Fluid JOURNAL

Official Journal of the Fluid Fertilizer Foundation

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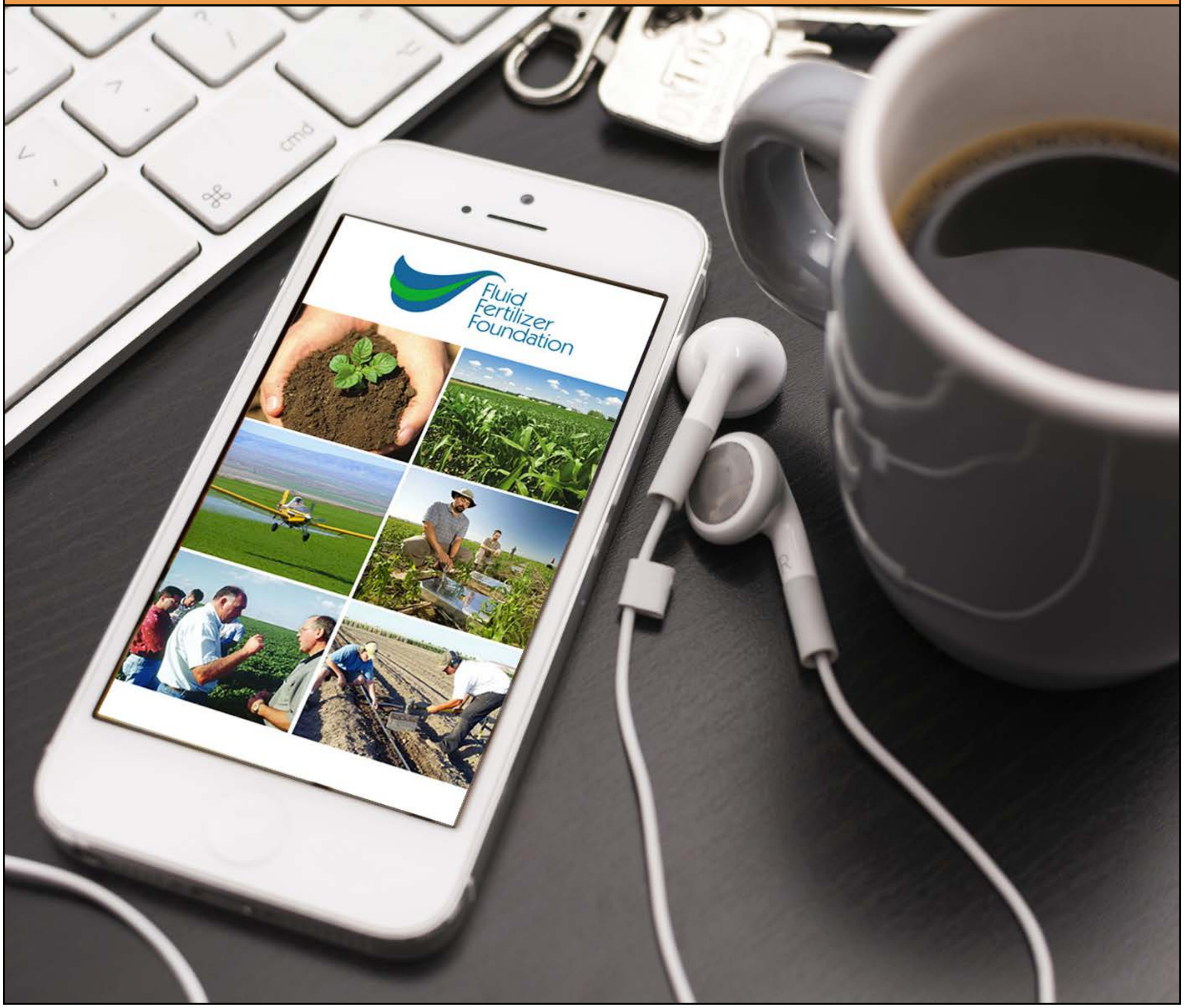

Join Us At The 2016 Fluid Forum

The Fluid Fertilizer Foundation was established by the fluid fertilizer industry 33 years ago! A few of the achievements of the Fluid Fertilizer Foundation since its inception in 1982 include:

- **Supported millions of dollars of applied crop production research**
- **Provided technical and agronomic education to thousands of agricultural professionals**
- **Published hundreds of scientific articles in our flagship publication, the *Fluid Journal***

This year's Fluid Forum will be at the Talking Stick Resort, 9800 East Indian Bend Rd. on February 15-16, 2016 in Scottsdale AZ 85256.

For additional information about the 2016 Forum, please see our website at http://www.fluidfertilizer.com/

Not a Fluid Fertilizer Foundation member yet? Please contact us at 785-776-0273 or by e-mail at fluidfertilizer@fff.kscoxmail.com

Fluid Fertilizer Foundation

Fluid JOURNAL

Official Journal of the Fluid Fertilizer Foundation

Spring 2015 • Vol. 22, No. 2, Issue #83

ARTICLES

THE FLUID JOURNAL - MISSION

The Fluid Journal is published by the Fluid Fertilizer Foundation. The FFF is a non-profit organization committed to researching and providing information about fluid fertilizer technology. Since its formation, the FFF has funded over $3 million in fluid fertilizer research. We have accumulated thousands of pages of research data. The main goal of the Fluid Journal is to transfer this technical information into easy to read form to farmers and dealers so they may be better informed as to the technological advancements that the fluid fertilizer industry has achieved.

FOCUS

The Fluid Journal is focused on disseminating fluid fertilizer technology to universities, dealers, equipment manufacturers and fertilizer producers. Our editorial matter focuses on several areas:

- Evaluate the agronomics of fluid fertilizers in the production of maximum economic crop yields
- Evaluate application techniques for fluid fertilizers.
- Investigate and inform our readers of innovative uses of fluid fertilizers under varied cultural, pest control and water management practices.
- Evaluate the efficiencies and conveniences of fluid fertilizer systems.
- Evaluate methods of controlling environmental problems with fluids.

From The Publishers

Moving on Ahead

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We commented several years ago about transitions we've had with the Fluid Journal since its inception in 1993 from print to the internet. It has vastly expanded our audience to where we are read in 104 countries and regions throughout the world, introducing or informing a vast sea of readers on all the advantages of using fluid fertilizers to nourish crops to produce even higher yields. We don't need to inquire of our readers by phone or mail about their interest in the proven value of applying fluid fertilizers to achieve higher crop yields as reported by university research and our vast dealership network. We know by electronic hits who our readers are, how long they stay on line, who are new and those who return regularly.

But, now in our lead article, you will learn from our digital publishing consultant, Ken Cooper, how we have expanded beyond the internet so that you can carry the wisdom of the entire Fluid Journal and its archives via a search App that fits in your pocket. No longer are you confined to any particular location. You can be in a farm field or traveling by air and search the vast field of information within the Fluid Journal.

And typical of that vast field are some penetrating articles in this issue of the Fluid Journal on subjects presented in February at this year's FFF Fluid Forum at Talking Stick Resort in Scottsdale, Arizona.

One covers an interesting study on the use of variable-rate seeding to manage in-field spatial variability. The study shows that relationship between plant population and yield follows a quadratic function where an optimal plant population can be applied to reach maximum yield. A higher level of fertility, such as phosphorus or higher organic matter content, can potentially indicate a higher seed rate.

"Moving ahead is our ever-enduring mission"

Another article covers closing yield gaps by reducing variables induced by weather and soil type. One study showed how when water was a non-limiting factor, yield variability was minimized and yield advantage, between farmer practice and use of a balanced approach, was maximized. It also demonstrated that closing sorghum yield gaps can be partially achieved when variability induced by weather and/or soil type is reduced.

These are but a couple of examples of the valuable information passed on concerning the advantages of using fluid fertilizers in crop production. Moving ahead by finding more and better ways to reach agriculturists who can use valuable tips on raising more productive crops via the advanced technology of fluid fertilizers is our ever-enduring mission.

The FFF Archives In Your Pocket

The Fluid Fertilizer Foundation's new search App delivers.

