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The effect of nitrogen supply on leaf area index, leaf chlorophyll and tuber nitrogen content in potato

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Summary

In this study the leaf area index (LAI), the leaf chlorophyll and the tuber nitrogen content of five potato genotypes (cultivar White Lady, Katica, Hópehely and Chipke, as well the S440 breeding line) were analyzed at three different nitrogen supply levels (N7.5, N3, N0.75). Potato tubers of uniform size (average 50.7 g) were planted in 3 l pots and were filled with quartz sand #30 (600 μm). Plants were grown in a greenhouse under semicontrolled conditions from March to July in 2013. The experiment was arranged in a randomized design in three replications. The results demonstrated genotype dependent variance for the tested characteristic. The most characteristic deficiency symptoms were detected on White Lady and Katica at N0.75 supply level. The effect of the treatment manifested later on

S440 than on the other genotypes. The answer to the treatment was the quickest of White Lady amongst the cultivars. Under N-limiting conditions LAI decreased but the level of this was genotype dependent. The differences in LAI values at the N7.5 and N0.75 supply levels were statistically significant (except for S440). Differences in tuber nitrogen content among the three treatments were statistically significant for all genotypes. All N supply levels were significantly correlated with LAI (0.578), leaf chlorophyll content on the 42nd treatment day (0.818) and also with the tuber nitrogen content (0.648). It is concluded that different nitrogen levels influence the LAI, the chlorophyll and nitrogen content in a genotype dependent manner. It means that different potato genotypes have different nitrogen needs.

1. Introduction and literature review

The doubling of agricultural food production worldwide over the past 40 years has been associated with a 7-fold increase in the use of nitrogen fertilizers (*Hirel et al.*, 2007). The N-fertilizer production is a resource-intensive process, that give rise to increase in prices. If we could improve the nitrogen use efficiency of crops it would have a notable economic and environmental effect. So it is closely reasoned to improve the efficiency of the N-fertilizers. It could be increased with agrotechnical methods till some extent but we need varieties with improved nitrogen utilization.

Genotype - nitrogen level interactions reflecting to differences in responsiveness have been observed in several studies (*Sanford et al.*, 1986, *Arsenault et al.*, 2001, *Gallais et al.*, 2004, *Marschner*, 2012). In potato genotypic differences in N-needs were studied, and it is concluded that for an increase in tuber yield and quality the optimization of N management is required (*Joern et al.*, 1995).

Significant variation in nitrogen use efficiency (NUE) was reported among commercial potato cultivars and among wild accessions of potato (*Kleinkopf et al.*, 1981, *Zebarth et al.*, 2004). If we understand the physiological basis of genotypic variation of NUE in potato would facilitate the development of technologies to improve NUE.

Recently, we started a NUE survey of the cultivars of the Potato Research Centre (*Hoffmann et al.*, 2010). In the frame of this program in this study we analyzed the variation of leaf area index, leaf chlorophyll and tuber nitrogen content of five potato genotypes under different N-supply levels in a pot experiment.

2. Materials and methods

In the experiment four potato cultivars of the Potato Research Centre (White Lady, Katica, Hópehely, Chipke) and the S440 breeding line (obtained from late professor Hanemann, Wisconsin University) have been tested at three nitrate supply levels. Potato tubers (*Solanum tuberosum* L.) were planted in pots in a greenhouse. The treatments consisted of three levels of nitrogen supply, 7.50, 3.00 and 0.75 mmol NO_3 concentrations (hereinafter N7.5, N3 and N0.75 respectively).

Potato tubers of uniform size (average 50.7 g) were planted in 3 l pots, filled with quartz sand #30 (600 µm). Plants were grown in a greenhouse under semicontrolled conditions from March to July in 2013. The experiment was arranged in a randomised design with three replications.

The plantlets were grown with half strength standard (N7.5) Hoagland nutrient solution (*Hoagland et al.*, 1933). When plants reached the five-six leaves stage we started the N-deficiency treatments (treatment day 0). Plants were randomly chosen to one of the three N treatments. The control treatment was the half strength standard (N7.5) Hoagland nutrient solution, that we used under the pre-growing. The two others are N-deficiency treatments (N3 and N0.75).

