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ALTERNATIVE CROP ROTATIONS IN THE SEMI-ARID CENTRAL GREAT PLAINS REGION HOW MUCH FALLOW? EVALUATING THE ECONOMICS

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Abstract

The traditional crop production system in the semi-arid Central Great Plains Region (CGPR) of the U.S.A. is winter wheat (*Triticum aestivum* L.)-summer fallow (WF) or one crop every two years. This system is not a long-term sustainable dryland system. It is conducive to soil degradation and provides minimal returns on investment in the CGPR. Recently utilizing no-till and more intensive cropping, we have shown several alternative rotations as superior to WF. Our objectives here are to evaluate several of these alternative rotations for economic yield, changes in soil quality, and economic returns. The economics returns to land labor and capital of 7 alternative rotation sequences (established in 1991) is compared and we report some of the effects of rotation intensity on changes in soil organic matter, soil aggregate stability. Specifically we evaluate how far we can push the system to eliminate fallow. Grain yields were measured in each rotation over an 11-year period starting 4 years after rotation establishment (1994-2004). The grain yield data was used to develop rules of thumb regarding long term average yields as affected by rotation sequence and then an economic analysis of net returns to land labor and capital was generated for the 7 rotations. That analysis indicated the most favorable sequences were wheat-millet (*Panicum miliacium* L.)-fallow (WMF) wheat-corn (*Zea mays* L.)-millet-fallow (WCMF) and wheat-millet (WM). The poorest performance was measured with WF and WCM. With respect to soil quality enhancement the best rotations were the continuously cropped WCM followed by WCMF and WCF and the poorest were with WF.

Materials and Methods

The experiment was established in 1990 with the first crop harvested in 1991at the USDA-ARS Central Great Plains Research Station in Akron Colorado. Detailed descriptions of the experiment can be found in Anderson et al 1999 and in Nielsen et al 2002. Akron is at 1420 m above sea level (40° 09 'N, 103° 09 W). The mean annual temperature is 9.2°C but ranges between –40°C to 43°C. The long-term annual precipitation for the location is 420-mm but ranges between 240 and 670-mm. Most of the annual precipitation (82%) comes in the spring and summer. Winter precipitation is less than 18% of the total precipitation. Evaporative demand is between 6 and 8 times the amount of precipitation. These climatic conditions help to explain how dry and difficult it is to farm in the CGPR. The first two replications of the experiment are established in a Weld silt-loam soil (fine smectic, mesic, Aridic, Argiustolls) the last replication grades into a Norca-Colby Complex (fine, silty, mixed mesic Aridic Argiustolls-fine, silty, mixed (calcareous) mesic Ustic Torrriorthents). The experiment includes 16 fixed crop rotations for which only 7 will be emphasized here. The 7 selected are those that over the years have been consistent performers economically some of which have soil enhancing benefits. All crop phases in a given rotation appear each year and all rotation sequences and phases are replicated three times. All crops are planted no-till into previous years stubble except in the WF plots that are managed with conventional sweep tillage (WF-ct). Weeds in no-till fallow and between crops are controlled with standard herbicide rates and practices. This includes pre-plant applications of atrazine for corn followed by in crop applications for late season broadleaf control with 2,4-D and dicamba. Glyphosate or paraquat is used to control weeds just prior to planting or during fallow periods. Crops are fertilized using regional university soil fertility recommendations based on soil tests. Grain and biomass yield is measured in each plot. To evaluate rotation sequence effects on yields and economics, we considered it more correct to complete one cycle of the four-year rotations before making comparisons among the treatments. And so, here we evaluate data collected in 1994 through 2004. All comparisons of the rotation yields are compared back to WF-nt. We felt that WF-nt was a fairer comparison than WF-ct which has always yielded less than WF-nt. Yield comparisons are made with the rotations: wheat-corn-millet-fallow (WCMF), wheat-corn-fallow (WCF), wheat-millet-fallow (WMF), wheat-corn-sunflower (*Helianthus annuus* L.)-fallow (WCSF), wheat-sunflower-fallow (WSF), wheat-corn-millet (WCM), wheat-millet (WM), WF-nt and WF-ct. For the economic analysis 7 rotations are evaluated these are: wheat-corn-millet-fallow (WCMF), wheat-corn-fallow (WCF), wheat-millet-fallow

(WMF), wheat-corn-millet (WCM), wheat-millet (WM), WF-nt and WF-ct. Production costs were tallied and 5 year and 10 year average commodity prices are used to calculate net returns from the long term average yields. All calculations were based on a 65 ha sized farm (160 acre farm). Periodic soil sampling of the surface 0-10 cm of the soil has been done to monitor changes in soil quality parameters in these plots these include soil organic matter (SOM) and particulate organic Matter (POM) and aggregate stability.

Results and Discussion

Wheat yields are significantly affected by rotation sequence (Table 1). Corn and millet yields (in general) are not affected by rotation sequence (Table 2). Because winter wheat is very dependant upon stored soil water that accumulates during the 14 month summer fallow period we see a large yield enhancement for wheat in rotations that have summer fallow. The summer crops corn and millet have only a short (9-10 month) winter fallow period before they are planted. Also corn and millet yields tend to be more dependant upon precipitation amounts received during the summer months. They are particularly sensitive to precipitation received during the critical flowering period in July and August. These differences in how winter wheat and the summer crops are impacted by summer versus winter fallow may partially explain the importance of rotation sequence on wheat as compared to corn and millet. The greatest wheat yields are measured in WCF and WCMF. In 1994, through 1998 (the first 5 years of the 11 years presented here) and in 2002 and 2003 the rotations WCMF and WCF had a positive effect on wheat yields (relative to WF-nt). In 1999, 2000 and 2001 these same rotations reduced wheat yields (Table 1). The key point is that in WCF and WCMF, wheat comes after fallow and so soil moisture storage should be similar to WF-nt. We evaluated in-season-precipitation and precipitation received during fallow and found no reasonable or consistent relationship between wheat yield increases in WCF/WCMF that could be explained by precipitation timing or amounts received. It seems plausible that WCF/WCMF may have stored more soil moisture than the other rotations with fallow but why the effect happens the first five years and for a total of 7 of the 11 years, and not in other years is not clear. Further analysis of pre-plant available stored water in these rotations may explain the effect. In any case, these rotations appear to significantly increase wheat yields above that measured in WF-nt and that effect happens 64% of the time. Other rotations (WSF, WCSF, WM, WCM) always reduce wheat yields. With these 4 rotations, the effect has been shown (in earlier work) as the result of less stored soil water. Sunflowers are efficient at extracting soil water to levels that are lower than other crops and continuous cropping doesn't allow any soil water recharge. For WCF and WCMF we suspect that the measured wheat yield advantage is a sort of "rotation effect". Perhaps being out of wheat for 2 or 3 years (a long break in weed, insect and disease cycles for winter wheat) is helping wheat do well in WCF and WCMF. There is evidence that corn serves as a better host for mycorrhizal infection then the other crops grown in these rotations. One could speculate that corn might increase mycorrhizae inoculum levels in the soil. The increased inoculum could benefit the subsequent wheat crop via more complete mycorrhizal infection. At this point we really do not know what the cause for better wheat yields in these rotations with corn.

We used the 1994 to 2004 average yields to develop the following grain yield performance "Rules of thumb". These are:

- Millet after corn (with or with out fallow in the rotation) averages 1910 kg ha^{-1} (34 bu/acre).
- Millet after wheat (with or without fallow in the rotation) averages 2190 kg ha^{-1} (39 bu/acre).

- Corn after wheat with fallow in the rotation averages 2950 kg ha^{-1} (47 bu/acre).
- Corn in continuous rotations averages 2570 kg ha^{-1} (41 bu/acre).

- Wheat after fallow with corn in the rotation averages 3030 kg ha^{-1} (45 bu/acre).
- Wheat after fallow with just millet averages 2760 kg ha^{-1} (41 bu/acre).
- Wheat in continuous rotations after millet averages 1550 kg ha^{-1} (23 bu/acre).

From these rules we generated economic returns from the rotation data. The rotations that produced the greatest returns to land labor and capital in this analysis were WM, WMF and WCMF (Table 2). Rotations that were less favorable were WF-ct, WF-nt, WCF and WCM. It was interesting to see that a continuous crop rotation ended up in both the favorable and unfavorable economic categories.

Using the "rules of thumb" listed above, we developed a theoretical rotation of wheat-millet-corn-millet-fallow (WMCMF, 4 crops in 5 years). Using this theoretical rotation we calculated net returns of $6670 based on the last 10-year average prices for a 65 ha (160 acre) farm. Net returns were $10297 based on the last 5-year average prices for corn and wheat and millet. These net return values are within $60 of the returns calculated for the WM rotation. The big advantage would be in the greater diversity with the WMCMF sequence compared to the WM rotation. The risk is spread over more enterprises than just wheat or millet.

Table 1. Wheat yield percentage increase/decrease as influenced by rotation sequence (1994-2001) in 9 rotations at USDA-ARS-CGPRS, Akron, Colorado relative to wheat fallow no-till (WF-nt).

Rotation	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	11 year average
WCMF	*+8*	*+18*	*+11*	*+3*	*+40*	-3	-11	-6	+9	+8	-25	*+5*
WCF	-6	*+19*	*+3*	*+13*	*+24*	-3	*+2*	-7	-3	+8	-15	*+4*
WMF	-8	*+1*	+7	-2	-2	-9	-7	-11	-8	+11	-5	-3
WCSF	-6	*+28*	+2	-15	-37	-12	-54	-28	-4	-6	-25	-21
WSF	-21	-6	-37	-23	-40	-45	-29	-32	-27	-5	+18	-22
WCM	-22	-18	-66	-40	-56	-64	-47	-45	-60	-1	-97	-47
WM	-51	-34	-66	-512	-46	-68	-49	-37	-71	-1	-85	-51
WF-nt	---	---	---	---	----	----	---	----	----	----	----	----
WF-ct	-13	-17	-26	-38	-4	-25	-28	-11	-19	-12	-60	-23
P>F	0.008	0.004	0.001	0.001	0.002	0.001	0.001	0.002	0.002	0.002	0.002	0.0001

We also measured improvements in soil organic carbon, and aggregate stability in the surface 10 cm of the soils in these plots. The best rotations for improving or maintaining soil quality are WCM>WCMF> WCF> WFnt>WFct. The greater total biomass production with greater cropping intensity combined with no tillage is suspected as being the explanation for improvements in measured soil quality parameters. Statistically significant increases in aggregate stability and increases in SOM and POM have been measured with increasing cropping intensity in these plots. We have also documented statistically significant increases in the plant availability of P, Zn, Cu and Fe in these plots with an increase in cropping intensity. These increases in availability are linked to reductions in soil pH that are the result of continued soil-surface applications of ammoniacal fertilizer in these no-till managed plots.

Conclusions

Increasing rotation intensity from 1 crop in 2 years to 2 crops in three years or to three crops in four years enhances economic returns for farmers in the CGPR. Not all rotations that are best for the soil are necessarily best for the farmers return on investment. For example WCM is a good rotation for the soil but performs poorly when we consider economic returns. Wheat is highly responsive to stored moisture during the long summer fallow period. And the greatest wheat yields are in rotations that have summer fallow. However, the long fallow period is expensive to manage and the increased cost of managing summer fallow reduces overall economic returns in WFnt and WFct. The greatest economic returns are found with WM, WMF and with WCMF.

Table 2. Ten-year average yields (1994-2004) and net returns for corn, millet and wheat in seven ACR rotations at Akron,

Colorado. Commodity prices used in the calculations are the last 5-year averages (2003-2008) of: April corn at $3.42/bu; January wheat at $5.52/bu wheat and November millet at $4.32/bu. Values in parenthesis are the returns based on the 10 year average prices of $3.72 January wheat, $2.59 April corn and $3.36 November millet (1994-2004).

Rotation	Corn	Proso millet	Wheat	$ U.S. Returns 65 ha farm
		------- kg/ha -------		$/farm
WCMF	3012	1905	2960	9513 (6210)
WCF	2887		3090	8837 (4960)
WMF		2186	2757	10303 (6650)
WCM	2573	1906	1547	8173 (5133)
WM		2130	1480	10356 (6840)
WF-no-till			2892	8544 (5540)
WF-ct (sweeps)			2018	4180 (2650)
P>F	0.54	0.35	0.0001***	

*** P>F This indicates statistical significance. Values smaller than 0.05 are considered statistically significant.

References cited

Anderson, R.L. , R.A. Bowman, D.C. Nielsen M.F. VigilR.M Aiken and J.G. Benjamin 1999. Alternative crop rotations for the Central Great Plains J. Prod. Agric. 12:95-99.

Nielsen D.C., M.F. Vigil, R.L. Anderson, R.A. Bowman and J.G. Benjamin. 2002. Cropping system influence on planting water content and yield of winter wheat. Agron. J. 94:962-967.

Designing a Weed Control Plan for Your Farm

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Successful weed control programs

- Properly identifying the weed problem
  - Weed identification
  - Presence of resistance weeds

- Using appropriate resources to manage the problem that has been identified
- Implementing the appropriate weed control strategies to manage the problem

Assumptions in this discussion

- Use the Kansas State University
  - 2014 Chemical Weed Control Guide
- http://www.ksre.ksu.edu/bookstore/pubs/SRP1099.pdf
- Available in County Ext. offices
- Available at Cover Your Acres

Assumptions in this discussion

- Certain principles of weed management in cropping systems that must be considered to develop a plan that maximizes effectiveness.
- Resistant weeds have or will changed the playing field!

Weed management principles

- <u>Crop rotation is important</u>
- The summer crop will be no-till planted into the wheat stubble. (assumption)
  - Residue is an essential part of the system and will have an adverse effect on weed seed germination and weed growth
  - Residue reduces evaporation and potentially can increase water use efficiency

Control weeds in your wheat!?

- If kochia is present, dicamba or Starane type chemistry must be in the mix.
- Subsequent crop will affect herbicide selection (read and follow label directions)
  - Be careful with sulfonylureas (Maverick and Glean are LONG residual), Finesse, Amber, Rave , and Ally all can have residual. Olympus, Osprey, PowerFlex HL and others all have residual. The residual is moisture and pH dependent. Check Weed Guide or review label.

Wheat Premixes
DuPont products

- Affinity Broadspec — Harmony + Express
- Affintiy Tankmix — Harmony + Express
- Agility — Harmony + Express + Ally + Dicamba
- Ally Extra — Harmony + Express + Ally
- Harmony Extra — Harmony + Express
- Finesse — Glean + Ally
- Finesse G&B — Glean + Everest
- Panoflex (DuPont) — Harmony + Express

Wheat Premixes
Syngenta Products

- Orion — Florasulam + MCPA
- Pulsar — Starane + Dicamba
- Rave — Amber + Dicamba

Wheat Premixes
Dow Products

- Curtail — Stinger + 2,4-D
- Curtail M — Stinger + MCPA
- Starane Flex — Starane + Florasulam
- Starane NXT — Starane + Bromoxynil
- Widematch — Starane + Stinger

Control weeds in your wheat!?

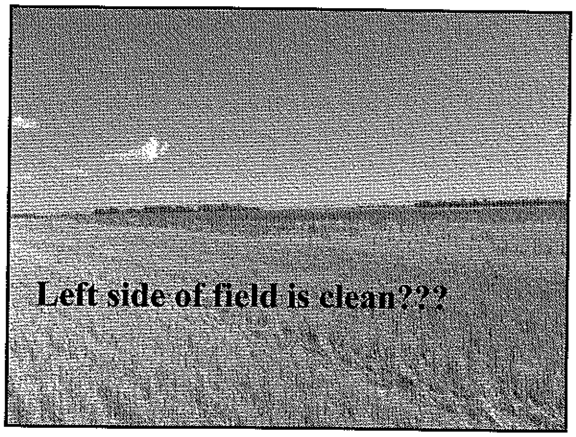
- Frequently weeds are not competitive in a good stand of wheat! This is a function of weed verses wheat emergence date, weed density, wheat stand, wheat growing conditions.

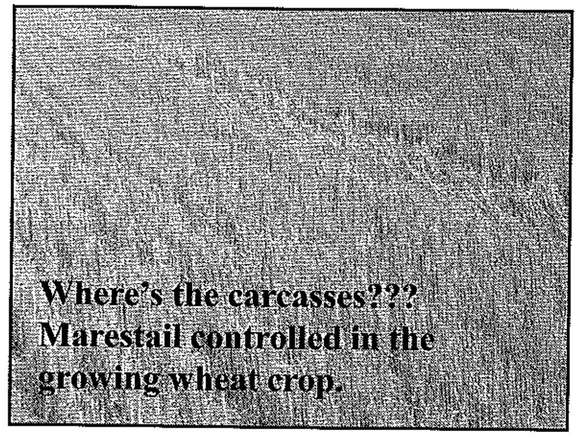
Control weeds in your wheat!?

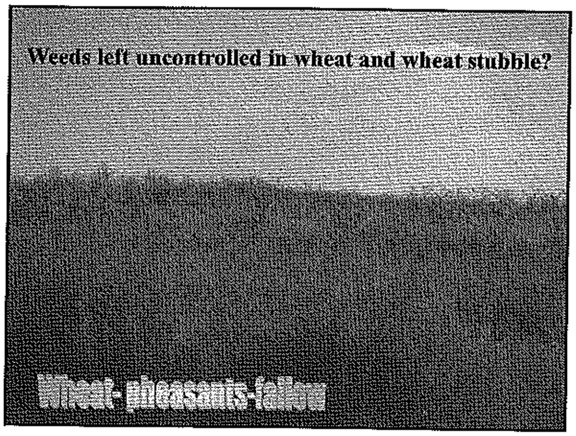
- Depending on preharvest burndown treatments in wheat are often not effective and can be costly!
- Start earlier IN CROP!

Control weeds in your wheat!?

- Effective control of weeds in a growing wheat crop can often delay the initial weed control operation needed after wheat harvest.







Weeds utilize

Moisture & Nutrients

And produce seed!

Fact! Not an assumption!

Weed control in No-till Fallow

- NOTE: Fallow periods can increase weed problems primarily when weeds are not controlled after an early season harvest (wheat, canola, spring cereals)
- Practice weed sanitation

Control weeds in no-till wheat stubble

- Moisture conservation for crop production
- Reduce weed seed bank - reduce future weed pressure
- Less residue to plant through if fallow is maintained weed free

Factors Affecting Weed Control in No-till Systems

- Soil active herbicides surface applied without incorporation
- Postemergence herbicide activity same as conventional
- Herbicide selection/residual may affected subsequent crop to be planted.

Weed Species Shifts in Notill

- Increase in Roundup Tolerant Weeds
  - prairie cupgrass, showy cloris, windmillgrass, tumblegrass, sanddropseed, yellow nutsedge, others
- Increase in Roundup Resistant Weeds
  - Kochia
  - Palmer amaranth
  - Marestail

Weed Species Shifts

- In Notill: Tend to have increase in small seeded grasses and broadleaf weeds
  - foxtails, crabgrass, stinkgrass, witchgrass, kochia, pigweeds, marestail, Russian thistle
- NOTE: Small seeded annual grasses can create significant problems in grain sorghum production.

Weed Species Shifts

- In Notill: Tend to have a decrease in large seeded weeds
  - bindweed, velvetleaf, cocklebur, morningglory, devilsclaw

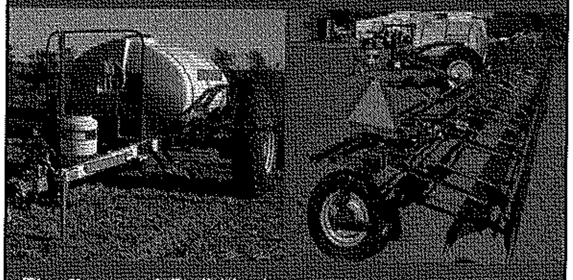
Why the Weed Species Shifts?

- Increase in the use of Roundup thus selection pressure will benefit Roundup tolerant weeds
- Small seeded weeds must emerge from shallow depths and often can germinate laying on a damp residue covered soil surface
- By leaving weed seed on the surface , large seeded weeds are less likely to germinate and grow and are destroyed through weathering or insect depredation

Timely postemergence weed control is essential!!!

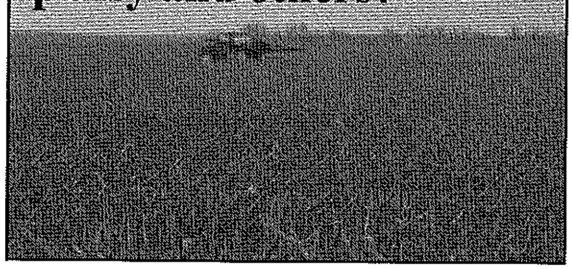
Remember, small weeds are easier to control than large weeds! Small weeds often have moisture available and are in better growing condition.

Do You Own Your Sprayer



Timeliness and flexibility in herbicide application can be important for effective weed management.

Fall herbicides to manage marestail, henbit, field pansy and others?



Fall (NOV) herbicide applications prior to spring planted crop

- Key strategy for managing glyphosate resistant Marestail ahead of spring planted crop
  - Ahead of corn and sorghum, glyphosate+atrazine, atrazine+ 2,4-D or dicamba.
  - Several other good tankmixes available

Fall (NOV) herbicide applications prior to spring planted crop

- Key strategy for managing glyphosate resistant Marestail
  - Ahead of soybeans or sunflower, glyphosate + 2,4-D or dicamba
  - Soybeans, Autumn Super, Authority First, Authority MTZ, Authority XL (rate restriction when pH above 7.0), All mix with 2,4-D or dicamba

February/March herbicide applications

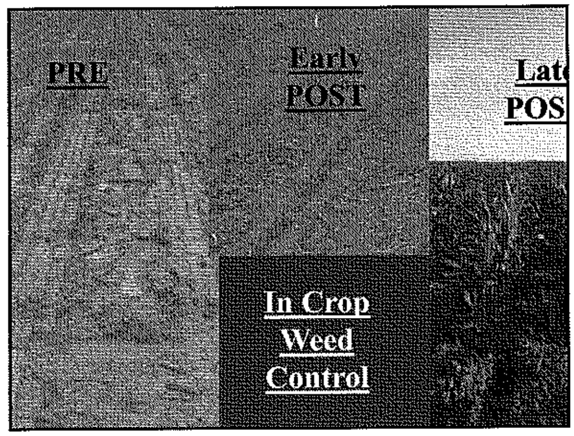
- Key strategy for managing <u>kochia</u> ahead of :
  - Corn and sorghum, minimum of atrazine+dicamba, or Balance Flexx, Corvus, and many others have looked excellent

February/March herbicide applications

- Key strategy for managing kochia either ahead of :
  - Soybean and sunflower, sulfentrazone (Spartan or Spartan Charge) provides excellent PRE control of Kochia. Dicamba not an option according to label ahead of sunflower or in soybean if annual precip is less than 25 in., other Authority based products and/or some metribuzin can be effective ahead of soybean

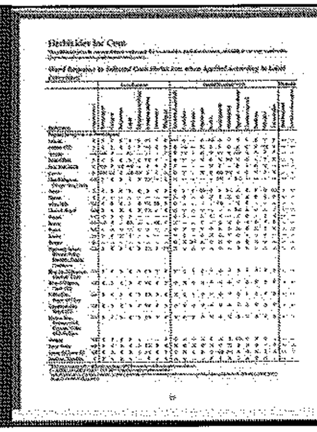
February/March herbicide applications

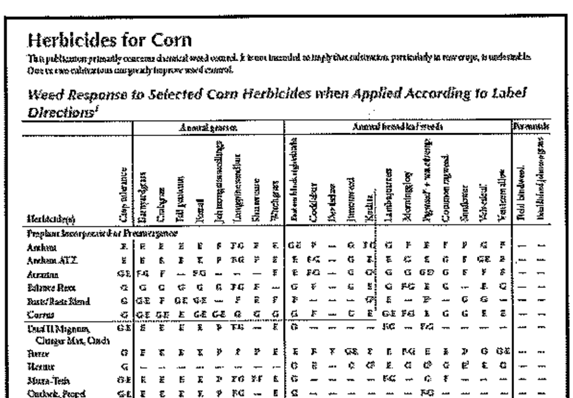
- Key strategy for managing kochia after summer crop prior to notill wheat planting
  - Fallow ahead of wheat planting, atrazine is prohibited. Metribuzin is a good substitute for atrazine and can be added to Balance Flexx or Corvus which is very effective. This can be used 4 or more months prior to planting wheat.



In Crop weed control:

- Use the Kansas State University
  - 2014 Chemical Weed Control Guide
- http://www.ksre.ksu.edu/bookstore/pubs/SRP1099.pdf




Herbicides for Corn

Weed Response to Selected Corn Herbicides when Applied According to Label Directions[1]

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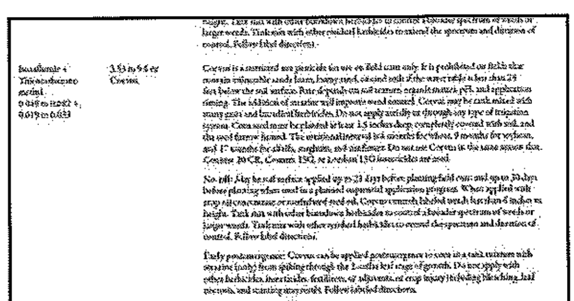

P. 32,

An entire session could be spent on utilizing this weed guide! KEY resource in planning.

Dryland and Limited Irrigation Fertility Management

Nitrogen and Phosphorus Fertilization of Irrigated Corn and Grain Sorghum

A. Schlegel and H.D. Bond

Summary
Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated corn and grain sorghum in western Kansas. In 2013, N applied alone to corn increased yields 69 bu/a, whereas P applied alone increased yields 21 bu/a. Nitrogen and P applied together increased yields up to 150 bu/a. This is similar to the 10 year average, where N and P fertilization increased corn yields up to 147 bu/a. Application of 120 lb/a N (with P) produced about 92% of maximum corn yield in 2013, which was similar to the 10-year average. Application of 80 instead of 40 lb P_2O_5/a increased average yields 3 bu/a. In 2013, N applied alone to grain sorghum increased yields 57 bu/a, whereas N and P applied together increased yields up to 84 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 70 bu/a. Application of 40 lb/a N (with P) was sufficient to produce about 80% of maximum sorghum yield in 2013 which was slightly less than the 10-yr average. Application of potassium (K) has had no effect on sorghum yield throughout the study period.

