MINIREVIEW

Biological Activities of Saccharides in Plant Cells (TIGG-11/02/89-MR-1)

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It is understood that in a variety of plants (such as leguminous, solanaceous and cucurbitaceous plants), the host plant produces an antibacterial substance (phytoalexin) in order to retard the growth of pathogenic organisms after their invasion. When the mechanism of its formation was studied in detail, it was elucidated that a saccharide (elicitor) derived from the cell wall of the host plant or the invasive organism triggers the production and accumulation of metabolites specific to given species (Table 1). These metabolites include not only phenolics but also a wide range of compounds such as sesquiterpenes, diterpenes, triterpenes, steroids, various alkaloids, quinones and straight-chain compounds. In addition, saccharides play an important role in promoting the production of normal secondary metabolites (berberine, strictosidine, benzophenanthridine, sanguinarine, shikonin, etc.), not to mention phytoalexin. The activation of a wide variety of metabolisms by saccharides is being characterized.

These findings have resulted in drawing attention to the physiological role of the cell walls and of the component sugars, in addition to a possible physical factor, which contribute to the arrangement of the shape of cells; the possibility has been suggested that oligosaccharides or polysaccharides are deeply involved not

Table 1. Saccharide-stimulated accumulation of various metabolites in plant cells

Product	Plant species	Origin of elicitor	Reporter
Acridone alkaloids	<i>Ruta graveolens</i>	chitosan, Botrytis, Sclerotinia	Eilert 1984
Benzophenanthridines	<i>Eschscholtzia californica</i>	yeast, <i>Penicillium</i>	Zenk 1987
Berberine	<i>Thalictrum rugosum</i>	yeast	Funk 1987
Dihydrosanguinarine	<i>Papaver somniferum</i>	Botrytis sp	Kurz 1988
Sanguinarine	<i>P. somniferum</i>	"	Kurz 1988
	<i>P. bracteatum</i>	Dendryphion sp	Cline 1986
Strictosidine	<i>Catharanthus roseus</i>	<i>Pythium aphanidermatum</i>	Kurz 1986
Capsidiol	<i>Nicotiana tabacum</i>	<i>P. megasperma</i> , <i>Pseudomonas lachrymans</i>	Chappell 1987
Gossypol	<i>Gossypium arboreum</i>	<i>Verticillium dahlia</i>	Henstein 1981
Lubimin	<i>Solanum tuberosum</i>	<i>P. megasperma</i>	Brindle 1983
Rhisitin	"	<i>P. infestans</i>	Coolber 1985
Casbene	<i>Ricinus communis</i>	plant cell wall, <i>Rhizopus stolonifer</i>	Nest 1982
Momilactone(oryzalexins)	<i>Oryza sativa</i>	plant cell wall, concanavalin	Kobayashi 1989
Triterpene	<i>Tabernaemontana</i> sp	<i>Aspergillus niger</i>	Heijden 1988
Diosgenin	<i>dioscorea deltoidea</i>	fungi(<i>Sclerotinia sclerotiorum</i> etc)	Rokem(1984)
Bergapten	<i>Petroselinum hortense</i>	<i>Alternaria carthami</i>	Tietjen 1983
Coumarins	"	<i>Phytophthora</i> , <i>Alternaria</i> , chitosan	Tietjen 1983
Isoflavones	<i>Vigna angulata</i>	<i>P. megasperma</i> , nigeran	Ohta 1985
Glyceollin	<i>Glycine max</i>	plant cell wall, <i>P. megasperma</i>	Albersheim
Glycinol	"	plant cell wall	Albersheim
Phaseollin	<i>Phaseolus vulgaris</i>	Botrytis, nigeran, chitosan	Albersheim
Pterocarpan	<i>Cicer arietinum</i>	yeast	Barz 1987
Echinatin	<i>Glycyrrhiza echinata</i>	yeast, alginic acid	Avabe 1986
6-Methoxymellein	<i>Daucus carota</i>	plant cell wall	Kurosaki 1984
Furanocoumarin	<i>Petroselinum crispum</i>	<i>P. megasperma</i>	Tietjen 1983
Anthraquinones	<i>Cinchona</i> sp	<i>Aspergillus niger</i>	Wijnmar 1986
Shikonin	<i>Lithospermum erythrorhizon</i>	pectic acid, agarosectin	Fukui 1983
Polyacetylenes	<i>Solanum melongena</i>	nigeran	Imoto 1988
"	<i>Bidens pilosa</i>	<i>Pythium aphanidermatum</i>	DiCosmo 1982

