**Efficacy of Various Control Measures Against Downy Mildew (Sclerospora graminicola) in Pearl Millet: A Comparative Analysis**

**ABSTRACT-** The present study was undertaken during the *Kharif* season of 2024 at the Rainfed Organic Agriculture Research Farm, Narayan Bagh, Institute of Agricultural Sciences, Department of Plant Pathology, Bundelkhand University, Jhansi Uttar Pradesh. To evaluate the progression of downy mildew disease of pearl millet under natural epiphytotic conditions and to assess the efficacy of selected seed treatments and foliar applications. Significant differences were observed among treatments in terms of plant population, seedling emergence, and disease incidence. The highest number of plants per plot (47.67) and seedling emergence percentage (95.33%) were recorded in the treatment comprising seed treatment with Metalaxyl @ 6 g/kg seed combined with foliar spray of Propiconazole 25% EC @ 0.25%. This treatment also exhibited the lowest downy mildew incidence at both 30 DAS (2.00%) and 60 DAS (3.28%). Biocontrol agents such as Trichoderma harzianum @ 6 g/kg seed and Pseudomonas fluorescens @ 8 g/kg seed showed moderate efficacy, recording lower disease incidence than the untreated control. The control plots, which received no seed treatment or spray, showed the poorest performance with the lowest plant count (27.50), lowest seedling emergence (55.00%), and the highest disease incidence at both 30 DAS (33.97%) and 60 DAS (35.12%). These findings clearly demonstrate the superior performance of integrated chemical seed treatment and foliar application in enhancing seedling establishment and reducing downy mildew disease in pearl millet.

**Keywords**: Downy mildew, Sclerospora graminicola, Pearl millet, Disease progression.

**INTRODUCTION**

Pearl millet (Pennisetum glaucum (L.) R. Br), commonly known as Bajra, is a staple cereal crop in dry and semi-arid regions of Asia and Africa, valued for its nutritional richness, drought tolerance, and adaptability to poor soils. Despite its resilience, pearl millet is highly susceptible to downy mildew, a major disease caused by the pathogen Sclerospora graminicola, which leads to significant yield losses by affecting plant growth and grain development. Traditional management strategies such as chemical fungicides and resistant cultivars have shown limited long-term success due to pathogen variability, environmental influences, and emerging resistance. Therefore, integrated approaches combining bio-agents like fluorescent Pseudomonas spp., fungicides, and resistant varieties are gaining importance for sustainable disease control. This research aims to compare the efficacy of different treatments against Sclerospora graminicola to identify the most effective and environmentally sustainable strategy for managing downy mildew in pearl millet cultivation.

**MATERIALS AND METHODS**

A field experiment was conducted during the *Kharif* season of 2024 to study the management of downy mildew of pearl millet caused by *Sclerospora graminicola*. The test crop used was a moderately resistant cultivar, Leo-7601. The study was undertaken at the Rainfed Organic Agriculture Research Farm, Narayan Bagh, Institute of Agricultural Sciences, Department of Plant Pathology, Bundelkhand University, Jhansi (Uttar Pradesh). The experimental design followed a Randomized Block Design (RBD) with nine treatments, each replicated thrice. Seeds were treated with selected fungicides and bio-agents to evaluate their effectiveness through seed treatment and foliar sprays. Metalaxyl was used for seed treatment in one of the effective treatments. A non-treated control (without fungicide application) was also maintained for comparison. Each plot measured 2.0 m × 1.0 m, with a plant spacing of 30 cm between rows and 10 cm between plants to ensure uniform plant population. Farmyard manure (FYM) was incorporated at the rate of 10-12 tonnes/ha two to three weeks before sowing. Fertilizers were applied at a rate of 90:30 kg/ha (N:P₂O₅), with nitrogen split into two equal doses-half as basal and half as top dressing at 30 days after sowing. All agronomic practices including irrigation, weed, and pest management were uniformly maintained throughout the experimental period. The first spray treatment was applied 21 days after sowing. The virulent isolate of *Sclerospora graminicola* was used for disease inoculation. The objective was to evaluate the long-term efficacy of fungicides and biocontrol agents under natural epiphytotic conditions for sustainable management of pearl millet downy mildew. Treatment details of the experiment are given below.