Procedures
This study was initiated in 1961 to determine responses of continuous corn and grain sorghum grown under flood irrigation to N, P, and K fertilization. This field study is conducted at the Tribune Unit of the Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 were N rates of 0, 40, 80, 120, 160, and 200 lb/a without P and K; with 40 lb/a P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O. No yield benefit to corn from K fertilization was observed in 30 years, and soil K levels remained high, so the K treatment for corn was discontinued in 1992 and replaced with a higher P rate (80 lb/a P_2O_5). All fertilizers are broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids [Pioneer 34N45 (2004 and 2005), Pioneer 34N50 (2006), Pioneer 33B54 (2007), Pioneer 34B99 (2008), DeKalb 61-69 (2009), Pioneer 1173H (2010), Pioneer 1151XR (2011), and Pioneer 0832 (2012-2013)] were planted at about 32,000 seeds/a in late April or early May. Sorghum (Pioneer 8500/8505 from 2003–2007, Pioneer 85G46 in 2008–2011, and Pioneer 84G62 in 2012-2013) was planted in late May or early June. Hail damaged the 2005 and 2010 crops. Irrigation is used to minimize water stress. Sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 15.5% moisture for corn and 12.5% moisture for grain sorghum.

Results
Corn yields in 2013 were greater than the 10-year average (Table 1). Nitrogen alone increased yields 69 bu/a, whereas P alone increased yields 21 bu/a. However, N and P applied together increased corn yields up to 150 bu/a. While maximum yield was obtained with the highest N and P rate, 160 lb/a N with 80 lb/a P_2O_5 caused less than a 2% yield reduction. Corn yields in 2013 (averaged across all N rates) were 3 bu/a greater with 80 than with 40 lb/a P_2O_5, which is less than the 10-year average of 6 bu/a.

Grain sorghum yields in 2013 were similar to the 10-year average yields (Table 2). Nitrogen alone increased yields 57 bu/a while P alone increased yields 15 bu/a. However, N and P applied together increased yields up to 84 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 70 bu/a. In 2013, 40 lb/a N (with P) produced about 78% of maximum yield, which is slightly less than the 10-year average of 85%. Sorghum yields were not affected by K fertilization, which has been the case throughout the study period.

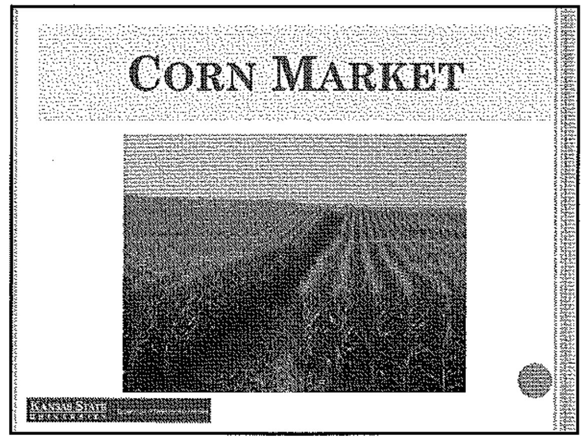
Table 1. Effect of nitrogen and phosphorus fertilization on irrigated corn, Tribune, KS, 2004-2013.

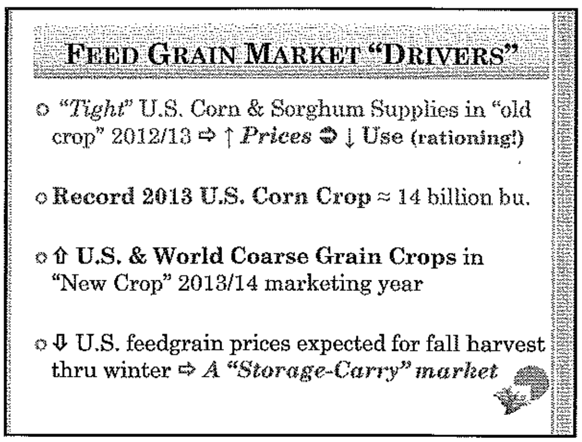
N	P_2O_5	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean
-------- lb/a --------		--					bu/a	--				
0	0	67	49	42	49	36	85	20	92	86	70	60
0	40	97	60	68	50	57	110	21	111	85	80	74
0	80	98	51	72	51	52	106	28	105	94	91	75
40	0	92	63	56	77	62	108	23	114	109	97	80
40	40	154	101	129	112	105	148	67	195	138	125	127
40	80	148	100	123	116	104	159	61	194	135	126	127
80	0	118	75	79	107	78	123	34	136	128	112	99
80	40	209	141	162	163	129	179	85	212	197	170	165
80	80	205	147	171	167	139	181	90	220	194	149	166
120	0	103	66	68	106	65	117	28	119	134	114	92
120	40	228	162	176	194	136	202	90	222	213	204	183
120	80	234	170	202	213	151	215	105	225	211	194	192
160	0	136	83	84	132	84	139	49	157	158	122	114
160	40	231	170	180	220	150	210	95	229	227	199	191
160	80	240	172	200	227	146	223	95	226	239	217	199
200	0	162	109	115	159	99	155	65	179	170	139	135
200	40	234	169	181	224	152	207	97	218	225	198	191
200	80	239	191	204	232	157	236	104	231	260	220	207
ANOVA (P>F)												
Nitrogen		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N × P		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Means												
Nitrogen, lb/a												
0		87	53	61	50	48	100	23	103	88	80	69
40		132	88	103	102	91	138	50	167	127	116	111
80		178	121	137	146	115	161	70	189	173	143	143
120		188	133	149	171	118	178	74	189	186	171	156
160		203	142	155	193	127	191	80	204	208	179	168
200		212	156	167	205	136	199	89	209	218	186	178
LSD (0.05)		11	10	15	11	9	12	9	13	10	10	8
P_2O_5, lb/a												
0		113	74	74	105	71	121	36	133	131	109	97
40		192	134	149	160	122	176	76	198	181	163	155
80		194	139	162	168	125	187	81	200	189	166	161
LSD (0.05)		8	7	11	8	6	9	7	9	7	7	6

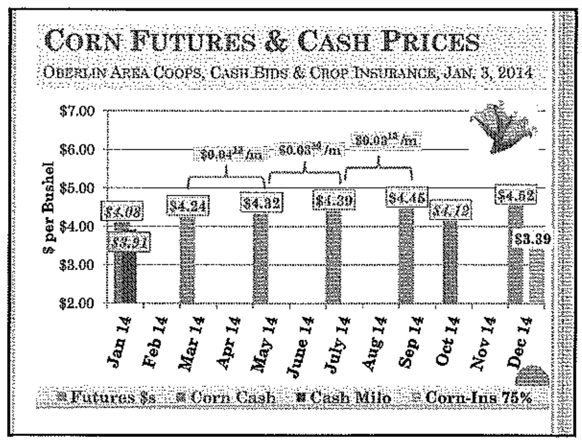
Table 2. Effect of nitrogen, phosphorus, and potassium fertilizers on irrigated grain sorghum yields, Tribune, KS, 2004-2013.

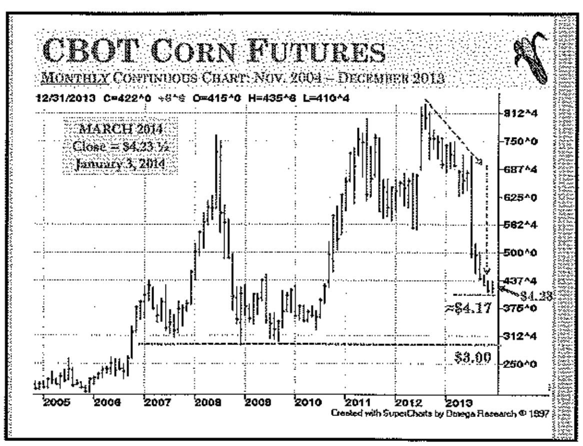
Fertilizer			Grain sorghum yield										
N	P_2O_5	K_2O	2004	2005*	2006	2007	2008	2009	2010	2011	2012	2013	Mean
- - - - - - lb/a - - - - - -			- - - - - - - - - - - - - - - - bu/a - - - - - - - - - - - - - - - -										
0	0	0	57	58	84	80	66	64	51	75	78	62	68
0	40	0	73	53	102	97	60	70	51	83	90	77	77
0	40	40	74	54	95	94	65	76	55	88	93	72	77
40	0	0	60	63	102	123	92	84	66	106	115	94	92
40	40	0	112	84	133	146	111	118	77	121	140	114	117
40	40	40	117	84	130	145	105	109	73	125	132	110	114
80	0	0	73	76	111	138	114	115	73	117	132	102	106
80	40	0	103	81	132	159	128	136	86	140	163	136	128
80	40	40	123	92	142	166	126	108	84	138	161	133	129
120	0	0	66	77	101	138	106	113	70	116	130	100	103
120	40	0	106	95	136	164	131	130	88	145	172	137	132
120	40	40	115	98	139	165	136	136	90	147	175	142	136
160	0	0	86	77	123	146	105	108	74	124	149	117	112
160	40	0	120	106	145	170	138	128	92	152	178	146	139
160	40	40	113	91	128	167	133	140	88	151	174	143	134
200	0	0	100	86	134	154	120	110	78	128	147	119	119
200	40	0	115	108	143	168	137	139	84	141	171	136	135
200	40	40	123	101	143	170	135	129	87	152	175	138	137
ANOVA (P>F)													
Nitrogen			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic			0.018	0.005	0.004	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P-K			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zero P vs. P			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P vs. P-K			0.121	0.803	0.578	0.992	0.745	0.324	0.892	0.278	0.826	0.644	0.999
N × P-K			0.022	0.195	0.210	0.965	0.005	0.053	0.229	0.542	0.186	0.079	0.071
Means													
Nitrogen, lb/a													
0			68	55	93	91	64	70	52	82	87	70	74
40			96	77	121	138	103	104	72	117	129	106	108
80			100	83	128	155	123	120	81	132	152	124	121
120			96	90	125	156	124	126	82	136	159	126	123
160			107	92	132	161	125	125	83	142	167	135	129
200			113	98	140	164	131	126	84	141	165	131	130
LSD (0.05)			11	10	11	9	7	11	5	8	9	8	5
P_2O_5-K_2O, lb/a													
0			74	73	109	130	101	99	68	111	125	99	100
40-0			105	88	132	151	117	120	80	130	152	124	121
40-40			111	87	130	151	117	116	79	133	152	123	121
LSD (0.05)			7	7	7	6	5	7	4	6	6	5	4

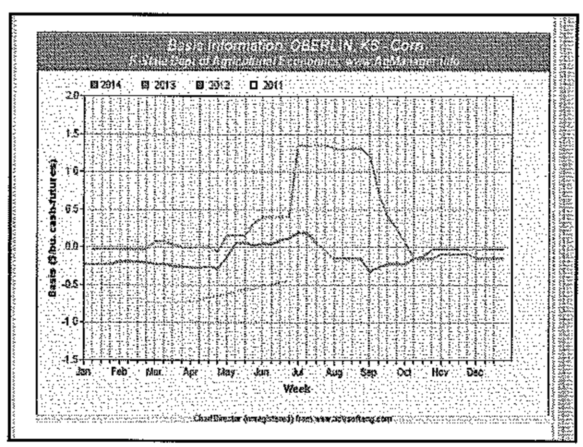

GRAIN MARKET OUTLOOK
COVER YOUR ACRES CONFERENCE
OBERLIN, KANSAS
JANUARY 21-22, 2014
Daniel O'Brien, Extension Ag Economist
KANSAS STATE
UNIVERSITY

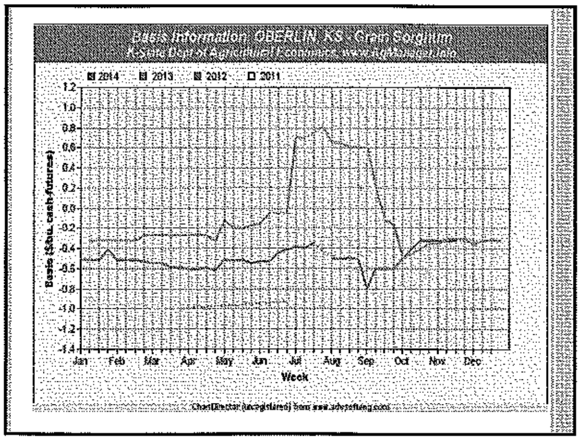

CORN MARKET


FEED GRAIN MARKET "DRIVERS"
"Tight" U.S. Corn & Sorghum Supplies in "old crop" 2012/13 ⇨ ↑ Prices ⇨ ↓ Use (rationing!)
Record 2013 U.S. Corn Crop ≈ 14 billion bu.
⇧ U.S. & World Coarse Grain Crops in "New Crop" 2013/14 marketing year
⇩ U.S. feedgrain prices expected for fall harvest thru winter ⇨ A "Storage-Carry" market


CORN FUTURES & CASH PRICES
OBERLIN AREA COOPS, CASH BIDS & CROP INSURANCE, JAN. 3, 2014
$ per Bushel
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$4.08
$3.91
$4.24
$4.32
$4.39
$4.45
$4.12
$4.52
$3.39
Jan 14
Feb 14
Mar 14
Apr 14
May 14
June 14
July 14
Aug 14
Sep 14
Oct 14
Nov 14
Dec 14
Futures $s
Corn Cash
Cash Milo
Corn-Ins 75%


CBOT CORN FUTURES
MONTHLY CONTINUOUS CHART: NOV. 2004 – DECEMBER 2013
12/31/2013 C=422^0 O=415^0 H=435^6 L=410^4
MARCH 2014
Close = $4.23 ½
January 3, 2014
812^4
750^0
687^4
625^0
562^4
500^0
437^4
375^0
312^4
250^0
$4.23
≈$4.17
$3.00
2005
2006
2007
2008
2009
2010
2011
2012
2013
Created with SuperCharts by Omega Research © 1997


Basis Information: OBERLIN, KS - Corn
2014
2013
2012
2011
Basis ($/bu. cash-futures)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Week



U.S. CORN SUPPLY-DEMAND

USDA WASDE REPORT: DECEMBER 10, 2013

	2011/12	2012/13	2013/14
Planted Ac. (mln.)	91.9	97.2	**95.3**
Harvested Ac (mln.)	84.0	87.4	**87.2**
Yield (bu./ac.)	147.2	123.4	**160.4**
Beginning Stocks	1,128	989	**824**
Imports	29	162	**30**
Production	12,360	10,780	**13,989**
Total Supplies	13,517	11,932	**14,842**
Ethanol	5,000	4,648	**4,950**
Other FSI	1,428	1,396	**1,450**
Exports	1,543	731	**1,450**
Feed & Residual	4,557	4,333	**5,200**
Total Use	12,528	11,108	**13,050**
End Stocks *(%S/U)*	*(7.9%)* 989	*(7.4%)* 824	*(13.7%)* 1,792
U.S. Avg. Farm $	*$6.22*	*$6.89*	*$4.05-$4.75*

KSU U.S. CORN S-D MY 2013/14 Dec. 2013

	Lower Yield 5% prob.	Likely Yield 90% prob.	Higher Yield 5% prob.
Planted Ac. (mln.)	95.3	95.3	95.3
Harvested Ac (mln.)	87.2	87.2	87.2
Yield (bu./ac.)****	156.7	**160.4**	**164.1**
Beginning Stocks	824	824	824
Imports	30	30	30
Production*****	13,667	13,989	14,310
Total Supplies	14,521	14,842	15,164
Ethanol	4,900	4,950	4,975
Other FSI	1,440	1,450	1,460
Exports	1,375	1,450	1,500
Feed & Residual	5,125	5,200	5,250
Total Use	12,840	13,050	13,185
End Stocks (%S/U)	*(13.1%)* 1,681	*(13.7%)* 1,792	*(15.1%)* 1,979
U.S. Avg. Farm $	*≈ $4.90*	*≈ $4.15*	*≈ $3.90*

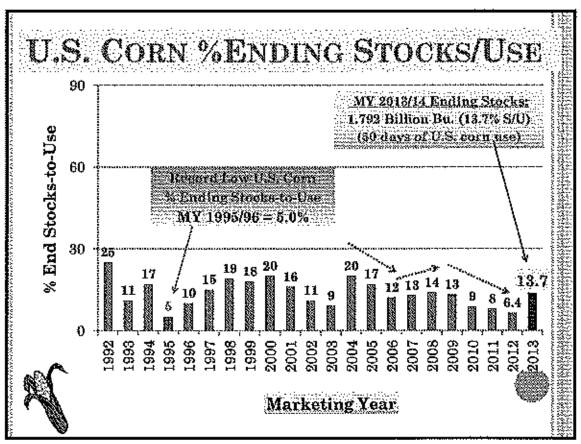
KSU-USDA U.S. CORN S-D MY 2013/14 Dec-13

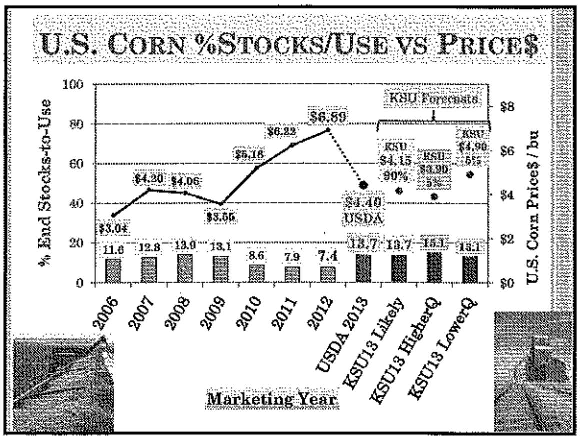
	USDA Dec 2013	Likely Yield 90% prob.	Higher Yield 5% prob.
Planted Ac. (mln.)	95.3	95.3	95.3
Harvested Ac (mln.)	87.2	87.2	87.2
Yield (bu./ac.)***	160.4	**160.4**	**164.1**
Beginning Stocks	824	824	824
Imports	25	30	30
Production***	13,989	13,989	14,310
Total Supplies	14,837	14,842	15,164
Ethanol	**4,950**	4,950	4,975
Other FSI	1,450	1,450	1,460
Exports	1,450	1,450	1,500
Feed & Residual	5,200	5,200	5,250
Total Use	13,050	13,050	13,185
End Stocks (%S/U)	*(13.7%)* 1,792	*(13.7%)* 1,792	*(15.1%)* 1,979
U.S. Avg. Farm $	*$4.40*	*≈ $4.15*	*≈ $3.90*

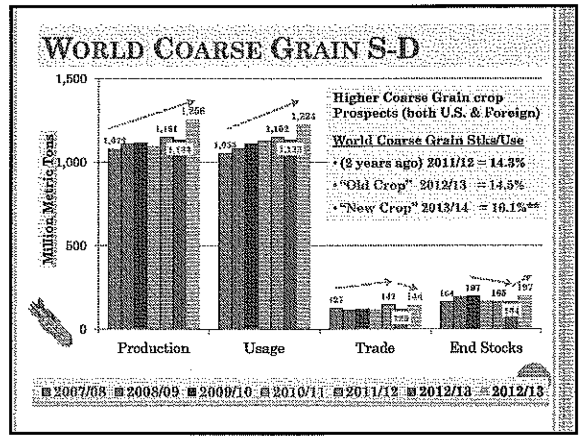
U.S. SORGHUM SUPPLY-DEMAND

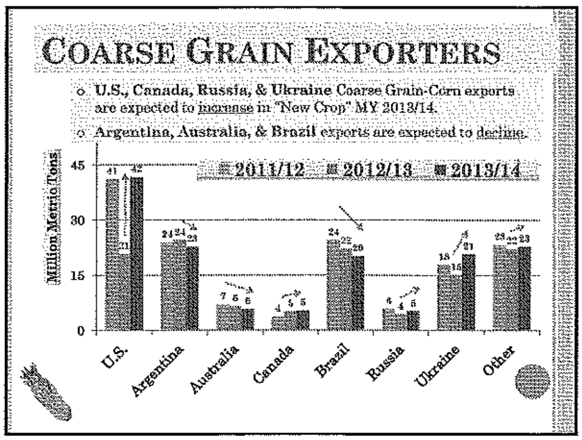
USDA WASDE REPORT: DECEMBER 10, 2013

	2011/12	2012/13	2013/14
Planted Ac. (mln.)	5.5	6.2	**8.1**
Harvested Ac (mln.)	3.9	5.0	**6.7**
Yield (bu./ac.)	54.6	49.8	**62.2**
Beginning Stocks	27	23	**15**
Imports	0	10	**0**
Production	214	247	**416**
Total Supplies	242	279	**431**
Food, Seed, Indust.	85	95	**120**
Exports	63	76	**180**
Feed & Residual	71	93	**100**
Total Use	219	264	**400**
End Stocks *(%S/U)*	*(10.5%)* 23	*(5.7%)* 15	*(7.8%)* 31
U.S. Avg. Farm $	*$5.99*	*$6.33*	*$3.75-$4.45*



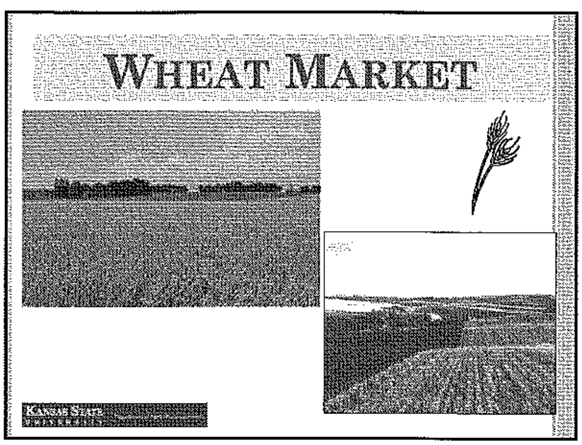






FEEDGRAIN MARKET PROSPECTS

- **Rationed "Old Crop" Use**
  - Tight basis ⇨ Spring-Summer 2013
- **2014 Acreage & Production??**
  - Corn vs Soybeans vs other crops
- **Winter-Spring Market Prospects?**
  - Likely to have a "Storage, Carry & Basis" market through Spring 2014
  - South American crop prospects in 2014 may affect US. Spring planting decisions ⇨ expecting *less* corn & *more* soybean production



WHEAT MARKET DRIVERS

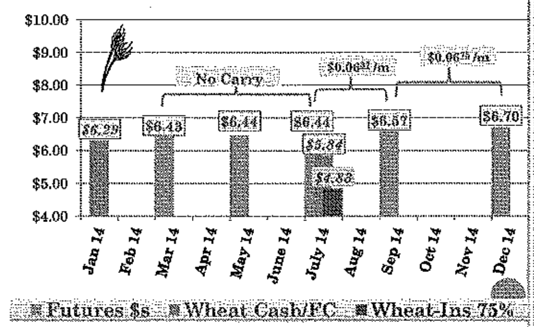
- **U.S. Wheat Market**
  - ⇩ HRW-Wheat production offset by ⇧ SRW-Wheat & "OK" 2013 HRS wheat production
  - Have had strong exports & wheat feeding through summer-early winter 2013, but may "fade" through May 2014
  - Wheat $'s "*stronger*" than other grains through late summer-fall, but have ⇩'d sharply over last few weeks!