Ken Cooper

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***Summary:** The Fluid Fertilizer Foundation (FFF) App has already proven to be as popular as our flagship Fluid Journal online digital edition. The search App is available at Apple App Stores for iPhones and iPads, as well as Google Play Stores for Android smart phones and tablets.*

For years the wisdom of the entire Fluid Journal archive has been available online in downloadable PDF form from the FFF website. However, web access was required. Then the Fluid Journal entered the age of digital publishing and began to publish new issues online at www.fluidjournalonline.com

The online digital edition enabled the Fluid Journal to extend its reach around the world. Today we are seen in 104 countries and regions around the world, and have had readership reports where pageviews ran in excess of 90,000 over a year's time. These are not guesstimates done by phone or mail surveys but electronic hits. We know session duration and bounce rates, who are new visitors, and returning visitors--all verified by sophisticated analytics.

But imagine now carrying the wisdom of the entire Fluid Journal and its archives in your pocket--whether you're in an automobile, on a trip overseas in an aircraft, or walking a farm field--having answers instantly available to you even to the most difficult agronomy questions anywhere and all without internet access. That's no longer a dream but a promise the FFF is now beginning to deliver.

Unique brainchild

The trigger bringing all this has been the worldwide adoption of smartphones and tablets that have created yet another opportunity called "Apps." Dr. Dale Leikam, President of the FFF, envisioned an App that would make the entire Fluid Journal archive accessible from anywhere, without undue complexity, slow search times, or even the need for internet access.

"Imagine carrying wisdom in your pocket."

The FFF Search App was created as a self-contained search engine in App form, providing instant access to the wealth of data and research contained in the Fluid Journal archive. Both simple and complex searches can be accomplished instantly and easily, even offline.

For those with internet access on their mobile devices, each article includes a download button, delivering the PDF of the article directly to the smartphone or tablet, complete with photos, diagrams, and formulas. For those without internet access, or those who want the fastest searches, the same content is instantly accessible in searchable text form.

All of the text contained in the FFF Search App is indexed for lightning fast results. Sophisticated searches using "and," "or," and "not," similar to a web search engine are simple and easy.

The FFF Search App works for both Apple iOS and Android mobile devices. Here are some examples of the searches that are possible with the FFF Search App:

- **Nitrogen** Results include all references to "nitrogen" in the entire Fluid Journal archive
- **Nitrogen potassium** Results include only the reference where "nitrogen" and "potassium" are present in the same article
- **Nitrogen or potassium** Results include only those references that include "nitrogen" or "potassium"
- **Nitrogen not potassium** Results include only those references that include "nitrogen" but not "potassium"
- **Nitrogen 1995** Results include only those references that include "nitrogen" and "1995"
- **Nitrogen leikam** Results include only those references that include "nitrogen" and "leikam"
- **Nitrogen leikam 1995** Results include only those references that include "nitrogen" and "leikam" and "1995."

Many advance search terms, like those used by Google, also work with the FFF Search App.

Additional updates

The latest version of the FFF Search App has been redesigned to be even easier to use on mobile devices. Updates include:

- Native controls
- Improved user interface
- Convenient keyword index
- Enhanced help features
- Additional great content

One favorite feature of the FFF website has been the handy index of keywords. For instance, clicking on the key word "nitrogen" will return results for all articles containing that term.

The FFF Search App now includes the same handy keyword list, so that relevant articles for topics can be found instantly with the tap of a finger. Furthermore, users can increase the size of the typeface for easy reading in the field and on their tablets.

Availability

The FFF Search App has already proven to be as popular as our flagship Fluid Journal online digital edition. The Search App is available at Apple App Stores for iPhones and iPads as well as Google Play Stores for Android smart phones and tablets.

iOS. The FFF Search App for iOS, including iPhone and iPad is: https://itunes.apple.com/us/app/fff-search/id854896180

Android. The FFF Search App for Android smartphones and tablets is: https://play.google.com/store/apps/details?id=net.theinnovationstudio.fffsearch

Summing up

For those looking for speed and mobility in searching out information from the Fluid Journal and its vast wealth of information and data accessible from anywhere, without undue complexity, or slow search times, we urge you to contact Dale Leikam at Dale.Leikam@cox.net or Ken Cooper, at studio@theinnovationstudio.net

Ken Cooper is the FFF's digital publishing consultant at The Innovation Studio in San Antonio, Texas.

Managing In-Field Spatial Variability

Variable-rate seeding appears to be the logical way.

Drs. L. Longchamps and R Khosla

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***Summary:** This study investigates the possibility of increasing crop productivity by optimizing seed rate based on soil fertility levels and productivity potential in various parts of the field. Corn was planted at different planting densities in a research field at Colorado State University. Soil properties were characterized for the entire study area and yield was recorded using a combine harvester equipped with a yield monitor. Results confirm that the relationship between yield and seed rate follows a quadratic curve. Results also indicate that optimal plant population and maximal yields were attained in parts of the field with higher fertility (e.g. higher yield class) than in locations of lower fertility (e.g. lower yield class).*

Spatial variability exists in most farming contexts and farmers are trying to find ways to further increase their productivity by managing this variability. Among the various input management options, variable rate seeding appears as a logical way to manage in-field spatial variability.

Worldwide

Within-field spatial variability of soil chemical and physical properties (Figure 1) exists in most agronomic environments around the world. There are many natural and anthropogenic (human-made) reasons ranging from geological properties, landscape positions, or climates to as simple as uneven hand broadcasting of inputs in small-scale farming, or merging of fields with different crop histories in medium- to large-scale farming.

Quantifying

Over the last two decades of precision farming, precision agronomists and soil scientists have developed methods to quantify spatial variability that exists at the field scale. This has led to the realization that employing average values for managing crop inputs often over-estimates prescription in some parts of the field and under-estimates it in other parts of the field. To avoid these over- and under-estimations, agronomists and farmers are trying to develop site-specific crop management techniques that will enable them to manage the spatial variability that exists in their fields.

Variable-rate seeding

Plant population appears as a legitimate component of site-specific crop management in addressing spatial variability existing in crop fields. There is a growing interest in variable-rate seeding among farmers and practitioners. This, in part, is driven by increasing seed prices. As seed companies stack additional desirable traits into future crop varieties, the cost of seed will continue to rise. Hence, the technology to vary seed rate, coupled with sound scientific knowledge, will chart the way to make cropping more productive, efficient, and profitable. Some may argue that technology to vary seeding rate has arrived. Others may rightly point out that science to support the decision-making process to gainfully use the current technology is lacking.

Objective

The goal of this study was to experiment with variable-rate application of seed in a field and assess its effect on yield.

Methodology

Location. The study was conducted in Colorado during the 2014 crop growing season (April 2014 to October 2014).

Climate. The climate of north-eastern Colorado is considered semi-arid as it receives less precipitation than potential evapotranspiration. However, 2014 received one inch above the normal level

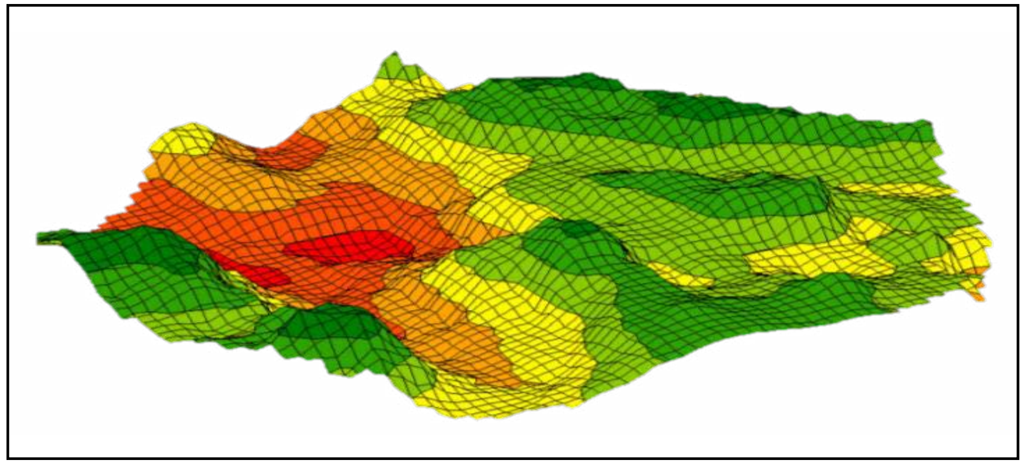

Figure 1. *A field showing spatial variability in soil properties as measured by grid soil sampling.*

