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Seed priming with plant gum biopolymers enhances efficacy of metalaxyl 35 SD against pearl millet downy mildew

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Abstract 'Priming' the plant and seed induces a physiological state in which plants are able to activate defense responses. Plant-based exudates are excellent gum biopolymers which contain plant growth-regulating hormones with priming potential without any side effects. In this study, gum exudates of *Acacia arabica*, *Moringa oleifera*, *Carica papaya* and *Azadirachta indica* were evaluated for synergistic effects of seed priming with exuded gum biopolymer combined with metalaxyl (Apron 35 SD) on pearl millet seed quality, growth parameters, and resistance to *Sclerospora graminicola*. Seeds of 7042S were primed with gum biopolymers and metalaxyl 35 SD and evaluated under laboratory and greenhouse conditions. Seed germination and vigor were synergistically enhanced using gum biopolymers solution (1:2 *w*/*v*) with 3 g kg^{-1} metalaxyl 35 SD. *A. arabica* and *A. indica* gum biopolymers alone or with 3 g kg^{-1} of metalaxyl 35 SD resulted in seed germination of >91%. Seed priming with 6 g kg^{-1} of metalaxyl 35 SD gave 89% seed germination and was not significantly different from control. A similar trend in vigor was observed among treatments. Seed priming with gum biopolymers alone provided varied disease protection levels when compared with the control. *A. arabica* or *A. indica* gum with 3 g kg^{-1} of metalaxyl 35 SD was the superior treatment, offering significant 86% disease reduction while exhibiting a growth-promoting effect. Synergistic use of gum biopolymers and metalaxyl 35 SD by seed priming is highly effective in growth promotion and management of pearl millet downy mildew disease.

Keywords Biopolymer gums · Downy mildew management · Pearl millet growth promotion · Seed pelleting

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Introduction

Seed coating with fungicides protects the seed from seedborne and soilborne pathogens and enables it to germinate and become a healthy seedling. Fungicide seed treatments come in a variety of formulations such as dry flowables, liquid flowables, true liquids, emulsifiable concentrates, dusts, wettable powders, suspoemulsions, water-dispersible granules and others (Knowles 2008). Delivery of a proper amount of active ingredient to the seed has become especially important with modern fungicides that require only a minimum amount of material. Conventional dry treatments generally are formulated with talc or graphite which adheres the treatment chemical to the seed. Certain liquid formulations can become nonhomogeneous on storage. Additional problems can arise such as unacceptable drying times, material buildup in the seed treater, low seed flowability, poor seed coverage and dust-off of the fungicide from the seed prior to planting. As a result, handling is rendered difficult and the biological efficacy of the seed treatment is reduced. There is a need for alternative new fungicide seed treatment compositions that are effective in both commercial and on-farm use.

In recent years much evidence has become available about several pesticides which act by priming plants and this shows promise for developing future practical applications in crop disease management.

In most studies fungicides are applied either by seed dressing or seed soaking along with methylcellulose in powder form (Ali et al. 2001). During pelleting the seeds are tumbled with an adhesive material such as gum arabic and carboxy methylcellulose (CMC) and fungicide powder is mixed throughout the coating material or can be added in discrete layers or in the outermost part of the pellet (Agarwal and Sinclair 1997; Mohanan and Sharma 1991). It has now been found that plant-derived gums used as seed coating polymers can provide excellent water-soluble or water-dispersible film, are stable in storage and have good adherence to seed. A number of trees like *Acacia arabica*, *Moringa oleifera*, *Carica papaya* and *Azadirachta indica* are well known to produce gum exudates during their different stages of growth. An approach employing these benefits can minimize the recommended dose of fungicides by reducing dust-off, and provides excellent control on plant pathogens (Elzein et al. 2006). The gum biopolymers have particular application in the protection of seeds against fungal diseases when combined with one or more fungicides (Prakash et al. 2007). Biopolymers dry quickly, dissolve rapidly in water and do not inhibit germination.