WHEAT MARKET DRIVERS

- **World Wheat Market**
  - ***"Stronger"* crop prospects** for World's major **export competitors** (Canada, Black Sea, Argentina, Australia, European Union)
  - **Strong export competition** for U.S. wheat from export competitors in late winter-early spring 2014 ⇨ ***"U.S. priced out of market ?!?"***
  - **With** large 2013 World feedgrain crops, ⇩ **feed wheat use** ⇨ ***"Weaker $s @ margin"***

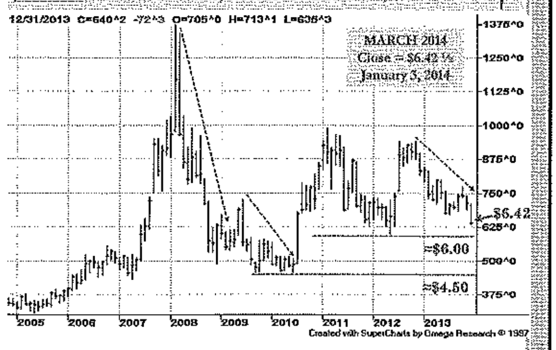
KC HRW WHEAT FUTURES & CASH$

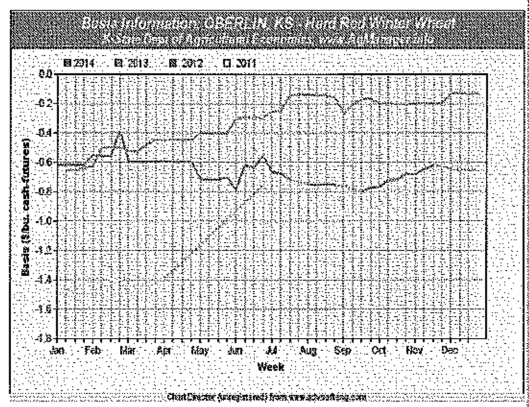
OBERLIN AREA COOPS, CASH BIDS & CROP INSURANCE, JAN. 3, 2014



KANSAS CITY WHEAT FUTURES

MONTHLY CONTINUOUS CHART, NOV. 2004 – DECEMBER, 2013



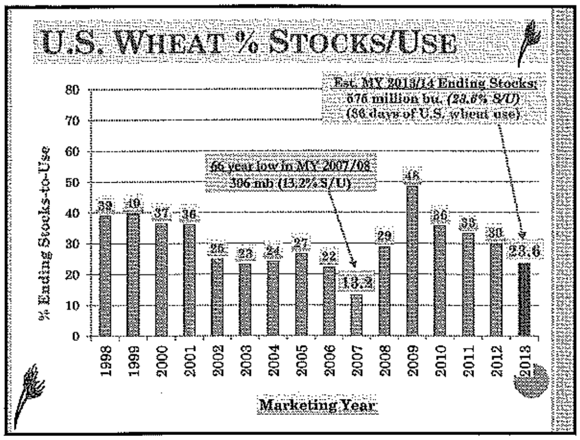


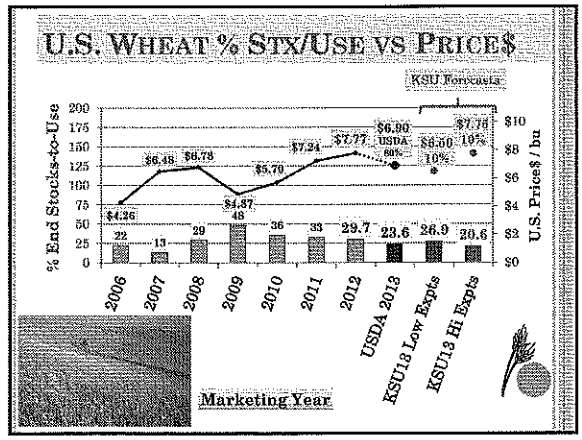
U.S. WHEAT SUPPLY-DEMAND (Dec. 10, 2013 WASDE)

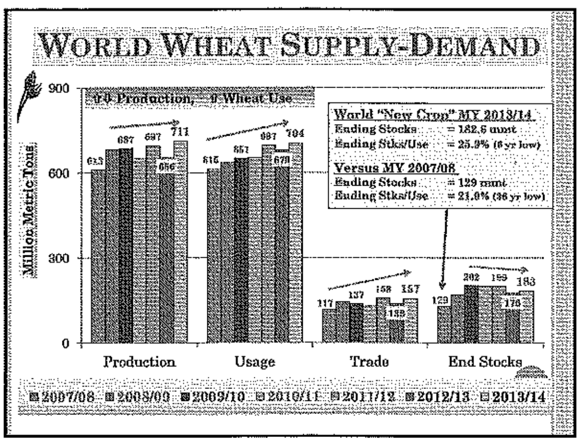
	2011/12	2012/13	2013/14
Planted Acres (mln.)	54.4	55.7	56.2
Harvested Ac. (mln.)	45.7	48.9	45.2
Yield (bu./ac.)	43.7	46.3	47.2
Beginning Stocks	862	743	718
Production	1,999	2,266	2,130
Imports	112	123	160
Total Supplies	2,974	3,131	3,008
Food & Seed	1,017	1,018	1,023
Exports	1,051	1,007	1,100
Feed & Residual	162	388	310
Total Use	2,231	2,414	2,433
End Stocks (%S/U)	(33.3%) 743	(29.7%) 718	(23.6%) 575
U.S. Ave. Farm $	$7.24	$7.77	$6.65-$7.15

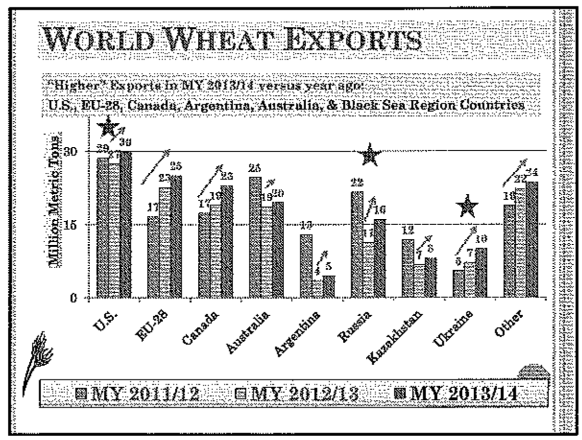
KSU-U.S. WHEAT S-D FOR MY 2013/14

	USDA-KSU 80% prob.	Low Exports 10% prob.	High Exports 10% prob.
Planted Ac. (mln.)	56.2	56.2	56.2
Harvested Ac (mln.)	45.2	45.2	45.2
Yield (bu./ac.)	47.2	47.1	47.1
Beginning Stocks	718	718	718
Production	2,130	2,130	2,128
Imports	160	160	160
Total Supplies	3,008	3,008	3,008
Food & Seed Use	1,023	1,023	1,023
Exports**(Wildcard!)	1,100	1,037	1,162
Feed & Residual	310	310	310
Total Use	2,433	2,370	2,495
End Stocks (%S/U)	(23.6%) 575	(26.9%) 637	(20.6%) 513
U.S. Avg. Farm $	$6.90	$6.50	$7.75



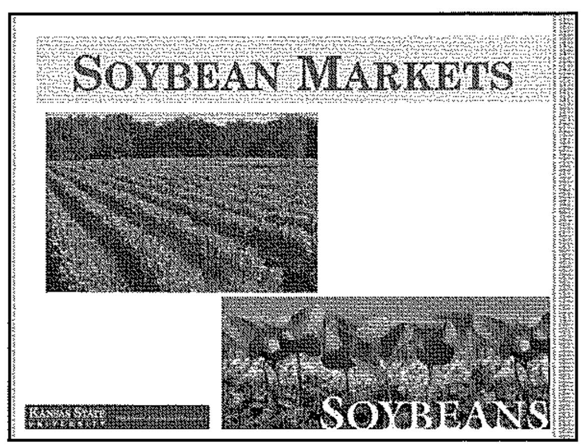






WHEAT MARKET PROSPECTS

- **U.S. Winter Wheat Acres in 2014?**
  - Wheat revenue & insurance coverage issues
  - ARE prospects for drought now *less* in U.S. Plains??
- **Risk to World Wheat Exporters' Crop Production in *late* 2013/14 – *early* 2014/15**
  - "Unanticipated" problems have a habit of happening in the United States, Australia, Argentina, EU, Black Sea Region, Canada, etc.
- **⇩ Feedgrain Cross-Market Effects**
  - With *record large* U.S. corn production in 2013 – is less support for wheat feeding

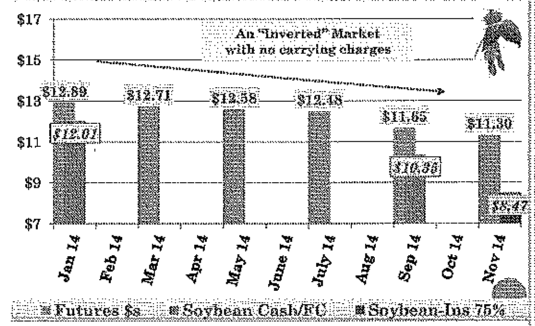


Soybean Market "Drivers"

- *"Tight"* U.S. Soybean Supply/Demand & *"Strong"* Chinese/World imports in "Old Crop" MY 2012/13
- **Large 2013 U.S. Soybean Crop: 3.258 bln bu**
  ⇨ *versus 2011 (3.09 bln bu) & 2012 (3.03 bln bu)*
- ⇧ **2014 U.S. & South American** soybean crops
- ⇩⇧ **Soybean $'s thru Winter-Spring 2014**
  depending on a) 2014 South American production, Chinese imports, & c) 2014 U.S. soybean acres

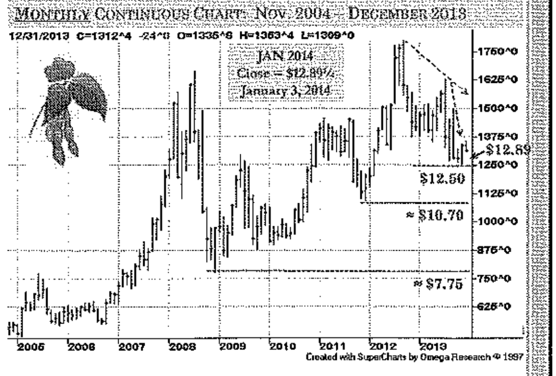
Soybean Futures & Cash$

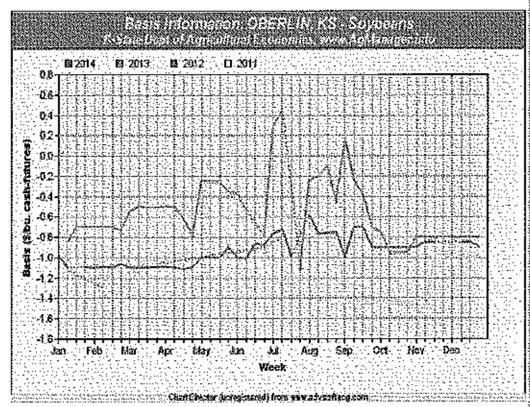
Oberlin Area Coops, Cash Bids & Crop Insurance, Jan. 3, 2014



CBOT Soybean Futures

Monthly Continuous Chart: Nov. 2004 – December 2013





U.S. Soybean Supply-Demand

USDA WASDE Report – December 10, 2013

	2011/12	2012/13	2013/14
Planted Acres (mln.)	75.0	77.2	76.5
Harvested Acres	73.8	76.2	75.7
Yield (bu./ac.)	41.9	39.8	43.0
Beginning Stocks	215	169	141
Imports	16	36	25
Production	3,094	3,034	3,258
Total Supplies	3,325	3,239	3,423
Crushings	1,703	1,689	1,690
Exports	1,365	1,320	1,475
Seed & Residual	88	90	109
Total Use	3,155	3,098	3,274
Ending Stocks	(5.4%) 169	(4.6%) 141	(4.6%) 150
U.S. Avg. Farm $	$12.50	$14.40	$11.50-$13.50

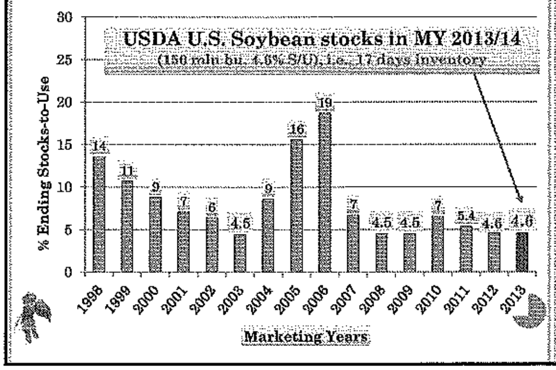
KSU: U.S. Soybean S/D: MY 2013/14

Dec. 10, 2013	Lower Yld-Q 10% prob.	Likely Yld-Q 80% prob.	Higher Yld-Q 10% prob.
Planted Acres (mln.)	76.5	76.5	76.5
Harvested Ac. (mln.)	75.7	75.7	75.7
Yield (bu./ac.)****	41.6	43.0	44.5
Beginning Stocks	141	141	141
Imports	25	25	25
Production****	3,147	3,258	3,369
Total Supplies	3,343	3,423	3,535
Crushings	1,660	1,690	1,730
Exports *Wildcard*	1,440	1,475	1,525
Seed & Residual	109	109	109
Total Use	3,209	3,274	3,364
Ending Stocks	(4.2%) 134	(4.6%) 150	(5.1%) 171
U.S. Avg. Farm $	$14.75	$13.50	$12.50

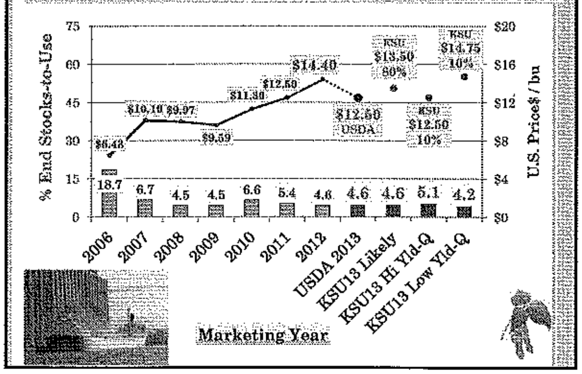
USDA & KSU: U.S. Soybean S/D - 2013/14

Dec 10, 2013	USDA Dec. 2013	Likely Yld-Q 80% prob.	Higher Yld-Q 10% prob.
Planted Acres (mln.)	76.5	76.5	76.5
Harvested Ac. (mln.)	75.7	75.7	75.7
Yield (bu./ac.)****	43.0	43.0	44.5
Beginning Stocks	141	141	141
Imports	25	25	25
Production**	3,258	3,258	3,369
Total Supplies	3,423	3,423	3,535
Crushings	1,690	1,690	1,730
Exports *Wildcard*	1,450	1,475	1,525
Seed & Residual	109	109	109
Total Use	3,274	3,274	3,364
Ending Stocks	*(4.6%)* 150	*(4.6%)* 150	*(5.1%)* 171
U.S. Avg. Farm $	$12.50	$13.50	$12.50

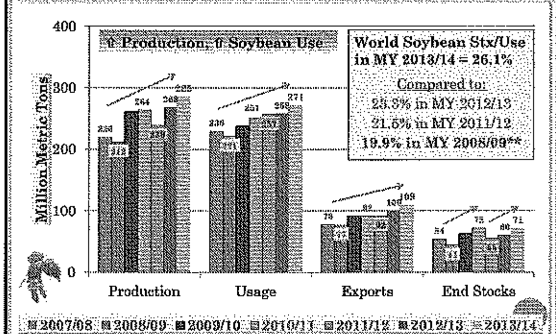
U.S. Soybean %End Stocks/Use



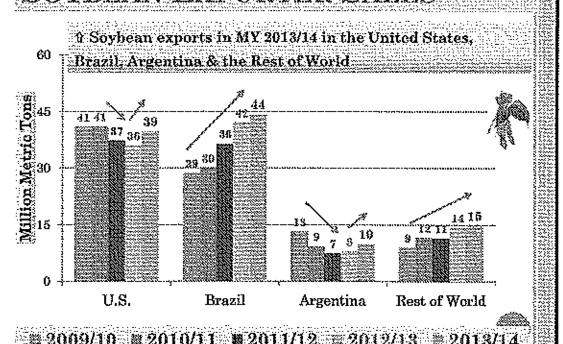
U.S. Soybean %Stx/Use vs Price$



World Soybean Supply-Demand



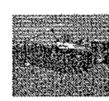
Soybean Exporter Sales



Soybean Market Prospects

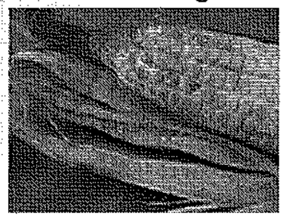
- **South America Exports**
  - Competing seasonally with U.S.
  - ⇩ U.S. exports in April-June 2014

- **U.S. Soybean Acres in 2014??**
  - 79-83 million acres planted next year?
  - IF Corn acres ⇩ – will lead to ⇧ U.S. soybean planted acres



- **Chinese Export Demand**
  - ***"Strong but narrow"*** base of World soybean export demand driven by China

Hot Topics in Corn Pest Management
Current Disease Management Issues



Doug Jardine
Extension Plant Pathologist

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Goss's wilt

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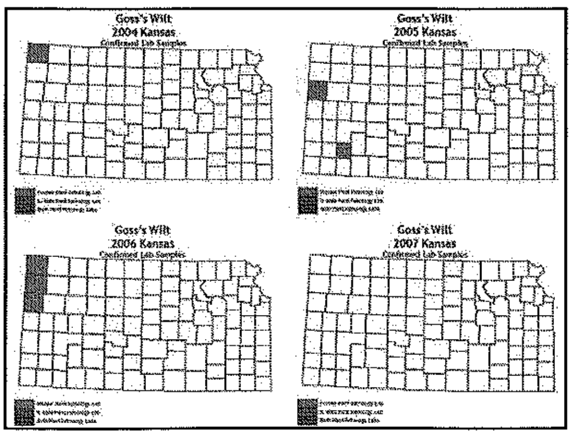

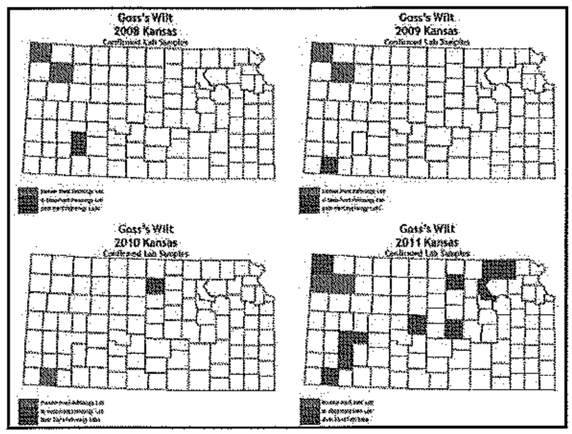

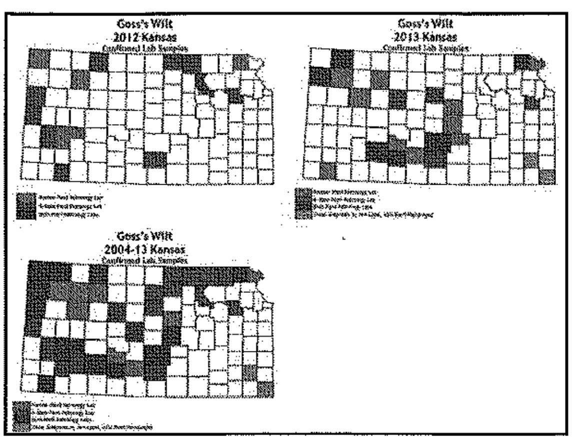

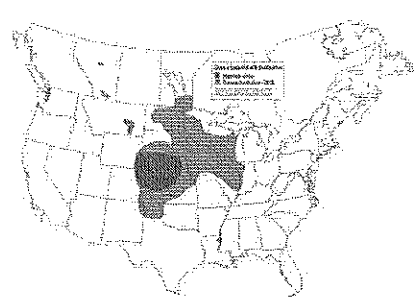

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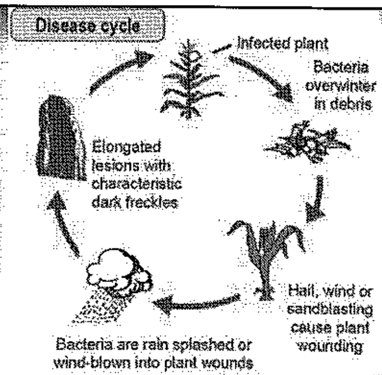

Courtesy of Dr. Tamra Jackson-Ziems, Univ. of Nebraska

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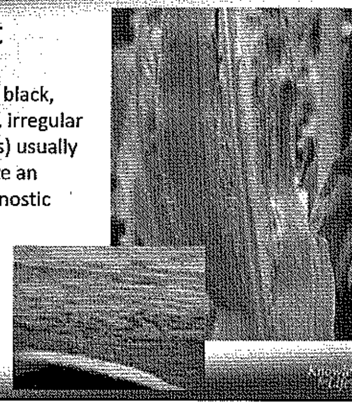
Goss's wilt

- Dark green to black, water-soaked, irregular spots (freckles) usually appear and are an excellent diagnostic symptom



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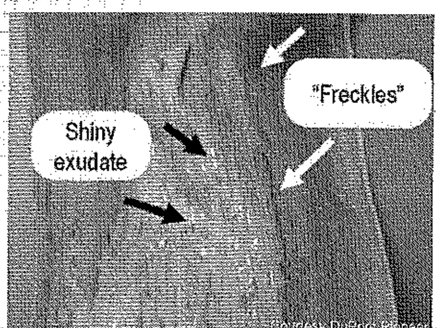
Goss's wilt



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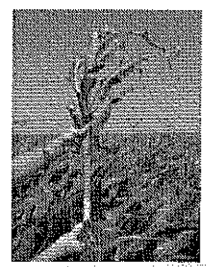
Early infections can lead to systemic symptoms



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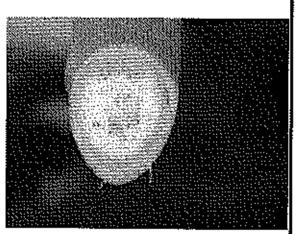
The amount of fields with systemic symptoms has increased the past two years

- Vascular bundles will be discolored
- This usually occurs when infection takes place early in the season (V5)



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Scorch

- Scald can look like Goss's wilt. It results from conditions of high heat (> 100 F), low soil moisture, and hot, dry winds
- Look for the freckles and/or bacterial exudate

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Goss's Wilt Management

- The best management program begins with the most tolerant hybrids
  - Companies are actively screening their germplasm and hybrids for resistance
  - So far, the best would be rated as moderately resistant

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Goss's Wilt Management

- Reduce corn residue
  - Crop rotation will have some effect
    - Less Goss's wilt is observed in corn planted into wheat residue than in corn planted into corn residue
  - While tillage is an option farther east, it would not be recommended in the western corn growing areas

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Goss's Wilt Management

- Control grassy weeds that may be alternate hosts
  - Green foxtail, barnyardgrass, shattercane and possibly others

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Goss's Wilt Management

- Fungicides are NOT EFFECTIVE against bacterial diseases so spraying is not currently an option

- Other bactericidal materials are currently being evaluated but so far they have not given consistent results

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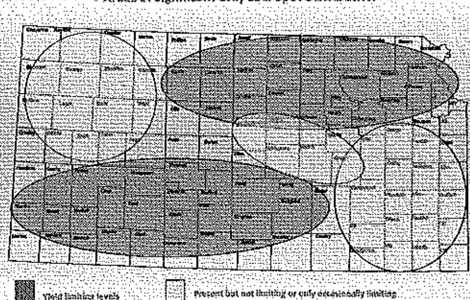
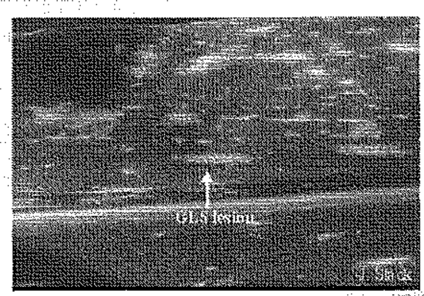
K-State Research and Extension

Areas of Significant Gray Leaf Spot Distribution



Knowledge for LIFE

Gray Leaf Spot



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"The plant health benefits may include improved host plant tolerance to yield-robbing environmental stresses, such as drought, heat, cold temperatures, and ozone damage. Headline can improve plant utilization of nitrogen and can increase tolerance to bacterial and viral infections."

Physiological effects of strobilurins

- Increases the activity of the nitrogen reductase enzyme (nitrate ⟹ nitrite)
  - This reportedly increases the efficiency of nitrogen usage

Physiological effects of strobilurins

- Inhibits the biosynthesis of ethylene
  - Ethylene is involved in flowering, fruit ripening and plant senescence
  - Ethylene production can be stimulated by stresses including flooding, heat or cold stress, lesion production by diseases, and drought
    - Decreasing ethylene can increase photosynthesis by prolonging the time tissue stays green

Physiological effects of strobilurins

- Increases the production of abcissic acid (ABA)
  - May decreases transpiration losses
- Acts as an antioxidant (ties up free radicals)
  - May be the basis for the claim of ozone damage reduction

Physiological effects of strobilurins

- Possibly turns on the plants own natural defense mechanisms (systemic acquired resistance)
  - This is the basis for the claims of an effect on bacterial and virus diseases

So, do these physiological benefits result in economic yield increase in the absence of disease?

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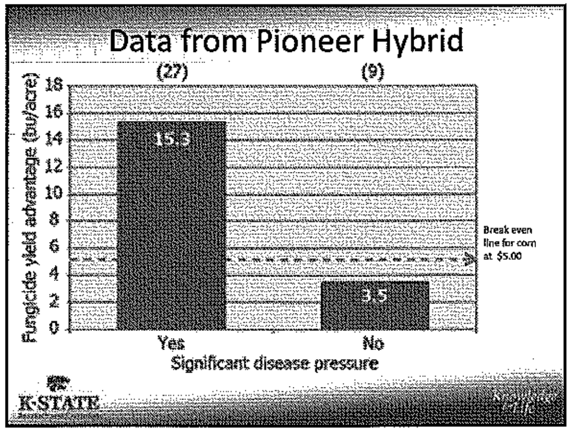

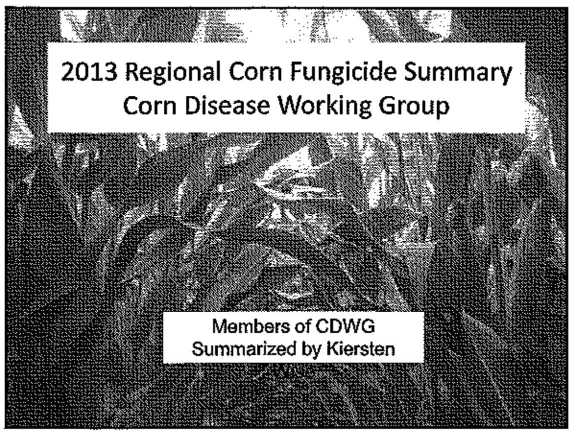

State/Province	Submitter	# of comparisons	Application timings
Arkansas	Travis Faske	14	R1
Illinois	Carl Bradley	72	VT/R1
Indiana	Kiersten Wise	45	V5, VT/R1, V5 + VT
Kansas	Doug Jardine	34	V5 through VT + 14
Kentucky	Paul Vincelli	12	V6 through VT
Louisiana	Clayton Hollier	7	VT
Michigan	Martin Chilvers	18	V5, VT/R1, V5 + VT
Nebraska	Tamra Jackson-Ziems	8	VT/R1
North Dakota	Mike Ostlie	54	In-furrow to VT
Ohio	Pierce Paul	39	V4/V5 through R1, V6 + VT
Ontario	Albert Tenuta	62	V5/V6, R1, V5 + VT
Tennessee	Heather Young-Kelly	54	V6, through VT/R1, V6 + VT
Wisconsin	Damon Smith	23	V6, V8, VT/R1
Total		442	

2013 data

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Break-even scenarios for corn

Corn price ($/bu)	Application cost ($/A)						
	$12	$16	$20	$24	$28	$32	$36
$3.00	4.0	5.3	6.7	8.0	9.3	10.7	12.0
$4.00	3.0	4.0	5.0	6.0	7.0	8.0	9.0
$5.00	2.4	3.2	4.0	4.8	5.6	6.4	7.2
$6.00	2.0	2.7	3.3	4.0	4.7	5.3	6.0
$7.00	1.8	2.3	2.9	3.4	4.0	4.6	5.1
$8.00	1.5	2.0	2.5	3.0	3.5	4.0	4.5
$9.00	1.3	1.8	2.2	2.7	3.1	3.6	4.0
$10.00	1.2	1.6	2.0	2.4	2.8	3.2	3.6

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Mean yield response compared to non-treated control in bu/A over time

	2010 N = 160	2011 N = 57	2012 N = 343	2013 N = 425
V5	3.4	2.1	-1.1	0.1
VT-R2	4.5	0.4	4.9	4.4
V5 + VT/R1	7.4	4.5	3.0	3.7

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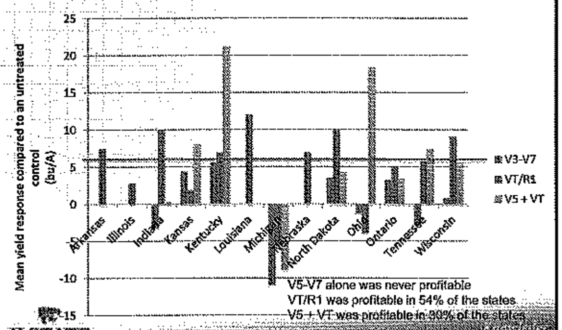
Effect of fungicide applications on yield by location 2013



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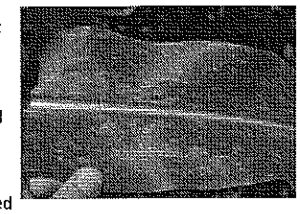
What about influence of final disease levels?

