Towards the optimization of pea nodulated root system architecture for improved water and nutrition acquisition

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Grain legumes like pea can meet their nitrogen demands through symbiotic nitrogen fixation (SNF) carried out by soil bacteria residing in root nodules. This ability makes legumes a source of N for low-input agroecosystems. However, pea productivity and yield are sensitive to drought events, which have increased incidence due to climate change. Soil water deficit associated with drought impairs SNF and nutrient uptake such as sulfur (S). Besides, the reduction of S emission and deposition associated with efforts to reduce greenhouse gas emissions has led to S deficiency in cropping systems, affecting plant growth and yield. S is a key element required for pea growth, seed protein formation and SNF. It is a key component of nitrogenase and leghemoglobin which are crucial for SNF, and of antioxidant glutathione which is involved in water stress mitigation. Considering these key roles of S in SNF and water stress, an experiment was conducted to understand the impact of water stress (WS S+), sulfur deficiency (WW S-) and their combination (WS S-) on pea growth and hydromineral acquisition with a structural functional analysis focusing on SNF and nutrient uptake. Root architecture, nodulation, nutrient uptake and allocation were studied in genotypes Kayanne, Cameor and Cameor mutant 2684 (which lacks vacoular sulfate transporter gene SULTR4) in RhizoTubes under single or double stress. We found that water stress, occurring alone or with S deficiency, strongly impacted plant traits compared to S deficiency. Under WS S+, both Kayanne and Cameor prioritized biomass, C and N allocation towards roots instead of shoot and nodules. In addition, WS decreased biomass and area of shoot and of nodules while increasing root depth. It also decreased plant concentration of essential nutrients like P, K and S. WW S- did not affect the overall plant growth, and only decreased shoot area, nodule area and biomass. It also decreased plant concentration of S, Mo, B and P (elements with key roles in SNF) and their allocation to the nodules. Compared to Kayanne, Cameor and 2684 showed a stronger decrease in N and S concentration and nodule area under WW S-. Double stress showed similar response to WS S+ in plant growth and nutrient uptake. WS affected both Cameor and mutant similarly, but WW S- caused a stronger reduction in nodule growth in 2684 compared to Cameor. This suggests that the two genotypes Kayanne and Cameor are similarly tolerant to water stress, but Cameor is more susceptible to S deficiency, and mutant 2684, with absence in S remobilization, is even more susceptible to S deficiency.