THE CERES TRUST ORGANIC RESEARCH INITIATIVE 2014

Selecting and Suppressing Triticale Cultivars for Organic No-till Rotations in Nebraska

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Summary

Our objective was to improve the viability of organic bean production in wheat-based rotations by achieving triticale crimping success and a reasonably early planting date for soybeans and string beans in a rotational-till triticale mulch system. This objective was met by: 1) developing and employing an improved roller crimper design; 2) selecting among early-flowering high biomass experimental triticale lines in several organic environments to replace rye as a mulch crop; and 3) providing seed of triticale cultivars that function well as a mulch crop for further research on a larger scale.

The first activity evolved into a design and manufacturing project involving UNL engineering students. Experiments on three farms and one university experiment farm made use of the new crimper fabricated in part through this grant. The angled feature of the new crimper tossed mulch diagonally across the row, which resulted in good weed suppression, but resulted in poor suppression of triticale where planter discs were unable to penetrate the angled mulch. Disc openers of a no-till drill were able to cut through modest biomass of the angled mulch to improve triticale suppression compared to when the crop was planted before crimping. Design plans are available on request.

High-biomass triticale lines, with anthesis dates 5 to 10 days earlier than commercially available UNL lines, were evaluated for suppression of weeds, volunteer seed production, and performance of soybeans at three wheat-based farm locations and string beans at a large market garden. Several triticale lines selected in the first year of study were tested the following two years in various environments (early and late planted triticale, and crimping before and after planting beans). In 2015, planting of triticale in mid-October delayed anthesis by an average of 5 days compared to planting a month earlier. In subsequent trials, triticale was planted as early as possible after the Hessian-fly free date. The earliest-flowering triticale lines were crimped at anthesis during the last week of May in 2015 and 2017, and mid-May in 2016. Elbon rye reached full anthesis six days before the earliest triticale line.

Seed of NT15421, the best performing early flowering triticale line in 2016, was increased to 7000 pounds in Arizona and is available as untreated seed in cold storage for large-scale mulch crop experiments. In 2017, plots were crimped immediately after all triticale lines had completed anthesis, resulting in better performance for medium-flowering NT15407 as a mulch crop than NT15421. Thus, NT15407 might be suitable for the practice of planting before crimping. One hundred pounds of breeder seed of NT15407 is available for further research of this practice. With further testing and additional analysis after selecting NT15421, (despite poor soybean performance of NT14407 in a minor trial in 2016), NT14407 appeared to perform as well as NT15421. Based on grain and forage yields, the Small Grains Breeding Program advanced NT14407 for more testing in 2018 trials, with the possibility of being released to the public within a few years.

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Introduction

Our long-term goal is to increase the sustainability of commercial organic grain farms in Nebraska. In eastern Nebraska, the control of weeds in soybeans is the biggest weed challenge for commercial organic grain farms, as it affects weed populations throughout the rotation and the marketability, yield and ease of harvest of the bean crop, as well as the planting date and yield of the subsequent wheat crop (in a typical soybean/wheat/corn rotation). Weeds in organic soybeans are typically controlled with several cultivations. Excessive tillage is considered an unsustainable practice as it disturbs soil life and structure, oxidizes soil organic matter, contributes to soil erosion, and uses much fossil fuel.

The primary challenge in using a mulch crop for weed suppression in soybeans, assuming adequate biomass of the mulch crop is achieved, is to be able to plant soybeans early enough to take advantage of early-season heat units to assure a good grain yield. For the practice of crimping before planting, lower soybean yields occurred when small grain termination and soybean planting dates were delayed until mid-June (40 bu/acre) compared to early June and late May (both approx.. 48 bu/acre) in Pennsylvania (Wallace et al. 2017). Nebraska research in conventional corn-soybean systems has demonstrated that for each day that soybean planting is delayed after May 1, the yield penalty per day ranges from 0.25 to 0.63 bushels per acre (Specht, 2012). Early soybean planting increases yield potential by allowing plants to generate more stem nodes (Bastidas et al. 2008). A review of efforts to use winter rye as a mulch for soybeans (Mirsky et al. 2013) listed the lack of cultivars with maturation times that match the desired planting dates for each region (ie, earlier flowering), as a key need for small grain mulch crops.

Earlier soybean planting can be achieved by employing an early-flowering small grain as the mulch crop or by planting soybeans into standing small grain and crimping later. For crimping to effectively kill the mulch crop, crimping must be delayed until the mulch crop reaches late flowering to early milk stage ((Mirsky et al. 2009 and Keene et al. 2017). Commercially available triticale cultivars do not reach this stage until early June in Nebraska, which would delay soybean planting as much as four weeks after the optimal planting date for the current practice of crimping before planting soybeans. The new practice of planting soybeans before crimping (at no later than the third trifoliate stage) has met with anecdotal success. The practice can speed up planting by two weeks and allow flexibility of the planting date to coincide with appropriate soil conditions, but lacks adequate research.

A second challenge in using a mulch crop for weed suppression in soybeans is to achieve adequate suppression of the mulch crop to avoid producing volunteer seed that would require tillage to eliminate. Wheat grain contamination by volunteer cereal rye after crimping ranged from 3 to 11% in Maryland and Pennsylvania (Keene et al. 2017). We addressed this problem by fine-tuning the crimping date and by designing and utilizing a more aggressive crimper.

In the first year of the current research, we followed the recommendation to crimp at 50% anthesis, which is the date at which 50% of the rye or triticale heads were showing pollen. Our experience, and that of a growing body of research, indicates that the small grain should be crimped at a later stage. Researchers in Pennsylvania and Maryland have recently concluded that rye should be crimped between 50% anthesis and early milk stages to maximize biomass while minimizing volunteer seed production. Rye that was crimped before 50% anthesis (Zadocks 65) tillered and set seed, contaminating the subsequent wheat grain crop by as much as 4%, while crimping after medium milk (Zadocks 75) allowed rye seed to mature on the ground (Keene et al. 2017), resulting in up to 12% contamination of the subsequent wheat grain crop.

To improve suppression of the cover crop we intended to modify the hitch on an existing 10-foot crimper to pull at an angle. However, we decided that the intended modification would cause the crimper to run off to the side rather than pulling at an angle. A remedy may have required an expensive guidance system; so we decided to find a way to achieve more objectives with available funds by using engineering students and farmer ideas to design a new crimper. Fabrication of the new crimper was made possible with funds allocated for the intended modification plus remaining funds from a related CERES project and other discretionary funds.

In Nebraska and other states where wheat is a dominant crop, rye is avoided in crop rotations that include wheat for the food market, and it is necessary to replace rye (Secale cereale L.) as the mulch crop with another small grain. Most of the small grain mulch crop research has been conducted using rye. However, since rye is self-incompatible, the survival traits of seed shattering and seed dormancy in volunteer rye can recombine from one generation to the next and become more prevalent than in the original cultivar. Because of this outcrossing mechanism, "Feral rye has become a troublesome weed in winter wheat production in western Nebraska. It is thought that our current rye problems in winter wheat originated when rye plants {in cover or pasture crops or soil conservation seed mixtures] escaped into cultivated fields. Since then, the rye plants with the most weedy characteristics. . .have thrived in continuous winter wheat and winter wheat-fallow rotations." (Lyon 2007)

A feral rye population quickly multiplies if it becomes established with a wheat crop because some rye grain typically matures and shatters before wheat harvest. The portion that shatters affects the subsequent wheat crop. As little as 21 feral rye plants/ square meter reduced wheat yield in Kansas by 45% (Stahlman et al. 1995 as cited in Roberts et al. 2001). The portion of the seed that does not shatter is difficult or impossible to remove from harvested wheat. The presence of feral rye in wheat grain is highly visible and will result in grade reduction if the amount of seed exceeds 1% by weight for Grade 1, 2% for Grade 2, 3% for Grade 3, and 10% for Grades 4 and 5 (USDA/GIPSA/FGIS 2014), with consequent reduction in price offered to the farmer, or rejection by the end user. Millers and bakers avoid buying wheat contaminated with rye because the resulting flour has poor baking quality (Lyon and Klein, 2007).

In Washington state, where wheat is a dominant crop and feral rye is widespread, cereal rye is considered a Class C noxious weed and control is recommended. According to a Lincoln County (Washington) brochure, "managing cereal rye in winter wheat requires a systems approach that integrates multiple control strategies into a comprehensive management plan during a period of several years." The strategy of increasing wheat seeding rate in Kansas from 53 to 145 lbs./acre reduced the number of rye seeds by 36% and increased yield of rye-infested wheat by 82% (Roberts et al. 2001).

Triticale, on the other hand, like wheat, is self-compatible and is therefore quite stable in its traits, so that it will not develop shattering and dormant seeds. Recombination of traits is minimal as pollen-mediated gene flow for triticale in large plots was shown to be only 2.2% at a distance of 0.2−1.6 m between plants, and was shown to diminish exponentially with further distance between pollen donor and acceptor plants (Kavanagh et al. 2012). Therefore, our focus was on screening early-flowering experimental triticale lines for use as a mulch crop for wheat-based rotations.

Preliminary Research

When crimped rye was used as a mulch crop in on-farm trials in eastern Nebraska, weed control in organic soybeans improved while hand-weeding was reduced and several cultivations were eliminated (data not published). A similar result was achieved when using a commercially available medium-late flowering triticale cultivar, NE96T411, developed at UNL.

Our success in previous research in Nebraska for suppressing triticale has been marginal. Part of the problem was that the research was conducted using a medium-late flowering triticale cultivar, NE96T411, that did not flower until mid-June. Crimping was conducted too early (at boot stage) to avoid planting the following soybean crop too late. In our trials, at least two crimpings were necessary to achieve 92% kill (Shapiro et al. 2017). Chevron and straight-blade crimpers were used. A straight-blade crimper designed in-house with blades staggered in 2-foot sections (similar to a Crush-Rite Crimper Roller from Riteway Mfg. Co. Ltd) was found to produce minimal vibration and to be somewhat more effective at suppressing triticale than the chevron crimper. When used on two farms in 2013, one with irrigation, and the other in dry rainfed conditions, a fair amount of triticale rebounded (termed "bounce-back" in other literature) when using either crimper, and continued to grow. Re-crimping one week later improved suppression, yet the triticale continued to grow and set seed. While several factors may have contributed to poor suppression (soil too hard for the crimping edge to be effective, not enough mulch crop biomass, or crimping too early), better crimping was achieved on the ends of the field where the straight-blade crimper was turned around, an indication that crimping could be more effective despite the listed factors. The farmer who made the observation attributed the improved suppression to the chafing action of the roller blade against the rye stem when the drum stopped rotating as the implement continued to move forward.

The UNL Small Grains Breeding Program has been developing and releasing triticale cultivars for over fifty years. Twenty-eight triticale lines were chosen for this project from lines advanced to the 2015 UNL F6 through F8 nurseries (6 to 8 generation cycles after making the cross) based on heading date, plant height, and forage dry matter. Flowering dates in 2014 had a narrower range than typical years, with chosen lines flowering only 2 to 8 days earlier than the medium-late check, NE422T, which flowered at 152 Julian days. Plant heights ranged from 41 to 60 inches, with a median of 51 inches, compared to the tall check, NE422T, at 54 inches. In 2014, forage dry matter for chosen experimental lines at Mead, Nebraska ranged from 5.5 – 7.9 MG/ha, compared to the nursery mean of 5.7 MG/ha. Forage yields in 2014 were less than in previous years (Baenziger et al. 2016). By comparison, forage dry matter nursery means for 2007 – 2013 at Mead were 8.3, 6.8, 9.5, 9.1,13.9 and 9.5 MG/ha respectively. Though we have not tested the experimental lines in northern locations, we expect them to be winter hardy. Winter hardiness is typically assured by screening early generations on bare soil at Mead, Nebraska. Wheat that is screened in this environment is typically winter hardy in South Dakota, with some UNL winter wheat cultivars (e.g. "Overland") being adapted and widely planted in North Dakota.

