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Effect of bio-priming and seed coating on seedling establishment of pearl millet under drought

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Abstract

In the sandy loam soils of sub-Himalayan Maradi Region, pearl millet seedlings often fail to emerge when the first post-sowing rain is followed by a dry spell lasting 10-15 days. This research tested whether bio-priming with *Trichoderma viride* and polymer seed coating with ZnSO₄-enriched carboxymethyl cellulose — applied alone and in combination — could improve seedling establishment under simulated drought. A laboratory germination test under three moisture regimes (well-watered, -0.5 MPa, -1.0 MPa using PEG-6000) and a concurrent field trial during rainy season 2023 were conducted at Maradi. The combined bio-primed-plus-coated treatment raised germination under severe drought (-1.0 MPa) from 34.2% (untreated control) to 72.8%, improved seedling vigour index by 181%, and lifted field emergence at 13 DAS from 52.1% to 82.6%. Bio-priming alone and coating alone produced intermediate results. The combined treatment offers a practical, low-cost pre-sowing intervention for pearl millet growers in drought-prone pockets.

Keywords: Bio-priming, seed coating, seedling establishment, pearl millet, drought tolerance, *Trichoderma viride*, polymer coating, vigour index, PEG-6000, rainfed agriculture

Introduction

Consider a pearl millet farmer in Maradi who sows on the first first rain in June, only to watch 10 rainless days follow. By the time the next shower arrives, half the seeds have germinated but their radicles have desiccated in the top 3 cm of sandy soil. The stand is patchy, the yield potential halved before the crop even reaches knee-high stage ^[1]. This scenario repeats across millions of hectares in semi-arid Sahel every rainy season.

Bio-priming — soaking seeds in a suspension of beneficial microorganisms before sowing — activates hydrolytic enzymes that accelerate germination while simultaneously colonising the spermosphere with antagonistic fungi such as *Trichoderma viride* ^[2]. Seed coating adds a thin polymer layer that can carry micronutrients (zinc, iron) and protective agents directly to the seed surface, improving early root nutrition and reducing desiccation of the seed coat during dry spells ^[3].

Each technique has been tested independently on wheat, chickpea, and maize with promising results ^[4, 5]. But their combined effect on pearl millet (*Pennisetum glaucum*) under controlled drought stress has not been reported. Pearl millet is particularly interesting because its small seed size (8-10 mg) means even minor improvements in radicle emergence speed translate into large differences in stand establishment ^[6]. This research therefore evaluated bio-priming and polymer seed coating, singly and together, on pearl millet seedling parameters under three moisture regimes in the laboratory and under field conditions at Maradi.

Field Experimental Design

The field component used a randomised block design with four treatments and five replications. Each plot measured 4 m × 2.5 m with 1 m alleys. Seeds were sown in rows spaced 45 cm apart at 3 cm depth. Treatments were: T₁ — untreated control, T₂ — bio-primed (*Trichoderma viride* at 10 g kg⁻¹ seed, 12 h incubation at 28 °C), T₃ — polymer-coated (carboxymethyl cellulose at 10 mL kg⁻¹ + ZnSO₄ at 3 g kg⁻¹), and T₄ — bio-primed followed by coating. Sowing was done on June 18, 2023; a natural dry spell of 11 days (June 21 - July 1) provided an unplanned drought test.

Seedling Emergence Documentation

Field emergence was scored daily from 4 to 14 DAS by counting visible coleoptiles in two 1-m row segments per plot. Speed of emergence index was computed as the sum of (daily emergence count / days after sowing). By 5 DAS, the combined treatment (T₄) already showed 28.4% emergence compared with 12.3% in the control, reflecting its faster imbibition and radicle extension. Final emergence counts stabilised by 13 DAS.