We measured the relative chlorophyll content with a SPAD 502 Plus Chlorophyll Meter (Konica Minolta, Osaka, Japan). It is a non-destructive method involving the measurement of the greenness or relative chlorophyll content of leaves. Data collections were on the treatment day 0, 1, 3, 7 and after then once every week. The treatment was applied for 42 days (treatment days called TD). Ten measurements were done on every plant based on leaf surface area to avoid the major vein of leaf (*Jongschaap et al.*, 2004). The chlorophyll content was measured on the middle foliar level because it determines the average SPAD value of the potato leaf canopy (*Víg et al.*, 2012).

After TD 42 the plants were harvested. The leaf area index (LAI) was determined with a ADC BioScientific Ltd. AM300 field portable leaf area meter. Three compound leaves from the middle of the canopy per plant were measured.

The N status of potato plant can be estimated by the analysis of N in the dry matter (*Mills and Jones*, 1996). To this, the tubers were dried at 65 °C. The nitrogen content of tubers was determined by the Kjeldahl method (*Persson et al.*, 2008) with a FOSS Tecator Digestor Systems.

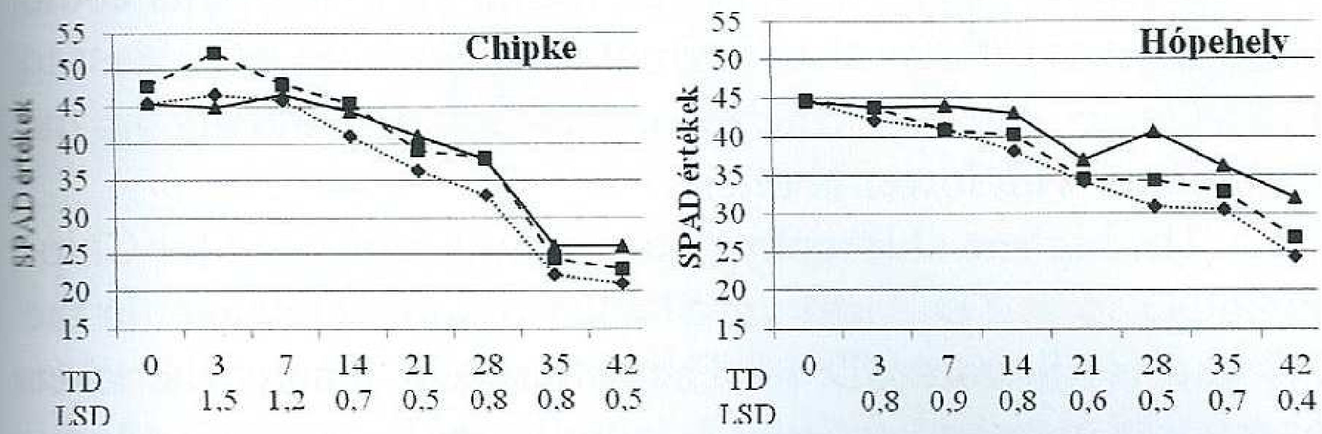
Data were examined by SPSS 20.0 for Windows software program with variance analysis and LSD post hoc test.