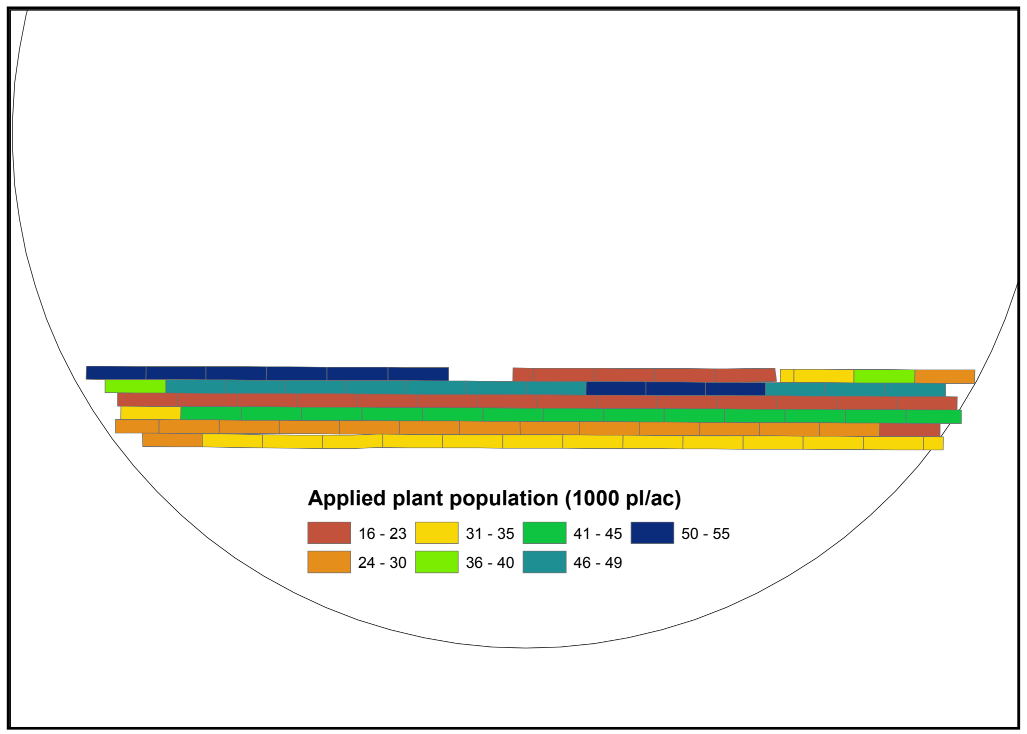

Figure 2. *Applied map of the plant population.*

of precipitation during the crop growing season.

Field. The 22-acre field is located at Colorado State University's Agricultural Research Development and Education Center in Fort Collins, Colorado.

Soil at this site is classified as a fine-loamy, mixed, super-active, mesic Aridic Haplustalf. Based on soil samples, texture was classified as a sandy clay loam.

Slope. Field slope is lower than two percent in a single plane gradient.

Site history is one of continuous maize production for ten years with conventional tillage.

Population. Corn hybrid Dekalb 4620 was planted at a population of 20,000, 27,000, 34,000, 41,000, and 48,000 plants/A (depending on plant population treatment strips) on April 29th 2014.

Seeds were planted using a precision planter in long strips crossing the entire field. The sequence of the population strips was randomly assigned.

Fertilizer. Monoammonium phosphate (100 lbs/A of 11-52-0) was applied in early spring (April 1), followed by a fluid fertilizer (UAN 32%) rate of 75 lbs of N/A at planting and 150 lbs of N/A at growth stage V8 of the crop.

Irrigation was supplied with a sprinkler irrigation system to compensate crop evapotranspiration, using the web-based irrigation scheduler eRams (www.eRams.com).

Vacuum planter. Plant population targets were programmed in a 6 rows Monosem (NG+3 Series) precision vacuum planter. This planter is equipped with sensors that monitor the actual seed rate at every location of the field and create an "as-applied" map of plant population (Figure 2). This map was used rather than the target map to analyze the data.

Harvesting. Corn was harvested on October 30th at corn maturation with a 6-rows Case IH combine harvester equipped with a yield monitor.

Data analysis

Cleaning. Yield data were cleaned to remove outliers using an algorithm rejecting all data above and below the average plus or the average minus three times the standard deviation.

Cluster. Yield was clustered in two classes based on productivity potential.

Groups. The low group was below average, while the high group was above yield average.

Quadratic function was used to model the relationship between yield and plant population, forcing the intercept to 0 on the basis that at plant population zero the yield has to be zero. The maximum of the quadratic function was considered as the optimal plant population to maximize yield.

"Seed rate potent way to measure variability in soil properties."

Soil properties were monitored at the location of each yield data point using geographic information system software. The soil properties investigated were:

- Percent sand, clay, and organic matter
- Cation exchange capacity
- Soluble salts, nitrates, phosphorus, potassium, magnesium, and calcium.

T-test. A Student's t-test was used to compare soil properties between the low and high yield data with a level of significance of 0.05.

Results

Grain yield ranged from 100 to 215 bu/A.

Quadratic relationship between plant population and yield was strong for the whole dataset, which is consistent with observations in other studies on the effect of seed rate on yield.

Dataset. When dividing the dataset in lower and higher yield based on yield average, it was possible to observe a higher optimal plant population for the higher yield dataset than for the lower yield dataset (Figure 3).

For the lower yield dataset, the optimal plant population was 37,500 plants per acre with a maximal modeled yield of 159 bu/A.

For the higher yield dataset, the optimal plant population was 40,550 plants per acre with a maximal modeled yield of 172 bu/A. The results are consistent with observations of Doerge, et al. (2015) who observed an increase in optimum economic seeding rate with increasing local yield potential.

Student's t-test. As per Student's t-test, several soil properties were significantly different between the locations of the lower yield level and the locations of the higher level (data not presented). In general, soil properties in the higher yield locations tended to indicate a more fertile soil (e.g., higher organic matter and phosphorus content, higher CEC, etc. in the higher yield locations).

However, even though Student's t-test p-values showed strong significant differences between the two classes, in an agronomic perspective, the differences are not considered very strong. Nevertheless, a synergetic combination of all these factors may have explained the higher yield obtained in these locations and hence the potential to reach higher yield with higher seed rate.

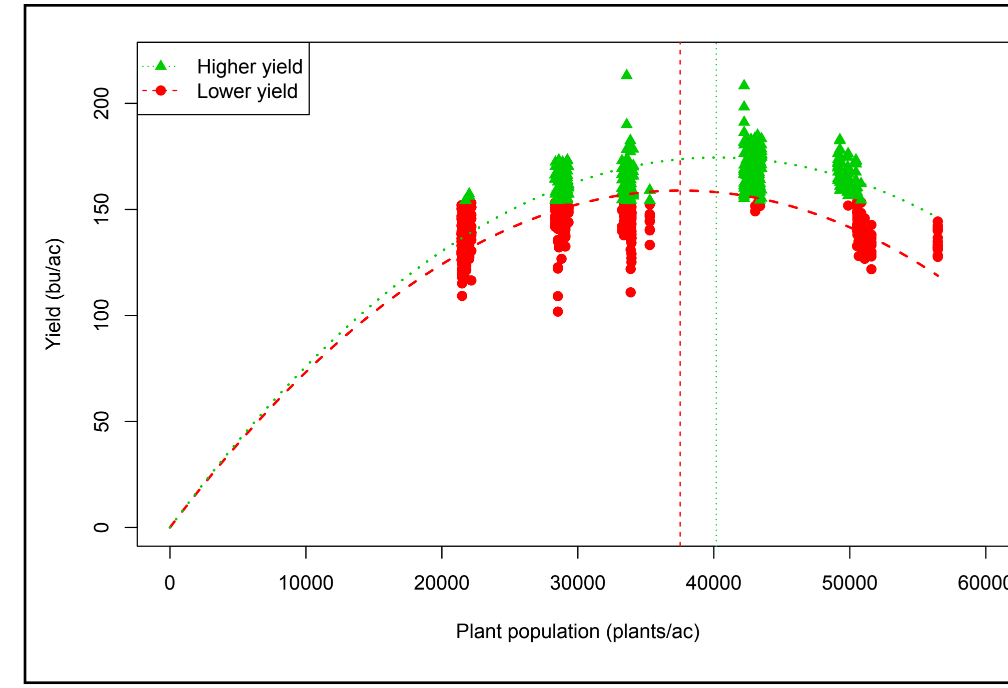

Figure 3. *Relationships between plant population and yield for two yield classes (lower or higher than yield average). Vertical lines indicate optimal plant population for each yield class.*

Summing up

Variable seed rate stands as a potent way to manage spatial variability in soil properties existing at field scale. This study showed that the relationship between plant population and yield follows a quadratic function where an optimal plant population can be applied to reach maximum yield. A higher level of fertility such as higher phosphorous or high organic matter content can potentially indicate a higher optimal seed rate.

