THE INTERNATIONAL SOCIETY OF PRECISION AGRICULTURE PRESENTS THE
13th INTERNATIONAL CONFERENCE ON
PRECISION AGRICULTURE
July 31-August 4, 2016 • St. Louis, Missouri USA

Maize seeing rate optimization in Iowa using soil and topographic characteristics

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A paper from the Proceedings of the
13th International Conference on Precision Agriculture
July 31 – August 4, 2016
St. Louis, Missouri, USA

Abstract

The ability to collect soil, topography, and productivity information at spatial scales has become more feasible and more reliable with many advancement in precision technologies. This ability, combined with precision services and the accessibility farmers have to equipment capable implementing precision practices, has led to continued interest in making site-specific crop management decisions. The objective of this research was to utilize soil and topographic parameters to optimize seeding rates to maximize grain yield. Five maize seeding rates (61,750; 74,100; 86,450; 98,800; and 111,150 seeds ha^{-1}) were used in a randomized complete block design with four or five replications in three central Iowa fields from 2012 to 2014. Soil samples were analyzed for P, K, pH, SOM, CEC, and texture. Topographic characteristics (elevation, slope, aspect, and curvature) were determined from publically available Light Detection and Ranging (LIDAR) data. There were no interactions between seeding rate and soil and topographic variables in four site-years. There was a seeding rate interaction with a single variable (pH, elevation, curvature) in three site-years and one site-year having an interaction with three variables (pH, CEC, SOM). A fifth site-year resulted multiple seeding rate interaction, however, optimized seeding rates were not meaningful because they were extrapolated below the lowest seeding rate. The mean optimized seeding rate at Ames in 2012 was 94,256 seeds ha^{-1} with a range of 2,471 seeds. At Ogden in 2012, 2013, and 2014 the mean optimized seeding rates were 83,270; 90,383; and 81,027 seeds ha^{-1} with a range of 22,408; 23,723; and 13,495 seeds respectively. Overall, no single soil parameter or topographic characteristic was consistently identified for maize seeding rate optimization.

Keywords

Variable rate, Corn, Topography, Soil properties, Seeding rate

Introduction

The use of field information and technological advancement to aid in crop management decisions in site-specific ways is the premise behind precision agriculture (Bouma 1999; Hoeft et al. 2000; Mulla and Schepers 1997; Rawlins 1996; Searcy 1995). Grid soil sampling, variable fertilizer applications, global positioning systems and yield mapping have led to the development of variable rate seeding capabilities with the advent of planter and monitor technologies (Bullock et al. 1998; Clark and McGuckin 1996; Daberkow and McBride 1999; Mackay 1997; Nafziger 2012; Taylor and Whelan 2010). Agronomists are now offering advice and services on variable rate seeding approaches. However, for adoption of variable rate seeding technology there needs to be relationships between yield and plant density that are influenced by topography and soil parameters (Bullock et al. 1998).

Initially variable rate seeding was determined by using past yield productivity with higher seeding rates in higher productivity areas (Butzen et al. 2012; Lowenberg-DeBoer 1999). Determination of variable rate seeding methodologies have evolved as additional advancements have been made. Now variable rate seeding determination is being based on soil fertility, soil texture, SOM, landscape position, in-field elevation or some combination thereof in addition to past yield productivity (Butzen et al. 2012; Doerge 1999; Gunzenhauser and Shanahan 2011).

This research was designed to 1) isolate soil and topographic parameters that could be used to determine variable maize seeding rates and 2) identify interactions between soil and topographic parameters and seeding rates that would influence maize grain yield.

Methods

Field experiments were conducted in 2012, 2013, and 2014 at three locations (Ames, Kelley, and Ogden) in central Iowa, USA. All fields were located in the Clarion-Nicollet-Webster soil association (Clarion [fine-loamy, mixed, mesic, Typic Hapluduolls], Nicollet [fine-loamy, mixed, mesic, Aquic Hapluduolls], and Webster [fine-loam, mixed, mesic, Typic Endoaquolls]). The three sites were in a maize following maize rotation and were used each year. The experimental design was a randomized complete block where experimental treatments consisted of five seeding rates (61,750, 74,100, 86,450, 98,800, and 111,150 kernels ha^{-1}). Plots were 16 rows wide at Ames and Kelley and 12 rows wide at Ogden by field length in a 76.2cm row spacing. Field length was approximately 400m at Ames and Kelley and 720m at Ogden.

