NITROGEN MANAGEMENT FOR POTATOES BY USING RAPID TEST METHODS

Milan POLJAK [1] – Tea HORVAT [1] – Adrijana MAJIĆ [3] - Ana POSPIŠIL [2] – Tomislav ĆOSIĆ [1]

[1] Department of Plant Nutrition, Faculty of Agriculture, University of Zagreb, Svetošimunska cesta 25, HR-10000 Zagreb, Croatia, e-mail: mpoljak@agr.hr
[2] Department of Field Crops, Forage and Grasslands, Faculty of Agriculture, University of Zagreb
[3] Faculty of Agriculture, University of Mostar

Abstract: To evaluate the efficiency of rapid field tests for potato nitrogen management, five N fertilizer treatments (0, 100, 150, 200 and 250 kg N ha^{-1}) were applied on three cultivars and replicated three times. Representative leaf samples were collected three times during vegetation at 10 day intervals, and nitrate in the petiole sap was immediately measured with a Cardy ion meter. Approximately 30 leaf chlorophyll readings were also taken. At the same time petiole samples were collected, with a portable, hand held Hydro N-tester chlorophyll meter. Petiole sap nitrate concentration and chlorophyll content index (CCI) increased with increasing fertilization levels and decreased as the season progressed. Highest correlations between the amount of nitrate nitrogen and chlorophyll in leaves were observed at approximately 50 days after planting. Furthermore, the methods were highly correlated. Yield was not related to the amount of petiole sap nitrate and chlorophyll content index during the vegetation.

Keywords: potato, nitrate nitrogen, chlorophyll content index, petiole sap analyses, nitrogen, yield

Introduction

Potatoes (*Solanum tuberosum* L) rate fourth in production volume among the world's field crops, playing an important role in economy of many countries. Potatoes as shallow- rooted crops need a high level of nitrogen to ensure acceptable yield (Darwish et al., 2006). Nitrogen management, rate and timing of nitrogen application are critical factors in optimizing potato tuber yield and quality (Haase et al., 2006, Poljak et al., 2007). Different methodological approaches have been developed and introduced to improve N-recommendation systems (Olfs et al., 2005). The main idea of in-field methods like chlorophyll measurements and plant petiole sap test is that the plant itself is the best indicator for N supply from any source within growth period. Nitrogen is the most often the limiting factor to rapid growth, chlorophyll content and photosynthetic activity of crops (Wu et al., 2006, Varga, et. al., 2007). The correlation between foliar N status and fertilizer needs provides a diagnostic method in many cases (Chang and Robinson, 2003, Izsáki and Németh, 2007, Széles, 2007). The objective of this study was to estimate the feasibility of using chlorophyll measurements and petiole sap rapid tests to monitor the N status of potatoes.

Materials and methods

The field experiment was conducted on a private farm (at Slovinska Kovačica), which is a typical area for processing potato cultivation in Croatia. The potato cultivars (Victoria, Red Star and Remarka) with similar duration of growth were mechanically planted in May 2002. At the beginning of experiments, the soil characteristics were as follows: pH 5.7; humus content 14 mg g^{-1}; extractable P_2O_5 108 and K_2O 110 mg kg^{-1}. Maize (*Zea mays* L.) was the previous crop. The experiment was arranged in a randomised split-plot design with three replications including 3 genotypes of potato (*Solanum tuberosum* L.) as main plots and five N rates (0, 100, 150, 200 and 250 kg ha^{-1}) as sub-plots. The sub-plot size were 4.3x10.0 m, with 200 plants. Nitrogen was applied half at pre-planting and half before hilling, while standard doses of P_2O_5 (140 kg ha^{-1}) and K_2O (210 kg ha^{-1}) were applied at pre-planting. The usual crop management was used for weed, pest and disease control. Potato leaf samples for petiole sap NO_3–N and chlorophyll content determination were taken 47, 62 and 78 days after sowing (DAS) from June through July, 2002. Samples of 30 potato leaves (usually the 4^{th} or 5^{th} leaf from the apex) were collected at around 10 a.m. from second and fifth row of each plot. Chlorophyll content index (CCI) were made on same leaves by a portable Hydro N-tester chlorophyll meter just before collecting leaves for petiole sap analyses. Leaflets were removed, and fresh petiole samples were transported on ice, sliced to small pieces and mixed thoroughly into a pile. A portion of the petiole samples was pressured by a garlic press and petiole sap was immediately taken for NO_3-N determination by Cardy ion meter. The results were used to assess the N status of the potato genotypes. Statistical data analyses were made according to GLM procedure by the SAS System (SAS Institute Inc., 1999-2001). Fresh tuber yield was calculated by harvesting two middle rows of each plot.