Methods

Crimper Design and Fabrication

William Dick, UNL professor of Mechanical Engineering, enlisted three students in his Senior Design class--Deborah Burns, Micah Collison, and Matthew Newman--to design a crimper frame according to specifications determined by cooperating farmers and in consultation with project staff, a contracted welder and machinists. The crimper frame was designed for attaching to a three-point hitch and a set of planter lift wheels on the back. Other criteria included: incorporating two 10-foot rollers already being fabricated; having the ability of the roller drums to flex with the terrain; having the ability of the farm operator to easily adjust the relative angle of the two drums; and having a folded width of no more than 8 feet to enable transporting on a flatbed trailer. Early designs were scrapped for exceeding the cost cap of $22,000, including the hitch and lift wheels. The final design was submitted at the end of April 2015

The crimper was completed in April 2016 for a total cost of $22,000. The crimper weighs about 4325 pounds (frame 725 pounds and each drum 1800 pounds). For extra weight during the crimping process 110 gallons of water can be added to each drum for an additional 3600 pounds across the 18-foot span. Machined parts were fabricated at Precision Machine Co., Inc. in Lincoln Nebraska. The crimper frame was fabricated according to the students' design in a local welding shop using raw steel, the machined parts, and purchased hydraulic cylinders and hoses. Two 10-foot crimper drums with angle irons at 6-inch rotational spacing were built and attached to the frame. Edges of the angle irons were reinforced with a welding bead. A scavenged Wetherell planter lift wheel assembly was welded to the rear, and a John Deere drill hitch assembly purchased from a local implement dealer was bolted to the front. Because the long frame was sagging in the middle, a truss was welded above the frame. A farm cooperator added chains spanning from the front of the frame to the outer edges of the unfolded drums to take pressure off of the hydraulic cylinders.

Seed Increases

2015 Increases

Each of the 28 experimental triticale lines was increased (for field trials in 2016) on certified organic land at the UNL Agro-Forestry Farm near Mead, NE, in 320-foot by 4.5-foot plots. Seed was planted an inch deep into wet soil on October 17, 2014. The triticale increases were severely affected by Fusarium head blight, as were other small grains throughout Nebraska and the Great Plains. The triticale yielded as anticipated at about a bushel per line. Despite removal of light kernels, germination on blotter paper for the selected lines was 12 to 32 %, but was higher when conducted in soil collected from the target farm. In respect to the germination rate in soil, there was enough seed to plant three reps of each line at only two locations at 110 pounds of pure live seed per acre, and still have about 15 pounds left over for increasing seed for the next year's experiments. Seed of seven selected lines was cleaned on a Carter-Day density seed blower to remove light kernels to prepare for planting in the fall.

2016 Increases

Ten pounds of seed for each of the seven selected triticale lines was planted on conventional UNL land near Mead, NE in September 2015 to serve as a seed source for 2017 trials. About 180 pounds of each line was produced for each triticale line.

2017 Increases

In November 2016, a bushel of the early-flowering triticale line, NT15421, was sent to Arizona to increase the seed. The increased seed was shipped to UNL in July 2017, was cleaned by the UNL Foundation Seed Plant, and has been kept in refrigerated storage. We now have 7000 pounds of clean untreated seed of NT15421. The selection of this line for increase was based on the trial data of 2015 and 2016 for the early-flowering lines. The 2017 data from SCAL indicates that when planting as late as June 1, the later-maturing NT15407 may be a better choice than the early-flowering triticale lines when conditions favor later-planted soybeans, or when using the new practice of planting before crimping. We have 100 pounds of NT15407 available in cold storage for increase.

Experimental Design and Layout

Experiments were constrained by the small amount of seed available. In the initial year there was only enough seed of the 30 experimental triticale lines for one experiment location and one increase location. The amount seed increased in the first year had been compromised by extreme conditions that resulted in many Fusarium-damaged kernels. After removing light, shriveled seeds, there was only enough seed the second year to plant a given triticale line at one, two, or three of the four locations. There was only enough seed for each site to be planted to three of the seven triticale lines in the 2016 trials. Only one triticale line, NT15421 was represented at three sites. Three lines were planted at two sites. Two lines were planted at only one site (Figure 2). Plenty of seed was available in the third year to plant all seven lines at two locations. However, one location was abandoned (see Stanislav Farm in 2017 Activities). Therefore, experiments could not be analyzed across years or locations.

The observation nurseries in 2015 had three reps of 28 triticale line (plus one late-flowering triticale line, NE422T and a wheat line) at two triticale planting/crimping dates, which was insufficient for statistical analysis: averages and standard deviations are provided. Experiments in 2016 and 2017 were randomized complete block designs, and were analyzed using SAS GLM procedure. Strip treatments in 2016 at four sites lacked degrees of freedom to separate means and were pooled for statistical analysis. The 2017 layout for SCAL had one soybean planting/crimping treatment, all seven triticale lines plus check plots (marked "x"), and four reps (Figure 3).

Major trials in 2016 were conducted at SCAL, with soybeans, and the Roh Farm, with string beans (Figure 1). The two sites had one triticale line in common, two other triticale lines and a check treatment (labeled "pennycress" for SCAL and "fallow" for Roh Farm) . The other two triticale lines were medium-flowering at SCAL and early-flowering at the Roh Farm. These sites originally had identical layouts, with one triticale planting date, two soybean planting/crimping treatments as strip plots in every other pass, and four reps for each treatment. The Roh Farm layout was adjusted to accommodate the mechanical string bean harvester that would drive over rows to the outside. Outside passes were planted on May 7 and inside passes were planted a week later in anticipation of needing to harvest the earlier planted soybeans first. Rye plots were planted at each end of the field and were treated as reps. However, at SCAL, the rye plots at one end of the field suffered from wheel traffic and were removed from analysis. Rye plots at SCAL was treated differently than the rest of the field: rye was crimped 6 days before the plots and was planted both a week before and 2 days after crimping.

Minor soybean trials in 2016 were conducted at Fendrich Farm and Stanislav Farm. These farm sites had identical layouts, with two triticale planting dates and three reps or each planting date (Figure 2). The two farms had one triticale line in common. Both had rye plots at either end of the field that were treated as reps. Rye that was planted in the middle of the field was used only for observations of anthesis date and plant height.

The 2017 layout for Stanislav Farm had two trials (one soybean trial and one string bean trial) of four reps of five triticale lines plus check plots. Triticale entries one and six typically flower about 4 days later than the other cultivars, and were not included in the Stanislav trial. The string bean site was later abandoned (see 2017 Stanislav Trial in Activities section).

Figure 1. 2016 Major Trial Layouts

2016 SCAL Triticale (planted 9-23-15)/Soybeans

30 ft	Elbon RYE Crimped May 6, Crimped again May 12, Soybeans Re-planted May 14							
30 ft	7	6	x	1	7	1	x	6
30 ft	6	x	1	7	6	7	1	x
30 ft	x	1	7	6	x	6	7	1
30 ft	1	7	6	x	1	x	6	7
	18 ft	18 ft	18 ft	18 ft	18 ft	18 ft	18 ft	18 ft
Soybeans Planted	6-May	14-May	6-May	14-May	6-May	14-May	6-May	14-May
Crimped	12-May	12-May	12-May	12-May	12-May	12-May	12-May	12-May

2016 Roh Triticale (planted 10-5-15)/String Beans

30 ft	RYE	RYE	RYE	RYE	RYE	RYE	RYE	RYE
30 ft	4	7	x	2	4	2	x	7
30 ft	7	x	2	4	7	4	4	x
30 ft	x	2	4	7	x	7	4	2
30 ft	2	4	7	x	x	x	7	4
30 ft	RYE	RYE	RYE	RYE	RYE	RYE	RYE	RYE
	17 ft	17 ft	17 ft	17 ft	17 ft	17 ft	17 ft	17 ft
String Beans Planted	7-May	7-May	15-May	15-May	15-May	15-May	7-May	7-May
Crimped	15-May	15-May	15-May	15-May	15-May	15-May	15-May	15-May

Figure 2. 2016 Minor Soybean Farm Trial Layouts and Triticale Allocation for all Trials

ENTRY	ID	FARM
1	**NT13443**	SCAL
2	**NT14407**	S R
3	**NT14408**	F
4	**NT14415**	F R
5	**NT14429**	F S
6	**NT15407**	SCAL
7	**NT15421**	S R SCAL

Stanislav 2016

30 ft	RYE	RYE	RYE
30 ft	2	5	7
30 ft	5	7	2
30 ft	7	2	5
30 ft	RYE	RYE	RYE
30 ft	5	7	2
30 ft	2	5	7
30 ft	7	2	5
30 ft	RYE	RYE	RYE
	18 ft	18 ft	18 ft

Fendrich 2016

30 ft	RYE	RYE	RYE
30 ft	3	4	5
30 ft	4	5	3
30 ft	5	3	4
30 ft	RYE	RYE	RYE
30 ft	4	5	3
30 ft	3	4	5
30 ft	5	3	4
30 ft	RYE	RYE	RYE
	18 ft	18 ft	18 ft

Figure 3. 2017 SCAL plot layout

	RYE	RYE	RYE	RYE	RYE	RYE	RYE	RYE	RYE	RYE
30 ft	RYE	2	7	6	3	5	1	x	4	RYE
30 ft	RYE	6	5	1	4	2	x	7	3	RYE
30 ft	RYE	x	3	7	5	6	4	2	1	RYE
30 ft	RYE	4	1	x	2	7	3	5	6	RYE
	RYE	RYE	RYE	RYE	RYE	RYE	RYE	RYE	RYE	RYE
	10 ft	18 ft	18 ft	18 ft	18 ft	18 ft	18 ft	18 ft	18 ft	10 ft

2015 Field Trial Activities

Evaluation of experimental triticale lines was conducted in 2015 at the Larry Stanislav certified organic farm in east central Nebraska. Each planting date treatment was 10 plots wide and 9 plots deep, with 3 reps of each triticale line arranged in a randomized complete block. Triticale lines were planted in adjacent trials on two dates, September 22 and October 20, 2014 at 107 lbs/acre using a no-till plot drill in 10-foot by 4.5-foot plots with 5-foot alleys. Prior to planting triticale, sweet clover in spring wheat residue was disked the first week in September. For the first planting, persistent red clover was under-cut 2 days before planting. Soil was worked with a power harrow 4 hours before planting. Seed was planted into very moist firm soil. Three days before the second planting, weeds, red clover and cover crops were shredded then disked three times. Soil was worked with a drag harrow one hour before planting triticale at 1.5 to 2 inches deep into very firm, somewhat moist soil under a dry surface.

A single crimping using the chevron crimper appeared to be only marginally effective, so we immediately crimped a second time. For the first triticale planting date treatment (September 22, 2014), we crimped twice in opposite directions on May 21, 2015, and crimped again on May 28. For the second triticale planting date treatment (October 20, 2014), we crimped twice in the same direction on May 28 and used skid steer tracks to re-crimp on June 3, as the chevron crimper was no longer available. Each triticale plot was rated for percent brown and flat stems a week after the initial crimping.