Dr. Longchamps is an Assistant Professor and Dr. Khosla is Professor of Precision Agriculture at Colorado State University in Ft. Collins, Colorado.

Controlling Variables One Key to Closing Yield Gaps

Reducing variability induced by weather and soil type cited.

Dr. Ignacio Antonio Ciampitti and Bailey McHenry

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Summary: *The factors that were tested include narrow-row spacing, plant population, balanced nutrition practices, including various timing of nitrogen (N), phosphorus (P) and potassium (K), and micronutrient applications; crop production with fungicide and insecticide application, plant growth regulator effects, and the use of precision Ag technology for maximizing yields, including a GreenSeeker meter for more precisely determining fertilizer N needs for grain sorghum. A high performing hybrid, NK7633 (Sorghum Partners), was used in all field experiments. Not withstanding the lack of treatment difference, the grain sorghum yield gap from a common practice to kitchen sink was 12 bu/A. In Rossville, KS (under irrigation) grain sorghum yields ranged from 101 to 151 bushels/A and from 38 to 99 bushels/A in Ottawa, KS (dryland). Rainfall was limited in Ottawa during the flowering and reproductive stages of growth, which limited yield potential quite drastically.*

The USA is among the top-5 producers around the world, together with Nigeria, India, Ethiopia, and Argentina. More than 75 percent of the sorghum production, in the central and south-central region known as the "Great Plains," is produced in the states of Kansas and Texas. Sorghum improvement in the last decades evolved at a lower rate as compared with corn. Thus, the influence of management practices (M component) on sorghum productivity need to be critically considered, but as a complex interaction between the genotype (G component) and environment (E component). A better understanding of sorghum response under diverse G x E x M scenarios would allow optimizing the use of all soil-plant resources, and then closing yield gaps by maximizing sorghum yield at each specific environment, soil by weather related.

Kansas grain sorghum producers currently face low attainable yields (as related to the yield potential). This project takes into account several of the factors that farmers are faced with in making decisions about quantifying the diverse interactions that can maximize the yields. The trial was implemented at three locations: one at East Central Kansas Experiment Field near Ottawa (KS), another at the Kansas River Valley Experiment Field near Rossville (KS), and another at the North Central Kansas Experiment Field near Scandia (KS).

Objectives

The objectives of the study were to:

- Identify management factors that contribute to high yields under different environments
- Examine dry mass and nutrient (N, P, and K) partitioning and movement between leaf and stem during the vegetative phase, and head, stem, and leaves during the reproductive phase (nutrient remobilization and reproductive nutrient uptake)
- Quantify the effect of diverse production systems in biomass and yield.

Site characteristics

Soil type at the Ottawa location was a Woodson silt loam. Rossville was an Eudora sandy loam. Scandia was a Crete silt loam.

Soil samples were taken before planting at Scandia and Ottawa to a total depth of 6 inches. Pre-season soil test results show contrasting features at the locations evaluated. The parameters analyzed were pH, Melich P, cation exchange capacity (CEC), organic matter (OM), and K availability (Table 1).

Experimental design. The study was conducted in field plots measuring 10 feet wide by 50 feet long at all locations. Each treatment was replicated five times in a randomized complete block design. The sorghum hybrid used was NK7633 (Sorghum Partners), a medium-full maturity, with excellent standability, stay-green and high yield potential. Eleven treatment combinations evaluated the effect of balancing nutrients and production practices for sorghum production (Table 2). Treatment 1 was the high-intensive use of these input combinations: "kitchen sink" with narrow-row spacing (15"), optimum plant population (40,000 to 50,000 pl/A), application of N using GreenSeeker technology, micronutrients, plant growth regulator (PGR), fungicide/insecticide, starter fertilizer (PK), and chloride application. Treatment 10 was the low-input treatment ("common farming practices") with wide row spacing (30"), lower plant population, and with a standard N application (planting fertilizer N application). Fertilizer N was applied pre-planting at each location using an anhydrous ammonia source. Further

Table 1: Pre-plant soil characterization at 0-6 inch depth at Rossville and Scandia sites

Soil parameters	Rossville	Scandia
Buffer pH (SMP)	7.4	6.6
Mehlich P (ppm)	22.7	27.2
Summation CEC (meq/100g)	5.6	28.5
OM (%)	1.2	2.8
K (ppm)	102.3	614.7

Table 2: Treatment description for all sites evaluated during the 2014 growing season

	Treatments										
	1 (KS)	2 (PD)	3 (RS)	4 (PD)	5 (F/I)	6 (Micros)	7 (PGR)	8 (NP)	9 (Cl)	10 (FP)	11 (KS+N)
Seeding rate	Optimum	Normal	Optimum	Optimum	Optimum	Optimum	Optimum	Optimum	Optimum	Normal	Optimum
Row Spacing	15"	15"	30"	15"	15"	15"	15"	15"	15"	30"	15"
N Program	GS	GS	GS	Standard	GS	GS	GS	GS	GS	Standard	GS
Fungicide/Insecticide	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Micronutrients	Fe, Zn	Fe, Zn	Fe, Zn	Fe, Zn	Fe, Zn	None	Fe, Zn	Fe, Zn	Fe, Zn	None	Fe, Zn
PGR	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes
Starter Fertilizer	NPKSZn	NPKSZn	NPKSZn	NPKSZn	NPKSZn	NPKSZn	NPKSZn	NP	NPKSZn	NP	NPKSZn
Chloride	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
GreenSeeker + N	No	No	No	No	No	No	No	No	No	No	Yes

Table 3: Fertilizer application, nutrient amount, expressed in lbs per acre

Treatment #	N	Average GreenSeeker N	Total N	P2O5	K2O	S	Cl	Fe	Zn
	lbs per acre								
1	20	35	55	20	20	20	20	2	2
2	20	39	59	20	20	20	20	2	2
3	20	20	40	20	20	20	20	2	2
4	20	0	20	20	20	20	20	2	2
5	20	30	50	20	20	20	20	2	2
6	20	27	47	20	20	20	20	0	0
7	20	27	47	20	20	20	20	2	2
8	20	30	50	20	0	0	0	2	2
9	20	33	53	20	20	20	0	2	2
10	20	0	20	20	0	0	0	0	0
11	20	78	98	20	20	20	20	2	2

#All nutrients were applied at planting time, except for the extra N diagnosed via GreenSeeker technology (V5-V8 growth stage).

details about all treatment combinations can be visualized in Table 2. Fertilizer application by nutrient (expressed in lbs per acre) per treatment combination is presented in Table 3. Herbicides and hand weeding were used to maintain no weed interference for the entire season, and soil nutrient concentrations (other than N) were maintained above the recommended critical levels (through inorganic P/K applications).

In-season measurements for soil testing were collected during V-5 to V-8 (five to eight leaves) growing stages of the grain sorghum. Soil samples were taken at 0-6 inches and 0-24 inches. Information for Ottawa and Scandia is presented in Table 4. Nutrient levels were quite different for this sampling time at the Scandia location from the pre-season soil test results. Soil samples from Ottawa were taken at this time. No pre-season data are available for Ottawa. The numbers presented show the averages across all treatment combinations.

Stand counts were taken by counting the final number of plants emerged in four 17.5-foot sections of row in each plot. Plant population counts were taken approximately at V5 stage (40 days after planting). Final plant population at each site is presented in Table 5. Final plant numbers were achieved successfully with exception of some treatments at diverse locations. Plant uniformity was also a challenge faced with the use of drills for the narrow-row spacing (15") combinations. The treatments with 30-inch row spacing (treatments #3 and #10) have a greater plant population as compared with the 15-inch row spacing treatment combinations. Except for Scandia, (poor planting conditions), Rossville and Ottawa sites, the plant populations were close to the targeted one of 40,000 plants/A (Table 5).

