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Title

Mechanisms of phosphorus efficiency in potato genotypes

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Introduction

In view of the high P fertilizer input required by potato, the use of genotypes /cultivars with high P efficiency is an option for sustainable production in low P soils. P efficiency is the ability of a genotype to give higher yield under P limiting condition (*Graham*, 1984). P efficiency normally arises either from P uptake efficiency (the ability to take up more P from deficient soil) and/ or P utilization efficiency (the ability to produce more dry matter for a given quantity of P taken up). The objective of this study was to evaluate potato genotypes for P efficiency and to identify the mechanisms of P efficiency.

Materials and methods

Four genotypes showing consistently contrasting P efficiency were investigated in a soil and nutrient solution experiment. In-vitro propagated plantlets were used.

Soil experiment

A sub-soil was fertilized with 100 mg P kg⁻¹ (low P) and 700 mg P kg⁻¹ (high P). Plantlets were transplanted to plastic pots (vol. 340 mL) filled with soil (bulk density 1.38 g cm⁻³). The plants were grown in controlled climate chamber with a day/night temperature of 23/ 16 °C, relative humidity of 70%/ 80% and light intensity of 200 μmol m⁻² s⁻¹, supplied for 16 hrs/day.

Nutrient solution experiment

The genotypes were grown under three P regimes (10, 45, and 90 μM P in form of KH₂PO₄). Plantlets were transplanted into aerated nutrient solution which was changed separately for each genotype when the highest P regime was depleted to 5 μM. The plants were grown with a day/ night temperature of 22/ 16 °C, relative humidity of 70/ 80% and an average light intensity of 250 μmol m⁻² s⁻¹ supplied for 12 hrs/ day.

Plant and soil analysis, statistical methods

The relative growth rate (RGR, g g⁻¹day⁻¹) was calculated assuming linear growth. Net assimilation rate (NAR, g m⁻² day⁻¹) was computed from NAR= RGR/LAR where LAR =leaf area ratio (m² g⁻¹). Leaf photosynthetic rate and leaf dark respiration rate was measured for the youngest fully expanded primary leaflet using the portable photosynthesis system Li-6400. Morphological root traits were determined as described by *Dechassa et al.* (2003). The treatments were replicated 6 times arranged in a RCBD. Data were analysed using the PROC GLM procedure of SAS. Treatment means were compared according to Tukey test at a significance level $\alpha = 0.05$.

Results

For evaluation of plant growth, the relative growth rate (RGR) was calculated since the initial size of seedlings was different between genotypes (Fig. 1A). At low P supply, genotypes CGN 17903 and CIP 384321.3 had higher RGR compared to the other genotypes. Thus, they are considered as P efficient. At high P supply, however, genotype CGN 22367 was superior to the other genotypes. Compared to low P supply, RGR at high P level increased on average by a factor of 2 for genotypes CGN 17903 and CIP 384321.3 and by a factor of 3.5 for genotypes CGN 22367 and CGN 18233. For all genotypes, root-shoot ratio at low P supply was about two-fold higher than at high P (Fig. 1B). The trend of difference in root-shoot ratio between genotypes was similar for both P levels. Genotypes CGN 18233 and CIP 384321.3 had higher root-shoot ratio than the two other genotypes at both P levels.

