,258 | 16,795 | 1.00 | 1,550 | 58.9 | 39.7 | 20.49 | 159 |
| | 9.2 inches | 18 | 3,148 | 14,375 | 1.00 | 1,544 | 65.2 | 39.2 | 18.61 | 172 |
| | | | 3,310 | 17,569 | 0.98 | 1,495 | 59.4 | 40.1 | 18.37 | 181 |
| | | | 3,480 | 19,747 | 1.00 | 1,414 | 58.0 | 41.5 | 18.75 | 187 |
| | | | 3,313 | 17,230 | 0.99 | 1,484 | 60.9 | 40.3 | 18.58 | 180 |
| Mean 1 inch/8 days | | | 3,286 | 17,013 | 0.99 | 1,517 | 59.9 | 40.0 | 19.54 b | 169 b |
| 1 in/12 d (6.26 in.) | None | 18 | 3,237 | 14,462 | 1.00 | 1,610 | 63.8 | 39.1 | 17.41 | 188 |
| | | | 3,126 | 17,772 | 0.98 | 1,280 | 64.9 | 39.9 | 17.18 | 183 |
| | | | 3,121 | 18,121 | 1.00 | 1,490 | 54.5 | 40.0 | 17.43 | 180 |
| | | | 3,161 | 16,785 | 0.99 | 1,460 | 61.0 | 39.7 | 17.34 | 183 |
| | 9.2 inches | 18 | 3,074 | 14,084 | 1.00 | 1,440 | 70.1 | 38.4 | 18.52 | 168 |
| | | | 3,487 | 18,992 | 0.99 | 1,478 | 57.5 | 39.8 | 18.47 | 191 |
| | | | 3,417 | 19,457 | 0.97 | 1,410 | 59.3 | 40.5 | 18.47 | 186 |
| | | | 3,316 | 17,424 | 0.99 | 1,440 | 62.6 | 39.5 | 18.49 | 181 |
| Mean 1 inch/12 days | | | 3,244 | 17,125 | 0.99 | 1,450 | 61.9 | 39.6 | 17.95 c | 182 a |
| Study-wide mean | | | 3,286 | 17,251 | 0.99 | 1,525 | 59.7 | 39.9 | 20.99 | 161 |
| Preseason irrigation | None | | 3,224 | 17,168 | 0.98 | 1,541 | 59.2 | 39.9 | 21.22 | 156 |
| | 9.2 inches | | 3,350 | 17,337 | 0.99 | 1,508 | 60.2 | 39.9 | 20.75 | 166 |
| Target plant population (1000 p/a) | | 18 | 3,160 b | 14,452 c | 1.00 | 1,586 | 63.7 a | 39.0 c | 20.83 | 156 |
| | | 23 | 3,294 ab | 17,530 b | 0.99 | 1,472 | 59.7 b | 39.9 b | 21.01 | 161 |
| | | 28 | 3,404 a | 19,781 a | 0.97 | 1,515 | 55.7 c | 40.8 a | 21.13 | 165 |

Shaded items within a column are significantly different at $P < 0.05$ when followed by a different lower-cased letter.

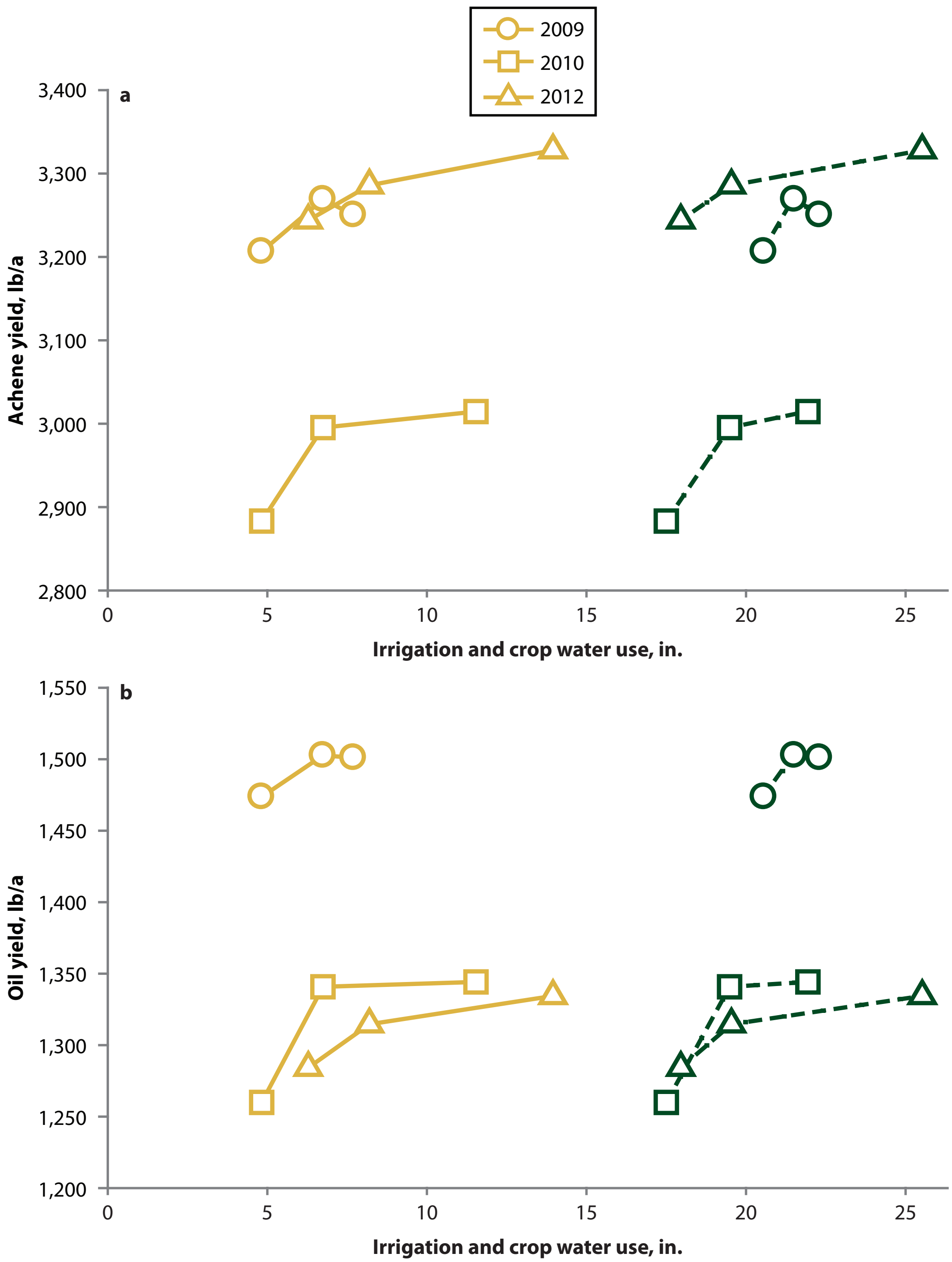



**Figure 1. Achene yield and oil yield as related to irrigation amount and total crop water use in a sprinkler irrigated sunflower study, Kansas State University Northwest Research-Extension Center, Colby, KS, 2009-2012. Irrigation responses are in yellow unbroken lines and crop water use responses in green dashed lines.**

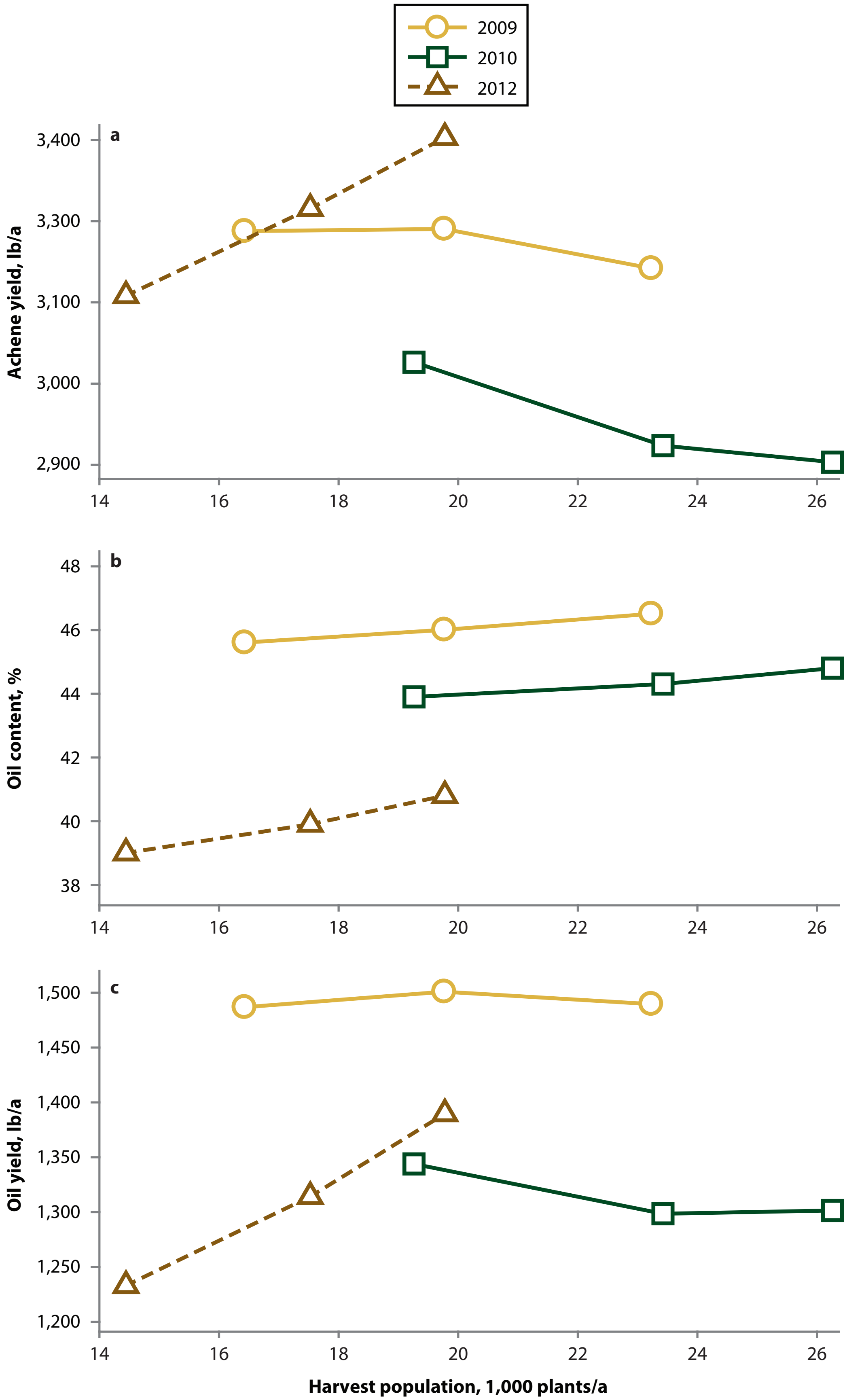



**Figure 2. Achene yield, oil content, and oil yield as related to harvest plant population in a sprinkler irrigated sunflower study, Kansas State University Northwest Research-Extension Center, Colby, KS, 2009-2012.**

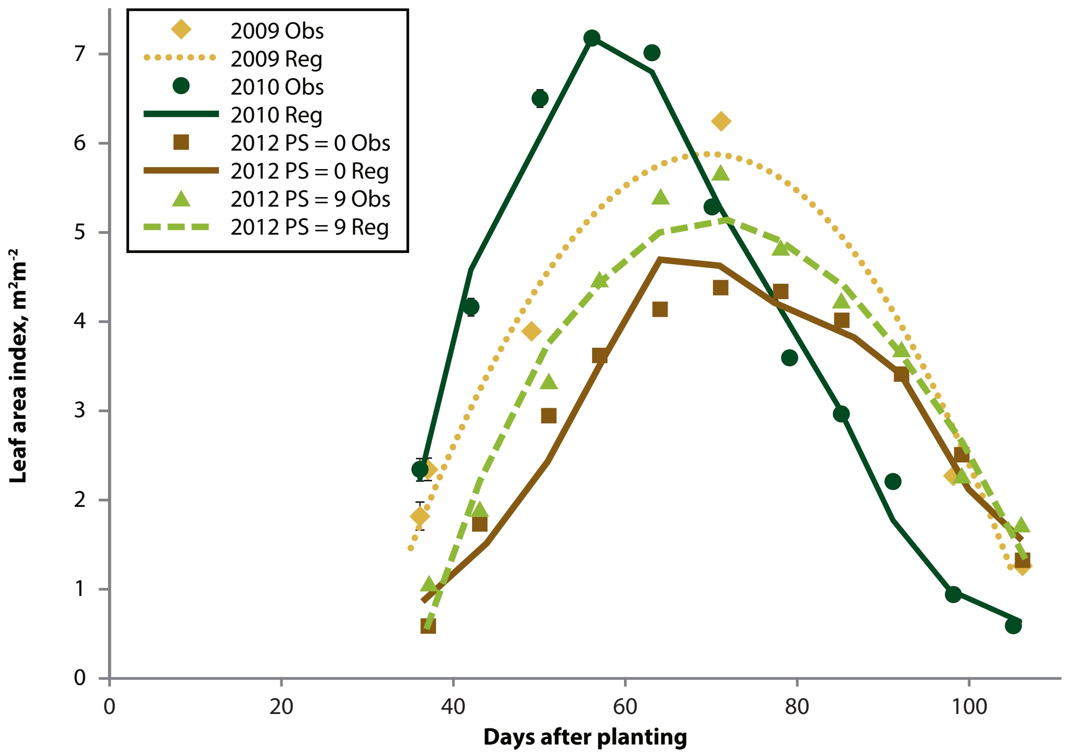



**Figure 3. Seasonal trends in canopy formation and senescence are shown in relation to days after planting for a sprinkler irrigated sunflower study, Kansas State University Northwest Research-Extension Center, Colby, KS, 2009-2012. Note that symbols represent field observations and lines represent a trend model. Preseason irrigation effects (0 or 9 inches) were detected in 2012.**

[1] Mention of tradenames is for informational purposes only and does not constitute endorsement by the authors or by the institutions they serve.

# Alternatives to Glyphosate for Palmer Amaranth Control in Wheat Stubble

*D.E. Peterson, C.R. Thompson, and C.L. Minihan*

## Summary
Glyphosate-resistant Palmer amaranth has become a serious weed problem in fields following wheat harvest. A field experiment was established in 2016 near Manhattan, KS, to evaluate herbicide alternatives to glyphosate for Palmer amaranth control in wheat stubble. The two most effective postharvest herbicides for control of Palmer amaranth were Gramoxone (paraquat) or Sharpen (saflufenacil). Clarity (dicamba) and 2,4-D treatments provided suppression of Palmer amaranth, but were inconsistent, and often some plants survived and produced viable seed. The tank-mix of Clarity plus 2,4-D was more effective than either herbicide alone, but not as good as Gramoxone or Sharpen.

## Introduction
Glyphosate plus 2,4-D and/or dicamba was a standard treatment for weed control in wheat stubble in the Great Plains region for many years. It was assumed that the 2,4-D and dicamba components were making a significant contribution to broadleaf weed control, but with the development of glyphosate-resistant weeds, especially Palmer amaranth, the treatment is no longer providing the desired level of weed control in many cases. Apparently, glyphosate was ultimately providing much of the weed control in the tank-mix combinations, especially with the modest rates of 2,4-D and dicamba that were typically included in the treatments. Consequently, cost-effective alternative treatments need to be developed to help manage weeds in wheat stubble to maintain the economic viability of no-till cropping systems.

## Procedures
A field experiment was established in a wheat stubble field near Manhattan, KS, in August, 2016. Treatments were applied to 4- to 24-inch Palmer amaranth and 1- to 6-inch large crabgrass on August 4 at 85°F, 58% relative humidity, mostly clear skies, and adequate soil moisture for active plant growth. Treatments were applied with a $CO_2$ backpack sprayer, delivering 15 gpa at 35 psi through AIXR110015 flat fan spray tips to the center 6.3 ft of 10 by 25 ft plots. The experiment was a randomized complete block design with four replications. Palmer amaranth and large crabgrass control were visually evaluated at 2 and 4 weeks after treatment (WAT).

## Results

The two most effective postharvest treatments for control of Palmer amaranth included Gramoxone SL at 3 pt/a and Sharpen at 2 oz/a. Palmer amaranth control with lower rates of Sharpen has not been as effective. Tank-mixing 2,4-D with Sharpen tended to improve control. Herbicide tank-mixes with Gramoxone did not enhance Palmer amaranth control in this experiment because of the high level of control achieved with Gramoxone alone; however, tank-mixes often improve broadleaf weed control with Gramoxone and would be a good herbicide-resistance management practice. Clarity or 2,4-D treatments provided suppression of Palmer amaranth but were inconsistent, and often some plants survived and produced viable seed. The combination of Clarity plus 2,4-D provided better Palmer amaranth control than either herbicide alone. The only herbicide in this experiment that provided good large crabgrass control was Gramoxone. However, grass control with Gramoxone may be inconsistent, especially with larger grasses and thicker weed canopies.

**Table 1. Palmer amaranth and large crabgrass control with post-harvest treatments in wheat stubble, Manhattan, KS, 2016**

| | | Palmer amaranth | | Large crabgrass | |
|---|---|---|---|---|---|
| Treatment* | Rate | 2 WAT | 4 WAT | 2 WAT | 4 WAT |
| | product/a | ------------------------(% control)----------------------- | | | |
| 2,4-D LV4 | 1 pt | 58 | 63 | 0 | 0 |
| 2,4-D LV4 | 2 pt | 69 | 75 | 0 | 0 |
| 2,4-D Amine 4 | 2 pt | 73 | 76 | 0 | 0 |
| Clarity | 0.5 pt | 58 | 66 | 0 | 0 |
| Clarity | 1 pt | 63 | 69 | 0 | 0 |
| 2,4-D + Clarity | 2 pt + 0.5 pt | 83 | 89 | 0 | 0 |
| Sharpen + MSO + AMS | 2 oz | 95 | 95 | 45 | 40 |
| Sharpen + 2,4-D LV4 + MSO + AMS | 2 oz + 2 pt | 99 | 98 | 48 | 45 |
| Gramoxone SL + NIS | 3 pt | 100 | 100 | 94 | 94 |
| Gramoxone SL + 2,4-D LV4 + NIS | 3 pt + 1 pt | 100 | 100 | 96 | 97 |
| Gramoxone SL + Sharpen + MSO + AMS | 3 pt + 1 oz | 100 | 100 | 94 | 94 |
| Gramoxone SL + Tricor + NIS | 3 pt + 6 oz | 100 | 100 | 97 | 97 |
| Least significant difference ($P < 0.05$) | | 6 | 6 | 4 | 4 |

* MSO = methylated seed oil applied at 1% v/v; AMS = liquid ammonium sulfate applied at 2.5% v/v; NIS = nonionic surfactant applied at 0.25% v/v; and WAT = weeks after treatment.

**Figure 1. Palmer amaranth at treatment time.**

**Figure 2. Application of 2,4-D LV4, 2 pt/a, at 3 weeks after treatment.**

**Figure 3. Clarity, 1 pt/a, at 3 weeks after treatment.**

**Figure 4. Application of 2,4-D LV4 + Clarity, 2 pt/a + 0.5 pt/a, at 3 weeks after treatment.**

**Figure 5. Sharpen + MSO + AMS, 2 oz/a + 1% v/v + 2.5% v/v, at 3 weeks after treatment.**

**Figure 6. Gramoxone SL + NIS, 3 pt/a + 0.25% v/v, at 3 weeks after treatment.**

# Sequential Weed Control Programs in No-Tillage Xtend Soybeans

*D.E. Peterson, C.R. Thompson, and C.L. Minihan*

## Summary
The development of glyphosate resistant weeds has greatly complicated weed control in soybeans. Roundup Ready 2 Xtend (dicamba tolerant) soybeans provide growers an alternative herbicide option for preplant and postemergence weed control in soybeans. Preplant programs that included dicamba provided excellent control of giant ragweed. Sequential programs consisting of Envive or Enlite plus glyphosate and dicamba preplant followed by postemergence treatments that included glyphosate and dicamba provided excellent control of henbit, giant ragweed, Palmer amaranth, and large crabgrass.

## Introduction
Weeds are a major production problem in soybeans, especially with the development of glyphosate resistant weeds. Roundup Ready 2 Xtend (RR2X) soybeans provide a new herbicide option for preplant and postemergence weed control in soybeans.

## Procedures
A field experiment was established near Manhattan, KS, on a Reading silt loam soil with 3.3% organic matter and a pH of 6.7. The plot area had a natural infestation of henbit, giant ragweed (moderate level of glyphosate resistance), Palmer amaranth, and large crabgrass. Preplant (PP) treatments were applied to blooming henbit, and 1- to 12-inch giant ragweed on May 3, 2016, at 72°F, 35% relative humidity, and mostly clear skies. Pioneer P31T52X RR2X soybeans were planted at 120,000 seeds/a in 30-inch rows on May 23, 2016. Postemergence (P) treatments were applied to 2-trifoliate-leaf soybeans (6 inch), 3- to 6-inch Palmer amaranth, and 1- to 6-inch large crabgrass on June 13, 2016, with 82°F, 35% relative humidity, and partly cloudy skies. Treatments were applied with a $CO_2$ backpack sprayer, delivering 15 gpa at 35 psi through TTI110015 flat fan spray tips to the center 6.3 ft of 10 by 25 ft plots. The experiment had a randomized complete block design with three replications. Crop injury and weed control were visually evaluated throughout the growing season.

## Results
All treatments eventually provided excellent control of all broadleaf weeds evaluated and very good control of large crabgrass. Postemergence Roundup PowerMax plus dicamba (Fexapan) and Cinch treatments caused minor leaf spotting, and postemergence treatments with Cobra caused more severe foliar burn to soybeans, but new growth was unaffected.

**Table 1. Weed control in RR2X soybeans on May 31, 2016, Manhattan, KS**

| Treatment* | Application timing | Application rate | Henbit | Giant ragweed | Palmer amaranth |
|---|---|---|---|---|---|
| | | oz/a | ------------------- | % control | ------------------ |
| Envive+RU PowerMax+Fexapan#/ RU PowerMax+Fexapan | PP/ P | 2.5+22+22/ 22+22 | 100 | 99 | 100 |
| Envive+RU PowerMax+Fexapan/ RU PowerMax+Cinch+Fexapan | PP/ P | 2.5+22+22/ 22+16+22 | 100 | 99 | 100 |
| Envive+RU PowerMax+Fexapan/ RU PowerMax+Cobra+Cinch | PP/ P | 2.5+22+22/ 22+10+16 | 100 | 99 | 100 |
| Enlite+RU PowerMax+Fexapan/ RU PowerMax+Fexapan | PP/ P | 3.5+22+22/ 22+22 | 100 | 100 | 100 |
| Enlite+RU PowerMax+Fexapan/ RU PowerMax+Cinch+Fexapan | PP/ P | 3.5+22+22/ 22+16+22 | 100 | 99 | 100 |
| Envive+RU PowerMax+Fexapan/ RU PowerMax+Cobra+Cinch | PP/ P | 3.5+22+22/ 22+10+16 | 100 | 100 | 100 |
| Least significant difference ($P < 0.05$) | | | NS | NS | NS |

* / indicates sequential application; PP = preplant; and P = postemergence.
# Non-labelled dicamba product actually applied, but equivalent Fexapan rates presented.

