Plant-based Approaches for In-season Detection of Nitrogen Stress in Potato

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INTRODUCTION

Nitrogen (N) management for irrigated potato (*Solanum tuberosum* L.) is a challenge because crop N uptake rates and soil N transformations/losses depend on the interaction of many complicated (and sometimes unpredictable) factors throughout the growing season. A logical strategy for determining the appropriate rate and timing of split applied post-emergence N fertilizer is to make adjustments based on in-season plant monitoring. Currently, the best management practice for potato production in Minnesota is to base the rate and timing of post-emergence N fertilizer applications on petiole nitrate-nitrogen (NO_3-N) concentrations (Rosen and Bierman, 2008). Petiole nitrate analysis is a destructive test based on the concept that the petiole is the transport organ of N from the roots and stems to the leaflets (in the form of NO_3^- and amino acids). The opportunity exists to use non-invasive sensing methods (e.g., chlorophyll meter readings or spectral reflectance measurements) to predict crop biophysical parameters in order to account for within-field spatial variability for variable rate application of N fertilizer.

OBJECTIVES

- Evaluate how total N and NO_3-N concentrations for petiole, leaflet, and entire leaf samples change throughout the season for Russet Burbank and Alpine Russet potato varieties
- Determine which tissue samples and spectral analysis techniques can best predict Grade A tuber yield at various growth stages

MATERIALS & METHODS

- A two year field study was conducted on an irrigated potato crop in 2010 and 2011 on Hubbard loamy sand soil in Becker, MN.
- Experimental design: randomized complete block design with a split plot restriction on randomization (4 replications)
  - Five N treatments: (in kg ha^{-1}): 34 early, 180 split, 270 split, 270 split + soil surfactant, and 270 early
  - Two varieties: Russet Burbank (RB) and Alpine Russet (AR)
- Measurements were collected on four dates in 2010 and five dates in 2011 and included: tissue samples (petioles, leaflets, and whole leaf), chlorophyll meter readings (SPAD), and narrowband reflectance (MSR16R Cropscan; Fig. 1).
  - Tissue samples were analyzed for NO_3-N and total N concentration.
  - Spectral indices evaluated in this study were: NDI2 (Normalized difference index 2; Datt, 1999) = $(R_{870}-R_{710})/(R_{870}-R_{660})$; NDVI (Normalized difference vegetation index; Lichtenthaler et al., 1996) = $(R_{810}-R_{660})/(R_{810}+R_{660})$; and SR8 (Simple ratio 8; Datt, 1998) = $R_{870}/(R_{560} \times R_{710})$.
- Linear regression analysis (REG procedure of SAS) was used to determine the ability of in-season measurements to predict Grade A tuber yield (tubers >85 g).

Fig. 1. *Collection of canopy-level spectral reflectance using the MSR16R Cropscan*

RESULTS & DISCUSSION

- Grade A tuber yield increased with increasing N rate, was generally higher for Alpine Russet than for Russet Burbank, and was higher in 2010 than 2011 due to favorable weather (Table 1).
- The main effects of N treatment and variety were generally significant for tissue samples on each sample date (data not shown).
- Leaf N concentration was at or above the sufficiency range for all N treatments on most dates (Fig. 2); petiole NO_3-N concentration was below the sufficiency range for all N treatments on most dates (Fig. 3); the low NO_3-N in petioles may in part be due to leaching caused by excessive rainfall.
- Tissue NO_3-N concentrations are very responsive to N fertilizer applications that occur within one week of the sampling date, and are therefore a good indicator of current plant N uptake (Fig. 3).
- Tissue NO_3-N concentrations depend on growth stage, as well as the number of days that have passed since the last N application.
  - Therefore, tissue samples analyzed for NO_3-N may not be the best indicator of overall crop N status and Grade A tuber yield.
- Overall, spectral indices predicted Grade A tuber yield consistently throughout the season, and they generally did so better than tissue N or NO_3-N concentrations (Table 2).
- Canopy-level spectral data are influenced by the effects of both tissue N and NO_3-N concentration and biomass/LAI (Daughtry et al., 2000).
  - This suggests that tissue N and NO_3-N concentrations alone may not be best suited to detect N stress in a potato crop as it relates to Grade A tuber yield.

Table 1. *Grade A tuber yield for Russet Burbank and Alpine Russet varieties in 2010 and 2011. Similar letters within columns are not significantly different (α = 0.05).*

N treatment	Grade A tuber yield (Mg ha^{-1})			
	Russet Burbank		Alpine Russet	
	2010	2011	2010	2011
34 early	31.6 d†	27.5 b	42.5 c	34.3 c
180 split	45.4 c	42.1 a	53.4 ab	48.6 a
270 split	51.5 a	43.1 a	55.0 a	49.2 a
270 split + s	50.2 ab	41.0 a	54.6 a	49.1 a
270 early	48.7 b	41.8 a	50.9 b	42.6 b

†Means followed by the same letter within a measurement date and variety are not significantly different (α=0.05).