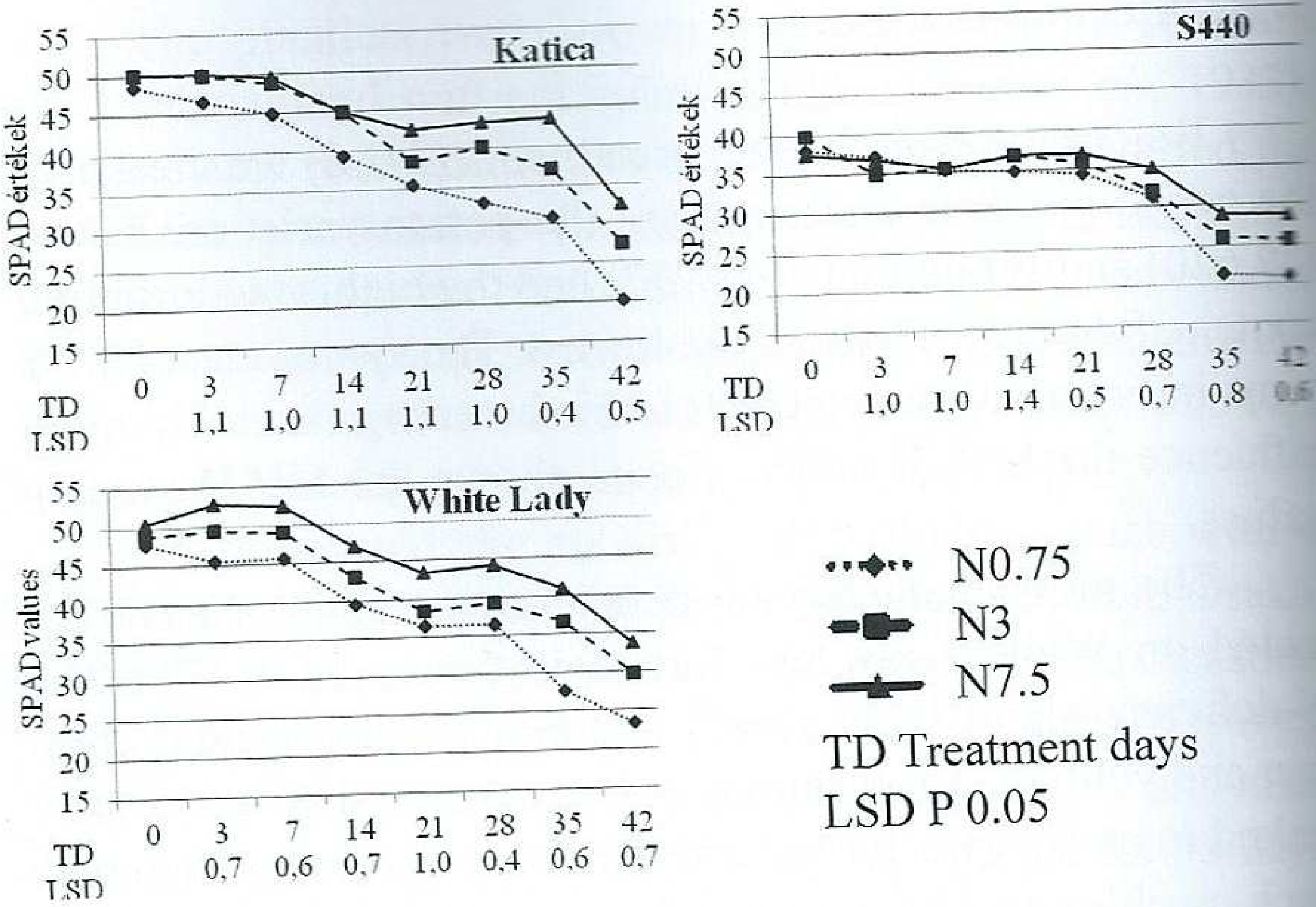
3. Results and discussion

Before the N-deficiency treatments (TD 0) we measured the genotypic differences among the potato varieties. Katica (49.620) and White Lady (48.937) had the highest chlorophyll content, S440 (38.426) had the lowest. The symptoms of PVY virus infection were detected on this breeding line so it might influence the SPAD values. *Fig. 1* shows the SPAD reading values.

The most characteristic deficiency symptoms were detected on White Lady and Katica in treatment N0.75. The N-deficient plants grew slowly, the leaves were lighter, slimmer and yellowy. Crop canopy colour ("greenness") is closely linked to crop characteristics determining light use efficiency, such as chlorophyll content and nitrogen status (*Jongschaap et al.*, 2004). These deficiency symptoms appeared only after TD 21 by the genotypes but these N-supply differences were indicated by SPAD readings before that.