Today, most seed companies treat pearl millet seeds with metalaxyl 35 SD fungicide at a rate of 6 g kg^{-1} (Singh and Shetty 1990) to control downy mildew. This paper examines seed treatment with various gums of plant origin as biopolymers with a reduced dose of metalaxyl 35 SD fungicides to control downy mildew of pearl millet.

Materials and methods

Host Seeds of pearl millet cultivar 7042S, highly susceptible to the downy mildew pathogen, were obtained from the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad, India, and All India Coordinated Pearl Millet Improvement Project, India, and used throughout the study.

Pathogen and inoculum preparation. Sclerospora graminicola (Sacc.) Schroet., isolated from pearl millet cv. 7042S grown under heavily infested field conditions, was used (Safeeulla 1976). The pathogen was maintained on its susceptible host before use. Leaves of pearl millet showing profuse sporulation of *S. graminicola* on the abaxial surface were collected in the evening from the plants maintained under greenhouse conditions (25–30°C, >95% r.h.), and washed thoroughly under running tap water to remove remnants of sporangia. The leaves were then blotted dry, cut into small pieces, and kept in a moist chamber for sporulation. The next morning the fresh sporangia were harvested into distilled water. For use as inoculum, the zoospore concentration was adjusted to 40,000 ml^{-1} with a haemocytometer.

Source and collection of gum biopolymers and preparation The gum biopolymers were collected in the form of natural exudation of gum from *Acacia arabica* (Fig. 1a), *Moringa oleifera, Carica papaya* and *Azadirachta indica* (Fig. 2a), trees grown in and around Mysore, Karnataka, India. The gum exudation from the bark of the trees was scraped using scalpels, dried under sun and the crystals formed were used.

Treatments

1. Gum biopolymers alone: The gum biopolymers were dissolved in water and different concentrations (1:1, 1:2, 1:3 and 1:4 *w*/*v*) were prepared. The gum biopolymer preparations were mixed with the seeds at the rate of 20 ml kg^{-1} seed (*v*/*w*) and kept in a rotary shaker for uniform coating and then shade-dried before use.
2. Gum biopolymers+half strength (3 g kg^{-1} seed) metalaxyl (Apron 35 SD) methyl-*N*-(2-methoxyacetyl)-*N*-(2.6-xylyl)-DL-alaninate supplied by Syngenta India.
3. Full strength metalaxyl (Apron 35 SD), 6 g kg^{-1} (Figs. 1 and 2b, c).

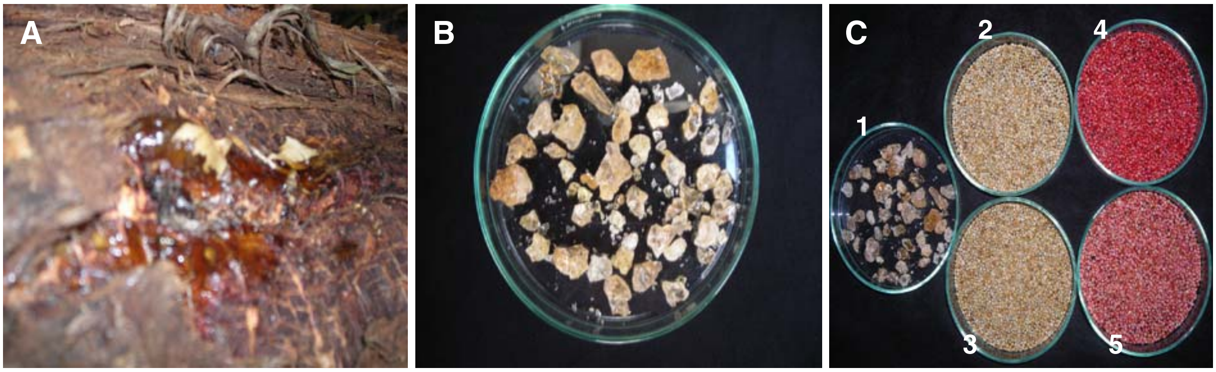

Fig. 1 **A** *Acacia arabica* gum on live tree, **B** eluted gum, **C** seed priming with *A. arabica* gum+metalaxyl 35 SD (3 and 6 g kg^{-1}), *C.1 A. arabica* gum, *C.2* untreated 7042S, *C.3 A. arabica* gum coated 7042S as controls, *C.4* metalaxyl 35 SD (6 g kg^{-1}), and *C.5 A. arabica* gum+metalaxyl 35 SD (3 g kg^{-1})