Biomass determination was performed from five consecutive plants per plot at three diverse growth stages:

- V5
- Flowering
- Physiological maturity

Each individual plant was cut at the stem base and separated into different fractions: leaves and stem (vegetative), head, leaves, and stem (reproductive). Each fraction was separately chopped and dried to constant weight at 60o C. Nutrient concentrations are currently evaluated by a commercial lab.

Table 4: In-season soil test characterization at Ottawa and Scandia sites.

Soil parameters	Ottawa	Scandia
Buffer pH	6.3	6.7
Mehlich P (ppm)	15.4	14.1
CEC (meq/100g)	22.3	22.9
OM (%)	2.93	2.69
K (ppm)	113.8	281.3
N03-N (24") (ppm)	1.6	3.8
NH4-N (24") (ppm)	6.3	9.5
Ca (ppm)	3232.3	2851.7
Mg (ppm)	514.8	465.5
S (ppm)	5.4	9.2
Zn (ppm)	1.3	0.7
Mn (ppm)	21.6	59.5
Fe (ppm)	112.6	111.4
Cu (ppm)	2.1	1.8

Table 5: Stand counts for each treatment combination at all sites, 2014 growing season.

Treatments	Rossville	Ottawa	Scandia
	-plants in 17.5-ft row length-		
1	43.4	43.6	40.4
2	29.4	38.2	46.8
3	81.8	85.6	42.4
4	43.2	41.8	43.4
5	42.2	43.2	35.8
6	42.2	43.4	27
7	42.8	43	27.8
8	41.8	42.8	28.6
9	42.6	43.8	29
10	60.8	54.2	32.6
11	43.4	42.4	34.4
C.V.	3.49	12.32	36.72
P-value	<0.0001	<0.0001	0.1883

C.V. = coefficient of variation (%).

Table 6: Crop phenology in calendar dates for all sites, 2014 growing season.

Plant Phenology	Rossville	Scandia	Ottawa
Planting Date	19-May	22-May	26-May
V-5 growth stage	27-Jun	2-Jul	1-Jul
Flowering	1-Aug	4-Aug	8-Aug
Mid-Reproductive	29-Aug	2-Sep	11-Sep
Harvest	26-Sep	14-Nov	30-Sep

Yield information is expressed in bushels per acre adjusted to 12.5 percent moisture content. Yield was collected from the central two rows (30-in. row spacing) or four rows (15-in. row spacing) (5 ft. x 50 ft).

Grain harvest index was estimated as the ratio between the grain yield to the whole-plant biomass collected at maturity.

Crop Phenology was documented for each site as to properly identified changes in plant growth and nutrient uptake rates (Table 6). The time from planting to flowering was similar at all locations, with approximately 72 to 75 days of duration of this phonological time interval.

Weather information at all sites was recorded and seasonal precipitation distribution, expressed in inches, was documented throughout the entire growing season (from planting to harvest time) for the sorghum crop (Figure 1). At Ottawa, low precipitation (~3 inch) was registered from mid-July to mid-August, which affected the flowering period (greater grain abortion), with a similar situation for Scandia from mid-June to the end of July (Figure 1).

Results

Sorghum grain yields were highly variable within the treatments evaluated and between experiments. A descriptive statistic for the parameter was performed, which demonstrates the dispersion of the yield distribution from all replications at each site (Table 7). The site most impacted by the drought stress experienced during the flowering time was the Ottawa study (Figure 1) with high variability on minimum and maximum yield, which was documented in the high CV number (close to 24%, Table 7). Minimum CV% was recorded at Rossville, highly influenced by the irrigation component.

For Scandia, the treatments evaluated did not present any significant difference for the yield factor (P=0.89). One of the lowest grain yields, 103 bu/A, was obtained when common practices were implemented (treatment #10) whereas yield was maximized at 115 bu/A when the "kitchen sink" approach was employed (treatment # 1). Although treatment was not statistically significant, the grain sorghum yield gap was 12 bu/A when high (treatment #1) vs low (treatment #10) input costs were compared (Figure 2).

In Ottawa, the cropping system approach did not influence sorghum grain yields, which may be related to the low yield potential explored in this location (reproductive-stage drought stress) (P =0.99).

In Rossville, the maximum yield gap documented between the highest-yielding treatment ("kitchen sink" without chloride application, treatment 9) and lowest-yielding scenario (check, treatment 10) was close to 20 bu/A (135 vs 114 bu/A, respectively). The diverse systems evaluated did not differ in sorghum grain yield, with a slightly

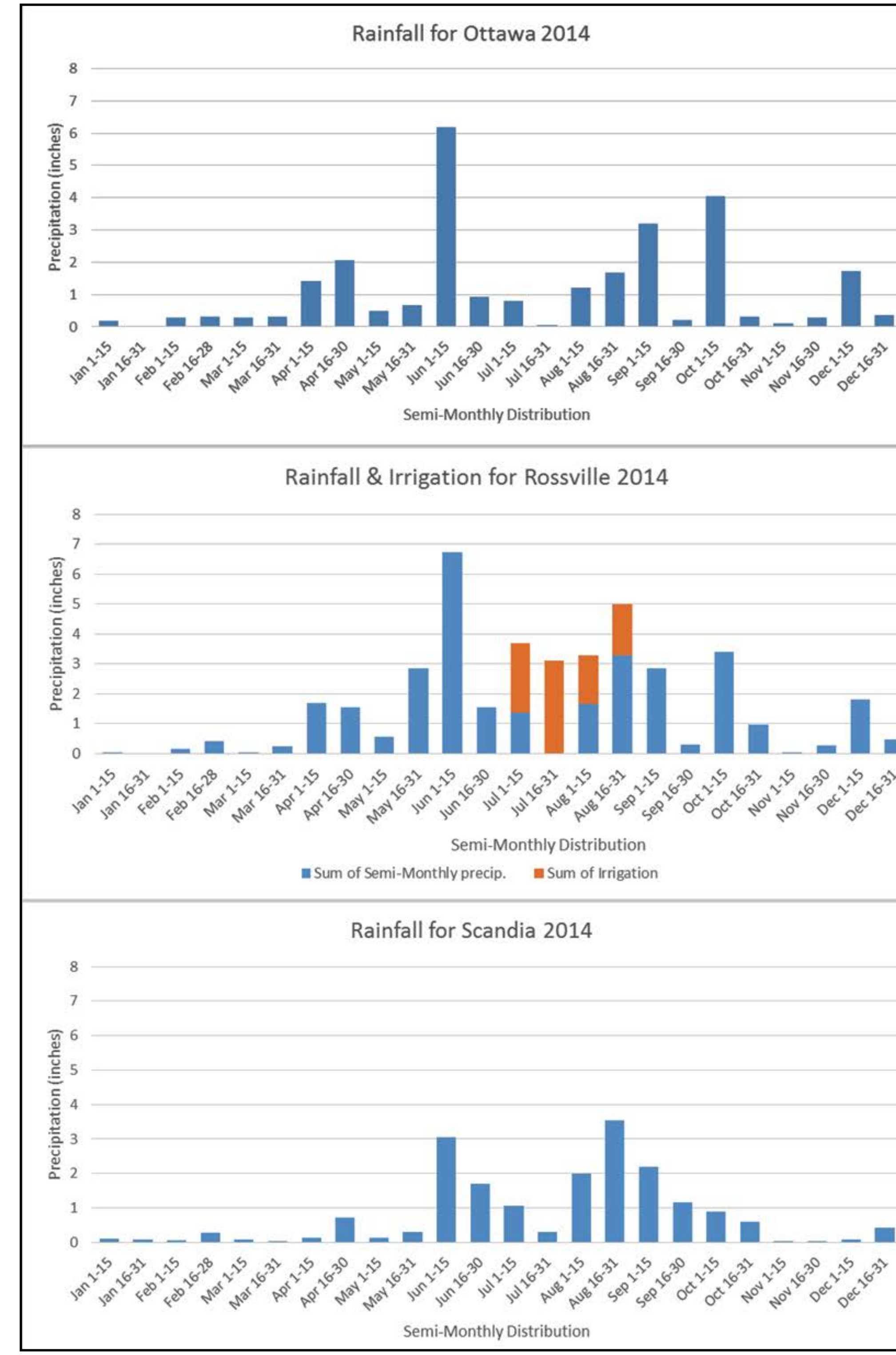

Figure 1. *Seasonal precipitation distribution (expressed in inches per 15-day time interval) at Ottawa, Rossville, and Scandia sites for sorghum crop during the 2014 growing season.*

Table 7: Descriptive statistics (mean, minimum, maximum, and coefficient of variation, CV) on yield parameter, expressed in bushels per acre, for all sites, 2014 growing season.

