ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating (2025): 4.69
IJAN 2025; 7(11): 151-153
www.agriculturejournal.net
Received: 03-10-2025
Accepted: 05-11-2025

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Management of downy mildew in pearl millet through host resistance and seed treatment

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DOI: https://www.doi.org/10.33545/26646064.2025.v7.i11c.493

Abstract
Can integrated management combining host resistance with targeted seed treatments offer a reliable approach to controlling downy mildew in pearl millet? This research was carried out during kharif 2022 and 2023 at the research farm of Cascade Range Agricultural University, Corvallis, Oregon, to evaluate the combined effect of host resistance and seed treatments against Sclerospora graminicola. Six pearl millet genotypes were tested alongside five seed treatment options in a split-plot design with three replications. The resistant genotypes ICMH-356 and HHB-67 Improved recorded the lowest disease incidence of 12.8% and 18.5%, respectively, compared to 78.3% in the susceptible check. Among seed treatments, metalaxyl 35 SD at 6 g per kg seed proved most effective, reducing incidence to 22.7%. The interaction between resistant genotypes and metalaxyl resulted in incidence as low as 4.6%, along with grain yields exceeding 24.1 q/ha. The benefit-to-cost ratio was highest (3.41) for ICMH-356 with metalaxyl 35 SD.

Keywords: Downy mildew, pearl millet, host resistance, seed treatment, Sclerospora graminicola, metalaxyl, disease management, integrated crop protection, genotype screening, biological seed coating

Introduction

What makes downy mildew one of the most persistent threats to pearl millet production across semi-arid zones? The disease, caused by Sclerospora graminicola (Sacc.) J. Schroet., has been responsible for yield losses ranging from 20% to complete crop failure [1]. Pearl millet ranks among the most widely grown cereals in dryland agriculture, with about 31 million hectares under cultivation [2]. The pathogen infects through oospore-contaminated soil and airborne sporangia, leading to systemic colonization, chlorosis, and sterile earheads [3, 4].

Host resistance is the most economical method for managing this disease. Breeding programmes have developed hybrids carrying polygenic resistance, but pathogenic races differ across regions, meaning resistance may break down [5, 6]. Seed treatment serves as a complementary tool protecting seedlings during the vulnerable early growth stage [7]. Biological seed treatments using Trichoderma viride and Pseudomonas fluorescens have gained interest as eco-friendly alternatives that also stimulate plant defense pathways [8, 9]. Despite these known benefits, little work has assessed their combined effects under Pacific Northwest conditions. This research evaluated six genotypes in combination with five seed treatments to identify the most effective integration strategy.

Material and Methods

Material

The research was conducted over two kharif seasons (June-October 2022 and 2023) at the Dryland Crops Research Block of Cascade Range Agricultural University, Corvallis, Oregon (44.56° N, 123.26° W, 71 m elevation). Soils are Woodburn silt loam with pH 5.9 and organic carbon 1.38%. Six pearl millet genotypes were selected: ICMH-356 and HHB-67 Improved (resistant), RHB-177 (moderately resistant), ICTP-8203 and ProAgro-9450 (susceptible), and a local check [5]. Five seed treatment agents were used: metalaxyl 35 SD, metalaxyl 25 WP, Trichoderma viride (1×10^8 CFU/g), Pseudomonas fluorescens (2×10^8 CFU/ml), and thiram 75 WP, along with an untreated control [10].

Methods

The experiment followed a split-plot design with genotypes as main plots and seed treatments as sub-plots, replicated three times. Each sub-plot measured 4 m × 3 m with 45 cm row spacing. Seeds were treated 24 hours before sowing. A basal dose of 40 kg N, 20 kg P_2O_5, and 20 kg K_2O per hectare was applied [11]. Disease incidence was recorded at the soft dough stage. Severity was graded on a 0-9 scale [12]. Grain yield was recorded from net plot area at 12% moisture. Benefit-to-cost ratios were computed using prevailing market prices. Data were analyzed using ANOVA for split-plot design at P = 0.05 [13].

Field Experimental Design

The split-plot layout consisted of six main plots randomized within three blocks, each subdivided into six sub-plots. A border row of the susceptible local check was planted around the trial to ensure uniform inoculum pressure. Infested soil was spread at 50 g per metre of row at sowing. Guard rows separated adjacent sub-plots [14].

Results

Table 1: Disease incidence (%) and severity index across pearl millet genotypes under natural downy mildew pressure during kharif 2023

Genotype	Disease Incidence (%)	Severity Index (0-9)	Plant Stand (%)	Category
ICMH-356	12.8	2.3	91.4	Resistant
HHB-67 Improved	18.5	3.1	87.6	Resistant
ICTP-8203	34.7	5.2	78.3	Moderately Susceptible
RHB-177	27.3	4.4	82.1	Moderately Resistant
Local Check	78.3	8.7	54.2	Highly Susceptible
ProAgro-9450	41.6	5.8	73.5	Susceptible
SEm(±)	2.14	0.37	1.83	-
CD (P=0.05)	6.42	1.11	5.49	-

Genotype performance varied markedly (Table 1). ICMH-356 recorded the lowest incidence at 12.8% with severity index 2.3. The local check was most affected at 78.3% incidence and 8.7 severity. Plant stand mirrored the resistance pattern, with resistant genotypes above 87% compared to 54.2% for the local check.