**Table 2. Weed control in RR2X soybeans on July 26, 2016, Manhattan, KS**

| Treatment* | Application timing | Application rate | Large crabgrass | Giant ragweed | Palmer amaranth |
|---|---|---|---|---|---|
| | | oz/a | ------------------- | % control | ------------------ |
| Envive+RU PowerMax+Fexapan#/ RU PowerMax+Fexapan | PP/ P | 2.5+22+22/ 22+22 | 94 | 100 | 100 |
| Envive+RU PowerMax+Fexapan/ RU PowerMax+Cinch+Fexapan | PP/ P | 2.5+22+22/ 22+16+22 | 97 | 100 | 100 |
| Envive+RU PowerMax+Fexapan/ RU PowerMax+Cobra+Cinch | PP/ P | 2.5+22+22/ 22+10+16 | 97 | 100 | 100 |
| Enlite+RU PowerMax+Fexapan/ RU PowerMax+Fexapan | PP/ P | 3.5+22+22/ 22+22 | 94 | 100 | 100 |
| Enlite+RU PowerMax+Fexapan/ RU PowerMax+Cinch+Fexapan | PP/ P | 3.5+22+22/ 22+16+22 | 97 | 100 | 100 |
| Envive+RU PowerMax+Fexapan/ RU PowerMax+Cobra+Cinch | PP/ P | 3.5+22+22/ 22+10+16 | 96 | 100 | 100 |
| Least significant difference ($P < 0.05$) | | | 3 | NS | NS |

* / indicates sequential application; PP = preplant; and P = postemergence.
# Non-labelled dicamba product actually applied, but equivalent Fexapan rates presented.

**Table 3. Soybean injury to RR2X soybeans on May 31, 2016, Manhattan, KS**

| Treatment* | Application timing | Application rate | Soybean injury | | |
|---|---|---|---|---|---|
| | | | June 20 | July 8 | July 26 |
| | | oz/a | ------------------- % control ------------------ | | |
| Envive+RU PowerMax+Fexapan#/ RU PowerMax+Fexapan | PP/ P | 2.5+22+22/ 22+22 | 2 | 0 | 0 |
| Envive+RU PowerMax+Fexapan/ RU PowerMax+Cinch+Fexapan | PP/ P | 2.5+22+22/ 22+16+22 | 5 | 0 | 0 |
| Envive+RU PowerMax+Fexapan/ RU PowerMax+Cobra+Cinch | PP/ P | 2.5+22+22/ 22+10+16 | 20 | 7 | 0 |
| Enlite+RU PowerMax+Fexapan/ RU PowerMax+Fexapan | PP/ P | 3.5+22+22/ 22+22 | 3 | 0 | 0 |
| Enlite+RU PowerMax+Fexapan/ RU PowerMax+Cinch+Fexapan | PP/ P | 3.5+22+22/ 22+16+22 | 5 | 0 | 0 |
| Envive+RU PowerMax+Fexapan/ RU PowerMax+Cobra+Cinch | PP/ P | 3.5+22+22/ 22+10+16 | 25 | 10 | 5 |
| Least significant difference ( $P < 0.05$) | | | 4 | 2 | 2 |

* / indicates sequential application; PP = preplant; and P = postemergence.
# Non-labelled dicamba product actually applied, but equivalent Fexapan rates presented.

**Figure 1. Application of Envive + Roundup Power Max + dicamba preplant followed by Roundup Power Max + dicamba postemergence.**

# Sequential Weed Control Programs in Liberty Link Soybeans

*D.E. Peterson, C.R. Thompson, and C.L. Minihan*

## Summary

The development of glyphosate-resistant weeds has greatly complicated weed control in soybeans. Liberty Link soybeans provide growers an alternative herbicide option for postemergence weed control in soybeans. Liberty Link programs can provide effective weed control in a sequential weed-control program that includes effective preemergence residual herbicides at planting time followed by timely applications of Liberty.

## Introduction

Weeds are a major production problem in soybeans, especially with the development of glyphosate-resistant weeds. Liberty Link soybeans provide growers an alternative herbicide option for postemergence weed control in soybeans.

## Procedures

A field experiment was established near Manhattan, KS, on a Reading silt loam soil with 2.7% organic matter and a pH of 5.8. The plot area had a natural infestation of Palmer amaranth (mixed population of glyphosate-susceptible and resistant biotypes), velvetleaf, and ivyleaf morning glory. Credenz CZ3841 Liberty Link soybeans were planted at 120,000 seeds/a in 30-inch rows on May 12, 2016, into a recently tilled seedbed. Preemergence (PRE) treatments were applied on May 13. A good, activating rain was received within 4 days after planting, and more than 5 inches of rain was received during a 4-day period 12 to 15 days after planting. Early postemergence (EP) treatments were applied to 2-trifoliate-leaf soybeans (6 inch), 1- to 2-inch Palmer amaranth, 1- to 3-inch velvetleaf, and 1- to 2-inch morning glory on June 3 at 83°F, 45% relative humidity, and mostly clear skies. Postemergence (P) treatments were applied to 5 trifoliate leaf soybeans (12 inch), 1- to 12-inch Palmer amaranth, 6- to 10-inch velvetleaf, and 1- to 4-inch morning glory on June 15, with 94°F, 45% relative humidity, and clear skies. Treatments were applied with a compressed-air tractor sprayer, delivering 15 GPA at 26 psi through AIXR110025 flat fan spray tips to the center 6.7 ft of 10 by 25 ft plots. The experiment had a randomized complete block design with three replications. Crop injury and weed control were visually evaluated throughout the growing season, and soybeans were harvested from the center 2 rows of the plots on October 24.

## Results

Good early rainfall resulted in good herbicide activity. Preemergence Valor XLT and Fierce caused some early-season soybean stunting, but soybeans recovered over time. Early postemergence (EP) treatments that included Anthem Maxx caused foliar burn to soybeans, but new growth was unaffected. No soybean injury was evident at the July 14 evaluation (data not presented). All PRE herbicide treatments provided excellent early-season Palmer amaranth control. All sequential herbicide treatments gave very good late-season Palmer amaranth control, which was better than single applications of Liberty, especially the postemergence (P) timing. All PRE treatments except Prefix provided good early-season velvetleaf control. All treatments except Liberty P gave 95% or better control of velvetleaf at the July 14 evaluation. All PRE treatments except Prefix and Boundary provided 85% or better morning glory control prior to EP applications. All treatments except Boundary followed by Liberty or single applications of Liberty provided 90% or better morning glory control by the final evaluation. Soybean yields were very high as a result of good precipitation through the growing season. Soybean yields generally corresponded to the level of weed control.

**Table 1. Weed control in Liberty Link soybeans on May 31, 2016, Manhattan, KS**

| Treatment* | Application timing | Application rate | Palmer amaranth | Velvet-leaf | Morning glory |
|---|---|---|---|---|---|
| | | oz/a | % control | | |
| Authority First/Liberty 280+AMS | PRE/EP | 6.4/29 | 100 | 96 | 96 |
| Authority Maxx/Liberty 280+AMS | PRE/EP | 6.4/29 | 100 | 89 | 93 |
| Valor XLT/Liberty 280+AMS | PRE/EP | 4/29 | 100 | 97 | 85 |
| Fierce/Liberty 280+AMS | PRE/EP | 3.75/29 | 100 | 100 | 87 |
| Prefix/Liberty 280+AMS | PRE/EP | 32/29 | 100 | 53 | 49 |
| Boundary/Liberty 280+AMS | PRE/EP | 32/29 | 100 | 95 | 17 |
| Authority Elite/Liberty 280+AMS | PRE/EP | 32/29 | 100 | 88 | 88 |
| Authority First/ Anthem Maxx+Liberty 280+AMS | PRE/ EP | 5/ 3+29 | 99 | 98 | 92 |
| Authority MTZ/Liberty 280+AMS | PRE/EP | 14/29 | 99 | 94 | 90 |
| Authority MTZ/ Anthem Maxx+Liberty 280+AMS | PRE/ EP | 14/ 3+29 | 99 | 92 | 88 |
| Liberty 280+AMS | EP | 29 | --- | --- | --- |
| Liberty 280+AMS | P | 29 | --- | --- | --- |
| Liberty 280+AMS/Liberty 280+AMS | EP/P | 29/29 | --- | --- | --- |
| Least significant difference ($P < 0.05$) | | | NS | 9 | 14 |

* / indicates sequential application; AMS = ammonium sulfate applied at 1.5 lb/a; PRE = preemergence; EP = early postemergence; and P = postemergence.

**Table 2. Weed control in Liberty Link soybeans on July 14, 2016, Manhattan, KS**

| Treatment* | Application timing | Application rate | Palmer amaranth | Velvet-leaf | Morning glory |
|---|---|---|---|---|---|
| | | oz/a | ------------------- | % control | ------------------- |
| Authority First/Liberty 280+AMS | PRE/EP | 6.4/29 | 98 | 100 | 97 |
| Authority Maxx/Liberty 280+AMS | PRE/EP | 6.4/29 | 100 | 98 | 96 |
| Valor XLT/Liberty 280+AMS | PRE/EP | 4/29 | 100 | 97 | 90 |
| Fierce/Liberty 280+AMS | PRE/EP | 3.75/29 | 99 | 97 | 95 |
| Prefix/Liberty 280+AMS | PRE/EP | 32/29 | 100 | 95 | 90 |
| Boundary/Liberty 280+AMS | PRE/EP | 32/29 | 100 | 100 | 83 |
| Authority Elite/Liberty 280+AMS | PRE/EP | 32/29 | 100 | 100 | 95 |
| Authority First/ Anthem Maxx+Liberty 280+AMS | PRE/ EP | 5/ 3+29 | 98 | 100 | 97 |
| Authority MTZ/Liberty 280+AMS | PRE/EP | 14/29 | 97 | 95 | 97 |
| Authority MTZ/ Anthem Maxx+Liberty 280+AMS | PRE/ EP | 14/ 3+29 | 98 | 97 | 94 |
| Liberty 280+AMS | EP | 29 | 92 | 95 | 83 |
| Liberty 280+AMS | P | 29 | 63 | 77 | 60 |
| Liberty 280+AMS/Liberty 280+AMS | EP/P | 29/29 | 97 | 100 | 92 |
| Least significant difference ($P < 0.05$) | | | 4 | 7 | 7 |

* / indicates sequential application; AMS = ammonium sulfate applied at 1.5 lb/a; PRE = preemergence; EP = early postemergence; and P = postemergence.

**Table 3. Soybean injury and yield of Liberty Link soybeans, Manhattan, KS, 2016**

| Treatment* | Application timing | Application rate | Soybean injury 5-31-16 | Soybean injury 6-15-16 | Soybean yield |
|---|---|---|---|---|---|
| | | oz/a | % control | | |
| Authority First/Liberty 280+AMS | PRE/EP | 6.4/29 | 0 | 0 | 78 |
| Authority Maxx/Liberty 280+AMS | PRE/EP | 6.4/29 | 0 | 2 | 81 |
| Valor XLT/Liberty 280+AMS | PRE/EP | 4/29 | 12 | 0 | 77 |
| Fierce/Liberty 280+AMS | PRE/EP | 3.75/29 | 15 | 5 | 76 |
| Prefix/Liberty 280+AMS | PRE/EP | 32/29 | 0 | 0 | 80 |
| Boundary/Liberty 280+AMS | PRE/EP | 32/29 | 0 | 0 | 74 |
| Authority Elite/Liberty 280+AMS | PRE/EP | 32/29 | 0 | 0 | 82 |
| Authority First/ Anthem Maxx+Liberty 280+AMS | PRE/ EP | 5/ 3+29 | 0 | 8 | 79 |
| Authority MTZ/Liberty 280+AMS | PRE/EP | 14/29 | 0 | 0 | 78 |
| Authority MTZ/ Anthem Maxx+Liberty 280+AMS | PRE/ EP | 14/ 3+29 | 0 | 6 | 77 |
| Liberty 280+AMS | EP | 29 | - | 0 | 70 |
| Liberty 280+AMS | P | 29 | - | - | 50 |
| Liberty 280+AMS/Liberty 280+AMS | EP/P | 29/29 | - | 0 | 77 |
| Least significant difference ($P < 0.05$) | | | 2 | 3 | 7 |

* / indicates sequential application; AMS = ammonium sulfate applied at 1.5 lb/a; PRE = preemergence; EP = early postemergence; and P = postemergence.

**Figure 1. Authority First PRE followed by Liberty postemergence.**

# Two Pass Weed Control Programs in Conventional Tillage Xtend Soybeans

*D.E. Peterson, C.R. Thompson, and C.L. Minihan*

## Summary
The development of glyphosate-resistant weeds has greatly complicated weed control in soybeans. Roundup Ready 2 Xtend (dicamba tolerant) soybeans provide growers an alternative herbicide option for postemergence weed control in conventional tillage soybeans. Two pass programs consisting of preemergence residual herbicides followed by postemergence Roundup Power Max plus dicamba provided excellent weed control, superior to a single postemergence treatment with Roundup Power Max plus dicamba.

## Introduction
Weeds are a major production problem in soybeans, especially with the development of glyphosate-resistant weeds. Roundup Ready 2 Xtend (RR2X) soybeans provide a new herbicide option for weed control in soybeans.

## Procedures
A field experiment was established near Manhattan, KS, on a Reading silt loam soil with 2.7% organic matter and a pH of 5.3. The plot area had a natural infestation of Palmer amaranth (mixed population of glyphosate susceptible and resistant biotypes), velvetleaf, and ivyleaf morning glory. Asgrow 34X6 Xtend soybeans were planted at 130,000 seeds/a in 30-inch rows into a recently tilled seedbed and preemergence (PRE) treatments were applied on June 1, 2016. Minimal precipitation occurred for 14 days after planting, after which only two small rainfall events occurred until 24 days after planting. Postemergence (P) treatments were applied to 2-trifoliate-leaf soybeans (6 inch), 3- to 16-inch Palmer amaranth, 2- to 8-inch velvetleaf, and 2- to 6-inch morning glory on June 20 at 88°F, 57% relative humidity, and clear skies. Treatments were applied with a $CO_2$ backpack sprayer, delivering 15 gpa at 35 psi through TTI110015 flat fan spray tips to the center 6.3 ft of 10 by 25 ft plots. The experiment had a randomized complete block design with four replications. Crop injury was visually evaluated throughout the growing season.

## Results
The small rain event 14 days after planting appeared to provide better activation of those PRE treatments that included a flumioxazin component (Fierce, Fierce XLT, and Rowel) than the other PRE treatments. Two pass programs were more effective than one pass glyphosate plus dicamba treatment for weed control, even with marginal activation of the PRE treatments initially.

**Table 1. Weed control in Xtend soybeans on June 20, 2016, prior to postemergence treatment, Manhattan, KS**

| Treatment* | Application timing | Application rate | Palmer amaranth | Velvet-leaf | Morning glory |
|---|---|---|---|---|---|
| | | oz/a | ------------------- | % control | ------------------ |
| Fierce/Roundup PMax+Xtendimax# | PRE/P | 3/32+22 | 82 | 65 | 73 |
| Authority Elite/RU PMax+Xtendimax | PRE/P | 25/32+22 | 33 | 10 | 68 |
| Boundary/RU PMax+Xtendimax | PRE/P | 32/32+22 | 30 | 0 | 0 |
| Fierce XLT/RU PMax+Xtendimax | PRE/P | 4/32+22 | 79 | 64 | 70 |
| Rowel+Warrant/RU Max+Xtendimax | PRE/P | 2+64/32+22 | 93 | 73 | 75 |
| Roundup Power Max+Xtendimax | P | 32+22 | --- | --- | --- |
| Least significant difference ($P$ < 0.05) | | | 8 | 18 | 18 |

* / indicates sequential application; RU PMax = Roundup Power Max; PRE = preemergence; EP = early postemergence; and P = postemergence.
# Non-labelled dicamba product actually applied, but equivalent Xtendimax rates presented.

**Table 2. Weed control in Xtend soybeans on July 18, 2016, for Palmer amaranth and velvetleaf and June 28 for ivyleaf morning glory, Manhattan, KS**

| Treatment* | Application timing | Application rate | Palmer amaranth | Velvet-leaf | Morning glory |
|---|---|---|---|---|---|
| | | oz/a | ------------------- | % control | ------------------ |
| Fierce/Roundup PMax+Xtendimax# | PRE/P | 3/32+22 | 99 | 100 | 95 |
| Authority Elite/RU PMax+Xtendimax | PRE/P | 25/32+22 | 96 | 99 | 89 |
| Boundary/RU PMax+Xtendimax | PRE/P | 32/32+22 | 95 | 98 | 73 |
| Fierce XLT/RU PMax+Xtendimax | PRE/P | 4/32+22 | 99 | 99 | 92 |
| Rowel+Warrant/RU PMax+Xtendimax | PRE/P | 2+64/32+22 | 99 | 100 | 96 |
| Roundup Power Max+Xtendimax | P | 32+22 | 85 | 100 | 74 |
| Least significant difference ( $P$ < 0.05) | | | 3 | 1 | 7 |

* / indicates sequential application; RU PMax = Roundup Power Max; PRE = preemergence; EP = early postemergence; and P = postemergence.
# Non-labelled dicamba product actually applied, but equivalent Xtendimax rates presented.

**Figure 1. Application of Fierce XLT PRE followed by Roundup Power Max plus dicamba postemergence.**

**Figure 2. Application of Roundup Power Max plus dicamba postemergence.**

# Comparison of Different Weed Control Technology Programs

*D.E. Peterson, C.R. Thompson, and C.L. Minihan*

## Summary
The development of glyphosate-resistant weeds has greatly complicated weed control in soybeans. Roundup Ready 2 Xtend and Liberty Link soybeans provide an alternative postemergence herbicide options for weed control in soybeans. Liberty Link and Roundup Ready 2 Xtend programs provided better overall weed control and slightly higher yields than Roundup Ready 2 Yield programs in this experiment. Yields of Roundup Ready 2 Yield soybeans were likely influenced by more weed competition and possibly crop injury from spray tank contamination by dicamba. Dicamba injury from tank contamination to Roundup Ready 2 Yield soybeans decreased with each subsequent treatment and also with time. At soybean maturity, injury from dicamba tank contamination was no longer evident.

## Introduction
Weeds are a major production problem in soybeans, especially with the development of glyphosate-resistant weeds. Alternative technologies including Liberty Link and Roundup Ready 2 Xtend soybeans provide growers with alternative weed control programs. Using a systems approach and alternating technologies may be beneficial for weed control and herbicide-resistant weed management.

## Procedures
A field experiment was established near Manhattan, KS, on a Reading silt loam soil with 2.7% organic matter and a pH of 5.8. The plot area had a natural infestation of Palmer amaranth (mixed population of glyphosate-susceptible and -resistant biotypes), velvetleaf, and ivyleaf morning glory and was field cultivated prior to soybean planting. Three different weed control programs were associated with three different traited soybeans, including Roundup Ready 2 Yield (RR2Y, glyphosate-resistant), Roundup Ready 2 Xtend (RR2X, glyphosate- and dicamba-resistant), and Liberty Link (LL, glufosinate-resistant). Asgrow 3634 RR2Y, Asgrow MON AG40X6 RR2X, and Credenz CZ3841 LL soybeans were planted at 120,000 seeds/a in 30-inch rows on May 12, 2016. Preemergence (PRE) herbicide treatments were applied to the soil surface on May 13 at 63°F, 60% relative humidity, and clear skies. A good, activating rain was received within 4 days after planting and more than 5 inches of rain was received during a 4-day period 12 to 15 days after planting. Postemergence (P) treatments were applied to 2-trifoliate-leaf soybeans (8 inch), 1- to 3-inch Palmer amaranth, 2- to 3-inch velvetleaf, and 2- to 3-inch morning glory on June 10, with 79°F, 65% relative humidity, and clear skies. Preemergence and P treatments on RR2Y and RR2X soybeans were applied with a compressed air tractor sprayer, delivering 15 GPA at 40 psi through TTI11002 flat fan spray tips to the center 6.7 ft of 10 by 25 ft plots. Postemergence treatments on LL soybeans were applied with the same equipment, delivering 15 GPA at 26 psi through AIXR110025 flat fan spray tips. The experiment had a randomized

complete block design with a split plot arrangement of three traits as the main plots, herbicide programs as the subplot, and three replications. Crop injury and weed control were visually evaluated throughout the growing season, and soybeans were harvested from the center 2 rows of the plots on October 24.

## Results

A good, activating rain was received within 4 days after planting and more than 5 inches of rain was received during a 4-day period 12 to 15 days after planting. Rowel and Valor caused minor early-season stunting of soybeans, but plants eventually recovered (data not presented). Failure to properly clean out the spraying system with just a single rinse between the RR2X and the RR2Y postemergence herbicide applications resulted in sprayer contamination and dicamba injury to the RR2Y soybeans. Dicamba injury decreased with each subsequent application and was minimal by the third treatment. Soybean injury ratings decreased over time but seemed to persist more for the second subsequent application. All PRE treatments provided excellent Palmer amaranth control initially, but control started to break in early June following excessive rains in late May, especially with Rowel and Valor treatments. Palmer amaranth populations were a mix of glyphosate-susceptible and resistant biotypes. Palmer amaranth control was excellent with all RR2X and LL herbicide programs. Control was less with RR2Y programs due to the presence of glyphosate-resistant Palmer amaranth. Most PRE herbicide treatments provided good early-season control of velvetleaf, and late-season control was excellent with all treatments following postemergence herbicide applications. All PRE herbicide treatments except Warrant plus Tricor gave good early-season control of morning glory, but some late emerging plants escaped control. RR2Y herbicide programs were less effective than RR2X or LL programs for late-season morning glory control. Soybean yields were very good as a result of good precipitation through most of the growing season. Untreated checks were not harvestable due to the heavy weed pressure, and soybean yields would have been minimal. Soybean yields were higher for RR2X and LL soybeans than the RR2Y soybeans, but that may have been confounded by the dicamba injury to RR2Y soybeans. However, Palmer amaranth control was also less for RR2Y programs, which also may have contributed to lower soybean yields. Yields generally were similar among the different herbicide programs for each trait technology. Soybean yields tended to increase slightly from herbicide program 1 through herbicide program 3 for the dicamba-damaged RR2Y soybeans, but differences were minimal and not significant despite the different degrees of dicamba injury. In general, yield impact appeared to be minimal from the dicamba injury to the RR2Y soybeans.

**Table 1. Soybean injury and yield, Manhattan, KS**

| Trait and herbicide treatment* | Application timing | Application rate | Soybean injury# July 7 | Soybean injury# August 12 | Soybean yield |
|---|---|---|---|---|---|
| | | oz/a | ------------- % ------------- | | bu/a |
| RR2Y | | | | | |
| Rowel/Roundup PMax | PRE/P | 3/32 | 25 | 6 | 70 |
| Warrant+Tricor/Roundup PMax | PRE/P | 48+5/32 | 15 | 12 | 72 |
| Warrant+Tricor/ Roundup+Warrant Ultra | PRE/P | 48+5/32+50 | 3 | 0 | 74 |
| RR2X | | | | | |
| Rowel/Roundup Xtend | PRE/P | 2/64 | 0 | 0 | 77 |
| Rowel+Xtendimax/Roundup Xtend | PRE/P | 2+22/64 | 0 | 0 | 78 |
| Rowel+Xtendimax/ RU Xtend+Warrant | PRE/P | 2+22/64+48 | 0 | 0 | 79 |
| LL | | | | | |
| Valor SX/Liberty | PRE/P | 2/29 | 1 | 0 | 80 |
| Authority Maxx/Liberty | PRE/P | 6.4/29 | 2 | 0 | 80 |
| Authority Maxx/Liberty+Zidua | PRE/P | 6.4/29+2 | 2 | 0 | 77 |
| Least significant difference ($P < 0.05$) | | | 3 | 3 | 4 |

* / indicates sequential application; all Liberty applications included ammonium sulfate at 1.5 lb/a; PRE = preemergence; and P = postemergence.

# Injury to RR2Y soybeans a result of spray tank contamination with dicamba following a single rinse and each subsequent application.