Effect of polymer with metalaxyl 35 SD fungicide seed priming on seed quality

Seeds were primed with gum biopolymers from *A. arabica*, *M. oleifera*, *C. papaya*, and *A. indica* alone (*w*/*v*), or with these gum biopolymers followed by half the recommended dose of metalaxyl 35 SD (3 g kg^{-1}) and seed priming with the recommended dose of fungicide metalaxyl 35 SD (6 g kg^{-1}) alone. Four repeated experiments with four replicates of 100 seeds per treatment were plated equidistantly on three layers of moistened blotter discs placed in petri plates to evaluate percent germination (Anonymous 1993) and another set of seeds similarly treated was subjected to between-paper method to record seedling vigor calculated using the formula (Abdul Baki and Anderson 1973):

$$\frac{(\text{Mean root length} + \text{mean shoot length}) \times 100}{\text{Percent germination}}$$

Distilled water treated seeds served as the control.

Greenhouse studies

Effect of gum biopolymer with metalaxyl 35 SD fungicide seed priming on downy mildew disease

Pearl millet seed was primed with gum biopolymers from *A. arabica*, *M. oleifera*, *C. papaya* and *A. indica*

Fig. 2 **A** *Azadirachta indica* gum on live tree, **B** eluted gum, **C** seed priming with *A. indica* gum+metalaxyl 35 SD (3 and 6 g kg^{-1}), *C.1 A. indica* gum coated 7042S, *C.2* untreated 7042S as controls, *C.3 A. indica* gum+metalaxyl 35 SD (3 g kg^{-1}) and *C.4* metalaxyl 35 SD (6 g kg^{-1})

alone 1:1 (*w*/*v*), with gum biopolymers followed by half the recommended dose of metalaxyl 35 SD (3 g kg^{-1}), or with the recommended dose of fungicide metalaxyl 35 SD (6 g kg^{-1}) alone. Treated seeds were sown in earthen pots containing 2:1:1 soil, sand and manure under greenhouse conditions. Two-day-old seedlings were inoculated with a zoospore suspension of 4×10^4 zoospores ml^{-1} (Singh and Gopinath 1985). Distilled water-treated seeds served as control. Each treatment consisted of 25 plants in four replications. Disease incidence was recorded when the plants were 30 days old. Observations were also made for phytotoxic symptoms such as epinasty, hyponasty, leaf tip burning and chlorosis in all fungicide treatments.

Growth effect

To evaluate growth promotion under greenhouse conditions, the seeds treated as described above were sown in plastic pots of 10 cm diameter and 250 ml capacity filled with autoclaved soil and sand (at a ratio of 2:1). Seedlings were irrigated and maintained under greenhouse conditions at 25–30°C and >95% r.h. Plants were watered daily and no artificial fertilizers were provided to the plants. The experiment was conducted with 20 replications, with five seedlings per pot. Seeds treated with sterile distilled water served as control. When the plants were 30 days old, height, fresh weight, dry weight, number of tillers and leaf surface area (automatic leaf analyzer, Licor-2100, ADC, Bioscientific Ltd., Herts, UK) were determined (Niranjan Raj et al. 2003; Sudisha et al. 2008).

Field studies

Field experiments were conducted in a *S. graminicola*-infected plot at the Department of Applied Botany and Biotechnology, University of Mysore, Mysore, India. The plot has been infected with oospore inoculum for over two decades and additional inoculum in the form of asexual spores was provided from spreader rows raised 21 days prior to sowing of experimental materials (Williams et al. 1981). Treatments in this trial consisted of seed primed with gum biopolymers from *A. arabica*, *M. oleifera*, *C. papaya* and *A. indica* alone 1:1 (*w*/*v*), seed primed with gum biopolymers followed by half the recommended dose of metalaxyl 35 SD (3 g kg^{-1}), or seed primed with the recommended dose of fungicide metalaxyl 35 SD (6 g kg^{-1}). Distilled water seed-treated plants served as control. Field plots were arranged in a randomized design in four replications per treatment and repeated twice, during 2005 and 2006. Downy mildew disease incidence was recorded after 15 days.

