Salicylic acid and heptanoyl salicylic acid show distinct modes of action on a wheat-powdery mildew interaction

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Abstract

Powdery mildew would be one of the most damaging wheat (*Triticum aestivum*) diseases without the extensive use of conventional fungicides. It is caused by *Blumeria graminis* f.sp. *tritici* (*Bgt*), an obligate biotrophic fungus that invades wheat aerial parts. Several resistance inducers have been shown to induce resistances in wheat against *Bgt*: trehalose, salicylic acid (SA), heptanoyl salicylic acid (HSA), Iodus40®, Milsana®, nonacetylated and acetylated oligogalacturonides (Reignault *et al*., 2001; Muchembled *et al*., 2006; Randoux *et al*., 2006; Renard-Merlier *et al*., 2007; Randoux *et al*., 2010). HSA is a SA derivative obtained by esterification of 2-OH benzoic acid with heptanoic acid (Muchembled *et al*., 2006). It has been shown to be twice as efficient as SA in preventive treatments: the protection levels against *Bgt* increased from 50% in SA-treated plantlets to 95% after HSA sprayings (Renard-Merlier *et al*., 2007), without any direct effect on conidia germination.

Our work aimed at characterizing and comparing for the first time at the molecular level the modes of action of both SA and HSA. The expression level of genes involved in several defence-related pathways was measured using real-time qPCR.

SA and HSA priming activities were assessed in plantlets pre-treated with these resistance inducers and subsequently challenged with *Bgt*. Compared with untreated inoculated plantlets, SA induced an additional late up-regulation of the *lox* gene whereas HSA-treated leaves showed an induced *lox* gene expression all over the time-course experiment. The *oxo* gene expression was induced shortly after SA spraying while no change occurred in HSA-treated leaves. The chitinases-encoding genes were up-regulated earlier in SA-treated leaves while their expression remained unchanged after HSA spraying. A single upregulation of the PR1-encoding gene expression was induced by SA, whereas HSA induced several additional upregulations over the time course. Neither SA nor HSA induced changes in the *pal*, *lipC2* and *gstf* genes expression patterns.

We also investigated SA and HSA eliciting activities in non-inoculated plantlets. Again, these resistance inducers showed differences in the induced gene expression patterns: while both SA and HSA induced *lox* and *lipC2* genes, SA and HSA modified expressions of *pal* and *ltp* genes, respectively. Moreover, in SA-treated plantlets, durations of *oxo* and *gstf* gene expression were extended. For other PR-proteins (chitinases and PR1), SA induced early expression changes while later and stronger inductions occurred after HSA treatment.
SA and HSA therefore exhibited different modes of action as resistance inducers in wheat against powdery mildew: timing, frequency and gene expression levels have been shown to differ, as well as some involved metabolic pathways. Whether the molecular modification of SA - that probably improved its penetration through the hydrophobic plant cuticle – or some HSA intrinsic properties explain the greater HSA efficacy will be discussed. The gain of efficacy and the corresponding mode of action may allow the characterization of efficient defence markers for the wheat/powdery mildew interaction.

Keywords: *Blumeria graminis* f.sp. *tritici*, *Triticum aestivum*, salicylic acid, heptanoyl salicylic acid, elicitor, resistance inducer, Real-Time PCR, gene expression.