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Radiation Degradation of Carbohydrates and Their Biological Activities for Plants

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Radiation effects on carbohydrates such as chitosan, sodium alginate, carageenan, cellulose, pectin have been investigated to improve the biological activities. These carbohydrates were easily degraded by irradiation and induced various kinds of biological activities such as anti-bacterial activity, promotion of plant growth, suppression of heavy metal stress, phytoalexins induction. Pectic fragments obtained from degraded pectin induced the phytoalexins such as glyceollins in soybean and pisatin in pea. The irradiated chitosan shows the higher elicitor activity for pisatin than that of pectin.

For the plant growth promotion, alginate derived from brown marine algae, chitosan and ligno-cellulosic extracts show a strong activity. Kappa and iota carageenan derived from red marine algae can promote growth of rice and the highest effect was obtained with kappa irradiated at 100 kGy. Some radiation degraded carbohydrates suppressed the damage of heavy metals on plants. The effects of irradiated carbohydrates on transportation of heavy metals have been investigated by PETIS (Positron Emitting Tracer Imaging System) and autoradiography using ^{48}V and ^{62}Zn.

1. Introduction

It is reported that the oligosaccharides from higher plant cell wall involved in capable of signal transduction, defense responses against pathogens and synthesis of phytoalexins[1]. Low molecular weight carbohydrates and oligosaccharides are usually prepared by enzymatic degradation but the radiation is one of the potent procedures for fragmentation of polysaccharides. Radiation generates various types of degraded fragments by random scission. In this study, radiation degradation of various carbohydrates and their effect on plants were investigated to improve the quality of natural polymers for plant cultivation.

2. Materials and Methods

2.1. Radiation

Carbohydrate samples were irradiated by gamma-rays from Co-60 or an electron beam (Dynamitron, 3 MeV, 25 mA) in liquid state or in solid state (powder form).

2.2. Growth test of plants

Rice (*Oryza sativa*) and barley (*Hordeum vulgare*) were mainly used for the experiments. Germinated seeds by immersion in water for three days at 27°C were sowed onto plastic net floating in plastic pots containing 1/2000-fold diluted hyponex solution (Hyponex, Japan).

3. Results and Discussion

3.1. Induction of phytoalexin by radiation-degraded polysaccharides

Radiation causes the cleavage of glycosidic link of polysaccharides, producing lower fractions[2-4]. Figure 1 shows the irradiation effect on molecular weight of alginate in liquid state (4% solution) and in solid state. Similar degradation was observed in case of pectin and chitosan by irradiation. Using these degraded pectine and chitosan, the induction of elicitor activity was examined[5]. Pectic fragments prepared by irradiation and oligogalacturonan obtained by enzyme digestion (endo-PG) of pectin induced glyceollins (a kind of phytoalexin). The pectic fragments obtained by irradiation with 1000 kGy were the

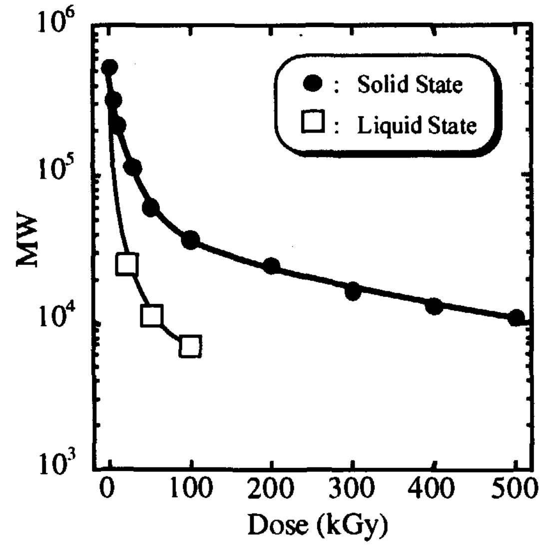

Fig. 1 Change in molecular weight of alginate by irradiation

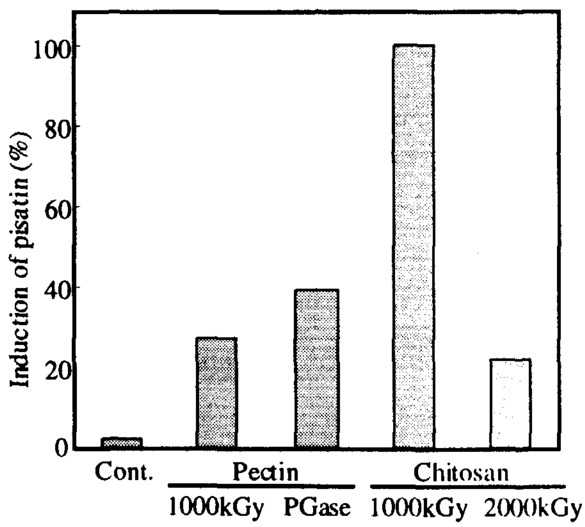

Fig. 2 Induction of pisatin in pea by irradiated pectin and chitosan

most effective for induction of glyceollins and induced almost the same amount of glyceollins induced by endo-PG. Pisatin, a phytoalexin induced in pea, was also effectively induced by irradiated pectin and chitosan (Fig. 2). Induction of pisatin by pectic fragments prepared by irradiation was lower than that of pectin-PGase. Chaitosan irradiated at 1000 kGy in solid state induced much higher activity than the pectic fragments but decreased at 2000 kGy. These results show that 1000 kGy is the optimum dose to obtain the effective fragments for induction of phytoalexins and a dose of more than 2000 kGy is too high to keep effective fragments.