Grain yield assessment

Field trials to determine the effects of the above treatments on grain yield were conducted following standard procedures of Williams and Singh (1981). Seed treatments with gum biopolymers as described above at a concentration of 1:1 were used; seed treatment followed by metalaxyl 35 SD fungicide treatment were compared with a non-treated control. Field plots were arranged in a randomized design in four replications per treatment and repeated twice, during 2005 and 2006. Each replicate consisted of four 4-m rows spaced 75 cm apart, with 15 cm between plants within the rows. Yield measurements were collected from the central 3.8 m of the two central rows (net plot size=5.7 m^2).

Statistics

Each experiment's data were transformed to arcsine values and analysis of variance (ANOVA) (JMP software, SAS Institute, Cary, NC, USA) was conducted, with significant effects of treatments determined by the magnitude of P value ($P<0.001$). Treatment means were separated by Tukey's HSD (Honestly Significant Differences) test.

Results

Seed quality assessment

When treatments were tested under in vitro conditions, they all showed enhanced seed germination and vigor (Table 1). Among the different concentrations of gum biopolymers used for seed priming, the ratio of 1:2 *w*/*v* with water provided the best results in terms of seed germination and seedling vigor and hence this concentration was used for further studies. *A. arabica* and *A. indica* gum alone at the concentration of 1:2 showed the highest germination, of 92%

Table 1 Effect of gum biopolymers and metalaxyl 35 SD seed priming on pearl millet seed germination and seedling vigor (values are means of four independent trials)

Treatment	Concentration (*w*/*v*)	Seed germination (%)±SE	Seedling vigor±SE
Acacia arabica gum seed priming alone	1:1	91±0.5a[a]	996±10f[a]
	1:2	91±0.9a	1022±12.6cd
	1:3	90±0.0ab	1015±9.1d
	1:4	90±1.0ab	993±8.6f
Azadirachta indica gum seed priming alone	1:1	91±0.9a	1070±8b
	1:2	92±1.0a	1192±7.2ab
	1:3	92±0.4a	1105±6.3e
	1:4	91±0.7a	1112±10.6d
Moringa oleifera gum seed priming alone	1:1	90±0.2ab	952±9g
	1:2	90±0.0ab	937±12.1i
	1:3	89±0.9b	959±10.3
	1:4	89±0.9b	942±6.7gh
Carica papaya gum seed priming alone	1:1	89±0.5b	950±4.9g
	1:2	90±0.2ab	963±5.6g
	1:3	90±1.0ab	947±2.7gh
	1:4	90±1.2ab	933±6.5i
A. arabica gum seed priming+3 g kg^{-1} metalaxyl 35 SD	1:1	91±0.8a	1123±13cd
	1:2	93±0.8a	1195±6.4ab
	1:3	92±0.6a	1162±4.9b
	1:4	92±0.1a	1129±4.4c
A. indica gum seed priming+3 g kg^{-1} metalaxyl 35 SD	1:1	91±0.3a	1167±5.7b
	1:2	92±0.0a	1220±8.8a
	1:3	93±0.9a	1206±8.1a
	1:4	93±0.5a	1193±9.4ab
M. oleifera gum seed priming+3 g kg^{-1} metalaxyl 35 SD	1:1	90±0.8ab	1057±7.7bc
	1:2	89±0.6b	1060±8.2b
	1:3	90±0.6ab	1100±10d
	1:4	90±0.6ab	1088±8.6b
C. papaya gum seed priming+3 g kg^{-1} metalaxyl 35 SD	1:1	90±0.1ab	1014±7.3
	1:2	91±0.1a	1059±7.0bc
	1:3	90±0.0ab	1005±7.9e
	1:4	90±0.3ab	1031±9.4c
Control-metalaxyl 35 SD (6 g kg^{-1})	6 g kg^{-1}	89±0.3b	993±8f
Control-7042S	Distilled water	88±0.9c	951±6g
P=<0.001; *df*=75			