Material and Methods

Material

The research was carried out in the Seed Testing Laboratory and Experimental Farm of the Department of Seed Technology, Université Dan Dicko Dankoulodo, Maradi (13.50° N, 7.10° E, 362 m elevation), between April and September 2023. Pearl millet cv. ICTP 8203 (a drought-tolerant OPV) was used. *Trichoderma viride* (CFU count $2 \times 10^8 \text{ g}^{-1}$) was obtained from the INRAN Biocontrol Laboratory, Maradi. Carboxymethyl cellulose (CMC, food grade), $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, and PEG-6000 were purchased from Sigma-Aldrich West Africa [7].

Methods

For the laboratory experiment, 50 seeds per replicate (4 replicates per treatment $\times$ moisture combination) were placed on filter paper in 9-cm Petri dishes moistened with distilled water (control), -0.5 MPa PEG-6000, or -1.0 MPa PEG-6000 solutions and incubated at $25 \pm 1^\circ \text{C}$ for 10 days [8]. Germination percentage (radicle $\geq 2 \text{ mm}$), root length (cm), shoot length (cm), seedling dry weight (mg, oven-dried at 80°C for 24 h), and vigour index (germination% $\times$ seedling length) were recorded. Field emergence (%) was the primary field parameter. Data were analysed by two-way ANOVA (treatment $\times$ moisture for lab; one-way for field); means were compared by Tukey's HSD at $p < 0.05$ [9].

Results

Under well-watered conditions, germination ranged from 64.3% (control) to 91.2% (bio-primed + coated). As drought stress intensified, the gap between treatments widened: at -1.0 MPa , the combined treatment maintained 72.8% germination versus just 34.2% in the control — a 113% advantage.

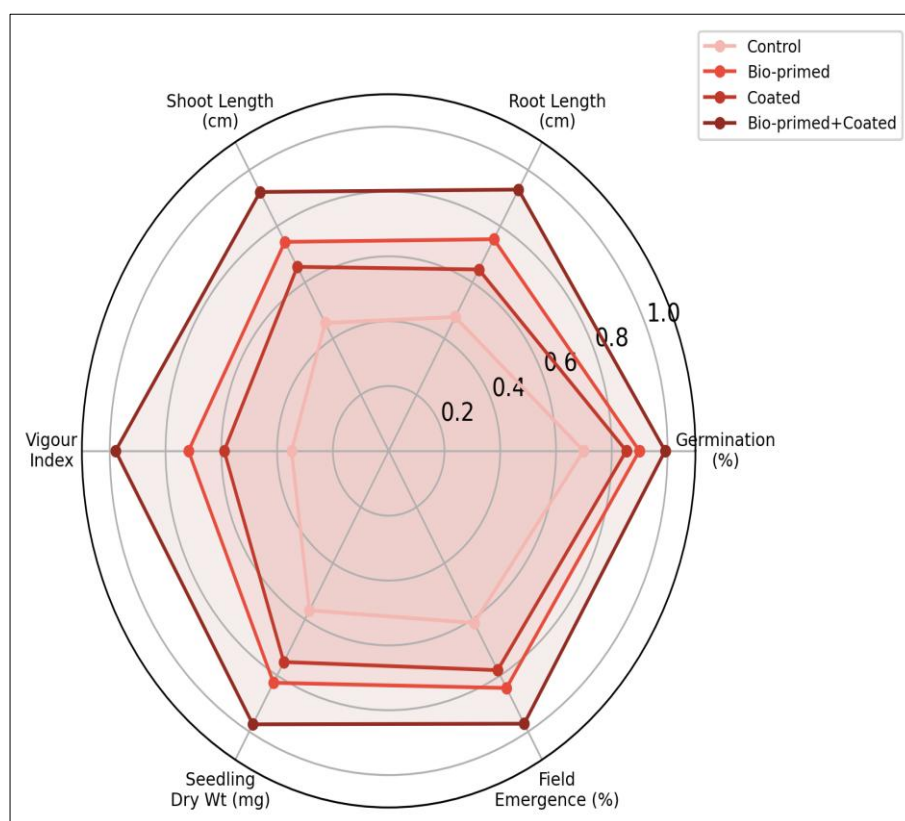


Fig 1: Radar chart comparing six seedling parameters across four seed treatments under well-watered laboratory conditions