Eight farmers, four researchers and a seed dealer participated in a field workshop on May 21, 2015. The schedule for the workshop was based on our prediction of 50% anthesis on that date for most of the lines. However, anthesis was delayed by extended cold and wet weather. In the early-planted triticale, only 25% of the lines were starting to flower. (Flowering for those plots was complete in another three or four days). Participants scored maturity (as indicated by length of the peduncle or presence of anthers) and biomass of triticale on a scale of 1 to 9, with 9 being assigned to the most mature triticale with the greatest biomass and canopy cover and 1 for plots that were the least mature and had the least biomass and canopy cover. The late-planted triticale had not yet started to flower.

UNL staff rated anthesis, biomass and plant height for the late-planted trial on May 28. Anthesis was projected as much as 4 days forward or backward. Plant height was measured in a non-traditional manner to the base of the flag leaf. Typically plant height would be measured to the top of the fully extended head excluding awns. However, at crimping time, heads of most plants were not yet fully extended, necessitating an alternative measure of plant height. Scores were standardized on a scale of 1 to 9 and were combined into separate indices for the two triticale-planting dates. Greater weights were assigned for anthesis date and weed density than for plant height and visual (participant) scores: Early or Late Index = 0.1 * height + 0.4 * anthesis + 0.15 * visual + 0.25 * grass + 0.1 * broadleaf.

All plots (for both triticale planting date trials) were planted to soybeans on May 28 at approximately 170,000 seeds/acre with a JD 750 no-till drill at seven-inch row spacing.

Watermark soil moisture probes were placed in one triticale plot at 6 inches and 12 inches, and in the row in nearby cultivated soybeans at 12 inches, for the duration of much of the growing season, June 3 – Aug 12. Readings every other hour were converted from kilopascals to % soil saturation, with the reading of 0-9 corresponding to 100% saturation, and a reading of 239 of air-dried sensors corresponding to 0% saturation.

Weeds were counted in each plot in categories of grass or broadleaf on July 1 along meter transects. Red clover was ubiquitous and uniform, and was not counted. Weeds that were past the cotyledon stage were counted. Perennial weeds such as dandelion and field bindweed were found in some plots, but were ignored in the selection decisions.

The seed increase plots at the UNL Agro-forestry farm near Mead, NE provided supplemental height, anthesis and biomass score data. Anthesis was recorded plus or minus two days. Biomass was scored visually on a scale of 1-9 at the time of recording anthesis. Height was recorded when the plants were mature on June 23 to the top of the head, excluding awns. Data was incorporated into the "Mead Index" = 0.5*anthesis+0.3*visualbiomass+0.2*height.

Indices for early-planted and late-planted triticale trials were averaged and combined with the Mead index to obtain an overall index. Final selections for further experimentation were based on the overall index, with consideration for extremes of any of the agronomic factors, weed indices and availability of seed.

2016 Field Trial Activities

Triticale lines were grouped to provide uniform flowering dates at each location, since there was only enough seed of each line for two locations. The latest flowering lines had less seed available and were sown only at SCAL. The experiment at each site was designed to accommodate the new 18-foot crimper with replications of strip plots for each planting date. When we learned of an early-flowering rye, "Elbon," we decided to add Elbon as a check in plots surrounding the trials, instead of using the late-flowering NE422T, which would have to be crimped at a different time.

Three reps of each triticale planting date were planted at Stanislav and Fendrich farms. Four reps were planted at SCAL and Roh farms. The seven selected triticale lines are listed in Figure 1, with the farm locations for each seed lot. Plot layouts in Figure 1 include planting errors (in red font) on the Roh farm. With the planting errors there were effectively three full reps at the Roh farm. Triticale and rye were planted in all field trials using a hoe-drill with 7-inch spacing between rows. Triticale was sown at a rate of 110 lbs/acre of pure live seed.

Plots were crimped at 7 mph with the crimper sections set at about 5 degrees from square with the frame (17 chain links). Since the crimper pulled to the left with the lift wheels in the floating position, the lift wheels were put down for slight ground contact.

2016 Roh Farm Trial

As explained to the grantor in a 9-2-16 email, we discovered that Mark Roh's vegetable portion of his farm operation is not organic. However, other than using fungicide-treated string bean seed, organic practices were used for the string bean experiment. Triticale and rye was planted at Roh farm on October 5, 2015 into slightly drier soil than the other locations. 'Bronco' string beans were planted in 36-inch rows with a JD 7000 double-disc planter on 5-7-16 and 5-15-16. Crimping was accomplished on 5-15-16. Bean harvest in each plot (Figure 3) was accomplished on July 26 with a mechanical bean picker on a single row that had the most uniform bean density. An on-board scale was used to measure bean yield. Notes on bean density in the 30-foot harvested row were taken directly after harvest. Young weeds that were less than 12 inches long were few and spindly and were judged as inconsequential. Only those weeds that were longer than 12 inches were counted in a 30-inch 10-foot transect including two adjacent bean rows two days after harvest.

2016 Stanislav and Fendrich Farm Trials

Trials at Stanislav and Fendrich farms were managed similarly, using the same equipment, planting rates and dates, and experimental design, except for two of the triticale cultivars being different. Triticale was planted at these two farms 0.5 to 1 inch deep on September 28, 2015, into soil that had just dried on the surface, but was saturated beneath the surface half inch. Both locations were planted to a group 2.9 soybean cultivar at 220,000 seeds/acre on May 6 and May 15 with a John Deere 750 no-till drill with single-disc openers, and were crimped on May 15.

Management of plots at the two farms differed in previous crop and method of termination of the previous crop. Stanislav's previous crop included red clover, which was tilled three times over a 2-week period. Moist conditions favored regrowth of red clover. Red clover and field bindweed made machine harvest impossible. Soybean plants were removed by hand from 2 yard-square quadrats per plot, and bundled for later threshing to obtain yield. Fendrich's previous crop was a late-planted oat cover crop that was tilled once the day before planting. Fendrich plots suffered from poor triticale stand from the beginning of the year, an effect of poor planting conditions. The only data taken was early optical sensor data was taken, since it appeared that the experiment was a failure.

2016 SCAL Trial

Triticale was planted at SCAL September 23, 2015, 1 inch deep into good moisture at 150 lbs. pure live seed per acre. The soil at SCAL had been fallowed in mid-August and early August using a disc, then was tilled with a culti-packer the day before planting after the soil surface dried out from recent rain. At SCAL, we planted three later-maturing triticale lines (of the seven) in addition to Elbon rye. Elbon unexpectedly flowered earlier than the triticale lines. On April 28, Elbon was fully headed and 20-50% flowering, entry 1 was at early boot stage, entry 6 was at mid-boot stage, and entry 7 was 50% headed. The surrounding field and end plots of Elbon rye (part of the trial) were crimped and planted on May 6. Crimping of triticale commenced on May 12 as the plan was to crimp when the first triticale line reached 100% anthesis, giving it an advantage over later-flowering lines. Rye was re-crimped, as the crimper could not be lifted while turning. On May 12, NT15421 was 100% flowered; and the two other triticale lines were 100% headed without flowers. Soybeans were planted May 14 to Group 3.4 Blue River 76347 soybean cultivar at 160,000 seeds per acre. Rye was replanted.

Crimping effectiveness was measured with a RapidScan near-infrared instrument on June 3 and visually ("triticale flatness") on July 29. The infrared scan indicated whether the triticale was dying (brown) or still alive (green).

In the control plots, pennycress was thick and uniform and was crimped along with the rest of the trial. Other weeds in the control plots were allowed to grow until July 7 (5 passes) and July 13 (the remaining 3 passes), when they were pulled by hand. Weeds included 1 to 2-foot tall lambsquarters and redroot pigweed, foxtail, wooly cupgrass, water hemp and dandelion. Alfalfa was sparse, but uniform throughout most plots. Alfalfa was not removed from the check plots. Because of the continuously moist soil conditions the alfalfa and the fairly sparse weed population in the check plots did not appear to affect soybean growth by early July. Soybean stand and weeds were counted in two yard-square quadrats per plot on July 29.

Moisture sensors were placed at SCAL in 1 plot of each soybean planting date treatment. A malfunction kept the data from recording continuously. Six manual observations in July were insufficient to provide a picture of soil moisture throughout the growing season.

Soybeans were harvested November 10 at 14 % to 16 % moisture with an Almaco plot combine equipped with a wheat header. Moisture and yield were measured for each plot using the Almaco automatic weighing system.

2016 SCAL Timeline

23-Sept	Planted rye and triticale at 150 lbs. PLS per acre.
28-April	Noted stage: Rye-30% flower, entry 1-early boot, entry 7-50% headed, entry 6-mid boot.
6-May	Planted soybeans in every other pass.
6-May	Crimped rye.
12-May	Noted stage: entry 1-100% headed, entry 7-100% flowered, entry 6-100% headed.
12-May	Crimped all triticale (and pennycress in control plots).
14-May	Planted soybeans in remaining passes and re-planted soybeans in rye plots.
3-June	Measured NDRE and soybean density.
7-July	Pulled weeds in control plots in 5 passes.
13-July	Pulled weeds in control plots in remaining 3 passes.
29-July	Counted weeds per square yard.
29-July	Scored soybean density and triticale flatness.
10-Nov	Harvested soybeans.

2017 Field Trial Activities

Triticale was sown in the fall of 2016 with four reps planted at SCAL for a soybean trial and 8 reps at Stanislav farm to accommodate 4 reps of a soybean trial and 4 reps of a string bean trial.

2017 SCAL Trial

All seven of the selected triticale lines were tested at SCAL to make it possible to compare all cultivars under the same conditions and treatments. A drawback for planting early and late flowering cultivars together is that the use of large crimping equipment necessitates crimping all plots on the same day; therefore some cultivars will not be crimped at the optimal stage.

Triticale planting was delayed to October 10 because the plot area had mistakenly been planted through with rye. To prepare the spot for triticale, the rye at 2-leaf stage was harrowed after a shallow disking, irrigated and disked again.

Crimping was delayed until May 31 after control plots were weeded and rototilled. Group 2.0 soybeans were planted into the crimped triticale at 210,000 seeds per acre on June 1 in 7.5-inch rows with at Great Plains no-till drill. Weeds and red clover in control plots were hoed on July 5. Weeds were counted in all plots on July 24 before the control plots were hand-weeded (seven weeks after soybeans were planted).

A score for appearance of individual soybean plants was combined with other data in a "soy/mulch score". The "overall score" combines the "soy/mulch score" with broadleaf and grass weed data (excluding alfalfa).

Triticale residue was removed on August 14 from three foot-square quadrats per plot and was weighed after drying at 90 ° F. for two weeks. For each plot, seed heads were removed from the residue and threshed on a Head Thresher (Precision Machine Co., Inc.). Debris and very light seeds were removed with a Density Seed Blower (Carter Day). Seeds were counted after broken kernels and common bunt balls were removed by hand. Germinated seeds (on blotter paper at room temperature for 7 days) were counted.

Soybeans were harvested with an Almaco plot combine with wheat header on November 10, 2016 at 12 to 15% moisture.

