List of some compounds known to act as resistance inducers

ELICITOR	TARGET PATHOGEN				
	Chromista	**Fungi**	**Bacteria**	**Viruses**	**Phytoplasma**
Acibenzolar-S-Methyl or Benzothiadiazole (BTH)	X	X	X	X	X
β-aminobutyric acid (BABA)	X	X		X	
Cerevisane	X	X			
Chitosan	X	X	X	X	X
Glutathion + oligosaccharines	X				X
Isonicotinic acid (INA)	X	X	X		
Jasmonic acid (JA, MeJA)		X			
Laminarin	X	X			
Phosetyl-Al	X	X	X		X
Potassium phosphyte	X	X			
Prohexadione-Ca			X		X
Protein hydrolysates	X	X			
Salicylic acid (SA)		X		X	X
Yeast extracts	X	X			

Romanazzi and Feliziani, 2016 CJPP

Projects on the use of resistance inducers at UNIVPM

ELICITOR	TARGET PATHOGEN				
	Chromista	**Fungi**	**Bacteria**	**Viruses**	**Phytoplasma**
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β-aminobutyric acid (BABA)	X	X		X	
Cerevisane	X	X			
Chitosan	X	X	X	X	X
Glutathion + oligosaccharines	X				X
Isonicotinic acid (INA)	X	X	X		
Jasmonic acid (JA, MeJA)		X			
Laminarin	X	X			
Phosetyl-Al	X	X	X		X
Potassium phosphyte	X	X			
Prohexadione-Ca			X		X
Protein hydrolysates	X	X			
Salicylic acid (SA)		X		X	X
Yeast extracts	X	X			

Investigated pathosystems

Gray mold of table grapes

Grapevine Bois noir

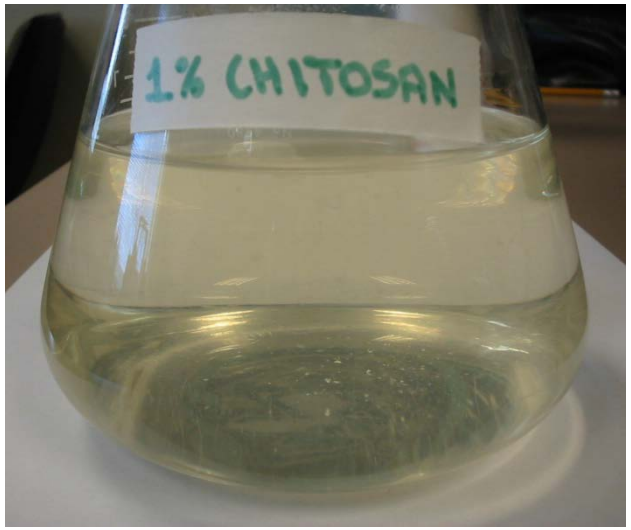
Grapevine downy mildew

Some of the most common fungicides to control gray mold

Names in red are registered for use in Italy

Active ingredient (%)	Trade name	Company	Chemical Group	FRAC code	PHI strawberry
Boscalid (50)	Cantus	Basf	Pyridine-carboxamides	7	-
Cyprodinil (37.5) + fluodioxonil (25)	Switch	Syngenta	Anilinopyrimidines + phenylpyrroles	9 + 12	7
Cyprodinil (75)	Vangard	Syngenta	Anilinopyrimidines	9	7
Fenhexamid (50)	Elevate/Teldor	Arysta LifeScience/Bayer CropScience	Hydroxyanilides	17	0/3
Fenpyrazamine (50)	Prolectus	Sumitomo Chemical Company	Amino-pyrazolinone	17	-
Fluazinam (40)	Omega/Ohayo	Syngenta	2,6-dinitro-anilines	29	-
Fluodioxonil (20.4)	Scholar	Syngenta	Phenylpyrroles	12	-
Fluodioxonil (50)	Geoxe	Syngenta	Phenylpyrroles	12	-
Fluopyram (41)	Luna Privilege	Bayer CropScience	Pyridinyl-ethyl-benzamides	7	-
Fluopyram (11.3) + Pyrimethanil (33.8)	Luna Tranquillity	Bayer Crop Science	Pyridinyl-ethyl-benzamides + Anilinopyrimidines	7 + 9	-
Iprodione (50)	Rovral	Basf	Dicarboximides	2	2
Pyraclostrobin (12.8) + boscalid (25.2)	Pristine	Basf	Methoxyl-carbamates + pyridine-carboxamides	11+7	0
Pyraclostrobin (6.7) + boscalid (26.7)	Signum	Basf	Methoxy-carbamates + Pyridine-carboxamides	11+7	3
Pyrimethanil (54.6)	Scala	Basf	Anilinopyrimidines	9	3
Tiram (80)	Pomarsol	Bayer CropScience	Dithio-carbamates	M3	7