For each location planting and harvesting equipment was the same each year. Planting dates and hybrids used were typical for the area (Table 1). Different hybrids were planted each site-year resulting in the use of nine hybrids. Tillage and herbicide operations were typical to the area. Phosphorus, potassium, and lime applications were based on university recommendations. Nitrogen application was targeted at 224 kg ha^{-1} each year and was applied as a split application at Ames and Ogden and as single spring pre-plant application at Kelley.

Table 1. Hybrid, planting date, and harvest date at the three central Iowa, USA field experiment sites from 2012 to 2014.

	Ames			Kelley			Ogden		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
Hybrid	P0528XR	1161XR	P1023AM	209-85VT3Pro	9910XR	34F07	1151HR	P0993HR	1360CHR
Planting Date	11 May	18 May	7 May	14 May	14 June	9 May	9 May	14 May	7 May
Harvest Date	28 Sept	16 Oct	20 Oct	2 Oct	28 Oct	30 Oct	20 Sept	7 Oct	11 Nov

Subplots were established within each replicated seeding rate treatment 30m apart. At each subplot soil samples analysis was determined for available P, exchangeable K, pH, soil organic matter, cation exchange capacity, and soil texture. Theoretical available water holding capacity was determined using soil texture and organic matter. Topographic indicators were determined from the

LIDAR 3m Digital Elevation Model (DEM) of Boone and Story counties (https://programs.iowadnr.gov/nrgislibx/) and ArcMap (ESRI, 2014). Ear samples were collected the day of combine harvest from each subplot for determination of yield components. Yield components selected for direct determination were zipper ears, kernel rows per ear, and kernel weight. Whole sample weight, individual kernel weight, and ear sample count were used to calculate kernel number per ear. Grain yields were determined from calibrated combine yield monitor data surrounding each subplot. Additionally, early summer and harvest stand densities were determined for each subplot. Yield monitor data were processed and cleaned using Ag Leader Technology SMS Basic (Ames, IA, USA) to ensure start/stop delays, flow shifts, offsets, and erroneous points were omitted before exporting to ArcMap. ArcMap was used to determine yield and grain moisture at the subplot level. Statistical analysis was conducted using SAS software (SAS, 2012).

Results and discussion

The site years of this study proved not only to have variable soil and topographic attributes but also considerable maize grain yield and optimum seeding rate variability. Individual sites exhibited different maize yield and seeding rate responses due in part to differences in field variability. Mean grain yields across site-years were highly variable ranging from 10.4 to 12.7 Mg ha^{-1} with CV values ranging from 5.3% to 33.2% (Table 2). The annual maize yield variability can be attributed to climatic conditions: 2012 was extremely dry; 2013 was cool and wet in April and May, followed by dry conditions; and 2014 was cool and wet throughout the growing season.

Table 2. Grain yield (Mg ha^{-1}) descriptive statistics at three central Iowa, USA field experiment sites from 2012 to 2014.

	Ames			Kelley			Ogden		
Year	Mean	Range	CV (%)	Mean	Range	CV (%)	Mean	Range	CV (%)
2012	12.2	4.8–15.4	12.6	11.3	5.8–13.7	11.8	12.7	5.1–16.2	13.9
2013	10.4	0.4–13.3	33.2	10.7	6.4–12.3	8.8	10.8	0.9–16.0	17.4
2014	11.6	5.6–14.1	12.0	11.0	2.1–13.8	20.7	12.3	10.4–14.4	5.3

Slope, curvature, in-field elevation, and soil organic matter were consistently be correlated with maize yield in dry climatic conditions of 2012 (Table 3). When the planting and growing season had normal to cool/wet conditions maize yield correlations to variables were less consistent. Regression models for all site years were inconsistent in the amount of yield variability accounted for by the soil and topographic variables (16% to 77%, not shown). In totality, soil and topographic parameters related to soil water drainage and storage will influence grain yield determination. This notion is confirmed by previous work but inconsistent depending on soil type topography, and climatic conditions of the research sites (Kaspar et al. 2004; Kravchenko and Bullock 2000; Runge and Hons 1999; Spitze et al. 1973).