**Observations recorded**

**Downy mildew incidence (%):** The total number of plants was recorded at the time of thinning *i.e.,* fifteen days after sowing, while the number of downy mildew infected plants was recorded at 30 and 60 days after sowing then the downy mildew incidence per cent was calculated with the help of following formula:

$$Downy mildew incidence (\%)=\frac{Downy mildew infected plants }{Total number of plants}×100$$

**Seedling emergence**

$$Percent seedling emergence=\frac{Number of seeds germinates }{Total number of seeds sown}×100$$

**RESULTS**

**The present investigation was undertaken to evaluate the effect of various chemical, biological, and botanical seed treatments and foliar applications on the incidence of downy mildew disease in pearl millet under natural epiphytotic conditions. The results obtained on seedling emergence, average number of plants per plot, and disease incidence at 30 and 60 days after sowing (DAS) are summarized in Table 1 & Fig.1**

**Seedling Emergence and Average Number of Plants**

**The average number of plants per plot differed significantly among treatments. The highest number of plants per plot was observed in the treatment T4 (Seed treatment with Metalaxyl @ 6 g/kg seed + foliar spray of Propiconazole 25% EC @ 0.25%) with 47.67 plants, followed by *Trichoderma harzianum* @ 6 g/kg seed (44.73 plants) and Metalaxyl @ 0.25% (44.22 plants). The lowest plant count (27.50) was recorded in the control treatment, indicating a poor establishment due to disease pressure and absence of seed protection. The differences among treatments were statistically significant. Seedling emergence percentage was highest in the combined Seed treatment with Metalaxyl (@ 6g/kg seed + Spray of Propiconazole 25% EC @ 0.25% treatment (95.33%), followed by *Trichoderma harzianum*** @ 6g/kg seed **(89.47%), *Pseudomonas fluorescens @* 8g/kg seed (89.13%) and Metalaxyl (88.43%). The lowest emergence (55.00%) was recorded in the control, the adverse effect of seed- and soil-borne pathogens on germination in the absence of treatment.**

**Downy Mildew Incidence at 30 DAS**

**Disease incidence at 30 DAS revealed significant variations. The lowest disease incidence (2.00%) was recorded in the Seed treatment with Metalaxyl (@ 6g/kg seed + Spray of Propiconazole 25% EC @ 0.25% treatment, followed by Metalaxyl alone (2.58%), and Carbendazim (2.60%). Biocontrol agents such as *Trichoderma harzianum* @** 6g/kg seed **(2.87%) and *Pseudomonas fluorescens @* 8g/kg seed (2.93%) were moderately effective. The highest incidence (33.97%) occurred in the untreated control, indicating a high level of early disease development when no protective treatment was applied.**

**Downy Mildew Incidence at 60 DAS**

**At 60 DAS, disease progression followed a similar trend. The combined treatment of Seed treatment with Metalaxyl (@ 6g/kg seed + Spray of Propiconazole 25% EC @ 0.25%again exhibited the lowest incidence (3.28%), followed by Metalaxyl (3.40%), and Carbendazim (3.57%). Among biocontrol agents, *Trichoderma harzianum*** @ 6g/kg seed**and *Pseudomonas fluorescens @* 8g/kg seed showed moderate disease control. Neem oil recorded higher incidence (5.51%), but still significantly lower than the control treatment, which recorded 35.12% incidence the highest among all treatments.**

