Efficacy of metalaxyl formulations in controlling downy mildew of pearl millet and their residues under arid climate

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ABSTRACT: A field experiment was conducted to evaluate the various formulations of metalaxyl for the control of downy mildew and its residue in pearl millet under two different rainy seasons in arid climate of Rajasthan. Seed treatment with Apron (4.2 g a.i. kg⁻¹ seed) + two Ridomil MZ 72 WP sprays (2.88 kg a.i. ha⁻¹) at 20 and 40 days after sowing (d.a.s.), seed treatment with Apron (2.1 g a.i. kg⁻¹ seed) + two sprays of Ridomil MZ 72 WP (1.44 kg a.i. ha⁻¹) and Apron seed treatment (4.2 g a.i. kg⁻¹ seed) + one Ridomil MZ 72 WP spray (2.88 kg a.i. ha⁻¹) were found effective in controlling the disease, where disease incidences were 0.9, 3.2 and 3.5%, respectively as compared to check (49.4%) at 70 d.a.s. Apron (4.2 g a.i. kg⁻¹ seed) was superior than 2.1 g.a.i. Kg⁻¹ seed. Spray of Ridomil MZ 72 WP alone was more effective than seed treatment with Apron. Efficacy of metalaxyl was found higher in the season less conducive to downy mildew development. Harvest time residues of metalaxyl and of mancozeb were either nil or in trace in soil, grain and straw of pearl millet.

Key words: Apron 35 WS, Ridomil MZ 72 WP, downy mildew, pearl millet

Pearl millet [Pennisetum glaucum (L.) R. Br.] is the staple diet of vast population of underdeveloped tropical and subtropical countries. Downy mildew [Sclerospora graminicola (Sacc.) Schrot.] is widespread and major production constraint of the pearl millet. The disease is widely distributed in the temperate and tropical areas of the world. Losses of 10 to 60% in grain yield have been reported in various countries of Africa and Asia (Nene and Singh, 1976). Gupta and Singh (1996a) estimated a yield loss of 34% from India, at downy mildew incidence level of 62%. Though, cultural practices have been found effective but most of these practices are location or season specific (Gupta and Singh, 1995). Use of disease resistant cultivars is the most economic method for disease control. But development of pearl millet varieties with durable resistance is difficult and time consuming (Gupta and Singh, 1996b). Seed treatment with metalaxyl (Apron 35 SD) @ 2 g.a.i. Kg⁻¹ seed controlled disease for about 30 days only (Williams and Singh, 1981; Gupta, 1984). Superiority of seed treatment coupled with one or two sprays of Ridomil MZ 72 WP over seed treatment alone has been reported (Rao et al., 1987; Appaji et al., 1989). The present investigations were carried out to evaluate the metalaxyl formulations as seed treatment and sprays for the control of downy mildew in two different seasons under arid climate and to determine the residue levels of metalaxyl and mancozeb.

MATERIALS AND METHODS

A field experiment was conducted during the 1991 and 1992 in a randomized block design (plot size 4 x 2.5 m), with three replications using a susceptible cv. HB 3. One year old oosporic powder, prepared by grinding and sieving the downy mildew infected leaves and ears of pearl millet plants, was incorporated in seed furrows (@ 3 g m⁻¹) and also as seed coating (@ 4 g kg⁻¹). Metalaxyl formulation- Apron 35 WS (Methyl-D-L-N (2, 6-dimethyl phenyl)-N (2-Methoxy acetylaminate) was used as a seed dressing and metalaxyl formulation-Ridomil MZ 72 WP (metalaxyl 8% + mancozeb 64%) as foliar spray at 20 and 40 days after sowing (d.a.s.). A total of nine treatments, including control was used (Table 1).

Per cent disease incidence was recorded at 42 and 70 d.a.s. Data were subjected to either square root transformation (\(\sqrt{n+0.5}\)) or arc sine angular transformation. For percentage data lying with in the range of 0 to 30% or 70 to 100%, square root transformation is used and for percentage data lying with in the range of 0 to 100%, arc sine transformation is used (Gomez and Gomez, 1984). Pooled analysis was carried out after

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performing Bartlett's test of homogeneity of variances (Panse and Sukhatme, 1967).