Modified from Romanazzi and Feliziani, 2014. *Botrytis cinerea*. In: Postharvest Decay (Silvia Bautista-Baños Ed.)



Dissolved in diluted acids

Effects of Pre- and Postharvest Chitosan Treatments to Control Storage Grey Mold of Table Grapes

G. ROMANAZZI, F. NIGRO, A. IPPOLITO, D. DI VENERE, AND M. SALERNO

ABSTRACT: The effectiveness of pre- and postharvest treatments with chitosan (0.1, 0.5, and 1.0%) to control *Botrytis cinerea* on table grapes was investigated. In postharvest treatments, small bunches dipped in chitosan solutions and inoculated with the pathogen showed a reduction of incidence, severity, and nesting of grey mold, in comparison with the control. Single berries artificially wounded, treated with the polymer, and inoculated with *B. cinerea* showed a reduced percentage of infected berries and lesion dia. Higher chitosan concentrations demonstrated greater decay reduction. All preharvest treatments significantly reduced the incidence of grey mold, as compared to the control. Table grapes treated with 1.0% chitosan showed a significant increase of phenylalanine ammonia-lyase (PAL) activity. Consequently, besides a direct activity against *B. cinerea*, chitosan produces other effects contributing to reduce decay.

Keywords: *Botrytis cinerea*, postharvest decay, PAL activity, sulphur dioxide, microflora

Introduction

GREY MOLD, INDUCED BY *BOTRYTIS CINEREA* PERS., CAUSES HEAVY losses of table grapes in the field and is a major obstacle to their long-distance transport and storage. The pathogen is able to develop at low temperature, shortening the length of storage and marketing (Ippolito and others 1998). In Italy, no synthetic fungicides are licensed to control decay of table grapes after harvest; sulphur dioxide is permitted as an adjuvant and is effective in reducing grey mold development during storage. However, alternatives to SO_2 are required in view of damage to bunches due to temperature increase, of hazards for human health, and of the difficulties in using SO_2 with colored grapes (Nelson and Pichard

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Fruits

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Effect of Chitosan Dissolved in Different Acids on Its Ability to Control Postharvest Gray Mold of Table Grape

Gianfranco Romanazzi, Franka Mlikota Gabler, Dennis Margosan, Bruce E. Mackey, and Joseph L. Smilanick

First author: Department of Environmental and Crop Science, Marche Polytechnic University, via Brecce Bianche, 60131 Ancona, Italy; second author: Institute for Adriatic Crops, Put Duilova 11, 21000 Split, Croatia; third and fifth authors: United States Department of Agriculture–Agricultural Research Service (USDA-ARS), San Joaquin Valley Agricultural Sciences Center, 9611 South Riverbend Ave. Parlier, CA 93648; and fourth author: Biometrical Services, USDA–ARS, Western Regional Research Center, 800 Buchanan Street, Albany, CA 94710-1105.

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ABSTRACT

Romanazzi, G., Mlikota Gabler, F., Margosan, D., Mackey, B. E., and Smilanick, J. L. 2009. Effect of chitosan dissolved in different acids on its ability to control postharvest gray mold of table grape. Phytopathology 99:1028-1036.

