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Use of Antitranspirant Epidermal Coatings for Plant Protection in China

Physical barriers that inhibit penetration of plants by fungal pathogens are important natural mechanisms of disease resistance or avoidance and have been studied extensively (1). However, such barriers have not been widely used as a practical method of disease control (4,8). For the past decade, my colleagues and I have been testing the potential effectiveness of a physical barrier to pathogen invasion (2,3,5–7) as a means to help China reduce the expense and environmental damage associated with the estimated current annual use of 5 million metric tons of pesticides to control diseases in our nation's vast farmlands, orchards, and grasslands.

The compound we have tested as a barrier to fungal invasion is an antitranspirant known in Chinese by the trade name *gao-zhi-mo* (GZM), meaning "high-quality lipid membrane." GZM is a stable water emulsion with dodecyl alcohol as the major component. When sprayed on the surface of plants, it forms a continuous film or membrane that permits diffusion of oxygen and carbon dioxide but inhibits the passage of water. In the field, the film is not readily washed off by rain and may remain intact for about 15 days. On the basis of results of a thorough study conducted by the Chemical Testing Institute of China's Ministry of Agriculture, GZM is considered to be relatively innocuous, with no known environmental toxicity at the concentrations being used in the field for disease control.

The first field experiments with GZM were conducted in 1980 to test the hypothesis that by acting as a barrier, GZM could reduce the occurrence of various diseases. Since then, GZM has been used in field trials to control numerous fungal diseases on a dozen different fruit, vegetable, grain, and fiber crops in China. GZM has also been shown to reduce damage caused by small insect pests. Evidence suggests that GZM's effectiveness may result from its ability to promote a healthy physiological state of the plant in addition to creating a physical barrier. The antitranspirant properties and the resulting reduction of heat loss in plants may help promote plant health under stressful environmental situations. We have also tested this compound for effectiveness in preserving freshness of plant material during storage and transport; in reducing desiccation during drought stress, high winds, or transplantation; and in reducing damage from cold. The success we have had with GZM in these aspects of plant protection is summarized here to encourage other workers to examine this concept.

For more information about GZM, contact the author or Michael S. S. Wong, Managing Director, AEFACHEMI (HK) Ltd., Room 1909, Hong Kong Plaza, 186-191 Connaught Road West, Hong Kong (telephone: 5591031).

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Control of Diseases

When apple (*Malus sylvestris* Mill.) fruits were sprayed four times at 15-day intervals with an aqueous solution of GZM at 2,000, 2,500, 3,300, 5,000, or 10,000 μg/ml, the incidence of bitter rot caused by *Glomerella cingulata* (Ston.) Spauld. & Schrenk was decreased 69, 66, 78, 84, and 84%, respectively (Fig. 1). The efficacy for disease control by GZM at 5,000 μg/ml was about the same as that by Bavistin (carbendazim) applied at 1,250 μg/ml, the concentration commonly used by the growers. GZM at 5,000 μg/ml was therefore selected for all subsequent field trials. At this concentration, 4.5–5.2 kg/ha of GZM has been sufficient to coat the target surface of apple crops.

Combining GZM with a fungicide has improved the degree of disease control with the latter. When leaves of tomato (*Lycopersicon esculentum* Mill.) were sprayed twice at a 10-day interval with 5,000 ppm of GZM, 1,670 μg/ml of Bavistin, or 5,000 μg/ml of GZM plus 1,670 μg/ml of Bavistin, the incidence of early blight caused by *Alternaria solani* Sorauer and of Septoria leaf spot caused by *Septoria lycopersici* Speg. was decreased 60, 38, and 73%, respectively (Fig. 2). Control of black rot of grape (*Vitis vinifera* L.) caused by *Guignardia bidwellii* (Ellis) Viala & Ravaz was tested with 5,000 μg/ml of GZM and 1,250 μg/ml of Topsin M (thiophanate-methyl

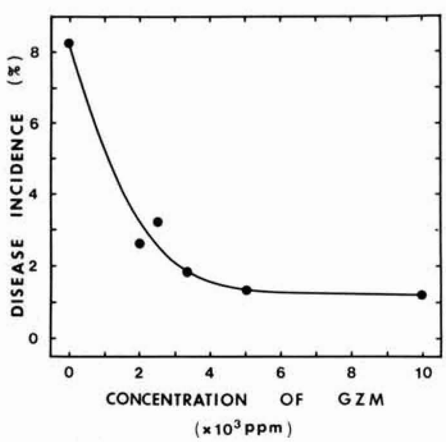

Fig. 1. Relationship between concentration of GZM applied and incidence of bitter rot of apple caused by *Glomerella cingulata*.