To determine residues of metalaxyl and mancozeb, samples of grain (25 g), straw (12.5 g) and basal soil (50 g) from 0-30 cm depth around the plants in triplicate (one sample from each replication) in 1991 and 1992 were taken at the time of crop maturity. Sampling was done in treatments where metalaxyl formulations' Apron for seed treatment and Ridomil MZ 72 WP for two sprays were used at lower (Apron @ 2.1 g a.i. kg⁻¹ seed and Ridomil MZ @ 1.44 kg ha⁻¹) and higher (Apron @ 4.2 g a.i. kg⁻¹ seed and Ridomil MZ @ 2.88 kg ha⁻¹) doses, respectively. Samples were stored at -20°C till analysis work. For extraction homogenized samples were shaken for 2 h in methanol. Clean up was done by DW-methanol/dichloromethane partitioning and passing through alumina preparative HPLC on silica. Metalaxyl was quantified by GLC with PN detector following the REM 16/76 modified method. Determination of mancozeb residue was done as CS₂ by spectrophotometer from the samples following the method of Keppel (1969). The analytical functions used to calculate residues (y = ax + b; x and y denoting detector response and standard amount injected, respectively) were computed by minimizing the sum of squares of the relative deviations of all measured points (method of least squares).

RESULTS

Pooled analysis (Table 1) revealed that downy mildew incidence at 42 d.a.s. was minimum when metalaxyl was used at higher rate as seed treatment followed by spray (T₄). Disease incidence in T₄ (0.13%) was statistically at par with all other treatments except the seed treatment @ 2.1 g a.i. Kg⁻¹ seed (T₅) and check (T₉), where the disease incidences were 5.25% and 9.69%, respectively. With the seed treatment at lower rate (2.1 g a.i. Kg⁻¹ seed) the incidence of disease was 45.82% lower than the check but the difference between them were statistically nonsignificant.

In 1991, all the seed treatment + spray incorporated treatments (T₁ to T₄) expressed no downy mildew symptoms up to 42 d.a.s., while in 1992, all these treatments had from 0.27 to 2.01% downy mildew incidences. In check, the disease incidence at 42 d.a.s. in 1992 was about 2 times greater of that in 1991.

As evident from the pooled data the lowest downy mildew incidence at 70 d.a.s. was recorded in T₄ (98.16% lower than the check), though it was statistically at par with that in spray incorporated treatments T₂ and T₃. Disease incidence in other spray treatments (T₁, T₇, and T₈) were though, statistically at par with T₂ and T₄, significantly higher than in T₅ and lower than in T₆p (only seed treatment) and T₉ (check). Apron applied @ 4.2 g a.i. kg⁻¹ seed (T₆p) was found superior than 2.1 g a.i. kg⁻¹ seed (T₅) in disease control. Disease incidence in check (49.40%) was at par with that in seed treatment at lower rate (T₅) but significantly higher than in seed treatment at higher rate (T₆p). Treatments having spray(s) alone (T₇ and T₈) were more effective than the seed treatment alone (T₅ and T₆p).

Table 1. Effect of Metalaxyl formulations on downy mildew incidence in pearl millet at Jodhpur

