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Research review

Efficacy of systemic fungicide metalaxyl for the control of downy mildew (*Sclerospora graminicola*) of pearlmillet (*Pennisetum glaucum*)

S D SINGH[1] and H S SHETTY[2]

International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh 502 324

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ABSTRACT

Research conducted on the systemic fungicide, metalaxyl, for the control of downy mildew [*Sclerospora graminicola* (Sacc.) Schroet.] of pearlmillet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz] is reviewed. All the formulations of metalaxyl tested as seed treatment or foliar spray controlled downy mildew with consequent increases in grain yield. However, the degree of control depended on the rate of application and level of varietal susceptibility. The higher the susceptibility of variety, the greater the amount of fungicide needed to control the disease. Metalaxyl is toxic to seed germination when used at rates more than 2 g ai/kg seed, particularly with the seed dressing (Apron 35 SD) formulation, though varieties differred in sensitivity. Metalaxyl is fungistatic. It can be used to protect varieties susceptible to downy mildew in farmers' fields and also in commercial seed production.

Although host-plant resistance is the most economical and feasible method of plant-disease control, alternative methods are needed when a given resistance becomes ineffective and other resistant varieties are not readily available for replacement. In India, such a situation occurred twice with pearlmillet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz] for resistance to downy mildew [*Sclerospora graminicola* (Sacc.) Schroet.]. First, a severe epidemic of downy mildew of pearlmillet occurred during 1970–71 on a popular hybrid, 'HB 3' recurring every year until 1976. Second, several widespread epidemics occurred on another popular F_1 hybrid 'BJ 104' during 1983–86. In anticipation of such epidemics, and to minimize losses, many fungicides were screened. These efforts were unsuccessful. A breakthrough came with the development of metalaxyl (Ridomil), a systemic fungicide during the 1970s. Metalaxyl has since been tested widely for the control of Peronosporales fungi (Urech *et al.* 1977). In 1985, the Government of India imported 20 tonnes of metalaxyl (Apron 35 SD formulation) to treat 'BJ 104' seed produced in Gujarat during summer 1985 (Siddiqui *et al.* 1987). In this paper, the progress made with metalaxyl in the control of downy mildew of pearlmillet in India is reviewed.

FUNGICIDE

Metalaxyl is a derivative of alanine, an amino acid. Its chemical name is methyl DL-(2, 6-dimethyl phenyl)-N (2' methoxyacetyl)-N alaninate. It is marketed under the trade names Ridomil since 1977. It is now available in many formulations and

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[1]Senior Plant Pathologist

[2]Professor, Department of Applied Botany and Seed Pathology, University of Mysore Karnataka 570 006

combinations, ie Ridomil 10 and 25 WP (10 and 25% CGA 48988 wettable powder), Ridomil 5 G (5% CGA 489988 granular), Ridomil MZ 72 WP (8% metalaxyl + 64% mancozeb), Ridomil ZM 280 FW (4% metalaxyl + 24% ziram), Ridomil M (metalaxyl + maneb), Ridomil plus 50 WP (15% CGA 48988 metalaxyl + 35% copper wettable powder), Ridomil combi (metalaxyl + folpet), Apron 35 SD (35% CGA 48988 seed dressing), Apron 70 SD (35 g metalaxyl + 350 g captan/kg), Fubol (metalaxyl + mancozeb), Ridomil 2 EC (2% metalaxyl, liquid formulation).

Mode of action

Limited information is available on its mode of action. Germination of sporangia suspended in 125 ppm Ridomil 25 WP was not affected. Although zoospore movement, germination and germ-tube growth remained unaffected at concentrations up to 31 ppm, these processes were completely halted at higher concentrations (Singh *et al.* 1984). Dang *et al.* (1983) and Muthuswamy and Narayanaswamy (1985) reported the inhibition of sporangial germination by metalaxyl. Shankara Rao *et al.* (1987) reported 10% germination of sporangia in 125 ppm of Ridomil 25 WP, but none at 250 ppm. They also reported inhibition of asexual sporulation on infected plants sprayed with 250 ppm.