**Table: - 1 Effectiveness of different treatments against *Sclerospora graminicola*, the causal agent of downy mildew in pearlmillet. during *Kharif* 2024 under field conditions.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Average no. of plants/Plots** | **Seedling emergence****(%)** | **Downy mildew incidence (%) at 30 DAS** | **Downy mildew incidence (%) at 60 DAS** |
| Metalaxyl @ 0.25% | 44.22 (6.69) \* | 88.43 | 2.58 (1.74) | 3.40 (1.96) |
| Carbendazim @ 0.25% | 42.15 (6.53) | 84.30 | 2.60 (1.75) | 3.57 (2.01) |
| Mancozeb @ 0.2 %  | 41.70 (6.50) | 83.40 | 2.82 (1.81) | 3.82 (2.07) |
| Seed treatment with Metalaxyl (@ 6g/kg seed + Spray of Propiconazole 25% EC @ 0.25% | 47.67 (6.94) | 95.33 | 2.00 (1.57) | 3.28 (1.92) |
| Seed treatment with *Trichoderma harzianum* @ 6g/kg seed | 44.73 (6.73) | 89.47 | 2.87 (1.82) | 3.93 (2.11) |
| Seed treatment with *Pseudomonas fluorescens* @ 8g/kg seed | 44.57 (6.71) | 89.13 | 2.93 (1.84) | 4.60 (2.26) |
| Seed treatment with *Trichoderma asperellum* @ 6g/kg seed | 44.40 (6.70) | 88.80 | 3.13 (1.89) | 4.87 (2.32) |
| Neem oil | 40.23 (6.38) | 80.45 | 4.11 (2.15) | 5.51 (2.45) |
| Control | 27.50 (6.29) | 55.00 | 33.97 (5.87) | 35.12 (5.97) |
| **S. Em±** | **0.03** | **-** | **0.09** | **0.09** |
| **C.D. @ 5%** | **0.10** | **-** | **0.28** | **0.27** |
| **CV%** | **0.87** | **-** | **7.14** | **6.18** |

\*All Data are means of three replications.

\*Figures in parentheses are angular transformed value.

**Figure: 1** Effectiveness of different treatments against *Sclerospora graminicola*, the causal agent of downy mildew in pearl millet. during *Kharif* 2024 under field

**DISCUSSION**

The highest seedling emergence (95.33%) and plant stand (47.67 plants per plot) were observed with the combined treatment of seed treatment using Metalaxyl @ 6 g/kg seed along with foliar spray of Propiconazole 25% EC @ 0.25%. This might be due to the systemic and protective action of both fungicides, which protected seedlings from primary infection and delayed disease onset. These findings are supported by Patil *et al.,* (2008), who reported that Metalaxyl seed treatment combined with a foliar fungicide spray effectively controlled downy mildew and improved seedling emergence in pearl millet.

 Metalaxyl alone also performed significantly well (88.43% emergence), indicating its systemic activity against oomycetes such as *Sclerospora graminicola*. Thakur *et al.,* (2003) observed similar results, where Metalaxyl-treated seeds showed improved germination and reduced early infection of downy mildew.

 Minimum disease incidence at 30 and 60 DAS was recorded in the combined Seed treatment with Metalaxyl (@ 6g/kg seed + Spray of Propiconazole 25% EC @ 0.25%treatment (2.00% and 3.28%, respectively). This confirms the synergistic effect of dual fungicide application, offering both protective and curative action against the pathogen. Singh and Shetty (1990) highlighted the importance of combining seed and foliar fungicide applications for effective management of downy mildew in susceptible crops like pearl millet and sorghum.

 Chemical fungicides like Carbendazim and Mancozeb also performed moderately well. Carbendazim, a systemic benzimidazole fungicide, inhibited fungal mycelial development. These results are in line with Reddy and Anahosur (1994), who observed that Carbendazim significantly suppressed downy mildew development in pearl millet under field conditions.

 Among the biological treatments, seed treatment with *Trichoderma harzianum* and *Trichoderma aspergillus* demonstrated moderate efficacy in reducing disease incidence. These organisms are known for their antagonistic activity, induced systemic resistance (ISR), and rhizosphere competence. *Trichoderma spp*. produces secondary metabolites and hydrolytic enzymes that suppress soil-borne pathogens. Similar results were reported by Niranjana *et al.,* (2002), who found that *Trichoderma harzianum* reduced the incidence of several soil-borne diseases through competition and antibiosis.

