Variability of Potato Petiole Nitrogen in Response to Nitrogen Fertilizer, Implications for Variable Management

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Impact: Potato petiole nitrogen varied significantly in the landscape and temporally during the growing season. These sources of variability should be considered when variably applying fertilizer during the growing season.

Abstract

Recent increases in the cost of fertilizer nitrogen have prompted producers to assess the potential to vary inputs in space and time to produce the highest marketable yield of potatoes. A study was conducted from 2005 to 2007 near Brandon, Manitoba Canada, to assess the spatial variability of potato yield in upper, middle and lower landforms on a sandy loam soil in response to a range of nitrogen fertilizer rates and split application. Petiole nitrogen, determined late in the growing season, was correlated with potato yield and was used to assess nitrogen sufficiency through the growing season. Petiole nitrogen varied with time during the growing season, from uniform levels in June across all fertilizer treatments, to those which varied with fertilizer treatment in July and August. Furthermore potato petiole nitrogen was higher in lower landforms during July and August, where higher total and marketable yields were recorded. The potential for split application of nitrogen in potatoes based on management zones or sensor readings will have to be carefully assessed to account for temporal and spatial variability.

Introduction

Nitrogen management for potato (Solanum tuberosum L.) is important from both production and environmental standpoints. Previous research indicated that split N application based on potato growth needs during the growing season would significantly improve N fertilizers use efficiency (NUE) (e.g. Westermann, and Kleinkopf, 1985; Errebhi et al., 1998). In Canada and in Israel large potato fields are grown on coarse-textured soils, and N applied at high rates early in the season can easily be leached below the rooting zone during heavily rainfall and excess irrigation events. This practice could result in ground water contamination by NO_3-N and substantial reduction in yields due to N deficiency. Errebhi et al. (1998) showed that nitrogen management reduces amounts of N applied at planting resulted in lower NO_3-N leaching, higher N recovery by the crops and improved marketable tuber yield. Meyer and Marcum (1998) indicated the need of pre-plant soil-N concentrations in determining appropriate applied N rates. Midseason N rates and timing may be evaluated by petiole NO_3-N concentrations (Meyer and Marcum, 1998).

Methods

The experimental site (49°57'10.62"N, 99° 36' 05.32 " W, legal location 28 11 16 W) selected for the study is in a cereal-cereal-potato rotation where irrigation is used in the third year of production when potatoes are grown. Wheat and fall rye are the cereals commonly used in the rotation at the site. The area is tilled during the fall in preparation for spring planting. Soils at the site are predominantly Orthic Black Chernozems (Typic Haplustoll) in the Stockton series, with a coarse sandy texture (Manitoba Land Resource Unit 1997). An experiment protocol was developed in 2005, based on the baseline analysis of landform and image analysis, with nitrogen treatments (0, 75, 150 and 225 kg ha^{-1} N shortly after seeding and 75 kg ha^{-1} plus 75, 150 and 225 kg ha^{-1} split application shortly after hilling) in a randomized complete block design located within upper, middle and lower landforms delineated with cluster analysis of the 2004 aerial photograph. Potato petiole samples were collected at 4 dates in two locations per plot during the growing season in 2005, 2006, and 2007. Sample dates varied between years due to weather conditions or the presence of the irrigation pivot in the plots which precluded data collection. Laboratory analysis of petiole N was conducted with a Carlo Erba 2500 elemental analyzer in 2005 and 2006 and a Carlo Erba 1500 in 2007. In addition, petiole nitrate nitrogen was determined for samples collected on July 23, 2007. Petioles were oven dried at 55 degrees C and were ground to pass a 2 mm screen prior to analysis. Using a method similar to Zebarth et al (2003), a 0.1 g subsample was extracted with distilled-deionized water using a 50 ml water extract ratio and 30 min shaking time. The extract was diluted 4000:1 using an automated diluter, and NO_3-N concentration in the extract determined colourimetrically on a LaChat Flow Injection Analyzer following reduction of nitrate to nitrite with hydrazine sulphate (Lachat Method 12-107-04-1-B). Statistical analyses were conducted with landform, treatment and the interaction as fixed effects with date and replicate as random effects in analysis of variance (REML) in JMP 7.01 (SAS Institute 2006).

