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Genetic Diversity of Potato Germplasm for Efficient Use of Phosphorus

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Phosphorus (P) use efficiency differs among genotypes due to the biodiversity in mobilization of insoluble phosphates. Seven genotypes of potato, including 'Atlantic', 'Harley Blackwell', 'La Chipper', 'Marcy', 'Satina', 'Red Lasoda', and 'Yukon Gold', were tested in a pot experiment conducted in Hastings, FL using local sandy soil. P treatments included either no supplemental P or 135 kg/ha (120 lb/acre) P_2O_5. Chlorophyll content did show differences between the tested genotypes but no difference between the treatments. Evaluation of shoot biomass between the no supplemental P vs. 135 kg/ha P_2O_5 treatment revealed the least difference for 'Satina' and 'Harley Blackwell' cultivars, with the greatest difference in 'Yukon Gold'. Therefore, the former two cultivars appear to be most efficient in mobilizing insoluble phosphates in soil, hence better able to adapt under P stress. The above response was also confirmed by SPAD meter readings, as an indicator of leaf chlorophyll content and photosynthetic ability of the cultivars.

Along with nitrogen (N) and potassium (K), P is one of the major essential nutrients for plant growth and development. Phosphorus plays an important role in several key functions, including photosynthesis, respiration, energy transfer, sugar and starch transformation, and nutrient translocation. Generally speaking, plants need 0.3 ppm soluble P in the soil to sustain productivity (Ozanne and Shaw, 1968). In order to meet crop P requirement, P fertilizers have been heavily used. Phosphate rock, the raw material of P fertilizers, is decreasing and unevenly distributed in the world. Economically mineable P reserves are estimated to be depleted within the next 50 years (Cisse and Mrabet, 2004). Because no substitute for P exists, the increased cost and depletion of phosphate rock reserves could seriously threaten global food security. In addition to the limitation of P reserves, the efficiency of applied P fertilizer is low (Shenoy and Kalagudi, 2005) due to chemical fixation of phosphate in soil. Furthermore, runoff from excess P fertilizer applied to the soil may pollute surface water, resulting in deterioration of water quality, also called eutrophication. In order to alleviate this P looming crisis, plant breeders have been working on breeding P-efficient cultivars. Root morphology, exudates (organic acid, chelators, and phosphatase), mycorrhizal symbiosis, P uptake kinetics and transporters may vary between plant species and genotypes, therefore greatly impacting the solubility of insoluble phosphates in soil and efficiency of plant P acquisition and leaf chlorophyll content (Raghothama, 1999). Poor use efficiency of P could lead to low photosynthesis rate (Foyer, 1986). The objective of this study was to evaluate if chlorophyll content can be used as an index to identify low-P stressed plants. This index could be a very helpful tool in selecting P-efficient genotypes.

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Materials and Methods

Plant materials and growth conditions. A pot experiment was conducted by using 3.5-gal black nursery pots filled with sandy soil from the IFAS research farm in Hasting, FL. Seven potato genotypes, 'Satina', 'Red Lasoda', 'Harley Blackwell', 'Atlantic', 'La Chipper', 'Marcy', and 'Yukon Gold', were tested. All the pots were fertilized according to the University of Florida IFAS recommended rate of 224 kg/ha N, 168 kg/ha K_2O (Zotarelli et al., 2011). P treatments included either no supplemental P or 135 kg/ha P_2O_5 as triple superphosphate (TSP). N and K rates were applied at 20%, 40%, 20%, and 20% of total rate on 1, 14, 28, and 35 d after planting, respectively. One emitter was placed in each pot. All the pots were irrigated with the same drip irrigation system at the same rate to keep the soil moist depending on the weather. There were three replicates of each treatment, and each replicate had five pots

Response evaluation. A SPAD meter (SPAD-502PLUS; Konika Minolta, Japan) was used to measure leaf chlorophyll content and measurements were made 30, 36, 41, 44, 52, 58, 63, and 70 d after planting. Shoots were harvested and dried in an oven at 70 °C for 72 h and dry weights were recorded.

Result and Discussion

The SPAD reading for a given cultivar was similar regardless of the treatments (135 kg/ha P_2O_5 application or no P application) but differed between the genotypes. A similar trend was observed across all cultivars (Fig. 1). Based on previous research, chlorophyll content is closely related to nitrogen supply (Costa et al., 2001; Netto et al., 2005). Since both P treatments were fertilized with the same rate of nitrogen, it may be able to explain the similarity in leaf chlorophyll contents across both P treatments. P fertilizer application seemed to have no significant influence on the leaf