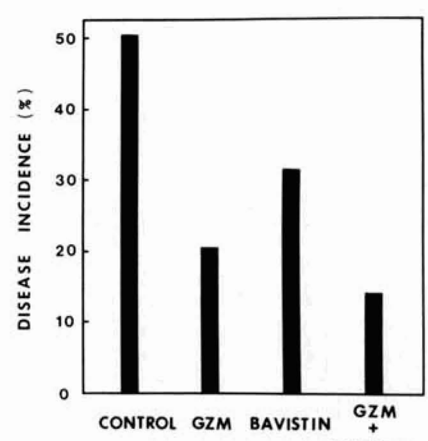

Fig. 2. Control of early blight caused by *Alternaria solani* and Septoria leaf spot caused by *Septoria lycopersici* on tomato by application of GZM and Bavistin (carbendazim) separately or in combination. Data represent a mixture of the two diseases.

Table 1. Yield increase and control of certain cucumber, watermelon, apple, and tomato diseases with GZM in the field

Crop	Disease, pathogen	Infected part	No. of sprays[a]	Leaves or fruits infected (%)		Fruit yield increase with GZM (%)
				Sprayed with water	Sprayed with GZM	
Cucumber	Downy mildew, *Pseudoperonospora cubensis*	Leaves	3	49.5	17.5	24
Watermelon	Anthracnose, *Colletotrichum lagenarium*	Leaves	3 or 4	29.1	9.2	49
Apple	Bitter rot, *Glomerella cingulata*	Fruit	4	29.6	8.8	23
Tomato	Early blight, *Alternaria solani* Septoria leaf spot, *Septoria lycopersici*	Leaves	3	72.0	19.6	111

[a]Crops were sprayed with 5,000 μg/ml of GZM at 10- to 15-day intervals before onset of infection. Spray timing and intervals were determined by the rate of new leaf production and state of host susceptibility.

70W), separately or in combination, on grape leaves and fruit eight times from mid-March until mid-June. After the last application, 72% of the grape fruit and shoots in control plots were infected, whereas disease incidence in treated plots was 4.0% with GZM, 3.5% with Topsin M, and 0.12% with GZM plus Topsin M.

At field trials conducted in various provinces in China, application of GZM consistently decreased incidence or severity of disease and increased yield (Table 1). Application of GZM to leaves of cucumber (*Cucumis sativus* L.) reduced the incidence of downy mildew caused by *Pseudoperonospora cubensis* (Berk. & Curt.) Rostov. about 70% (Fig. 3) and increased the fruit yield by about 24%. The incidence of anthracnose caused by *Colletotrichum lagenarium* (Pass.) Ell. & Halst. on leaves of watermelon (*Citrullus vulgaris* Schrad.) sprayed with GZM was reduced 57%, and fruit yield was increased 49%. Control of bitter rot of apple and leaf diseases of tomato with GZM also resulted in 23 and 111% increases in fruit yield, respectively.

Fig. 3. Downy mildew of cucumber caused by *Pseudoperonospora cubensis* treated with (A) GZM and (B) water as the control.

Field trials conducted by many researchers at various institutes across China over a number of years show that GZM is effective against many plant diseases caused by fungi. In addition to diseases of cucumber, watermelon, apple, and tomato, GZM has been shown to be effective in controlling diseases of wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), sugar beet (*Beta vulgaris* L.), and asparagus (*Asparagus officinalis* L.) (Table 2). On rice, GZM was effective against both neck rot caused by *Pyricularia oryzae* Cav. and sheath blight caused by *Rhizoctonia solani* Kühn. Pathogens of diseases listed in Tables 1 and 2 include members of Oomycetes, Ascomycetes, Basidiomycetes, and Deuteromycetes.

Soilborne spores that are splashed or blown up onto cotton (*Gossypium hirsutum* L.) plants are important as inoculum for boll rot caused by *Colletotrichum gossypii* Southworth, *Fusarium moniliforme* Sheld., and *Phytophthora boehmeriae* Sawada. GZM sprayed on the soil surface appears to impede dissemination of the pathogen from soil. The incidence of rotten bolls was 60% after GZM was applied three times to the plant surface, 50% after GZM was sprayed on the soil surface only, and 10% when GZM was sprayed on both plant and soil surfaces; incidence of boll rot in control plots was 100%.