- Compared VT/R1 observations of states that submitted rating data
  - Across all fungicides
- Less than 5% disease rated on non-treated control:
  +4.28 bu/A
- More than 5% disease rated on non-treated control:
  +6.15 bu/A



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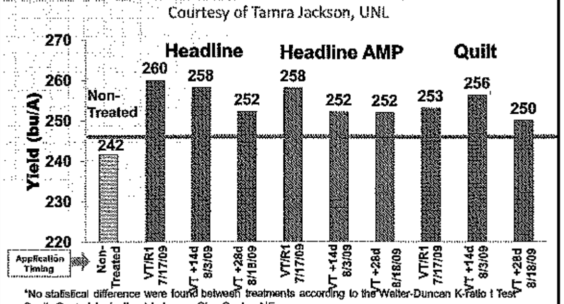
2009 Fungicide Timing Trial in NE

DKC 60-18 (GLS rating = 7/fair - poor)
Courtesy of Tamra Jackson, UNL



*No statistical difference were found between treatments according to the Walter-Duncan K-ratio t Test South Central Agricultural Lab near Clay Center, NE

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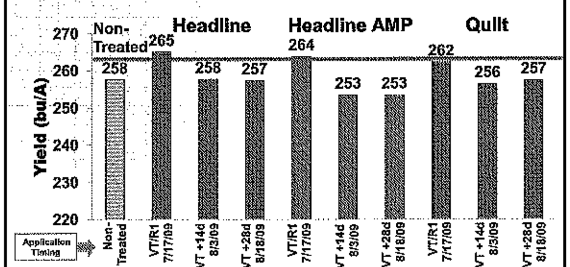
2009 Fungicide Timing Trial in NE

DKC 62-54 (GLS rating = 4/very good)
Courtesy of Tamra Jackson, UNL



*No statistical difference were found between treatments according to the Walter-Duncan K-ratio t Test. South Central Agricultural Lab near Clay Center, NE

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Fungicide Application Recommendations

- Scout just prior to tassel emergence
- Consider spraying when:
  - **Susceptible hybrids**
    - Disease symptoms are present on the third leaf below the ear or higher on 50% of the plants
  - **Intermediate hybrids**
    - Disease symptoms are present on the third leaf below the ear or higher on 50% of the plants **AND** there is surface residue present from a previous corn crop
  - **Resistant hybrids**
    - Fungicide applications are generally not recommended

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Twitter: Doug1954@KSU_CropDoc

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Current Insect Pest Management Issues in Corn

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This presentation covers a review of common insect pests of corn and an emerging issue involving western corn rootworm control in corn. A brief summary is below.

Western bean cutworms

- Occasional problem in western Kansas. Begin field scouting at the first sign of tasseling and continue until silks turn brown. Look for round, white eggs in groups of 5 to 200 on the upper surface of upper leaves. Eggs gradually become darker in color, hatching in five to seven days. An average of eight plants with eggs or small larvae per 100 plants (when corn is 95 percent tasseled) is required to justify control measures. Control will be reduced if applications are delayed until all silks have emerged or if larvae have entered the ear tips. Typically, scouting should be concentrated between July 18 and 30 in southwest Kansas and about a week later in northwest Kansas. Some of the new Bt corn hybrids have some resistance to the western bean cutworm so take this into account when selecting hybrid seed.

Corn earworm

- Infestations can occur from June until frost. Insecticidal control is usually considered impractical in field corn. Current Bt corn hybrids provide some suppression of corn earworm feeding

Southwestern corn borer & European corn borer

- Larvae feed in corn stalks and can cause significant yield losses. Bt corn hybrids that are resistant to corn borer feeding are currently the primary means of preventing damage by this pest.

Western corn rootworm

- Corn rootworm larvae may be a pest where corn is planted continuously for three or more years. Corn rootworm beetles lay most of their eggs in corn fields from late summer through early fall. If corn is planted in the same fields the following spring some type of management often will be needed to avoid serious root injury. Planting time options for control ling corn rootworm larvae include planting resistant corn hybrids and applying soil insecticides at planting.

Corn rootworm issues

- The adoption of Integrated Pest Management (IPM) in the United States was facilitated by a common goal of reducing pesticide exposure to the environment and humans by using an integrated approach to control pests. This combined approach uses knowledge of the biology of the pest as well as knowledge of all control methods to create a plan that is both economically sound and minimizes the hazardous substance exposure to the environment.
- Insect Resistance Management (IRM) plans are used to maintain insects susceptible to management tactics and to further the longevity of the management tactic for future use. Hybrid corn incorporating genes from *Bacillus thuringiensis* (Bt) were introduced to control target pests and have been widely accepted because they were highly effective, brought value to the grower, reduced the need for pesticides, and limited harm to non-target species and the environment. The U.S. Environmental Protection Agency (EPA) requires IRM plans with each Bt hybrid registered for commercial sale and this involves planting a certain percentage of the Bt field or nearby fields with refuge or non-Bt plants. The theory behind the refuge use is based on a high-dose refuge strategy where resistance alleles are assumed to be recessive, and the rare resistant insect that survives the Bt will mate with those more abundant susceptible insects from the refuge to create susceptible offspring and thereby inhibit the evolution of resistance.
- In high dose Bt corn, such as those that target European corn borer, the mortality rate is nearly 100%, therefore survivors from the Bt crop are extremely rare. The rootworm-targeted Bt hybrids currently on the market are all low to moderate dose, **so some WCR**

larvae are expected to survive. Populations of rootworms resistant to Bt have been fairly established in laboratory experiments within just a few generations and resistance has been documented in fields in several states across the corn belt including Iowa, Illinois, Minnesota, Nebraska, and South Dakota. Field failures in Colorado and Kansas have been documented for several years in some areas however resistance has not been confirmed for sure.

- The occurrence of WCR resistance to Bt has been attributed, in part, to possible refuge compliance issues and the repetitive use of the same management tactics.
- Using an integrated approach to control the WCR is essential to slow the evolution of resistance to Bt corn

"kitchen sink" approach

- Soil insecticides are being used at a greater rate in conjunction with Bt, due to the Cry3Bb1 resistance problem. Prophylactic use of soil insecticides is occurring where rootworm infestations may not be high enough to warrant the application of insecticides. Insecticides are being applied on top of pyramided Bt hybrids in areas where rootworm pressure may be high, however the Bt proteins alone should be enough to reduce rootworm populations to acceptable levels.
- IS rootworm thresholds being met before control tactics are applied?
- What rootworm pressure is actually present in a field?
- A major benefit of the adoption of Bt is the reduced use of insecticides, but with soil and foliar insecticides being used in conjunction with Bt, these benefits essentially disappear. The goal of IPM is to use management options in an integrated manner, not all at the same time as what some are calling the "kitchen sink" approach.

K-STATE RESEARCH & EXTENSION

Cover Your Acres-2014

January 21-22, 2014

Pushing Wheat Yields to the Next Level

Does pushing wheat yields to the next level mean it's going to cost you more money?

The gentleman asked-

"why are we growing wheat?"
"You have to put all that extra stuff on it to make it yield"
"I grow wheat so I can plant no-till corn into it."

Let me ask you- How much does it cost you per acre to grow wheat?

What is your yield goal?

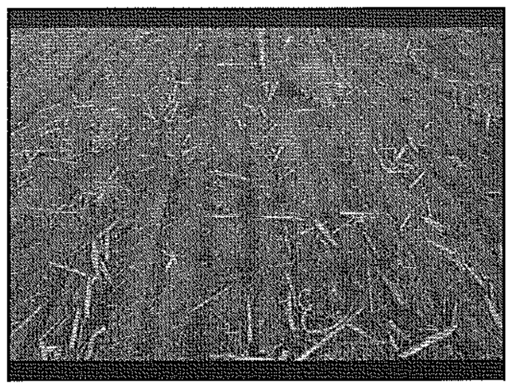
Kansas Wheat Yield Contest

2013	70 bu	SY Wolf
2012	85 bu	Snowmass
2011	61 bu	Winterhawk
2010	90 bu	PostRock

Thomas County Wheat Performance Test Yields-bu/a

2007	2008	2009	2010	2011	2012	2013
76	61	81	73	40	61	40

You Can't Control the Weather



What are the production practices that you CAN manage?

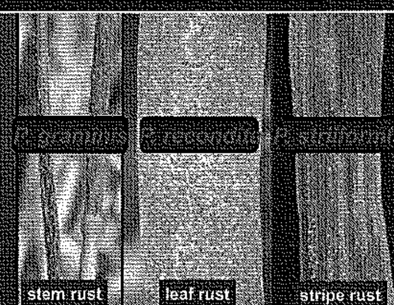
You Can Manage . . .

- Variety
- Pests
- Seeding Date & Rate
- Seeding Depth
- Fertility
- Tillage
- Rotations

The Pre-Plant Decision: Western KS Varieties

	Name	Leaf Rust	Stripe Rust	Septoria Leaf Blotch	Tan Spot	Powdery Mildew	Summary Index
Less likely to need a fungicide	Sy-Wolf	1	5	3	3	5	17
	WB-Cedar	5	3	4	5	2	19
	T-153	7	1	6	6	2	22
	T-154	7	3	5	5	2	22
	TAM 304	2	6	5	7	3	23
	T-158	7	2	7	5	3	24
	Armour	5	7	6	5	2	25
	Everest	3	8	5	7	3	26
More likely to need a fungicide	WB-Redhawk	2	6	5	6	7	26
	1863	7	3	6	5	6	27
	TAM 112	7	8	5	6	1	27
	Fuller	6	7	6	6	6	31
	Winterhawk	7	6	7	6	6	32
	TAM 111	8	8	6	6	6	34
	PostRock	7	7	8	5	8	35
	Jagalene	9	9	4	7	9	38

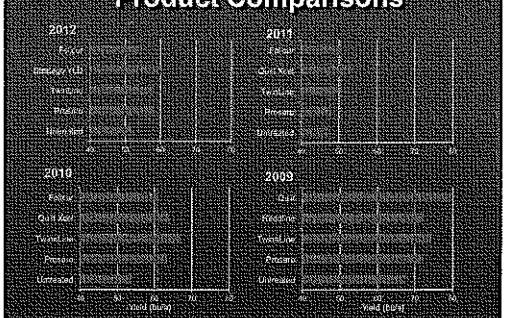
Three Rusts of Wheat



Fungicide Timing

- Single fungicide applications are most effective when applied between flag leaf emergence and flowering
  - Target: disease control on last two leaves

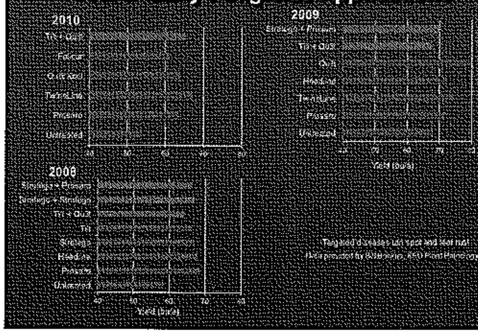
Product Comparisons



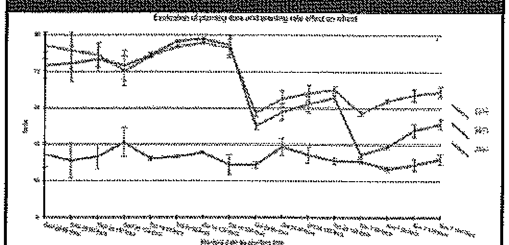
What do you think of early fungicide applications?

- Early applications generally result in only a small yield increase
- Most reasonable when combined with second application at boot or heading
- Most of the yield response comes from 2nd application

Tests of Early Fungicide Applications



Wheat Planting Dates and Rates Colby 2009-11



Effect of Planting Date on Fall and Spring Tiller Numbers

Plant date	Fall Max	Fall Prod	Spring Max	Spring Prod	Spikes #/yd^2
Sept 28	1266	281	584	195	476
Oct 11	916	360	659	192	552
Oct 28	183	152	600	272	424
Nov 13	147	117	213	144	260

Thiry et al., 2002

Effect of Planting Date on Fall and Spring Tiller Numbers

Plant date	Spikes #/yd^2	Yield Bu/a	TKW gm
Sept 28	476	39	24.2
Oct 11	552	58	29.3
Oct 28	424	55	29.1
Nov 13	260	30	27.7

Thiry, et al., 2002

How many tillers or heads do we need?

If you want 500 heads/sq yd

A 60 lb/a seeding rate @ 15,000 seeds/lb and 85% emergence you need 56 stems per sq ft (18 main culms and 38 are tillers) or 2.16 tillers per seed

Or

A 90 lb/a seeding rate @ 15,000 seeds/lb and 85% emergence you need 56 stems (26 main culms and 29 are tillers) or 1.1 tillers per seed

If you want 600 heads/sq yd

A 60 lb/a seeding rate @ 15,000 seeds/lb and 85% emergence you need 67 stems per sq ft (18 are main culms and 49 are tillers) or 2.79 tillers per seed

Or

A 90 lb/a seeding rate @ 15,000 seeds/lb and 85% emergence you need 67 stems per sq ft (27 are main culms and 40 are tillers or 1.5 tillers per seed

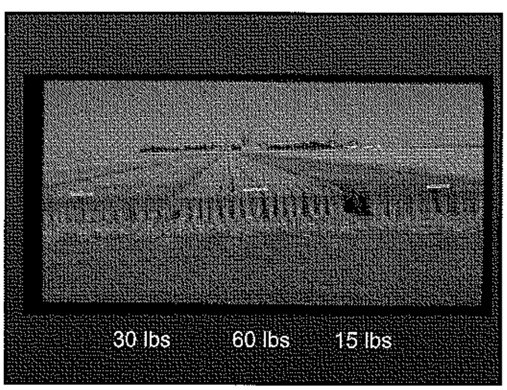
Some Wheat Truths

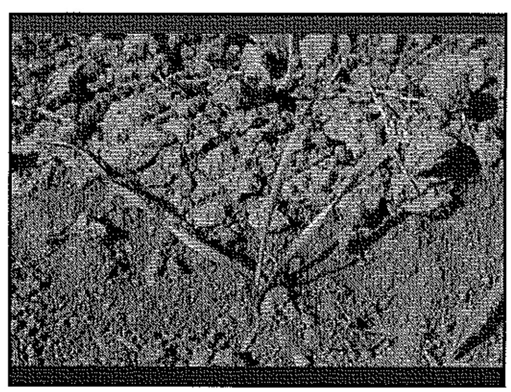
Main stems yield more than tillers

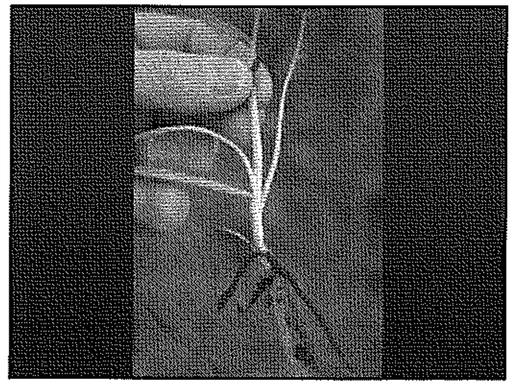
Fall tillers yield more than spring tillers

Some have suggested to raise the seeding rates so there are more main culms or stems compared to tillers

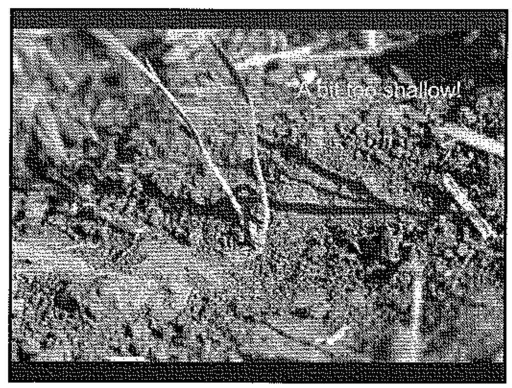
That's good logic, but . . .

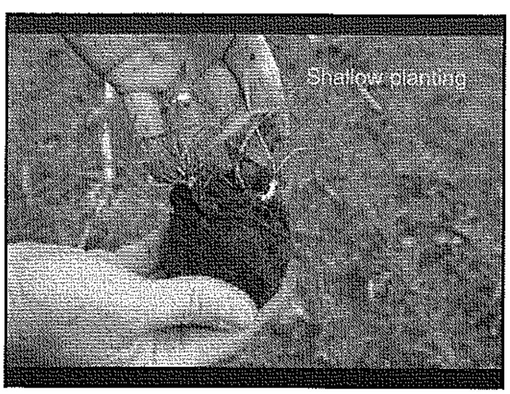






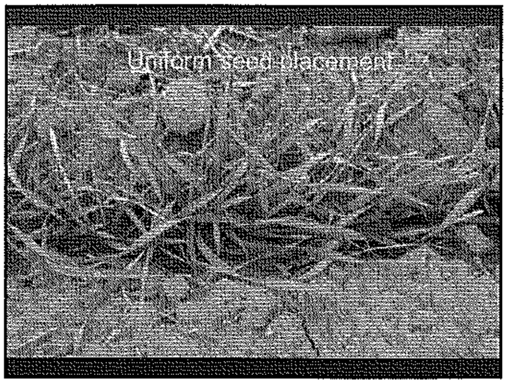
Seeding depth and seed quality



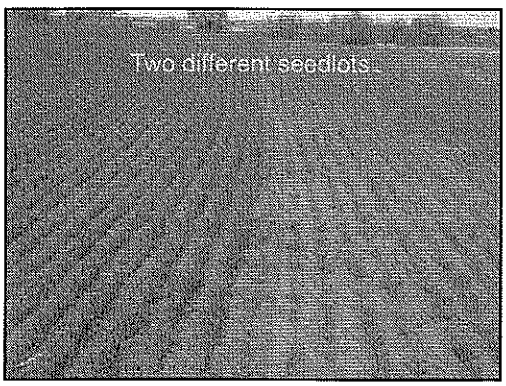


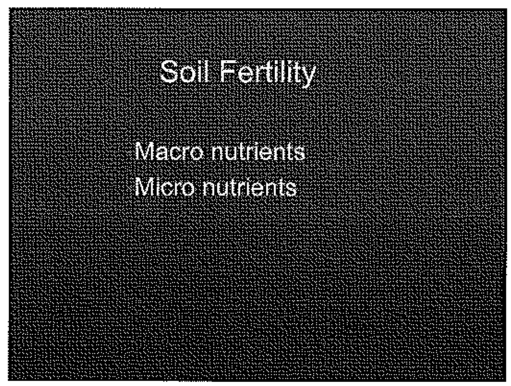
Seeding depth affects . . .

Tillering
Winter damage

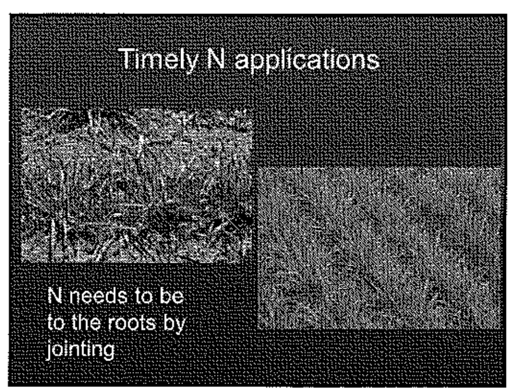

Uniform seed placement

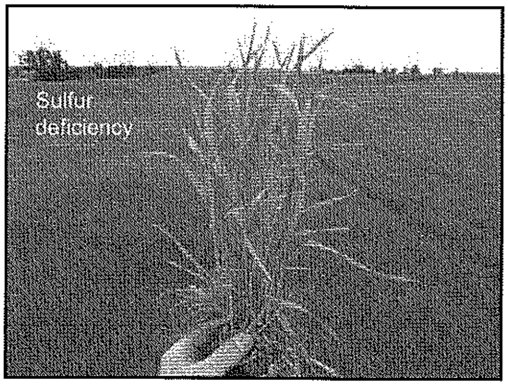

Avoid Skips

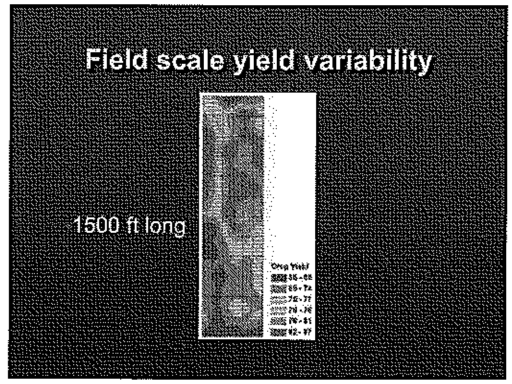

Two different seedlots

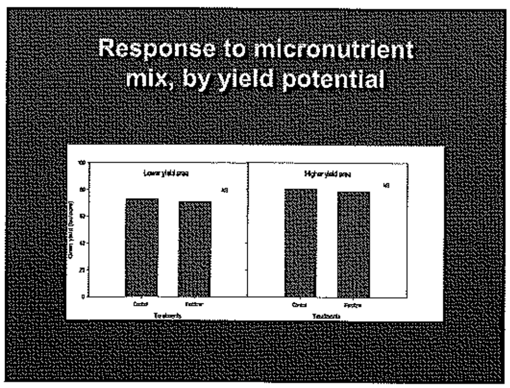

Soil Fertility
Macro nutrients
Micro nutrients

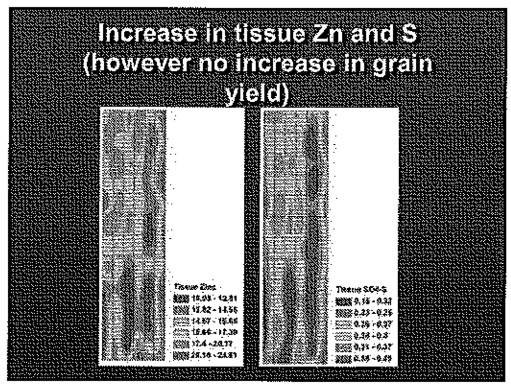

Soil Test


Timely N applications
N needs to be to the roots by jointing









Average grain yield (bu/acre)

Treatment	All Locations	w/o Ashland	Ashland
Mix	82	87	64
Mn	80	86	61
Zn	77	84	60
S	76	86	57
Cu	76	82	56
Fe	76	84	51
B	75	82	49
Control	75	84	48

The Bottom Line is . . .

- You don't necessarily have to spend more to push the yield limits
- You do have to manage what you can control

Improving efficiency of crop production with no-till in a semi-arid climate

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No-till has dramatically improved land productivity in central South Dakota. One no-till producer, Ralph Holzworth, Gettysburg SD, recently summarized his yield levels (*see Leading Edge 2010, volume 8, issue 3, page 548*). For the past 6 years, his corn yields have averaged 150 bu/ac. We were surprised with this yield level, as corn yields in eastern South Dakota (Brookings County) averaged 140 bu/ac during this same time interval. One reason for our surprise is that yearly precipitation in Gettysburg is 5 inches less than in Brookings County (Table 1). Secondly, Ralph plants corn at 22,000 plants/ac, contrasting with a common density of 32,000 plants/ac in Brookings County. Corn fields in Gettysburg produce 7% more grain with 5 inches less water and 10,000 fewer plants/ac. An individual corn plant in Ralph's fields produces 45% more grain than a corn plant in Brookings County.

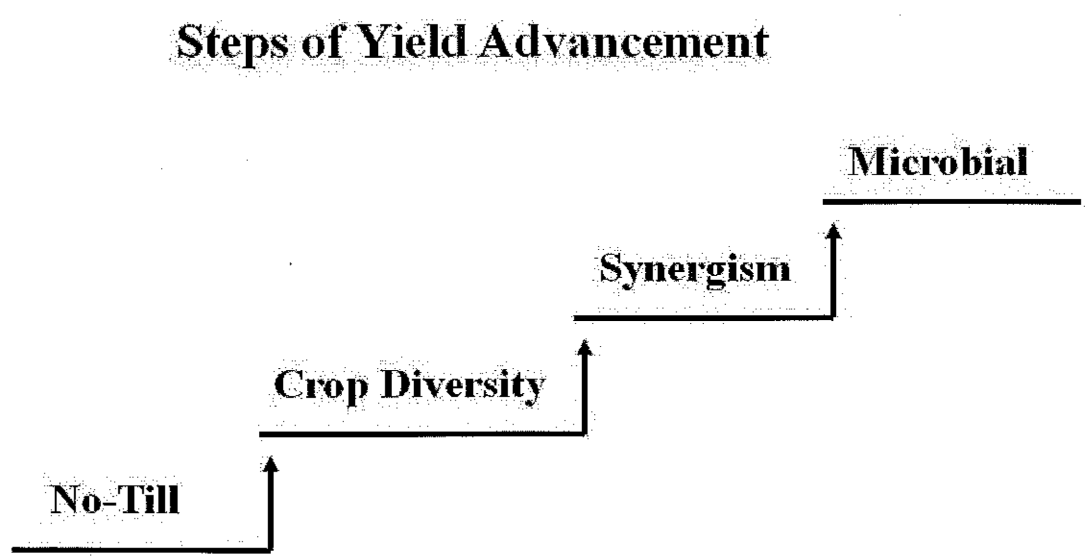
We discussed possible reasons for these seemingly anomalous yields with Ralph. Previous to adopting no-till, Ralph followed a winter wheat-corn-fallow rotation where corn yielded near 70 bu/ac. He noticed an immediate jump in corn yield when he started no-till practices 20 years ago, because no-till and residue preservation on the soil surface increase water supply for crop growth. A second gain in corn yield occurred when Ralph diversified his rotations to reduce plant diseases. His rotations now include four to six crops; one typical rotation is winter wheat-corn-dry pea-corn-soybean-oat (Table 1). In contrast, producers in Brookings County grow only corn and soybean in a tillage-based system.

Table 1. *Yield of corn at Ralph Holzworth's farm compared with corn production in Brookings County, eastern South Dakota. Abbreviations are W, winter wheat; C, corn; P, dry pea; SB soybean; and O, oat. Source: NASS 2012.*

	Holzworth	Brookings County
Corn Yield (bu/ac)	150	140
Precipitation (inches)	18	23
Corn Population (plants/ac)	22,000	32,000
Management		
Tillage	No-Till (20+ years)	Chisel Plow, Disking
Rotation	W-C-P-C-SB-O	C-SB

However, we speculate that additional factors may be involved in these yield gains. For example, growing dry pea in front of corn caused another jump in yield. Furthermore, corn yields are higher than expected based on nutrient and water supply. We suggest that these further gains in crop yield involve synergism among crops and changes with the soil microbial community. We viewed improved corn yields in no-till systems resulting from steps of yield advancement across time (Figure 1), where no-till and crop diversity lead to further biological benefits. Our reasoning for this perspective is based on recent research with soil biology in no-till cropping systems.