When seeding rate optimization was performed, only three of nine site-years resulted in meaningful seeding rate response curves that warranted use of variable seeding rate across fields). A fourth site-year resulted in a seeding rate optimization with a range of seeding rates (93,000 to 95,400 seeds ha^{-1}) too narrow to justify variable rate seeding. There was considerable variation of attributes included in the optimization model. The optimization model utilized slope curvature, in-field elevation, and pH interactions with seeding rate to determine the slope of the optimization response curve at Ogden in 2012, 2013, and 2014 respectively (Figure 1). Even in those site-years, there was considerable variation of the optimization model. These findings support the notion that for variable rate seeding to be viable there is a need for seeding rate to be influenced by soil attributes and topographic characteristics (Bullock et al., 1998) but an additional need is for consistency of seeding rate interaction with soil attributes and topographic characteristics from year to year and field to field.

Table 3. Significant Pearson correlation coefficients of maize grain yield to soil and topographic parameters, 2012 to 2014.

	Ames			Kelley			Ogden		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
Seeding rate	0.17**	ns	–0.55***	–0.38***	–0.27***	–0.15*	–0.10*	ns	–0.16***
P	0.55***	ns	–0.22**	0.27**	ns	–0.34***	0.15**	ns	0.43***
K	0.63***	ns	ns	0.30***	ns	–0.29***	ns	–0.26***	0.31***
pH	ns	–0.29***	–0.70***	Ns	ns	–0.44***	0.09*	–0.26***	–0.40***
SOM	0.46***	–0.29***	–0.50***	0.36***	ns	–0.42***	0.19***	–0.37***	0.09*
CEC	0.43***	–0.33***	–0.42***	0.40***	ns	–0.33***	0.10*	–0.27***	ns
Sand	–0.52***	0.13*	ns	Ns	ns	ns	–0.19***	ns	ns
Silt	0.46***	ns	–0.14*	Ns	ns	ns	0.19***	–0.11**	ns
Clay	0.22**	ns	0.16*	Ns	ns	ns	0.09*	ns	ns
Slope	–0.46***	0.24**	0.27***	–0.20**	ns	0.18**	–0.19***	0.28***	–0.09*
Curvature	–0.19**	ns	ns	–0.34***	ns	0.44***	–0.14**	ns	ns
Aspect	ns	ns	–0.29***	0.16*	ns	ns	–0.16**	0.11**	–0.14**
Elevation	–0.58***	0.24**	0.39***	–0.24**	ns	0.44***	–0.31***	0.53***	ns

Minimum and maximum number of observations for the correlation parameters: Ames-2012, n=187-220; Kelley-2012, n=180-220; Ogden-2012, n=352-554; Ames-2013, n=193-220; Kelley-2013, n=220; Ogden-2013, n=553-554; Ames-2014, n=219-220; Kelley-2014, n=220; Ogden-2014, n=552-554.

*, Significant at the 0.05 probability level; **, Significant at the 0.01 probability level; ***, Significant at the 0.001 probability level; ns, not significant.