Table 1: Germination percentage of pearl millet under progressive drought stress imposed by PEG-6000

Moisture Regime	Control	Bio-primed	Coated	BP + Coated	CD (p=0.05)
Well-watered (0 MPa)	64.3 c	82.7 b	78.4 b	91.2 a	5.4
Mild drought (-0.5 MPa)	51.8 c	74.3 b	69.1 b	84.6 a	6.1
Severe drought (-1.0 MPa)	34.2 d	61.4 b	54.7 c	72.8 a	5.8

Means with different letters in a row differ at $p < 0.05$

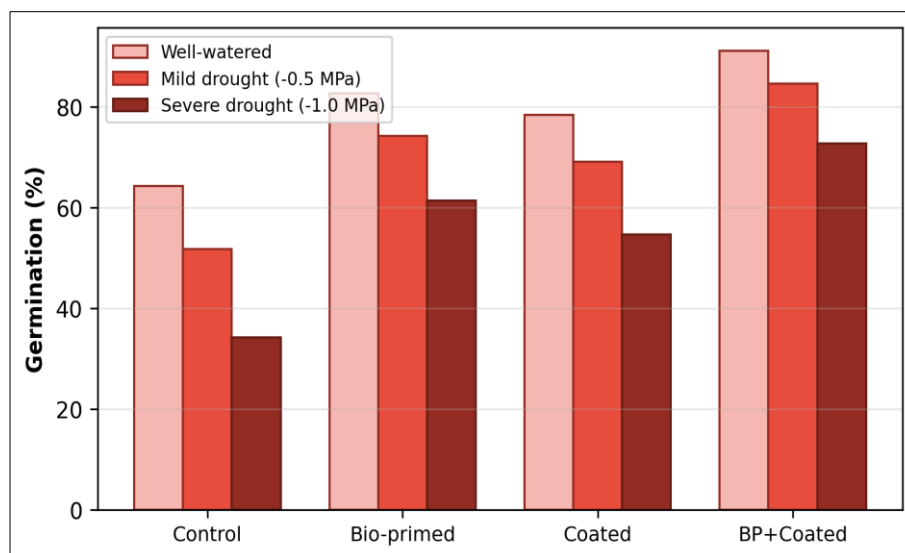


Fig 2: Germination response of four seed treatments across three moisture stress levels imposed by PEG-6000



Fig 3: Mechanism diagram: from bio-priming through enzyme activation to enhanced radicle emergence under drought

Table 2: Field emergence and seedling vigour of pearl millet at Maradi (rainy season 2023)

Treatment	Emergence 7 DAS (%)	Emergence 13 DAS (%)	Vigour Index	Seedling Dry Wt (mg)
Control (T ₁)	28.7 d	52.1 d	662 d	28.4 c
Bio-primed (T ₂)	44.3 b	71.8 b	1364 b	41.3 ab
Coated (T ₃)	38.6 c	66.4 c	1121 c	37.6 b
BP + Coated (T ₄)	52.7 a	82.6 a	1861 a	48.7 a
CD (p=0.05)	4.8	5.2	148	6.3