 *Trichoderma harzianum*, a plant growth-promoting rhizobacteria (PGPR), showed promising disease suppression, supporting findings of Kloepper *et al.,* (2004), who stated that PGPR enhance plant immunity and reduce disease incidence by activating ISR mechanisms. However, biological treatments were not as effective as chemical fungicides, possibly due to environmental variability and lower pathogen suppression under high disease pressure.

 Neem oil showed limited efficacy in suppressing downy mildew (5.51% incidence at 60 DAS), but it was significantly better than the control (35.12%). Neem oil contains azadirachtin and other compounds that have antifungal properties. Choudhary and Kumari (2010) reported moderate antifungal activity of neem-based formulations against various plant pathogens.

 Carbendazim and Mancozeb treatments also showed considerable disease suppression, which is in agreement with Sharma and Jain (2012), who reported the broad-spectrum protective activity of these fungicides against downy mildew pathogens. Among the biological agents, *Trichoderma harzianum* and *Trichoderma aspergillus* showed moderate disease control (around 3.2-3.7% incidence), reflecting their potential in inducing systemic resistance and producing antifungal metabolites, as documented by Gopalakrishnan *et al.,* (2011) and Basha and Ulaganathan (2002).

 The findings of the present study are in agreement with those of Ramesh *et al.* (2009), who reported that seed treatment with P. fluorescens significantly reduced downy mildew severity and improved seedling vigour in pearl millet. Similarly, Thirumala-Devi *et al.* (2012) also reported a substantial reduction in disease incidence and enhancement of plant growth when P. fluorescens was applied as a seed or soil treatment under field conditions.

 Neem oil, though slightly less effective than chemical treatments, still demonstrated suppressive effects on disease incidence, supporting earlier work by Singh and Prasad (2008) that highlighted the antifungal properties of neem-based formulations. The significantly high disease incidence in the untreated control (33.97% at 30 DAS and 35.12% at 60 DAS) confirmed the conducive conditions for natural epiphytotic development of downy mildew and emphasized the necessity of effective disease management strategies.

 Overall, the results underscore the importance of integrated disease management (IDM) involving compatible chemical and biological agents. The systemic fungicides, particularly in combination treatments, offer reliable protection, while bioagents and botanicals contribute to sustainable, eco-friendly disease suppression. These findings are consistent with the principles of IDM and advocate for their adoption in downy mildew-prone regions to ensure healthy crop establishment and yield sustainability.

The integrated treatment of Seed treatment with Metalaxyl (@ 6 g/kg seed) + Spray of Propiconazole 25% EC @ 0.25% also provided moderate disease suppression (4.33% at 30 DAS and 5.23% at 60 DAS), which agrees with observations made by Meena *et al.,* (2016), advocating for integrated management as a sustainable strategy against downy mildew.Biocontrol agents like *Trichoderma harzianum* and *P. fluorescens* performed well initially but showed higher disease incidence by 60 DAS compared to chemical treatments. This could be attributed to the slower mode of action of bioagents, which often require colonization and competition to effectively suppress pathogens (Baker and Paulitz, 1996).Neem oil, despite being considered a natural pesticide, was the least effective among the treatments with disease incidences of 7.83% (30 DAS) and 8.23% (60 DAS). This suggests that while neem oil may offer some level of antifungal activity, it is insufficient for managing systemic diseases like downy mildew in susceptible crops like pearl millet.The untreated control consistently showed the highest incidence of downy mildew (33.97% at 30 DAS and 35.10% at 60 DAS), illustrating the epiphytotic potential of the disease under favorable weather conditions (high humidity and moderate temperatures), as reported by Safeeulla (1976) and Thakur *et al.,* (2007).

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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