[a] Within columns, means followed by a common letter do not differ significantly according to Tukey's HSD

and 91%, respectively. *A. arabica* gum biopolymer seed priming with 3 g kg^{-1} of metalaxyl 35 SD showed maximum seed germination of 93%; seed priming with 6 g kg^{-1} of metalaxyl 35 SD gave 89% seed germination, which was not significantly different from the control. A similar trend in vigor was noticed among treatments, whereby the vigor index of 951 in the control was enhanced to a maximum of 1,137 by *A. indica* gum polymer with 3 g kg^{-1} metalaxyl 35 SD, followed by *A. arabica* gum polymer with 3 g kg^{-1} metalaxyl 35 SD, with a vigor index of 1,123 (Table 1).

Greenhouse studies

Effect of gum biopolymers and fungicide on downy mildew

When downy mildew disease was studied under greenhouse conditions, a varied level of disease protection was noticed between the treatments. Seed priming with gum biopolymers alone provided a significant increase in disease protection levels of 37%, 29%, 24% and 21% in treatments with *A. arabica*, *A. indica*, *M. oleifera* and *C. papaya*, respectively, when compared with the control, which offered no disease protection. *Acacia arabica* and *A. indica* gum+ 3 g kg^{-1} of metalaxyl 35 SD proved to be the best treatments, offering significant disease protection of 86%, which was comparable to seed priming with 6 g kg^{-1} of metalaxyl 35 SD alone. *Moringa oleifera* and *C. papaya* seed biopriming+3 g kg^{-1} of metalaxyl 35 SD resulted, respectively, in 57% and 41% disease protection (Fig. 3).

Effect of seed treatment with gum biopolymers and metalaxyl 35 SD on growth promotion

Acacia arabica gum and *A. indica* gum and metalaxyl 35 SD proved very efficient in growth promotion (Table 2). At the 30-day-old stage, plants with *A. arabica* gum polymers+3 g kg^{-1} of metalaxyl 35 SD treatment recorded a height of 34.2 cm (which was 49% taller than the control), 30% and 27% greater fresh weight and dry weight, respectively, over the control. Seedlings from seed treatment with *A. indica* gum+3 g kg^{-1} of metalaxyl 35 SD were 42% taller, and had 25% and 23% more fresh and dry weight, respectively, than the control, which was 33.9 cm in height, and 12.5 and 3.4 g fresh and dry weight, respectively. Seed treatment with *A. arabica* gum and *A. indica* gum+3 g kg^{-1} of metalaxyl 35 SD resulted in plants with 29.4% and 22.7% greater leaf area than the control, with 37.1, 34.8 and 31.3 cm^2 leaf areas, respectively. Seed treated with 6 g kg^{-1} of metalaxyl 35 SD resulted in significantly enhanced growth parameters: 30.3 cm height, 10.8 g fresh weight, 3 g dry weight, 31.3 cm^2 leaf area and three tillers. The other treatments also followed a general trend of growth promotion and all the treatments tested showed an increase in all the parameters over that of the distilled water control.

Field studies

All eight treatments tested inhibited downy mildew development significantly ($P<0.001$) (Fig. 3). Seed treated with *A. arabica* gum provided the greatest disease control and protection of 48% was achieved, which was further increased to 96% disease protection when seed was treated with *A. arabica* gum+3 g kg^{-1} of metalaxyl 35 SD. Seeds treated with *A. indica* and *M. oleifera* gums showed slightly reduced protection