only in the relationship between the plants and pathologic organisms but also in the control of plant growth cycle. Table 2 summarizes the biological activities of the saccharides reported so far. Of these activities, some are believed to inhibit the invasion of pathogens and their growth such as the inhibition of proteinases (inhibition of the bacterial degradation of cells), the formation of lignin (enhancement of cell strength), the generation of saccharases (production of elicitors) and the necrosis of cells. It is interesting to note that some examples are known to be heavily involved in the life cycle of plants such as the stimulation of plant hormone production (ethylene), the activation of anti-plant hormones (anti-auxin) and the regulation of budding. Unfortunately, since the saccharides for use in the detection of these biological activities are extraneous, it seems essential to describe the relationship between the quantitative and qualitative changes in the intrinsic saccharide and the expression of physiological phenomena.

Biologically active saccharides include a wide range of saccharides of bacterial and plant cell origin such as rhamnogalacturonan, oligogalacturonide, glucan, xyloglucan, chitosan and hemicellulose; on the other hand, however, many crude extracts and hyphae per se are frequently used in the detection of activities. For this reason, in order to recognize the physiological significance of saccharides in a broad field of plant physiology and further elucidate the relationship between the structure and the biological activities of saccharides, it is important to increase the purity of saccharides for use in the determination of biological activities and characterize the types and polymerization degree of component saccharides. It is hoped that the methodologies of saccharide purification and

Table 2. Biological activities of saccharides in plant cells

Activity	Plant species	Origin of saccharides	Type of saccharide
Proteinase inhibitor formation	Lycopersicon esculentum	L. esculentum	rhamnogalacturonan I MW 5-10kD
Chitinase formation	Solanum tuberosum Daucus carota	Phytophthora infestans Chaetomium globosum	crude insoluble mycelium
Glucanase formation	Solanum tuberosum	P. infestans	crude
Callose formation	Catharanthus roseus Petroselinum crispum	commercial	chitosan (DP>1000)
Hydroxyproline-rich glycoprotein	Phaseolus vulgaris	Colletotrichum lindemuthianum	chitosan (DP>1000)
Lignin formation	Phaseolus vulgaris Daucus carota	C. lindemuthianum Chaetomium globosum	hot-water soluble
Ethylene formation	Triticum aestivum Cucumis melo	Puccinia graminis Co. lagenarium	high-molecular mass insoluble mycelium >100kD
Morphogenesis	Glycine max Nicotiana tabacum	P. megasperma plant cell wall Acer pseudoplatanus	hot water extract (EtOH-soluble) glucan I hot water extract oligogalacturonide frag. hemicellulose frag.
Necrosis	Vigna unguiculata Daucus carota	V. unguiculata Ch. globosum mycelium	polygalacturonase mycelium
Anti-auxin	Pisum sativum	Rosa sp.	xyloglucan (DP>3) (fucose)
Anti-viral activity	Pisum sativum (AlMV) Nicotiana tabacum (TMV)	Acer pseudoplatanus commercial	xyloglucan (DP 9) chitosan
Inhibition of protein synthesis	Acer pseudoplatanus	P. megasperma A. pseudoplatanus	glucan (>2000D) >1000D
Effect on plasmalemma potential	Petroselinum hortense	Alternaria sp	hot water extract
Generation of active oxygen	Oryza sativa	(xylanase, pectin lyase)	(enzyme activity)

chemical analysis will be further simplified in order to clarify the physiological significance of saccharides.

The saccharides express genetic information via receptors, and phytoalexin is produced and accumulated by de novo synthesized enzymes. However, with regard to the mechanism of intracellular information transfer, some reports have suggested the involvement of protein kinase, cAMP, phosphatidylinositol and calcium such as for animal cells; on the other hand, some data denying this were published. Whether it is due to the difference in species is, together with other questions, a very interesting problem to solve in the future.

I would like you to consult the following references for your information on the details of each topic mentioned above.

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Diverse Specificity of Endo- β -Galactosidase
(TIGG-11/02/89-MR-2)

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"Endo- β -galactosidase" is a generic term for enzymes that act on internal β -galactosyl linkages within sugar chains of various glycoconjugates. Endo- β -galactosidase of Escherichia freundii has made great contributions to the studies of complex carbohydrates. This would be comparable