3.2. Effect of radiation-degraded polysaccharides on plant growth

Growth-promotion of plant was tested under hydroponic cultivation condition. For rice, degraded alginate in 4% alginate solution irradiated at 100 kGy (MW ca. 7000) or from powder irradiated at 500 kGy impact remarkable effect on growth promotion. The suitable

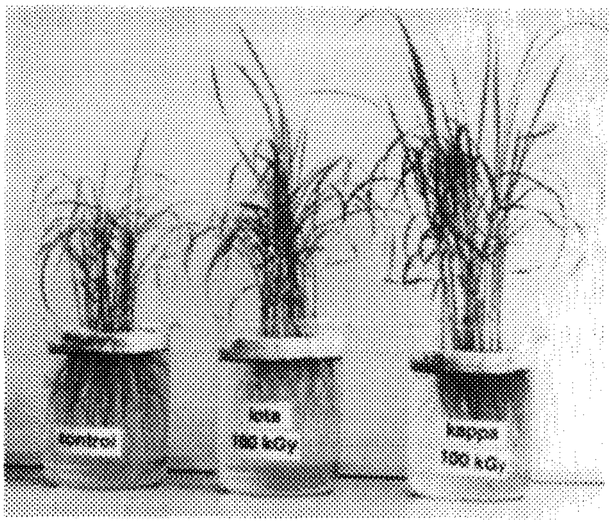

Fig. 3 Enhancement of rice growth by irradiated carageenan

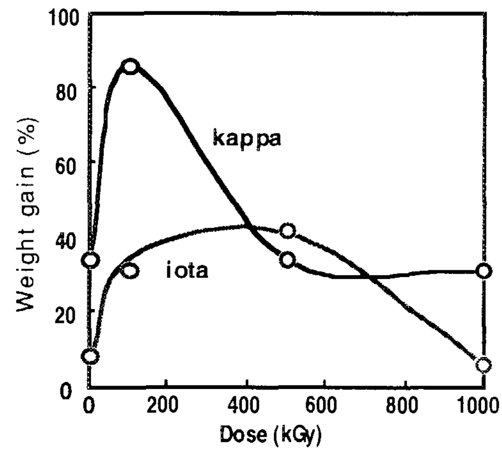

Fig. 4 Effect of irradiation dose on carageenan for rice growth

range of degraded alginate concentration was 20- 50 ppm. The results suggest that foliar spraying degraded alginate at certain concentration causes increasing in biochemical and physiological functions of plant that lead to increase in dry matter. Preliminary results on field test of foliar spraying of degraded alginate on tea, carrot and cabbage with concentration of 20 to 100 ppm, led the increase of productivity of ca. 15 to 40%. Similar effects were also observed by chitosan, lignocellulose extracts and carageenan. Kappa and iota carageenan derived from red marine algae can promote growth of rice (Fig. 3) and the highest effect was obtained with kappa irradiated at 100 kGy (Fig. 4).

3.3. Suppression of heavy metals stress on plants by radiation degraded polysaccharides

Heavy metals such as vanadium (V) and zinc (Zn) show the strong stress on soybean, rice, wheat and barley seedlings, whose roots were clearly injured at 5 ppm V (in VCl_3) in solution cultures. These damages were relatively reduced by application of radiation degraded chitosan. The recovery of growth and reduction of V levels in seedlings were obtained by the treatments with 100 and 200 ppm chitosan irradiated at 100 kGy in 1% solution (Table 1). Thus, the chitosan irradiated at suitable doses could be suggested as heavy metal eliminators in crop production. The uptake, translocation and distribution of ^{48}V and ^{52}Zn in plant were analyzed by PETIS[6] and autoradiography with BAS. Very weak uptake and transportation of heavy metalls into the shoot were observed in the plants treated with irradiated chitosan.

Table 1. Effect of V and irradiated chitosan on plant growth

Treatment		Dry weight of seedlings (mg/10 plants)			
		wheat		rice	
V(ppm) +	Chitosan(ppm)	Biomass	%	Biomass	%
0	0	385 ± 42	100	190 ± 17	100
0	100	544 ± 47	141	206 ± 16	108
0	200	540 ± 39	140	236 ± 30	124
10	0	229 ± 37	59	143 ± 12	75
10	100	350 ± 35	91	214 ± 18	113
10	200	392 ± 39	102	210 ± 18	111

Seedlings of plants grown for 9 days under V stress with chitosan irradiated at 100 kGy were measured.

The results suggest that the fractions of polysaccharides act on plants as phytohormone-like compounds for growth and suppression of environmental stress such as heavy metals and salts.

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