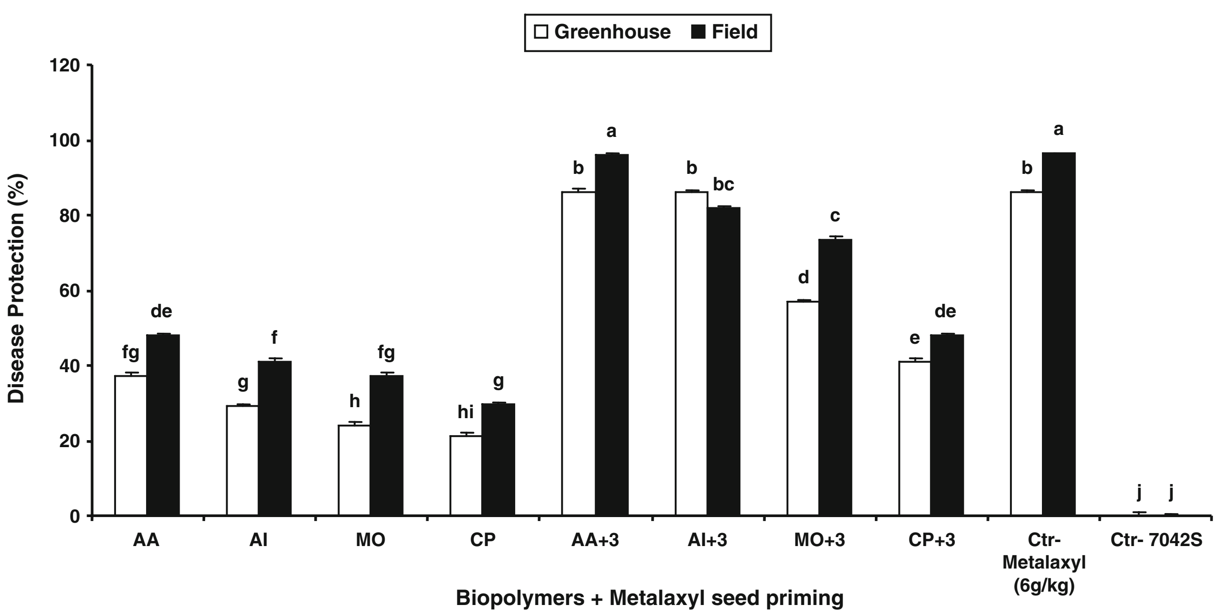

Fig. 3 Effects of gum biopolymers with metalaxyl 35 SD seed priming treatments against downy mildew disease of pearl millet under greenhouse and field conditions "AA", *Acacia arabica* gum; "AA+3", *A. arabica* gum+3 g kg^{-1} metalaxyl; "AI", *Azadirachta indica* gum; "AI+3", *A. indica* gum+3 g kg^{-1} metalaxyl; "MO", *Moringa oleifera*; "MO+3", *M. oleifera*+3 g kg^{-1} metalaxyl; "CP", *Carica papaya*; "CP+3", *C. papaya*+3 g kg^{-1} metalaxyl. Values are means of four replicates. *Bars* represent SE. $P<0.001$; $df=75$ *Columns labeled with a common letter* do not differ significantly according to Tukey's HSD

Table 2 Effect of gum biopolymers and metalaxyl 35 SD seed priming treatments on growth of pearl millet cultivar 7042S under greenhouse conditions (Values are means of four independent trials)

Treatment	Height (cm)	Fresh weight (g) (avg/plant)	Dry weight (g) (avg/plant)	Leaf area (cm^2)	No. of basal tillers (avg/plant)
Acacia arabica gum seed priming alone	33.7±0.9a[a]	12.9±0.5a[a]	3.7±0.8a[a]	35.2±1.0ab[a]	3±0.4a[a]
Azadirachta indica gum seed priming alone	33.1±0.9ab	12.7±0.5a	3.5±0.2abc	34.8±0.9b	3±0.6a
Moringa oleifera gum seed priming alone	31.6±0.2b	11.1±1.0bc	3.3±0.9ab	32.4±0.2bc	3±0.2a
Carica papaya gum seed priming alone	31.8±0.7b	12±0.6b	3.1±0.7bc	33.2±0.2b	3±0.4a
A. arabica gum seed priming+3 g kg^{-1} metalaxyl 35 SD	34.2±0.1a	13±0.6a	3.5±0.3a	37.1±0.6a	3±0.0a
A. indica gum seed priming+3 g kg^{-1} metalaxyl 35 SD	33.9±1.0a	12.5±0.5ab	3.4±0.4ab	35.3±0.5ab	3±0.7a
M. oleifera gum seed priming+3 g kg^{-1} metalaxyl 35 SD	32.3±0.5ab	12.1±0.5ab	3.6±0.9a	33.9±0.1b	3±0.3a
C. papaya gum seed priming+3 g kg^{-1} metalaxyl 35 SD	32.2±1.0ab	11.9±0.6b	3.4±0.6ab	31.8±1.2c	3±0.5a
Control-metalaxyl 35 SD (6 g kg^{-1})	30.3±0.2cd	10.8±0.1c	3.0±0.8c	31.3±1.0cd	3±0.1a
Control-7042S	29.8±1.1d	10.6±0.1c	2.9±0.1cd	31.3±0.6cd	2±0.1b
P=<0.001; *df*=75					
F	484.526	361.72	34.822	583.167	9.721