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Season I</th>
<th></th>
<th>Season II</th>
<th></th>
<th>Pooled</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>42 d.a.s.</td>
<td>70 d.a.s.</td>
<td>42 d.a.s.</td>
<td>70 d.a.s.</td>
<td>42 d.a.s.</td>
<td>70 d.a.s.</td>
</tr>
<tr>
<td>T₁</td>
<td>ST-1 + 1 spray-1</td>
<td>0.00(0.71)*</td>
<td>4.70(12.55)**</td>
<td>2.01(1.55)*</td>
<td>4.58(12.24)**</td>
<td>1.01(1.13)*</td>
</tr>
<tr>
<td>T₂</td>
<td>ST-2 + 1 spray-2</td>
<td>0.00(0.71)</td>
<td>3.04(8.98)</td>
<td>1.65(1.44)</td>
<td>4.05(11.49)</td>
<td>0.82(1.07)</td>
</tr>
<tr>
<td>T₃</td>
<td>ST-1 + 2 sprays-1</td>
<td>0.00(0.71)</td>
<td>2.56(8.87)</td>
<td>0.70(1.01)</td>
<td>3.87(11.27)</td>
<td>0.35(0.86)</td>
</tr>
<tr>
<td>T₄</td>
<td>ST-2 + 2 sprays-2</td>
<td>0.00(0.71)</td>
<td>0.88(5.35)</td>
<td>0.27(0.85)</td>
<td>0.95(5.53)</td>
<td>0.13(0.78)</td>
</tr>
<tr>
<td>T₅</td>
<td>ST-1</td>
<td>4.43(2.15)</td>
<td>43.67(41.35)</td>
<td>6.07(2.52)</td>
<td>41.12(39.84)</td>
<td>5.25(2.33)</td>
</tr>
<tr>
<td>T₆</td>
<td>ST-2</td>
<td>2.58(1.74)</td>
<td>28.50(32.25)</td>
<td>2.73(1.77)</td>
<td>33.96(35.60)</td>
<td>2.65(1.75)</td>
</tr>
<tr>
<td>T₇</td>
<td>No ST + 1 spray-1</td>
<td>2.02(1.58)</td>
<td>4.93(12.74)</td>
<td>2.46(1.72)</td>
<td>9.21(17.44)</td>
<td>2.24(1.65)</td>
</tr>
<tr>
<td>T₈</td>
<td>No ST + 2 sprays-1</td>
<td>0.75(1.08)</td>
<td>4.13(11.60)</td>
<td>2.39(1.70)</td>
<td>5.82(13.74)</td>
<td>1.57(1.39)</td>
</tr>
<tr>
<td>T₉</td>
<td>No treatment (check)</td>
<td>6.24(2.57)</td>
<td>50.82(45.48)</td>
<td>13.15(3.67)</td>
<td>47.99(43.84)</td>
<td>9.69(3.12)</td>
</tr>
</tbody>
</table>

CD 5% Treatments (0.49) (5.52) (0.50) (5.57) (0.98) (5.98) (NS) (NS)

Years

* Square root (Jn+0.5) transformation, ** Arc sine angular transformation.
ST-1 = seed treatment with Apron 35 WS (@ 2.1 a.g.i. kg⁻¹ seed), ST-2 = seed treatment with Aprin 35 WS (@ 4.2 a.g.i. kg⁻¹ seed), Spray-1 = Ridomil MZ 72 WP spray (@1.44 kg ha⁻¹), Spray-2 = Ridomil MZ 72 WP spray (@2.88 kg ha⁻¹), d.a.s. = days after sowing
Table 2. Meteorological factors up to 60 days after sowing in 1991 and 1992

<table>
<thead>
<tr>
<th>Meteorological Factor</th>
<th>Up to 30 days of sowing</th>
<th>From 31 to 60 days of sowing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (mm day⁻¹)</td>
<td>2.30(7)</td>
<td>4.60(10)</td>
</tr>
<tr>
<td>Daily % relative humidity-maximum</td>
<td>80</td>
<td>84</td>
</tr>
<tr>
<td>Sunshine (h day⁻¹)</td>
<td>6.5</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Figures in parentheses are number of rainy days

Analysis of the samples revealed no detectable residues of metalaxyl and mancozeb in soil, grain and straw in 1991. In 1992, however, there was no metalaxyl residue in straw samples, it was detected in soil as 0.01 and 0.02 µg g⁻¹ at lower and higher doses of metalaxyl, respectively. In grains, again, there was no metalaxyl at lower dose and it was 0.01 µg g⁻¹ at higher dose of metalaxyl. No detectable residues of mancozeb were found in any of the samples (Table 3).

**DISCUSSION**

The disease incidence in check and in seed treated plot at lower rate (2.1 g.a.i. kg⁻¹ seed) were at par with 70 d.a.s. in both the seasons. This might be due to the fact that the seed treatment remain effective only up to 30 days (Dang et al., 1983; Gupta, 1984). The use of metalaxyl (Apron) at higher concentration might have protected the crop for a longer period, resulting in significantly lower disease as compared to apron at lower rate. Appaji et al. (1989) also noticed mean downy mildew incidence levels from 25 d.a.s. to harvest, 40.1 and 23.6 % in 1987 and 37.0 and 23.1 % in 1988 with seed treatment @ 4 g and 8 g kg⁻¹ of Apron, respectively.