Figure 1. *Steps in yield advancement in no-till cropping systems as observed by producers and scientists in the Great Plains.*



No-till: preserving crop residue on the soil surface

Crop yield increased rapidly during the initial phases of no-till systems because more water is available for crop growth. Crop residue cover on the soil surface increases the efficiency of precipitation storage in the soil; in some cases, the quantity of precipitation stored can be almost doubled (Peterson et al. 1996).

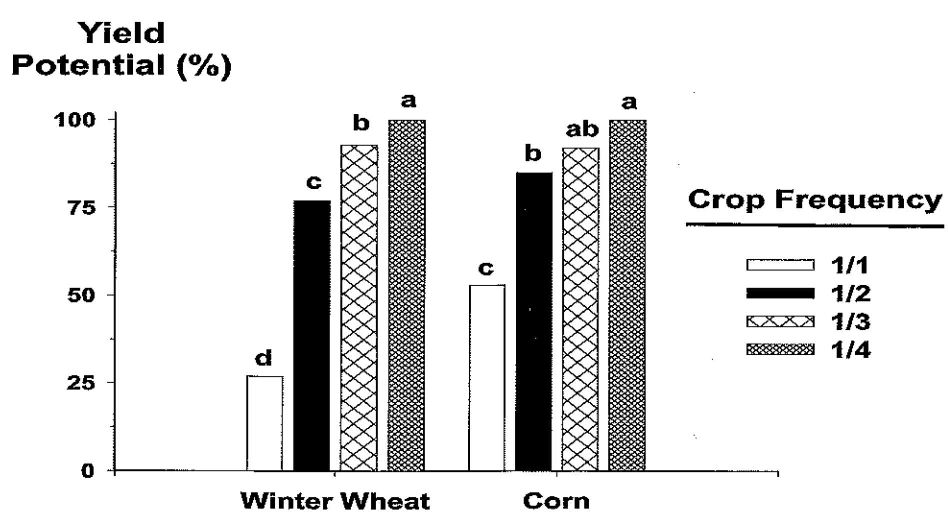
A further benefit of no-till and maintaining crop residue on the soil surface is improved soil porosity; precipitation infiltrates soil of no-till systems more readily than tilled soils (Shaver et al. 2002). One long-term study found that infiltration at a no-till (17 years) site with continuous cropping was 3-fold higher than a tilled, wheat-fallow rotation (Liebig et al.

2004). This gain in soil porosity is related to two factors. First, higher levels of organic matter develop in the top 5 cm of soil with no-till; organic matter levels have increased 35 to 50% after 15 years of no-till and continuous cropping (Liebig et al. 2004). Second, no-till favors the fungi community in soil, such as mycorrhizae and basidiomycetes (Carter 2002). Fungi interact with OM to build soil aggregates and increase porosity (Rillig 2004). Shaver et al. (2002) found that a direct relationship exists between crop residue quantity on the soil surface and improved soil porosity.

Crop diversity: increasing yield with the rotation effect

When producers first started no-till, they used their conventional rotations of one or two crops. Crop yield was often reduced because of plant diseases (Seymour et al. 2012). Adding alternative crops to the rotation reduced the frequency a crop is grown and the antecedent plant diseases, thereby increasing crop yield. For example, winter wheat yields 70% more when grown once every four years compared to continuous wheat (Figure 2). Similarly, grain yield of corn is 43% higher when corn is grown once every four years compared to monoculture corn. Corn residue is toxic to corn seedlings grown the following year; suppressed seedling growth leads to lower yields.

Figure 2. *Response of winter wheat or corn to frequency of cropping in rotations. Yield expressed as a percentage of the highest yield within a crop. Bars within a crop with an identical letter are not significantly different at the 5% level of probability. Crop frequency is defined as how often a crop is grown in sequence: 1/1 means the crop is grown every year, whereas 1/4 means the crop is grown once every four years. Source: Anderson 2008.*

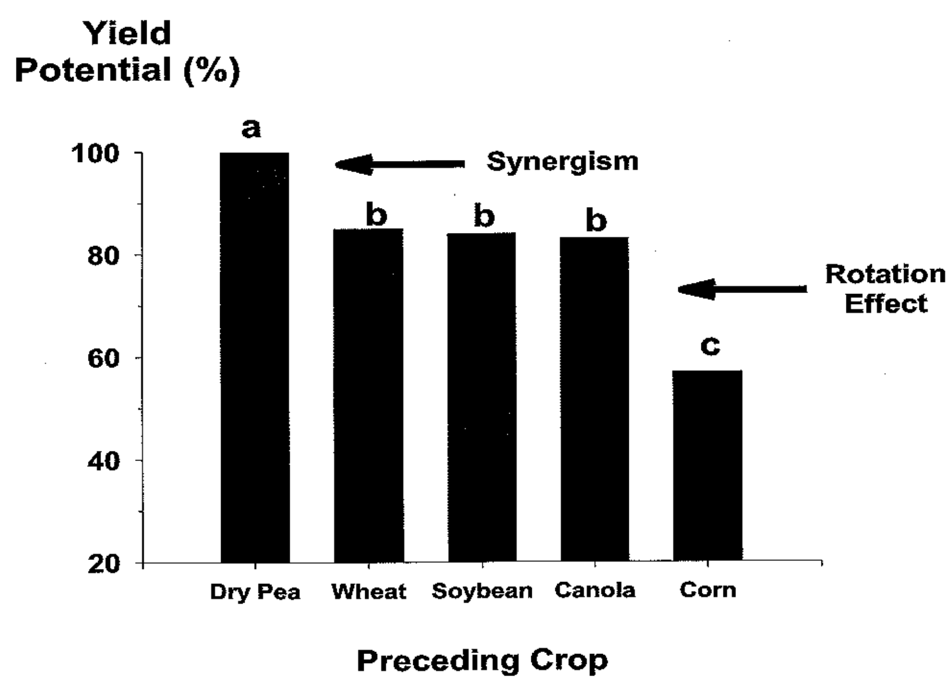


Crop plants are healthier when the crop is not grown so frequently in the rotation. Healthy plants are more effective in using resources such as water to produce grain (Angus and van Herwaarden 2001).

Synergism: improving crop efficiency in using resources

Yield gains due to crop diversity (*rotation effect*) and improved water relations with no-till were expected by producers. However, a surprising gain in corn yield occurred when dry pea was grown before corn in the rotation. To understand this unexpected trend, we compared five preceding crops for impact on corn yield (Anderson 2011). Corn yield was reduced 43% following itself due to root diseases and mycotoxins (Figure 3). Growing any crop other than corn, such as spring wheat, soybean, canola, or dry pea, increased corn yield by eliminating the negative effect of growing corn on corn, *i.e.* the rotation effect. But, corn yielded 12 to 15% more following dry pea than wheat, soybean, or canola. Fertility levels and water supply for corn did not differ among preceding crops; dry pea provided an additional benefit beyond the rotation effect by improving corn response to the same resource supply. We refer to this trend as synergism.

***Figure 3**. Impact of preceding crop on corn yield potential. Yield expressed as a percentage of the highest yielding treatment. Study was conducted with no-till practices in Brookings County, South Dakota. Data collected across 4 years; bars with an identical letter are not significantly different at the 5% level of probability. Source: Anderson 2011.*

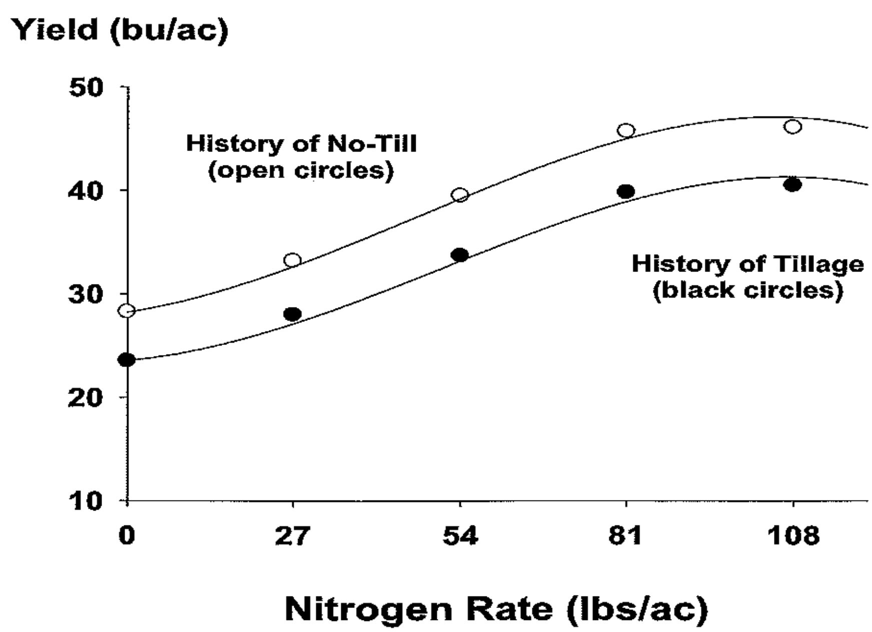


A further benefit of dry pea synergism to corn is that corn yields more at lower plant densities (Anderson 2011). Corn yielded the same at 21,000 plants/ac following dry pea as at 30,000 plants/ac following soybean or spring wheat; individual corn plants were more productive following dry pea than the other crops. In some way, dry pea improves growth efficiency of corn, as this yield gain could not be attributed to increased plant size or greater nutrient use.

Dry pea also improves growth efficiency of winter wheat. Compared with several other crops, winter wheat is 10 to 25% more efficient in using water following dry pea (Anderson 2011; Seymour et al. 2012).

Resource-use-efficiency by crops also improves with changes in soils due to no-till. Lafond et al. (2011) found that spring wheat used N more efficiently in no-till soil compared with tilled soil. Comparing two sites with different tillage history (23 years of no-till versus tilled cropping), spring wheat produced approximately 15% more yield at the same fertilizer rate in no-till (Figure 4). Adding more N fertilizer to the tilled site did not compensate for this yield benefit with no-till. Spring wheat uses N more efficiently because of improved soil health and functioning.

Figure 4. *Spring wheat yield as affected by N fertilizer rate and tillage history. The study compared a field in no-till for 23 years to a field in conventional tillage for the same interval. In the 24th year, a no-till spring wheat-canola rotation was established in both fields, with both crops present in each year. Means averaged across 8 years following initiation of study in the 24th year. Study conducted in Saskatchewan, Canada. Source: LaFond et al. 2011.*



Microbial ecology: enhancing the microbial impact on crop growth

The beneficial effect of dry pea on following crops is attributed to rhizobacteria, a class of bacteria associating with crop roots. Lupwayi et al. (2004a) found that density of rhizobacteria on spring wheat roots was 700-fold higher following dry pea than following wheat. Corn yield also increases with higher densities of rhizobacteria on its roots (Riggs et al. 2001). Yield is higher because rhizobacteria improve resource-use-efficiency of crops. For example, photosynthetic efficiency of rice was 12% higher when rice roots were inoculated with rhizobacteria (Peng et al. 2002).

We noted earlier that mycorrhizae density in soil increases with no-till. Crops such as dry pea and corn respond favorably to mycorrhizal colonization of roots because mycorrhizae improve nutrient uptake and stress tolerance in crops (Auge 2001). A further benefit for producers, however, is that synergy between mycorrhizae and rhizobacteria can enhance their effect. In one experiment, crop biomass increased 28% due to synergism between mycorrhizae and rhizobacteria (Paula et al. 1992).

Ralph is hoping to further increase the soil microbial impact on crop growth in his fields. He is now examining cover crops as *'primer plants'*, to condition the soil for *'microbial-induced promotion'* of crop growth.

A Growing Awareness of Systems Benefits

We presented yield gain advancements in a step-like fashion because no-till and crop diversity are needed first to accrue the benefits of synergism and microbial changes. For example, density of mycorrhizae increases in soil with no-till. Crop diversity also enhances the benefits of mycorrhizae, as Johnson et al. (1992) showed that monoculture cropping of either corn or soybean favored populations of mycorrhizae that were less beneficial or even detrimental to the crop in which they proliferate. Including dry pea in the rotation not only increased rhizobacteria density in soil, but also enhanced the opportunity for synergism between mycorrhizae and rhizobacteria to further improve yield.

Earlier, we noted that corn yields approximately 45% more per plant in Ralph's no-till, diverse rotation compared with corn-soybean in a tilled system (Table 1). We attribute this improved plant yield to the complex interactions among no-till, crop diversity, crop synergism, soil microbial community, and soil functioning improving resource-use-efficiency. Thus, producers with no-till systems are increasing crop yield without necessarily adding more inputs such as fertilizer. This improvement in crop yield with complex systems has been observed elsewhere. In Australia, Watt et al. (2006) noted that major gains in crop productivity often result from synergistic interactions among many factors working together, but seldom when management emphasizes one factor.

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Rotation Design: A Critical Factor for Sustainable Crop Production in a Semiarid Climate: A Review

Randy L. Anderson

Abstract The concept of "fallow" has been a prominent management tactic in semiarid regions of the world, enabling producers to compensate for low precipitation. However, fallow phases lead to soil degradation. For example, winter wheat (*Triticum aestivum* L.)-fallow with tillage has been used for decades in the semiarid steppe of the United States; organic matter levels in soils have declined almost 60%. Thus, producers in this region are concerned about the future sustainability of this rotation. No-till practices, however, improve water relations such that more crops can be added to the winter wheat-fallow rotation. This change in cropping patterns has led producers to seek cropping systems that are economically viable, restore soil health, improve resource-use-efficiency, and reduce the need for external inputs such as pesticides and fertilizers. Long-term rotation studies in the steppe show that continuous cropping with no-till can accrue these four goals. However, with water supply often being limiting, rotation design is critical for success with continuous cropping. Designing rotations in a cycle-of-four with a diversity of crops, increases net returns four-fold while reducing the cost of weed management 50% compared with conventional systems. Continuous cropping for 12 years increased soil organic carbon by 37% and nitrogen by 20% in the top 5 cm of soil, and also improved soil porosity and aggregate stability. Consequently, soil productivity has increased two-fold. Also, the cycle-of-four design provides a crop niche for legumes in this semiarid climate, which further enhances soil function. Some crops improve water-use-efficiency of the following crops by 20–35%, thus ameliorating the impact of low precipitation. Continuous cropping with no-till has initiated a spiral of soil regeneration.

Keywords Soil restoration · Crop diversity · No-till · Resource-use-efficiency

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Contents

1 Introduction

Winter wheat is the predominant crop grown in the central steppe of the United States an area in eastern Colorado and Wyoming and western Kansas, Nebraska, and South Dakota. It is grown in a winter wheat-fallow rotation to adjust for low precipitation, which ranges from 350 to 450 mm and occurs mainly from April through August. Neither crops nor weeds are allowed to grow during the fallow phase, therefore precipitation is stored in soil. Soil water gained during fallow periods reduces yield variability and crop loss due to drought stress.

But winter wheat-fallow has led to extensive soil degradation. Almost 60% of the original organic matter present in the soil has been lost (Bowman et al., 1990) and soil is especially prone to wind erosion during fallow periods (Peterson et al., 1993). A further aspect of winter wheat-fallow is its inefficiency in using precipitation for crop growth. Less than half the precipitation received during the two years is used by winter wheat; the rest is lost to evaporation, run-off, or leaching below the crop rooting zone (Farahani et al., 1998).

No-till practices preserve crop residue on the soil surface and improve water relations, allowing producers to add more crops to the winter wheat-fallow rotation (Peterson et al., 1996). Corn (*Zea mays* L.), proso millet (*Panicum miliaceum* L.), sunflower (*Helianthus annuus* L.), and dry pea (*Pisum sativum* L.) are now grown in sequence with winter wheat and fallow fields. This change in cropping practices has stimulated producers to examine their long-term goals with farming systems. Economics of more diverse rotations have been favorable (Dhuyvetter et al., 1996), but producers also want to repair the damage to soils caused by winter wheat-fallow.

In recent years, scientists and producers have contemplated sustainable cropping systems. Defining sustainability has been somewhat elusive, but producers in the steppe have four goals: economically viable rotations, that restore soil health,

improve resource-use-efficiency, and reduce need for external inputs. A goal of soil health is to increase the quantity of organic matter that subsequently improves nutrient cycling, soil aggregation, precipitation infiltration, water storage, and soil microbial functioning (Carter, 2002; Rasmussen and Collins, 1991). Soil productivity has been directly related to soil organic matter levels (Bauer and Black, 1994). Because water supply is limited in this semiarid region, producers would like to improve the water-use-efficiency of crops. They also would like cropping systems that are not so dependent on agrochemicals.

Several long-term rotation studies have been established in the steppe in the past 20 years, and trends with yield, economics, and soil changes across time have been quantified. These trends may provide insight for achieving these four goals. However, we are also intrigued by philosophical discussions related to sustainability. Hill and MacRae (1995), analyzing various approaches to sustainable systems, suggested redesigning cropping systems based on ecological principles rather than modifying existing systems in response to a specific issue. Brummer (1998) encouraged scientists to prioritize the design of sustainable systems, and then focus research on crop productivity within that design. This approach contrasts with the historical perspective of emphasizing the productivity of crops without regard to rotation design. Therefore, we also consider rotation design when evaluating trends with these rotation studies. Our assessment may provide insight for the development of sustainable systems not only in the U.S. steppe, but also in other semiarid regions of the world.

2 Biological Trends with No-till Cropping Systems

In the 1980s, long-term rotation studies were started in the central steppe of the United States at three sites in Colorado (Peterson et al. 1993; Anderson et al. 1999) and two sites in South Dakota (Beck, 2007; Stymiest et al., 2007). These studies compared various combinations of crops, ranging from winter wheat-fallow to continuous cropping; rotations with continuous cropping did not include a 12- to 14-month fallow period. Rotations included both cool- and warm-season crops. Cool-season crops were winter wheat, spring wheat, and dry pea, which are planted either in September or late March. Warm-season crops, planted in May or June, were corn, proso millet, sunflower, chickpea (*Cicer arietinum* L.), and soybean (*Glycine max* (L.) Merr.). The studies were established in Mollisol soils of the grass steppe. All phases of each rotation were included in each study. After several years of these studies, we examined yield, soil changes, and pest populations to identify production choices that favor sustainability with semiarid cropping systems.

2.1 Land Productivity and Economics

Adding summer crops, such as corn, to winter wheat-fallow increases land productivity. For example, annualized yield per land area can be almost doubled with some rotations. Annualized yield is calculated by adding the yields of all crops in a rotation for a given year, then dividing by the number of years in the rotation. This value includes the investment of fallow periods in crop production. At a rotation study near Akron, Colorado, productivity of winter wheat-corn-fallow (W-C-F), winter wheat-corn-proso millet-fallow (W-C-M-F) or winter wheat-corn-proso millet (W-C-M), was two-fold greater than winter wheat-fallow (W-F). For example, the annualized yield of W-F was 970 kg/ha, contrasting with W-C-M-F producing 1,910 kg/ha—an increase of 97%. An intriguing trend was that continuous cropping, W-C-M, also yielded two-fold more than W-F. Similar results occurred at the other studies in the steppe; land productivity increased two-fold with rotations comprised of several crops (Peterson et al., 1993; Stymiest et al., 2007).

Rotations with more crops and less fallow time also improve economics. Net returns for diverse rotations were 25% higher compared with W-F throughout the central steppe (Dhuyvetter et al., 1996). Crop diversity in rotations also reduced financial risk.

2.2 *Soil Restoration*

After eight years with the Akron, Colorado study, soil organic carbon (SOC) increased 20% in the top 5 cm of soil with continuous cropping, compared with W-F (Fig. 1). However, SOC did not increase if a 12- to 14-month fallow period was included in a rotation, even when three crops were grown before a fallow period. In a second study in the region, 12 years of continuous cropping increased SOC by

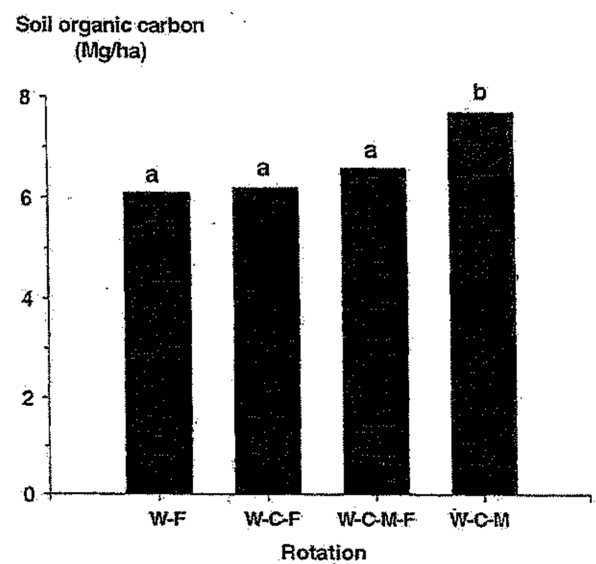

Fig. 1 Rotation design influences level of soil organic carbon in the 0–5 cm depth of soil. Abbreviations are: W = winter wheat; F = fallow; C = corn; M = proso millet. The conventional rotation in this region (W-F) included tillage, whereas W-C-F, W-C-M-F, and W-C-M were no-till. Data collected in the eighth year of the rotation study at Akron, Colorado (Adapted from Bowman et al., 1999)

37% as compared to W-F (Sherrold et al., 2003). At both studies, fallow fields in any rotation minimized the gain in SOC by continuous cropping.

Continuous cropping also increased aggregate stability compared with W-F in the Akron, CO study (Wright and Anderson, 2000). However, aggregate stability did not improve with any rotation that included fallow fields, even rotations such as W-C-M-F. Shaver et al. (2002) found a similar trend in another study; continuous cropping increased aggregate development and soil porosity, subsequently improving precipitation infiltration and water availability for crops. But improvement in soil structure was eliminated by fallow periods, even if fallow fields occurred only once in four years. In all studies, increasing crop residue production and preserving residues on the soil surface was essential for soil restoration.

Shaxson (2006) suggested that cropping systems designed to enhance the functioning of the microbial community will favor soil renewal. No-till cropping systems in the steppe are achieving this goal also; soil microbial biomass C is 70% higher in continuous cropping as compared with W-F (Sherrold et al., 2005).

2.3 *Resource-Use-Efficiency*

2.3.1 Water

No-till practices improve precipitation-storage efficiency (PSE) during fallow periods. With tilled systems, PSE is less than 30%, whereas no-till and crop residue preservation on the soil surface improves PSE to 40% (Peterson et al., 1996). Another trend with PSE in no-till fallow fields is that storage efficiency is highest over the winter, but lowest during the summer months (Tanaka and Anderson, 1997). Adding warm-season crops like corn improves PSE during the shorter fallow intervals to more than 50% (Farahani et al., 1998).

In addition to improving PSE during fallow periods, no-till and diverse crop rotations increase the amount of precipitation converted into crop yield. Winter wheat-fallow converts 40–45% of precipitation received during the two years of this rotation into grain (Farahani et al., 1998). In contrast, rotations such as W-C-M-F convert almost 60% of precipitation into grain, whereas conversion with continuous cropping is 75%. Continuous cropping improves the conversion rate by minimizing the inefficiency of fallow periods.

Crop diversity provides an additional benefit for water use; some crops improve water-use efficiency (WUE) of the crops that follow (Anderson, 2005b). Winter wheat produces 20–35% more grain with the same water use in W-C-F, compared to W-M-F or W-F. For example, winter wheat will yield 3,930 kg/ha in W-C-F with 300 mm of water use, whereas the yield will be 2,940 kg/ha in W-M-F (Fig. 2). A similar gain in WUE occurs when corn precedes proso millet; proso produces 20–25% more grain with the same water use in W-C-M as compared with W-M. A surprising trend, however, was that fallow periods eliminated this synergistic interaction between corn and proso millet. Proso millet WUE and yield were the same in W-C-M-F and W-M—approximately 20% less as compared to W-C-M. We are

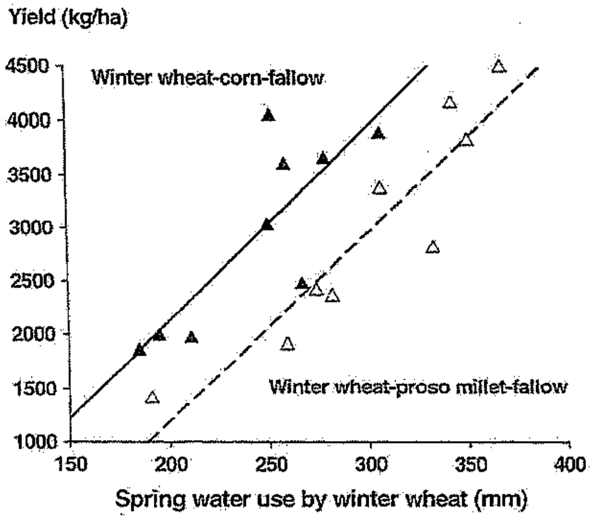

Fig. 2 Crop sequence can improve the grain yield-water use relationship for winter wheat. Two rotations are compared: winter wheat-corn-fallow (*black triangles* and *solid line*) and winter wheat-proso millet-fallow (*white triangles* and *dashed line*). Regression equation for winter wheat-corn-fallow was $Y = 18.4X - 1587$, $r^2 = 0.67$; and for winter wheat-proso millet-fallow it was $Y = 17.5X - 2323$, $r^2 + 0.86$. Data averaged across three years; study conducted at Akron, Colorado. (Adapted from Anderson, 2005b)

unable to explain why this synergistic trend occurs, but including corn in the rotation improves the WUE of other crops.

2.3.2 Nitrogen and Phosphorus

As found with SOC, continuous cropping increases soil organic N (SON) levels over time. Both Bowman et al. (1999) and Sherrold et al. (2003) reported that SON increased 15–20% with continuous cropping as compared with W-F. Also, both research teams found that a 12- to 14-month fallow period eliminated this gain in SON, even with rotations comprised of three crops and one fallow season.

Soils in the steppe with higher SON improve crop N-use efficiency. Maskina et al. (1993) found that corn yielded 10% more in high SON treatment as compared with a low SON treatment in a long-term crop residue study, even with adequate N fertilizer. The high SON treatment apparently increased the growth efficiency of corn, as the 10% yield difference remained regardless of the N fertilizer rates used.