Fig. 1: SPAD values of the analyzed genotypes during the treatment period (LSD, P 0.05)



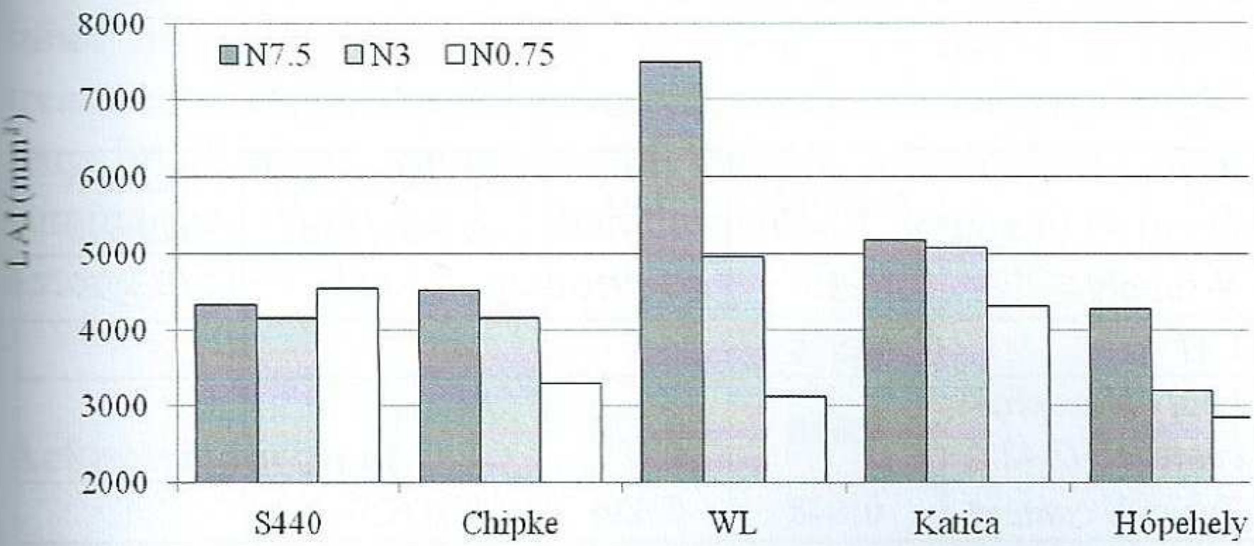


Increase in SPAD readings in potato leaves with increase in N rate was reported by other authors too. Similar was observed by *Minotti et al*. (1994) on 'Allegheny' and 'Castile', and by *Busato et al.* (2010) on varieties 'Atlantic', 'Agata', 'Monalisa' and 'Asterix'. In these experiments the SPAD values decreased with the plant age for all cultivars. This could have been caused by the N remobilization from the oldest to the younger leaves, which occurred more markedly in the treatments with lower N rates.

The highest chlorophyll content was registered for Chipke in N3 from TD 3 and the SPAD reading were equal in the N3 and N7.5 from TD 14 The differences among the three N-treatments were statistically significant just on TD 42. By far the largest SPAD values were measured in Hópehely in N7.5 then in N3 and N0.75. This difference became significant on TD 28. On TD 3 we found statistically significant decrease for Katica in N0.75. In spite that for this genotype the largest significant difference between N7.5 and N3 was noticed this difference was manifested later only from TD 21 then for the other genotypes. In S440 the effect of the treatment was detected after longer time then in other genotypes. The answer to the treatment was the quickest by White Lady, because the chlorophyll content changed significantly from TD 3.

The relationship between LAI and N uptake is directly proportional (*Hirel et al.*, 2007). In our study LAI decreased under N-limiting conditions but the level of this was found to be genotype dependent (*Fig 2*). The difference in LAI values between N7.5 and N0.75 were statistically significant (except for S440).

Fig. 2: Leaf area index (mm²). LSD = 758,6 P 0.05



In potato tuber dry matter concentration of nitrogen varies between 3.5% (ample supply in nitrogen) and 0.5% (deficient in nitrogen) (*Haverkort et al.*, 2006). In this study values between 1.2% and 2.3% were registered (*Fig 3*). Differences in tuber nitrogen content among the three treatments were statistically significant in all cases.