Infectivity of sporangia varied with the concentration of metalaxyl. Sporangia suspended in 19 ppm or higher concentrations of Ridomil 25 WP did not cause systemic infection on young seedlings; but could do so at a concentration of 4 ppm. When systemically infected plants were sprayed with Ridomil 25 WP, they recovered, but symptoms reappeared as infection of nodal tillers and or green ears even in the absence of external inoculum in glass-house (Singh *et al.* 1984). This research demonstrated that in the absence of sporangial inoculum, the reappearance of symptoms was caused by the mycelium present in the plants before treatment. Dilution of the fungicide in the growing plant allowed the fungus to reactivate and infect the nodal tillers (Singh *et al.* 1986). These findings suggest that metalaxyl is fungistatic (Singh *et al.* 1984).

Uptake, translocation and persistence

Metalaxyl is readily taken up by plant parts on which it is applied. From the seed surface it diffuses with water inside the seed (Reddy 1988). The fungicide is ambimobile (Singh *et al.* 1986, Reddy 1988), and can be detected in all plant parts raised from treated seed (Reddy 1988). However, seed and roots did not indicate its presence at harvest (Singh *et al.* 1986). Although it can be detected up to 45 days in all plant parts, leaves showed residue up to 60 days when dust, slurry or seed-soak treatments were carried out. When soil and seed treatments were followed by foliar spray (25 days after soil treatment), residues were detected in roots, stems and leaves up to 90 days. The fungicide accumulated more in leaves than in roots or stems (Reddy 1988). But the amount of metalaxyl in leaves at maturity is generally quite low and does not jeopardize their use as fodder (Singh *et al.* 1986).

Stability with storage time and temperature

The storage of seed treated with different formulations for various durations and temperatures showed variable effects on seed germination and the disease controlling ability of the fungicide. Reddy (1988) determined that Apron 35 SD used as dust or slurry did not affect germination of treated seed for 15 months, whereas soaking of seed in fungicide suspension and applied at the same rate (2 g ai/kg seed) was toxic even after 3 months of storage at 25–30°C. Further, soaking in Ridomil 280 FW was toxic even 1 month after seed treatment. Chandrasekhara Rao *et al.* (1988) also found no reduction in seed germination after treatment with Ridomil 25 WP (2 g ai/kg) and storage at 5–45°C up to 12

months. A greater degree of disease control and significantly higher grain yield were obtained only when the treated seed used was stored at 5°C. These studies demonstrate that if the treated seed is to be stored, it should be done at 5°C.

METHOD AND RATE OF FUNGICIDE APPLICATION

Several metalaxyl formulations [Ridomil 10, 25, and 50 WP, Apron 35 SD, Ridomil 2 EC (liquid formulation) and Ridomil MZ 72 WP] were tested for their ability to control downy mildew. These formulations were used by 5 application methods.

Dust

Ridomil 10, 25, and 50 WP, Ridomil MZ 72 WP, and Apron 35 SD were applied as dust. Dry seed was thoroughly shaken with dry formulations. Dusting was carried out @ 0.5 g ai – 4 g ai/kg seed.

Soak

Seeds were stirred or immersed in aqueous formulation of Ridomil 25 WP for 2–4 hr @ 2 g ai/litre water/kg seed. Soak treatment was also given in Ridomil 2 EC liquid formulation. Seed was stirred in an aqueous suspension of liquid formulation for 6 hr (6 ml fungicide formulation + 994 ml water/kg seed), and 12 and 24 hr (6 ml fungicide formulation + 1 194 ml water/kg seed).

Stick

Dry formulations (wettable, Ridomil 10 and 25% WP) were suspended in 1% methyl cellulose, prepared in water. Seeds were stirred in this formulation @ 2 g ai in 750 ml 1% methyl cellulose/kg seed until fully coated. They were then removed from the suspension and allowed to dry.

Slurry

Ridomil 25 WP and Apron 35 SD formulations were used. The fungicide @ 2–4 g ai/kg seed was added to 10 ml water and shaken with the seed until fully coated.

Spray

Ridomil 25 WP formulation suspended in water (13–2 000 ppm product) was used. The suspension was sprayed on systemically infected plants at different growth stages after symptom expression.