A consequence of W-F has been the leaching of nitrates in the soil profile. Westfall et al. (1996) found that nitrate levels in the soil are lower in rotations with less fallow time; nitrate quantity in the upper 2 m of soil was 42% less in W-C-M-F as compared with W-F. In the Akron, Colorado study, nitrate quantity in the soil was further reduced by continuous cropping; in contrast, all rotations with fallow time favored nitrate accumulation and leaching in the soil profile (Anderson, 2005c). Zentner et al., (2002) reported similar results in the semiarid steppe of Canada; continuous cropping reduced nitrate leaching in soil as compared to rotations with fallow periods. They attributed less leaching in continuous cropping to greater synchrony between N release by mineralization and N uptake by the crop.

Rotation design also affects phosphorus-use efficiency. Bowman and Halvorson (1997) found that concentration of P in winter wheat was 13–30% greater in continuous cropping in comparison to rotations that included a 12- to 14-month fallow period. This trend was attributed to the recycling of P through plant residue; P is more available for plant uptake in the organic phase with plant biomass or organic matter. During fallow times, chemical reactions in soil convert P into inorganic forms that are less accessible for plants, whereas yearly contributions of plant biomass in continuous cropping favor the organic phase of P.

2.4 Pest Management

2.4.1 Root Diseases

Root diseases often reduce crop yield in the steppe (Cook, 1990). In the Akron, Colorado study, crop yield was related to how frequently the crop was grown in rotation (Anderson, 2005c). Grain yield of sunflower, corn, and winter wheat was 17–60% higher when grown once every four years, as compared with a cropping frequency of two years (Fig. 3). Diversity of crops in rotation reduces the severity of root diseases by disrupting the population dynamics of pathogens.

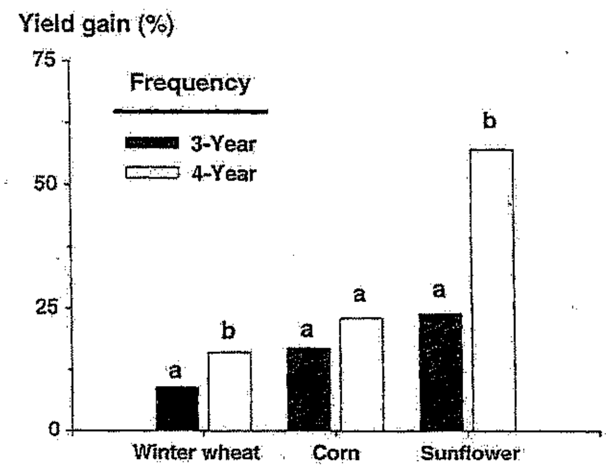

Fig. 3 Yield increases when a crop is grown less frequently than once every two years. Rotations compared for wheat (W-F, W-C-F, and W-C-M-F); for corn (M-C, W-C-F and W-C-M-F); and for sunflower (M-Sun, W-Sun-F, and W-C-Sun-F). Abbreviations are: W = winter wheat; F = fallow; C = corn; M = proso millet; and Sun = sunflower. Means reflect yield gain when compared to the crop in a two-year rotation. Data averaged across four years. Bars with an identical letter within a crop are not significantly different based on Fisher's Protected LSD (0.05). Means for all crops differed from a cropping frequency of two years. Study conducted at Akron, Colorado. (Adapted from Anderson, 2005c)

The drastic differences in yield with the frequency of sunflower is due to phoma (*Phoma macdonaldii* Boerma)—a fungi present in soil (Anderson et al., 1999). Phoma infects roots and the lower stem, reducing water and nutrient movement in the plant, and often causing plant lodging before harvesting. Bailey (1996) found a similar response of other oilseeds to the frequency of cropping in the semiarid steppe of Canada; she recommended growing oilseed crops once every four years.

A prevalent root disease of winter wheat is common root rot, caused by *Fusarium* and *Cochliobolus* fungi. For example, winter wheat yields are low following proso millet with W-M or W-C-M, yielding only 50% of winter wheat grown in W-C-M-F (Anderson et al., 1999). Wildermuth and McNamara (1991) found that proso millet is a host for the *Fusarium* and *Cochliobolus* species; common root rot severity in winter wheat following proso millet is similar to continuous winter wheat. Replacing proso millet with chickpea (a non-host legume) in the W-C-M rotation increased winter wheat yield by 28% across a seven-year interval (Stymiest et al. 2007).

2.4.2 Weed Management

Rotating cool- and warm-season crops helps weed management because different planting and harvest dates among these crops provide opportunities to prevent either plant establishment or seed production by weeds. The benefit of this strategy is related to weed seed survival in soil. With annual weeds, approximately 20% of the seeds are alive one year after seed shed, whereas less than 5% of their seeds are alive after two years. Rotating crops with different life cycles enables producers to favor the natural loss of weed seeds over time by preventing new seeds from being added to the soil.

However, rotation studies in the steppe show a surprising trend. Weed density declines over time when rotations are comprised of two cool-season crops followed by two warm-season crops (Anderson, 2008; Anderson and Beck, 2007). In contrast, weed density increases when rotations consist of one cool-season crop followed by one warm-season crop, such as W-M. Comparing trends across three rotation studies, weed density was six-fold greater in two-crop rotations as compared with rotations comprised of two cool-season crops followed by two warm-season crops (Fig. 4). Weed density in three-crop rotations was also higher than with four-crop rotations.

A second trend noted with these studies is that crops also need to differ within a seasonal interval of four-year rotations. For example, if two winter wheat crops were grown in succession for a cool-season interval, the density of winter annual grasses like downy brome (*Bromus tectorum* L.) escalated rapidly. In one study, downy brome density was forty times higher in four-year rotations with two years of winter wheat, as compared to rotations with a sequence of dry pea and winter wheat (Anderson et al., 2007). Dry pea is planted in late March, which provides an opportunity to control downy brome emerging over winter. A similar benefit is gained with crop diversity during the warm-season interval.

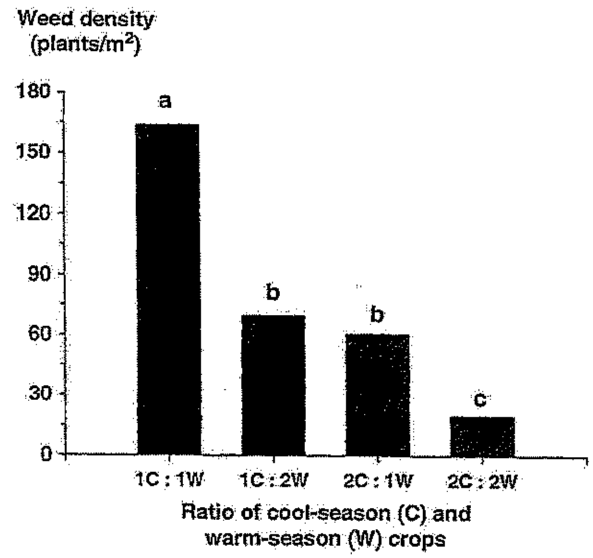

Fig. 4 Weed community density is affected by the ratio of cool-season to warm-season crops in rotations. Cool-season crops included winter wheat, spring wheat, and dry pea; warm-season crops are corn, proso millet, sunflower, chickpea, and soybean. Data averaged across three long-term studies in the U.S. steppe. Bars with an identical letter are not significantly different based on Fisher's Protected LSD (0.05). (Adapted from Anderson, 2008)

Weed management in these studies included conventionally-used herbicides, yet weed density was still affected by rotation design. Producers using rotations of two cool-season crops followed by two warm-season crops, such as Pea-W-C-M, are managing weeds with 50% less costs in comparison to rotations of fewer crops (Anderson, 2005a).

3 Rotation Design and Sustainability

One of our objectives with this assessment was to consider rotation design in relation to producers' goals for sustainability. Continuous cropping, such as W-M or W-C-M, is favorable for soil restoration and resource-use efficiency. However, these rotations have major limitations, especially with crop yield, residue production, and pest management. Winter wheat yield after proso millet is often less than 50% of yields after fallow periods. Root diseases are one cause of low yield, but a second reason is that it is difficult to convert more than 75% of precipitation into crop growth in this semiarid climate (Farahani et al., 1998). With W-M and W-C-M, average yields would require 85% of precipitation to be converted into crop growth (Anderson, 2005c).

Another limitation with W-C-M is that crop residue production by winter wheat is low, which reduces corn yield in the following year. Corn yields 15% less in W-C-M in comparison with W-C-M-F because of less favorable water relations with low residue quantities on the soil surface (Anderson et al. 1999). Furthermore, weed density escalates over time with W-M and W-C-M, and increases management costs (Fig. 4; Anderson, 2005a).

Designing rotations in a cycle-of-four, such as W-C-M-F, is favorable for land productivity and pest management. Grain yields of most crops are highest when grown once every four years (Fig. 3), whereas land productivity is two-fold greater than W-F. Weed density declines with the cycle-of-four design, enabling producers to reduce the cost of weed management (Anderson, 2005a). Based on these trends, we suggest that four-crop rotations may be the most favorable for achieving our four goals of sustainability, but only if crop sequencing can be developed for continuous cropping. The 12- to 14-month fallow period is detrimental for soil restoration, eliminating benefits gained by continuous cropping with SOC, SON, phosphorus uptake, aggregate stability, and soil porosity (Bowman et al., 1999; Wright and Anderson, 2000; Shaver et al., 2002; Sherrold et al., 2003). Also, fallow time leads to nitrate leaching in soil (Westfall et al., 1996; Anderson, 2005c). We question whether soil restoration and sustainability can be achieved in this region with any rotation that includes fallow periods.

3.1 Can We Replace Fallow Time with a Crop in this Semiarid Climate?

A concern with continuous cropping and eliminating the 12- to 14-month fallow period is water supply. For example, winter wheat can be planted two years in a row. However, grain yield and residue production of both winter wheat crops is 25–50% lower than wheat after fallow because of root diseases and inadequate water (Anderson, 2005c; Stymiest et al., 2007). A further consequence of this sequence is that weed density in winter wheat escalates rapidly (Anderson et al. 2007).

Legumes provide a more favorable option, especially for soil restoration. Legumes contribute N with its symbiotic production, which is especially valuable in the U.S. steppe, as most crops grown are cereals. Drinkwater and Snapp (2007) noted that in cereal-based rotations, legumes facilitate the accumulation of SOC and SON in soil; the higher level of SON improves the N uptake by following crops and reduces the need for fertilizers.

Furthermore, legumes provide flexibility for water management because they can be grown for forage or green fallow (terminated after six to eight weeks of growth) to adjust for water supply. A W-C-M-Pea (for forage) rotation uses approximately 75% of precipitation across four years for crop growth (Anderson, 2005c), near the conversion limit observed with continuous cropping in this region (Farahani et al., 1998). When dry pea is grown as green fallow in this rotation, precipitation use for crop growth is near 70%. Yet, even with short intervals of growth, dry pea or other legumes still increase SOC, SON, and soil microbial activity (Zentner et al., 2004; Biederbeck et al., 2005).

An additional benefit with legumes is higher yields of following crops. In one rotation study in the steppe, dry pea increased winter wheat yield by 5–15% compared with winter wheat after a fallow period (Beck, 2007). Yield increases because the WUE of winter wheat is 12% higher following dry pea as compared with fallow time (Fig. 5). In contrast, the WUE of winter wheat is 21% and 35% less following

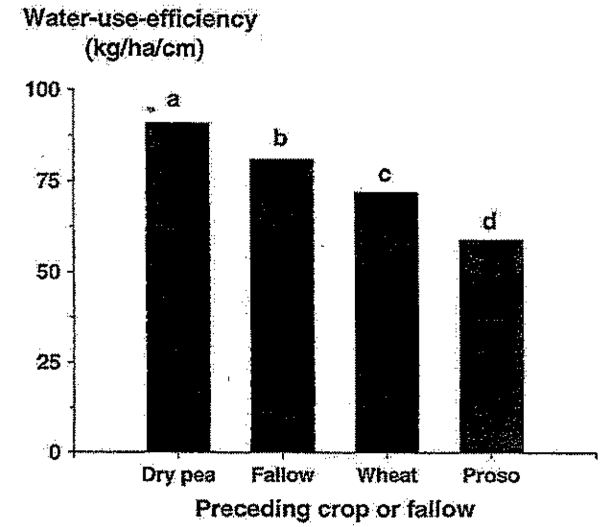

Fig. 5 Preceding crops affect the water-use-efficiency (WUE) of winter wheat. Data collected from rotational sequences of W-C-M-Pea, W-C-M-F, and W-C-M-W at Akron, Colorado. Abbreviations are: W = winter wheat; C = corn; M = proso millet; Pea = dry pea for forage; and F = fallow. WUE was defined as grain yield divided by total water use (growing precipitation plus soil water extraction). Data averaged across two years; bars with an identical letter are not significantly different based on Fisher's Protected LSD (0.05). (Adapted from Anderson, 2005c)

winter wheat and proso millet, respectively, as compared with dry pea as a preceding crop. Dry pea improves the WUE of winter wheat by suppressing root diseases (Cook, 1990) and favoring microbial interactions with winter wheat (Lupwayi and Kennedy, 2007). Winter wheat roots following dry pea are more readily colonized with mycorrhiza and contain more endophytic rhizobia; these microbial associations improve the plant's ability to withstand drought stress and to absorb nutrients. Also, Rice (1983) found that root exudates of dry pea improve the photosynthesis efficiency of cereal crops.

Dry pea as forage or green fallow also preserves the synergism with WUE between corn and proso millet, consequently increasing proso yields (Anderson, 2005c). Fallow eliminates this WUE synergism in the W-C-M-F rotation. The cycle-of-four design provides a niche for legumes in this semiarid region to improve crop yield and accelerate soil restoration.

3.2 Benefits of Rotations with the Cycle-of-Four Design

Planning rotations in a cycle-of-four allows producers to grow a diversity of crops with different water requirements and growth periods. Crop diversity is necessary for water management, especially to improve WUE and precipitation conversion to grain. Pest management and nutrient-use efficiency are also improved to reduce production costs. Importantly, the cycle-of-four design with crop diversity can eliminate the need for a 12- to 14-month fallow period and enhance soil restoration with continuous cropping.

A striking change in yield occurs with soil restoration. When no-tillage was first used in the steppe, winter wheat yield increased by 20–30% as compared with tilled systems (Smika, 1990). Now, the yield potential of winter wheat is two-fold higher in no-tillage rotations (Anderson, 2005c). With W-F and tillage, winter wheat yield rarely exceeds 2,650 kg/ha. In contrast, wheat yields more than 5,400 kg/ha during favorable years with no-tillage and cycle-of-four rotations. Similarly, proso millet yield in some years exceeds 4,500 kg/ha in four-year rotations with no-tillage, whereas in W-M-F with tillage, proso rarely yields more than 2,000 kg/ha. Yields in no-tillage rotations greatly exceed the projected yields based on water supply and fertilizer inputs, demonstrating improved efficiency of the biological system.

Economic returns are also higher. In the early years of no-tillage, the net return was 25% higher in rotations with crop diversity as compared with W-F (Dhuyvetter et al., 1996). Now, net return is four-fold greater with no-tillage crop rotations (Anderson, 2007). Profit for W-F is $25/ha, whereas no-tillage rotations with crop diversity yield $100/ha. Improved economics reflect both higher land productivity and lower costs for weed management. Managing weeds costs $38/ha in no-tillage rotations arranged in the cycle-of-four, contrasting with $75/ha spent by producers to control weeds in W-F. Producers with cycle-of-four rotations are growing proso millet (Anderson, 2000) and winter wheat (Anderson, 2005a) without herbicides because weed density is so low.

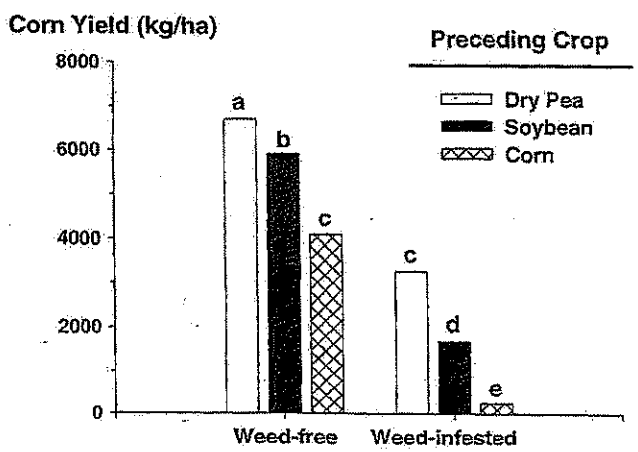

Fig. 6 Preceding crop influences yield of corn in both weed-free and weed-infested conditions. Study was established with no-till in the U.S. steppe. A uniform stand of foxtail millet represented the weed community in corn. Data averaged across two years; bars with an identical letter are not significantly different based on Fisher's Protected LSD (0.05). (Anderson R.L., research in progress)

Planning rotations with four crops is also effective in other climatic regions. For example, multifunctional rotations are used in the Netherlands to improve pest management, soil health, and nutrient cycling (Vereijken, 1992); maximum improvement occurs when rotations consist of at least four crops (Boller et al., 2004). This rotational design increases crop yield while reducing inputs with pesticides and fertilizers (Lewis et al., 1997).

Rotations with crop diversity may provide additional benefits. For example, we recently found that the preceding crop influences crop tolerance to weed interference. Corn tolerance to weeds in no-tillage is five-fold greater when following dry pea as compared to a corn monoculture (Fig. 6). Corn yield was also two-fold higher following dry pea as compared with soybean in weed-infested conditions. An intriguing trend was corn following dry pea, which yielded the same amount in weed-infested conditions as in continuous corn in weed-free conditions. Corn residues release toxins that damage corn seedling growth (Crookston, 1995), and reduce its competitiveness with weeds.

4 A Spiral of Soil Regeneration

No-tillage systems and residue management have transformed crop production in the semiarid steppe, doubling land productivity and reducing the need for fallow periods. Cropping patterns in the region also have changed; for example, dryland corn hectarage in Colorado increased from 4,000 ha in 1990 to more than 165,000 ha in 2000 (Anderson, 2005c).

Furthermore, soil health is being restored. Lal (2007) noted that removing crop residues from the farming system starts a spiral of soil degradation. No-tillage cropping systems in the U.S. steppe have reversed this spiral and are regenerating soil health (Anderson 2005c). Higher yields with four-crop rotations and no-tillage also increase crop residue production, which subsequently improves water relations to increase crop yields even more in following years. Thus, the system is self-perpetuating for soil restoration. As we gain more knowledge of beneficial interactions among crops, and improved soil functioning, we may be able to further accentuate this spiral of soil regeneration while alleviating the impact of low water supply. A key will be the design of rotations, especially if more crop sequences that are synergistic for resource-use efficiency can be identified.

Planning rotations in a cycle-of-four provide numerous benefits for producers in the semiarid steppe of the United States. We suggest that scientists and producers in other dry regions of the world may be able to gain a similar array of benefits with rotations comprised of several different crops and establish no-tillage practices.

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Sulfur and micronutrient fertilization for wheat in Kansas

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Introduction

- Frequent reports of sulfur deficiency (wheat, more frequent in recent years).
- Interest in micronutrients to complement fertility programs (especially for higher yield environments).
- Use of tissue analysis as diagnostics tool for micronutrients.

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Soil and tissue for micronutrients

- 14 locations for wheat (strip trial and small plot).
- Fertilizer treatments:
  - Seven treatments: 5 individual nutrients, a mix, and a control.
  - S= 15 lbs/acre
  - Mn, Zn, Cu= 10 lbs/acre
  - B= 5 lbs/acre
  - Mix

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Soil and tissue for micronutrients

- Soil sampling: 0-6 in pre-plant from each plot.
  - DTPA Zn, Mn, Cu. Hot water B. Ca-Phosphate S.
- Tissue (Zn, Cu, B, Mn, and S) at time of flag-leaf emergence for wheat; uppermost trifoliate at R3 for soybean.
- Yield.
- Post-harvest soil sampling: 0-6 in from each plot.

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Soil test levels before fertilizer application

Soil test	Min	Mean	Max
		ppm	
STP	16	44	127
STK	147	641	1242
DTPA-Mn	10.1	45.6	84.6
DTPA-Cu	0.5	1.6	2.4
DTPA-Zn	0.2	1.1	3.4
Hot water B	0.5	0.8	2.0
Soil pH	4.9	6.3	8.0
SOM (%)	0.6	2.3	3.6

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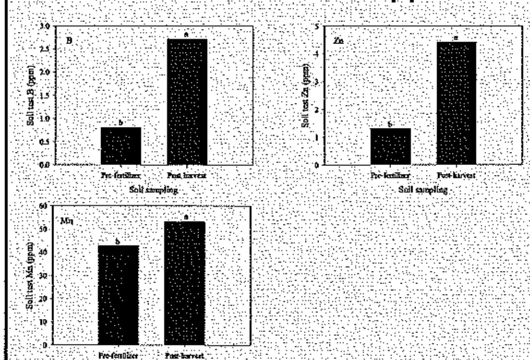
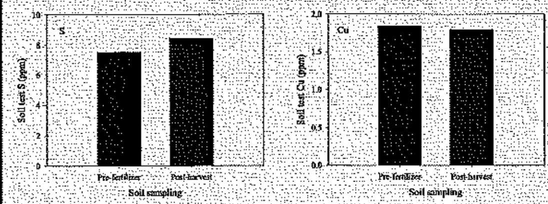
Soil test with fertilizer application



20 sites, 4 reps

Soil test with fertilizer application



20 sites, 4 reps

Fertilizer to increase 1 ppm ST

Nutrient	Lbs as fertilizer
Zn	4
Mn	1
B	3

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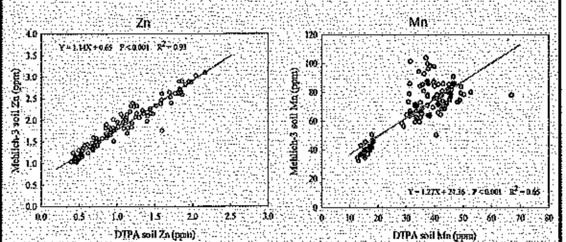
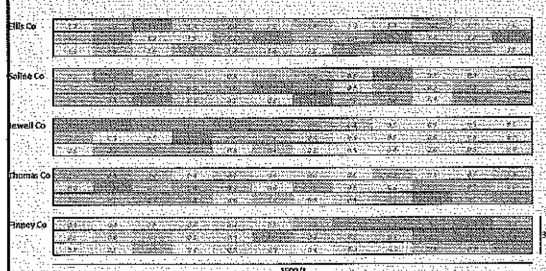
Soil test micros: DTPA by AA and Mehlich-3 by ICP



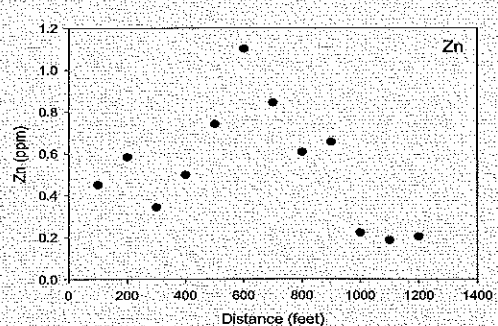
Cu and Fe : similar to Mn. Zn show the best correlation

Field variability soil Zn



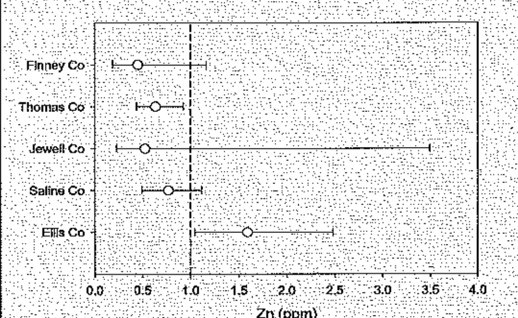
Zn (DTPA)

Field variability soil Zn

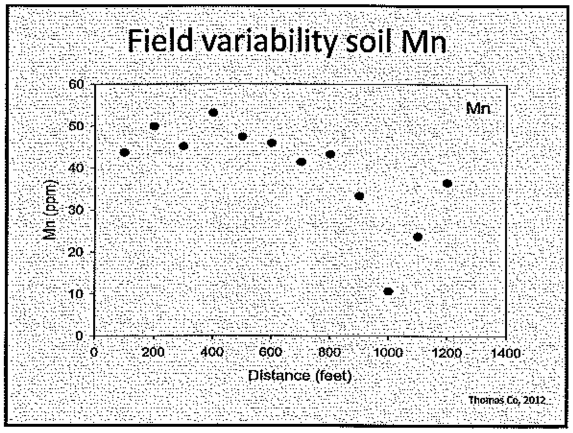


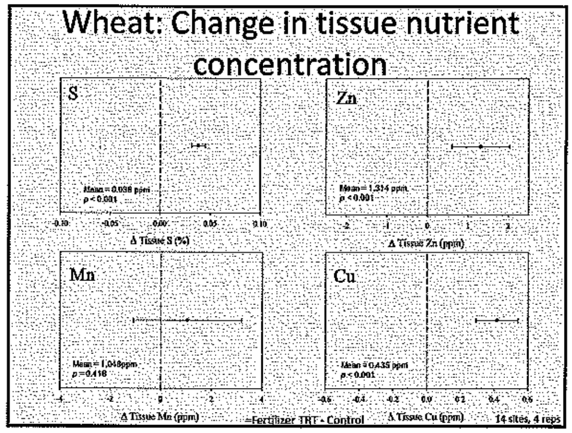
Zn (DTPA) Thomas Co, 2012

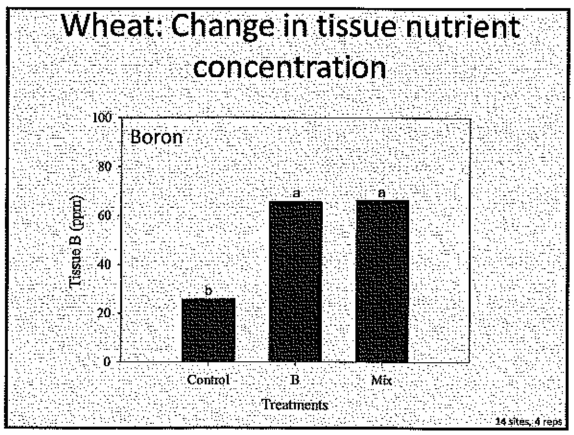
Field variability soil Zn

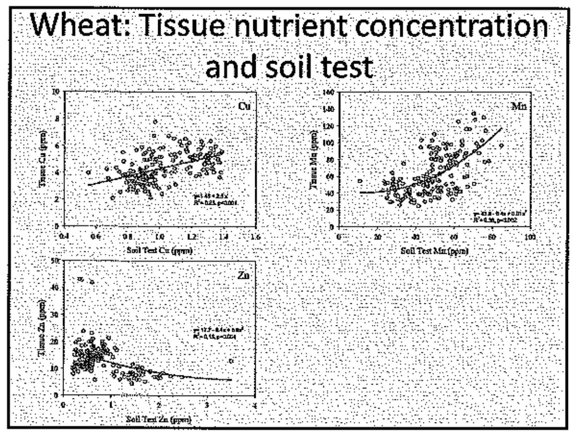


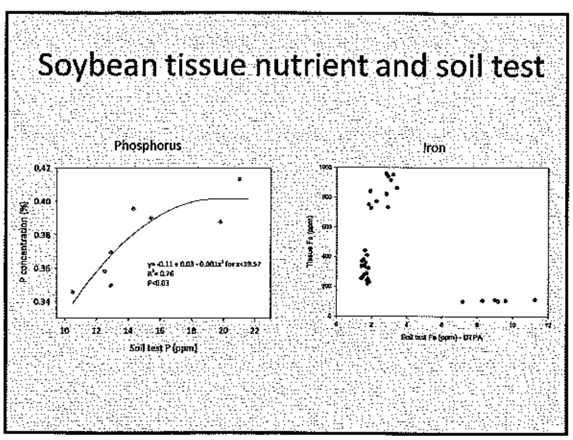
Zn (DTPA)