Other Uses for GZM

Preservation of freshness. In China, seed potatoes (*Solanum tuberosum* L.) are produced in the northern regions, where environmental factors favor superior quality. The seed tubers then are transported to other parts of the country and stored until planting. Researchers from the Southwest Agricultural University in Sichuan Province soaked seed pieces of potatoes harvested in northern regions in GZM for 1 minute, air-dried them, then packed them for transport; the seed potatoes were cut and ready for planting before GZM treatment. After shipment to Sichuan and 41 days of storage, the GZM-treated seed pieces had lost only 28% of their original weight, whereas seed pieces treated with water had lost 62%. Treatment with GZM also reduced decay of seed pieces and did not interfere with the normal emergence of buds.

To preserve oranges (*Citrus sinensis* (L.) Osbeck) during storage, fruits harvested in autumn in Sichuan Province were soaked in a solution of GZM, in a solution of 2,4-D plus Bavistin, or in water for 1 minute. After 105 days at 10 C with adequate ventilation, fruits treated with GZM and those treated with 2,4-D plus Bavistin showed 83 and 81%, respectively, less rot caused by common molds and less deterioration, including change of color and loss of water, than water-treated fruits.

GZM has also been used to preserve the freshness of mulberry (*Morus alba* L.) leaves in the rearing of silkworms. During the rearing process, mulberry leaves must be harvested daily to feed silkworms. Mulberry leaves sprayed with GZM after harvest remained fresh for 7–9 days. Silkworms fed with mulberry leaves treated with GZM on the same day showed no developmental abnormalities and produced cocoons the same weight as those produced by silkworms fed with control leaves. Hence, GZM can be used to preserve mulberry leaf freshness, thereby allowing storage of leaves and alleviating the need for daily leaf harvest.

Reduction of plant desiccation. The traditional methods of extensive vegetable production used in China rely on the transplanting of seedlings from seedbeds into the field. Desiccation of seedlings after planting is an important factor in seedling loss in the field. When seedlings of Chinese cabbage (*Brassica chinensis* L.) were sprayed with GZM 3 days before being transplanted, only 1.9% died; 9.3% of control seedlings died. At harvest, the yield was 45% greater in GZM-treated plots than in control plots.

Loss of vegetable seedlings can be compounded by the strong winds that occur frequently in the spring in some parts of China. In early spring in Guangdong Province, recently transplanted seedlings of Chinese waxgourd (*Benincasa hispida* (Thunb.) Cogn.) were sprayed once with GZM. Strong winds averaging 5–6 miles per second occurred

Table 2. Effectiveness of GZM for control of various plant diseases in the field

Crop	Disease, pathogen	Infected part	No. of sprays[a]	Plant parts infected (%)	
				Sprayed with water	Sprayed with GZM
Wheat	Powdery mildew, *Erysiphe graminis*	Leaves	2 or 3	85.7	31.3
Cucumber	Powdery mildew, *Sphaerotheca fuliginea*	Leaves	4	36.0	0.0
Rice	Sheath blight, *Rhizoctonia solani*	Leaves	2	76.5	31.7
	Neck rot, *Pyricularia oryzae*	Panicles	2	32.0	5.0
Sugar beet	Cercospora leaf blight, *Cercospora beticola*	Leaves	2	19.6	4.2
Asparagus	Stem blight, *Phoma asparagi*	Stems	6	41.5	23.8

[a]Crops were sprayed with 5,000 μg/ml of GZM at 10- to 15-day intervals before onset of infection. Spray timing and intervals were determined by the rate of new leaf production and state of host susceptibility.

13 and 14 days after application, damaging many of the leaves. The GZM-treated plots, however, showed 34% less wind damage, as measured by number of broken leaves, than the control plots.

In northern China, during the early stage of head maturation of wheat, strong, hot wind always causes death of leaf tissues and induces early maturation of heads, which in turn decreases the grain weight. A onetime application of GZM greatly reduced the damage of wheat leaves by wind (Fig. 4) and increased grain weight from 41.7 g/1,000 grains from the control plants to 43.1 g/1,000 grains from the treated plants.

GZM has been tested also in protecting nursery crops during transport and transplantation. One day before being dug for transplantation, 2-year-old orange tree seedlings were sprayed with GZM. Two days after being packed, transported, and transplanted, 35% of nontreated seedlings showed drying of branches, which eventually led to leaf drop and death of the transplant. Branches on 4% of the GZM-treated trees showed slight drying, but there was no leaf drop and no transplant death.

Reduction of cold injury. Orange tree seedlings also experience cold injury when shipped from warm areas where nurseries are located to cooler production regions. For example, many orange tree seedlings grown in nurseries in southern China are shipped in the early spring to Henan Province, where minimum daily temperatures may still drop well below 0 C. In one such shipment of orange seedlings, GZM was tested for ability to reduce cold damage. Upon arrival in Henan and before being transplanted, the seedlings were exposed to temperatures as low as −11.5 C. Leaves of all nontreated seedlings dropped and parts of branches on all trees died, whereas none of the seedlings sprayed with GZM after transplanting showed leaf loss or branch death. We speculate that GZM protected the seedlings by reducing evapotranspiration, thereby reducing heat loss.