**Table 2. Weed control prior to P treatment on June 10, 2016, Manhattan, KS**

| Trait and herbicide treatment* | Application timing | Application rate | Palmer amaranth | Velvet-leaf | Morning glory |
|---|---|---|---|---|---|
| | | oz/a | ------------------ | % control | ------------------ |
| RR2Y | | | | | |
| Rowel/Roundup PMax | PRE/P | 3/32 | 82 | 93 | 88 |
| Warrant+Tricor/Roundup PMax | PRE/P | 48+5/32 | 92 | 83 | 7 |
| Warrant+Tricor/Roundup+Warrant Ultra | PRE/P | 48+5/32+50 | 94 | 88 | 7 |
| RR2X | | | | | |
| Rowel/Roundup Xtend | PRE/P | 2/64 | 77 | 92 | 90 |
| Rowel+Xtendimax/Roundup Xtend | PRE/P | 2+22/64 | 80 | 93 | 98 |
| Rowel+Xtendimax/RU Xtend+Warrant | PRE/P | 2+22/64+48 | 85 | 90 | 97 |
| LL | | | | | |
| Valor SX/Liberty | PRE/P | 2/29 | 85 | 95 | 90 |
| Authority Maxx/Liberty | PRE/P | 6.4/29 | 98 | 87 | 97 |
| Authority Maxx/Liberty+Zidua | PRE/P | 6.4/29+2 | 98 | 83 | 95 |
| Least significant difference ( $P < 0.05$) | | | 4 | 9 | 7 |

* / indicates sequential application; all Liberty applications included ammonium sulfate at 1.5 lb/a; PRE = preemergence; and P = postemergence.

**Table 3. Weed control prior to P treatment on July 7, 2016, Manhattan, KS**

| Trait and herbicide treatment* | Application timing | Application rate | Palmer amaranth | Velvet-leaf | Morning glory |
|---|---|---|---|---|---|
| | | oz/a | % control | | |
| RR2Y | | | | | |
| Rowel/Roundup PMax | PRE/P | 3/32 | 88 | 100 | 75 |
| Warrant+Tricor/Roundup PMax | PRE/P | 48+5/32 | 95 | 98 | 65 |
| Warrant+Tricor/Roundup+Warrant Ultra | PRE/P | 48+5/32+50 | 95 | 98 | 63 |
| RR2X | | | | | |
| Rowel/Roundup Xtend | PRE/P | 2/64 | 96 | 100 | 82 |
| Rowel+Xtendimax/Roundup Xtend | PRE/P | 2+22/64 | 95 | 100 | 82 |
| Rowel+Xtendimax/RU Xtend+Warrant | PRE/P | 2+22/64+48 | 100 | 100 | 85 |
| LL | | | | | |
| Valor SX/Liberty | PRE/P | 2/29 | 100 | 100 | 88 |
| Authority Maxx/Liberty | PRE/P | 6.4/29 | 100 | 100 | 95 |
| Authority Maxx/Liberty+Zidua | PRE/P | 6.4/29+2 | 100 | 100 | 96 |
| Least significant difference ( $P < 0.05$) | | | 5 | 2 | 11 |

* / indicates sequential application; all Liberty applications included ammonium sulfate at 1.5 lb/a; PRE = preemergence; and P = postemergence.

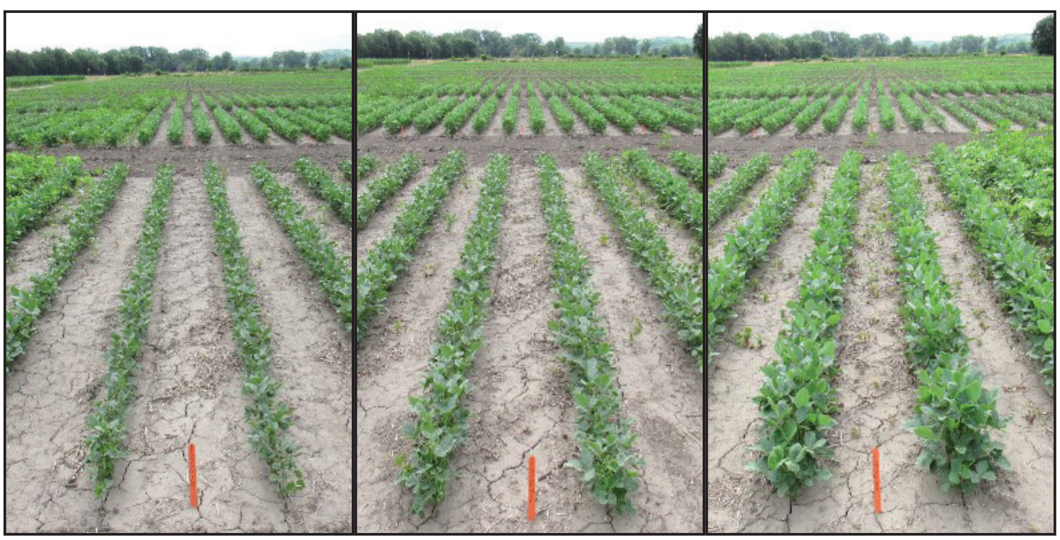


**Figure 1. Soybean response from dicamba sprayer contamination following a single rinse and each subsequent application.**

# Weed Control Programs for Xtend Soybeans in No-Tillage

*D.E. Peterson, C.R. Thompson, and C.L. Minihan*

## Summary
The development of glyphosate-resistant weeds has greatly complicated weed control in soybeans. Roundup Ready 2 Xtend (dicamba tolerant) soybeans provide growers an alternative herbicide option for preplant and postemergence weed control in no-tillage soybeans. Preplant programs that included dicamba provided excellent control of giant ragweed. All sequential programs provided excellent control of the weeds present in the experiment.

## Introduction
Weeds are a major production problem in soybeans, especially with the development of glyphosate-resistant weeds. Roundup Ready 2 Xtend (RR2X) soybeans provide a new herbicide option for preplant and postemergence weed control in no-tillage soybeans.

## Procedures
A field experiment was established near Manhattan, KS, on a Reading silt loam soil with 3.3% organic matter and a pH of 6.7. The plot area had a natural infestation of henbit, giant ragweed (moderate level of glyphosate resistance), Palmer amaranth, and large crabgrass. Preplant (PP) treatments were applied to blooming henbit, and 1- to 12-inch giant ragweed on May 3, 2016, at 72°F, with 35% relative humidity and mostly clear skies. Asgrow 34X6 RR2X soybeans were planted at 120,000 seeds/a in 30-inch rows on May 23, 2016. Postemergence (P) treatments were applied to 2 trifoliate leaf soybeans (6 inch), 3- to 6-inch Palmer amaranth, and 1- to 6-inch large crabgrass on June 13 at 84°F, with 58% relative humidity, and partly cloudy skies. Treatments were applied with a $CO_2$ backpack sprayer, delivering 15 GPA at 35 psi through TTI110015 flat-fan spray tips to the center 6.3 ft of 10 by 25 ft plots. The experiment had a randomized complete block design with three replications. Crop injury and weed control were visually evaluated throughout the growing season.

## Results
None of the herbicide treatments caused any important crop injury (data not presented). All treatments eventually provided very good control of all weeds evaluated.

**Table 1. Weed control in RR2X soybeans on May 31, 2016, Manhattan, KS**

| Treatment* | Application timing | Application rate | Henbit | Giant ragweed | Large crabgrass |
|---|---|---|---|---|---|
| | | oz/a | ------------------ | % control | ----------------- |
| RU Power Max+Xtendimax#/<br>RU Power Max+Xtendimax | PP/<br>P | 32+22/<br>32+22 | 100 | 93 | 87 |
| RU Power Max+Xtendimax+Valor/<br>RU Power Max+Xtendimax | PP/<br>P | 32+22+2.5/<br>32+22 | 100 | 100 | 92 |
| RU Power Max+Xtendimax+Fierce/<br>RU Power Max+Xtendimax | PP/<br>P | 32+22+3/<br>32+22 | 100 | 100 | 97 |
| RU Power Max+Xtendimax+Fierce/<br>RU PMax+Xtendimax+Warrant | PP/<br>P | 32+22+3/<br>32+22+48 | 100 | 100 | 97 |
| Least significant difference ( $P < 0.05$) | | | NS | NS | 10 |

* RU Power Max and RU PMax = Roundup Power Max; / indicates sequential application; all treatments included nonionic surfactant at 0.25% v/v; PP = preplant; and P = postemergence.

# Non-labelled dicamba product actually applied, but equivalent Xtendimax rates presented.

**Table 2. Weed control in RR2X soybeans on July 26, 2016, Manhattan, KS**

| Treatment* | Application timing | Application rate | Henbit | Giant ragweed | Large crabgrass |
|---|---|---|---|---|---|
| | | oz/a | ------------------ | % control | ----------------- |
| RU Power Max+Xtendimax#/<br>RU Power Max+Xtendimax | PP/<br>P | 32+22/<br>32+22 | 100 | 93 | 87 |
| RU Power Max+Xtendimax+Valor/<br>RU Power Max+Xtendimax | PP/<br>P | 32+22+2.5/<br>32+22 | 100 | 100 | 92 |
| RU Power Max+Xtendimax+Fierce/<br>RU Power Max+Xtendimax | PP/<br>P | 32+22+3/<br>32+22 | 100 | 100 | 97 |
| RU Power Max+Xtendimax+Fierce/<br>RU PMax+Xtendimax+Warrant | PP/<br>P | 32+22+3/<br>32+22+48 | 100 | 100 | 97 |
| Least significant difference ( $P < 0.05$) | | | NS | NS | 10 |

* RU Power Max and RU PMax = Roundup Power Max; / indicates sequential application; all treatments included nonionic surfactant at 0.25% v/v; PP = preplant; and P = postemergence.

# Non-labelled dicamba product actually applied, but equivalent Xtendimax rates presented.

**Figure 1. Application of Fierce plus Roundup Power Max plus dicamba preplant followed by Roundup Power Max plus dicamba postemergence.**

# Winter Annual Grass Control in Winter Wheat

*D.E. Peterson, C.R. Thompson, and C.L. Minihan*

## Summary

Winter annual grasses can be difficult to manage in winter wheat. A field experiment was established near Manhattan, KS, in 2016 to evaluate various preemergence and postemergence herbicide treatments for control of downy brome, cheat, and feral rye. Most treatments were less effective for control of downy brome than cheat. Preemergence and fall postemergence treatments provided better downy brome control than spring postemergence treatments. All herbicide treatments evaluated provided excellent control of cheat, but postemergence treatments were slightly better than preemergence treatments. The only herbicide to control rye was Beyond, which provided better control when applied fall postemergence than spring postemergence.

## Introduction

Winter annual grasses are difficult to manage in winter wheat because of the similarities in biology and life cycle. Several herbicide treatments are registered to control winter annual grasses in wheat, but control can vary depending on grass species, application timing and environmental conditions.

## Procedures

A field experiment was established near Manhattan, KS, on a Reading silt loam soil with 2.4% organic matter and a pH of 6.5. Downy brome, cheat, and rye seed were spread in strips across the plot area and incorporated with a field cultivator prior to seeding wheat. DoubleStop CL Plus (2-gene Clearfield) hard red winter wheat was seeded at a rate of 60 lb/a with a double-disk drill on October 5, 2015. Preemergence (PRE) herbicide treatments were applied to the soil surface the same day as wheat was planted at 61°F, with 75% relative humidity and overcast skies. The first precipitation event following planting totaled 0.61 inches on October 30. Fall postemergence (FP) treatments were applied to 3-leaf and 2-tiller wheat, 1-leaf downy brome, 1-leaf cheat, and 3-leaf, 2-tiller rye on November 10, with 52°F, 64% relative humidity, and partly cloudy skies. Spring postemergence (SP) treatments were applied to multi-tillered wheat, downy brome, cheat, and rye on March 10 at 69°F, with 38% relative humidity and mostly clear skies. Treatments were applied with a $CO_2$ backpack sprayer, delivering 15 GPA at 35 psi through AIXR110015 flat fan spray tips to the center 6.3 ft of 15 by 28 ft plots. The experiment had a randomized complete block design with three replications. Wheat injury and grass control were visually evaluated throughout the growing season and wheat was harvested from the center 5 ft of the plots on June 22.

## Results

None of the herbicide treatments caused any significant crop injury (data not presented). Minimal downy brome and cheat germinated prior to the first rain, and consequently, PRE treatments generally provide good control of both species, which was comparable to most FP treatments. Preemergence Zidua and Anthem Flex tended to provide a little better control of downy brome than preemergence Olympus. Fall postemergence treatments provided better downy brome control than comparable spring postemergence treatments. All postemergence treatments provided complete control of cheat, which was slightly better than preemergence treatments. The only treatments to control rye were the Beyond treatments. Rye control with Beyond was better with fall than spring postemergence applications. Wheat yields were not different among treatments (data not presented).

**Table 1. Winter annual grass control in winter wheat on May 31, 2016, Manhattan, KS**

| Treatment* | Application timing | Application rate | Downy brome | Cheat | Rye |
|---|---|---|---|---|---|
| | | oz/a | ------------------ | % control | ----------------- |
| Olympus | PRE | 0.6 | 87 | 96 | 0 |
| Zidua | PRE | 1.5 | 93 | 95 | 0 |
| Anthem Flex | PRE | 3 | 94 | 94 | 0 |
| Olympus+NIS | FP | 0.9 | 96 | 100 | 0 |
| PowerFlex HL+NIS | FP | 2 | 91 | 100 | 0 |
| Beyond+MSO+UAN | FP | 4 | 96 | 100 | 100 |
| Olympus+NIS | SP | 0.9 | 81 | 100 | 0 |
| PowerFlex HL+NIS | SP | 2 | 79 | 100 | 0 |
| Beyond+MSO+UAN | SP | 4 | 80 | 100 | 81 |
| Olympus/Olympus+NIS | PRE/SP | 0.6/0.6 | 89 | 100 | 0 |
| Zidua/PowerFlex HL+NIS | PRE/SP | 1.5/2 | 90 | 100 | 8 |
| Olympus+NIS/Olympus+NIS | FP/SP | 0.9/0.3 | 95 | 100 | 0 |
| Least significant difference ( $P < 0.05$) | | | 7 | 3 | 4 |

* NIS = nonionic surfactant applied at 0.25% v/v; MSO = methylated seed oil applied at 1% v/v; UAN = 28% liquid urea ammonium nitrate applied at 10% v/v; / indicates sequential applications; PRE = preemergence; FP = fall postemergence; and SP = spring postemergence.

# Optimum Seeding Rate for Different Wheat Varieties in Kansas

*R.P. Lollato, G.L. Cramer, A.K. Fritz, and G. Zhang*

## Summary

Seeding rate is an important management practice affecting wheat yield. Wheat varieties differ in their tillering capacity and therefore in their yield response to seeding rate. Our objectives were to evaluate the tillering and yield response of different modern wheat varieties to seeding rate. The study was conducted in Hutchinson and Manhattan, KS, during the 2015-16 growing season. Seven wheat varieties (Everest, KanMark, 1863, Joe, Tatanka, Larry, and Zenda) were sown at five different seeding rates (0.6, 0.95, 1.3, 1.65, and 2 million seeds per acre). Tiller number and grain yield were measured in the spring. Increasing plant population decreased the number of spring tillers sustained by the different varieties from more than eight tillers per plant at 600,000 seeds per acre to fewer than four tillers per plant at 2 million seeds per acre. There were varietal differences in tillers per plant, with the variety Joe standing out as a high-tillering variety. At both locations, wheat grain yield increased with increased seeding rates and was maximized at approximately 0.8-0.95 million emerged plants per acre. Further increases in seeding rate did not affect grain yield.

## Introduction

Plant population density is among the major factors determining the crop's ability to capture resources such as water, nutrients, and solar radiation. The response of wheat to plant density is largely determined by competition for resources with neighboring plants, and increased competition can result in reduced survival, dry matter production, and grain yield of individual wheat plants. Wheat plants subjected to high density generally have fewer tillers and grains than widely spaced plants; on the other hand, too widely spaced plants can result in few plants per unit area and consequently fewer grains per unit area, explaining the typical parabolic response of grain yield to plant density. Consequently, appropriate management of population density may allow maximum yields per unit area to be achieved. Given the difference in wheat lines regarding their ability to tiller as well as their response to intra-canopy competition for resources, it is possible that different varieties require different seeding densities to maximize yield. Thus, the main objective of this project was to better understand the response of different wheat lines and varieties to seeding density and ultimately to provide better recommendations to producers about seeding rate per variety.

## Procedures

One experiment was conducted at two locations in Kansas: the South Central Kansas experiment field near Hutchinson, and the Agronomy North Farm in Manhattan. Trials were established in a randomized complete block design with four replications. Seven varieties (Everest, KanMark, 1863, Larry, Zenda, Tatanka, and Joe) and five seeding rates (0.6, 0.95, 1.3, 1.65, and 2 million seeds per acre) were tested, for a total of 35 treatments. Plots were 7 rows wide in Manhattan, at a 7.5-inch row spacing, and 6 rows wide in Hutchinson, at a 10 inch row spacing. Plots were approximately 20-ft long at both locations. Management practices adopted at both locations are described in Table 1. Nitrogen (N) fertilization at both locations was performed with a yield goal of approximately 70 bushels per acre, considering 2.4 lb of N needed for each bushel of yield goal. Weeds and foliar diseases were controlled at both locations so these were not confounding factors in the study.

Stand count was conducted at approximately 3-4 weeks after sowing, which was used to calculate plants per acre. All remaining analyses were performed using plants per acre rather than seeding rate. Tiller counts occurred during the spring, and a 1-meter row subsample was clipped from each plot at harvest time for biomass, harvest index, head count, average grain weight and head size. Plots were harvested using a small plot combine at both locations. Moisture and test weight were automatically measured by the combine in Hutchinson, and manually measured from the plots in Manhattan. Grain yield was adjusted for 13.5% moisture content. Statistical analysis included analysis of variance and regression, depending on the variable being evaluated.

# Results

### *Growing Season Weather*

The weather at both locations was characterized by a warm and moist fall, followed by a dry and mild winter and a cool and moist spring. Growing-season precipitation total was 20.5 inches in Hutchinson and 24.4 inches in Manhattan, mostly concentrated during the fall (approximately 1/3 of total precipitation) and spring (approximately 2/3 of total precipitation). The high yield potential led by abundant precipitation during the spring may have affected the results of grain yield.

### *Tillers Per Plant*

Tillers were counted from a 1-meter row from all plots during late March/early April at both locations. Number of tillers per plant was significantly affected by both variety and plant population in Hutchinson, and by plant population in Manhattan (Table 2). In Manhattan, there was a trend ($P < 0.1$) for tillers per plant to be affected by variety, although this was not significant at $P < 0.05$. At the plant population of approximately 1 million plants per acre, each plant had approximately 3.8 tillers in Hutchinson. Decreasing plant population significantly increased the number of tillers per plant so that a population of about 700,000 plants per acre had 4.8 tillers per plant; and a further decrease to 400,000 plants per acre significantly increased tillers per plant to 8.2. Likewise, increasing the plant population to 1.2 million plants per acre significantly decreased the number of tillers each plant produced and maintained, but further increase in sowing density to 1.4 million plants per acre did not decrease tillers per plant. Varieties also differed in their ability to tiller. In Hutchinson, Everest, KanMark, and Zenda resulted in lower numbers of tillers per plant (3.7, 3.7, and 3.9, respectively) than did Joe (5.3). The varieties 1863, Larry, and Tatanka (4.2, 4.2, and 4.1, respectively), were statistically similar to both Joe and the lowest tillering group. Results obtained in Manhattan were similar to those obtained in Hutchinson. Joe and Larry produced numerically greater number of tillers (4.9 and 4.8, respectively) than did Tatanka, Zenda, 1863, and KanMark (4.5, 4.3, 4.2, and 4.4, respectively), and Everest had the lowest number of tillers per plant (4.0). Again, this was only a trend as these differences were not statistically significant at $P < 0.05$. The effects of plant population on the number of tillers per plant in Manhattan were similar to those measured in Hutchinson. A plant population of approximately 450,000 plants per acre resulted in 7.4 tillers per plant, and increasing plant population to 700,000 and 900,000 plants per acre significantly decreased the number of tillers per plant to 4.9 and 4.8, respectively, which are statistically equal. A further increase in plant population to 1.1 and 1.3 million plants per acre significantly decreased number of tillers per plant to 3.5 and 3.3, respectively, which are statistically the same.

### *Tillers Per Acre*

Similarly to tillers per plant, tillers per acre were significantly affected by variety and plant population density in Hutchinson, and by plant population density in Manhattan (Table 2). In Hutchinson, the number of tillers per acre was only greater at the highest plant population of 1.3 million plants per acre. The 1.3 million plants per acre plant population had a total of 4.4 million tillers per acre, which is statistically greater than the number of tillers per acre for the plant populations of 400,000 plants per acre (3.8 million tillers per acre), 700,000 plants per acre (3.6 million tillers per acre), and 1 million plants per acre (3.8 million tillers per acre). The 1.2 million plants per acre rate resulted in 4 million tillers per acre, which is not statistically different from the numbers resulting from the higher and the lower plant populations. There was a significant effect of variety on the number of tillers per acre in Hutchinson. The variety 1863 had the highest number of tillers per acre (4.3 million tillers per acre). Zenda, Tatanka, and Joe had an intermediate number of tillers per acre (4.0, 4.1, and 3.9 million, respectively), and Larry, Everest, and KanMark resulted in the lowest readings (3.7, 3.6 and 3.7 million tillers per acre, respectively). In Manhattan, the number of tillers per acre was only greater at the highest plant population of about 1.3 million plants per acre, which is similar to the response measured in Hutchinson. The 1.3 million plants per acre resulted in a greater number of tillers per acre than that measured in the 500,000 and 800,000 plants per acre populations (4.5 versus 3.7 and 3.7 million tillers per acre, respectively). Meanwhile, the 1.1 and 1.3 million plants per acre populations resulted in similar numbers of tillers per acre (4.2 and 4.1 million tillers per acre, respectively) to those of the lower rates and the higher rate. There was no significant effect of variety in number of tillers produced per acre in Manhattan, although Joe and Larry had numerically more tillers per acre than the other varieties.

These results illustrate the capacity of the different varieties to compensate for a thin stand. Despite significantly fewer plants per acre at the lowest plant populations, these plants produced many more tillers per plant, so that the final number of tillers per acre was not as much affected as the final population. Joe stood out in its tillering capacity at both Manhattan and Hutchinson, as did Larry in Manhattan.

### *Grain Yield*

There was a great difference in yield potential between both study locations. Across all varieties and plant population densities, the trial in Manhattan averaged 44 bushels per acre while the trial in Hutchinson averaged 78 bushels per acre. At both Hutchinson and Manhattan, grain yield was significantly affected by variety and population density, but there was no significant interaction (Table 2). In other words, there were differences between varieties, differences between population densities, but all varieties responded similarly to the change in population density, precluding the need for an analysis by variety.

In Hutchinson, plant populations of 700,000, 1 million, 1.2 million, or 1.4 million plants per acre resulted in statistically similar yields (Figure 1). The lowest population density, 400,000 plants per acre, resulted in a lower grain yield than the remaining population densities. As far as varieties, Tatanka yielded statistically more than Everest and Zenda. KanMark, 1863, Larry, and Joe were placed in the middle group and yielded similarly to Everest, Zenda, and Tatanka.

In Manhattan, a similar trend to that measured in Hutchinson occurred, with the exception that both 500,000 and 800,000 plants per acre yielded fewer than 1.4 million plants per acre (Figure 2). The fact that 800,000 plants per acre resulted in a lower grain yield than the highest plant population density as opposed to the results in Hutchinson can be a function of the no-tillage system, which generally requires increased seeding rate to compensate for the lack of seedbed preparation, cooler soils promoting less tillering, and increased disease incidence from pathogens. The intermediate plant population rates of 900,000 and 1.1 million plants per acre resulted in statistically similar yields to both the lowest and the highest yielding groups. Joe resulted in greater yield than did all the other varieties, while KanMark was the lowest yielding variety. Everest, 1863, Larry, Zenda, and Tatanka were classified in the intermediate yielding group.

### *Individual Variety Response to Seeding Rate*

Although the analysis of variance did not call for analysis of the interaction of variety by plant population, we unfolded the interaction effects to better understand each individual variety's response to density. Each variety's yield response to plant population density was first modeled as an exponential rise to the maximum, following the trend measured in the main factor plant population at both locations and considering that there was no variety by plant population density interaction. Linear and quadratic response models were tested afterward to determine if the latter resulted in a better fit to the data.