Field Site	Mean Yield	Min. Yield	Max. Yield	Coefficient of Variation
	- bushels per acre-			%
Scandia	109	82	139	13.7
Rossville	129	101	151	8.3
Ottawa	68	38	99	23.8

statistically significant yield difference from all treatments versus the check (P = 0.07), a common-practice approach (treatment 10), Figure 2.

Grain harvest index (HI) did not show any significant trend at Scandia and Ottawa, with overall grain HI values below 55 units. At Rossville, grain HI for treatment #1 was greater than 60 units, which demonstrates a superior biomass partition to the grain as compared with the whole plant biomass (above-ground biomass) (Figure 3). The farmer practice (FP, treatment #10) depicted the lowest grain HI coefficient, 56 units. The lowest efficiency in partitioning biomass to the grain was correlated to the inferior yield obtained for this treatment (FP, treatment #10) at the end of the growing season (Figure 3).

Individual plants were measured (approximately 1,500 plants for two sites) in nondestructive areas for each treatment combination. Various morpho-physiological measurements were taken primarily at V5 (vegetative period) and at R1 stages (reproductive period). The plant height measured from the stem base to the collar of the uppermost leaf and stem diameter by recording maximum diameter at the stem base. The information collected from the plant height and stem diameter was used to calculate the allometric relationship between the per-plant stem volume [estimated via the cylindrical formula-based, stem volume calculation = 3.1416 *(stem diameter/2)* plant height].

"Further site x year evaluation is needed to confirm findings."

This approach was previously used for estimating biomass for corn, but as far as the extent of our knowledge, it was never implemented for sorghum. The stem volume parameter (calculated using the plant height and stem diameter measured at flowering) was correlated with the per-plant dry mass values obtained in sorghum plants for all treatment combinations at Scandia and at Ottawa (Figure 4). The correlation presented for the above-mentioned association can be used as a pragmatic tool for estimating plant growth rates under diverse production practices for sorghum crops.

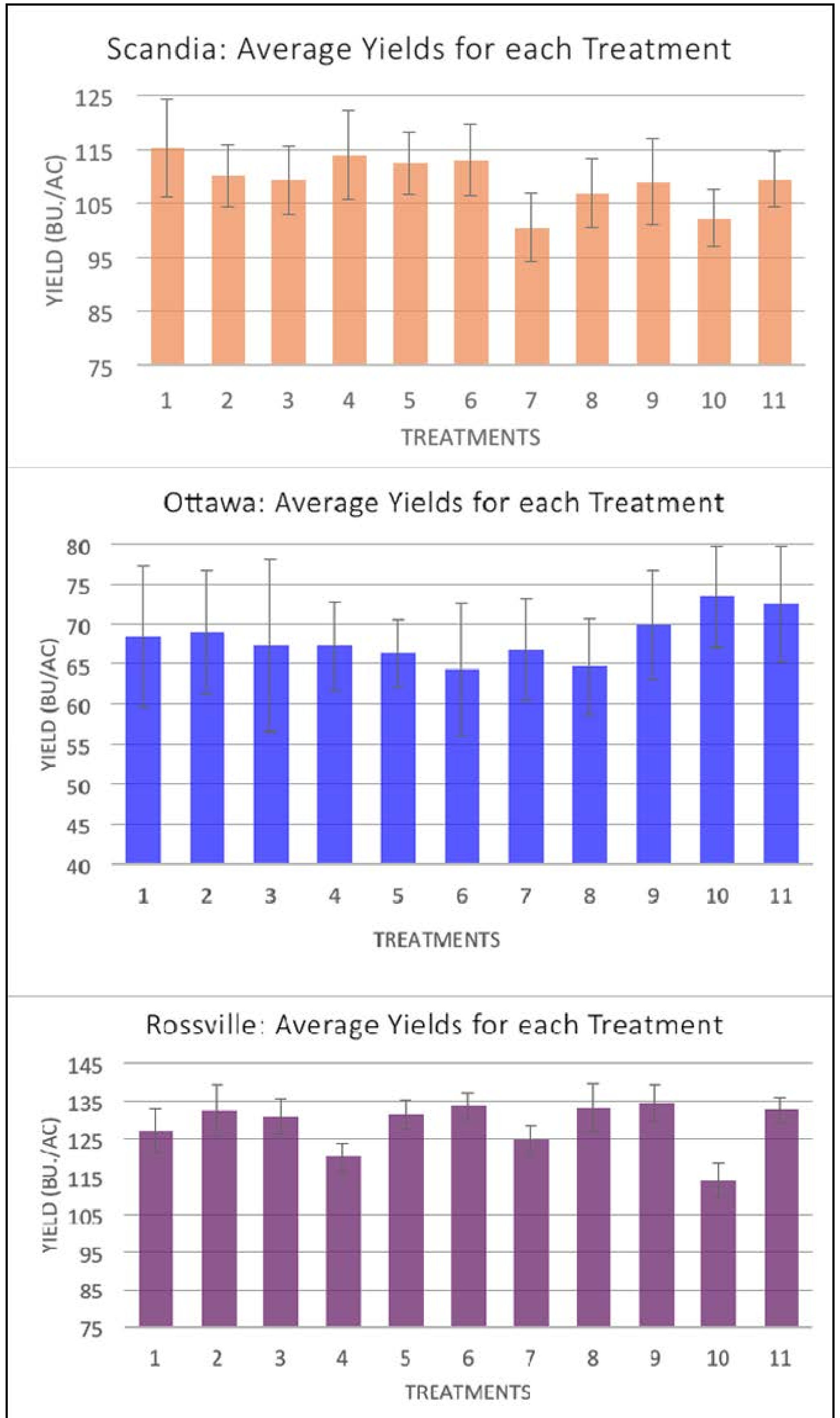

Figure 2. *Sorghum grain yield, in bu./acre, under diverse cropping systems approaches at Scandia, Ottawa, and Rossville, 2014 growing season. Treatment description: 1= Kitchen Sink (KS); 2= Plant Density (PD); 3= Row Spacing (RS); 4= Pre-plant nitrogen only (Pre-N); 5= Fungicide/Insecticide (F/I); 6= Micronutrients (Micros); 7= Plant Growth Regulator (PGR); 8= N and Phosphorous (P) (NP); 9= Chloride (Cl); 10= Farmer Practices (FP); 11= KS + extra 50 lbs N/acre (KS+N).*