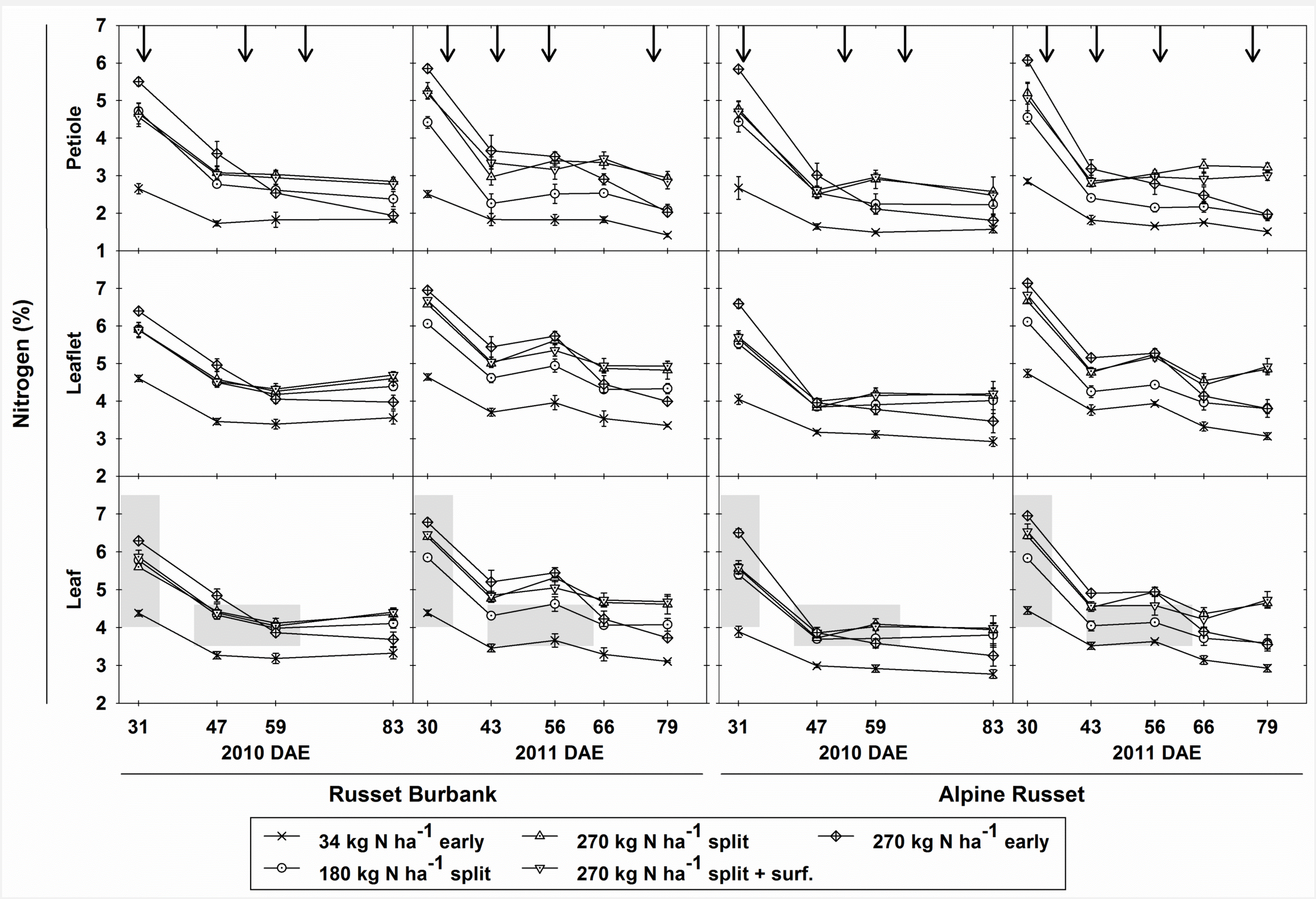

Fig. 2. *Petiole, leaflet, and whole leaf N concentrations under various N treatments for Russet Burbank and Alpine Russet potato varieties on different days after emergence (DAE) in 2010 and 2011. Means are presented with standard error bars. Gray shaded areas represent leaf N sufficiency levels (Rosen & Eliason, 2005; Westermann, 1993). Arrows indicate the timing of post-emergence N fertilizer applications.*