Discussion

Petiole Nitrogen

Potato petiole nitrogen increased from upper to lower slope positions in an interaction with fertilizer treatment and sampling date (Table 1, 2). Nitrogen fertilizer significantly increased petiole N in July and August (Table 2), though no significant effect was observed in June of 2005 and 2006. However split application did not significantly increase petiole N relative to application at seeding. Petiole nitrogen also decreased during the growing season when averaged across fertilizer treatments and landform (Table 3). The correlation between petiole nitrogen at the last sampling date, and potato yield was significant ($P<0.001$) accounting for 41.7 % of the variance. Similar trends were observed for 2007, with significant differences due to fertilizer treatments in July.

Table 1. Petiole nitrogen (%N) by sample date, year and landform for 2005, 2006 and 2007.

	Petiole Nitrogen (%N)										
Site Year	2005				2006				2007		
Landform	June 13	July 12	July 26	Aug 19	June 8	June 19	July 5	July 18	July 4	July 25	July 31
Lower	6.0A[z]	4.5A	4.0A	4.7A	6.3A	6.8A	4.3A	5.1A	5.4A	4.3A	4.2A
Middle	5.8A	4.3B	3.8A	3.6B	6.4A	6.5AB	4.2AB	5.0A	5.3A	4.1A	4.1A
Upper	5.5B	3.9C	3.5B	3.4B	6.4A	6.3 B	3.9B	4.7B	5.1A	4.1A	4.1A
SE[y]	0.08	0.05	0.06	0.11	0.06	0.09	0.09	0.13	0.12	0.13	0.12

[z] Landforms followed by the same letter are not significantly different (P=0.05) Tukey HSD test

[y] Standard error of the mean

Table 2. Petiole nitrogen (%N) by sample date and fertilizer treatment combined for 2005, 2006 and 2007.

Fertilizer treatment [y]	Petiole Nitrogen (%N)			
	2005			
N kg ha^{-1}	June 13	July 12	July 26	Aug 19
225	5.9A[z]	4.4A	4.0A	3.6AB
150	6.0A	4.4A	3.9AB	3.6AB
75-225	5.8A	4.2B	3.7AB	4.4A
75-150	5.7A	4.1BC	3.7AB	4.4A
75-75	5.7A	4.1C	3.7AB	4.2AB
75-0	5.8A	4.2B	3.7AB	3.5B
0-0	5.5A	4.0C	3.6B	3.4B
SE [x]	0.14	0.11	0.10	0.21
	2006			
	June 8	June 19	July 5	July 18
225	6.3AB	6.5A	4.1AB	5.6A
150	6.4AB	6.6A	4.1AB	5.6AB
75-225	6.5A	6.5A	4.0B	5.3AB
75-150	6.6A	6.9A	4.7A	5.1BC
75-75	6.4A	6.8A	4.3AB	4.7CD
75-0	6.4AB	6.5A	4.0B	4.4DE
0-0	6.0B	5.9B	3.7B	3.9E
SE [x]	0.08	0.11	0.12	0.11
	2007			
	July 4	July 25	July 31	
225	5.7AB	4.1BC	4.2BC	
150	5.8A	4.1BC	4.0CD	
75-225	5.0CD	4.8A	4.7A	
75-150	5.1BCD	4.5AB	4.6AB	
75-75	5.5ABC	4.7A	4.6AB	
75-0	5.2BCD	3.6CD	3.6DE	
0-0	4.7D	3.3D	3.3E	
SE [x]	0.15	0.14	0.11	

[z] Fertilizer treatments followed by the same letter are not significantly different (P=0.05) Tukey HSD test

[y] N fertilizer applied shortly after seeding, May 13 and 16, 2005, May 10 and 11, 2006, May 18, 2007, second application July 22, 2005, July 5, 2006, June 22, 2007

[x] Standard error of the mean

Table 3. Petiole nitrogen (%N) by sample date averaged across treatments and landforms for 2005, 2006 and 2007.