METHOD OF FUNGICIDE EVALUATION

The efficacy of the fungicide was tested in downy-mildew screening nurseries (Williams *et al.* 1981) at all the test locations. These nurseries contained an unknown number of oospores and had been used for screening pearlmillet for resistance to downy mildew for many years. Sporangial inoculum was provided throughout crop growth from infector rows planted earlier. High humidity necessary for the development of the disease was provided by perfosprays (a mist irrigation system) or frequent furrow irrigation. Thus the fungicide was tested against soil-borne oospores as well as sporangial inoculum of the pathogen.

METHOD OF DISEASE EVALUATION

Generally, downy mildew was evaluated twice by each researcher. The first record was taken soon after the appearance of the disease, 10–25 days after planting. In this record, downy-mildew incidence was calculated. To count early infected plants that may die and disappear before the second record (resulting in underestimating the disease, particularly in the control plots), a red-topped bamboo peg was placed alongside each infected plant. In the final recording, taken 61–75 days after planting, individual plants were rated on a rating scale of 5. This rating was used to calculate disease severity index.

TOXICITY

Effect on seed germination

The effect of metalaxyl (Ridomil 25 WP

and Apron 35 SD) on seed germination in petri-plates varied with variety (Singh 1983). Certain varieties like 'BJ 104' showed significantly reduced germination even at a low rate of treatment (2 g ai/kg seed), whereas others like 'NHB 3' showed reduced germination only at high rates of application (≥4 g ai/kg seed). In general, seed treatment at rates higher than 2 g ai/kg seed (particularly with Apron 35 SD) was toxic (Singh 1983). Adverse effect on germination was also reported in Mali (Schuring J F, *personal communication*). Hence for treating a new variety with metalaxyl, it should first be tested for its sensitivity to the fungicide.

Effect on emergence

In general, the emergence of seedlings grown from seeds treated with Ridomil 25 WP and Apron 35 SD formulations was not adversely affected in pot trials even at high rates of seed treatment (4 g ai/kg seed). However, the effect varied with variety. For instance, 'ICH 105' showed reduced emergence, whereas the emergence of 'NHB 3', '7042' and 'BJ 104' remained unaffected (Singh 1983). Although no data exist concerning the effect of seed treatment on emergence under field conditions, visual observations indicate that emergence is not affected. This may be because less fungicide remains associated with the seed due to leaching caused by rains or irrigation water. However, test for field-emergence should be conducted before undertaking large-scale seed treatment for commercial application.

EFFICACY

Downy-mildew control

Metalaxyl in WP, liquid, or SD formulation, applied to seed as dust, stick, slurry, soak or spray on to diseased plants controls downy mildew (AICMIP, Pune 1978, 1979, 1981, 1982, 1986, Singh and Williams 1978 a, b, Venugopal and Safeeulla 1978, Dang and Thakur 1982, Dang *et al.* 1983, Subramanya *et al.* 1982, Chandrasekhara Rao 1983, Singh 1983, Singh *et al.* 1984, Muthuswamy and Narayanaswamy 1985, Singh 1986, Shankara Rao *et al.* 1987). However, the degree of control varied with the rate of application, variety and method of application. The higher the rate of application from 1–4 g ai/kg seed, the greater was the degree of control (AICMIP, Pune 1979, Williams and Singh 1981, Singh 1983). In general, seed-dressing formulation was more effective than WP formulation at the similar rate of application (AICMIP, Pune 1979, Singh 1983). The higher the level of susceptibility, the greater the amount of fungicide needed to obtain an acceptable level of control. For instance, on a 95–100% susceptible '7042', even 4 g ai/kg seed could not give an acceptable level of control, whereas 2 g ai/kg seed successfully controlled downy mildew on other susceptible varieties, like 'NHB 3' (Singh 1983).

Soaking of seed in aqueous suspensions of Ridomil 2 EC or Ridomil 25 WP gave better control than other seed treatments (AICMIP, Pune 1978, Williams and Singh 1981). However, the treatment is cumbersome and cannot be applied by farmers. Slurry treatment did not prove superior to dusting (Singh 1983).