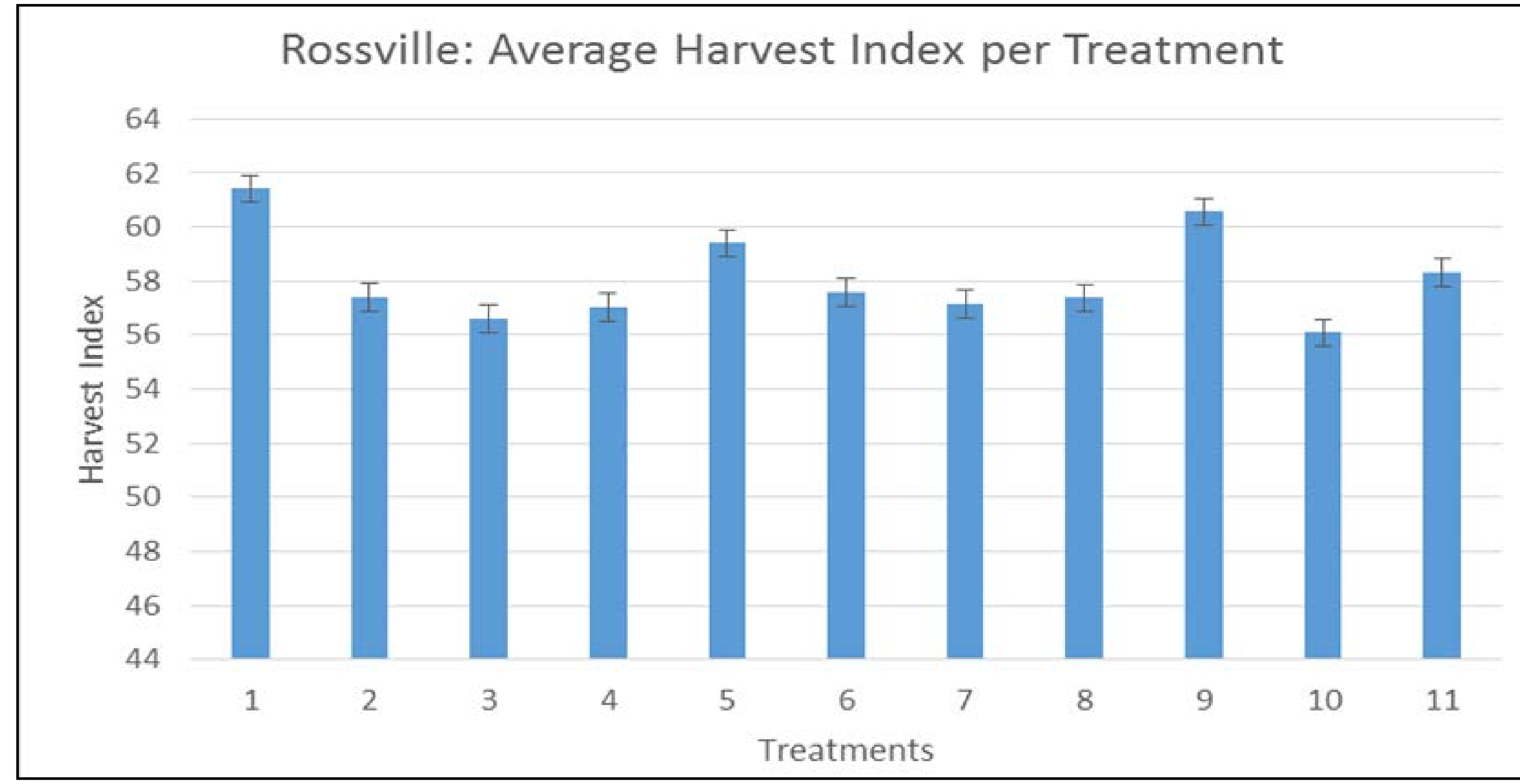

Figure 3. *Sorghum grain harvest index, estimated as the grain yield to the whole-plant biomass ratio, under diverse cropping systems approaches for the Rossville site during the 2014 growing season. Treatment description: 1= Kitchen Sink (KS); 2= Plant Density (PD); 3= Row Spacing (RS); 4= Pre-plant nitrogen only (Pre-N); 5= Fungicide/Insecticide (F/I); 6= Micronutrients (Micros); 7= Plant Growth Regulator (PGR); 8= N and Phosphorous (P) (NP); 9= Chloride (Cl); 10= Farmer Practices (FP); 11= KS + extra 50 lbs N/acre (KS+N).*

Summing up

The 2014 sorghum growing season presented early-season challenges in plant uniformity and biomass conversion due to late-season drought.

At Rossville when water was a non-limiting factor, yield variability (expressed as a CV%) was minimized and yield advantage between the farmer practice and the use of a balanced approach ("kitchen sink") was maximized. Yield gain was primarily related to whole-plant biomass and biomass conversion (measured via grain HI).

This study demonstrates that closing sorghum yield gaps can be partially achieved when variability induced via weather and/or soil type is reduced. When water was not limiting sorghum yields, a balanced nutrient application and optimization of production practices did increase grain sorghum yields ("kitchen sink" vs. "farmer practice"). Evaluation of nutrient uptake and partitioning in different plant fractions is critical for properly understanding the effect of diverse practices.

Balanced nutrient application for maximizing yields under crop management practices should be further studied for grain sorghum under diverse environments. Further site x year evaluation is needed to confirm the findings that high-yielding grain sorghum systems can be maximized via balancing nutrient applications and pushing production intensity (e.g. narrowing rows).

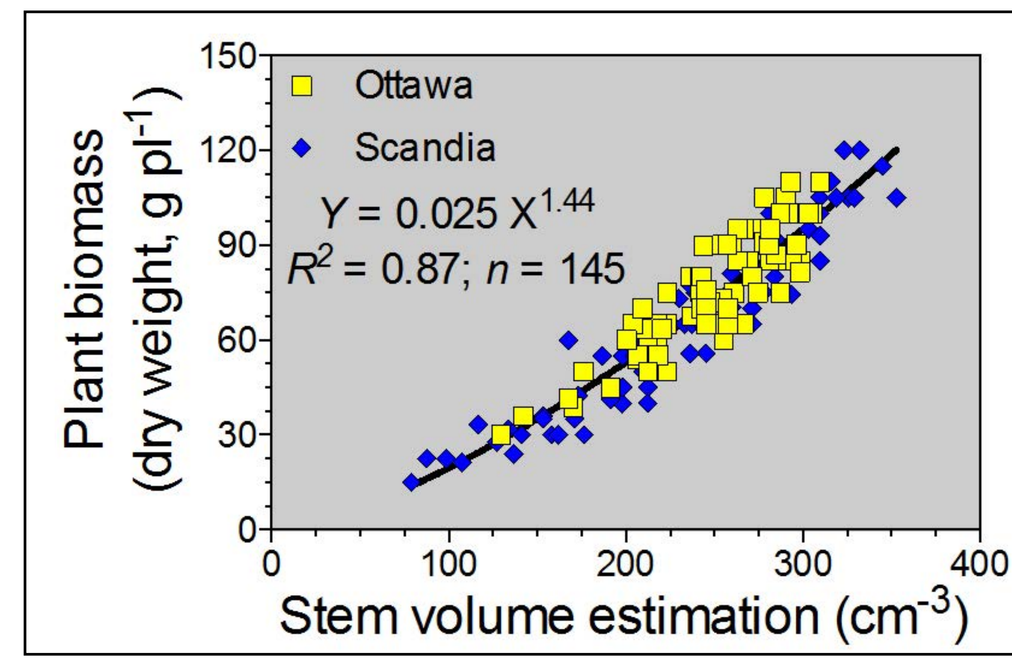

Figure 4. *Plant biomass versus stem volume calculation, implemented via determination of the stem diameter (maximum diameter at stem base) and plant height (distance from soil surface [stem base] to the collar of the uppermost extended leaf) at the flowering stage for sorghum crop at Ottawa and Scandia sites, 2014 season.*

Dr. Ignacio Ciampitti is an Assistant Professor in Crop Production and Cropping Systems Specialist and Ms. Bailey McHenry is a graduate student at Kansas State University.

Micronutrients Promote Nutrient Use, Pest, and Disease Control

Phenotypic expression of modern genetic traits another plus.

Dr. Julian Smith and Vatren Jurin

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Summary: *We are on the threshold of a new era for seed treatment methodology and agronomic application that will routinely include micronutrients to realize maximum nutrient use, pest and disease control, and phenotypic expression of modern genetic plant traits. Our work shows that seed treatment with micronutrients can be a valid component of an integrated total crop production program. In time, we visualize genotypic matching for such programs from germination to harvest by maximizing season-long gene expression.*

One of many treatments in a constant evaluation of different nutrient combinations, this one showing soybeans with top row containing Manganese and Calcium.

Our early research on the subject of micronutrient seed treatments revealed the following:

- It is not a new concept
- Most data point to a positive agronomic response
- It is not easy at a practical dealer/farmer level
- Early-season applications do not necessarily cover entire growing seasons.

The seed of most common crop species is a phenomenal physiological capsule equipped with the genetics (DNA) of the next generation, ready to create the next iteration as an identical cultivar or a hybrid. This is a fact that agriculture has been taking advantage of for eons. The mineral content of the seed serves two purposes:

- Nutrition to the consumer
- Nature's starter for the next planting.