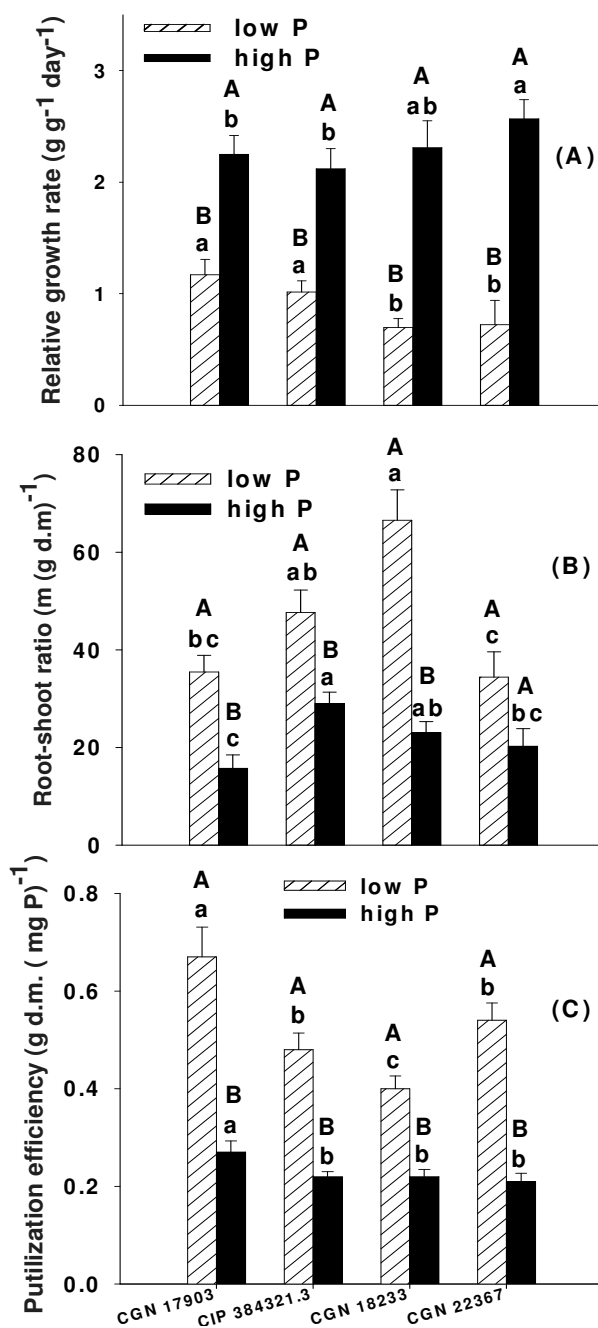


Fig.1 Relative growth rate (A) root-shoot ratio (B) and P utilization efficiency (C) of potato genotypes as affected by P supply in soil (*different small letters indicate significant difference between genotypes at the same P level whereas different capital letters indicate significant difference between P levels for the same genotype, $\alpha = 0.05$ probability level*)

The root radius (0.12 – 0.09 mm) did not differ between genotypes at both P levels. At low P level, the efficient genotypes CGN 17903 and CIP 384321.3 had root hair length of 0.28 mm which was about 0.05 mm longer compared to the other genotypes. With all genotypes, root hair length increased at low P supply by 0.04 mm (data not shown). The pattern of ranking the genotypes for root hair length was similar at both P levels. However, genotypes did not differ in P uptake rate per unit of root length at low P supply which was in the range of $0.02 \mu\text{g (cm root)}^{-1} \text{ day}^{-1}$. At high P supply, P uptake rate was on average 4.5 times higher than at low P level (data not shown). For evaluation of P utilization efficiency the reciprocal of shoot P concentration was calculated (Fig. 1C). Utilization efficiency was higher for genotype CGN 17903 both at low and high P level and genotype CGN 18233 had the lowest P utilization efficiency at low P supply.

To investigate whether the P utilization efficiency was related to physiological (photosynthesis, respiration) or morphological traits (leaf area ratio) or to both, potato genotypes were grown in nutrient solution. For all genotypes, net assimilation rate (NAR) per unit leaf area was enhanced significantly as P supply increased from low to medium P supply (Fig. 2A).

However, at high P supply NAR was not further affected. At low P supply, both efficient genotypes CGN 17903 and CIP 384321.3 showed higher NAR values compared to genotypes CGN 18233 and CGN 22367.