Results and discussion

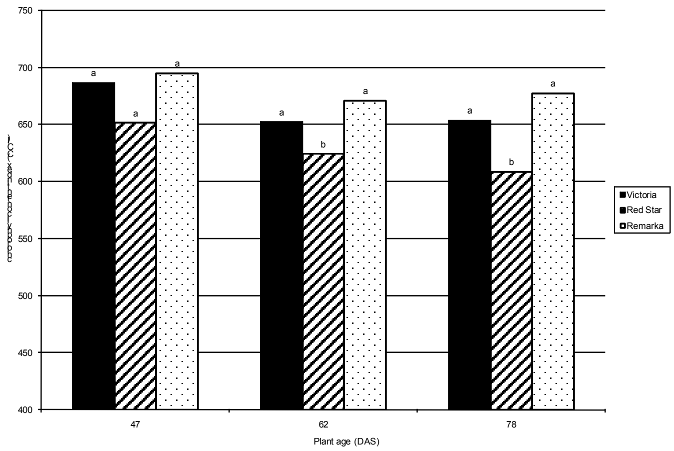
The analysis of the variance showed that N dose and measurement date as indices of plant age as well as genotype considerably influence the chlorophyll content and NO_3-N concentration in petiole sap. Under the specific conditions in which the experiment was conducted all parameters were significantly affected by the three factors under study, viz. the N rate, genotype, and plant age. The chlorophyll content increased linearly and significantly with increasing nitrogen rates, but decreased significantly with plant ageing (Table 1).

Table 1 Mean chlorophyll content index (CCI) and petiole sap NO_3-N concentrations for five fertilization rates during growing season in 2002. Different letters indicate significant differences ($p\leq 0.05$).

Treatment	CCI			NO_3-N mg kg^{-1}		
kg N ha^{-1}	Plant age - DAS			Plant age - DAS		
	47	62	78	47	62	78
0	604 c	587 c	599 c	3267 c	2611 c	2800 c
100	671 b	646 b	639 b	4767 b	3700 b	4878 b
150	697 a	657 ab	655 a	5567 ab	4744 a	5667 ab
200	698 a	673 ab	665 a	5800 ab	4833 a	6567 a
250	719 a	684 a	675 a	6878 a	5256 a	6789 a

Nitrogen applications were reflected in CCI reading value. Treatment differences between 0, 100 and 150 kg N ha^{-1} at 47 and 78 DAS were shown consistently. Similar results were found by Wu et al., 2007. It seems normal for potatoes, as Rodrigues et al., 2005 showed that N-use efficiency could be high between 10 to 48 days after emergency. Potato cultivars showed significant differences in CCI value at 62 and 78 DAS but not at 47 DAS. On average, Red star exhibited significantly less chlorophyll content compared with Remarka or Victoria. All potatoe genotypes showed a decreasing trend in chlorophyll content with plant ageing (Fig. 1).

Figure 1. Means of chlorophyll content index (CCI) for three cultivars during growing season. Same letters indicate insignificant difference ($p \leq 0.05$).



Potato cultivars showed significant differences in petiole sap NO_3-N concentration only on the first measurement date, but there was no significant interaction effect at fertilization. No significant effect may have been caused by unusually low temperatures in May 2002. Nitrogen supply caused a significant increase in NO_3-N concentration in respect to unfertilized plants, especially at 250 kg N ha^{-1} on all measurement dates (Table 1). Small and insignificant differences in NO_3-N concentration were found between 150, 200 and 250 kg N ha^{-1} on all measurement dates. However, nitrate concentrations progressively decreased with plant ageing between 47 and 62 DAS, and slightly increased between 62 and 78 DAS. Usually petiole NO_3-N concentration decreased as the season progressed, since the reduction and binding into organic compounds took place. However, such effects are probably a reflection of favourable environmental condition for a higher N mineralization in late growth period or a reflection on water stress. Regardless of that, chlorophyll content has shown no such effect. In each measurement interval the NO_3-N petiole sap concentration in the unfertilized treatment was significantly lower and showed a progressively decreasing concentration with plant ageing. Wu et al., 2007 suggested a petiole sap NO3-N test as better method in detection of treatment differences later in season but we have not proved that.

From these results it follows that under the ecological conditions of continental Croatia potatoes respond by an enhanced N uptake, as the fertilization rate increases. In this study, the increasing petiole sap NO_3-N content and CCI values as a result of increasing N-fertilization rates illustrate this very well. However, the utilization of the nitrogen did not follow this trend. There was no clear difference between 150, 200 and 250 kg N ha^{-1} fertilization rates which confirms that plants take in only the amounts of nitrogen they need, regardless of how much nitrogen they absorb from the soil. Hence, this would allow the potato producer to reduce N fertilization in such agro-environmental conditions. A very strong correlation between the methods was also recorded (Table 2). Yield was not related to the concentration of petiole sap NO_3-N and CCI in leaf during vegetation season.

Table 2. Correlation coefficients (r_{xy}) and significance correlations between petiole sap NO_3-N concentration and chlorophyll content index and among tuber yield during plant ageing. * $p \leq 0.05$.

	Plant age DAS	NO_3-N mg kg^{-1} 47	62	78	CCI 47	62	78	Fresh tuber yield
NO_3-N mg kg^{-1}	47		0.74*	0.67*	0.48*	0.47*	0.24	0.16
	62			0.83*	0.74*	0.73*	0.58*	0.14
	78				0.71*	0.68*	0.56*	0.02
CCI	47					0.80*	0.68*	-0.11
	62						0.83*	-0.17
	78							0.31*

Conclusions

The results of present investigation confirm and extended previous studies which showed that CCI in combination with petiole sap nitrate test can be used in field conditions to detect differences in the response of a potatoes genotype to nitrogen supply. However, growers should understand that the chlorophyll meter is only able to reveal deficiency situations. Sap tests are accurate enough to be used on a practical basis as a decision-making tool that can increase the efficiency of fertilizer use. Nitrogen utilization varies in different potato cultivars, and more detailed research over a wide range of soil and climate conditions needs to be conducted to determine the simplest, but most comprehensively reliable method for applying this technology to potato.

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