Enhancement of flower retention and fruit set. Additional attempts to protect orange trees and increase fruit yield were made by applying GZM to orange blossoms. Three applications to blossoms during the peak of the blooming period in Guangdong Province increased fruit set by 6.5–11.2% over that in control trees. Application of GZM to tomato flowers resulted in only 43% premature flower abortion, whereas 66% of flowers dropped prematurely in control plants. The treatment also caused a 70% increase in tomato fruit set.

Control of pests. GZM may reduce populations of certain insect pests. Application to rice grown in Anhui Province resulted in a 98% decrease in the average population of rice thrips on leaf blades. The mortality rate of citrus rust mites on orange trees grown in Sichuan Province was 97% after application of GZM, 94% after application of Comite (propargite), but only 64% after no treatment during the same period. In Hepei Province, fruit deformity of peach (*Prunus persica* (L.) Batsch) caused by gall mites was effectively controlled by GZM spray (Fig. 5).

Conclusions and Outlook

Clearly, GZM holds great promise for protecting and enhancing the yield and quality of plants. On the basis of the results reported here, a concerted effort is being made in China to produce, distribute, and encourage the use of GZM nationwide. The 11 January 1988 issue of the *Guangzhou Daily* reported that the Pearl River Electrochemical Factory in Guangzhou had begun production of GZM at an estimated rate of 2,000 metric tons annually.

The effectiveness of GZM in preserving plant freshness, reducing desiccation losses, and protecting plants in the ways described in this report is most likely due to the substance's antitranspirant properties. But the mechanism of action of GZM in controlling fungal disease is unclear. In laboratory experiments, we first sprayed GZM on the surface of potato-dextrose agar, then placed spores of *Colletotrichum gloeosporioides* (Penz.) Sacc. on the membrane surface. The spores germinated and the germ tubes readily penetrated the membrane surface and colonized the medium, suggesting that GZM does not create a physical barrier to penetration by fungi. However, spores placed on the surface of the medium before application of GZM did not germinate or grow well after the membrane was applied. Perhaps the diffusion of gases through the GZM membrane is reduced slightly, enough to inhibit the growth of fungi but not enough to affect the growth of the plant. This phenomenon, coupled with the general enhancement of the physiological health of the plant, may explain in part why GZM is effective in controlling fungal diseases. As there probably is no

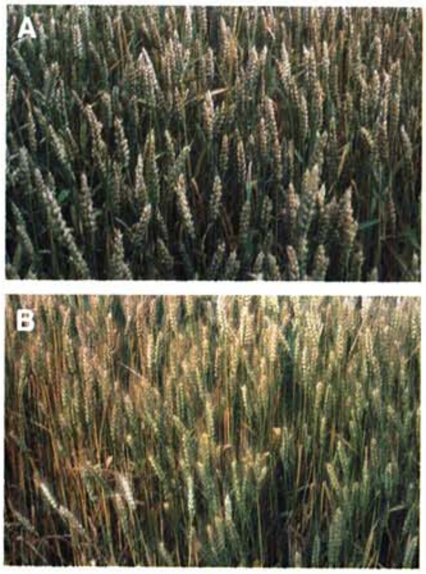

Fig. 4. Injury to wheat leaves caused by strong, hot wind treated with (A) GZM and (B) water as the control.

Fig. 5. Fruit deformity of peach caused by gall mites treated with (left) GZM and (right) water as the control.

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target site of action of GZM against fungi, widespread and frequent use of this substance is not likely to result in the buildup of resistant populations of pathogens.

Future studies of the use of GZM in plant protection promise to be exciting and challenging. In addition to addressing the question of GZM's mechanism of action, we should consider how to adapt spray schedules of this substance to the epidemiology of the disease in question, how to incorporate it into integrated pest control programs, and in what other preharvest and postharvest situations it can be used to protect our limited food supply. Further studies should also be conducted to support the evidence we have already gathered that GZM is safe for the user and the environment.

Acknowledgments

The extensive testing of GZM reported here was accomplished with the enthusiastic cooperation of the members of many research institutes, universities, and plant protection stations across China. I am very grateful for the effort and devotion they have given to this work over the past decade and regret that there are too many to name individually here. Special thanks are also given to Wen-hsiung Ko, University of Hawaii, for his encouragement to introduce this work abroad and for assistance in preparing the manuscript, and to Cindy Morris, Beijing Agricultural University, for composing and typing the English manuscript.

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