Fig. 3: Nitrogen content of tubers (%). LSD = 0.016 P 0.05

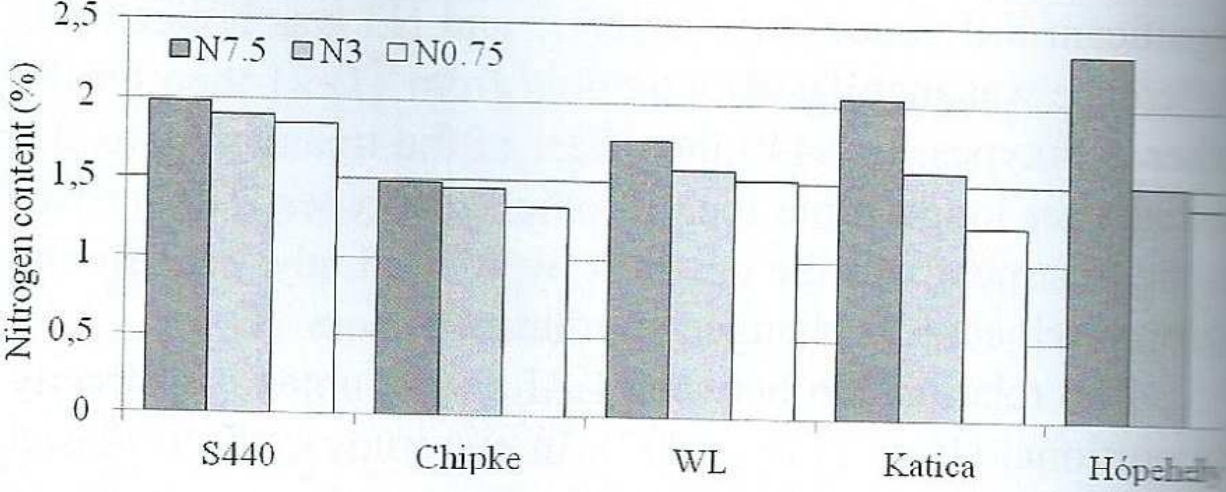


Table 1 shows the positive correlation among various traits under different N supply. Particularly, the N supply (N7.5, N3, N0.75) was positively significantly correlated with LAI (0.578), leaf chlorophyll content on TD 42 (0.818) and tuber nitrogen content (0.648).

Table 1: Correlation coefficient (r) among the analyzed traits

	N-supply	*LAI*	*Leaf chlorophyll content TD 42.*	*Tuber N content*
N-supply	1			
LAI	0.578	1		
Leaf chlorophyll content TD 42.	0.818	0.572	1	
Tuber N content	0.648	0.420	0.629	1

4. Conclusions

Different nitrogen treatments resulted in different LAI, leaf chlorophyll and tuber nitrogen contents. But these traits have a variant tendency by all tested cultivars. White Lady had the quickest and largest answer to the treatments in point of chlorophyll content and LAI. Thus, it can be concluded that White Lady was the most reactive to N-supply from among the tested genotypes.

The higher nitrogen supply increased significantly the nitrogen content of the tubers, but the level of this increase was genotype dependent. From among the analyzed genotypes the tuber nitrogen content increased the most in Hópehely and Katica at higher nitrogen supply.

The current study confirms and extends previous observations (*Vos et al.*, 1993, *Joern et al.*, 1995, *Haverkort et al.*, 2006, *Busato et al.*, 2010) showing marginal effects of nitrogen supply on the rate of leaf chlorophyll content, LAI and tuber nitrogen concentration. Nitrogen supply has been found to be closely correlated with leaf chlorophyll index, LAI and tuber nitrogen concentration in potato. Different nitrogen treatments resulted in different chlorophyll and nitrogen contents in all tested genotypes with variable tendency. It can be summarized that there is a characteristic difference in N-needs among the tested potato genotypes.

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