In Hutchinson, the grain yield of Everest, KanMark, Zenda, and Larry was well modeled by an exponential rise to maximum model in the plant population range from 400,000 to 1.4 million plants per acre (Figure 3). These results indicate that, for these varieties, the best plant population for the studied growing season was in between the populations of 1.0 and 1.4 million plants per acre, both with no clear definition of a specific value. These results were most likely influenced by the above-average spring precipitation, which ensured enough moisture for tiller survival and grain yield under high population densities. KanMark and Larry seemed to maximize yields towards higher plant populations (1.1 - 1.3 million plants per acre), whereas Zenda seemed to maximize around 1 million plants per acre. The varieties 1863 and Tatanka did not show yield decrease at low population densities, meaning that their yields were the same regardless of plant population ranging from 400,000 to 1.4 million plants per acre. Joe showed a quadratic response of grain yield as affected by population. Although Joe's yield in the 700,000, 1.0, and 1.3 million plants per acre population was not statistically different, solving the quadratic equation indicates that the optimum population for Joe to maximize yields was about 980,000 plants per acre.

In Manhattan, all varieties except Everest showed an exponential rise to the maximum response (Figure 4). Everest had a linear grain yield response to plant population, indicating that if the maximum yield was achieved in the study, it was achieved at 1.3 million plants per acre and possibly could show even greater yield increase in response to population. The varieties Joe, Tatanka, Zenda, and 1863, seemed to have reached their maximum in between plant population densities of 0.9 and 1.3 million plants per acre as these did not differ among each other. KanMark and Larry, on the other hand, seemed to maximize yields towards higher plant populations (1.3 million plants per acre).

## Acknowledgment

The authors wish to acknowledge the Kansas Wheat Alliance for funding and providing the seed necessary to perform this research.

**Table 1. Location (latitude, longitude, and elevation) and management practices adopted at both study locations during the 2015-16 growing season**

| | Hutchinson | Manhattan |
|---|---|---|
| Latitude | 37.9313° N | 39.2181° N |
| Longitude | 98.0246° W | 96.5907° W |
| Elevation | 1535 ft | 1020 ft |
| Soil type | Ost loam | Kahola silt loam |
| Tillage | Conventional till | No-tillage |
| Previous crop | Wheat | Corn |
| Sowing date | 10/07/2016 | 10/08/2016 |
| Row spacing | 10 inches | 7.5 inches |
| Topdress N rate | 107 lb N/a | 99 lb N/a |
| Topdress N date | 2/19/2016 | 02/28/2016 |
| Herbicide rate | Powerflex – 2 oz/a<br>MCPE – 1 pt/a<br>AMS – 2.8 lb / 100 gal mix | Harmony Extra – 0.7 oz/a<br>MCPA Ester – 16 oz/a<br>NCIS – 16 oz / 100 gal mix |
| Herbicide date | 2/19/2016 | 03/10/2016 |
| Fungicide rate | Quilt Xcel – 12 fl. oz/a | Quilt Xcel – 14 fl. oz/a |
| Fungicide date | 4/25/2016 | 04/22/2016 |
| Harvest date | 6/16/2016 | 06/24/2016 |

N = Nitrogen.

**Table 2. Significance of the source of variation on the number of tillers counted per plant in Hutchinson and Manhattan, KS, during the 2015-16 growing season**

| Response | Effect | Hutchinson | Manhattan |
|---|---|---|---|
| Tiller per plant | Variety | *** | *P* = 0.07 |
| | Plant population | *** | *** |
| | Variety × plant population | ns | ns |
| Tiller per acre | Variety | * | ns |
| | Plant population | *** | *** |
| | Variety × plant population | ns | ns |
| Grain yield | Variety | *** | *** |
| | Plant population | * | *** |
| | Variety × plant population | ns | ns |

Ns = not significant.
* - significant at $P < 0.05$
*** - significant at $P < 0.001$

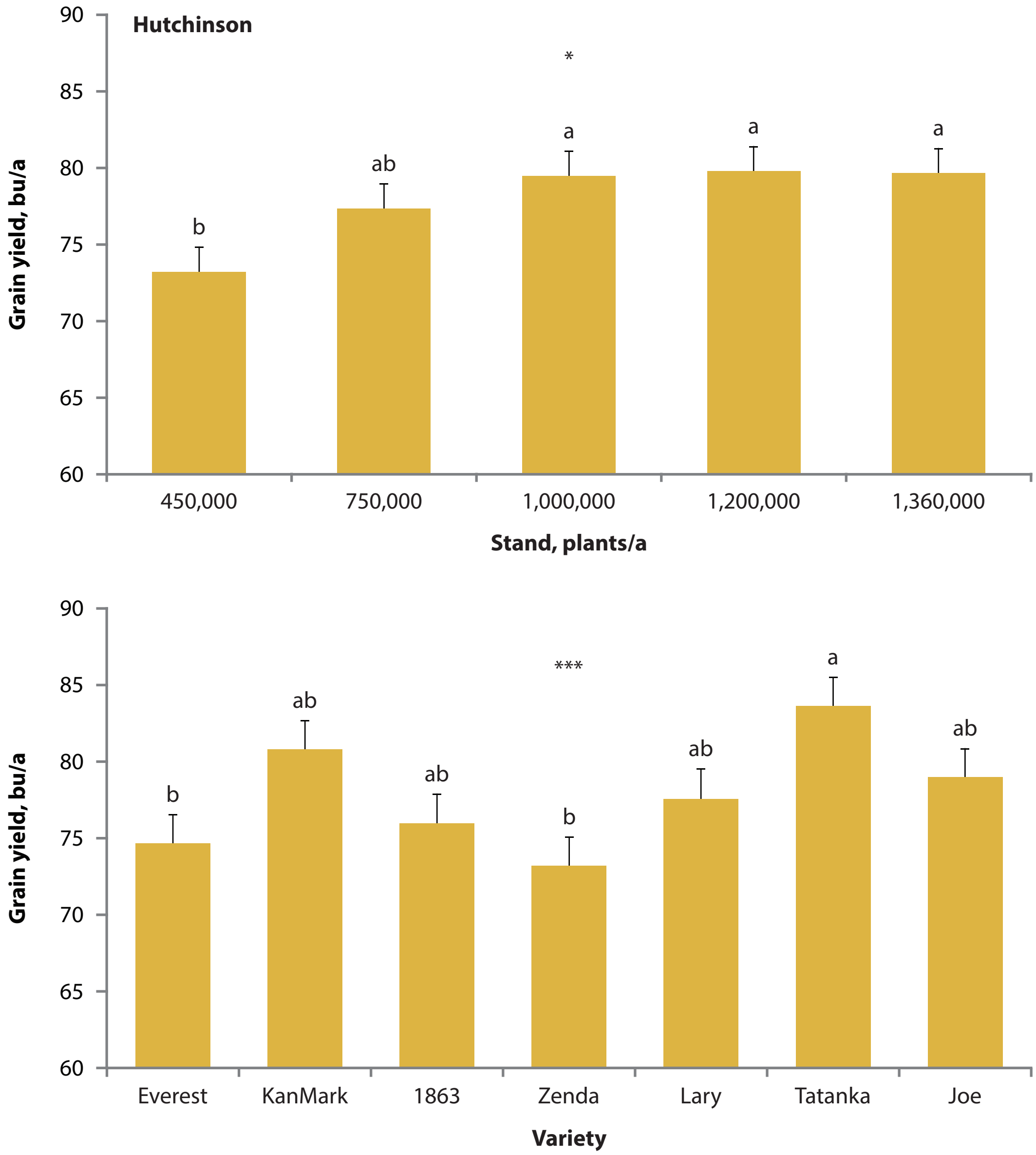
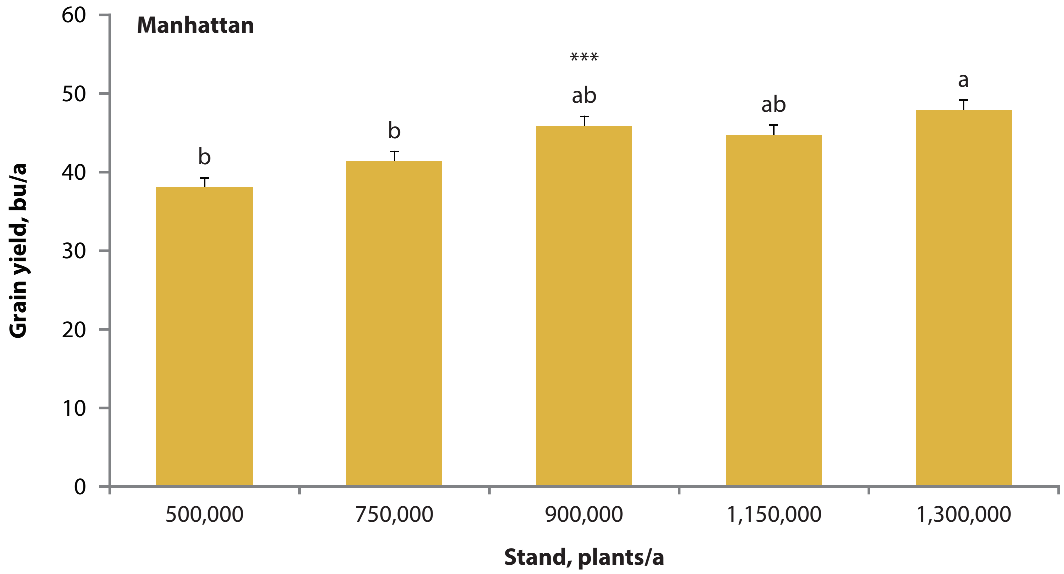



**Figure 1. Wheat grain yield as affected by seeding rate and variety during the 2015-16 growing season in Hutchinson, Kansas. The *, *** indicates that the main effect plant population was statistically significant at $P < 0.05$, and the main effect variety (lower chart) was statistically significant at $P < 0.001$.**



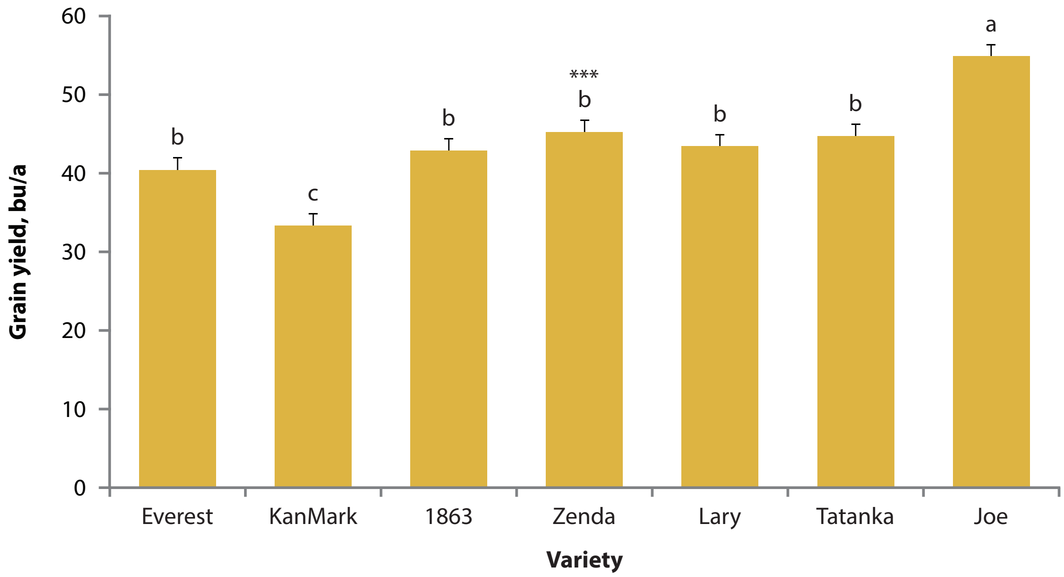




**Figure 2. Wheat grain yield as affected by seeding rate and variety during the 2015-16 growing season in Manhattan, Kansas. The *** indicates that the main effects plant population (upper chart) and variety (lower chart) were statistically significant at $P < 0.001$.**

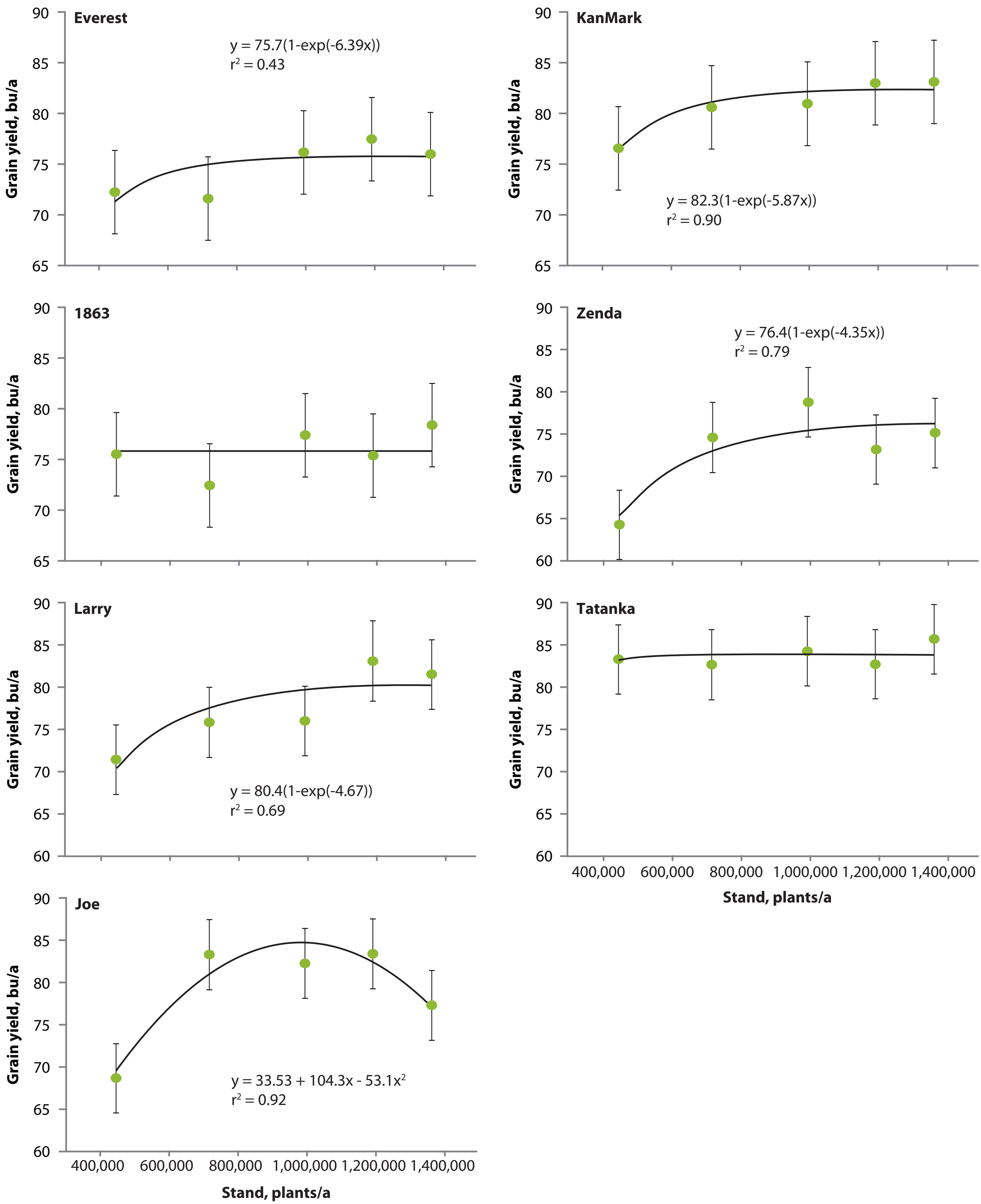



**Figure 3. Grain yield response to plant stand of each individual variety at Hutchinson, KS, during the 2015-16 growing season.**

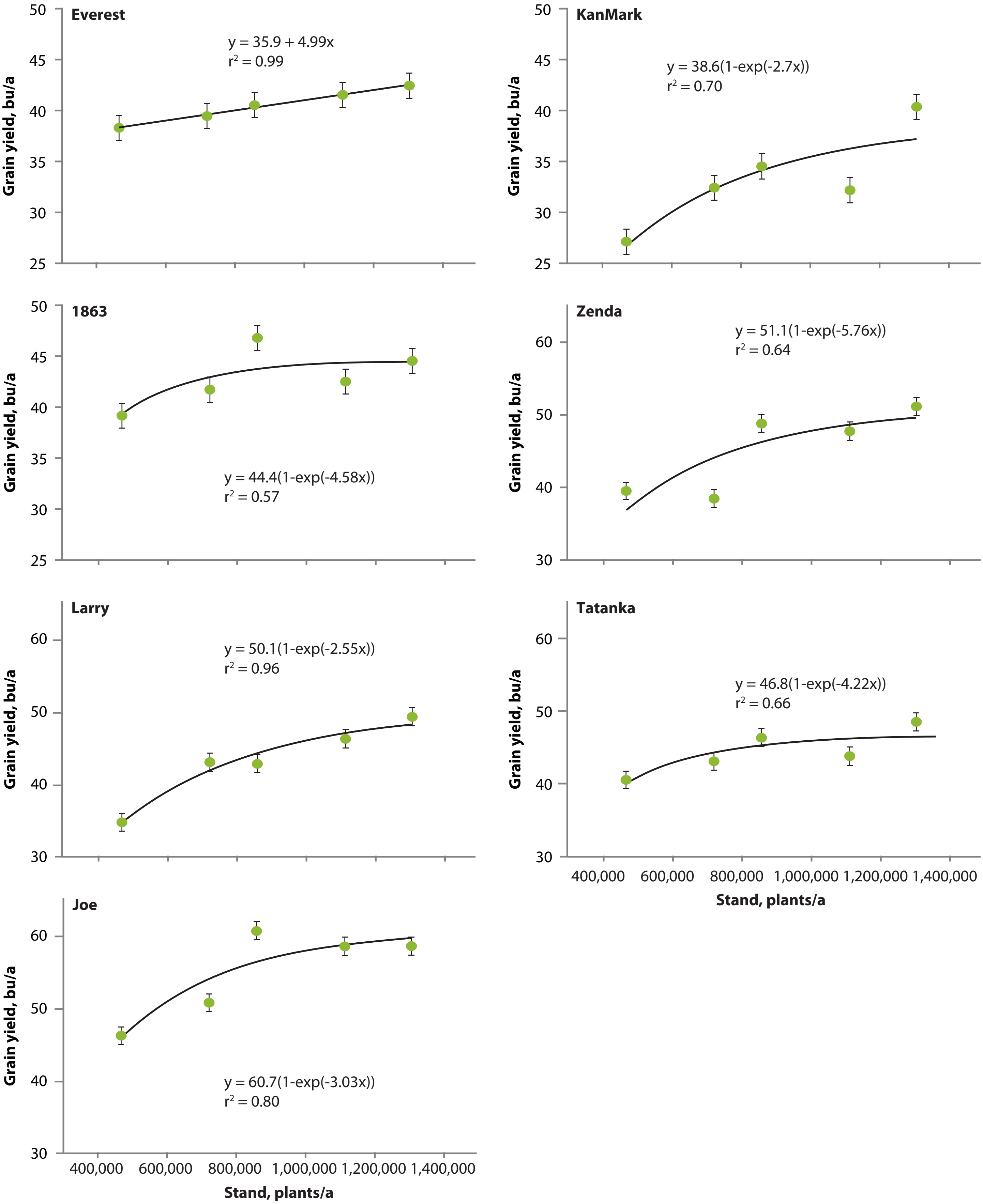



**Figure 4. Grain yield response to plant stand of each individual variety at Manhattan, KS, during the 2015-16 growing season. Notice the difference in scale between Everest, KanMark, and 1863, compared to the other varieties.**

# Intensive Management Strategies to Close Wheat Yield Gaps in Central Kansas

*B.R. Jaenisch and R.P. Lollato*

## Introduction

Winter wheat is the most widely sown crop in Kansas, and yields had not surpassed 50 bushels per acre until 2015-16, when average state wheat yield was 57 bushels per acre. However, recent estimates of the long-term winter wheat yield potential in central Kansas indicate that it lies around 75 bushels per acre. A particular crop's yield gap in a given region is determined by the difference between potential and actual yields. The long-term yield gap in Kansas is approximately 45 bushels per acre, which corresponds to more than 50% of the yield potential. Yield gaps have the potential to be economically reduced to approximately 30%. The two possible ways to reduce yield gaps are through improved agronomic management or increasing yield potential through improved genetics. Our hypothesis is that improved management can largely contribute to closing wheat yield gaps in central Kansas. Our objectives were to quantify the partial contribution of different management strategies toward closing the wheat yield gap in central Kansas, including fertilization, plant population density, fungicide, and growth regulator applications, all individually or in combination.

## Procedures

Field studies were conducted as a randomized complete block design with an incomplete factorial treatment structure and six replications at three locations during the growing season of 2015-16. Locations included the North Central Kansas experiment field in Belleville, the South Central experiment field in Hutchinson, and the North Agronomy Farm in Manhattan, KS. The trial was conducted under rainfed conditions at all locations, and the wheat variety Everest was sown. Seed was treated with 5 oz. Sativa IMF Max across the entire study, so fungicide or insecticide seed treatment was not a limiting factor. Soil samples were taken for soil nutrient analysis at sowing at each location for the 0-6 and 6-18 inch soil depths and analyzed by the Kansas State University Soil Testing Laboratory.

The treatment combinations were set up with two control treatments: a standard "farmer practice" and an intensive "kitchen sink" management approach. Yield goals in these treatments were 70 and 120 bushels per acre, respectively. Agronomic management strategies that were modified from the standard to the intensive treatment and also evaluated individually consisted of high vs. low seeding rate (110 vs. 75 pounds per acre), nitrogen (N) at sowing and top-dressed (Feekes 3-4) vs. additional 100 pounds N per acre nitrogen applied early spring (Feekes 5-6), sulfur or chloride applied during Feekes 5-6, two foliar fungicide applications (Feekes 6-7, 10.5), and growth regulator (Feekes 6-7). The standard control consisted of: low seeding rate and N applied at sowing and top-dressed for a yield goal of 70 bushels per acre. Next, treatments were added individually to the standard control totaling six low-input treatments plus a control (Table 1). The intensive control consisted of: nitrogen applied at sowing and top-dressed similarly to the standard treatment, an additional 100 pounds of nitrogen per acre at Feekes 6, high seeding rate, sulfur, chloride, two applications of fungicide, and growth regulator. Conversely, treatments were removed individually from the intensive approach for a total of an additional six high-input treatments plus a control (Table 1). A total of 14 treatment combinations were evaluated in this study. Plants were harvested using a small plot combine, and grain moisture was corrected for 13.5% moisture content. Protein content was measured using near-infrared spectrometry. In this report, we discuss the effects of the treatments on wheat grain yield and protein content.

## Results

The weather at all three locations had a warm and moist fall, followed by a mild and dry winter, and a cool and moist spring. A total of 20 inches of precipitation occurred in Hutchinson, 18.2 inches in Belleville, and 23.4 inches in Manhattan during the growing season. Late winter (late February/early March) drought hindered some of the yield potential as dry fertilizers were not dissolved into the soil profile and root zone in a timely manner and spring tillering was delayed. However, the cool and moist spring observed from mid-April until physiological maturity provided excellent grain filling conditions for the wheat crop.

### *Grain Yield*

Significant differences in grain yield occurred among the locations during the 2015-16 growing season, and significant treatment effect occurred at all locations. Belleville averaged the highest yield among the three locations, averaging 86 bushels per acre. Hutchinson and Manhattan followed Belleville, averaging 59 and 57 bushels per acre, respectively. The main reason for the reduced yields in Hutchinson was the delayed sowing of October 29, 2015, which is considered late for that area. Late sowing dates reduce the amount of fall-produced tillers, which may directly affect the number of heads per plant.

