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Interplay Between Phospholipids and Digalactosyldiacylglycerol in Phosphate Limited Oats

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ABSTRACT

Phosphate is an essential nutrient. In most soils it is limiting, which has resulted in that phosphate is supplied as fertilizer to increase crop yield. Through evolution, plants have adapted several mechanisms to increase phosphate uptake from the soil and to household with acquired phosphate. A recent discovered house-holding mechanism is that plants utilize the phosphate bound in the headgroups of phospholipids: under phosphate-limiting conditions, phospholipids can be replaced by the non-phosphate containing lipid digalactosyldiacylglycerol (DGDG), previously assumed to reside in plastid membranes. The extra-plastidial phospholipid-to-DGDG replacement occurs in plasma membrane, tonoplast and mitochondria and has led to discoveries of new enzymes and metabolic pathways in plants.

This thesis reports that phosphate limitation-induced biochemical and lipid compositional changes in oat root plasma membranes occur prior to any morphological changes in the oat. The phospholipase kinetics suggests that the plasma membrane is continuously supplied with phospholipids and that the products of plasma membrane lipase activities, phosphatidic acid and diacylglycerol, both are removed from the membrane. Furthermore, the phospholipid-to-DGDG replacement is reversible and when phosphate is resupplied the proportion of phospholipids increases and DGDG decreases in the oat root plasma membrane.

Membrane lipids are more than a two dimensional liquid where membrane proteins reside. The specific lipid composition and distribution enables the membrane to function as a barrier to solutes and the interactions between lipids and proteins are important for the correct function. The lateral and transversal lipid distribution in oat root plasma membranes shows that DGDG does not replace phospholipids molecule for molecule; whereas phospholipids occur in both leaflets of the plasma membrane, DGDG is almost exclusively localized in the cytosolic leaflet. Model membrane studies suggests that one of the reasons that DGDG is absent in the apoplastic leaflet is its incompatibility to properly interact with the high sterol content of this leaflet.

The oat seed contains enough phosphate to complete an entire generation without any exogenously supplied phosphate. The overall seed yield is much lower in phosphate-limited oat compared to fully fertilized oat, but the seed quality (starch, β-glucan, lipid, soluble protein) is very similar, including that the phospholipids-to-DGDG replacement is absent from the mature oat seeds, here membrane lipid composition is conserved. Oat thus produce a few seeds of acceptable quality rather than more seeds of poor quality.

Keywords: acyl chain order; *Avena sativa*; DGDG; digalactosyldiacylglycerol; oat; liquid order; phosphate; phospholipase; plasma membrane; stress

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