One of the problems with seed treatment is the development of disease in the treated plots about 30 days after planting. This has been observed at even higher rates (4 g ai/kg seed). The disease may develop on late-formed basal tillers and or on nodal tillers, perhaps because the fungicide applied on seed becomes diluted with the increase in growth of plant, and therefore the plant fails to protect the newer growth from continual supply of sporangial inoculum, particularly in the disease nursery (Williams and Singh, 1981, Singh *et al.* 1984, Singh *et al.* 1986). The problem does not become important if only nodal tillers become infected, as they do not contribute much to yield. But they may, add to oosporic inoculum. This problem becomes serious in seed-production plots when basal tillers

show disease symptoms. In such situations, spray with the fungicide 20–25 days after planting will protect the late-formed tillers from infection (Dang *et al.* 1983, AICMIP, Pune 1986).

Metalaxyl spray is also effective in controlling the disease (Singh and Williams 1979, Muthuswamy and Narayanaswamy 1980, Dang and Thakur 1982, Singh 1983, Dang *et al.* 1983). A concentration of 31 ppm (ai) or more is required for satisfactory control. The objective of spraying is to get recovery from systemic infection, which can occur 7 days after a spray (Singh *et al.* 1984). This operation becomes important when the disease attacks in the seedling stage. Though recovery can occur at any stage of plant growth, panicle length is reduced if spray is given later than 20–25 days after planting (Muthuswamy and Narayanaswamy 1980, Singh *et al.* 1984). This is because in systemically infected plants, panicle malformation begins with panicle initiation. Once a panicle is transformed, metalaxyl sprays can stop disease development on the leaves produced after spraying, but cannot reverse the malformed panicles. The problem with 1 early spraying is the production of nodal tiller infection by recovered plants at a later stage, even in glass-house (Singh *et al.* 1984).

Grain yield

Metalaxyl in all the tested formulations and applied by any method increased the yield of treated plots compared with non-treated plots in susceptible or moderately susceptible varieties (AICMIP, Pune, 1978, 1979, 1981, 1982, 1986, Dang and Thakur 1982, Dang *et al.* 1983, Chandrasekhara Rao 1983, Singh 1983, Singh *et al.* 1984, Shankara Rao *et al.* 1987). The degree of increase in grain yield, however, varied with the rate of fungicide application and the degree of disease control. The greatest yield increase was obtained with susceptible varieties. In resistant varieties, no difference was seen between yields of treated and non-treated plots because of the lack of differences in the disease level (Singh 1983).

From the foregoing discussion, it is evident that all the formulations applied by various methods were effective in controlling the disease. However, all the application methods cannot be easily used by the farmers, eg slurry, soaking and stick treatments. Also, metalaxyl has controlled the disease at rates ranging from 1 to 4 g ai/kg seed, but adequate level of disease control without any adverse effect was obtained @ 2 g ai/kg seed. Therefore, use of metalaxyl in WP or SD formulations @ 2 g ai/kg seed would be ideal to provide an acceptable level of disease control in farmers' fields. In case complete control of the disease is needed, metalaxyl (Ridomil MZ 72 WP 3000) should be sprayed approximately 30 days after sowing.

CONCLUSION AND RECOMMENDATIONS

Metalaxyl is effective for the control of downy mildew.

Since it is a narrow-spectrum fungicide, it is likely that the pathogen may develop resistance to the fungicide, as has been reported in several cases (Cohen 1986). Edgington *et al.* 1980 and Cohen (1986) reported the use of fungicide mixture to overcome this problem.

Metalaxyl formulations containing zineb and maneb have been developed and they should be used on the following guidelines (Recommendations are based on the deliberation of an expert panel discussion, held on 12 September 1988 at the Central Plant Protection and Training Institute, Rajendranagar, Hyderabad, Andhra Pradesh).

1 Apply metalaxyl (@ 2 g ai/kg seed) to protect varieties that have become susceptible, but must still be cultivated for lack of alternative cultivars. Such varieties, however, should not be continued for more than 2 years as prolonged use may produce resistant pathotypes.
2 Do not use metalaxyl on resistant

genotypes as the practice may increase the chances of step-wise build-up of resistance in the pathogen population.

3 Use metalaxyl (@ 2 g ai/kg seed) to grow seed crop for the production of disease-free seed. A foliar spray (Ridomil MZ 72 WP, 3 000 ppm) is recommended if disease incidence exceeds 0.05% in seed crop. The treatment should be used for more than 2 years, discontinued for a few years, and used again, if needed. This discontinuity may likely discourage adaptation of the fungicide by the pathogen.

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