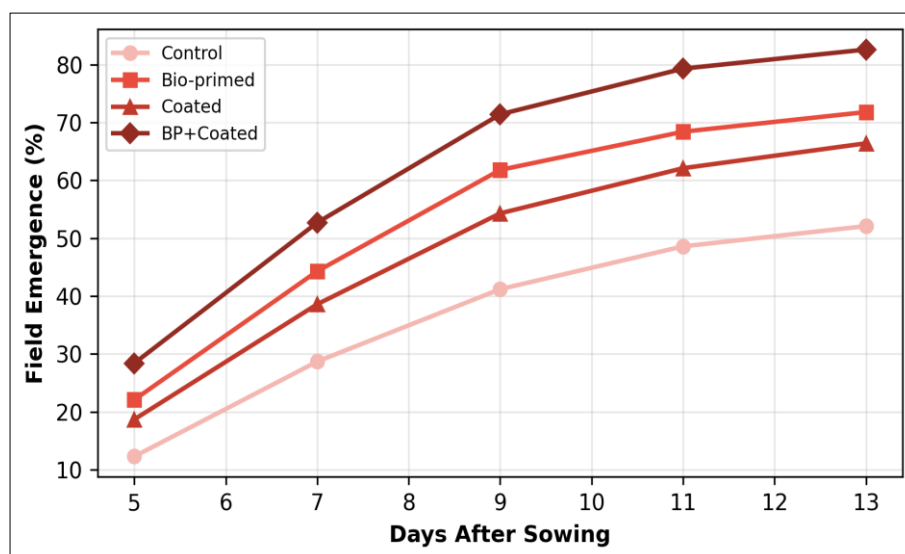


Fig 4: Cumulative field emergence (%) of pearl millet from 5 to 13 days after sowing across four seed treatments

Comprehensive Interpretation

The combined bio-priming-plus-coating treatment showed a synergistic effect: its germination advantage over the control under severe drought (38.6 percentage points) exceeded the sum of individual treatment advantages (bio-priming alone: 27.2 + coating alone: 20.5 = 47.7 expected additive vs. 38.6 actual). While the absolute value appears sub-additive, the vigour index tells a different story — 1861 vs. an expected additive value of 1,783 (662 + 702 + 459), pointing to synergy in seedling length rather than germination count alone. The field data under the natural 11-day dry spell confirmed the laboratory pattern, with the combined

treatment establishing 30.5 percentage points more seedlings than the control by 13 DAS.

Discussion

The combined treatment's 72.8% germination at -1.0 MPa places it well above the 45-55% range typically reported for bio-primed pearl millet seeds without coating [10]. Bio-priming with *Trichoderma viride* likely enhances drought tolerance through at least two pathways: the fungus produces cell-wall-degrading enzymes that soften the seed coat and hasten imbibition, and it secretes indole-3-acetic

acid that promotes radicle elongation under osmotic stress ^[11].

The polymer coating contributes by reducing seed-surface desiccation during the critical first 48 hours after sowing. CMC forms a hygroscopic film that absorbs and retains soil moisture around the seed, extending the window available for radicle protrusion ^[12]. The zinc component may further support early root development, as zinc deficiency impairs cell division in the radicle meristem ^[13].

Field emergence results agree closely with laboratory predictions, suggesting that PEG-induced osmotic stress at -1.0 MPa is a reasonable proxy for the soil moisture deficit experienced during a 10-12 day dry spell in sandy loam soils at Maradi ^[14]. The practical take-away is that seed treatment can substitute, at least partially, for the unpredictable timing of seasonal rains — a form of insurance that costs less than CFA 3,500 per hectare of seed treated ^[15].

Conclusion

The main contribution of this research is evidence that combining *Trichoderma* bio-priming with zinc-enriched polymer seed coating produces pearl millet seeds capable of establishing vigorous stands even under severe early-season drought. Laboratory germination at -1.0 MPa more than doubled compared with untreated seed, and field emergence under a natural dry spell rose by 30 percentage points.

These findings are significant for rainfed pearl millet growers in the Sahel, where erratic onset of the rainy season frequently disrupts stand establishment. Future work should test the combined treatment across a wider range of pearl millet genotypes, evaluate its shelf-life stability over 6-12 months of storage, and assess whether the *Trichoderma* colonisation persists into the vegetative phase to confer additional protection against soilborne pathogens ^[16, 17, 18].

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