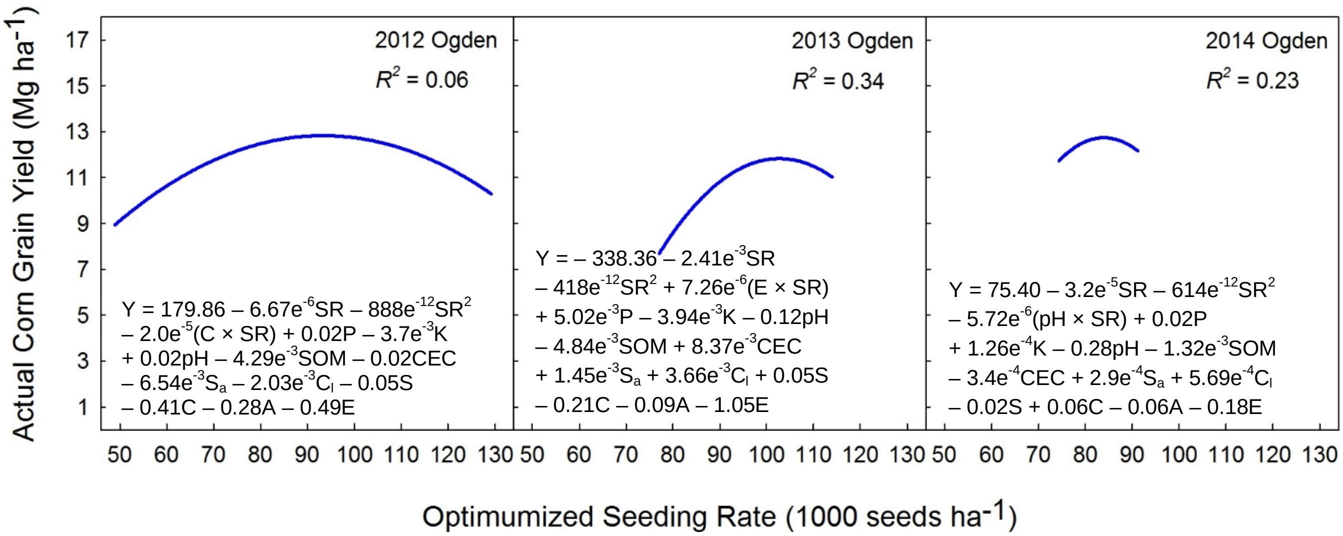

Figure 1. Maize grain yield at the optimized seeding rate for Ogden in 2012 to 2014.

The importance of maize seeding rate on grain yield components was evident in this research. As seeding rates increased, kernel weight, kernel rows, and kernel number per ear decreased. Additionally, increases in seeding rate resulted in a higher occurrence of zipper ears and plant barrenness, especially in 2012 when rainfall and soil moisture was limiting. The results did not show consistent evidence of seeding rate interactions with soil attributes or topographic characteristics, however, the main effects of available P and soil pH did influence kernel number per row, kernel weight, and kernel density. Additionally, there was strong evidence that in-field elevation combined with reliable rainfall forecasts can be used to determine field areas with potential for greater kernel weight and kernel density.

Conclusions

Determining a single optimum seeding rate methodology based on soil and/or topographic variables across a farming operation seems unlikely due to seeding rate response and interactions with variability of climatic conditions and field characteristics. Slope, curvature, in-field elevation, and SOM seemed to consistently be correlated with maize yield in dry climatic conditions of 2012. When the planting and growing season had normal to cool/wet conditions maize yield correlations to variables were less consistent. Seeding rate optimization resulted in meaningful seeding rate response curves for 33% site years. And in those site years there was substantial variation of the optimization model.

Based on this study, further research needs to be conducted to better understand how seeding rate optimization can be accomplished effectively. Development of seeding rate response curves for individual management zones based on indices that can account for the influence of soil fertility, water holding capacity, and landscape position on seeding rate response curves would be of great value.

References

Bouma, J. (1999). Precision agriculture: A unique tool to unify production and environmental requirements in agriculture. In P. C. Robert, R. H. Rust, & W. E. Larson (Eds.), *Precision Agriculture* (pp. 595-601). Madison, WI, USA: ASA/CSSA/SSSA.

Bullock, D. G., Bullock, D. S., Nafziger, E. D., Doerge, T. A., Paszkiewicz, S. R., Carter, P. R., et al. (1998). Does variable rate seeding of corn pay? *Agronomy Journal, 90*(6), 830-836.

Butzen, S., Gunzenhauser, B., & Shanahan, J. (2012). Putting variable-rate seeding to work on your farm. Johnston, IA, USA: DuPont Pioneer.