[a] Within columns, means followed by a common letter do not differ significantly according to Tukey's HSD

of 41% and 37.2%, respectively, which was increased to 81.9% and 73.6% disease protection when seed was treated with *A. indica* and *M. oleifera*+3 g kg^{-1} of metalaxyl 35 SD. With *C. papaya* gum+3 g kg^{-1} metalaxyl 35 SD seed treatments the disease protection was lower, at 48.2%. Seed treatment with 6 g kg^{-1} metalaxyl 35 SD provided significant disease protection of 96.4% and was the best among the other

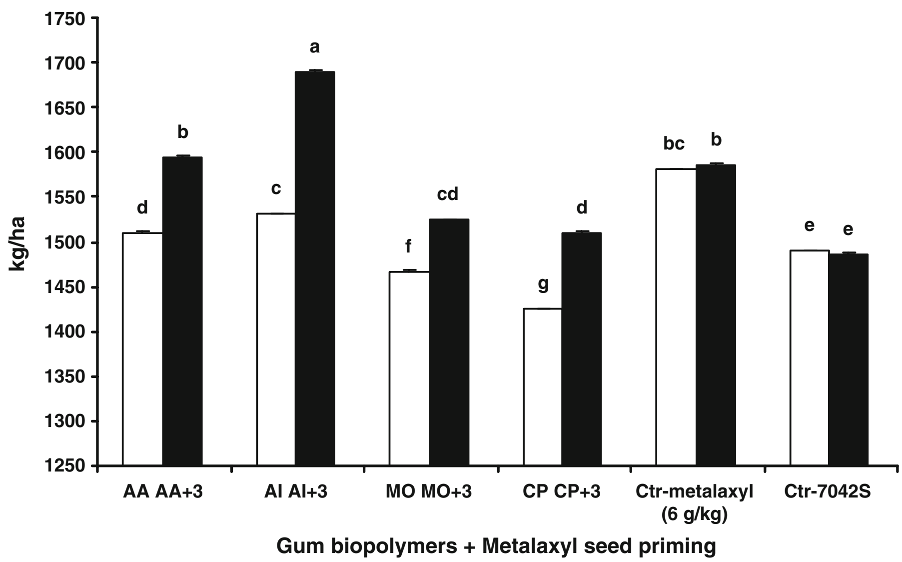

Fig. 4 Performance of gum biopolymers with metalaxyl 35 SD seed priming on grain yield of pearl millet under field conditions "AA", *Acacia arabica* gum; "AA+3", *A. arabica* gum+3 g kg^{-1} metalaxyl; "AI", *Azadirachta indica* gum; "AI+3", *A. indica* gum+3 g kg^{-1} metalaxyl; "MO", *Moringa oleifera*; "MO+3", *M. oleifera*+3 g kg^{-1} metalaxyl; "CP", *Carica papaya*, "CP+3", *C. papaya*+3 g kg^{-1} metalaxyl. Values are means of four replicates. *Bars* represent SE. *P*<0.001; *df*=75 *Columns labeled with a common letter* do not differ significantly according to Tukey's HSD

treatments when compared with the control, which had a disease incidence of 97%.