Belleville and Hutchinson both experienced yield increases resulting from the application of foliar fungicide due to significant amount of spring precipitation, which promoted a severe incidence of stripe rust. Foliar fungicide protected the canopy from injury and significantly improved grain yield increase. On the other hand, split-nitrogen application and increased plant population resulted in a significant improvement in grain yield increase in Manhattan. The increased grain yield resulting from both of these management practices can be partially attributed to the no-till farming system adopted in this location, which increased the surface residue and inhibited the achievement of a good seed-to-soil contact, warranting increased plant population. Additionally, the high N immobilization rates typically experienced from broadcast N into heavy residue, as well as by soil microbes, can partially explain the yield gain from increasing N rate. Additionally, minimal rainfall occurred after the fertilizer application, allowing for some of the urea to be lost by volatization.

In Belleville, the standard low-input control had a grain yield of 52 bushels per acre, which was similar to all six treatments with individual additions to the standard control, except the addition of two fungicide applications, which significantly increased grain yield to 78.4 bushels per acre (Figure 1). The intensive treatment had a grain yield of 84 bushels per acre, which was statistically the same as the standard treatment plus fungicide. This yield was greater than the removal of fungicide from the intensive treatment, which significantly decreased the yield to 55 bushels per acre. Grain yield response to treatments in Hutchinson followed the same trend as Belleville, where fungicide was the only significant factor. The standard treatment resulted in a yield of 37.8 bushels per acre, and the addition of fungicide significantly increased grain yield to 49.8 bushels per acre. The intensive treatment had a grain yield of 51.2 bushels per acre and was statistically similar to all treatment removals from the intensive, except the removal of fungicide which significantly reduced the yield to 32.5 bushels per acre. In Manhattan, the standard treatment had a yield of 47.6 bushels per acre with no significant differences within the standard treatment additions. However, the intensive treatment had a yield of 49.9 bushels per acre, and the removal of split-nitrogen, sulfur, plant population, or fungicide significantly reduced yields to 42.6, 46.1, 45.4, and 46.1 bushels per acre, respectively.

### *Grain Protein Concentration*

In Belleville, wheat protein concentration for the standard treatment averaged 11.6% and was statistically the same as all other standard treatments, except for the spilt-nitrogen and the growth regulator additions, which significantly increased protein concentration at 12.1 and 12% (Figure 1). Wheat protein concentration averaged 12.3% for the intensive treatment; however, removing the split-nitrogen significantly lowered the protein concentration to 11.6%. The standard treatment for Hutchinson resulted in an average of 12.4% wheat protein concentration, and the fungicide application significantly increased the protein concentration by 1%. Likewise, the intensive treatment had an average wheat protein concentration of 13.8%, with no significant differences recorded among the other intensive management treatments. In Manhattan, average protein concentration was 11% in the standard treatment and was statistically the same as all other standard management strategies, except when the split-nitrogen was added, which significantly increased the protein concentration to 11.9%. The intensive treatment resulted in protein concentration of 12.1%, removal of split-nitrogen application was the only factor that significantly decreased the protein concentration, resulting in 11.1%.

### *Preliminary Conclusions*

With the high year-to-year environmental variability, three site-years are not enough to make definite recommendations based on an intensive vs. standard management strategy. However, some tendencies can be identified across the studied locations. For instance, fungicide significantly increased yields in heavy-disease years, and nitrogen and plant population were more important factors in no-till conditions. For two studied locations, Belleville and Hutchinson, fungicide increased yield and test weight. Because of a severe outbreak of stripe rust for the growing season, fungicide application resulted in more than 25 bushel per acre yield gain in Belleville and over 15 bushel per acre in Hutchinson. The no-till conditions experienced in Manhattan resulted in a yield gain from the split-nitrogen application and the increased plant population. Regarding wheat protein concentration, additional N seems to be the leading factor, as the application of 100 pounds of N per acre raised the protein concentration for all three studied locations.

## Acknowledgments

We would like to thank Andrew Esser, Gary Cramer, and Dustin Ridder for helping us with project establishment, management, and harvest at the experiment fields. We would also like to thank the Kansas Wheat Commission for the funding to allow us to conduct this research, and DuPont for partial funds to support research, and for providing the fungicide products Aproach and Aproach Prima used in this study. We also acknowledge Syngenta for providing the Palisade growth regulator used in this study.

**Table 1. Standard and intensive treatments were the low and high input controls, respectively**

| Treatment | Description | Rate |
|---|---|---|
| 1-Standard | 75 lb/a, top-dress N at Feekes GS 3 | Yield Goal: 70 bushels/a |
| 2 | + Split nitrogen at Feekes GS 5 | + 120 lb N/a |
| 3 | + Sulfur at Feekes GS 5 | + 40 lb S/a |
| 4 | + Chloride at Feekes GS 5 | + 40 lb Cl/a |
| 5 | + Plant population | 110 lb/a |
| 6 | + Fungicide at Feekes GS 6 and 10.5 | + 2 applications |
| 7 | + Growth regulator at Feekes GS 6 | + 1 application |
| | | |
| 8- Intensive | All treatments 2-7 combined | Yield Goal: 120 bushels/a |
| 9 | – Split nitrogen | – 120 lb N/a |
| 10 | – Sulfur | – 40 lb S/a |
| 11 | – Chloride | – 40 lb Cl/a |
| 12 | – Plant population | 110 lb/a |
| 13 | – Fungicide | – 2 applications |
| 14 | – Growth regulator | – 1 application |

Description of the individual treatment strategy for each addition (+) or removal (–) of an input from the respective control.
N = nitrogen.
GS = growth stage.
S = sulfur.
Cl = chloride.

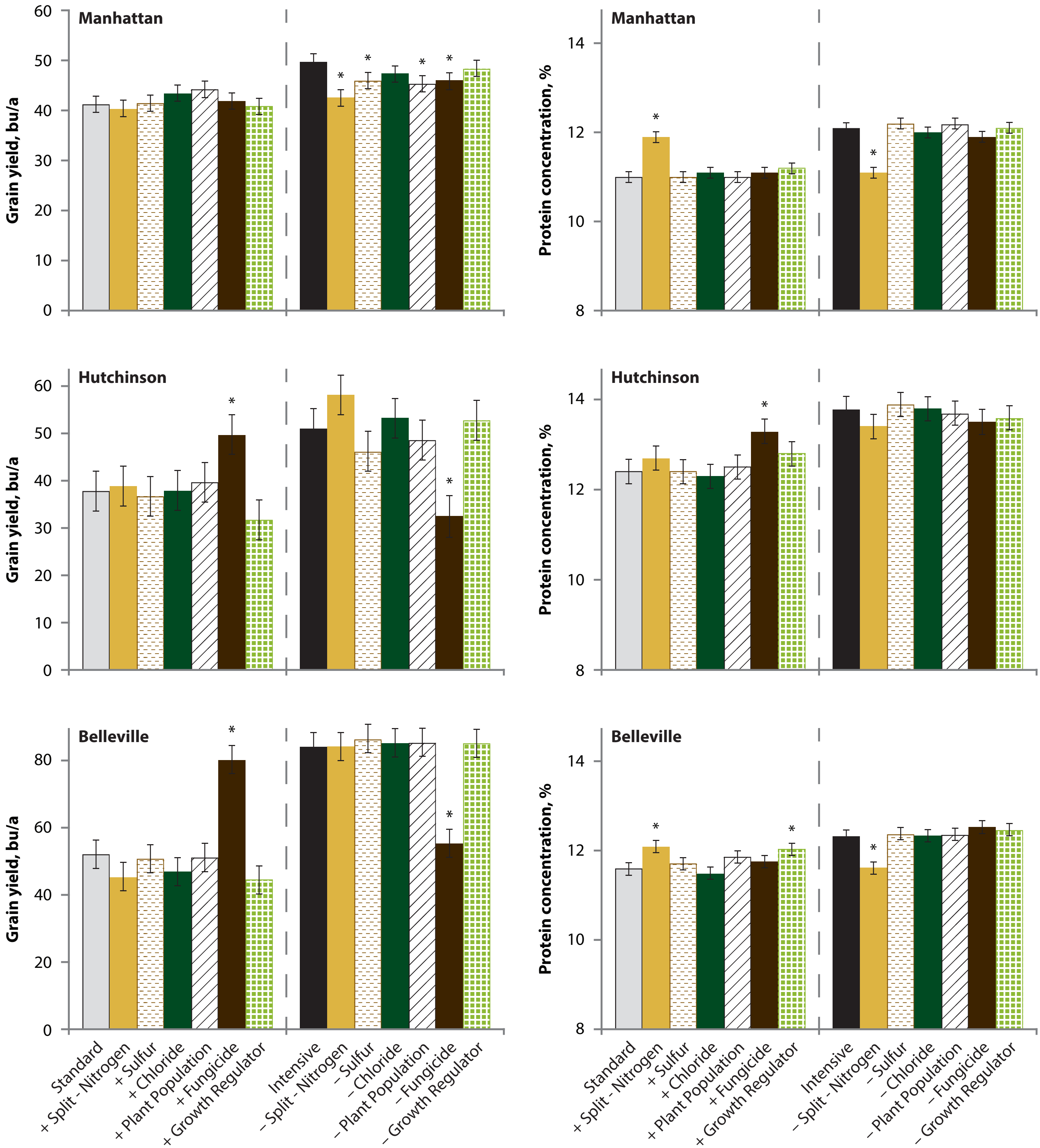



**Figure 1. Winter wheat grain yield (left panels) and grain protein concentration (right panels) as affected by management strategies in Manhattan, Hutchinson, and Belleville, KS, during the 2015-16 growing season. Dashed lines separate the two treatment controls (standard and intensive), which were analyzed separately; asterisk (*) indicates significance at $P < 0.05$ from the respective control.**

# Wheat Variety Response to Intensive vs. Standard Management Strategies to Narrow the Yield Gap in Kansas

*A. de Silva, A.K. Fritz, and R.P. Lollato*


## Summary

Farmer-reported wheat grain yield in Kansas is approximately 35 bushels per acre lower than the estimated yield potential of ~75 bushels per acre. Our objective was to determine the influence of variety selection and management on grain yield to elucidate methods to decrease the wheat yield gap in Kansas. Field experiments were conducted at three locations (Ellsworth, Conway Springs and McPherson) in Kansas during the 2015-2016 growing season to evaluate variety-specific response to nitrogen (N) and foliar fungicide. At each site, 35 to 44 winter wheat varieties were evaluated under standard management practice (SM) based on current farmer's practice of each region, versus intensive management (IM) with an additional 40 pounds of N per acre applied at Feekes growth stage 3 (GS3) and two fungicide applications (Feekes GS6 and GS10). Yield gap between the IM and SM ranged from 4 bushels per acre in McPherson to 19 bushels per acre in Ellsworth, due to a severe stripe rust (*Puccinia striiformis* Westend) epidemic. Varieties more susceptible to stripe rust had 50% cumulative probability yield gain of 13 bushels per acre across all locations studied in KS by switching from SM to IM, while resistant varieties gained 5 bushels per acre. The probability of breakeven was about two times greater in susceptible varieties as compared to resistant varieties. Our results indicate that selecting varieties with resistance to major fungal diseases can sustainably narrow the wheat yield gap in most years, reducing the need for additional fungicide. Notwithstanding, optimized management system is warranted for varieties that lack the aforementioned genetic resistance.


## Introduction

Farmer-reported wheat grain yield in Kansas is approximately 35 bushels per acre lower than the estimated yield potential of ~75 bushels per acre. Although a few research studies and yield contests have reported wheat yields of ~100-120 bushels per acre in Kansas, the state average yield of ~40 bushels per acre has remained about the same for the past 30 years. This difference between average producer yield and the yield potential is known as yield gap. Previous research studies have suggested that the yield gap in the southern Great Plains is possibly due to suboptimal management practices rather than inferior genetic potential of current varieties. Yield gain from fungicide applications has been inconsistent depending on variety resistance, disease pressure, crop management and climate variability, while split-N application has increased yield and N use-efficiency in wheat in several studies. Hence, development of studies with variety-specific crop management strategies is crucial to improve yield in diverse farming systems. Furthermore, a comprehensive characterization of varieties under a wide range of cropping systems will assist producers to select varieties best suited to their area and consequently narrow the yield gap in wheat production with profitability. This study was conducted to determine the influence of variety selection and management on grain yield to elucidate methods to reduce the wheat yield gap in Kansas.

## Procedures

Rainfed on-farm research studies were conducted in three locations in Kansas during the 2015-2016 growing season: Conway Springs (CO), Ellsworth (ELL), and McPherson (MP) (Table 1). Weather data were collected on a daily basis (from sowing to harvesting) from the Kansas Mesonet station located at the vicinity of the experiment sites (Table 1). The predominant soil type was Bethany silt loam in CO and Crete silt loam in ELL and MP (Table 1). At all sites, the seeding rate was 60 lb/a. Conventional tillage was performed in the fall prior to wheat sowing for all locations. Wheat field trials were sown with a 6-row Hege small plot cone sower with row spacing of 7.5 inches and plot length of 15 feet. Insect and weed occurrence was minimal and controlled with commercially available chemical products as needed.

A total of 35 to 44 wheat varieties commercially available and experimental units were tested at each location, in combination with the official K-State Wheat Performance tests (Table 2). Varieties differed in year of release, maturity range, disease resistance, and yield potential. Only the average of varieties will be discussed in this report. The experimental design was a strip plot with variety as the main factor and management practices as the sub-factor. The varieties were arranged in a randomized complete block design with three replications, while the two management practices were non-randomized and applied as strips. The management treatments tested were (i) standard management (SM), with the N rate calculated based on K-State fertilizer recommendations for approximately 70 bushels per acre yield goal and no fungicide application; and (ii) intensive management (IM), comprising the SM treatment, the additional N rate of 40 lb N/a applied as urea (46-0-0) at Feekes GS 3, and two fungicide applications at Feekes GS 6 and 10.5 for KS (Table 2). For the SM treatment, the N rate, source and timing of application slightly varied across locations depending on soil N profile and each farmer's practice (Table 2).

Plots were harvested with a small plot combine (Wintersteiger Delta) and grain yield was adjusted to 12% moisture. The average yield recorded for the past 3- to 5-years prior to the establishment of the field trials in these regions were 49, 60, 62 bu/a for ELL, CO, and MP.

Statistical analysis was conducted using SAS 9.4 (SAS Institute Inc., Cary, NC). The yield differences (or yield gap) between management treatments were estimated prior to analysis and used as a dependent variable. At each location, the yield gap was estimated by subtracting the yield from the standard management (SM) by the yield from the intensive management (IM). Varieties were grouped into three categories of resistance levels to stripe rust (resistant (RES), intermediate (INT) and susceptible (SUS)) for the yield gap, cumulative probability of yield gain, and probability of breakeven analyses.

## Results

The weather conditions were conducive to high wheat yield during the 2015-2016 growing season in KS. The mild temperature and adequate precipitation during the fall helped with the early vegetative growth of the crop. Although very dry conditions and few freezing events were observed during the winter, the increase of precipitation events in the spring, together with cool temperatures, promoted a good grain filling period.

However, the latter conditions also benefited the occurrence of the stripe rust disease (*Puccinia striiformis* Westend).

The average yield across all varieties for each management treatment at each location was 73 and 54 bu/a, 74 and 68 bu/a, and 66 and 62 bu/a, respectively for the IM and SM management practices in ELL, CO, and MP locations (Table 2). The minimum and maximum yield observed when averaged for all varieties and management treatments at each location were 24 and 126 bu/a in ELL, 45 and 96 bu/a in CO, and 30 and 97 bu/a in MP.

This large yield variability was due to the variety differences in resistance levels to stripe rust, and consequently in response to the fungicide applications. At all locations, varieties that are more susceptible (SUS) to stripe rust or have intermediate (INT) susceptibility to stripe rust had larger yield gaps than resistant (RES) varieties. One example of the yield obtained under IM and SM for different wheat varieties in the ELL location is shown in Figure 2. Yield gain was significantly greater in varieties susceptible to stripe rust as compared to resistant varieties. The greatest yield gap of ~19 bu/a was observed in the ELL location, possibly due to the severe stripe rust epidemics relative to CO and MP locations with yield gap of 6 and 4 bu/a, respectively, during the growing season (Figure 3).

Likewise, probability of yield gain resulting from the IM treatment was larger for susceptible than for resistant varieties (Figure 4). Susceptible varieties had 50% cumulative probability yield gain of 13 bu/a across all studied locations in KS by switching from SM to IM, while resistant varieties gained 5 bu/a. Additionally, stripe rust decreased late-season green canopy cover in susceptible varieties from as much as 99% under IM to 56% or less for the SM (Figure 5). On average of the three locations, the probability of breakeven was about two times greater in susceptible varieties as compared to resistant varieties (42 vs. 21%) (Figure 5). Breakeven probability (%) was estimated using $4/bu wheat price and total nitrogen and fungicide cost of $52/a.

### *Preliminary Conclusions*

Our results indicate that selecting varieties with resistance to major fungal diseases may narrow the wheat yield gap in Kansas most years, potentially reducing the need for additional fungicide. On the other hand, intensive management may be a viable alternative for varieties that lack the aforementioned genetic resistance. This study is an initial step towards reducing the current yield gap in wheat production by assisting producers to implement variety-specific management.

**Table 1. Site information**

| Location | Coordinates | Sowing date | Harvesting date | Previous crop | Cum PPT (in.) | Cum ET (in.) |
|---|---|---|---|---|---|---|
| Ellsworth | 38°34'36.16"N 98°18'44.78"W | 10/9/2015 | 7/19/2016 | Wheat | 20 | 674 |
| Conway Springs | 37°27'34.94"N 97°37'43.33"W | 10/13/2015 | 6/7/2016 | Soybean | 30 | 793 |
| McPherson | 38°15'56.99"N 97°35'34.04"W | 10/7/2015 | 6/28/2016 | Wheat | 20 | 772 |

Note: There were no solar radiation data available for the fall period in Ellsworth, therefore average evapotranspiration in this location represents values from January to June (harvesting).
Plot coordinates, sowing and harvesting dates, previous crop, cumulative precipitation (Cum PPT) in inches and cumulative evapotranspiration (Cum ET) in inches at each location during the 2015-2016 growing season in Kansas.

**Table 2. Number of varieties tested, total nitrogen (N) rate (lb/a) and average grain yield (bu/a) at 12% moisture adjustment for standard management and intensive management at each location in the 2015-2016 growing season in Kansas**

| | | N rate (lb/a) | | Grain yield (bu/a) | |
|---|---|---|---|---|---|
| Location | Varieties # | IM | SM | IM | SM |
| Ellsworth | 35 | 155 | 115 | 73 | 54 |
| Conway Springs | 44 | 244 | 140 | 74 | 68 |
| McPherson | 44 | 135 | 95 | 66 | 62 |

Differences in total N rate reflect variation in soil $NO_3$-N profile at each location.
SM = Standard management.
IM = Intensive management.

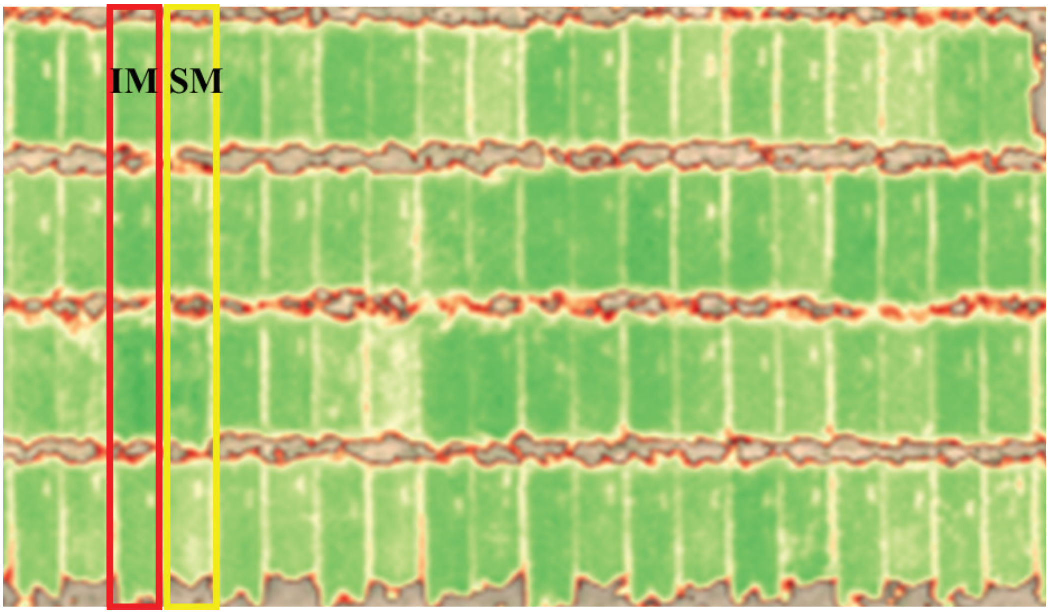



**Figure 1. Paired plot design and experiment layout for three locations Conway Springs (CO), Ellsworth (ELL), and McPherson (MP) in Kansas, 2016.**

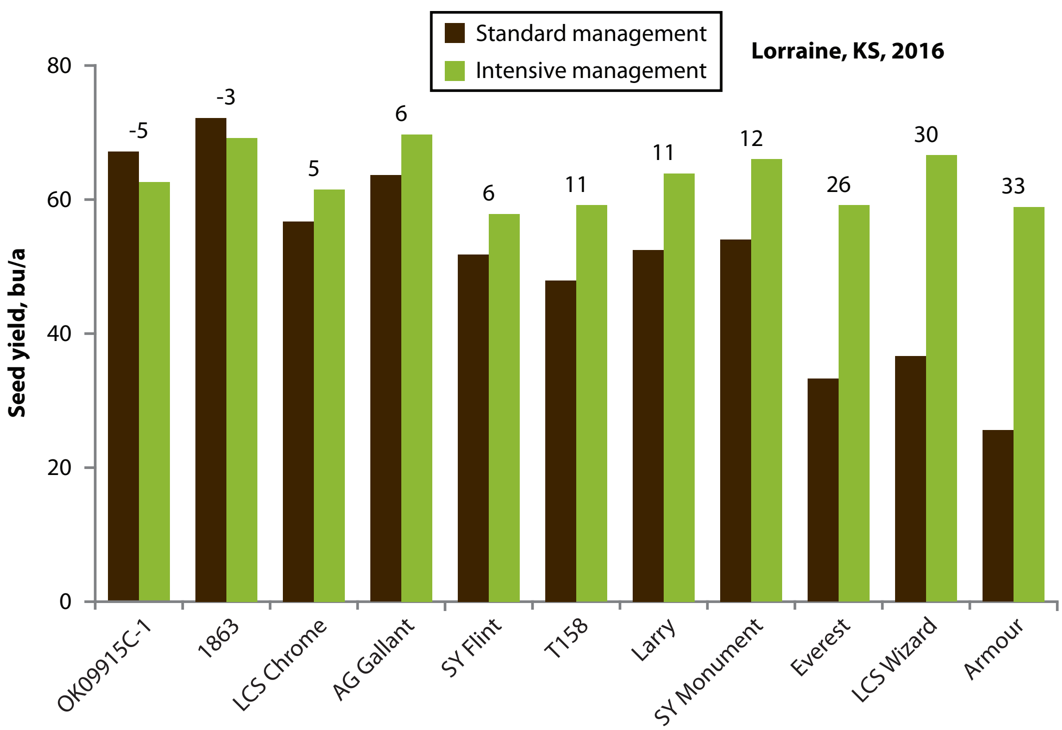



**Figure 2. Wheat grain yield as affected by variety and management strategy in Lorraine and Ellsworth, KS, during the 2015-2016 growing season. Varieties with greater susceptibility to stripe rust, such as Everest, LCS Wizard, and Armour, also show the greatest yield gap.**

