Application of Induced Resistance in Cucumber Disease Control

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Induced resistance in plants increases the ability of susceptible plants to withstand pathogens in a non-genetic way. Induced systemic resistance can be an effective control strategy since it often leads to control of multiple pathogens. The resistant reaction usually is not race-specific, and in some cases may result in simultaneous resistance to fungi, bacteria and viruses.

The phenomenon of induced resistance was first reported by Bernad (1909). Chester (1933) later reported the systemic resistance in plants. However, the term systemic acquired resistance (SAR) was officially proposed by Ross (1961), who reported the resistance in tobacco plants following local infection with tobacco mosaic virus.

Resistance-inducing factors include both biotic and abiotic ones. In cucumber, a primary inoculation with the fungus *Colletotrichum lagenarium* induced SAR against a dozen diseases caused by fungal and bacterial as well as viral pathogens. Resistance can persist for a few days to many weeks. Inoculation of the first leaf, followed 2-3 weeks later by a second booster inoculation, protected plants up to flowering in cucumber.

Kloepper and Schroth (1978) reported that certain root-colonizing bacteria could promote radish growth in greenhouse and field trials and named the bacteria plant growth-promoting rhizobacteria (PGPR). Recently, it was reported that certain PGPR strains protected plants through mechanisms associated with SAR against pathogens that cause foliar disease symptoms. Field experiments in cucumber demonstrated that plants grown from seed treated with PGPR sustained a significantly lower incidence of bacterial wilt disease. PGPR strains have been selected that, when applied as seed treatments, induce systemic resistance of cucumber against anthracnose. Some strains protect plants against damage from several pathogens[7,14].

The induction of resistance in parts remote from the site of primary inoculation is postulated to result from the translocation of systemic signal produced at the site of primary infection. This signal primes the plant against further pathogen attacks, probably triggering a complexity of defense responses.

Induced resistance may several kinds of mechanisms. It may involve a higher rate of papillae formation in previously uninfected leaves in cucumber[6], the production of pathogenesis-related proteins, an oxidative burst, etc.[5,15].

Induced resistance depends on the initial stimulus. There are different signal transduction pathways. These pathways rely on endogenous regulators such as salicylic acid (SA), ethylene and jasmonic acid to induce defense reactions. In defense against pathogens, SA is a key component of the signal transduction pathway that activates resistance against many plant pathogens, including fungi, bacteria, and viruses[8]. Components of the early signal transduction pathway include nitric oxide (NO), which activates G proteins and opens Ca^{2+} channels. Aconitase is a possible target of NO and may regulate the iron availability required for the production of the toxic hydroxyl radical that could be involved in HR cell death.

Biochemical studies showed that many new proteins accumulate after induction of SAR, including small acidic and basic proteins. In cucumber, galacturonic acid, gallic acid, oxalic acid, protocatechuic acid, phloroglucinol, salicylic acid, trimelletic acid etc., can act as elicitors to induce systemic resistance to *Colletotrichum lagenarium*. Salicylic acid as an elicitor can induce resistance to *Cladosporium cucumerinum*, where chitinase accumulates only in treated leaves.

Conventional induced resistance requires prior inoculation of plants with a necrosis-inducing pathogen, which makes practical use in agriculture unlikely. Several research groups are currently testing chemical compounds as foliar sprays to induce resistance.

For inorganic compounds, spray treatment of the lower leaves of cucumber plants with phosphate salts induced local and systemic resistance against

Colletotrichum lagenarium and *Sphaerotheca fuliginea*[10,11]. Calcium sequestration at the site of application by phosphates is thought to generate an endogenous SAR signal. In cucumber, powdered SiO_2 preparations induce SAR accompanied by enhanced activities of chitinase, β-1,3-glucanase, peroxidase, and polyphenoloxidase[12]. Si applied to the soil protects cucumber against *Pythium* spp., with the induction of biochemical changes related to defense[2]

For natural organic compounds, salicylic acid can induce systemic resistance to *Colletotrichum lagenarium* in cucumber. Plant extracts of *Reynoutria sachalinensis* induced peroxidases, β-1,3-glucanase and phenolic compounds to powdery mildew infection.[3]. Chitosan can induce resistance to *Pythium aphanidermatum* in cucumber[4]. Experiments showed that the oligomers of chitosan from fungus can protect cucumber leaves against *Sphaerotheca fuliginea*. Inoculation with bacterium *Pseudomonas syringae* pv. *syringae* (Pss61) resulted in systemic protection in cucumber, inducing PR-genes and SAR against several pathogens[13].