Grain yield assessment

Significant improvement in grain yield was observed in all the treatments (Fig. 4). Seed treatment alone with *A. indica*, *A. arabica* and *M. oleifera* gums resulted in grain yields of 1,531, 1,510 and 1,467 kg ha^{-1}, respectively. When seed treatment with polymers was combined with 3 g kg^{-1} metalaxyl 35 SD, yields of 1,690, 1,595 and 1,524 kg ha^{-1} were obtained from treatments of *A. indica*, *A. arabica* and *M. oleifera* gums, respectively. However, 6 g kg^{-1} metalaxyl 35 SD alone increased yield over the control seed treatment.

Discussion

The use of synthetic fungicides to control phytopathogenic fungi in crops is a widespread practice that can increase yields. Recently there has been a trend towards introducing surfactants, which are themselves more environmentally friendly in terms of biodegradability and ecotoxicity (Maude 2002). For example, surfactants based on sugar ethers, such as alkyl polysaccharide, have good biodegradability and low ecotoxicity and are being used increasingly as biological enhancing adjuvants.

The present study demonstrated that seed treatments can improve seed quality parameters of pearl millet. A maximum germination of 91% was observed by seed priming with *A. arabica* and *A. indica* gums as biopolymers alone (1:2) or with gum biopolymers +3 g kg^{-1} of metalaxyl 35 SD. A maximum vigor index of 1,137 was obtained by *A. indica* gum polymer+3 g kg^{-1} metalaxyl 35 SD.

In the greenhouse, the seed priming treatments inhibited disease to various levels, the maximum inhibition being achieved by *A. arabica* and *A. indica* gum+3 g kg^{-1} of metalaxyl 35 SD and seed priming with 6 g kg^{-1} of metalaxyl 35 SD, which proved to be the best by offering 86% disease protection. A similar trend in disease protection was evident under field conditions, where seed treated with *A. arabica* gum offered highest disease control—protection of 48%, which was further increased to 96% when seed was treated with *A. arabica*+3 g kg^{-1} of metalaxyl 35 SD. Assessment of the antibacterial activity of acacia gum suggested that it has great clinical value (Clark et al. 1993).

All the seed priming treatments tested exhibited a general trend towards growth promotion in pearl millet. *A. arabica* gum polymers+3 g kg^{-1} of metalaxyl 35 SD treatment led to a significant increase in the plant height, fresh weight, and dry weight, with also a significant increase in the leaf area when compared to most other treatments and the distilled water control. However, the extent of growth enhancement and disease suppression varied with the seed priming with gum biopolymer and metalaxyl 35 SD fungicide.

A significant improvement in grain yield was observed in all the treatments. Seed treatment alone with *A. indica*, *A. arabica* and *M. oleifera* gum biopolymers resulted in grain yields of 1,531, 1,510 and 1,367 kg ha^{-1}, respectively. In earlier studies, integration of fungicide metalaxyl XL (at a rate of 0.5 ml kg^{-1} of seeds) with *Striga*-mycoherbicides (Foxy2 & PSM197) and resistant maize cultivars using seed treatment technology and gum arabic adhesive, showed significant reduction in *Striga* emergence by 81% and 90% compared with the respective resistant and susceptible controls (Elzein et al. 2007).

Thus, it can be concluded that application of some natural polymers as seed treatment with a reduced dose of recommended metalaxyl 35 SD fungicide would prove beneficial, cost effective, ecofriendly and could be a potential component of integrated pest management. These natural polymer seed coatings, in addition to their action against downy mildew, are interesting in that they can be good growth promoters—which is an added advantage. Such products and formulations can be safer and more convenient to use, more effective at much lower rates, less toxic to non-target species, and with lower impact on the environment generally (Knowles 2008).

These compounds may provide the user with a convenient, safe product that will not deteriorate over a period of time, and to obtain the maximum activity inherent in the active ingredient. As environmental concerns are gaining ground throughout the world and reduced use of hazardous chemical pesticides and fertilizers seems inevitable, plant-based gum polymers hold hope for the future as potential biopesticides and biofertilizers that are more cost effective, provide better yields and minimize the use of dangerous and residual chemicals.

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