The primary seed proteins (phytin) are phosphate-rich and are the original starter fertilizer. As nitrogen (N), phosphorus (P), and potassium (K) fluid mixes soared in popularity during the 1960s and 1970s to supplement seed reserves, it became clear that early-season or at-planting applications of fluid starters or pop-ups actually hindered yield in certain circumstances. The fluid fertilizers in question were predominantly ammonium polyphosphate solutions. Though highly effective in delivering much needed P to the germinating seed, such a high P content in the immediate root zone reduced zinc (Zn) uptake to effectively retard early growth and subsequent gene expression.

At this juncture, the introduction of micronutrients to seed application of starter or pop-up fluids became a fairly widespread practice. However, chemistry prevailed largely over agronomics. Compatibility with fluid fertilizer was an issue. It is a very harsh chemical environment but eventually EDTA and related true, strong chelates became the norm. The original complete starter was born. "Close to the seed but not in damaging proximity" was the new maxim established by Glenn Brandt, Bill Lohry, and other early pioneers of the new "NPK fluid plus micronutrient" concept.

Early issues

Salt index, free ammonia, and positional availability of the nutrients were all issues with the starter, strip, split regimes that included the early crude (agronomically) micronutrient inclusions. Nowadays, superior chemistry, application, and timing prevail to allow continued use of seed-placed NPK, plus micronutrient fluid formulations, tailored to the crop in question.

Another early use of fluid fertilizers with micronutrients and seed gained some popularity in the 1980s, the so-called seed and feed applications. Suspension type fluid NPK fertilizers were mixed directly with the seed (such as wheat and alfalfa) prior to broadcast application via flood jets. Intimate contact of nutrient and seed was thus assured at critical early growth stages of the crop.

In earlier and later crop protection developments, micronutrient applications to seed became somewhat of an accidental tourist, yet widely accepted as the progenitor to modern seed micronutrient treatment options for many crops. The inclusion of dithiocarbamate fungicides with seeds to prevent fungal pathogens would include nutritionally significant levels of zinc, manganese, and copper or combinations thereof. Subsequent widespread use of other seed fungicide treatment has perhaps further justified specific micronutrient application to the seed.

Seed treatment

There is ample evidence that in-season micronutrient applications, combined with a multitude of husbandry and environmental factors, strongly influence the expression of the genes carried by the seed. However, seed treatment with micronutrients has hitherto proved problematic from a widely adopted agronomic perspective. One of the major practical issues of seed treatment lies in the morphology of the seed coat itself.

Early seed treatments were mostly fine powder dusts that relied upon static charges to adhere to the seed. Some micronutrient powders can still be applied in this manner, but separation during seed handling may be an issue resulting in an irregular dose rate per seed. As with fluids, the seed coat will also influence adherence of the seed treatment and dictate dosage rates. Wheat and cotton, for example, have a relatively coarse seed surface, which assists in the buildup of a liquid or dry seed treatment. Canola and soybeans, on the other hand, have very smooth "slick" seed coats, which can limit both treatment dose and therefore ingredient inclusion. In the case of most fluid micronutrients, concentration of the metal is a limitation, as too much liquid is required to provide an agronomically significant level of metal, particularly when the desired level of fungicide, insecticide, and possibly a microbial inoculant are already standard in the seed treatment liquid.

Experimentation

Recent advances in polymer and inert technology and the process of seed treatment have all contributed to a renewed interest in practical application of early-season micronutrients to the seed. Our early experimentation concentrated on chelated metals, such as EDTA manganese, added as a fluid to the seed treatment mix and introduced into the treatment machinery with the seed. Concentration was indeed an issue as was the integrity of different polymers used as a sticker in the process. On a number of occasions, we could produce a solid fifty-pound seed "brick" in the bag or at best a poorly flowable seed mix, which would "bridge" in the planter boxes, resulting in missed seed planting and clogged planters. Needless to say, even if the agronomics made perfect sense, the practicality of the technique did not. Elsewhere, other teams had reported varying degrees of field success with soybean (dry EDDHA iron) and rice (zinc oxysulfate/oxide suspension) seed treatment.

We had chosen fluid EDTA chelates as we recognized the need for a soluble plant-available micronutrient from germination onwards in the plant life cycle. Concentrated suspensions can be made with inorganic salts such as metal sulfates and oxides, but water solubility (soil solution, rhizosphere) and plant availability are a concern. Release and uptake of the metal are often reliant on root exudates, including solubilizing organic acids as the plant grows--such a process is heavily species and environmentally dependent, another practical uncertainty.

Solid contender

We are optimistic that progress in material chemistry advances have put practical, reliable seed treatment with dry chelated micronutrients as a solid contender for future agronomic uses. Moreover, our current experimentation includes the interaction of metal with fungicide, insecticide, and inoculant treatments and increasingly a variety of bio-stimulants. Such treatments are also contrasted with major fluid fertility options including starter fertilizers, strip banding, and side-dressing. The subsequent use and rationale of in-season foliar micronutrients to further supplement plant growth and development is another important dimension.

Worldwide references

A review of literature on the subject of micronutrient seed treatment reveals many worldwide references covering zinc, boron, manganese, molybdenum, cobalt, copper, and iron. Much of the research has concentrated on easy seed application techniques for developing countries to enhance the nutritional quality of grains and legumes with varying success. Our information suggests that for high yield and intensive crop production, supplemental foliar or side-dress applications will be required to assist grain and seed concentration of micronutrients at harvest.

Probing deeper

Much of the foregoing has covered seed coating and/or pelleting techniques, the norm in developed agriculture. A continuous layer over the seed coat is designed to influence early micronutrient nutrition at a very intimate soil/seed interface, notably zinc. Such influence can improve yield and stress resistance. Since a great deal of stress mitigation after herbicide application or drought is through metalloproteins acting within cells to detoxify compounds or mop up free radicals (e.g. stress induced peroxides), this makes perfect sense. Interestingly, boron seed coats have increased yields of a number of crop species, including legumes. By contrast, early experiments cautioned over use of boron because of phytotoxicity. In legumes, however, adequate root B levels are positively correlated with nodulation--low levels, foiling colonization by N-fixing bacteria.

Our early data show a very positive effect from manganese seed treatment in soybeans in the absence of "deficiency". We postulate a role for metalloprotein synthesis and phosphate availability as a possible mechanism. Nickel and molybdenum have also been included in seed costs but concentration can be problematic--Mo can kill inoculant bacteria in some cases and Ni can be a fairly effective herbicide if over-dosed. Nonetheless, molybdenum/cobalt mixes are fairly popular seed applications in South American soybeans.

Seed priming

An old gardener's trick is to soak seeds in water prior to planting to speed germination and emergence after sowing. In such a manner seeds are partially hydrated and permit the start of metabolic processes without germination. In an agricultural context, such seed priming has involved dilute solutions of micronutrients to elevate seed and young shoot tissue levels to produce positive agronomic effects, including faster emergence, drastic reductions in soil application rates, early growth and subsequent yield enhancement. Such priming with zinc solutions, for example, has improved early seeding development, hormone synthesis (cell extension), stress mitigation, and resistance to soil pathogens. Similarly, seed priming with boron can improve early physiological functions including protein sythesis, hormone production, cell wall integrity, and N metabolism. Molybdenum is also intimately involved with N assimilation in legumes (N-fixation) and non-legumes (soil N utilization, reduced leaf nitrate accumulation). Some others have postulated that seed priming with Mo solutions can be much more effective than soil applications yet the antagonism toward N–fixing bacteria needs further evaluation. The beneficial effects of seed priming with Cu, Co, and Mn have also been documented.

Summing up

In conclusion, we believe we are on the threshold of a new era for seed treatment methodology and agronomic application that will routinely include micronutrients to attain maximum major nutrient use, pest and disease control, and phenotypic expression of modern genetic plant traits. Much of the positive effects will not necessarily require traditional deficiency levels but will improve cellular and organelle functions to improve productivity on the modern farm matched with modern genetics for many crop species. Seed treatment with micronutrients can be a valid component of an integrated total crop production program. In time, we visualize genotype matching for such programs from germination to harvest by maximizing season-long gene expression.

Dr. Smith is Director of Discovery and Innovation and Mr. Vatren Jurin is Director of Agronomy Services at Brandt Consolidated in Springfield, IL. Dr. Smith is also past president, chair, and current Board member of the Fluid Fertilizer Foundation and Mr. Vatren Jurin has served on the Research and Education Committee for the FFF. Brandt Consolidated, Inc. is also one of the founding members of the FFF.