2017 SCAL Timeline

10-Oct	Rye was at 2-leaf stage. Planted triticale.
25-May	Crimped the surrounding rye field at post-anthesis.
30-May	Mowed and rototilled control plots. Measured plant height.
31-May	Crimped plots at 100% anthesis to post-anthesis.
1-June	Planted soybeans at 210,000 seeds/acre.
5-July	Hoed and pulled weeds in control plots.
5-July	Took soy stand count per 2 square yards.
24-July	Counted weeds per square yard.
14-Aug	Bagged residue.
29-Aug	Weighed dried residue.
5-Sept	Threshed, cleaned and counted seeds in preparation for germination tests.
23-Oct	Harvested soybeans.

2017 Stanislav Trial

For 2017, we consolidated the three farm trials to the Stanislav farm to take advantage of his equipment and certification status. We left rye out of the Stanislav trial because Stanislav's rotation is a tight soybean-wheat rotation in which rye could become a noxious weed. The large increase of quality triticale seed in 2016 enabled us to plant larger plots than the previous year (60-ft*15-ft versus 30-ft*15-ft). In the trial design, plots were lengthened to 60 feet to enable the crimper and string bean harvester to get up to speed to do a good job. We planned to use an entire 1.8-acre strip on the Stanislav farm to accommodate both the string bean and the soybean trials.

Triticale planting was delayed until after soybeans were harvested. We abandoned our plans to no-till plant triticale into the soybean residue when it was apparent that the cultivation ridges were too steep to allow crimping the following spring. There was also a large amount of field bindweed visible in the harvested soybean field that needed to be controlled. We chose an alternative land strip that was covered with a mix of buckwheat, turnips, radish and volunteer wheat. Since there was no red clover in this strip this year, it seemed like a reasonable choice. Plots were planted a half-inch deep using a John Deere 750 no-till drill on October 24, a day after the cover crop was shredded and mowed within a quarter inch of the ground. Soil was moist a half inch below the dry surface.

Figure 4. Stanislav spring 2017 modification of plot layout showing previous strip boundaries

	green beans	green beans	soybeans	soybeans
60 ft	5	3	4	7
60 ft	x	7	2	5
60 ft	2	4	x	3
60 ft	3	2	5	2
60 ft	7	x	3	x
60 ft	4	5	7	4
60 ft	3	4	2	x
60 ft	5	2	5	7
60 ft	7	x	3	4
60 ft	2	3	7	5
60 ft	4	5	x	3
60 ft	x	7	4	2
	15 ft	15 ft	15 ft	15 ft

Abandoned

Previous Strip Boundaries

2	NT14407
3	NT14408
4	NT14415
5	NT14429
7	NT15421
x	no triticale

Strip boundaries were changed in the past couple of years leaving 20 feet of the trial in one phase of the rotation and the remaining 40 feet in another phase of the rotation. The 30 feet intended for a green been trial in this 40-foot width were abandoned due to extreme infestation with downy brome grass (photos in Figure 4) resulting in a very poor triticale stand, and were replanted to row-cropped soybeans (upper left corner of Figure 4 photos). Twenty feet of the retained 30 feet had a better, though poor, stand of triticale. In the area that was retained for the trial, (30 ft * 720 ft), Group 2.0 soybeans were planted in 7.5-inch rows at 320,000 seeds/acre into standing triticale on May 13, using a John Deere 750 no-till drill and were crimped on June 2. Soybeans were harvested on October 20 with an Almaco plot combine with a wheat header.

Field Environment

Since testing of triticale in a range of environments rather than in optimal environments was desired, we did not alter the normal fertility practices of any site. SCAL and Stanislav farms relied primarily on legumes for nitrogen fertility. The SCAL trials followed 2 years of unharvested red clover or alfalfa, with triticale planted in place of corn in a corn-soybean-winter wheat/vetch-popcorn-perennial legume rotation). Triticale in Stanislav trials followed a cover crop mix of turnips, buckwheat and red clover. Fields were in transition to a soybean-wheat-mixed cover crop rotation. The Roh site was a highly fertile pastured feed yard before recent cultivation. Triticale at the Mead location replaced wheat in a winter wheat-fall manure-corn-soybean rotation. The Fendrich trial was abandoned and is not detailed.

The Stanislav farm, which was used as the prime location to make first year selections, produced triticale that was very short and low in biomass, in contrast to the Roh and Mead farms. When plants are short, the range in height is compressed so that it is difficult to observe distinctions among lines. A high level of perennial plants (field bindweed, downy brome or red clover) the Stanislav environment created several problems: perennials were encouraged by mulch; evaluations of annual weeds and crop yields were confounded by the effects of competition with perennial weeds; and it was difficult to harvest the crop.

2015 Environment

Soil moisture was retained longer at 12 inches deep under the triticale mulch compared to under the soybean canopy in a cultivated soybean row. Soil moisture at 6 inches deep under the triticale mulch was similar to soil moisture at 12 inches deep in the cultivated row.

Figure 5a. 2015 Soil Moisture Comparisons at Cooperating Farms

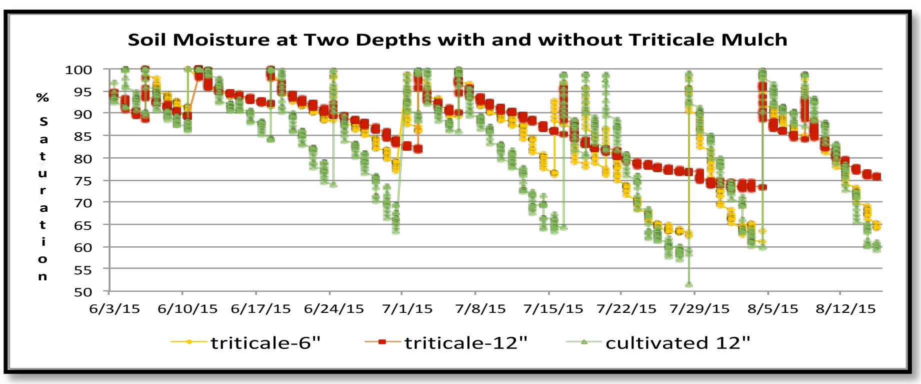
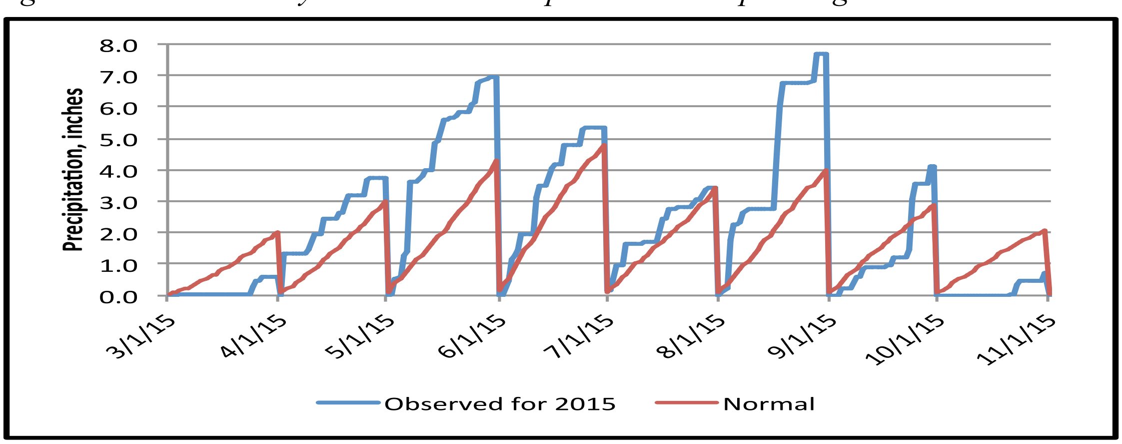


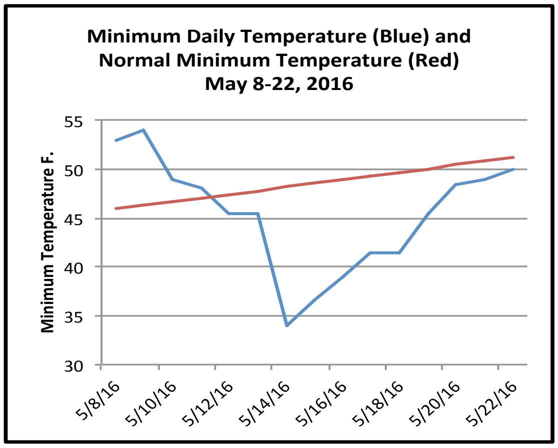
Figure 5b. 2015 Monthly Cumulative Precipitation at Cooperating Farms



2016 Environment

A cold, wet snap mid-May 2016 affected performance of drilled-crimped beans on cooperating farms. Precipitation was well above normal each month except for March and June (Figure 6a). SCAL experienced dry weather leading up to and during the first month of soybean development, and frequent low-intensity precipitation thereafter (including 2 irrigations) until a major rain in mid-October that delayed harvest (Figure 6b).

Figure 6a. 2016 Observed versus Normal Temperature and Precipitation at Cooperating Farms



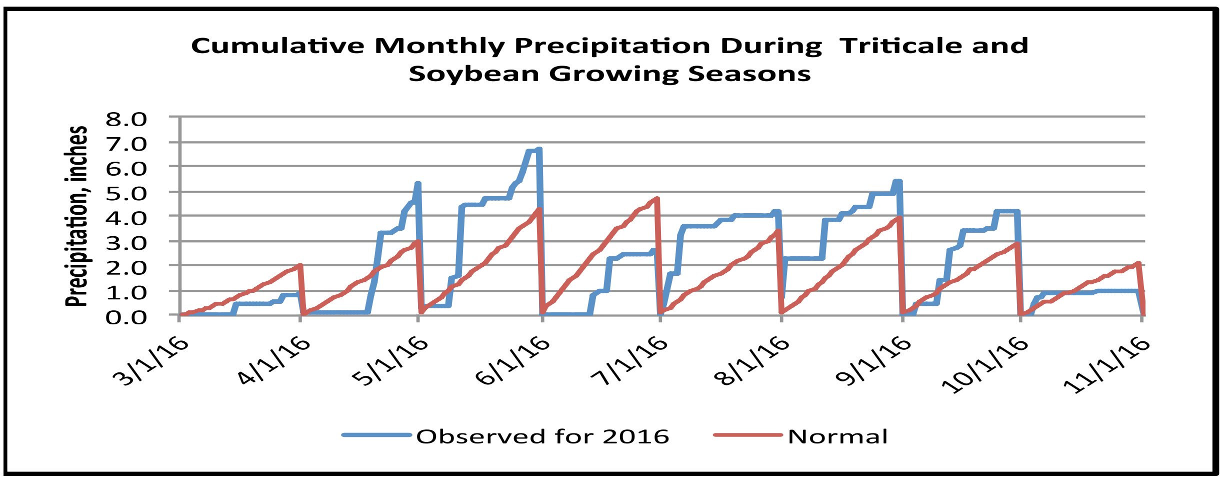
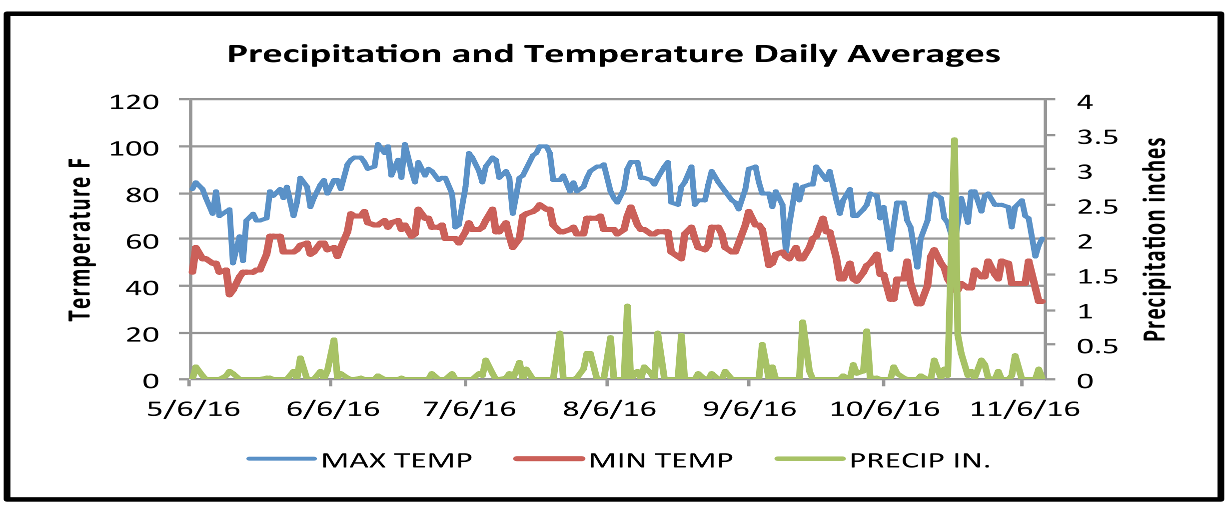