Clark, R. L., & McGuckin, R. L. (1996). Variable rate application technology: An overview. In P. C. Robert, R. H. Rust, & W. E. Larson (Eds.), *Precision Agriculture* (pp. 855-862). Madison, WI, USA: ASA/CSSA/SSSA.

Daberkow, S. G., & McBride, W. D. (1999). Adoption of precision agriculture technologies by U.S. Corn producers. In P. C. Robert, R. H. Rust, & W. E. Larson (Eds.), *Precision Agriculture* (pp. 1821-1831). Madison, WI, USA: ASA/CSSA/SSSA.

Doerge, T. (1999). Site-specific management guidelines: Management zone concepts. SSMG-2. Norcross, GA, USA.

ESRI (2014). Arcgis 10.2.2. *ArcMap* (10.2.2.3552 ed.). Redlands, CA, USA: ESRI (Environmental Systems Resource Institute).

Gunzenhauser, B., & Shanahan, J. (2011). Using multi-year yield analysis to create management zones for variable rate seeding. Johnston, IA, USA: DuPont Pioneer.

Hoeft, R. G., Nafziger, E. D., Johnson, R. R., & Aldrich, S. R. (2000). *Modern corn and soybean production* (First ed.). Champaign, IL, USA: MCSP Publications.

Kaspar, T. C., Pulido, D. J., Fenton, T. E., Colvin, T. S., Karlen, D. L., Jaynes, D. B., et al. (2004). Relationship of corn and soybean yield to soil and terrain properties. *Agronomy Journal, 96*(3), 700-709.

Kravchenko, A. N., & Bullock, D. G. (2000). Correlation of corn and soybean grain yield with topography and soil properties. *Agronomy Journal, 92*(1), 75-83.

Lowenberg-DeBoer, J. (1999). Economics of variable rate planting for corn. In P. C. Robert, R. H. Rust, & W. E. Larson (Eds.), *Precision Agriculture* (pp. 1643-1651). Madison, WI, USA: ASA/CSSA/SSSA.

Mackay, D. (1997). Precision farming: Connecting the pieces. In D. A. Lobb (Ed.), *Precision Farming: Challenges and Opportunities for Atlantic Canada*. Charlottetown, Prince Edward Island, Canada.

Mulla, D. J., & Schepers, J. S. (1997). Key processes and properties for site-specific soil and crop management. In F. J. Pierce, & E. J. Sadler (Eds.), *The State of Site-Specific Management for Agriculture* (pp. 1-18). Madison, WI, USA: ASA/CSSA/SSSA.

Nafziger, E. D. (2012). Corn. In *Illinois Agronomy Handbook*. Champagne-Urbana, IL, USA: University of Illinois Extension and Outreach.

Rawlins, S. L. (1996). Moving from precision to prescription farming: The next plateau. In P. C. Robert, R. H. Rust, & W. E. Larson (Eds.), *Precision Agriculture* (pp. 283-294). Madison, WI, USA: ASA/CSSA/SSSA.

Runge, E. C. A., & Hons, F. M. (1999). Precision agriculture - development of a hierarchy of variables influencing crop yields. In P. C. Robert, R. H. Rust, & W. E. Larson (Eds.), *Precision Agriculture* (pp. 143-158): ASA/CSSA/SSSA.

SAS Institute (2012). The SAS System for Windows. Release 9.3. Cary, NC, USA: SAS Institute.

Searcy, S. W. (1995). Engineering systems for site-specific management: Opportunies and limitations. In P. C. Robert, R. H. Rust, & W. E. Larson (Eds.), *Proceedings of the 2nd International Conference on Site Specific Managmeent for Agricultural Systems* (pp. 595-604). Madison, WI, USA: ASA/CSSA/SSSA.

Spitze, D. C., Rehm, G. W., & Moomaw, R. S. (1973). An effective educational approach for working with adult farmers. *Journal of Agronomic Education, 2*, 36-39.

Taylor, J., & Whelan, B. (2010). A general introduction to precision agriculture. Grains Research and Development Corporation. http://www.agriprecisione.it/wp-content/uploads/2010/11/general_introduction_to_precision_agriculture.pdf. Accessed 9 September 2014.