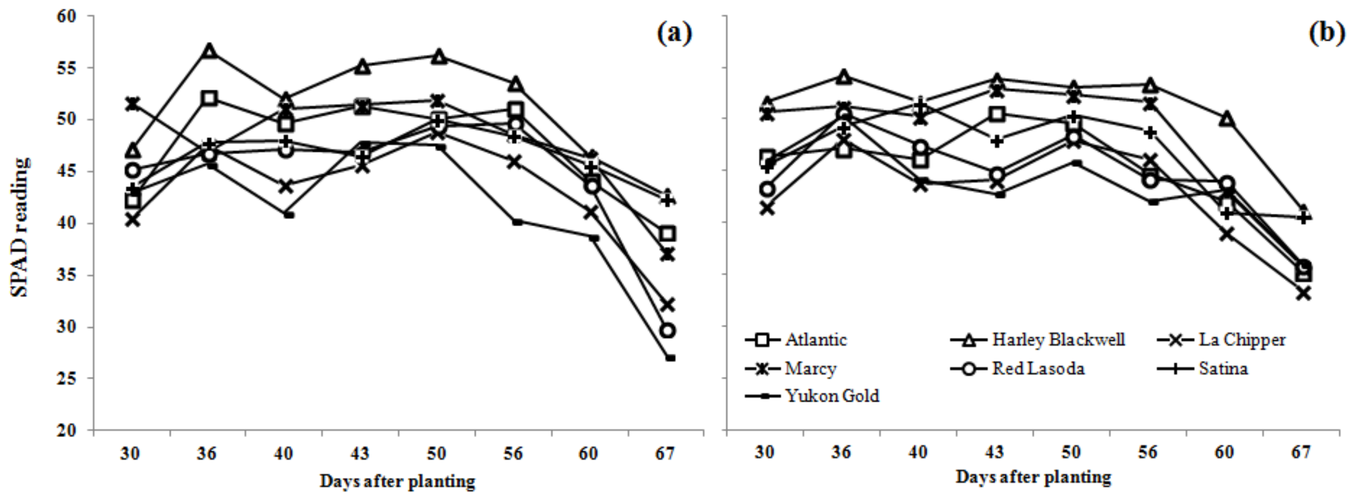

Fig. 1. Genotypic differences in the SPAD readings: (**a**) 135 kg/ha P_2O_5 and (**b**) no P fertilization.

chlorophyll content according to this experiment. Differences between cultivars' greenness might be a result of their genetic variations. 'Harley Blackwell' had the highest chlorophyll content while 'Yukon Gold' was the lowest on SPAD readings (Fig. 1).

Shoot biomass accumulation could be another obvious index for low-P stressed plants. 'Satina's shoot biomass was not significantly influenced by differential P treatments ($\alpha > 0.05$ is considered significant) according to the Tukey HSD (Table 1). Percent increases in shoot biomass of the seedlings that received P application in relation to the no P applied treatment were 26.3%, 16.3%, and 8.8% for 'Atlantic', 'Satina', and 'Harley Blackwell', respectively. The shoot biomass weights across all genotypes were in the range of 18 to 68 g and 31 to 81g for the no supplemental P and 135 kg/ha P_2O_5 treatments, respectively. In the no supplemental P treatment, plants can take up P only from that which was made available from insoluble P in the soil. A genotype with the least difference in biomass between the no supplemental P and 135 kg/ha P_2O_5 treatments is considered as the one with the best P mobilization ability. On the basis of this parameter, 'Satina' and 'Harley Blackwell' may have the potential to mobilize the insoluble P in sandy soil while other genotypes were inefficient. The ability to better mobilize the fixed P in the soil could greatly reduce the demand for P fertilizer, which is crucial to alleviate the potential P crisis that might take place. 'Yukon Gold' and 'Marcy' had the most significant difference between P treatments, 49.47% and 49.15% difference, respectively. It was interesting that 'Yukon Gold' showed the least difference among seven genotypes both in chlorophyll content and shoot biomass accumulation between the P treatments. In future studies, further confirmation of P use efficiency can be achieved by measuring P uptake, phosphatase content, and root structure of the given genotype. The biomass data showed that 'Harley Blackwell' and 'Satina' had the least difference between P treatments, while 'Yukon Gold' showed the greatest difference. SPAD readings for 'Harley Blackwell' were always the highest, but for 'Yukon Gold, the least. 'Harley Blackwell' and 'Satina' seemed to be P-efficient and 'Yukon Gold' a P-inefficient cultivar. This study demonstrated that SPAD readings may have the potential to preliminarily identify P-efficient genotypes.

Table 1. Differences in shoot biomass of seven cultivars grown in a sandy soil with no supplemental P (–P) or with 135 kg/ha P_2O_5 (+P).

	Shoot biomass (g/pot)		Relative biomass
Cultivars	–P	+P	(%)[z]
Atlantic	38.10	51.66	74 bc
Harley Blackwell	53.60	58.83	91 a
La Chipper	30.29	42.43	71 bc
Marcy	31.77	62.48	51 c
Red Lasoda	23.68	42.46	56 c
Satina	67.67	80.89	84 b
Yukon Gold	15.54	30.74	51 c

[z]Means with similar letters are not significantly different at $P < 0.05$.

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