Figure 6b. SCAL 2016 Temperature and Precipitation for Soybean Growing Season



2017 Environment

Soil temperatures under the triticale mulch were depressed as much as 10° F after rains in May and July compared to readings on conventional soil. More growing degrees than normal were accumulated daily during the month of June. During the hot dry period from May 23 to July 9, soil moisture under the triticale mulch decreased steadily for the control plot at both 6- and 12-inch soil depths and for the triticale plot at 12-inches deep, but decreased only slightly for the triticale plot at 6 inches deep. Rain events appeared to depress the soil temperature at 4 inches deep under triticale mulch (red line) more than the nearby soil temperature in clean-tilled soil (lavender line).

Figure 7. Environmental conditions for triticale/soybean plots at SCAL, May 1-July 31, 2017.

Figure 7a. Soil moisture saturation at 6 and 12 inches deep for NT15421 and the control plot.

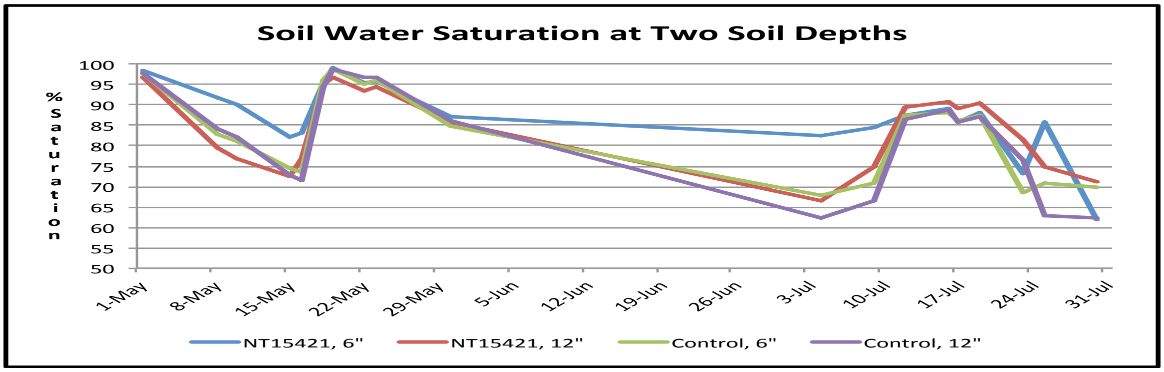
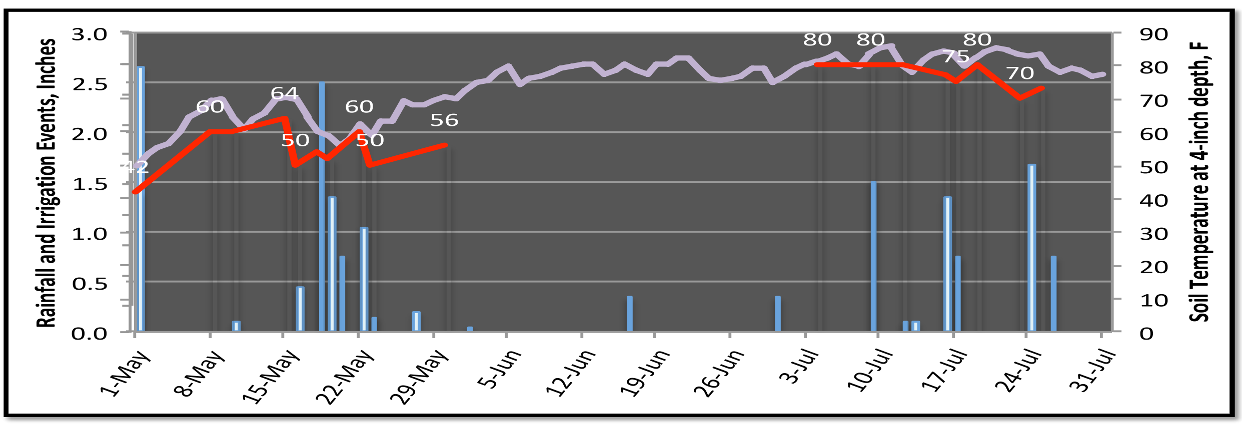
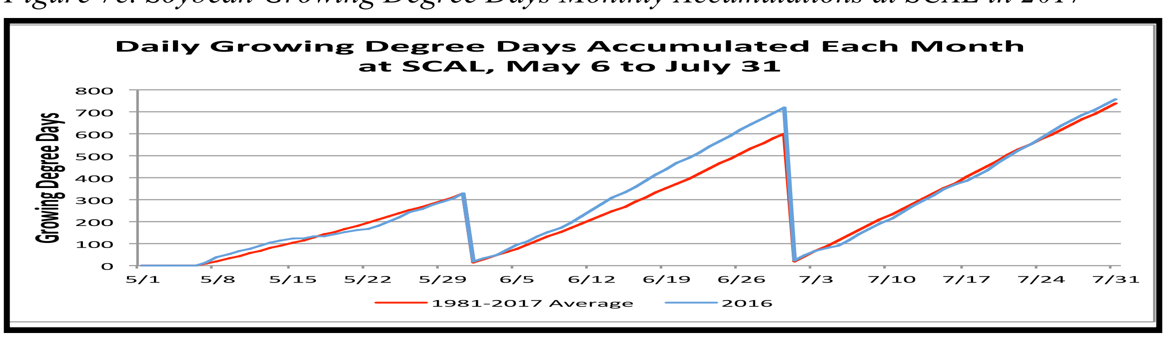


Figure 7b. Soil temperature at 4-inch depth and rainfall and irrigation events at SCAL in 2017.



The red line with white numbers represents soil temperatures taken in the triticale plot (at the same time and place as soil moisture readings were taken). The lavender line indicates soil temperatures from a nearby weather station on conventional soil (HPRCC. 2017).

Figure 7c. Soybean Growing Degree Days Monthly Accumulations at SCAL in 2017



(HPRCC. 2017)

Results

New Crimper Deployment

The crimper traveled well on the road while attached to the tractor. Transportation of the crimper between locations farther than 40 miles was a challenge. The long crimper required a 30-foot trailer, which in turn required that the driver have a commercial driver's license. The alternative of adding a two-wheel dolly in front so that it could be pulled by a pickup truck was not pursued. Making the crimper road-worthy with installation of rear lights was beyond the scope of this project.

Figure 8a. Debut of Crimper in an Elbon Rye Field at SCAL in 2016

Tests on a rye field included various angles for the offset rollers and two speeds. The crimper is shown in action in the rye field adjacent to the test plots in Figure 8a. When treatments were compared a week after crimping and planting rye, the higher speed (8 mph--right photo) and more acute roller offset angle (6 mph--middle photo) appeared to be more effective at killing the rye than pulling the rollers straight at 6 mph (left photo) (Figure 8b). We found that crimping triticale at an angle lays the straw at an angle. Therefore, the triticale covered more of the soil between the rows than when the roller drum is pulling straight with the rows. The soybean planter drill openers aided the kill by slicing through the straw that covered the rows, perhaps the primary advantage for planting after, rather than before, crimping. The population of volunteer plants after harvest, (Figure 8c), is an indicator of effectiveness of suppression of the mulch crop.

Figure 8b. Suppression of Triticale a Week after using the New Crimper

Figure 8c. Volunteer Triticale at Harvest at SCAL on October 23, 2017

2015 Evaluation of 30 Triticale Lines for 2 Triticale Planting/Crimping Dates

Triticale Suppression with Chevron Crimper

Anthesis for the later triticale planting date was five days later than the earlier triticale planting date. On the average, the number of grassy and broadleaf weeds was greater for the later triticale planting date, although the standard deviations were very high (Figures 9 and 10). After the initial crimping on May 21 for the early-planted triticale, we determined that we had crimped a week too soon, and should have crimped at late anthesis or even at a later stage, rather than at 10% anthesis for the earliest-flowering lines. On May 28, upon noting that triticale was severely "goose-necked" with perhaps 20% of stems standing up, we re-crimped the plots. The late-planted triticale was treated similarly (crimping on May 28 and June 3) with similar results.

When evaluated on June 3, three of the earliest flowering lines, NT14421, NT14408, and NT07403, were suppressed better than all other entries, with greater than 55% of stems being brown and flattened (data not shown).

Triticale Cultivar Evaluation

The late triticale-planting/crimping date environment flowered an average of 5 days later and had 6 more weeds per 3-foot transect (Figure 9). Yet, indices for the two environments were fairly consistent (r = 0.75, data shown only for selected lines in Figure 12).

Figure 9. Comparison of Early and Late Planted Triticale Evaluations at Stanislav Farm, 2015

	Late Minus Early Planted Triticale¥					
	Height	Anthesis	Visual Score	Weeds in 3-foot transect, 3-rep average		
	inches	days from May 1	1 - 9, 9 is best	grass	broadleaf	perennial
ave	1	5	-1	3	3	0
min	2	5	1	4	1	0
max	2	-1	1	2	5	0
¥ Excluding NT13443						

Anthesis for six of the experimental triticale lines (May 21) was two weeks earlier than the late-flowering triticale check, NE422T (June 4). Eight of the 30 triticale experimental lines and cultivars had a promising combination of scores for anthesis and biomass/canopy cover (Figures 10 and 11). One triticale line that appeared to perform very well on both planting dates, NT14421, was overwhelmed with both grassy and broadleaf weeds when evaluated on July 1 (Figure 10).