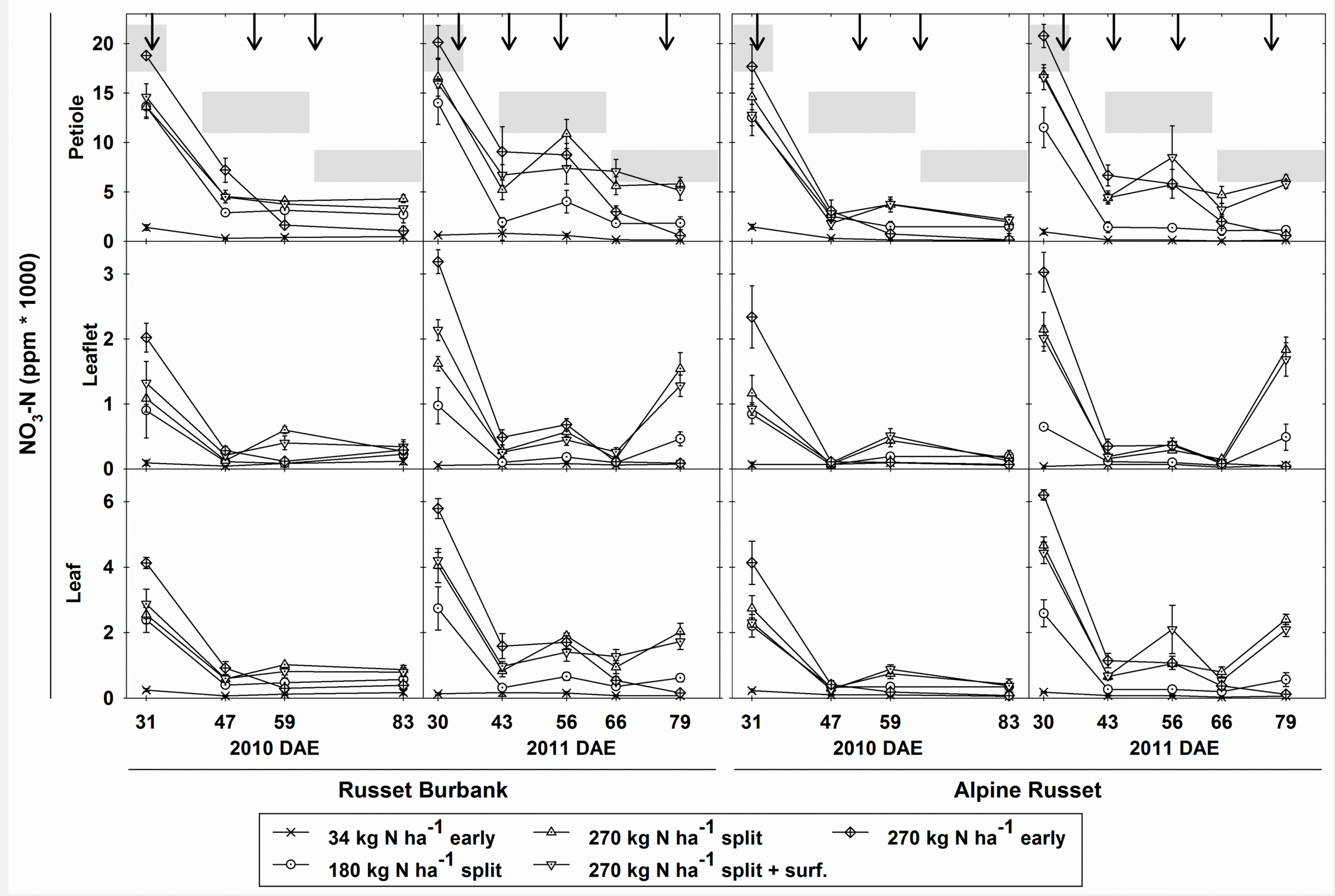

Fig. 3. *Petiole, leaflet, and whole leaf nitrate-nitrogen (NO_3-N) concentrations under various N treatments for Russet Burbank and Alpine Russet potato varieties on different days after emergence (DAE) in 2010 and 2011. Means are presented with standard error bars. Gray shaded areas represent petiole NO_3-N sufficiency levels (Rosen & Eliason, 2005). Arrows indicate the timing of post-emergence N fertilizer applications.*

Table 2. *The coefficients of determination (r^2) for the relationship between Grade A tuber yield and each predictor on different days after emergence (DAE) in 2010 and 2011 for the Russet Burbank variety only.*

Measurement	2010 DAE				2011 DAE				
	31	47	59	83	30	43	56	66	79
					r^2				
Leaf nitrogen	0.67	0.53	0.45	0.27	0.44	0.39	0.30	0.51	0.39
Petiole NO_3-N	0.58	0.31	0.34	0.21	0.61	ns	ns	0.22	ns
Leaf area index	ns†	0.23	ns	0.50	ns	0.39	0.24	0.31	ns
Chlorophyll meter	0.54	0.59	0.57	0.40	0.71	0.48	0.40	0.44	0.43
NDVI	0.60	0.69	0.73	0.81	0.54	0.57	0.74	0.69	0.71
NDI2	0.63	0.70	0.71	0.81	0.64	0.57	0.63	0.64	0.59
SR8	0.58	0.73	0.70	0.36	0.56	0.57	0.61	0.56	0.30

†Only significant r^2 values are presented (α=0.05).

CONCLUSIONS

- Nitrate-nitrogen concentrations were always higher in petioles than whole leaves or leaflets, and total N was always higher in whole leaves and leaflets than petioles. In general, this indicates that the diagnostic criteria should change based on the tissue part sampled and the form of N tested.
- Tissue total N and NO_3-N concentrations were highest early in the growing season, but they leveled off as the season progressed; tissue NO_3-N was more responsive to recent N fertilizer applications.
- The spectral indices, especially NDVI and NDI2, predicted Grade A tuber yield best and resulted in consistent r^2 values throughout the season; their success was attributed to spectral data being sensitive to both tissue N concentrations and biomass.

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