Date	Petiole Nitrogen (%)
2005	
June 13	5.8A[z]
July 12	4.2B
August 19	3.9C
July 26	3.8C
SE[y]	0.05
2006	
June 19	6.5A
June 8	6.4B
July18	4.9C
July 5	4.1D
SE[y]	0.05
2007	
July 4	5.3A
July 23	4.2B
July 30	4.2B
August 7	4.1B
SE[y]	0.10

[z] Dates followed by the same letter are not significantly different (P=0.05) Student's t test
[y] Standard error of the mean

Petiole Nitrate

Petiole nitrate nitrogen was determined in 2007, and the results were similar to those for petiole nitrogen, with an interaction between fertilizer rate and landform. Analyses of petiole nitrate nitrogen and petiole nitrogen were significantly correlated (P=0.0001, R^2=0.77) in 2007.

Conclusions

Petiole nitrogen varied significantly between landforms, fertilizer treatments and later in the growing season near the middle of July. Variability of petiole nitrogen later in the growing season should be considered when variably applying N fertilizer during short growing seasons typical of Manitoba, Canada.

Acknowledgements

The authors wish to acknowledge funding from the Canada and United States-Israel Binational Agricultural Research and Development Fund (BARD) and Matching Investment Initiative of Agriculture and Agri-Food Canada. John and Jack Adriaansen, potato producers in the Brandon area, provided land, seed and pesticide management. In addition the technical assistance of Grant Gillis, Shirley Neudorf, Josh Price and Roger

Fortier, casuals (Kyle Able, Bryce Granger, Shaun Parkins), interns (Lisa Bidinosti and Patricia Garrod) and summer students (Hayley Haberoth, Mark Fenwick, Duane Allen, Blair Yaremchuk) at the Brandon Research Centre is acknowledged. Dean James and Duaine Messer and Rod Lunggren (Semi-Arid Prairie Agricultural Research Centre, Swift Current Saskatchewan) conducted laboratory analyses in 2007. Technical staff from the Canada Manitoba Centre for Crop Diversification provided equipment and assistance with potato harvest. Mitch Long, and Nicole Rabe in cooperation with John Van Oosterveen from PFRA, supervised students from Assiniboine College and conducted elevation and conductivity surveys.

References

1. Errebhi, M., Rosen, C. J., Gupta, S. C., and Birong D. E. (1998). Potato Yield Response and Nitrate Leaching as Influenced by Nitrogen Management. Agron. J. 90:10–15.
2. Manitoba Land Resource Unit, 1997. Soils and Terrain. An Introduction to the Land Resource. Rural Municipality of North Cypress. Information Bulletin 97-24, Brandon Research Centre, Research Branch, Agriculture and Agri-Food Canada.
3. Meyer, R. D. and D. B. Marcum. 1998. Potato yield, petiole nitrogen, and soil nitrogen response to water and nitrogen. Agron. J. 90:420-429
4. SAS Institute Inc. 2006. JMP. Version 7.01. Cary, NC: SAS Institute Inc..
5. Westermann, D.T., and G.E. Kleinkopf. 1985. Nitrogen requirements of potatoes. Agron J 77:616-621.
6. Zebarth, B. J.; Rees, H.; Tremblay, N.; Fournier, P., and Leblon, B. 2003. Mapping spatial variation in potato nitrogen status using the “N Sensor”Tremblay, N., ed. Fertilization strategies for field vegetable production. XXVI International Horticultural Congress; Toronto, Canada. Acta Hort.627:267–273.