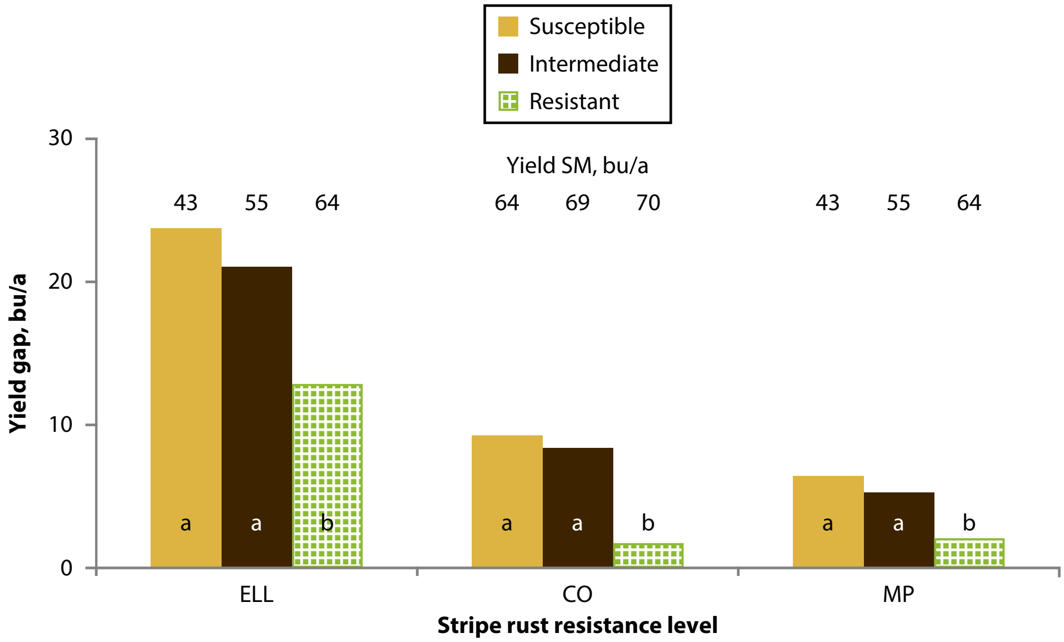



**Figure 3. Yield gap between standard (SM) and intensive management (IM) for different variety resistance levels to stripe rust disease at three locations in Kansas, 2016. Within location, means for each resistance level with the same letter are not significantly different at *P* < 0.05 (LSD).**

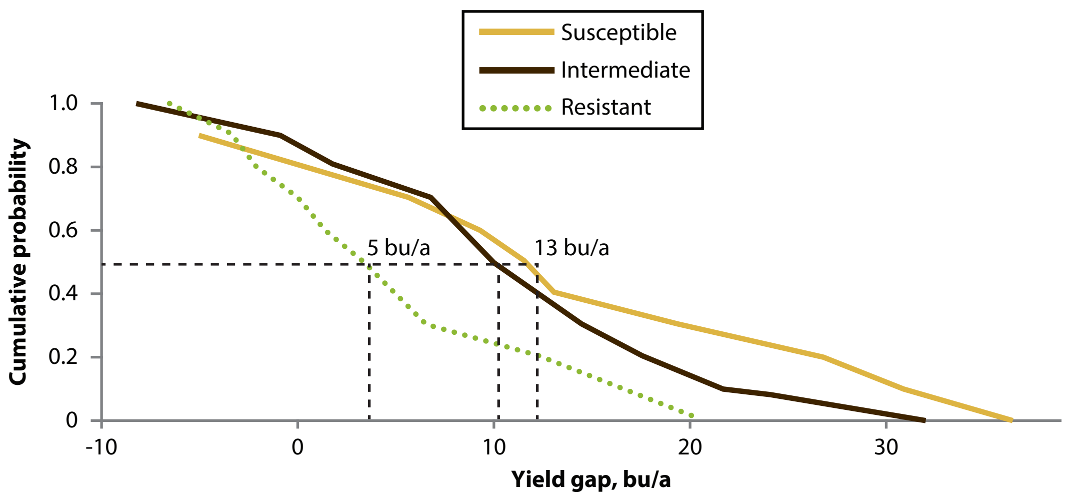



**Figure 4. Cumulative probability of yield gain from standard (SM) to intensive management (IM) for different variety resistance levels to stripe rust disease at three locations (ELL, CO, and MP) in Kansas, 2016.**

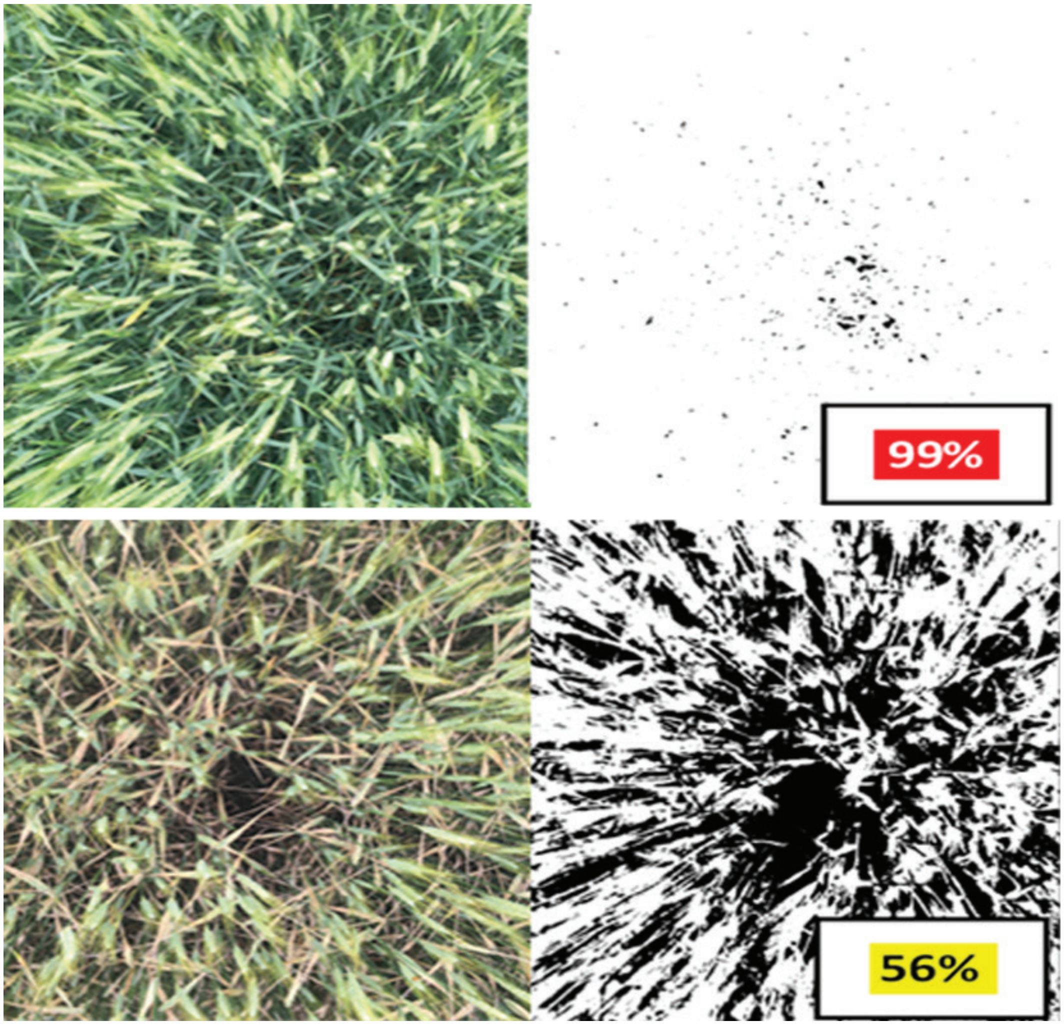



**Figure 5. Comparison of green canopy coverage between intensive (IM) and standard management (SM) for a susceptible variety at the Ellsworth location in Kansas, 2016.**

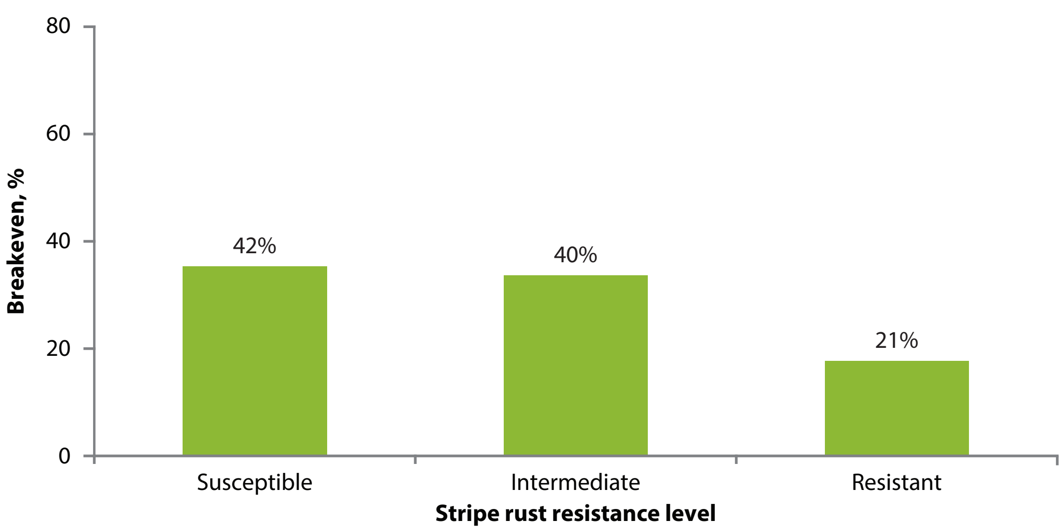



**Figure 6. Probability of breakeven (%) for the additional nitrogen rate (40 lb/a) and two fungicide applications. Means for three locations Conway Springs (CO), Ellsworth (ELL), and McPherson (MP) in Kansas, 2016.**

# Wheat Variety Response to Seed Cleaning Method and Pesticide Seed Treatment Following a Growing Season with Severe Infestation of Fusarium Head Blight

*R.P. Lollato, R. Maeoka, B.R. Jaenisch, and A. de Oliveira Silva*

## Summary

Fusarium head blight (scab) is a common concern in eastern and central Kansas. Wheat seed quality might be compromised following a growing season with severe infestation of scab. Our objectives were to evaluate the effects of variety, seed cleaning method, and seed treatment, on wheat stand establishment and yield following a growing season where scab was severe. A trial was established during the 2015-16 growing season using seed harvested from the 2014-15 growing season, which was characterized by severe infestation of scab. Three commonly grown wheat varieties with differing levels of scab resistance (Everest, SY Wolf, and WB Grainfield) were submitted to three different seed cleaning methods (unclean, air screened, or top-gravity table) and two different pesticide seed treatments (no seed treatment versus Gaucho XT fungicide and insecticide). Plots were 30 feet long by 5.6 feet wide and sown at 1.2 million seeds per acre. Seed cleaning method affected wheat seed size, with top-gravity table resulting in larger seed size, approximately 3,000 fewer seeds per pound compared to unclean seed. Seed cleaning method also increased stand establishment from 10.4 emerged plants per row foot resulting from the unclean seed to 11.9 emerged plants per row foot resulting from the top-gravity table. Notwithstanding, there was no effect of variety or seed treatment on stand establishment. Grain yield, on the other hand, was increased from 55.6 to 61.3 bushels per acre in response to seed treatment and was significantly different among varieties. The variety WB Grainfield yielded 68.4 bushels per acre, which was statistically greater than the 53 bushels per acre achieved by both Everest and SY Wolf. There was no effect of seed cleaning method on grain yield.

## Introduction

Head scab is a recurring issue in the central and eastern portions of the wheat-producing regions of Kansas. Producers in the region often use genetic resistance to suppress the development of this disease by making extensive use of the wheat variety Everest, which offers the best levels of resistance available among current wheat varieties. Additionally, some producers opt to perform one additional fungicide application around anthesis, when the infection by this disease generally occurs. Still, genetic resistance only provides partial control of the disease, and even varieties with high resistance ratings might become infected in years when the weather is conducive to high disease incidence and severity. Furthermore, fungicide applications targeted specifically to control head scab are challenging. These applications require near perfect timing as well as the use of particular active ingredients, such as Metconazole or Prothioconazole, given that other active ingredients can in fact enhance the development of the disease instead of controlling it. Therefore, product selection becomes an important factor in the success of scab control. The wheat seed available in years following a growing season with severe infestation of Fusarium head blight is often of low quality, and understanding the best strategies to manage Fusarium-induced low-quality seed is warranted. The objectives of this research were to test the effects of wheat variety, seed cleaning method, and seed treatment, on wheat stand establishment and grain yield following a growing season where head scab was predominant across many portions of Kansas.

## Procedures

A research project was established in Manhattan, KS, with the objective of understanding the effects of seed cleaning method, pesticide seed treatment, and variety selection on wheat stand establishment and grain yield following a growing season with severe head scab infestation. Wheat seed was collected from three commonly grown wheat varieties (Everest, WB Grainfield, and SY Wolf) following the 2014-15 growing season, when head scab was a major issue across most of eastern and central Kansas wheat growing regions. Genetic diversity to scab resistance existed among varieties, with Everest presenting the greatest levels of resistance to head scab. Seed was sourced from three different timings within the seed cleaning process with Ohlde Seeds, near Palmer, KS: unclean seed, air-screened seed, and top of gravity table seed. Seed size was measured by weighting three one-thousand kernel samples per variety per seed cleaning process. The seeds were then divided in two cohorts, one of which received Gaucho XT insecticide and fungicide seed treatment at 3.4 fluid ounces per hundred weight of seed, and the other which received no pesticide seed treatment.

The project was established in a 3-way factorial treatment structure in a randomized complete block design with 4 replications, with the objective of evaluating three seed cleaning processes, two seed treatment factors, and the three aforementioned varieties. The trial was sown on October 9, 2015 at 1.2 million seeds per acre. Plots were 30 ft long by nine 7.5-inch spaced rows wide. No-tillage practices were adopted, following a maize crop. Weeds and insects were controlled according to the recommendations of Kansas State University for best management practices, and a foliar fungicide was applied at flag leaf emergence so fungal diseases were not a confounding factor. Nitrogen (N) fertility ensured sufficient N was present for a yield goal of 70 bushels per acre, using a total 2.4 pounds of N per bushel per acre yield goal between applied mineral fertilizer and residual soil nitrate-nitrogen credits. Stand count was performed approximately 3-4 weeks after sowing, and grain yield was measured at harvest maturity, using a small plot combine.

## Results

### *Seed Size as Function of Seed Cleaning Process*

There was a clear effect of seed cleaning process and variety on seed size, measured in 1000-kernel weight and converted to seeds per pound prior to sowing (Figure 1). Adopting no strategy to clean the seeds resulted in the smallest seed size, ranging from 15,400 seeds per pound for SY Wolf to 17,300 seeds per pound for WB Grainfield. The average size of seeds increased when smaller than average seeds were screened out, or eliminated by gravity when running the seeds through an air screen, and selecting the seeds from the top of the gravity table resulted in even larger seeds. Seed sizes ranged from 12,400 seeds per pound for SY Wolf to 14,100 seeds per pound for WB Grainfield. Everest consistently resulted in average seed size as compared to SY Wolf (larger seed) and WB Grainfield (smaller seed). Performing the entire cleaning process (air screening followed by gravity table) increased seed size an average 3,000 seeds per pound (Figure 1).

### *Stand Establishment*

There was no significant interaction between variety, seed cleaning process, or seed treatment on final wheat stand establishment; thus, the individual effects of each factor are discussed in this report. There was no effect of variety on stand count, as all varieties ranged between 10.9 to 11.4 emerged plants per row foot (Figure 2). On the other hand, seed cleaning significantly affected stand establishment, as the unclean seed lot resulted in 10.6 emerged plants per row foot while the top gravity table resulted in 11.9 emerged plants per row foot (Figure 2). When analyzing these data, it is important to consider that plots were sown in seeds per acre rather than pounds per acre, possibly explaining these results. Had the plots been sown in pounds per acre, the resulting number of emerged plants per area might have differed from these results, once there were more seeds per pound in the unclean seed lot. While seed treatment did not result in significant differences in stand count (Figure 2), there was a trend of increased stands when a fungicide and insecticide seed treatment was applied as compared to no pesticide applied (11.4 vs. 10.7 emerged plants per row foot).

### *Grain Yield*

Similarly, to our measurements of stand establishment, there was no significant interaction between variety, seed cleaning process, or seed treatment on wheat grain yield; thus, the individual effects of each factor are discussed in this report. Notwithstanding the results obtained for stand establishment, the opposite trend was measured on grain yield as affected by the different treatments evaluated: there were significant variety and seed treatment effects, and no significant effect of seed cleaning method. The variety WB Grainfield yielded statistically more than did Everest or SY Wolf (68.4 vs. 53 bushels per acre for the latter two varieties) (Figure 3). Additionally, the average of all treatments receiving a Gaucho XT seed treatment was 61.3 bushels per acre, which was statistically greater than the 55.6 bushels per acre achieved without a pesticide seed treatment. This yield gain from seed treatment was most likely observed due to the low quality of the scab-infected seed used as seed source in this study. The lack of response to seed cleaning process is, on the other hand, likely a response to plant population. The wheat crop has a very high tillering capacity, and the difference in plant population as a result from seed cleaning (10.6 plants per row foot in the unclean versus 11.9 plants per row foot in the top gravity table) were most likely masked by the wheat's tillering capacity.

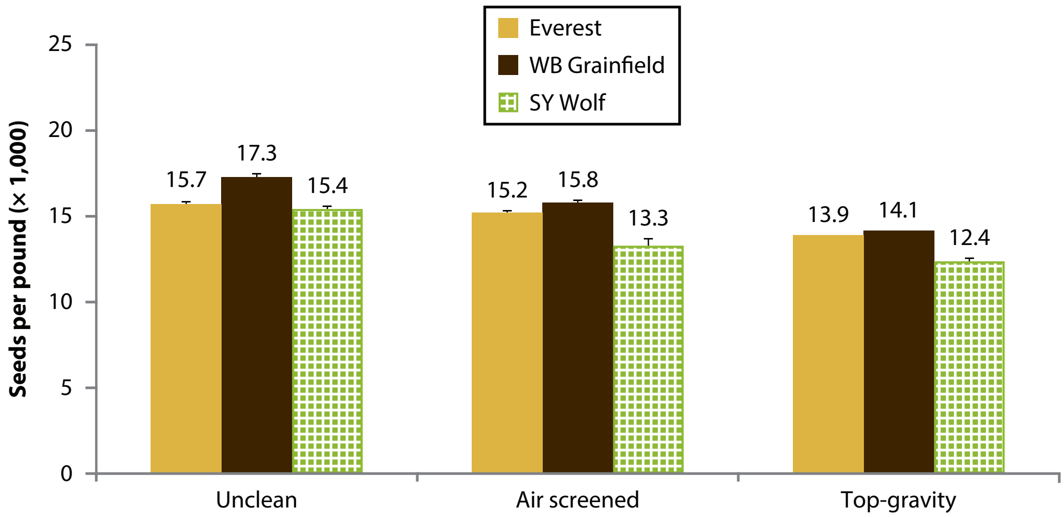



**Figure 1. Wheat seed size (seeds per pound) as affected by wheat variety and seed cleaning process following a growing season with severe infestation of Fusarium head blight.**

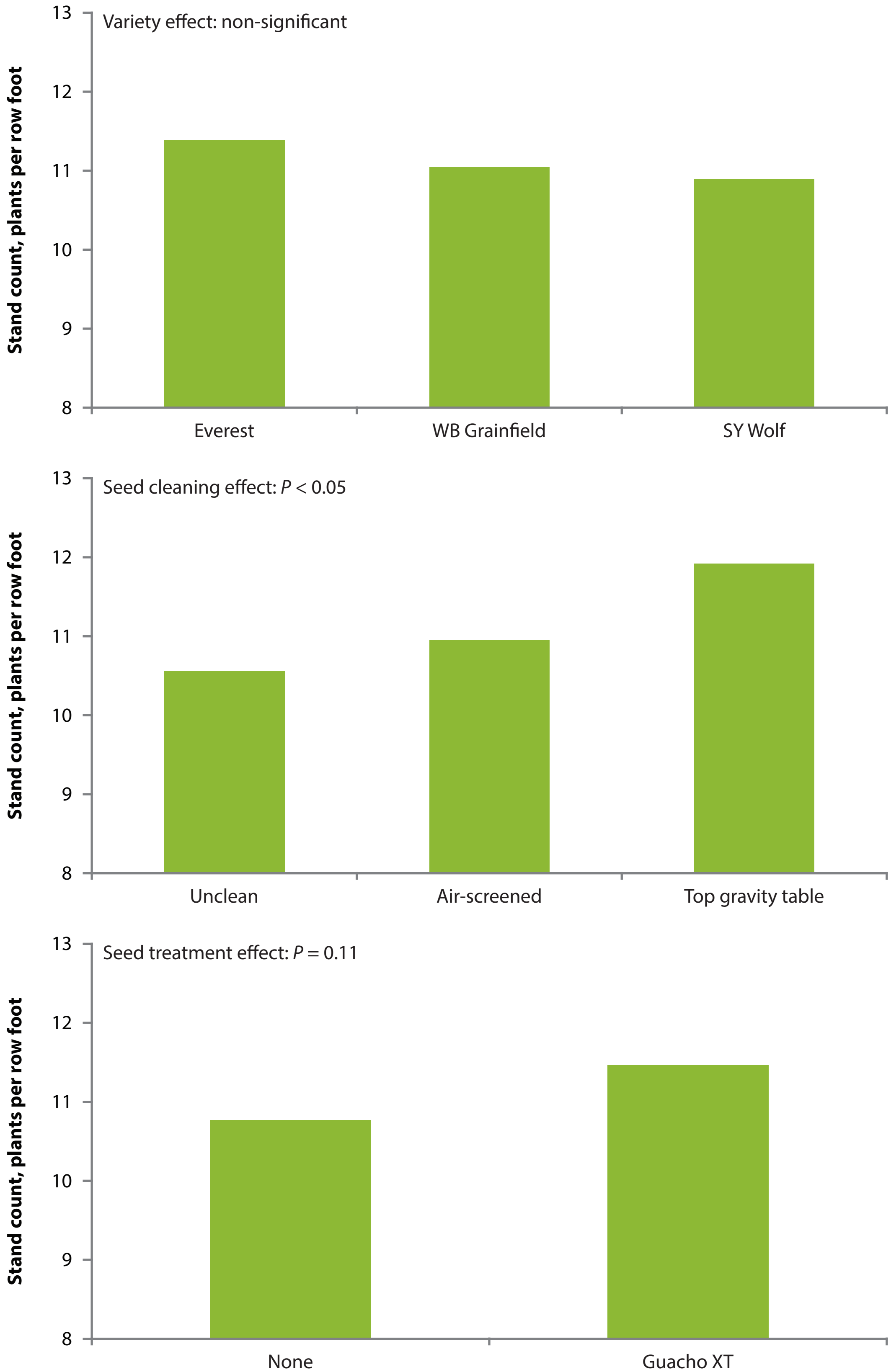



**Figure 2. Effect of variety (top panel), seed cleaning (middle panel), and seed treatment (bottom panel) on wheat stand establishment measured 3-4 weeks after sowing in Manhattan, KS, during the 2015-16 growing season.**