Table 2: Effect of seed treatments on downy mildew incidence and grain yield of pearl millet

Treatment	Dose	Incidence (%)	Yield (q/ha)	B:C Ratio
Metalaxyl 35 SD	6 g/kg seed	22.7	19.2	2.84
Metalaxyl 25 WP	4 g/kg seed	31.4	16.8	2.37
Trichoderma viride	8 g/kg seed	45.6	14.3	1.92
Pseudomonas fluorescens	10 g/kg seed	52.1	13.1	1.74
Thiram 75 WP	3 g/kg seed	58.9	11.7	1.53
Untreated Control	-	78.3	8.4	1.00
SEm(±)	-	3.27	1.06	-
CD (P=0.05)	-	9.81	3.18	-

Metalaxyl 35 SD was the best treatment, reducing incidence to 22.7% and pushing yield to 19.2 q/ha (Table 2). T. viride reduced incidence by 41.7% compared to the control and achieved 14.3 q/ha.

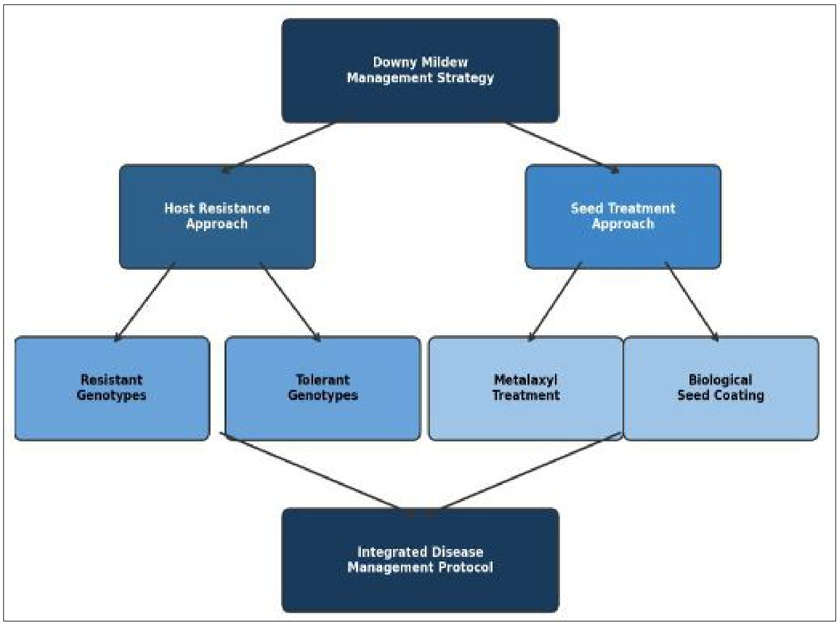

Fig 1: Integrated disease management strategy combining host resistance and seed treatment for downy mildew control in pearl millet

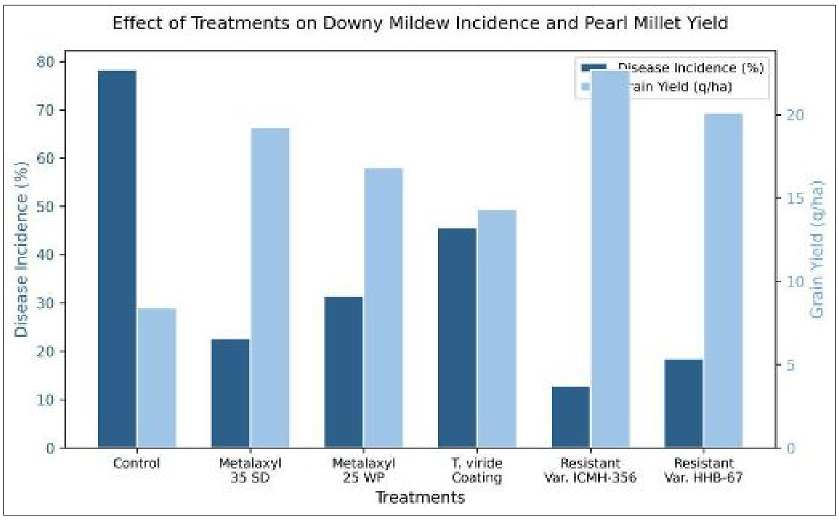

Fig 2: Effect of treatments on downy mildew incidence and grain yield (pooled data, 2022-2023)

Comprehensive Interpretation

The combination of ICMH-356 with metalaxyl 35 SD produced the lowest disease incidence of 4.6% and the highest grain yield of 24.1 q/ha. Even in moderately resistant RHB-177, metalaxyl lowered incidence from 27.3% to 9.8%. Seed treatment alone could not fully compensate for genetic susceptibility, as the local check with metalaxyl still showed 38.4% incidence.

Discussion

The superiority of ICMH-356 and HHB-67 Improved aligns with earlier screening trials [1, 5]. The resistance appears polygenic, as these genotypes maintained low infection levels even under supplemented inoculum [6]. Metalaxyl 35 SD performed best among chemical treatments, consistent with reports on its systemic activity against oomycetes [7]. But its benefit was greatest when paired with resistant genotypes, indicating that chemical protection alone may not suffice under heavy pressure. The biological agents showed moderate efficacy, matching observations of 35-48% disease reduction under field conditions [8]. Their advantage lies in long-term soil health contribution and reduced chemical load [9]. The decline in metalaxyl efficacy between years may point to early resistance buildup in the local pathogen population, underscoring the need for tactic rotation [15]. The benefit-cost analysis supports integrated management as the most practical recommendation.

Conclusion

This research confirms that pairing host resistance with seed treatment provides a reliable strategy for managing downy mildew. ICMH-356 and HHB-67 Improved maintained incidence below 20% without seed dressing. Metalaxyl 35 SD gave the highest protection, and the combination of resistant genotypes with metalaxyl recorded incidence as low as 4.6% and yields above 24 q/ha. Trichoderma viride remains viable for low-input systems. Farmers should adopt resistant varieties as the first defense line and supplement with seed treatment, rotating agents to delay fungicide resistance.

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