Chitosan is a natural biopolymer that must be dissolved in an acid solution to activate its antimicrobial and eliciting properties. Among 15 acids tested, chitosan dissolved in 1% solutions of acetic, L-ascorbic, formic, L-glutamic, hydrochloric, lactic, maleic, malic, phosphorous, and succinic acid. To control gray mold, table grape berries were immersed for 10 s in these chitosan solutions that had been adjusted to pH 5.6. The reduction in decay among single berries of several cultivars (Thompson Seedless, Autumn Seedless, and grape selection B36-55) inoculated with *Botrytis cinerea* at 1×10^5 conidia/ml before or after immersion in chitosan acetate or formate, followed by storage at 15°C for 10 days, was ≈70%. The acids alone at pH 5.6 did not control gray mold. Decay among clusters of two cultivars (Thompson Seedless and Crimson Seedless) inoculated before treatment was reduced ≈60% after immersion in chitosan lactate or chitosan acetate followed by storage for 60 days at 0.5°C. The viscosity of solutions was 1.9 centipoises (cp) (ascorbate) to 306.4 cp (maleicate) and the thickness of chitosan coating on berries was 4.4 µm (acetate) to 15.4 µm (ascorbate), neither of which was correlated with solution effectiveness. Chitosan acetate was the most effective treatment which effectively reduced gray mold at cold and ambient storage temperatures, decreased CO_2 and O_2 exchange, and did not injure the grape berries.

Additional keywords: carbon dioxide, oxygen, *Vitis vinifera*.

Plant Pathology (2010) Doi: 10.1111/j.1365-3059.2010.02312.x

Inhibition of *Botrytis cinerea* growth and suppression of botrytis bunch rot in grapes using chitosan

T. Reglinski[a*], P. A. G. Elmer[a], J. T. Taylor[a], P. N. Wood[b] and S. M. Hoyte[a]

[a]*Ruakura Research Centre, New Zealand Institute for Plant and Food Research Limited, Private Bag 3123, Hamilton; and* [b]*Hawkes Bay Research Centre, New Zealand Institute for Plant and Food Research Limited, Private Bag 1401, Havelock North 4157, New Zealand*

Chitosan inhibited growth of *Botrytis cinerea* in liquid culture and suppressed grey mould on detached grapevine leaves and bunch rot in commercial winegrapes. Germination of *B. cinerea* was completely inhibited in malt extract broth containing chitosan at concentrations greater than 0·125 g L^{-1}. However, treated conidia were able to infect detached Chardonnay leaves and pathogenicity was not affected, even after incubation for 24 h in chitosan at 10 g L^{-1}. When added after conidial germination, chitosan inhibited *B. cinerea* growth and induced morphological changes suggestive of possible curative activity. The effective concentration of chitosan that reduced mycelial growth by 50% (EC_{50}) was 0·06 g L^{-1}. As a foliar treatment, chitosan protected detached Chardonnay leaves against *B. cinerea* and reduced lesion diameter by up to 85% compared with untreated controls. Peroxidase and phenylalanine ammonia-lyase activities were also induced in treated leaves. In vineyard studies, Chardonnay winegrapes exhibited 7·4% botrytis bunch rot severity at harvest in 2007 after treatment with an integrated programme that included chitosan sprays from bunch closure until 2 weeks preharvest, compared with 15·5% in untreated controls and 5·9% with fungicide treatment. In the following season, botrytis bunch rot severity was 44% in untreated Chardonnay at harvest and the integrated programme (21%) was less effective than fungicides (13·8%). However, in Sauvignon blanc winegrapes, the integrated and the fungicide programme each reduced botrytis bunch rot severity to 4% and were significantly different from the untreated control (11·5%). This study provides evidence that suppression of botrytis in winegrapes by chitosan involves direct and indirect modes of action.

Which are the mechanisms of action of resistance inducers?