Gaspe flint maize as a model to study the effect of phosphorus on growth and development of maize from seed to seed

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Introduction

Today *Arabidopsis* is the main model system for laboratory studies in basic plant biology. Understanding *Arabidopsis* nutrient transport will assist in understanding and improving nutrient acquisition efficiency in crop plants which could eventually lead to the development of environmentally sound agricultural practices with low inputs of inorganic fertilizers. However, it has to be noted that some biological phenomena, such as species-specific plant pathogen interactions, mycorrhizal symbiosis or nitrogen fixation, cannot be studied in this model plant (Poirier and Bucher, 2002). It is also difficult to translate this data on role of Pi deficiency on reproductive organs of Arabidopsis to crop plants like maize. In view of these shortcomings, specifically for phosphate nutrition, gaspe flint was evaluated to see if it was suitable as a model to study the effect of phosphorus on growth and development from seed to seed in a hydroponics system. The following characteristics of gaspe flint make it a model for phosphate nutrition studies. Gaspe flint is a dwarf maize genotype with a short life cycle. Interestingly the gaspe flint life cycle can be completed within eight weeks, similar to that of Arabidopsis. This short life cycle provides a unique opportunity to examine the effect of Pi deficiency on all aspects of plant growth under controlled conditions. Pollination occurs 28-30 days after emergence and results in 50-150 mature seed within four weeks of pollination. Furthermore, it is well adapted to different environmental conditions. Gaspe flint grows well under long day photoperiod conditions (14 hours light, 10 hours dark) and under varying temperature (between 18 °C to 32 °C). The seedlings normally emerge within five-six days after sowing. Plants attain microspore meiosis by about 14-16 days after emergence. Tillers begin to form 14 days after emergence and they contain cobs while tassels are clearly visible in about three weeks after emergence. Pollen shedding begins four weeks after emergence. The ear is generally harvested four weeks after pollination even though the plants are still green. Therefore, this unique maize line was used as a model to study the effect of phosphate on growth and development of maize from seed to seed. Gaspe flint became useful as a maize model plant for phosphorus studies.

Methodology

Gaspe flint seeds were germinated and one-week-old seedlings were removed from the soil medium. The roots were washed free of media and the plants were transferred to a hydroponics set-up containing half-strength modified Hoagland's solution (Liu et al., 1998). One week after transferring the seedlings to hydroponics the experimental treatments were initiated. Sets of plants were transferred to half strength nutrient solution with different concentration of Pi (0, 5, 10, 25, 50, 100 and 250 micromolar). The solutions were changed every two days during the treatment period to maintain the concentration of nutrients and pH. Furthermore, after 15 days of growth under P+ and P- conditions, roots, stem, young leaves and old leaves were harvested separately for physiological, biochemical and molecular evaluation. Some plants were maintained until maturity to evaluate the effect of varying concentrations of phosphorus on plant growth and reproductive organ development.

Results and Discussion

The results presented here clearly show that all the phosphate starvation responses are replicated in gaspe flint. This plant has shown a profound effect on development of female reproductive organ (cobs) correlated with the phosphate availability in the nutrient solution. This observation supports the notion that phosphorus deficiency results in a delay in flower development and reduction in fruit set, in addition to a range of vegetative phenotypes (Marschner, 1995). The lack of synchrony between male and female gametophytes resulting in lack of pollination is a major factor affecting corn yield in phosphate deficient soils. This feature of maize reproduction could be used to select Pi efficient genotypes in the field. This is one example where significant new information on plant response was obtained using a model plant. Anthocyanin content and acid phosphatase activity increased with decreasing concentration of Pi in the medium. Interestingly the maize plants accumulated significant quantities of anthocyanins in the roots. This was a clear correlation between anthocyanin accumulation in gaspe flint plants and phosphorus concentration in the nutrient solution. Accumulation of anthocyanins in photosynthetic tissues, which is one of the most characteristic visible symptoms of phosphate deficiency, appears to serve a photoprotective role by optical masking of chlorophyll and by facilitating the conversion of excess absorbed light energy to heat (Niyogi et al., 1997; Field et al., 2001).

Use of gaspe flint as a crop model plant enhanced our ability to analyze the tissue specific expression of phosphate transporters. The results showed expression of *ZmPT* in all parts of the plant while older leaves showed strong expression of most of the transporters. The root specific expression correlates well with those functions in phosphate uptake. There were striking differences in the expression pattern of *ZmPTs* in response to Pi resupply. When plants starved for Pi were replenished with phosphate, the rapidity with which transcript levels decreased was markedly different for the four transporters. The replenishment experiments further confirm the innate ability of plants to regulate Pi uptake based on availability and demand for Pi.

The results presented in this study clearly support our choice of using Gaspe flint as a crop model to study physiological, morphological, biochemical and molecular aspects of phosphate starvation response. Furthermore, Gaspe flint can serve as an efficient model plant for analyzing many nutrient deficiencies from seed to seed.

References

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