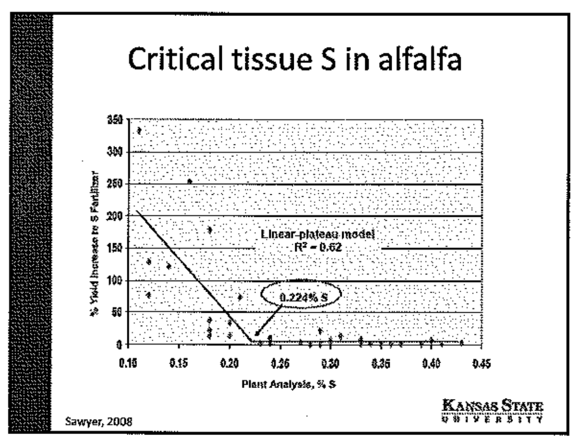

Field variability soil Mn
Mn
Mn (ppm)
Distance (feet)
0
10
20
30
40
50
60
0
200
400
600
800
1000
1200
1400
Thomas Co, 2012


Wheat: Change in tissue nutrient concentration
S
Zn
Mn
Cu
Δ Tissue S (%)
Δ Tissue Zn (ppm)
Δ Tissue Mn (ppm)
Δ Tissue Cu (ppm)
=Fertilizer TRT - Control
14 sites, 4 reps

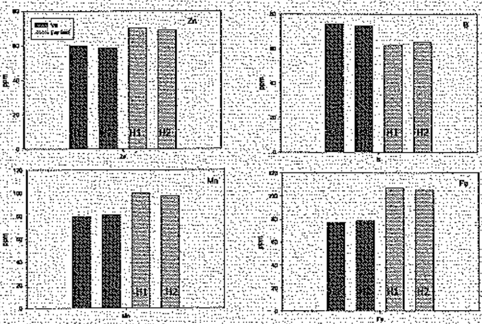

Wheat: Change in tissue nutrient concentration
Boron
Tissue B (ppm)
0
20
40
60
80
100
b
a
a
Control
B
Mix
Treatments
14 sites, 4 reps


Wheat: Tissue nutrient concentration and soil test
Cu
Mn
Zn


Soybean tissue nutrient and soil test
Phosphorus
Iron

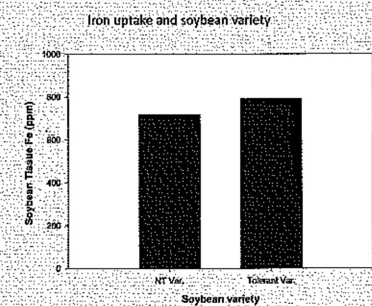

Critical tissue S in alfalfa
Linear-plateau model
R² = 0.62
0.224% S
% Yield Increase to S Fertilizer
Plant Analysis, % S
0
50
100
150
200
250
300
350
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Sawyer, 2008
Kansas State University

Plant sampling and analysis



Ruiz Diaz, 2011 Two corn hybrids

Plant sampling and analysis



Diagnostic Tissue Analysis

K-State Research and Extension
Soil Testing Laboratory
2308 Throckmorton Plant Sciences Center, Manhattan, KS 66506-5503 Tel: (785)532-7897 Fax(785)532-7412

Date Submitted: 4-25-2012
Date Reported: 5-1-2012

Submitted by: Cody Miller

Lab ID	Sample ID	N%	P%	K%	SO_4-S %	Chloride ppm
P302	Bad	1.11	0.104	1.79	0.092	4427
P304	Good	1.09	0.248	2.95	0.180	13516

Diagnostic Tissue Analysis

K-State Research and Extension
Soil Testing Laboratory

SUBMITTED BY:

Date Received: [illegible]
Date Reported: [illegible]

FOR:

Lab ID	Sample ID	N%	P%	K%	Ca %	S %	Mg %	Fe ppm	Zn ppm	Mn ppm
P253	[illegible] Poor	2.29	0.283	2.21	0.475	0.108	[illegible]	171	14	31
P254	[illegible] Good	3.64	0.299	2.40	0.437	0.233	[illegible]	121	21	31

Plant sampling and analysis

- Any plant stress (drought, heat, soil compaction etc) can have a serious impact on nutrient uptake and plant tissue nutrient concentrations.
- A low value in the plant doesn't always mean the nutrient is low in the soil and the plant will respond to fertilizer.
- Tissue data interpretation can be more challenging for some nutrients.

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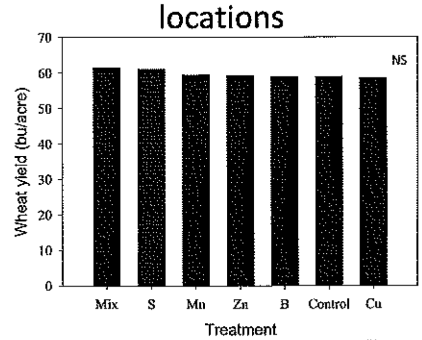
Wheat yield response across locations



Mix-Cu= 3 bu/acre

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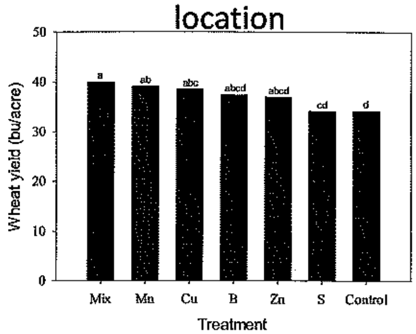
Wheat yield at one responsive location



Mix-Control= 6 bu/acre

Low OM, sandy soil

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Summary

- Soil applied Cu, Zn and B fertilizer generated significant increase in tissue concentrations.
  - Tissue S and Mn response different for wheat and soybean.
- The responsive wheat site showed the highest yield with the "mix" treatment.
- Post harvest soil analysis showed significant increase of soil test Zn, B, Mn with fertilizer application. Average increase in soil S.

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Summary

- Potential response at sites with sandy soil with low OM.
- Soil test methods (DTPA vs Mehlich-3) correlate well for Zn.
- Significant variability within-field for soil test micros.
  - Starter or variable rate micros?

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Correlation-calibration for micros?

- Response is uncommon and highly variable.
- Lab analysis methods (for soil and tissue) should be evaluated.
- Poor correlation between soil and tissue values with current test methods.
- Tissue analysis show high variability (many factors influencing concentration?)

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Tissue analysis

- Combination of soil + tissue analysis useful for diagnostic purpose.
- Tissue test for some secondary and micros are good and currently used (sulfur, chloride).
- Can be useful as "quality control" and monitoring purpose.

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Secondary and micronutrients for wheat: On-farm research

- High yield potential and effect on uptake of secondary-micronutrients.
- Nutrient demand may limit yields under some conditions.
- Supplementary micronutrients for high-yielding wheat crops may help to enhance yields.
- The objective of this study was to evaluate wheat response to secondary and micronutrient fertilizers to maximize yields.

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Secondary and micronutrients for wheat: On-farm research

- Access to combine with yield monitor.
- Strip trial approach: > 1200 ft long and 40-60 ft wide for each strip.
- Two treatments, with and without fertilizer.
- The fertilizer treatment include a mix of S, Zn, Mn, Cu, B.
- Value as field demonstration for the producer in the farm.

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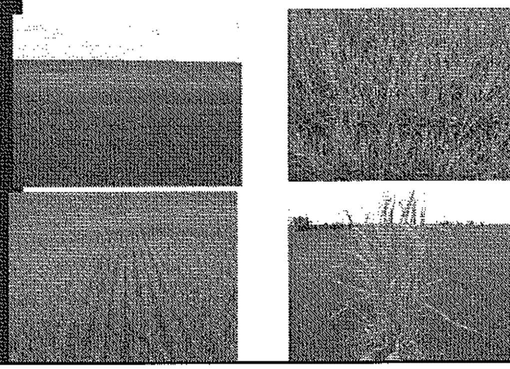
Field scale variability



Replication of strip trials

One rep (side by side):
8 bu/acre increase

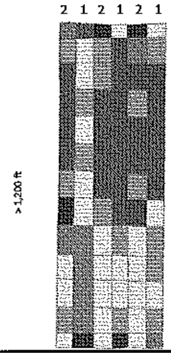
1- With fertilizer treatment
2- W/o fertilizer treatment

29.490425 - 45.666150
45.666151 - 62.110163
62.110164 - 69.303343
69.303344 - 73.165000
73.165001 - 80.283400

Jewell Co, producer's field, 2012

Kansas State University

On-farm strip trials



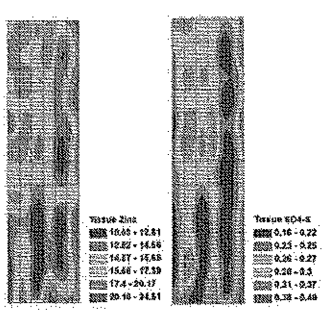
1- With fertilizer treatment
2- W/o fertilizer treatment

29.490425 - 45.666150
45.666151 - 62.110163
62.110164 - 69.303343
69.303344 - 73.165000
73.165001 - 80.283400

Jewell Co, producer's field, 2012

Kansas State University

Tissue Zn and S



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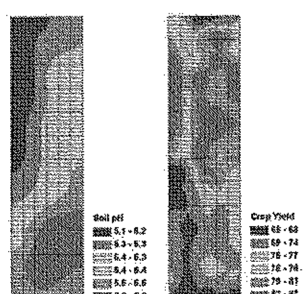
Soil pH and yield



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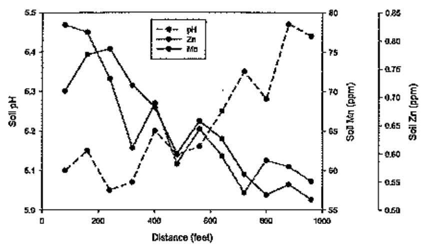
Soil pH and micronutrient availability



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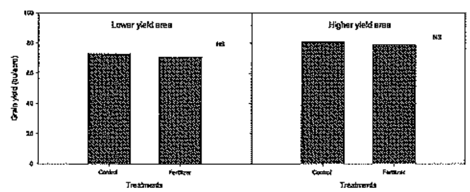
Response by yield level



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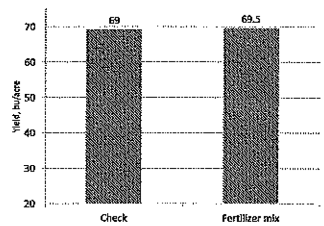
Average yield of 6 locations



No statistically significant difference

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On-farm strip trials

Should ideally have previously met the rigors of research testing on small plot.

Strip trial can help growers evaluate new practice/products on their farms.

The primary purpose of on-farm strip tests is to give the grower an opportunity to try these new practice/product and to find response areas within a field.

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On-farm strip trials

On-farm trials should be kept as simple as possible.

Replicated trials should have all variables well controlled and results statistically repeatable.

Three replications of the treated and check strips in each field or farm allow for a statistical analysis.

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Summary-micronutrients for wheat

Wheat yield response vary by soil type (across the field).

- Sandy areas may show response.
- May provide an "insurance" for highly variable fields – perhaps capture some yield response.

Yield potential and response to treatments should be evaluated.

- Higher yield level would show more response to micronutrients?

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A quick look at the Relationship between N fertility and Wheat Protein

Merle F. Vigil., Susan Latshaw, Scott Haley and D. J. Poss

Introduction

To make bread rise when mixed with yeast water and sugar (for quality bread making), the wheat flour must have adequate amounts of gluten (a sticky protein complex). Bakers prefer wheat protein contents higher than 12 % to obtain enough gluten so the bread will rise. In our research at USDA-ARS we have been able to show that wheat protein content is directly related to fertilizer nitrogen (N) rate and to yield potential. The question that we are commonly asked is "what is the actual relationship between N fertilizer and wheat protein content?"

The relationship

Nitrogen is a major component in amino acids and amino acids are the primary component in wheat proteins. Wheat proteins including the protein components in wheat gluten (glutenin and gliadin) are made up of a combination of several amino acids. Below is one example of the amino acid arginine:

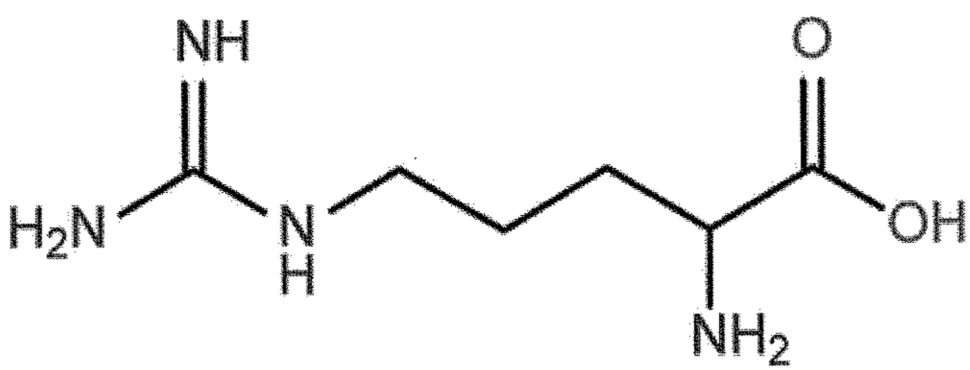


Fig 1. The amino acid arginine ($C_6H_{14}N_4O_2$)

In the structure of the amino acid arginine there are 4, N amino groups. The N is 32 % of the total weight of this amino acid. Wheat gluten is made of several amino acids including arginine. The point is, wheat protein is made up of amino acids containing N, and so making lots of N available to the wheat plant theoretically should increase N content in the grain. Multiple years of field plot research at Akron shows that greater N application (making more N available to the plant) increases wheat grain protein contents. The relationship between N availability and wheat protein content is a positive correlation. In other words increases in N availability result in increases in wheat protein content.

Research results at USDA-ARS Akron, Colorado

A look at Figure 2 shows some typical wheat yields in a replicated wheat-summer fallow, reduce–till fertilizer N rate experiment. The plots were fertilized at 0, 30, 60 and 90 lbs of N per acre on the station over a 6 year period. All of the N fertilizer was top dressed just prior to planting in the fall as either dry urea or as ammonium nitrate. We are showing you this data to make a few important points. First, in a poor yielding year (1998) at all N rates the protein levels are elevated (the 11.6 and 13.2 numbers are grain protein contents associated with the 0 and 30 lb N rates). In 1998, wheat proteins as high as 17.2 % were measured at the highest N rate of 90 lbs/acre. Also in Fig 2, we observe a bump up in wheat protein of at least 1% as we increased the N rate from 0 to 30 lbs of N per acre. The 1% bump up in wheat protein with each 30 lb increase in N rate is especially apparent in 1996. That relationship between protein and fertilizer rate tends to hold. As we increased the N rate another 30 lbs from 30 to 60 lbs of N per acre we got another increase in wheat protein of about 1 % in 1996. We went from 12.5% at the 30 lb N rate to 13.6% protein at the 60 lb N rate. As you increase the N rate the protein contents tend to go up. In 1998 the increase in wheat protein with N rate is even greater than the 1% bump up seen in 1996 with each 30 lb N rate. In fact it is almost a 2% increase in protein with each 30 lb increase in N rate. This is becuase1998 was a dry low yielding year. This is an example of the "dilution effect". That is in dry years when yields are low protein levels are elevated and in wet years when yields are high protein levels are less or are "diluted out" by the high yields.

Fertilizer was applied preplant as a surface broadcast. Ammonium nitrate and top dressed dry urea was the N source.

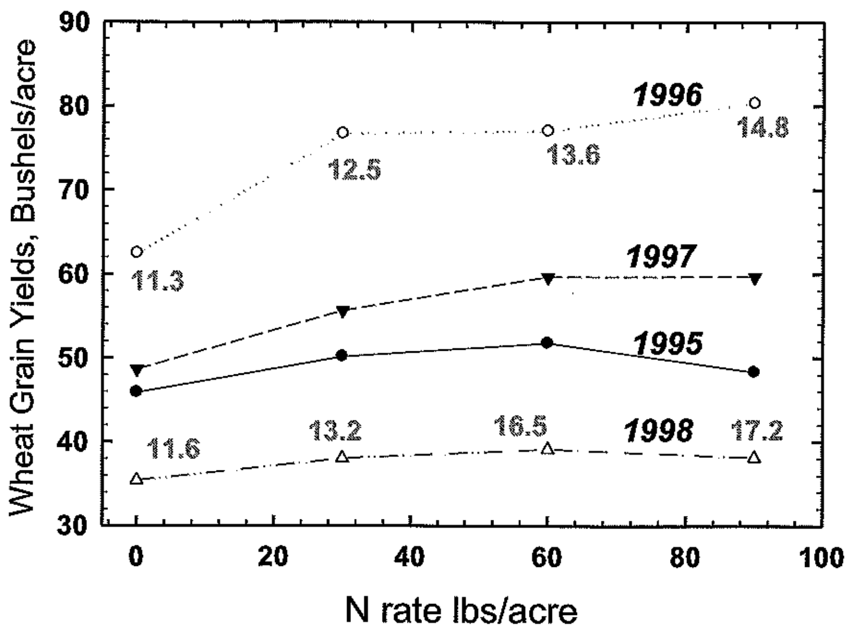


Fig 2. Wheat grain yields and protein contents as a function of N rate in 1995, 1996, 1997 and 1998 (associated wheat grain protein contents are placed near the symbols (triangles and circles in red).

Summary Statements

The actual relationship between fertilizer N applied and wheat protein that you observe on your farm depends on your residual soil N levels, the inherent N fertility of the soil (how much organic matter you have), the weather you get in a given year, and most importantly how much N is applied on your fields.

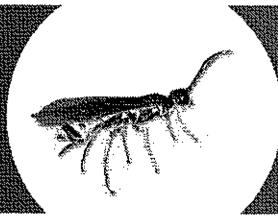
Soil testing and grain protein testing gives a farmer wonderful feedback on a field's N status. Specifically soil testing and grain protein testing can tell a farmer if a field has had enough available N or not. If your wheat proteins are consistently coming back from testing at less than 11.5% protein you need more fertilizer N in your wheat enterprise. This is especially true if low proteins are measured in a dry year when wheat proteins tend to be naturally elevated.

In Susan Latshaw's research (harvested in 2011-2012) we evaluated 20 different wheat cultivars (new and old cultivars) at 5 N rates. In all cases for all 20 wheat varieties, as we increased the N rate the wheat proteins increased. In the second year (2012) we looked specifically at two cultivars Snowmass and Byrd. The magnitude of the protein content increase was slightly different for each of the cultivars. However, the same trend for increased protein content with an increase in N rate was observed for both varieties. In both years the lowest proteins were at the zero N rate and the highest proteins were at the high N rates. Wheat proteins were all above 12% at the 75lb N rate in both years the study was conducted. However, in the low yielding year just 25 lbs of N was enough to get all 18 of the 20 varieties to proteins above 12%.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

KANSAS CROP PESTS

K-STATE Research and Extension



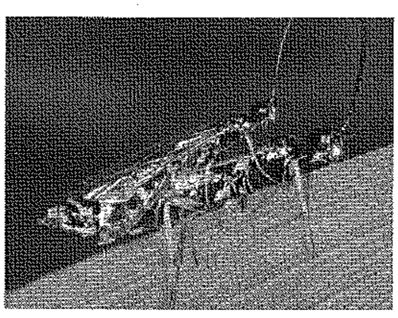
Wheat Stem Sawfly

History

The wheat stem sawfly, *Cephus cinctus* Norton (Hymenoptera: Cephidae), is a herbivorous wasp that attacks a number of native grass species in North America. It was first reported attacking wheat in Canada in 1896 and soon spread to become a serious pest of spring wheat throughout the Dakotas, Montana, and Wyoming. The wheat stem sawfly has long been present in wild grass species over a much broader range, including Nebraska and Kansas, although neighboring wheat fields were unaffected.

Historically, only spring wheat was attacked. It was not until the 1980s that infestations were observed in winter wheat. By 1996, scientists working in Montana determined that the pest had evolved faster development and was emerging some 20 days earlier than it previously had, enabling it to survive in early-maturing winter wheat. Recent observations in Nebraska (2012) indicate that 50 percent of adults emerged by May 22, although this was a particularly early spring.

Collectively, research suggests that attacks on winter wheat may have been occurring for some time but went unnoticed because larvae did not complete development and cut stems. This may be the case in Kansas currently, with populations under strong selection to evolve faster development. It is not yet clear if recent winter wheat infestations in the Nebraska panhandle and northeastern Colorado result from local populations evolving to exploit winter wheat, or the southerly range expansion of an adapted strain. Local populations express significant variation in biology, behavior, and genetics that suggest regional adaptations. Presently, Kansas is on the southeastern boundary of the region experiencing wheat stem sawfly problems in winter wheat.



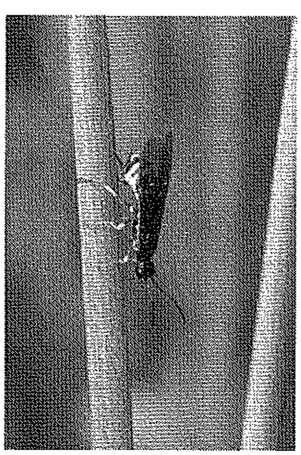


Figure 1. Adult wheat stem sawflies mating (above)

Figure 2. Female wasp ovipositing (right)

Identification

The adult wasp is about half an inch long with a black body and three broad, transverse yellow bands on the abdomen. Legs are yellow and wings are a dark, smoky grey. Females are significantly larger than males (Figure 1) with a short, curved ovipositor that is externally visible (Figure 2). Eggs are whitish and elongate, difficult to observe, and usually laid in the uppermost portions of the stem (Figure 3). Larvae are initially colorless (Figure 4), soon turning cream-colored with a dark head capsule; they feed inside stems, moving to the base of the plant as they mature. Infested stems typically contain abundant frass that looks like sawdust, and larvae wriggle into a characteristic S-shape when removed (Figure 5). Another insect commonly occurring in wheat stems is the wheat stem maggot, *Meromyza americana* Fitch. Its larvae are smaller and legless. Cleanly severed stems and stubble ends packed with frass (Figure 6) indicate the presence of wheat stem sawfly.

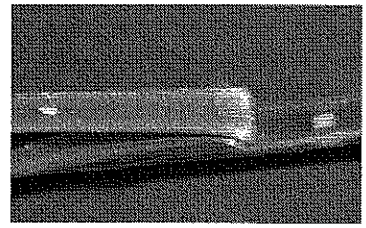


Figure 3. Eggs

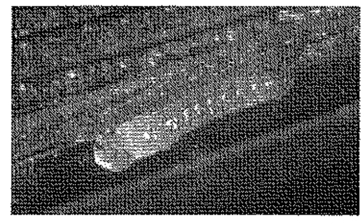


Figure 4. First instar larva

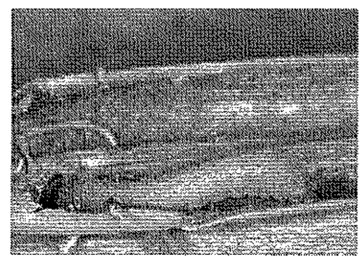


Figure 5. Mature larva in stem

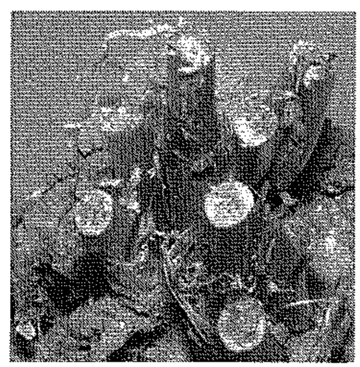


Figure 6. Stubble cut by wheat stem sawflies

Biology and Behavior

The wheat stem sawfly has only one generation per year. Adults emerge from the previous year's stubble over a period of three to five weeks in spring. As with most insects, the emergence timetable is dictated by temperature and varies with latitude and among regional populations. Males emerge slightly ahead of females and mating takes place as soon as females emerge, unless severe weather delays activity. Adults do not feed and live only about a week, but each female emerges with a full complement of up to 50 eggs. Like many other wasps, mothers can control the sex of their offspring. Fertilized eggs develop into daughters and unfertilized eggs, into sons. Females are more sensitive to host plant quality than males because body size is correlated with stem diameter and larger females emerge with more eggs. Consequently, females tend to lay fertilized eggs in larger diameter stems.

Taller, more developmentally advanced, plants tend to be preferred for oviposition. There is a strong edge effect; field margins sustain higher infestation levels when wheat stem sawflys immigrate from adjacent fields. Notably, females do not avoid laying eggs in plants already infested, even though larvae cannibalize each other until only one remains, usually the first to hatch. Western wheatgrass is a preferred host among wild grasses; smooth brome and quackgrass are also infested. Emergence from wild grasses occurs later than emergence from wheat, so wild hosts do not appear to serve as a major source of wheat infestation and probably support a different host race. Barley is a poor host relative to wheat; rye and oats are accepted for oviposition but do not support complete larval development. Recent research has shown that specific volatile chemicals emitted by host plants influence the oviposition preferences of the female and account for differences in attractiveness among some wheat varieties.