In synthetic compounds, 2,6-dichloroiso-nicotinic acid results in systemic protection in cucumber against various foliar diseases besides *Sphaerotheca fuliginea*, and against damping-off and seedling rot of cucumber caused by *Rhizoctonia solani.*[9]. Benzo-thiadiazole (BTH), a chemical activator of plant disease resistance, has no known direct antifungal effect and is thought to play a role similar to that of salicylic acid in the signal transduction pathway leading to systemic acquired resistance. BTH, when applied to cucumber, induced systemic resistance to *Pythium* damping-off, *Colletotrichum lagenarium* and induced accumulation of chitinase to *Cladosporium cucumerinum*[1]. BABA (DL-3-amino-butyric acid) induced resistance in cucumber against *Sphaerotheca fuliginea.* DF-391, a novel non-fungicidal synthetic pyridine derivative, is active against cucumber anthracnose .

The nature of the systemic induced resistance response of cucumber against pathogens will soon be determined by using cytological, biochemical and molecular techniques. As more and more SAR genes are transferred into plant genomes, many trangenic resistant plants will be developed. In the near future, more such genes will be cloned and applied to agriculture.

Literature Cited

1. Benhamou, N. and R.R. Belanger, 1998. Induction of systemic resistance to *Pythium* damping-off in cucumber plants by benzothiadiazole: Ultra-structure and cytochemistry of the host response. Plant Journal 14: 13-21.
2. Cherif M., A.Asselin, and R.R. Belanger. 1993.Defense responses induced by soluble silicon in cucumber roots infected by *Pythium spp*. Phytopathology 82:236-242.
3. Daayf, F., A. Schmidtt, and R.R. Belanger. 1995. The effects of plant extracts of *Reynoutria sachalinensis* on powdery mildew development and leaf physiology of long English cucumber. Plant Disease 79, 577-580.
4. El Ghaouth, A., L. Arul, J. Grenier, N. Benhamou, A. Asselin, and R. Belanger. 1994. Effect of chitosan on cucumber plants: suppression of *Pythium aphanidermatum* and induction of defense reactions. Phytopathology 84, 313-320.
5. Kastner, B., R. Tenhaken, and H. Kauss. 1998. Chitinase in cucumber hypocotyls is induced by germinating fungal spores and by fungal elicitor in synergism with inducers of acquired resistance. Plant Journal 13: 447-454.
6. Kovats, K., A. Bindeer, and H.R. Hohhl. 1991. Cytology of induced systemic resistance of cucumber to *Colletorichum lagenarium*. Planta 183: 484-90.
7. Liu, L., J.W. Kloepper, S. Tuzun. 1995. Induction of resistance in cucumber by plant growth-promoting rhizobacteria: duration of protection and effect of host resistance on protection and root colonization. Phytopathology 85: 1064-1068.
8. Metraux, J.P., H. Siger, J. Ryals, et al. 1990. Increase in salicylic acid at the onset of systemic acquired resistance in cucumber. Science 250, 1004-1006.
9. Metraux, J.P., P. Ahl-Goy, T. Staub, et al. 1991. Induced systemic resistance in cucumber in response to 2,6-dichloro-isonicotinic acid and pathogens. In: Advances in Molecular genetics of Plant-Microbe Interactions, ed. H Hennecke, DPS Verma, pp. 432-439. Amsterdam: Kluwer.

10. Reuveni, M., V. Agapov, and R. Reuveni. 1996. Controlling powdery mildew caused *Sphaerotheca fuliginea* in cucumber by foliar sprays of phosphate and potassium salts. Crop Protection 15: 49-53.
11. Reuveni, M., V. Agapov, and R. Reuveni. 1995. Suppression of cucumber powdery mildew (*Sphaerotheca fuliginea*) by foliar spray of phosphate and potassium salts. Plant Pathology 44: 31-39.
12. Schneider, M. and WR. Ullrich 1994.Differential induction of resistance and enhanced enzyme activities in cucumber and tobacco caused by treatment with various abiotic and biotic inducers. Physiol. Mol. Plant Pathol. 45:291-304.
13. Smith, J.A., R. Hammerschmidt, and D.W. Fulbright. 1991. Rapid induction of systemic resistance in cucumber by *Pseudomonas syringae* pv. *syringae*. Physiol. Mol. Plant Pathol. 38: 223-235.
14. Wei, G., J.W. Kloepper, and S. Tuzun. 1995. Induced systemic resistance to cucumber diseases and increased plant growth by plant growth-promoting rhizobacteria under field conditions. Phytopathology 86: 221-224.
15. van Loon, L. C. (1997). Induced resistance in plants and the role of pathogenesis-related proteins. European Journal Plant Pathol 103, 753-6