## What flavonoid mechanisms might influence enzyme activity?

### As a carbon source

Flavonoids are 15-carbon polyphenolic compounds (Jain, 2009, Symonowicz and Kolanek, 2012) that represent a considerable proportion of the output of root exudates (Hassan and Mathesius, 2012). Narasimhan et al. (2003) found that flavonoids represented approximately 40% of all secondary metabolites, based on a metabolomic approach to the analysis of the root exudates of *Arabidopsis thaliana* (Landsberg erecta). Flavonoids contribute to changes in the biological, chemical and physical properties of the rhizosphere and soil (Watkins et al., 2009). Some microbes in the soil are able to utilise a range of flavonoids; however, these flavonoids have inhibitory effects on some microbial communities in the rhizosphere (Hassan and Mathesius, 2012, DeBruijn, 2013). In addition, some flavonoids, such as anthocyanin subgroups, are conjugated to different types of sugars (Jain, 2009), which means they have the ability to store chemical energy as carbon form and deliver them. Increased exudation of flavonoids by the Arabidopsis abcg30 mutant has been found to change total microbial community structure in the rhizosphere because of the increasing number of species that can use flavonoids as a carbon source (Hassan and Mathesius, 2012, Badri et al., 2009). Plant species are generally thought to be associated with specific rhizosphere microbial species or communities; this is because different plants supply different exudates to the rhizosphere to support different microbial functions (DeBruijn, 2013). Microbial enzyme activities are one of these functions and are highly related to root exudation and microbial communities in the rhizosphere (Gianfreda, 2015). Chitinase and α-glucosidase activities were significantly higher in the rhizosphere of *Salix helvetica* than in most other plants, while phosphatase, xylosidase and β-glucosidase activities were elevated in the rhizosphere of *Agrostis gigantea* and α-glucosidase and sulfatase were elevated under *Rhododendron ferrugineum* (Welc et al., 2014). The input of a substance-inducing flavonoid as a carbon source can activate the microbial synthesis of intracellular and extracellular enzymes or can serve as an energy source for the production of extracellular enzymes (Gianfreda, 2015). The higher activity of rhizosphere enzymes can be interpreted as a greater functional diversity of the microbial community (Gianfreda, 2015). Gianfreda (2015) and Brzostek et al. (2013) showed that the exudation of carbon forms by tree roots stimulates microbial activity and production of extracellular enzymes in the rhizosphere. However, in *Pinus densiflora* seedlings, Kim et al. (2010) recorded rhizosphere activity incensements of β-glucosidase, N-acetylglucose amidase and phosphatase with decreases of soil moisture, nitrate concentration and the concentration of soil phenolic compounds (Gianfreda, 2015), such as flavonoids (Jain, 2009, Symonowicz and Kolanek, 2012). In general, the synthesis of intracellular and extracellular enzymes, and subsequently their activities, increased as result of the activation of soil microorganisms by the addition of the carbon source (Kuzyakov et al., 2000, Zhu et al., 2014). In addition, findings demonstrated that soil enzyme activities, and particularly rhizosphere enzymes, may serve as effective indicators of microbial functional diversity (Caldwell, 2005). Rodriguez-Kabana et al. (1983) found that chitinase activity was correlated with soil fungal population. DeAngelis (2005) and Ladd and Butler (1972) also found that protease activity is a function of total bacterial cell counts.