Higher efficacy of sprays without seed treatment (T₁ and T₂) over the seed treatment alone (T₃ and T₄) may be ascribed to the effectiveness of metalaxyl sprays in checking appearance of symptoms of primary incidence and early phase of secondary spread to an appreciable level (Gupta and Verma, 1991). The highest disease control with seed treatment and subsequent spray application was due to their combined effect on the pathogen and disease. Metalaxyl might be inhibiting oospore germination and/or further mycelial growth, and thus, helping in containing the primary seedling infection from soil borne oospores and reducing the sporangia available for infection of later formed tillers (Williams and Singh, 1981). Metataxyl is reported to be fungistic (Singh et al., 1984) and as inhibitory to mycelial growth (Farih et al., 1981). The symptoms may reappear from the mycelium present inside the host (Singh et al., 1984) when the effect of seed treatment is over. Efficacy of Ridomil spray in the control of downy mildew may be through, (1) blocking of sporulation process by slowing down the fungal growth (Appaji et al., 1989) and (ii) blocking of secondary haustoria and mycelial growth inside the leaf and lesion formation (Bruck et al., 1980). Ridoniil also inhibits sporangial germination (Muthuswamy and Narayanswamy, 1985; Rao et al., 1987). The infectivity of sporangia varied with the concentration of metalaxyl (Singh and Shetty, 1990). At higher concentration it completely prevented the movement and ger-

Table 3. Harvest time residues (µg g⁻¹) of metalaxyl and mancozeb in pearl millet grains, straw and soil under arid climate of Jodhpur during the seasons 1991 and 1992

<table>
<thead>
<tr>
<th>Samples</th>
<th>At higher dose*</th>
<th>At Lower dose**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>meta</td>
<td>manco</td>
</tr>
<tr>
<td>Grains</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Straw</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Soil</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

* = Apron 35 WS @ 4.2 g.a.i. kg⁻¹ seed and two sprays of Ridomil MZ 72 WP @ 2.88 kg ha⁻¹
** = Apron 35 WS @ 2.1 g.a.i. kg⁻¹ seed and two sprays of Ridomil MZ 72 WP 1.44 kg ha⁻¹
ND = Not detected (nil), d.a.s. = days after sowing, meta = metalaxyl, manco = mancozeb
mination of zoospores and germ tube growth (Singh et al., 1984). This may explain the better efficacy of metalaxyl at higher concentration in the present study. Moreover, antispore potential of mancozeb (a constituent of Ridomil MZ 72 WP) has also been reported by Bains and Jhooty (1978).

The climatological data (Table 2) reveal that the weather conditions up to 30 d.a.s. remained more favourable for disease development in 1992 than in 1991 as evident by higher mean daily rainfall coupled with more number of rainy days and high mean daily maximum relative humidity in 1992 as compared to 1991. In the following 30 days the weather conditions, specifically relative humidity, was almost similar in both the seasons. Lower mean daily rainfall with more number of rainy days in 1991 and higher mean daily rainfall with less number of rainy days in 1992 did not keep mean daily maximum relative humidity much different in both the years. Relative humidity was found to have a high positive correlation with downy mildew incidence and favours the expression of primary as well as secondary infection and spread of downy mildew (Gupta and Singh, 1999.) However, the higher incidence at 42 d.a.s. in check plot in 1992 than in 1991 may be because of more favourable weather in season 1992 than in 1991. The efficacy of metalaxyl seems to be higher in the season less favourable for disease development as evident from the comparison of disease incidence at 42 d.a.s. during two seasons.

No residue hazards of metalaxyl compounds (Apron and Ridomil MZ) with even higher doses are expected from the crop as well as soil, as all the residue levels detected in soil and grain were zero or practically near to zero under and climate. But to have long lasting use of metalaxyl it should not be used continuously for complete protection of pearl millet crop from downy mildew, neither susceptible varieties should be used using metalaxyl extensively. Such practices may lead to build up of resistance in this pathogen against the metalaxyl as happened with downy mildew pathogen of cucurbits (Katan and Bashi, 1981).

As opined by Singh (1995) the best results from metalaxyl can be obtained by restricting its use for one to two years only, if a known popular cultivar has become susceptible and no resistant cultivars are immediately available.

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