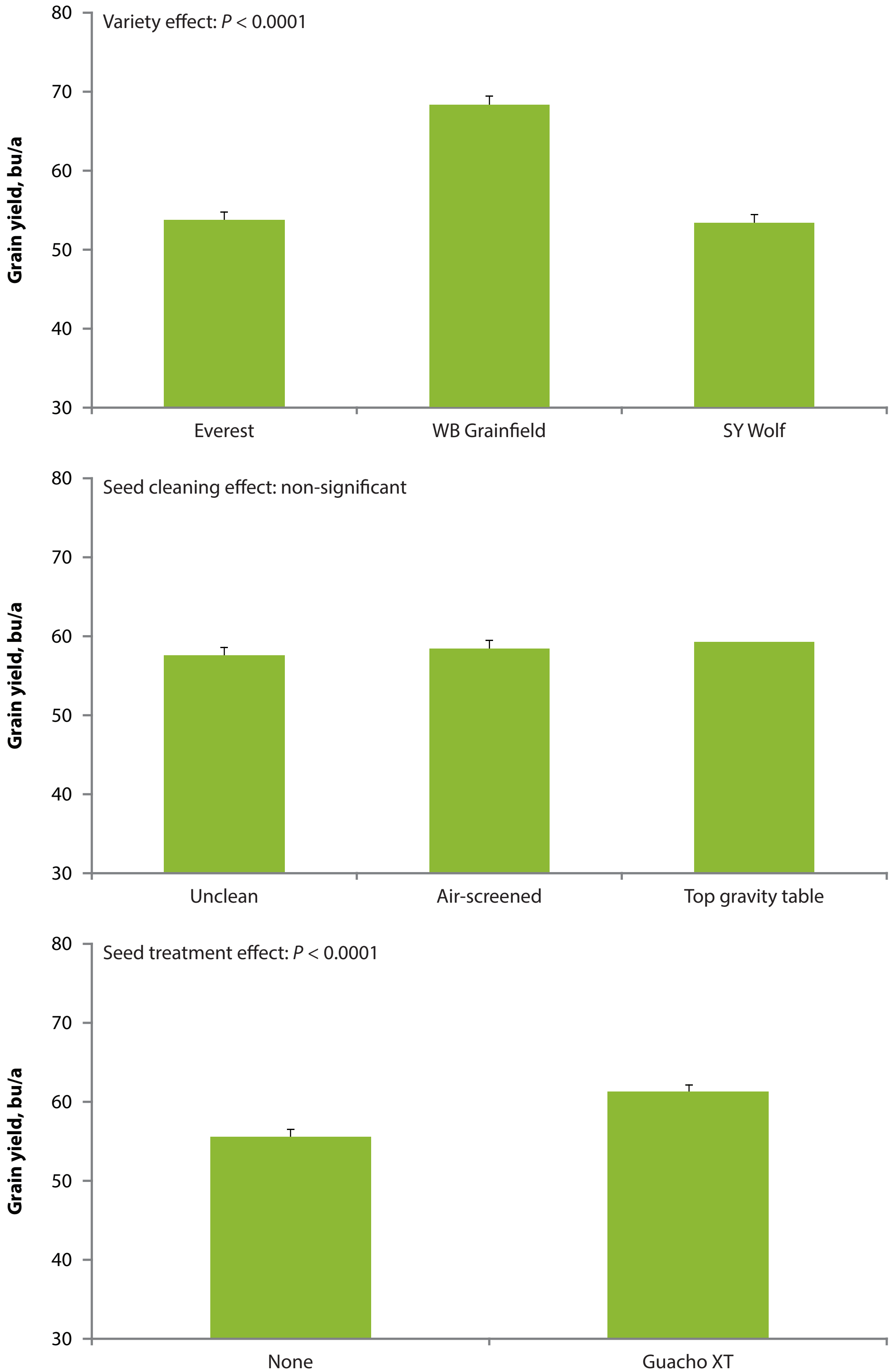



**Figure 3. Effect of variety (top panel), seed cleaning (middle panel), and seed treatment (bottom panel) on wheat grain yield in Manhattan, KS, during the 2015-16 growing season.**

# Optimum Seeding Rate for Different Wheat Varieties in Kansas

*R.P. Lollato, G.L. Cramer, A.K. Fritz, and G. Zhang*

## Summary
Seeding rate is an important management practice affecting wheat yield. Wheat varieties differ in their tillering capacity and therefore in their yield response to seeding rate. Our objectives were to evaluate the tillering and yield response of different modern wheat varieties to seeding rate. The study was conducted in Hutchinson and Manhattan, KS, during the 2015-16 growing season. Seven wheat varieties (Everest, KanMark, 1863, Joe, Tatanka, Larry, and Zenda) were sown at five different seeding rates (0.6, 0.95, 1.3, 1.65, and 2 million seeds per acre). Tiller number and grain yield were measured in the spring. Increasing plant population decreased the number of spring tillers sustained by the different varieties from more than eight tillers per plant at 600,000 seeds per acre to fewer than four tillers per plant at 2 million seeds per acre. There were varietal differences in tillers per plant, with the variety Joe standing out as a high-tillering variety. At both locations, wheat grain yield increased with increased seeding rates and was maximized at approximately 0.8-0.95 million emerged plants per acre. Further increases in seeding rate did not affect grain yield.

## Introduction
Plant population density is among the major factors determining the crop's ability to capture resources such as water, nutrients, and solar radiation. The response of wheat to plant density is largely determined by competition for resources with neighboring plants, and increased competition can result in reduced survival, dry matter production, and grain yield of individual wheat plants. Wheat plants subjected to high density generally have fewer tillers and grains than widely spaced plants; on the other hand, too widely spaced plants can result in few plants per unit area and consequently fewer grains per unit area, explaining the typical parabolic response of grain yield to plant density. Consequently, appropriate management of population density may allow maximum yields per unit area to be achieved. Given the difference in wheat lines regarding their ability to tiller as well as their response to intra-canopy competition for resources, it is possible that different varieties require different seeding densities to maximize yield. Thus, the main objective of this project was to better understand the response of different wheat lines and varieties to seeding density and ultimately to provide better recommendations to producers about seeding rate per variety.

## Procedures
One experiment was conducted at two locations in Kansas: the South Central Kansas experiment field near Hutchinson, and the Agronomy North Farm in Manhattan. Trials were established in a randomized complete block design with four replications. Seven varieties (Everest, KanMark, 1863, Larry, Zenda, Tatanka, and Joe) and five seeding rates (0.6, 0.95, 1.3, 1.65, and 2 million seeds per acre) were tested, for a total of 35 treatments. Plots were 7 rows wide in Manhattan, at a 7.5-inch row spacing, and 6 rows wide in Hutchinson, at a 10 inch row spacing. Plots were approximately 20-ft

long at both locations. Management practices adopted at both locations are described in Table 1. Nitrogen (N) fertilization at both locations was performed with a yield goal of approximately 70 bushels per acre, considering 2.4 lb of N needed for each bushel of yield goal. Weeds and foliar diseases were controlled at both locations so these were not confounding factors in the study.

Stand count was conducted at approximately 3-4 weeks after sowing, which was used to calculate plants per acre. All remaining analyses were performed using plants per acre rather than seeding rate. Tiller counts occurred during the spring, and a 1-meter row subsample was clipped from each plot at harvest time for biomass, harvest index, head count, average grain weight and head size. Plots were harvested using a small plot combine at both locations. Moisture and test weight were automatically measured by the combine in Hutchinson, and manually measured from the plots in Manhattan. Grain yield was adjusted for 13.5% moisture content. Statistical analysis included analysis of variance and regression, depending on the variable being evaluated.

# Results

### *Growing Season Weather*

The weather at both locations was characterized by a warm and moist fall, followed by a dry and mild winter and a cool and moist spring. Growing-season precipitation total was 20.5 inches in Hutchinson and 24.4 inches in Manhattan, mostly concentrated during the fall (approximately 1/3 of total precipitation) and spring (approximately 2/3 of total precipitation). The high yield potential led by abundant precipitation during the spring may have affected the results of grain yield.

### *Tillers Per Plant*

Tillers were counted from a 1-meter row from all plots during late March/early April at both locations. Number of tillers per plant was significantly affected by both variety and plant population in Hutchinson, and by plant population in Manhattan (Table 2). In Manhattan, there was a trend ($P < 0.1$) for tillers per plant to be affected by variety, although this was not significant at $P < 0.05$. At the plant population of approximately 1 million plants per acre, each plant had approximately 3.8 tillers in Hutchinson. Decreasing plant population significantly increased the number of tillers per plant so that a population of about 700,000 plants per acre had 4.8 tillers per plant; and a further decrease to 400,000 plants per acre significantly increased tillers per plant to 8.2. Likewise, increasing the plant population to 1.2 million plants per acre significantly decreased the number of tillers each plant produced and maintained, but further increase in sowing density to 1.4 million plants per acre did not decrease tillers per plant. Varieties also differed in their ability to tiller. In Hutchinson, Everest, KanMark, and Zenda resulted in lower numbers of tillers per plant (3.7, 3.7, and 3.9, respectively) than did Joe (5.3). The varieties 1863, Larry, and Tatanka (4.2, 4.2, and 4.1, respectively), were statistically similar to both Joe and the lowest tillering group. Results obtained in Manhattan were similar to those obtained in Hutchinson. Joe and Larry produced numerically greater number of tillers (4.9 and 4.8, respectively) than did Tatanka, Zenda, 1863, and KanMark (4.5, 4.3, 4.2, and 4.4, respectively), and Everest had the lowest number of tillers per plant (4.0). Again, this was only a trend as these differences were not statistically significant at $P < 0.05$. The effects of plant population on the number of tillers per plant in Manhattan were similar to those measured in Hutchinson. A plant population of approximately 450,000 plants per acre resulted in 7.4 tillers per plant, and increasing plant population to 700,000 and 900,000 plants per acre significantly decreased the number of tillers per plant to 4.9 and 4.8, respectively, which are statistically equal. A further increase in plant population to 1.1 and 1.3 million plants per acre significantly decreased number of tillers per plant to 3.5 and 3.3, respectively, which are statistically the same.

### *Tillers Per Acre*

Similarly to tillers per plant, tillers per acre were significantly affected by variety and plant population density in Hutchinson, and by plant population density in Manhattan (Table 2). In Hutchinson, the number of tillers per acre was only greater at the highest plant population of 1.3 million plants per acre. The 1.3 million plants per acre plant population had a total of 4.4 million tillers per acre, which is statistically greater than the number of tillers per acre for the plant populations of 400,000 plants per acre (3.8 million tillers per acre), 700,000 plants per acre (3.6 million tillers per acre), and 1 million plants per acre (3.8 million tillers per acre). The 1.2 million plants per acre rate resulted in 4 million tillers per acre, which is not statistically different from the numbers resulting from the higher and the lower plant populations. There was a significant effect of variety on the number of tillers per acre in Hutchinson. The variety 1863 had the highest number of tillers per acre (4.3 million tillers per acre). Zenda, Tatanka, and Joe had an intermediate number of tillers per acre (4.0, 4.1, and 3.9 million, respectively), and Larry, Everest, and KanMark resulted in the lowest readings (3.7, 3.6 and 3.7 million tillers per acre, respectively). In Manhattan, the number of tillers per acre was only greater at the highest plant population of about 1.3 million plants per acre, which is similar to the response measured in Hutchinson. The 1.3 million plants per acre resulted in a greater number of tillers per acre than that measured in the 500,000 and 800,000 plants per acre populations (4.5 versus 3.7 and 3.7 million tillers per acre, respectively). Meanwhile, the 1.1 and 1.3 million plants per acre populations resulted in similar numbers of tillers per acre (4.2 and 4.1 million tillers per acre, respectively) to those of the lower rates and the higher rate. There was no significant effect of variety in number of tillers produced per acre in Manhattan, although Joe and Larry had numerically more tillers per acre than the other varieties.

These results illustrate the capacity of the different varieties to compensate for a thin stand. Despite significantly fewer plants per acre at the lowest plant populations, these plants produced many more tillers per plant, so that the final number of tillers per acre was not as much affected as the final population. Joe stood out in its tillering capacity at both Manhattan and Hutchinson, as did Larry in Manhattan.

### *Grain Yield*

There was a great difference in yield potential between both study locations. Across all varieties and plant population densities, the trial in Manhattan averaged 44 bushels per acre while the trial in Hutchinson averaged 78 bushels per acre. At both Hutchinson and Manhattan, grain yield was significantly affected by variety and population density, but there was no significant interaction (Table 2). In other words, there were differences between varieties, differences between population densities, but all varieties responded similarly to the change in population density, precluding the need for an analysis by variety.

In Hutchinson, plant populations of 700,000, 1 million, 1.2 million, or 1.4 million plants per acre resulted in statistically similar yields (Figure 1). The lowest population density, 400,000 plants per acre, resulted in a lower grain yield than the remaining population densities. As far as varieties, Tatanka yielded statistically more than Everest and Zenda. KanMark, 1863, Larry, and Joe were placed in the middle group and yielded similarly to Everest, Zenda, and Tatanka.

In Manhattan, a similar trend to that measured in Hutchinson occurred, with the exception that both 500,000 and 800,000 plants per acre yielded fewer than 1.4 million plants per acre (Figure 2). The fact that 800,000 plants per acre resulted in a lower grain yield than the highest plant population density as opposed to the results in Hutchinson can be a function of the no-tillage system, which generally requires increased seeding rate to compensate for the lack of seedbed preparation, cooler soils promoting less tillering, and increased disease incidence from pathogens. The intermediate plant population rates of 900,000 and 1.1 million plants per acre resulted in statistically similar yields to both the lowest and the highest yielding groups. Joe resulted in greater yield than did all the other varieties, while KanMark was the lowest yielding variety. Everest, 1863, Larry, Zenda, and Tatanka were classified in the intermediate yielding group.

### *Individual Variety Response to Seeding Rate*

Although the analysis of variance did not call for analysis of the interaction of variety by plant population, we unfolded the interaction effects to better understand each individual variety's response to density. Each variety's yield response to plant population density was first modeled as an exponential rise to the maximum, following the trend measured in the main factor plant population at both locations and considering that there was no variety by plant population density interaction. Linear and quadratic response models were tested afterward to determine if the latter resulted in a better fit to the data.

In Hutchinson, the grain yield of Everest, KanMark, Zenda, and Larry was well modeled by an exponential rise to maximum model in the plant population range from 400,000 to 1.4 million plants per acre (Figure 3). These results indicate that, for these varieties, the best plant population for the studied growing season was in between the populations of 1.0 and 1.4 million plants per acre, both with no clear definition of a specific value. These results were most likely influenced by the above-average spring precipitation, which ensured enough moisture for tiller survival and grain yield under high population densities. KanMark and Larry seemed to maximize yields towards higher plant populations (1.1 - 1.3 million plants per acre), whereas Zenda seemed to maximize around 1 million plants per acre. The varieties 1863 and Tatanka did not show yield decrease at low population densities, meaning that their yields were the same regardless of plant population ranging from 400,000 to 1.4 million plants per acre. Joe showed a quadratic response of grain yield as affected by population. Although Joe's yield in the 700,000, 1.0, and 1.3 million plants per acre population was not statistically different, solving the quadratic equation indicates that the optimum population for Joe to maximize yields was about 980,000 plants per acre.

In Manhattan, all varieties except Everest showed an exponential rise to the maximum response (Figure 4). Everest had a linear grain yield response to plant population, indicating that if the maximum yield was achieved in the study, it was achieved at 1.3

million plants per acre and possibly could show even greater yield increase in response to population. The varieties Joe, Tatanka, Zenda, and 1863, seemed to have reached their maximum in between plant population densities of 0.9 and 1.3 million plants per acre as these did not differ among each other. KanMark and Larry, on the other hand, seemed to maximize yields towards higher plant populations (1.3 million plants per acre).

## Acknowledgments

The authors wish to acknowledge the Kansas Wheat Alliance for funding and providing the seed necessary to perform this research.

**Table 1. Location (latitude, longitude, and elevation) and management practices adopted at both study locations during the 2015-16 growing season**

| | Hutchinson | Manhattan |
|---|---|---|
| Latitude | 37.9313° N | 39.2181° N |
| Longitude | 98.0246° W | 96.5907° W |
| Elevation | 1535 ft | 1020 ft |
| Soil type | Ost loam | Kahola silt loam |
| Tillage | Conventional till | No-tillage |
| Previous crop | Wheat | Corn |
| Sowing date | 10/07/2016 | 10/08/2016 |
| Row spacing | 10 inches | 7.5 inches |
| Topdress N rate | 107 lb N/a | 99 lb N/a |
| Topdress N date | 2/19/2016 | 02/28/2016 |
| Herbicide rate | Powerflex – 2 oz/a<br>MCPE – 1 pt/a<br>AMS – 2.8 lb / 100 gal mix | Harmony Extra – 0.7 oz/a<br>MCPA Ester – 16 oz/a<br>NCIS – 16 oz / 100 gal mix |
| Herbicide date | 2/19/2016 | 03/10/2016 |
| Fungicide rate | Quilt Xcel – 12 fl. oz/a | Quilt Xcel – 14 fl. oz/a |
| Fungicide date | 4/25/2016 | 04/22/2016 |
| Harvest date | 6/16/2016 | 06/24/2016 |

N = Nitrogen.

**Table 2. Significance of the source of variation on the number of tillers counted per plant in Hutchinson and Manhattan, KS, during the 2015-16 growing season**

| Response | Effect | Hutchinson | Manhattan |
|---|---|---|---|
| Tiller per plant | Variety | *** | *P* = 0.07 |
| | Plant population | *** | *** |
| | Variety × plant population | ns | ns |
| Tiller per acre | Variety | * | ns |
| | Plant population | *** | *** |
| | Variety × plant population | ns | ns |
| Grain yield | Variety | *** | *** |
| | Plant population | * | *** |
| | Variety × plant population | ns | ns |

Ns = not significant.
* - significant at $P < 0.05$
*** - significant at $P < 0.001$

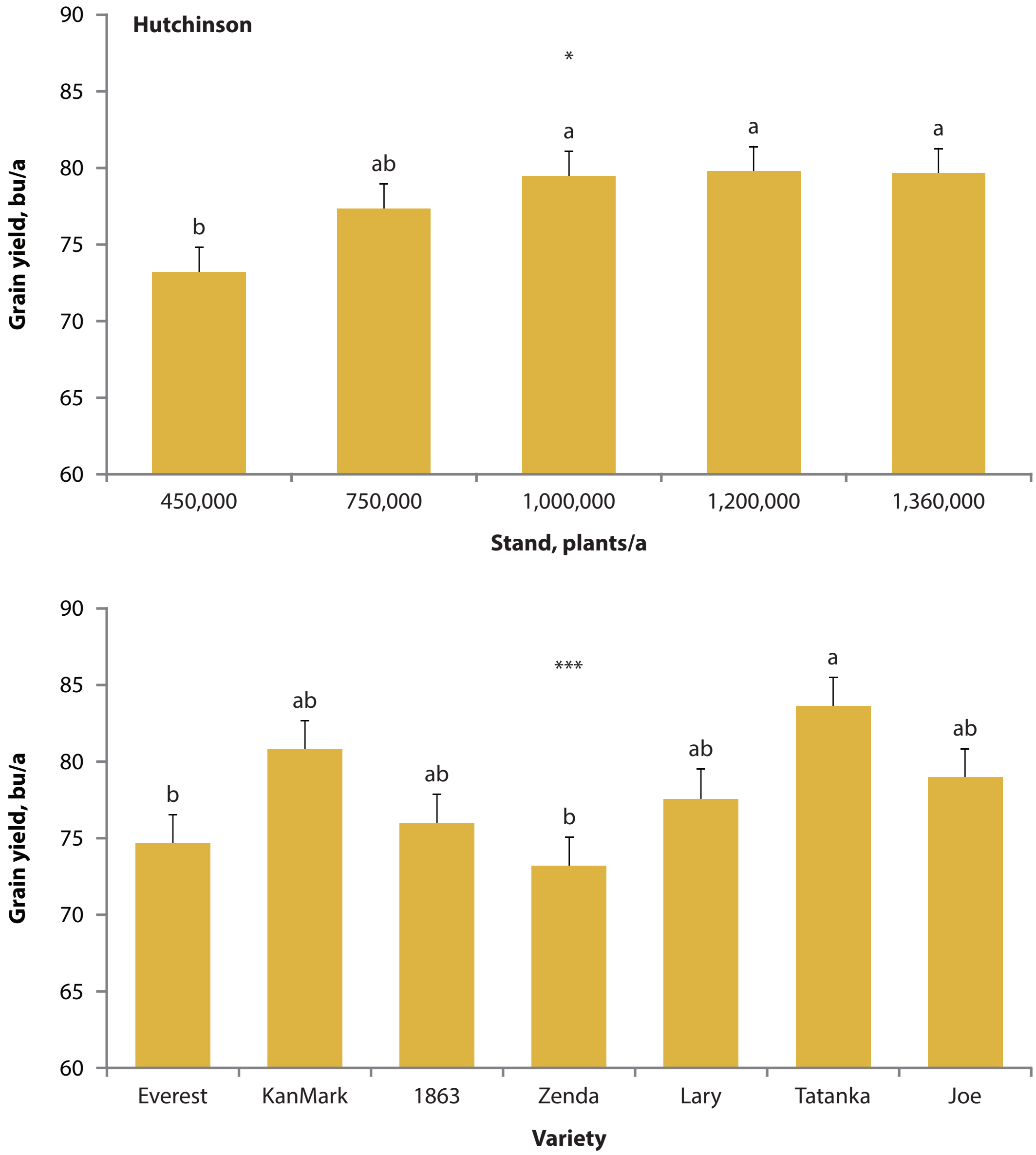



**Figure 1. Wheat grain yield as affected by seeding rate and variety during the 2015-16 growing season in Hutchinson, Kansas. The *, *** indicates that the main effect plant population was statistically significant at $P < 0.05$, and the main effect variety (lower chart) was statistically significant at $P < 0.001$.**

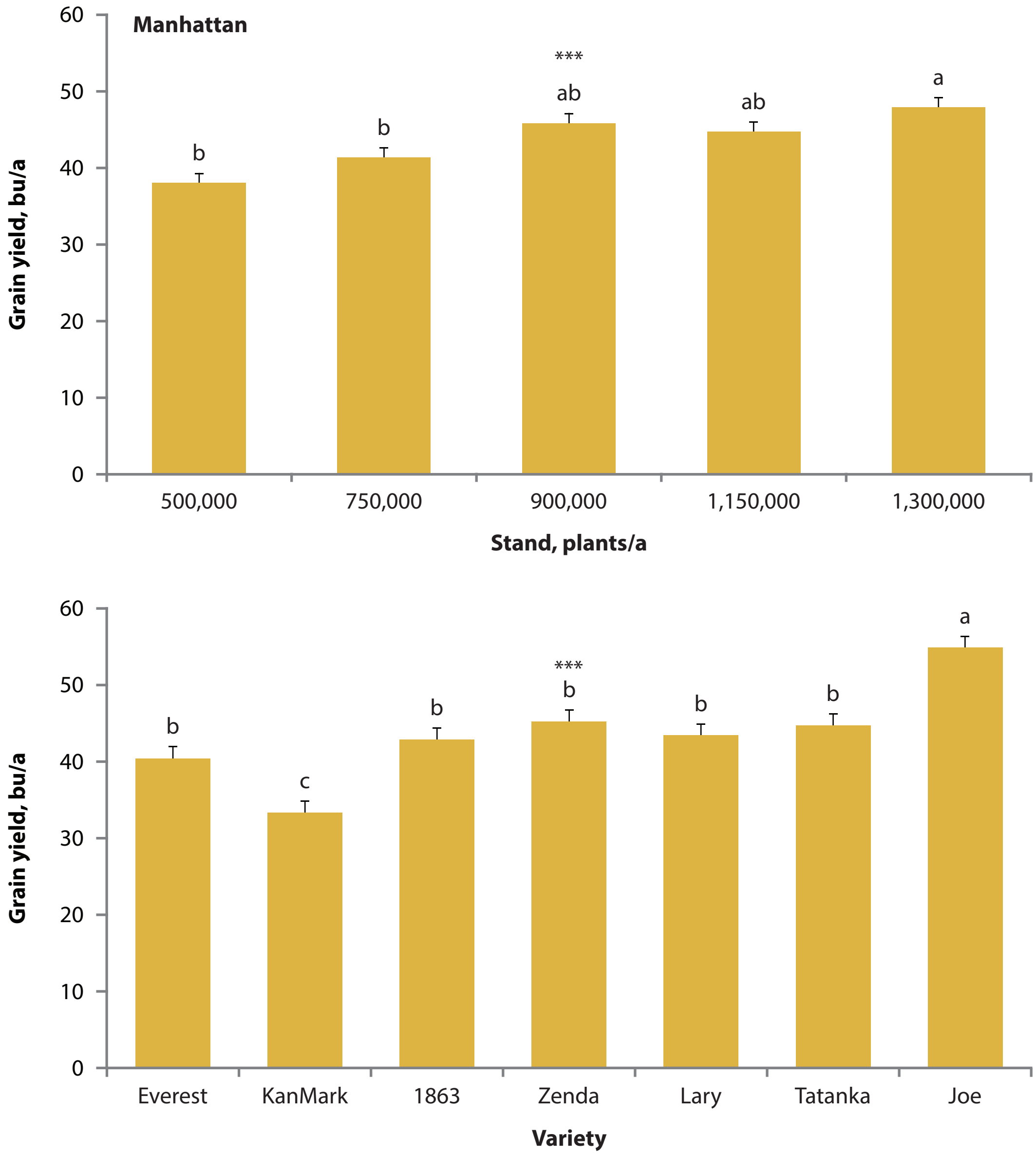



**Figure 2. Wheat grain yield as affected by seeding rate and variety during the 2015-16 growing season in Manhattan, Kansas. The *** indicates that the main effects plant population (upper chart) and variety (lower chart) were statistically significant at $P < 0.001$.**