Figure 10. Triticale Evaluation at Stanislav Farm and Mead Agro-Forestry Farm, 2015

	Stanislov Plots Average						Mead Increase Plots		
	Height	Anthesis	Visual Score	Weeds in 3-foot transect, 3-rep average			Height	Anthesis	Biomass
Triticale Experimental Line ID	inches	days from May 1	1 - 9, 9 is best	grass	broadleaf	perennial	inches	days from May 1	1 - 9, 9 is best
NE422T	33	35	3	6	1	0	71	33	4
NT05421	31	29	4	6	3	1	58	26	4
NT06422	30	27	5	7	2	0	54	23	4
NT07403	29	25	5	16	3	0	52	22	4
NT10418	33	27	6	14	3	0	67	24	6
NT12403	29	28	5	6	2	0	56	23	5
NT06427	29	28	4	14	2	0	55	24	7
NT13416	31	28	4	7	4	1	61	24	8
NT13443	34	30	6	8	2	0	70	28	9
NT14407	31	26	6	9	3	0	62	23	8
NT14408	31	25	7	10	3	0	62	23	8
NT14415	31	25	6	12	2	0	57	22	6
NT14421	32	24	8	17	5	0	57	27	5
NT11410	28	29	4	13	3	1	53	24	4
NT14426	30	29	4	10	2	0	66	24	7
NT14429	33	26	5	5	2	2	58	23	8
NT14434	32	27	5	7	3	1	61	24	8
NT12406	30	29	5	14	2	1	58	26	7
NT15407	34	28	5	12	3	1	70	28	8
NT15417	29	29	4	12	3	0	61	25	9
NT15420	29	30	4	13	3	1	61	27	6
NT15421	32	25	5	16	3	0	58	23	8
NT12425	32	30	4	12	1	0	65	25	6
NT15424	30	27	5	17	3	0	57	27	4
NT15425	30	30	5	12	2	0	67	25	6
NT15432	32	27	5	17	4	1	65	24	7
NT15433	29	27	5	12	2	0	53	25	4
NT15446	34	25	7	19	2	1	65	23	4
NT15447	34	27	5	9	1	0	65	25	3
xHF09011_306	29	32	2	8	2	1	47	27	1
ave	31	28	5	11	2	0	60	25	6
stdev	1.9	2.3	1.1	3.9	1.0	0.4	5.9	2.3	2.0
max	34	35	8	19	5	2	71	33	9
min	28	24	2	5	1	0	47	22	1

We found it necessary to supplement the height and biomass scores with observations from Mead increase plots (Figure 10), since triticale on the Stanislav Farm appeared stunted and low in biomass. Allowing eight inches for the difference between measurement to the flag leaf (Stanislav) and measurement to the top of the head (Mead), triticale at the Stanislav Farm was 16 inches shorter than the triticale increase plots grown at Mead. This was an early indicator that triticale selection decisions based on performance on the Stanislav Farm might be different than selections made in a different environment and that the Stanislav data may represent a worse-case scenario for obtaining enough biomass to suppress weeds.

The contrasting Mead environment for biomass and plant height had somewhat consistent indices (r = .47) with the Stanislav environment that confirmed selections of five lines, but showed enough differences among entries to promote the selection of NT15407 for its height and to de-select NT15447 and NT12403 for poor biomass score (Figures 10 and 11). Seed quality and yield of selected lines limited the extent of planting the following season (Figure 12).

Figure 11. Final Selection of Triticale Lines for Subsequent Experiments, 2015

	Indices (1-9, 9 is best)						
Triticale ID	Mead index	Stanislav index	Overall Index	June Plot Evaluation	Score Summary	Mead Notes	Verdict
NE422T	3	5	4				
NT05421	3	5	4				
NT06422	5	6	6		too short		
NT07403	6	5	5	maybe	too short		
NT10418	6	5	5				
NT12403	6	6	6		reconsider	poor biomass	
NT06427	6	4	5				
NT13416	6	5	5				
NT13443	5	5	5		tallest without outlier data	Flowers late, otherwise great (tallest)	keep
NT14407	7	6	6		reconsider	good TW, yield	keep
NT14408	7	7	7	contender	second best overall	poor TW, disease, dark red seed	keep
NT14415	7	6	6	best early planting	best early	best TW, yield	keep
NT14421	3	6	5	best late planting	many weeds	Flowers too late	
NT11410	4	4	4				
NT14426	6	4	5		late flowering	tall, late, good TW, not enough seed	
NT14429	7	7	7	contender	overall best	good TW, moderate yield, nice heads	keep
NT14434	6	5	6				missed
NT12406	4	4	4				
NT15407	5	5	5			tallest, late, poor TW, disease	keep
NT15417	6	3	4				
NT15420	3	3	3				
NT15421	7	5	6	maybe	many weeds	best TW, yield	keep
NT12425	5	4	5				
NT15424	3	4	4				
NT15425	5	4	4				
NT15432	6	4	5				
NT15433	4	5	5				
NT15446	6	6	6	best late planting	too many weeds		
NT15447	4	6	5	best early planting		poor biomass at Mead	
xHF09011_306	1	3	2				

Preliminary Soybean Evaluation

On June 3, soybeans were emerging, with the appearance of a uniform and acceptable stand. However, Stanislav commented that he would have liked a higher soybean density to compete with the red clover. Harvest and further evaluation of soybeans was outside the scope of this preliminary trial.

Figure 12. Triticale Lines Selected for Subsequent Experiments for Four Farm Locations

	Indices (1-9, 9 is best)		50% flowering date		Plant Height					
	early planting index	late planting index	May		Inches					
ID			S†	M†	S†	M†	Farm	Germ %	lbs. seed needed	lbs. seed available
NT13443	5	5	30	28	34	70	CC	45	20	38
NT14407	6	6	26	23	31	62	S R	60	30	44
NT14408	6	7	25	23	31	62	CC F	58	31	42
NT14415	7	5	25	22	31	57	F R	42	43	47
NT14429	7	7	26	23	33	58	F S	56	32	41
NT15407	6	4	28	28	34	70	CC	52	17	31
NT15421	5	6	25	23	32	58	R S	73	37	47

† S= Stanislav Farm, M =Mead (UNL Agro-Forestry) Farm
CC = Clay Center (SCAL), S = Stanislav Farm, R=Roh Farm, F = Fendrich Farm

2016 Evaluation of Seven Triticale Lines for Two Soybean Planting Dates

2016 SCAL Trial

There was no lodging of triticale to report; whereas there was considerable lodging of rye at the Roh farm and some lodging of rye at SCAL.

The infrared scan captured the better effectiveness of crimping rye than of crimping the triticale (Figure 13). On June 3, the plots that were planted after crimping ("crimped-drilled") were more brown, a reflection of damage inflicted by the planter discs on the prostrate crimped straw. Together, the measures captured the poor crimping of NT13443, the effective crimping of rye, which may reflect the difference in stage of anthesis at crimping time, and the intermediate effectiveness of crimping for the other triticale lines.

Figure 13. Soybean and mulch evaluations at SCAL from June and July 2016 observations.

Small Grain Cultivar	Soybean Planting Date	Crimping Effectiveness (inverse of NDRE vegetative index)	Soybean Density	Triticale Flatness	Soybean Density	Individual Soybean Plant Growth	Soy/mulch Score	Weeds	Alfalfa	Overall Score	Note
		6/3/16		7/29/16				7/29/16		7/29/16	
		score 1 to 9, where 9 is best						plants per 2 sqyd		score, 9 is best	
NT13443	6-May	2	5	2	4	4	4	2	4	5	
NT13443	15-May	4	6	6	6	7	6	3	2	6	
NT15407	6-May	2	5	5	6	5	5	2	3	6	
NT15407	15-May	4	6	7	6	7	6	1	3	7	
NT15421	6-May	2	6	7	6	7	7	7	2	5	
NT15421	15-May	4	6	8	6	8	7	3	4	6	
None	6-May	4	6		5	9	7		5	7	
None	15-May	6	6		6	9	8		4	7	
Elbon RYE	6-May			5	6	4	5	4	0	6	
Elbon RYE	15-May	8	5	8	7	7	7	3	2	7	double-crimped

Where the soybeans were planted before crimping ("drilled-crimped") , the soybean seedlings had difficulty emerging and were pushing up the straw to make the mulch fluffier and less effective as a weed barrier. The soybean stand was sparse for all plots (Figure 13). In retrospect, the planting rate of 160,000 seeds per acre should have been increased to at least 220,000. Weeds were thick in the check plots, but were pulled by hand the first week in July. Weeds included 2-foot tall lambsquarters, water hemp, a few foxtail and dandelion, scattered wooly cupgrass and alfalfa, and a few 1 to 2-foot tall redroot pigweed. Except for plots with NT15421 (entry 7), weed populations were not much different between the two triticale planting dates.

The overall score for all data up to July 29 for rye for both planting/crimping treatments and NT15407 for the crimping-planting treatment was similar to the weeded check plots and better than the other small grain lines (Figure 13).

Photos were taken every three weeks or so from April through October to aid data interpretation. Figure 14a shows plots on May 12 before the crimp-drill treatment, (a week after soybeans had been planted in every other pass). Rye in the foreground and background had already been crimped. The plots with uniformly short plants are check plots with volunteer pennycress weeds. Figure 14b shows variation in regrowth of triticale among cultivars on 7-29-16. Through the end of July, when the photo was taken, there were very few weeds, despite the sparse crop canopy.

Figure 14a. Photo of Triticale Plots at SCAL in 2016 Immediately before Crimping.

Figure 14b. Photo at SCAL Showing Regrowth of Triticale on July 29, 2016.

There were definite soybean grain yield differences (LSD = 4.5 for treatment means) between the drilled-crimped (16 bu/acre) and crimped-drilled (24 bu/acre) treatments (Figure 15). For triticale lines alone, the crimped-drilled treatment yielded on average 53% more than drilled-crimped treatment. For the weeded check, the drilled-crimped treatment yielded 48% more than the crimped-drilled treatment. Since the weeded check and triticale plots had similar soybean yield responses, it is likely that weather conditions or damage to seedlings by the crimper may have affected soybean yields when crimping after drilling. NT15421 resulted in a better score for "flatness" and 50% higher soybean yield than NT15407. Plots for both of these triticale lines had significantly higher soybean yields than NT13443 plots.

The rye mulch was suppressed better than any of the triticale lines or the weeded check plots as revealed by scores of "flatness" and loss of green color (NDRE score) (Figure 15). The rye data does not represent the same treatments, but is included as an optimal comparison for soybean performance. Rye had high soybean planting populations (double the population used in the triticale plots) and multiple crimping passes a week before and again immediately before planting soybeans. It is also evident that the rye, which flowered earlier than the triticale, was crimped at a more optimal time than the triticale.