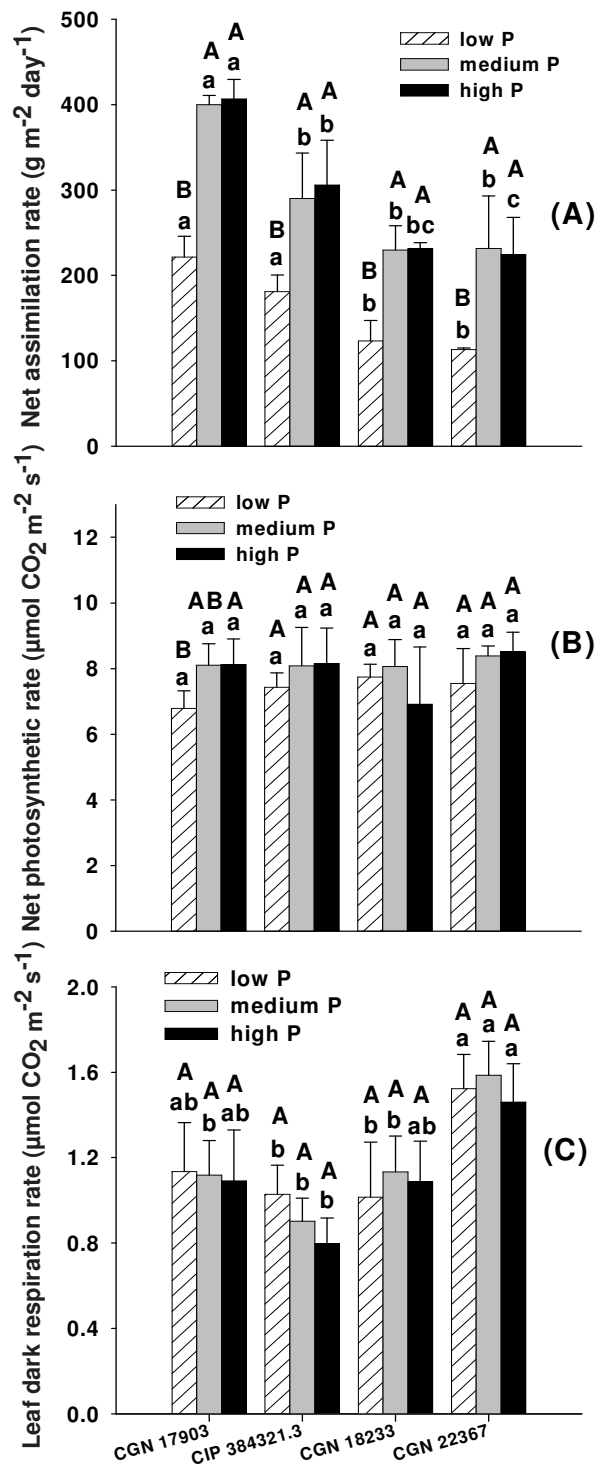


Fig.2 Net assimilation rate (A) Net photosynthetic rate (B) and leaf dark respiration (C) rate of potato genotypes as affected by P supply in nutrient solution (different small letters indicate significant difference between genotypes at the same P level whereas different capital letters indicate significant difference between P levels for the same genotype, $\alpha = 0.05$ probability level)

At medium and high P supply, genotype CGN 17903 had the highest NAR compared to all other genotypes. Leaf area ratio (LAR) increased as P supply was enhanced from low to medium P supply. For the three P regimes different patterns in LAR were observable between genotypes. At low P supply genotype CGN 22367 had lower LAR compared to all others which were very similar. At the two higher P regimes, genotype CGN 22367 had still the lowest LAR whereas genotype CIP 38432.3 had the highest LAR. Photosynthetic rate per unit leaf area of the genotypes measured at growth chamber light intensity ($250 \mu\text{mol photons m}^{-2} \text{s}^{-1}$) was affected neither by P regime nor by genotype except for genotype CGN 17903, in which it was lower in the low as compared to the high P regime (Fig. 2B). Leaf respiration rate measured in the darkness was not influenced by P regime for all genotypes (Fig. 2C). However, the leaf respiration rate of genotype CGN 22367 was higher compared to genotype CIP 384321.3 for all three P regimes. This tendency was also observed comparing genotype CGN 22367 with genotypes CGN 18233 and CGN 17903.

Discussion

Potato genotypes grown in soil differed significantly in RGR at low P supply (Fig. 1A) and this difference was related to both P uptake (Fig. 1B) and P utilization efficiency (Fig. 1C). Superiority of genotype CGN 17903 was related to high P utilization efficiency whereas that of genotype CIP 3284321.3 was related to both uptake efficiency in terms of higher root-shoot ratio and intermediate utilization efficiency. The P-efficient genotypes with

higher RGR under P limiting condition exhibited higher NAR compared to the P-inefficient genotypes (Fig. 2A). Since LAR did not differ much among the genotypes, it is suggested that the higher RGR of the P-efficient genotypes at low P supply resulted from the enhanced NAR. The low NAR of P-inefficient genotypes were not explicable by differences in net photosynthetic rate (Fig. 2B) but rather to higher leaf dark respiration rate in case of the P-inefficient genotype CGN 22367 (Fig. 2C). However, with the P-inefficient genotype CGN 18233, leaf dark respiration rate was still similar to that of P-efficient genotypes. Based on the relatively larger root dry matter proportion (data not shown), we speculate that the lower NAR of the P-inefficient genotype CGN 18233 could be accounted for by enhanced root respiratory demand for carbon or carbon exudation or both.

References

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