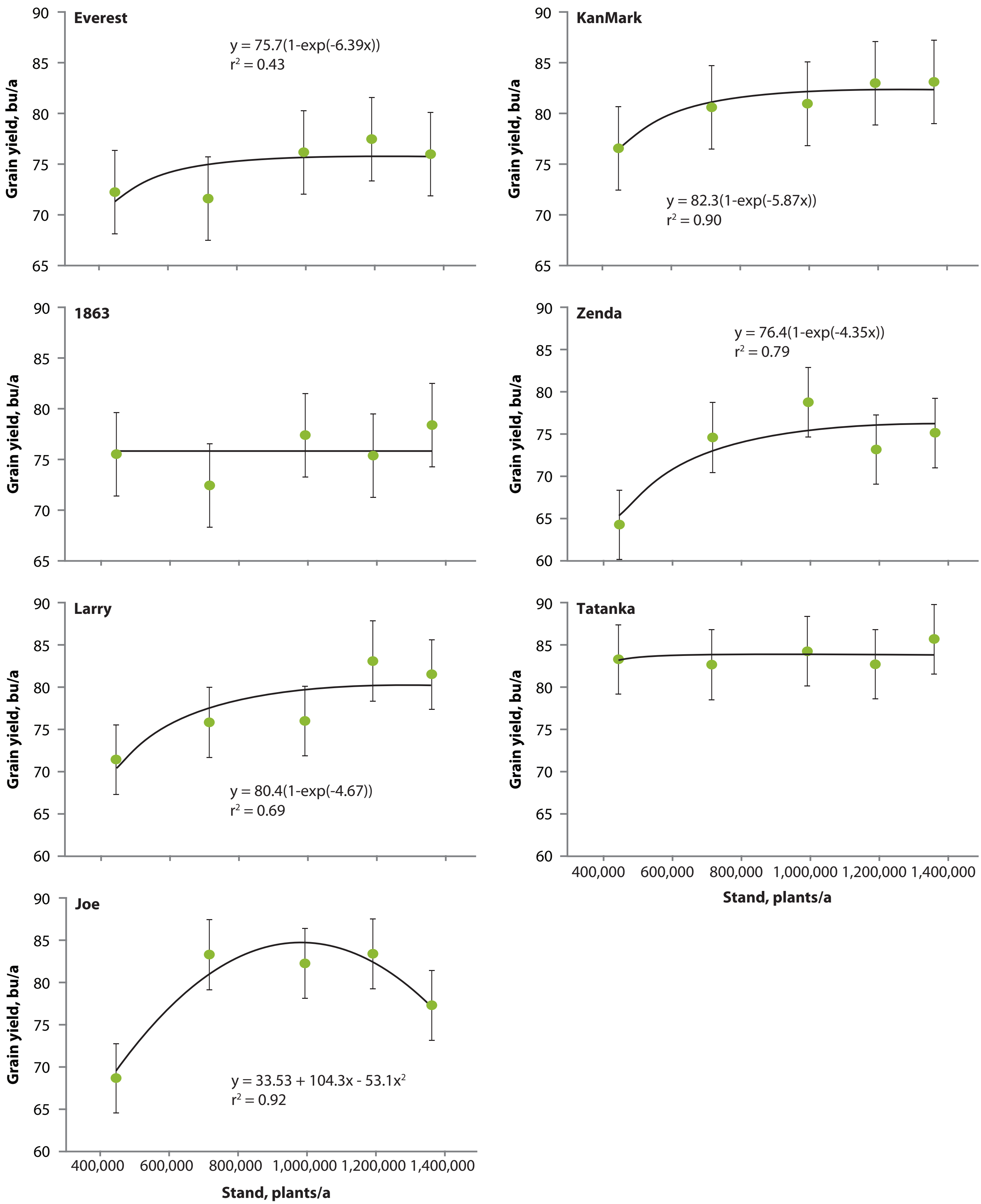



**Figure 3. Grain yield response to plant stand of each individual variety at Hutchinson, KS, during the 2015-16 growing season.**

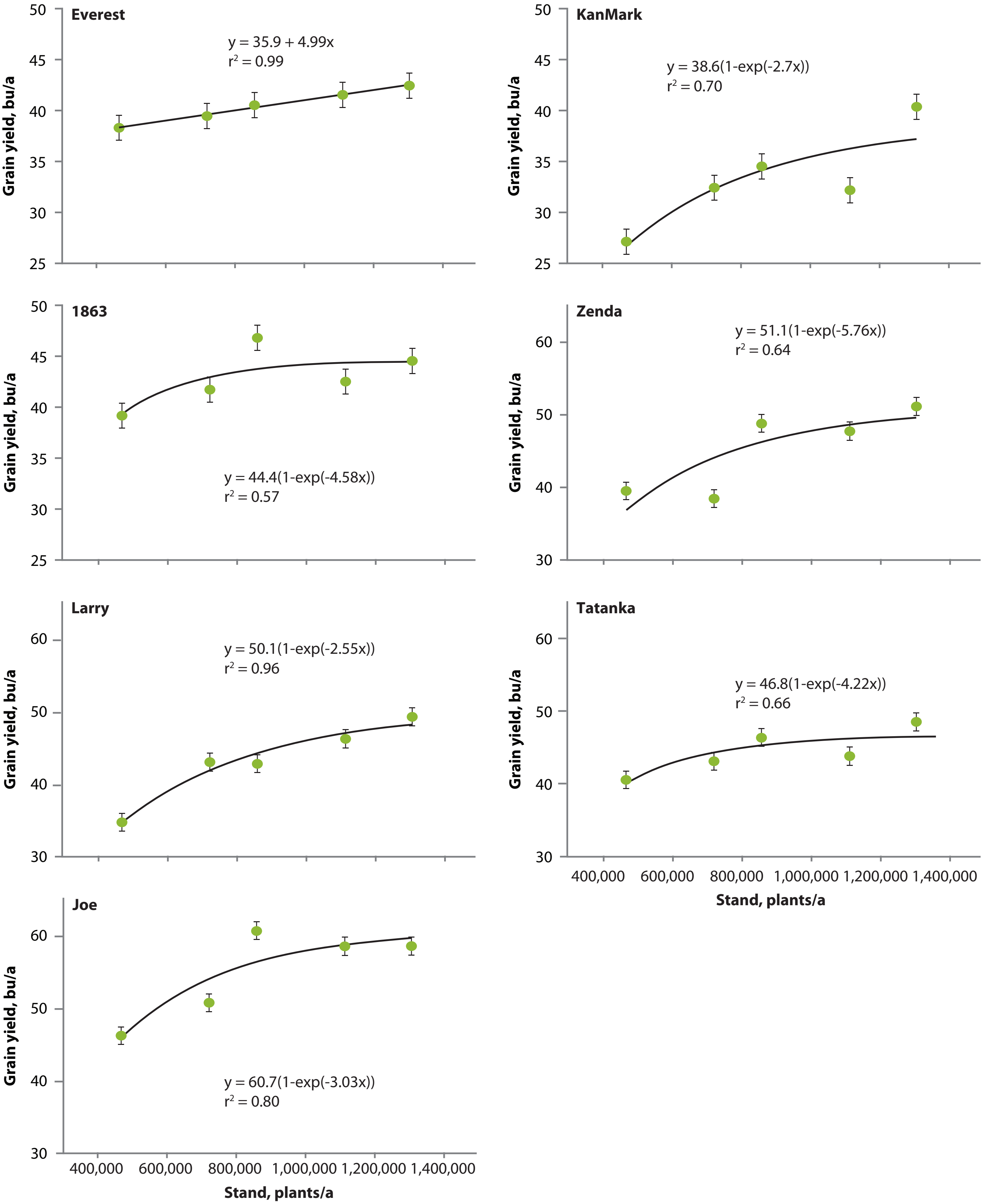



**Figure 4. Grain yield response to plant stand of each individual variety at Manhattan, KS, during the 2015-16 growing season. Notice the difference in scale between Everest, KanMark, and 1863, compared to the other varieties.**

# Timing and Positioning of Simulated Hail Damage Effects on Wheat Yield in Kansas

*R.P. Lollato, B.R. Jaenisch, R. Maeoka, A. de Oliveira Silva, and C. Sciarresi*

## Summary

Hail events often decrease wheat yields in Kansas; however, estimates of yield loss due to hail event timing and position relative to the flag leaf are only available for old varieties. Our objectives were to quantify wheat yield losses as affected by timing of hail event relative to the crop development and positioning of the damage relative to the flag leaf. A total of 12 hail damage treatments including six different timings during the growing season (boot, anthesis, milk, soft dough, hard dough, and ripe) and two different positionings relative to the flag leaf (above or below) were evaluated in a trial conducted in Manhattan, KS, during the 2015-16 growing season. Hail damage was simulated by bending 100% of the stems within each plot. Wheat yield loss due to stem bending treatment ranged from 5.8 bushels per acre (9.0%) for treatment imposed below the flag leaf during hard dough to as much as 23.7 bushels per acre (36.7%) for treatment imposed during the milk stage, above the flag leaf. The greatest loss in wheat grain test weight was 4.5 pounds per bushel (8.1%) for treatments established during the milk stage. More years of research are needed to achieve robust estimates of wheat yield loss due to hail damage, but these preliminary data indicate that the milk stage of development is more sensitive to hail damage than other studied stages.

## Introduction

Winter wheat is often subjected to several environmental yield-reducing events throughout the growing season in Kansas. Drought conditions are common during the majority of the growing seasons, winterkill might occur in particular years mostly due to lack of snow cover or abrupt shifts in air temperature. Spring freeze often causes some level of yield loss in different portions of the state, and heat stress during late season often reduces the duration of the grain filling phase. Still, one of the most devastating weather events to wheat grain yield is hail. Hail damage might fully compromise a particular field's productivity, and a solid estimation of hail damage can help producers and crop insurance agencies make better decisions regarding maintaining a hail-damaged crop for grain yield. The objectives of this project were to understand the wheat yield losses associated with stem positioning and timing of stem bending to simulate hail damage, and to ultimately improve the yield loss estimates performed when assessing hail-damaged wheat fields.

## Procedures

One experiment was conducted at the Kansas State University Agronomy North Farm in Manhattan, KS. The experiment was conducted in an incomplete factorial treatment structure established in a randomized complete block design with six replications. One variety (WB Cedar) was exposed to six different timings of stem bending at two different positions in regards to the flag leaf (Table 1). Stem bending timing treatments were at the following stages of wheat development: boot, anthesis, milk, soft dough, hard dough, and ripe. Position of stem bending was above or below the flag leaf. One hundred percent of the stems in the plot were bent at treatment application. Treatment structure was an incomplete factorial because it is not possible to bend the stems above the flag leaf at boot stage.

The trial was sown October 20, 2015, in a continuous wheat field under conventional tillage in a Smolan silty clay loam soil. Plots were seven 7.5-inch row spacing wide by approximately 8 ft long. Nitrogen (N) fertilization was performed with a yield goal of 75 bushels per acre, considering approximately 2.4 lb of N was needed for each bushel of yield goal. The trial had about 49 lb N/a at sowing in the 0- to 6-inch soil depth and another 93 lb N/a in the 6- to 24-inch profile and approximately 2.7% organic matter. Therefore, topdress N fertilization was performed with an additional 42 lb N/a on February 28, 2016. Weeds and foliar diseases were controlled so these were not confounding factors in the study. Weeds were controlled on March 10, 2016 with 0.3 oz/a Finesse, 16 oz/a MCPA Ester, and 32 oz/100 gal spray mix NIS, and foliar diseases were controlled April 22, 2016, with 14 oz/a Quilt Xcel. Measurements included grain yield, grain moisture content, and grain test weight. Plots were harvested using a small plot combine. Moisture and test weight were measured in the lab immediately following wheat harvest, and grain yield was corrected for 13.5% moisture content. Statistical analysis was performed to compare: hail vs. non-hail, above vs. below flag leaf, and between each timing of treatment application pooled across the bending position. Regression analysis between percent heads affected by hail and percent grain yield relative to the control were also performed.

## Results

### *Growing Season Weather*

The weather in Manhattan was characterized by a warm and moist fall, followed by a dry and mild winter and a cool and moist spring. Growing season precipitation total was 24.4 inches, mostly concentrated during the fall (approximately 1/3 of the total precipitation) and spring (approximately 2/3 of the total precipitation, Figure 1).

### *Grain Yield*

There was a significant treatment effect on wheat grain yield and grain test weight (Table 2). The control, where no stem bending treatment was imposed, yielded 64.6 bushels per acre, which was highest grain yield among all treatments and was only statistically similar to treatment imposed at soft or hard dough below the flag leaf (56.9 and 58.8 bushels per acre, respectively). The lowest grain yield (or highest grain yield loss) due to simulated hail occurred when treatments were imposed during milk stage or anthesis (above and below flag leaf) and during soft dough stage above flag leaf (Table 3). During these stages, bending the stem more likely decreased nitrogen and carbohydrate translocation from vegetative organs to the developing grain, which would ultimately contribute to the measured yield losses. Stem bending before anthesis (i.e. boot stage) yielded slightly higher than the aforementioned treatments, most likely because of new heads that emerged from secondary tillers to compensate for tiller loss due to stem bending. Delaying treatment to hard dough, when most of the photosynthates have already been translocated to the grain, also decreased grain yields when compared to the control, especially when stem bending occurred above the flag leaf.

Similarly, treatments imposed at harvest maturity (i.e. "Ripe") decreased grain yield when compared to the control, possibly due to increased pre-harvest shattering due to an upside-down head position, which may have increased the likelihood of wheat grains to fall off the head. Wheat yield loss due to stem bending treatment ranged from 5.8 bushels per acre (9.0%) for treatment imposed below the flag leaf during hard dough to as much as 23.7 bushels per acre (36.7%) for treatment imposed during the milk stage, above the flag leaf (Table 3).

**Yield Loss as Affected by Positioning of Stem Bending**

Yield losses were greater when the breakpoint was above the flag (average yield 47.8 bushels per acre) as compared to below the flag leaf (51.8 bushels per acre), most likely due to the importance of photosynthates produced in the flag leaf to fill grain. When the breakpoint occurred below the flag leaf, the stem between the flag leaf and the developing grain was still intact, and there was no physical constraint for photosynthate translocation between flag leaf and grain, resulting in less yield loss than when the breakpoint was above the flag leaf (Table 2).

**Yield Loss as Affected by Wheat Growth Stage**

Stem bending resulted in similar yield loss when it occurred during anthesis or soft dough (48 vs. 49.6 bushels per acre), during soft dough or ripe (49.6 vs. 54.7 bushels per acre), and during hard dough or ripe (56.1 vs. 54.7 bushels per acre, Table 2). Otherwise, stem bending during anthesis resulted in more severe yield loss than when it occurred at hard dough or ripe (48 vs. 56.1 or 54.7 bushels per acre), and less severe yield loss when compared to milk stage (41.6 bushels per acre). Stem bending during the milk stage resulted in significantly lower yields than at any other stage (Table 2), and stem bending at soft dough resulted in greater yield loss than at hard dough (49.6 vs. 56.1 bushels per acre).

Figure 1 shows an interesting analysis of the yield loss as affected by days after boot and stem bending positioning in regards to the flag leaf. The greatest decrease in grain yield when the breakpoint was below the flag leaf occurred when treatments were imposed at milk stage, whereas the lowest yield for the treatment imposed above the flag leaf occurred during soft dough. The biggest difference in grain yields between above and below the flag leaf occurred when treatments were imposed at soft dough, when the breakpoint above the flag leaf had a much greater decrease in grain yield as compared to the breakpoint above the flag leaf (Figure 1). This difference was still present, but at a lower magnitude, when treatments were imposed at hard dough.

***Grain Test Weight***

Wheat test weight was also significantly affected by treatment application, but at a smaller magnitude than grain yield was (Tables 2 and 3). Similarly to grain yield, test weight was most affected by stem bending during the milk stage of growth, which was significantly lower than any other treatment. Test weight measured from the treatments imposed later on the growing season (hard dough, ripe, and soft dough below the flag leaf) did not differ statistically from the control. Stem bending during boot stage decreased test weight significantly from the control, most likely as a consequence of newly emerged heads that had a slightly later grain filling period than the primary heads. This delayed grain fill exposed the later developing grains to hotter temperatures, reducing test weights. Simulated hail decreased test weight (59.3 vs. 58.4 pounds per bushel) but there was no difference between treatments imposed above or below the flag leaf. Performing the stem bending during milk stage of growth significantly reduced test weights when compared to any other treatment, and treatments imposed when the crop was ripe resulted in higher test weight than during anthesis or soft-dough. Test weight was positively affected by later treatments (hard dough below the flag leaf and ripe, non-significant) and the greatest loss in test weight was 4.5 pounds per bushel (8.1%) for treatments established during the milk stage (Table 3).

## Acknowledgment

The authors would like to acknowledge the National Crop Insurance Services for providing funds necessary to perform this research.

**Table 1. Treatment description, stage of treatment establishment, breakpoint regarding the flag leaf, tentative date for treatment application, and actual date treatment was applied for simulated hail damage trial near Manhattan, KS, during the 2015-16 growing season**

| Treatment | Stage | Breakpoint regarding flag leaf | Tentative date for treatment application | Date treatment applied |
|---|---|---|---|---|
| 1 | Control | - | - | |
| 2 | Boot | Below | 4/20/2016 | 4/17/2016 |
| 3 | Anthesis | Below | 5/1/2016 | 4/26/2016 |
| 4 | Anthesis | Above | 5/1/2016 | 4/26/2016 |
| 5 | Milk | Below | 5/10/2016 | 5/15/2016 |
| 6 | Milk | Above | 5/10/2016 | 5/15/2016 |
| 7 | Soft dough | Below | 5/15/2016 | 5/27/2016 |
| 8 | Soft dough | Above | 5/15/2016 | 5/27/2016 |
| 9 | Hard dough | Below | 5/20/2016 | 6/3/2016 |
| 10 | Hard dough | Above | 5/20/2016 | 6/3/2016 |
| 11 | Ripe | Below | 6/1/2016 | 6/13/2016 |
| 12 | Ripe | Above | 6/1/2016 | 6/13/2016 |

**Table 2. Wheat grain yield and test weight as affected by stem bending treatment in Manhattan, KS, during the 2015-16 growing season**

| Stage | Breakpoint (flag leaf) | Yield | | Test weight | |
|---|---|---|---|---|---|
| | | ------------ bu/a ------------- | | ------------ lb/bu ------------- | |
| Control | - | 64.6 | a | 59.3 | ab |
| Boot | Below | 49.6 | cde | 57.7 | c |
| Anthesis | Above | 47.4 | def | 58.5 | bc |
| Anthesis | Below | 48.6 | def | 59.3 | ab |
| Milk | Above | 40.9 | f | 55.5 | d |
| Milk | Below | 42.2 | ef | 54.8 | d |
| Soft dough | Above | 42.2 | ef | 58.2 | bc |
| Soft dough | Below | 56.9 | abc | 59.2 | ab |
| Hard dough | Above | 53.4 | bcd | 58.9 | abc |
| Hard dough | Below | 58.8 | ab | 59.9 | a |
| Ripe | Above | 54.9 | bcd | 60.0 | a |
| Ripe | Below | 54.4 | bcd | 59.9 | a |

Same letters within column indicate no statistical difference between treatments.

**Table 3. Wheat grain yield and test weight loss (in measured unit and in percent of control) when compared to the control treatment near Manhattan, KS, during the 2015-16 growing season**

| Stage | Breakpoint (flag leaf) | Yield loss | | Test weight loss | |
|---|---|---|---|---|---|
| | | bu/a | % | lb/bu | % |
| Control | | | | | |
| Boot | Below | 15.0 | 23.2 | 1.6 | 2.7 |
| Anthesis | Above | 17.2 | 26.6 | 0.8 | 1.3 |
| Anthesis | Below | 16.0 | 24.8 | 0.0 | 0.0 |
| Milk | Above | 23.7 | 36.7 | 3.8 | 6.4 |
| Milk | Below | 22.4 | 34.7 | 4.5 | 7.6 |
| Soft dough | Above | 22.4 | 34.7 | 1.1 | 1.9 |
| Soft dough | Below | 7.7 | 11.9 | 0.1 | 0.2 |
| Hard dough | Above | 11.2 | 17.3 | 0.4 | 0.7 |
| Hard dough | Below | 5.8 | 9.0 | -0.6 | -1.0 |
| Ripe | Above | 9.7 | 15.0 | -0.7 | -1.2 |
| Ripe | Below | 10.2 | 15.8 | -0.6 | -1.0 |

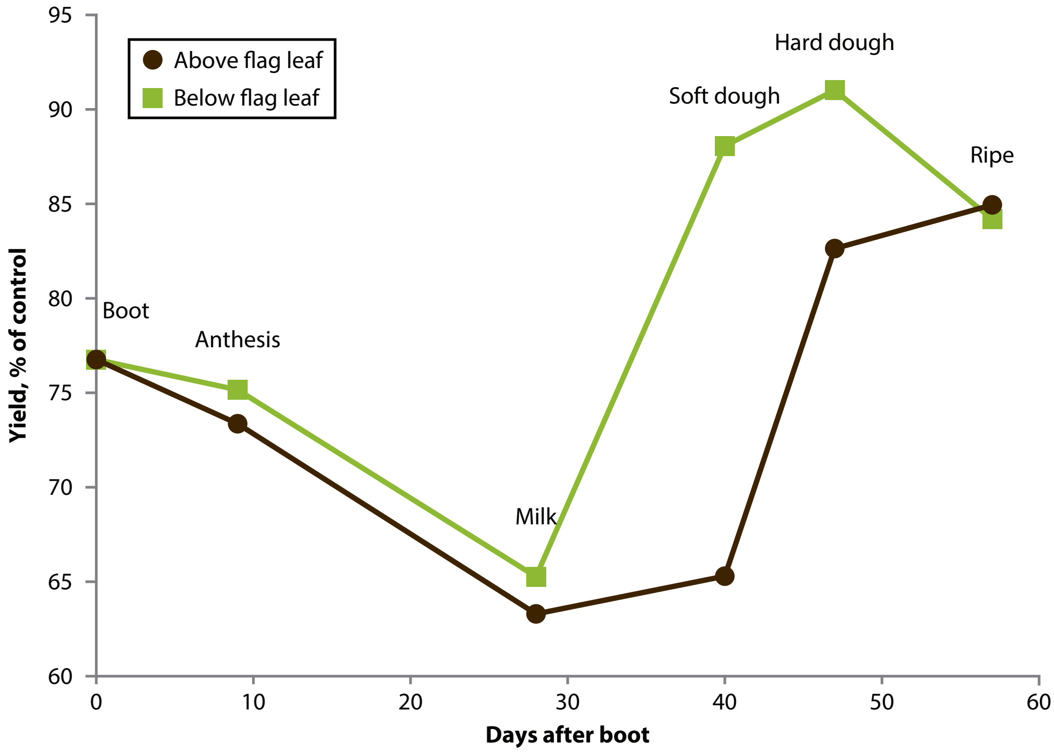



**Figure 1. Wheat grain yield shown as percent of the yield attained by the control treatment and affected by days after boot and positioning of stem bending treatment in regards to the flag leaf near Manhattan, KS, during the 2015-16 growing season.**

# Kansas Field Research 2017



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