Figure 15. 2016 Soybean Performance and Triticale Suppression at SCAL for Drilled-Crimped and Crimped-Drilled Treatments (Early and Late Soybean Planting Dates)

		Soybean Grain Yield			Weed Count			Soybean Density	Triticale or Rye Flatness			NDRE
	Plant Date	*early*	*late*	*ave.*	*early*	*late*	*ave.*	*ave.*	*early*	*late*	*ave.*	*ave.*
		Harvested Nov. 10			Observed July 29							3-Jun
entry	Small Grain Cultivar	bu/acre, 13% m.b.			Weeds per 10 square yards			score 1 to 9, where 9 is best				
triticale 1	NT13443	11	24.5	17.9	9	15.0	11.9	6.0	2	6.3	4.3	3.3
triticale 6	NT15407	19	30.6	24.6	10	5.0	7.5	5.8	5	7.0	6.1	3.3
triticale 7	NT15421	28	33.4	30.6	33	16.3	24.4	5.9	7	8.3	7.6	3.3
weeded check	None	16	24.1	20.3	0	21.0	0.0	6.3				5.1
mulch check	Elbon Rye 2x¥			37.3			14.4	5.1			8.0	7.8
Least Significant Difference (P<0.05)				5.6			12.1	NS			1.0	1.5

¥ Rye was double planted and double crimped

<u>*2016 Roh Farm Trial*</u>

At the Roh Farm, growth of rye and triticale was lush from high soil fertility conditions (located on previous feedlot), and rye was lodged considerably. Plant height to the base of the flag leaf just before crimping was 42, 44 and 47 inches for entries 2, 7 and 4 respectively. On 5-13-16, the Elbon rye, NT14415 and NT15421 (entries 4 and 7) were fully headed, and NT14407 (entry 2) was 90% headed. On 5-15-16 (the day of the tour and of crimping) rye was 75% flowered, NT15421 showed some yellow anthers, and the other two lines had very few plants that were beginning to flower. The double-disc openers on the JD 7000 planter did not always fully penetrate the thick mat of triticale or rye, and left many bean seeds on the soil surface. Fortunately, seeds were kept moist under the mulch from continual rains, so that emergence in many rows was adequate. In the fallow check plots, the seeds were planted up to two inches deep, and had not started to emerge at the time of crimping.

Figure 16. Roh Farm Triticale Mulch and String Bean Photos

String beans in check plots were about a week more mature than in mulched plots. String beans in mulched plots were at an ideal maturity stage on the day of crimping, with only a few that were too mature. Most triticale and rye plots had very few weeds. The earlier bean planting had more weeds and a poor bean stand in many rows. The later planting had a good stand and few weeds in most plots.

For the crimped-planted treatment, bean density was optimal in the check plots and about the same in rye plots (108 and 102 plants per 30 feet); bean populations were thinner in the triticale plots (82 to 88 plants per 30 feet) (Figure 17). Planted-crimped beans had about half the population density as for the crimped-planted beans, accounting for a portion of the 30 to 60% lower yield per plot. (However, yields were also 15 to 40% less per plant for the planted-crimped treatment). A factor in the poor bean stand might be a cold wet spell that Roh said had reduced yields in early-planted conventional beans in neighboring fields (Figure 6). However, Roh remarked that the bean plant architecture in the conventional field appeared different than in the mulched crop plots, and it is possible that the beans in the mulched crop responded differently to the cold spell in other ways. Whether or not the cold spell affected bean population density, it was obviously difficult for the seedlings to penetrate the thick mulch. The high levels of triticale and rye biomass in the fertile Roh Farm environment resulted in too few weeds to distinguish among triticale lines, despite the high weed density in control plots. Despite the lack of a weed effect and the lack of difference in bean density, string bean yield in the crimped-planted treatment for NT14415 plots was distinctly lower than for NT15421 and NT15407 plots.

The wide-spaced planter disc openers did not contribute much to the suppression or kill of triticale, resulting in large amounts of mature viable seeds, at levels of 9 to 25 bushels per acre. This created a thick mat of volunteer triticale that could not be terminated without tillage, as it was not vernalized and stayed in a vegetative state.

Figure 17. 2016 String bean Performance, Weed Density and Volunteer Seed Production on Roh Farm for two Soybean Planting/Crimping Treatments

Mulch Culitivar	Weed Density 30 ft. row	Green Bean Yield lbs./ 30 ft.	Viable Triticale Seeds bu/acre	Bean Density in Harvested 30 ft. row	Bean Yield lbs./plant	Grass Weed Density > 12 " tall in 30 ft. row	Broadleaf Weed Density > 12" tall in 30 ft. row
Planted-Crimped Treatment (Planted May 7, Crimped May 15)							
RYE	19	216	7	48	4.5	4	14
Triticale NT15421	14	187	25	44	4.2	6	8
Triticale NT14407	12	188	15	54	3.4	2	11
check	111	117	0	54	2.0	33	78
Triticale NT14415	16	131	15	37	3.6	8	9
Crimped-Planted Treatment (Crimped May 15, then Planted May 15)							
RYE	4	535	6	102	5.4	1	4
Triticale NT15421	4	436	21	88	5.1	1	3
Triticale NT14407	9	432	16	82	5.4	6	3
check	47	383	0	108	3.6	14	33
Triticale NT14415	12	343	9	86	3.9	7	5

Mulch Culitivar	Weed Density 30 ft. row	Green Bean Yield lbs./ 30 ft.	Volunteer Triticale Seeds bu/acre	Bean Density in Harvested 30 ft. row	Bean Yield lbs./plant	Grass Weed Density > 12 " tall in 30 ft. row	Broadleaf Weed Density > 12" tall in 30 ft. row
Combined Analysis							
RYE	11	375	6	75	5.0	2	9
Triticale NT15421	9	312	23	66	4.7	3	6
Triticale NT14407	10	310	15	68	4.4	4	7
check	75	275	0	80	2.8	24	51
Triticale NT14415	15	230	12	60	3.8	8	7
Least Signif. Diff.	21	119	9	17		9	12

<u>2016 Fendrich Farm Trial</u>

Because of the thin triticale mulch, soybean stand was good throughout the field. Triticale had much regrowth in all plots. The plots were abandoned in mid-August as a local flock of Canada Geese raided the plots to eat triticale seeds and destroyed many of the bean plots. Unfortunately, NT14408 (entry 3) was grown only on the Fendrich farm and was not evaluated in 2016.

<u>2016 Stanislav Farm Trial</u>

Three days before crimping, entries 2 and 7 (NT14407 and NT15421) were fully headed, and entry 5 (NT14429) and Elbon rye were fully flowered. Soybeans planted May 6 were just starting to emerge at the time of crimping, but were protected by the mulch and were not harmed by the crimper. Triticale had thicker, juicier stalks than rye and appear to be laid flat by the crimper more effectively. Rye had rebounded substantially, bending upward from each joint. However, no significant differences were detected among triticale and rye for vegetation index (data not shown).

On June 2, two and a half weeks after crimping, soybean density appeared adequate, ranging from 7 to 13 plants on average per 2 feet (Figure 18). The Stanislav environment favored NT15421 over rye and NT14407 for soybean yield (46 vs. 35 and 31 bu/acre, respectively). Differences among treatments for soybean yield could not be analyzed.

Figure 18. Soybean Population and Grain Yield at Stanislav Trial, 2016

		Soybean Plants per 2 feet			Soybean Yield (bu/acre)		
trt	entry	trt*entry	entry	trt	trt*entry	entry	trt
drilled-crimped	NT14407	13	11	10	35	31	37
drilled-crimped	NT14429	9	10		38	39	
drilled-crimped	NT15421	12	11		40	46	
drilled-crimped	rye	8	8		32	35	
crimped-drilled	NT14407	9		9	28		39
crimped-drilled	NT14429	10			41		
crimped-drilled	NT15421	10			51		
crimped-drilled	rye	7			37		
LSD						10	NS

Soybean yield is at 13% moisture basis for two planting dates (trt*entry) with crimping on the latter planting date, and averaged for entries across planting dates (entry) and for crimping treatments (trt) across entries.

The soybeans in the Stanislav plots appeared satisfactory through the middle of July, when red clover started to take over. By mid-August, red clover started to dominate the plots. By mid-October the red clover was very thick in most of the plots and obscured soybeans and triticale, making it impossible and irrelevant to obtain weed data. Photos throughout the crop season documented a better stand of soybeans where soybeans were planted after crimping (Figure 19).

Figure 19. Photos of Triticale Plots with Red Clover in Soybeans, 2016 Stanislav Trial

2017 Evaluation of Seven Triticale Lines for One Triticale and One Soybean Planting Date

2017 SCAL Evaluation of Triticale Suppression

There was little difference among triticale lines (2.4 to 2.7 tons/acre) and rye (2.8 tons/acre) for residue dry matter in mid-August, the time at which residue is important for suppressing late-season weeds (Figure 20). Germinated seeds (on blotter paper at room temperature for 7 days) were counted.

All lines were past anthesis when crimped on May 31. On May 25, rye had completed anthesis, and the earliest triticale lines were at 100% anthesis. Unfortunately, anthesis dates were not recorded. Rye was fully headed on May 12, but had not yet begun to flower. Relative anthesis and plant height from 2015 data is included in figures 20 and 24.

The number of viable seeds varied greatly among triticale and rye lines. The higher number of viable seeds for rye (424 seeds per square yard) than for any of the triticale lines can likely be attributed to the rye's earlier maturity and more advanced seed development at the time of crimping (Figure 20). Similarly, the lower number of viable seeds for NT15407 and NT13443 can likely be attributed to later flowering and less advanced seed development at time of crimping. Among the 5 early-flowering triticale lines, the number of viable triticale seeds for NT15421 and NT14407 (47 and 59 seeds/sqyd) was much lower than for the other three lines (79,129 and 252 seeds/sqyd).

Figure 20. 2017 SCAL Triticale Seeds and Biomass with 2015 Anthesis and Plant Height

entry	2017 Triticale				2015	2015
	germination of seeds in residue 14-Aug	viable seeds in residue 14-Aug	biomass of residue 14-Aug	plant height 30-May	relative anthesis	plant height
	%	seeds/sqyd	tons/ acre	inches	days	inches
control						
NT15407	55	27	2.5	56.0	11	70
rye	63	424	2.8	59.5	0	
NT13443	60	21	2.7	55.5	11	70
NT14407	81	59	2.4	48.5	6	62
NT15421	65	47	2.6	48.0	6	58
NT14429	66	129	2.7	48.0	11	58
NT14408	58	252	2.7	47.5	6	62
NT14415	56	79	2.7	47.5	5	57
Least Significant Difference (P< 0.05)				0.2		

Figures 21 and 22 show representative photos of growth, residue and weed density for NT15407 and NT15421. Photos in Figure 23 illustrate data presented in Figure 24: the typical high density of volunteer plants in rye plots and red clover in NT15407; the typical loss of soybean yield from shattering due to unavoidably late harvesting, and the significantly high levels of red clover infestation in NT15407.

Figure 21. 2017 Triticale Plots at Post Anthesis on May 30

NT15407 NT15421

Figure 22. Residue and Weeds in 2017 SCAL Plots on August 10

NT15407 NT15421

Figure 23. Photos of residue, soybean shattering and living matter at harvest time, 2017

Volunteer rye in rye plot | Typical soybean shattering | Red clover in NT15407 plot

2017 SCAL Weed Suppression and Soybean Performance

Soybeans were mature the last week in September; but continual heavy rains delayed harvest for four weeks. On October 23 soybeans were harvested (using an Almaco plot combine with a wheat header) at 10 to 12 % moisture in 2 strips of 5 feet by 30 feet for each soybean plot. Shattering of soybeans was observed but not quantified.

Soybean yields for NT15407 plots, the control plots and Elbon rye plots were equivalent and were significantly greater than for any of the other triticale cultivars (Figure 24). There were significantly more broadleaf weeds in the control plots than in the mulched plots. One triticale line, NT14429 had significantly fewer grass and broadleaf weeds than Elbon rye or the control plots, but the soybean yield was 5 to 7 bushels per acre less. Soybean yield appeared to be correlated with triticale plant height (r=0.44) (Figure 24) and was somewhat correlated with the presence of broadleaf weeds on July 24 (r=.26). The relatively late soybean planting may have favored higher soybean yields for later-flowering triticale mulch lines.