After feeding for about a month and passing through five instars, mature larvae descend to the base of the plant where they may girdle the stem (Figure 7), plugging the lumen of the stem with frass and overwintering in a silken coccoon in the chamber beneath. Although stem cutting tends to be associated with drying of the wheat, the behavior is variable and may interact with other environmental factors. Stems are not cut unless larvae complete development; a significant proportion of stubs may be cut at, or just below, ground level, and some larvae may mature without cutting at all. Significant variation in cutting propensity exists among regional populations, and the proportion of infested plants that are cut can vary greatly from site to site and year to year. Complete development requires a 90-day period of larval diapause under cold temperature conditions, followed by a pupation period that lasts up to three weeks. Pupation occurs within the stem (Figure 8) and adults emerge in mid to late spring. Although adults have been known to disperse as far as one mile, they are relatively weak fliers and tend to orient to the nearest suitable host plants.

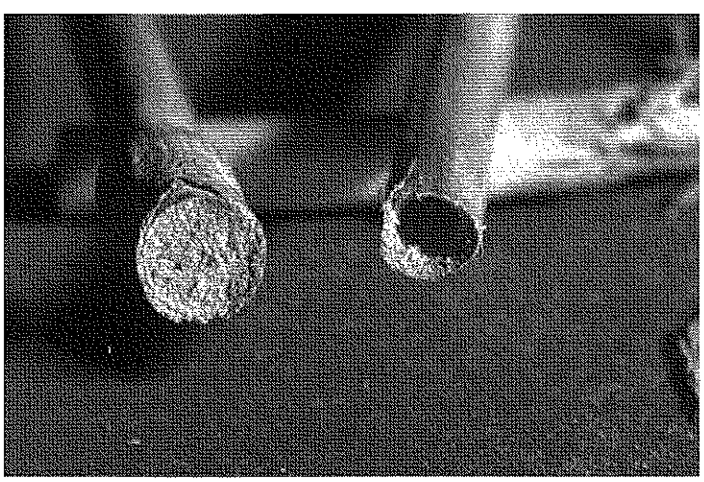


Figure 7. Cut stubble showing frass plug (left) and emergence hole (right)

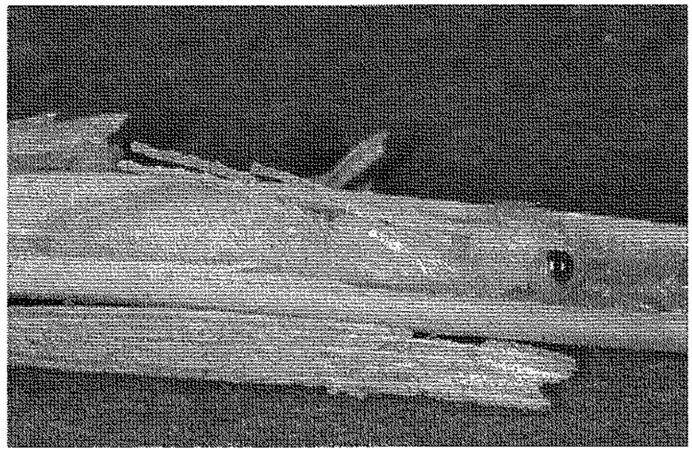


Figure 8. Pupation occurs within the stem

Larval girdling severely weakens the stem and leads to plants that lodge easily when stressed by wind. The main economic impact of wheat stem sawfly is lodged plants that cannot be picked up by the combine, and reduced harvest efficiency as slower combine speeds are required to salvage girdled plants. In addition, larval feeding disrupts translocating tissues and diminishes the photosynthetic capacity of the plant during the critical period of grain fill, reducing test weight and protein content. Both kernel weight and the number of kernels per head are affected, reducing grain weight by 10 to 25 percent and protein content by around 1 percent. However, estimates of per-plant yield reduction may underestimate yield impact at field level because of the tendency of larger plants with greater yield potential to be preferentially infested. Shriveled and misshapen kernels are another indication of wheat stem sawfly infestation (Figure 9), but these symptoms also may have other causes.

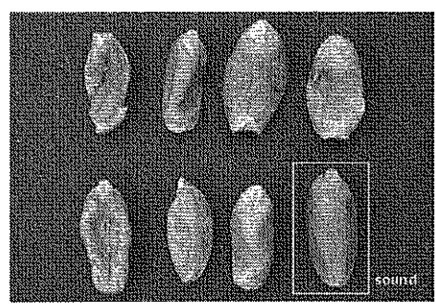


Figure 9. Shriveled and misshapen kernels may indicate infestation

Management

Cultural Control

Various cultural tactics are essential components of an effective wheat stem sawfly management strategy. It is most important to avoid planting wheat continuously in the same field once the wasp has been detected as this can lead to a very rapid increase in populations. Non-host grains such as oats and rye can be planted as trap crop strips along field borders adjacent to last year's stubble. This approach can reduce infestation of wheat and decrease wheat stem sawfly populations, but is not effective when wheat stem sawfly is abundant or emerging from stubble within the same field.

Increasing wheat stem sawfly problems have been attributed to adoption of no-till practices that favor overwintering survival of immature stages. Thus, tillage has been suggested as a control tactic. Shallow tillage can be used to disturb and expose infested stubble on the surface, causing larvae within to either desiccate in summer or freeze in winter. Unfortunately, no-till is the most important means of soil moisture conservation on rain-fed acreage, so tillage is not an acceptable control tactic for this region. Additionally, tillage can yield inconsistent results in reducing adult wheat stem sawfly populations, because of its dependence on environmental factors to produce mortality. It also has negative impacts on beneficial parasitoids. Burning of stubble is also ineffective and associated with more negative (loss of organic matter) than positive impacts on the cropping system.

Work in North Dakota suggests that early swathing of wheat (once grain moisture drops below 40 percent) can be used to salvage yield and is usually recommended if infestation reaches or exceeds 15 percent of stems as the crop approaches maturity. Swathing requires investment in additional equipment and results in higher energy costs than direct combining. Sampling should be conducted at different places in the field — if the infestation is low, only field borders may need to be swathed. Swathing at a high cutting height (just below the heads) is recommended to help preserve beneficial parasitoids that pupate higher up in the stem.

Host plant resistance

Solid-stemmed (SS) wheat varieties have stems filled with pith to varying degrees. The SS trait presents mechanical resistance to boring larvae and has been effective in reducing both yield losses and local wheat stem sawfly populations. Early solid-stemmed varieties, such as 'Rescue' were developed in the 1950s and suffered from considerable yield drag, but more recently developed varieties have yield comparable with high-yielding, hollow-stemmed varieties. Newer solid-stemmed varieties include Choteau, released in 2003 from the Montana Agricultural Experiment Station; AC Lillian, released in 2006 from Agriculture Canada; and Mott released in 2009 from the North Dakota Agricultural Experiment Station. However, because expression of the SS trait interacts with environmental factors such as sunlight and temperature, cloudy and rainy weather can prevent the filling of the stem with pith and render solid-stemmed varieties more susceptible. Larvae in solid-stemmed plants have lower survival and less impact on yield, although they remain equally susceptible to parasitism. If wheat stem sawfly infestation reaches or exceeds 15 percent of plants, a solid-stemmed variety is recommended for planting in subsequent years. Although use of solid-stemmed varieties is currently a cornerstone of wheat stem sawfly management in the northern Great Plains, no such varieties have yet been developed for this region.

Chemical control

Insecticides are not recommended for wheat stem sawfly control for a variety of reasons. Wheat is a low-value crop grown on large acreage, making pesticide applications relatively expensive. Immature stages of the pest are all protected within the stem and trials indicate that seed treatments are ineffective, so treatments must target adults before eggs are laid. A number of insecticide labels claim to "aid in control of adults," but unfortunately, wheat stem sawfly adults emerge over an extended period and do not feed, substantially reducing their exposure. Adults must come into direct contact with an insecticide to be killed and are able to enter fields shortly after an insecticide application with minimal knockdown. Some insecticide trials timed sprays to target early, mid, and late emergence of wheat stem sawfly and found that as many as three applications of a pyrethroid insecticide only reduced infestation by half, a benefit that was far exceeded by application costs. In addition, pesticides will reduce populations of parasitoids and predators that will provide more cost effective natural control, even if it is not complete.

Biological control

Various natural enemies attack the wheat stem sawfly in its immature stages and help to suppress populations to varying degrees in different localities. The primary parasitoid of wheat stem sawfly larvae is the wasp *Bracon cephi* (Gahan), although *B. lissogaster* Muesebeck also contributes mortality in natural grassy areas. These wasps are ectoparasitoids that lay their eggs on wheat stem sawfly larvae within the stem (Figure 10), and then feed externally on their host. Although the parasitized larva feeds for some time, it does not survive to cut the stem and as a result, plant damage and yield impact are substantially diminished. Unlike the wheat stem sawfly, parasitoids have a second generation close to, or just after, wheat harvest and their effectiveness in different localities may partly depend on their ability to find alternative hosts for overwintering. Wheat should be harvested with a high cutting height (just below heads) to conserve parasitoids that pupate higher in wheat stems. Parasitoids have tracked infestations of wheat stem sawfly into Colorado and Nebraska, and they can be expected to contribute to mortality in Kansas, although no data is yet available.

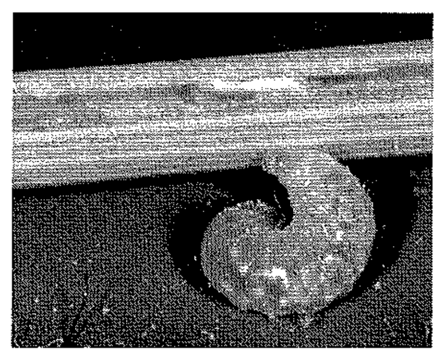
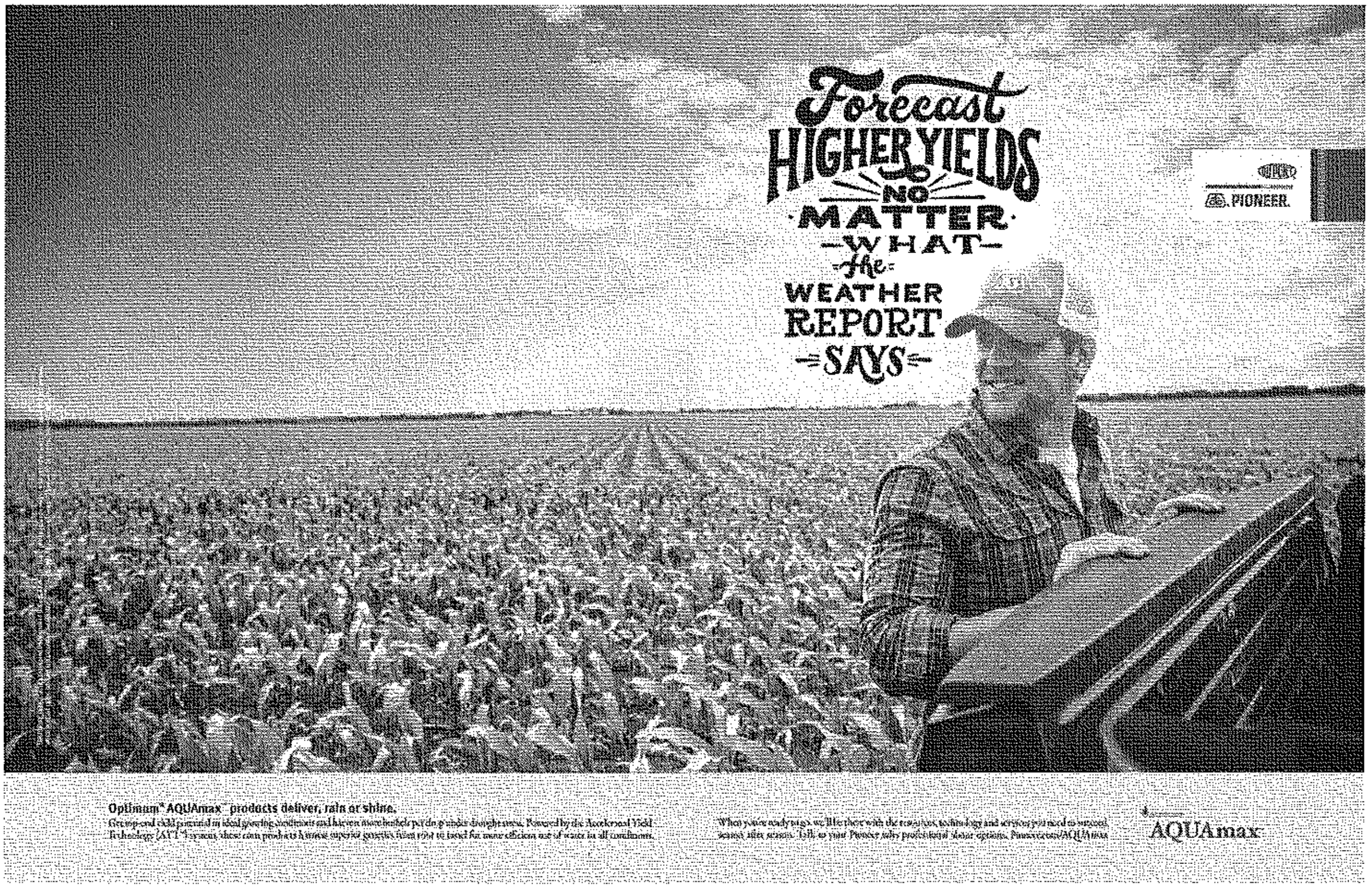


Figure 10. Larva of Bracon cephi.



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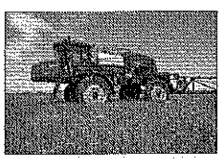

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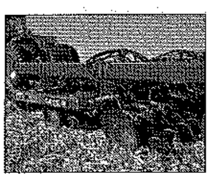

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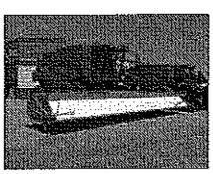

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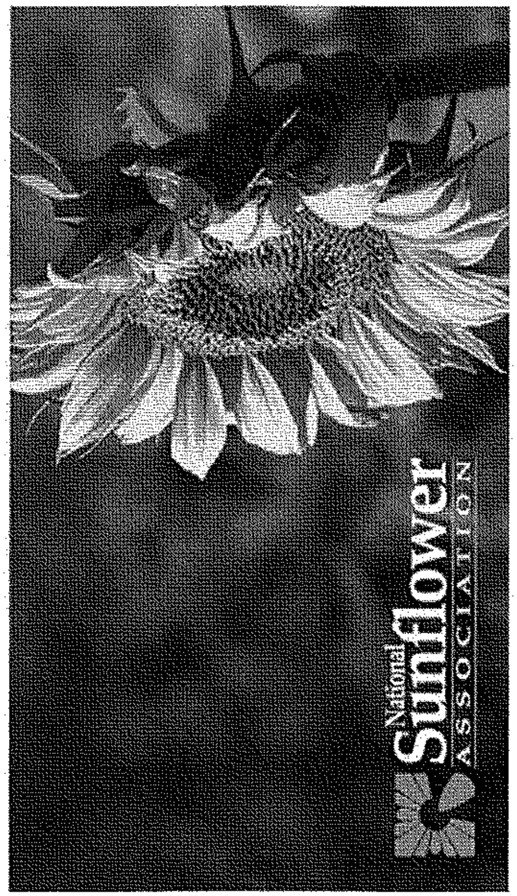

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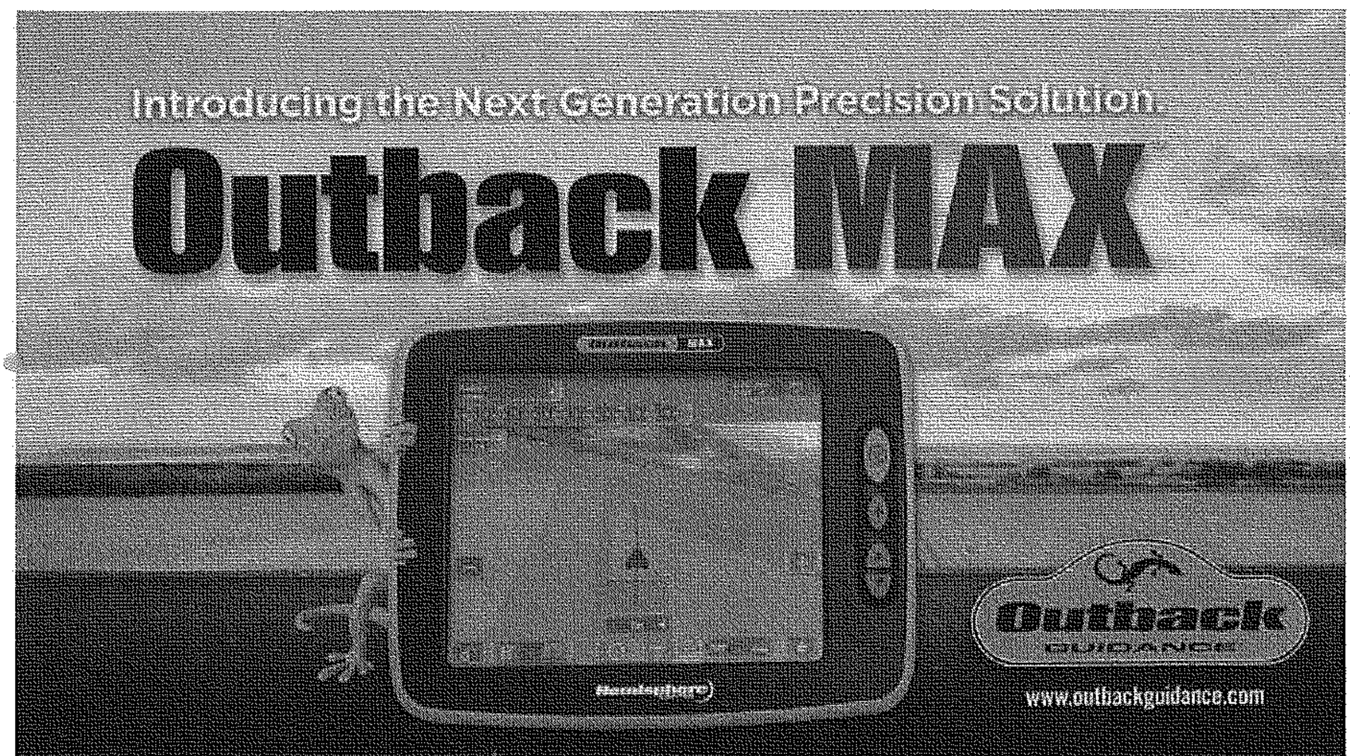

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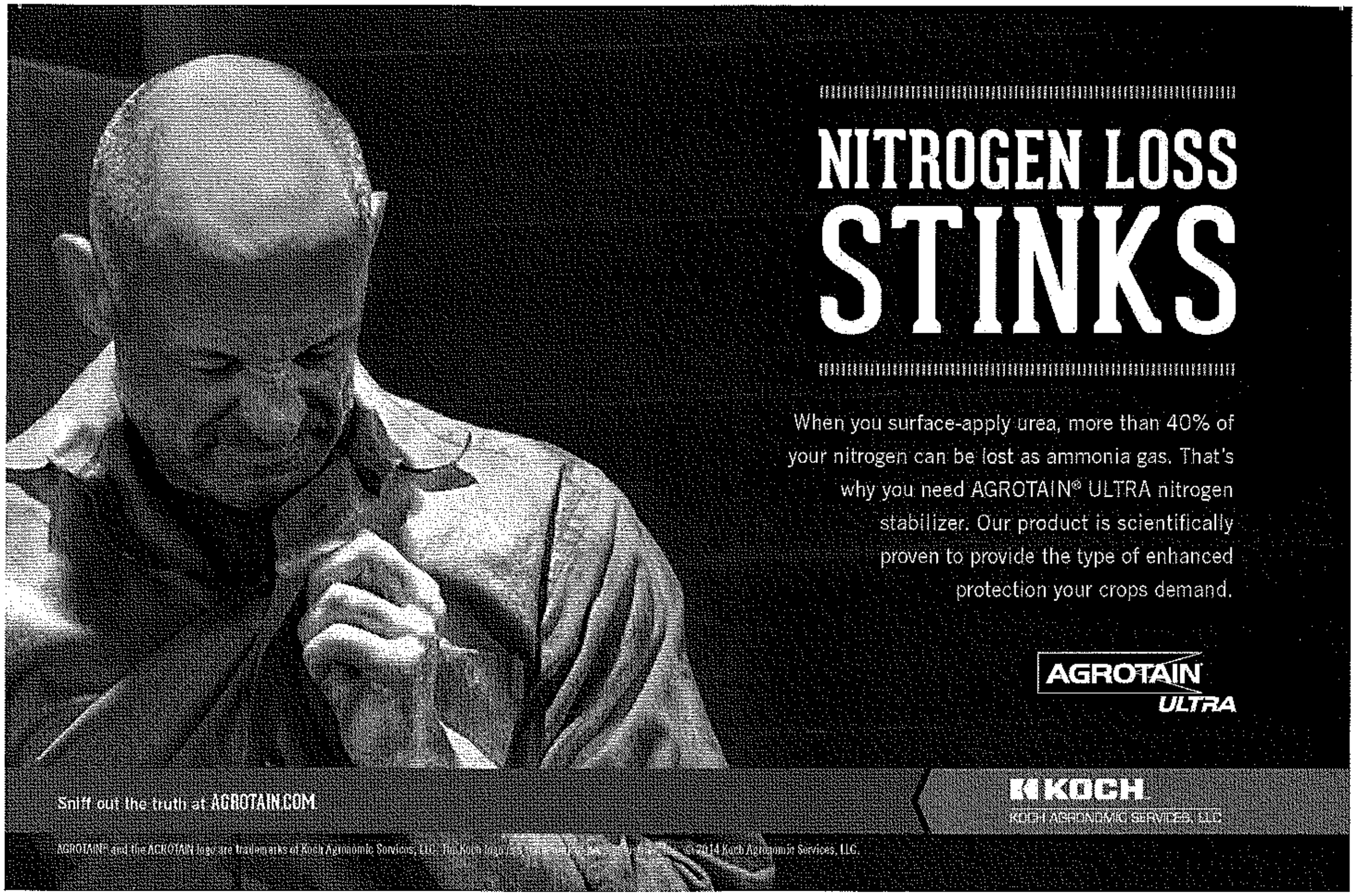
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Weather:	
National Weather Service	www.weather.gov
CoCoRahs	www.cocorahs.org
The Weather Channel	www.weather.com
Weather Underground	www.wunderground.com
Drought Monitor	www.droughtmonitor.unl.edu
Markets:	
Chicago Board of Trade	www.cbot.com
DTN	www.dtnprogressivefarmer.com
Dow Jones	www.dowjones.com
News:	
Ag Web (Farm Journal)	www.agweb.com
Agriculture.com (Successful Farming)	www.agriculture.com
Farm Progress (Kansas Farmer)	www.farmprogress.com
Grass and Grain	www.grassandgrain.com
High Plains Journal	www.hpj.com
University:	
K-State Research and Extension	www.ksre.ksu.edu
K-State Department of Agronomy	www.agronomy.ksu.edu
K-State Ag Economics Extension	www.agmanager.info
K-State Department of Entomology	www.entomology.ksu.edu
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K-State Department of Bio and Ag Engineering	www.bae.ksu.edu
K-State Mobile Irrigation Lab	www.mobileirrigationlab.com
K-State Western Kansas Ag Research Centers	www.wkarc.org
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Kansas Wheat (Kansas Wheat Commission & Kansas Assoc of Wheat Growers)	www.kswheat.com
Herbicide Labels:	
Greenbook	www.greenbook.net
CDMS	www.cdms.net
Discussion Boards:	
New Ag Talk	www.newagtalk.com

The plan for the day...

	Room 1	Room 2	Room 3	Room 4
7:45 8:15	*Registration*			
8:15 8:20	*Welcome*			
8:30 9:20	Weed Control Plan for Your Farm[1,2] *(C. Thompson)*	Steps of No-till Yield Advancement[1] *(R. Anderson)*	Hot Topics on Corn Pest Mgmt[1,2] *(D. Jardine/S. Zukoff)*	*BCS Kochia Solutions (Bayer Crop Science) (I)*
9:30 10:20	Pushing Wheat Yields to the Next Level[1] *(J. Shroyer)*	Cropping Intensity: Are there limits?[1] *(M. Vigil)*	Dryland/Limited Irrg. Fertility Mgmt[1] *(A. Schlegel)*	*AquaMAX Hybrid Perform (DuPont Crop Science) (I)*
10:20 10:50	*View Exhibits*			
10:50 11:40	Ag Policy[1] *(B. Flinchbaugh)*	Wheat Stem Sawfly & Wheat Pests[1,2] *(J. Michaud)*	Steps of No-till Yield Advancement[1] *(R. Anderson)*	*Sunflower Production Update (Nat'l Sunflower Assoc) (I)*
11:50 12:40	Hot Topics on Corn Pest Mgmt[1,2] *(D. Jardine/S. Zukoff)*	Pushing Wheat Yields to the Next Level[1] *(J. Shroyer)*	*Lunch*	
12:50 1:40	Dryland/Limited Irr. Fertility Mgmt[1] *(A. Schlegel)*	Cropping Intensity: Are there limits?[1] *(M. Vigil)*		
1:50 2:40	Ag Policy[1] *(B. Flinchbaugh)*	Weed Control Plan for Your Farm[1,2] *(C. Thompson)*	Wheat Fertility Mgmt[1] *(L. Haag/M. Vigil)*	*Resistant Weed Mgmt (Monsanto) (I)*
2:40 3:10	*View Exhibits*			
3:10 4:00	Producer Discussion Panel	Wheat Stem Sawfly & Wheat Pests[1,2] *(J. Michaud)*	2014 Feedgrain & Wheat Markets[1] *(D. O'Brien)*	*Strategies for Weed Control (Sims Fertilizer) (I)*
4:10 5:00	2014 Feedgrain & Wheat Markets[1] *(D. O'Brien)*	Wheat Fertility Mgmt[1] *(L. Haag/M. Vigil)*	*Nitrogen Efficiency & Technologies (Koch) (I)*	*Getting Started-Precision Ag (PacLeader Technology) (I)*

(I) indicate industry sessions.

[1] Indicate Certified Crop Advisor CEUs applied for.

[2] Indicate Commercial Applicator CEUs applied for.

This conference is organized by a committee of producers and K-State Research & Extension personnel. Co-chairs of this committee are Lucas Haag, K-State Northwest Area Agronomist and Jeanne Falk Jones, K-State Multi-County Agronomist.

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