Figure 24. 2017 Weed Density and Soybean Performance at SCAL

	Weeds			Soybeans		Triticale	2015 Triticale	
entry	grass 24-Jul	broad leaf 24-Jul	clover 24-Jul	stand 5-Jul	grain yield @13% m.b. 23-Oct	plant height 30-May	relative anthesis	plant height
	plants/sqyd			plants/sqyd	bu/acre	inches	days	inches
control	2.5	3.4	0.3	24.1	37.6			
NT15407	1.6	1.1	3.0	22.0	37.0	56.0	11	70
rye	2.9	0.6	1.1	23.2	36.0	59.5	0	
NT13443	1.9	0.4	1.1	25.0	32.5	55.5	11	70
NT14407	2.9	0.9	2.6	24.1	31.7	48.5	6	62
NT15421	2.2	0.6	1.8	26.1	31.5	48.0	6	58
NT14429	0.9	0.9	2.0	23.8	30.6	48.0	11	58
NT14408	1.3	0.6	1.0	20.7	28.6	47.5	6	62
NT14415	1.7	0.8	2.0	22.1	27.5	47.5	5	57
LSD (0.05)	1.5	1.3	1.3	NS	3.5	0.2		

2017 Stanislav Farm Trial

On May 17, soybeans were at the cotyledon stage, and triticale was fully headed, but was short and thin without much tillering. There were very few weeds. The crimper was finally available to use on June 2 when the soybeans were about 4 inches tall, the triticale was past the flowering stage, and soil had become dry enough for crimping and wheel traffic. Damage to soybeans was noted only where the crimper edge landed (about every eight inches).

The soybeans yielded 17 to 21 bushels per acre , with standard deviations of 3.2 to 7.6. For lack of enough degrees of freedom, analysis of variance could not be employed to detect differences among triticale mulch cultivars. Where the adjacent plots had been tilled, replanted, cultivated and flamed by the farmer, the soybeans yielded 40 to 45 bushels per acre.

Discussion

Triticale Evaluation

The late planting of triticale in the first year showed an increase of 5 days to anthesis (Figure 9). From this experience we concluded that a late triticale planting date was detrimental to our goal of achieving early planting of beans, Thereafter, triticale evaluations were based on environments with one triticale planting date as early as possible after the Hessian fly-free date (September 25 for all locations in this study), when the previous crop was removed.

Testing in a range of environments allowed us to select a triticale line that should be suitable as a mulch crop for early planting of beans in Nebraska and surrounding states to the north and east. Desired traits for triticale as a mulch crop of early anthesis, winter-hardiness, lodging resistance and high biomass were achieved in the initial selection from UNL breeding trials. Despite problems with perennial weeds and low triticale biomass at the Stanislav location for the 28 experimental triticale lines in 2015 and three triticale lines and rye in 2016, indices for biomass ratings showed definite distinctions among lines that were mostly confirmed by observations in contrasting environments for the related measures of plant height and biomass score at Mead in 2015 and Roh Farm in 2016. The SCAL plots in 2016 and 2017 were intermediate for triticale height and biomass score and provided reliable data for selecting among the seven experimental lines.

The selection of NT15421, from among the seven triticale lines advanced from the initial trial, was based on its 2016 observations at SCAL and Roh Farm, and was confirmed by harvest data in 2016 at all three sites as the best performer among early-flowering lines, along with NT14407. At SCAL in 2016, NT15421 excelled over the two medium-flowering triticale lines in the drilled-crimped treatment for both triticale flatness score (7 vs. 5 and 2) and soybean grain yield (28 bu/acre vs. 19 and 11). At Stanislav farm in 2016, soybeans in the NT15421 mulch yielded 46 bu/acre compared to the other two early-flowering lines (NT14409 and NT14407 at 39 and 31 bu/acre, respectively). Data from 2017 at SCAL did not confirm or disprove the selection of NT15421, as there was little distinction among early-flowering lines for soybean grain yield.

Crimping failed to suppress the production of volunteer triticale and rye seeds, and the experiments failed to make a meaningful comparison of lines for this measure. In 2016, the three early-flowering triticale lines tested on the Roh Farm had significantly different yields of volunteer triticale seeds, yet all lines yielded much more than the normal seeding rate for small grains, and resulted in a thick mat of volunteer plants. In 2017, the comparison of triticale lines for suppression was confounded by variations in anthesis date (with the mix of early-flowering and medium-flowering lines in the experimental design), without varying the crimping date. The doubled planting rate and doubled crimping treatment for Elbon rye was more effective at suppressing regrowth (observed as flatness) and produced more soybeans than the normal planting population rate and single crimping for triticale cultivars.

At SCAL in 2016, of the two medium-late-flowering triticale lines, NT15407 mulch resulted in significantly greater soybean yields than NT13443 mulch at both planting/crimping treatments. Despite having a larger number of weeds, the early-flowering NT15421 plots had soybean yields on par with NT15407 plots in the crimped-drilled treatment and 50% more in the drilled-crimped treatment. In 2017, soybean yields for the weeded control, Elbon rye, and NT15407 were at par, and were significantly greater than for all other triticale lines.

Above average biomass for NT15421 and NT14407 was supported in a 2016 forage trial conducted by the Small Grains Breeding Program (Figure 25, data compiled from Baenziger et al. 2016 and Baenziger et al. 2017). NT15421 did not make the cut in the breeding program because high grain yield was emphasized in most of the selection decisions. Judging by grain and forage yield, NT15406 might be promising as a mulch crop, despite its short stature, but it was not tested in our mulch crop trials.

Figure 25. Triticale Mulch Crop and Small Grains Breeding Program Selection Comparisons

Mulch Obs Trial	Mulch Obs Trial Selections	Breeding Program Selections	Breeding Program Selections		Grain Yield	Heading Date	Plant Height	Forage Dry Matter	Bacterial Streak
2015	2016	2016	2017	name	2 years 3 locations lbs/a	2 years 2 locations D after Jan.1	2 years 3 locations (in)	1 year 1 location (tons/acre)	1 year 1 location (1-9)
*				NE422T	2406	147	63	5.9	1.5
*				NT05421	3285	139	55	7.8	2.3
*				NT06422	3079	137	54	6.5	3.1
*				NT06427	3273	139	48	6.1	1.6
*				NT07403	3411	134	48	6.5	2.4
				NT09423	2920	140	51	6.0	2.2
				NT11428	3501	140	57	6.1	2.3
*				NT12403	3682	136	50	6.1	4.1
*				NT12406	2983	139	52	5.9	3.6
*				NT12425	3436	138	50	6.7	4.0
*				NT13416	3878	137	53	6.5	2.2
*	*		*	NT14407	3430	136	52	7.2	2.4
			*	NT14433	2629	139	61	6.9	3.3
		*	*	NT15406	3933	134	50	6.8	2.2
*	*	*		NT15421	3229	136	53	6.8	1.7
*		*		NT15425	2695	138	57	7.3	1.6
		*	*	NT15428	3522	136	50	6.2	3.0
		*	*	NT15440	3495	141	55	7.1	1.4
				NT441	2048	146	60	5.3	3.1
				OVERLAND	2470	142	41	5.5	3.8
				Average	3202	138	54	6.5	2.6

Crimper Evaluation

Triticale crimping was not effective for the drilled-crimped treatment for either string beans or soybeans, as measured in "triticale flatness" in the soybean experiment (Figure 15) and in "broadleaf weed density" in the string bean experiment (Figure 17). We observed seedlings pushing up the mulch and having difficulty emerging, as reflected in lower crop density in all early planted string bean plots, and in the NT13443 (medium-late flowering) plots for soybeans. In these plots, the new crimper's feature of throwing the triticale and rye diagonally across the row may have made it more difficult for the crop to emerge. It is possible that the diagonal plant-tossing feature of the new crimper impeded planter disc penetration of heavy residue. The Roh Farm trial is the only trial where the residue was thick enough to affect disc penetration;

On the other hand, the diagonal plant-tossing feature of the new crimper may have improved the ability of planter discs to aid the suppression and kill of triticale and rye. When planting at 7.5-inch spacing after crimping, planter discs that cut through the triticale likely contributed to better kill of the mulch crop and also removed the mulch barrier directly above the emerging seedling for easier emergence. The no-till soybean drill at 7.5-inch spacing was more effective in aiding the suppression of the mulch crop than the string bean drill at 36-inch spacing in 2016. In 2017, the number of viable seeds in 10 square yards of mulch residue after soybean harvest ranged from 24 for the medium flowering lines to 113 for the early-flowering lines and 424 for the very early-flowering rye. For the string bean trial (Roh Farm) in 2016, the planter did not help suppress triticales, as evidenced by very high production of viable volunteer triticale seeds (6 to 25 bu/acre), attributed to wide spacing (36 inches) and poor planter disc penetration of residue.

Future Research

We will use the 7000 pounds of NT15421 in our SCAL rotation and are promoting it for collaborative rotational tillage research projects in the northern United States. We are encouraging researchers to test the use of NT15407 as a mulch crop crimped a couple of weeks after planting pulse crops.

Prior to the Arizona seed increase, we did not have access to enough early-flowering triticale to use it on a large scale. Instead, we conducted large-scale mulch-crop experiments at SCAL using Elbon rye (an early-flowering rye). In 2016 the rye was used as a mulch crop for soybean production on one 3-acre organic strip with success for soybean production, yet with the likely development of volunteer rye problems. In 2017, we expanded the mulch crop to three of our seven organic strips for a total of 9 acres. We have been impressed enough with the weed control and the performance of soybeans planted into this mulch crop, that we have re-designed the organic crop rotation at SCAL to include triticale mulch before soybeans. Winter wheat will precede triticale rather than the other way around, to eliminate the possibility of volunteer triticale coming up in the wheat. The 18-ft. crimper now resides at SCAL and will be an essential component of the organic production system there. An organic farmer 20 miles from SCAL plans to use our crimper for collaborative research using NT15421 as a mulch crop.

Organic Farmer Involvement and Dissemination of Results

2015 Farmer Involvement

Four farmers were involved in providing input and feedback on the crimper design at meetings on the farm and at UNL with engineering students. UNL staff and the participating farmer organized a May 21 plot tour at the Stanislav Farm. The timing was not good for farmer turnout, but was necessary for involving farmers in making observations when triticale was flowering. OCIA included the triticale plots (soybeans by then) on their August 22 tour of organic farms. Over 40 organic farmers were present. UNL co-sponsored and advertised both tours. A website was developed to cover the activities of this project and was updated throughout the 2015 season at http://agronomy.unl.edu/mulchcropping.

2016 Farmer Involvement

Field days occurred in May (Roh Farm crimping and planting with one participant other than farm cooperators) and August (OCIA tour with over 40 participants). The May date was scheduled to coincide with triticale anthesis. We did not expect a large turnout because of late rescheduling due to rain, and the conflict with farmers planting soybeans. However, scheduling a tour helped to coordinate the crimping and planting activities of the farmer cooperators. The

August OCIA tour included a half hour viewing and discussing the new crimper and another 20 minutes at the Stanislav plots discussing crimping effectiveness and triticale vs. rye mulch crops.

2017 Dissemination of Results

A SARE-sponsored group of about 50 people toured the plots at the Larry Stanislav farm on August 15, 2017. At the tour, Richard Little presented conclusions about conditions needed for successful soybean/mulch-cropping in Nebraska. At the MOSES 2017 Conference, Little shared a poster with farmers and researchers on 2016 results for mulch cropping and on the related challenges to reducing tillage in Nebraska organic cropping systems.

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