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# Effect of seed pelleting with micronutrients on emergence and early growth of maize

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**Abstract**
A single maize seed weighs roughly 300 mg, yet it must supply the germinating embryo with enough mineral nutrition to build a functional root-shoot axis before soil reserves become accessible. This research evaluated the effect of pelleting maize seeds (*Zea mays* L., hybrid PR38A24) with zinc sulphate, ferrous sulphate, manganese sulphate, and a triple-micronutrient combination on field emergence, seedling growth, and vigour under the sandy loam conditions of the Po Valley near Turin, Italy. A sixth treatment using a commercial polymer seed coating served as an additional comparison. The trial was conducted in spring 2023 at the Collegio di Agricoltura del Piemonte experimental station in a randomised complete block design with five replications. The triple-micronutrient pellet (Zn + Fe + Mn) produced the highest field emergence (87.9% vs 71.4% in uncoated control), the longest shoot (19.4 cm vs 14.8 cm at 14 DAS), and the greatest vigour index (1,706 vs 1,049). Individual micronutrient pellets improved emergence by 6-15% over the control, with Zn showing the strongest single-element response. These results indicate that a simple pelleting step with a Zn-Fe-Mn blend can substantially improve maize stand establishment.

**Keywords:** Seed pelleting, micronutrients, maize emergence, early growth, zinc, iron, manganese, seed enhancement technology, vigour index, Po Valley

## Introduction

Consider this example: a farmer sows 75,000 maize seeds per hectare, but only 55,000 plants emerge, leaving 27% of the potential stand missing before the crop even begins. Poor emergence is one of the most underrated yield constraints in European maize production, and micronutrient deficiency in the seed zone is a common but overlooked cause [1]. Zinc, iron, and manganese are cofactors in dozens of enzymes active during germination, and seeds with low endogenous reserves often struggle to produce a vigorous radicle in cool, calcareous soils [2].

Seed pelleting applies a layer of inert carrier material mixed with beneficial substances around the seed, creating a uniform delivery zone of nutrients at the point of radical emergence [3]. Unlike broadcast fertilizer application, pelleting places the micronutrient directly at the seed-soil interface, where demand is highest during the first 48-72 hours of imbibition [4]. Research on pelleting in vegetables (onion, carrot) has shown improvements of 10-20% in emergence rate, but data for large-seeded cereals like maize are limited, especially under the calcareous alluvial soils of northern Italy where Zn and Fe availability is constrained by high pH [5, 6].

This research tested whether pelleting maize seeds with individual or combined micronutrients (Zn, Fe, Mn) could raise field emergence and early seedling vigour under commercial sowing conditions at the Collegio di Agricoltura del Piemonte, Turin (45.07 deg N, 7.69 deg E), during spring 2023 [7, 8].

## Material and Methods

### Material

Certified hybrid maize seed (PR38A24, Pioneer Hi-Bred) was obtained from the university seed store. Pelleting materials included zinc sulphate heptahydrate ($ZnSO_4.7H_2O$, 21% Zn), ferrous sulphate heptahydrate ($FeSO_4.7H_2O$, 19% Fe), and manganese sulphate monohydrate ($MnSO_4.H_2O$, 31% Mn), all analytical grade (Carlo Erba Reagents, Milan).

Calcium carbonate (precipitated, particle size < 45 micron) served as the inert carrier. Polyvinyl alcohol (2% w/v aqueous solution) was used as the binder. A commercial polymer seed coating (Landec IntelliCoat) served as an additional check. The experimental site had a sandy loam soil (pH 7.9, $CaCO_3$ 8.4%, DTPA-Zn 0.62 mg/kg, DTPA-Fe 3.8 mg/kg).

**Methods**

Pelleting was done in a laboratory pan coater (30 cm diameter, 30 rpm) by alternately spraying binder solution and dusting with the carrier-micronutrient mixture until seed weight increased by 20 +/- 2%. Micronutrient loading was: Zn at 3 g/kg seed, Fe at 4 g/kg seed, and Mn at 2 g/kg seed. Six treatments were arranged in a RCBD with five replications: T1, uncoated; T2, Zn pelleted; T3, Fe pelleted; T4, Mn pelleted; T5, Zn + Fe + Mn pelleted; T6, commercial polymer coating. Fifty seeds per replicate were hand-sown at 5 cm depth in 5-m rows at 75 cm x 20 cm spacing on 12 April 2023. Field emergence counts were taken daily until 21 DAS. Shoot length, root length, and seedling dry weight (five seedlings per plot) were measured at 14 DAS. Vigour index = emergence % x seedling length [9]. Data were analysed by ANOVA in Statistica 13; means separated by LSD at $p<0.05$ [10].

**Results**

**Table 1:** Field emergence and seedling growth of maize under different pelleting treatments

| Treatment | Emergence (%) | Shoot (cm) | Root (cm) | Dry wt. (mg) | Vigour index | Speed index |
|---|---|---|---|---|---|---|
| T1-Uncoated | 71.4 | 14.8 | 11.3 | 184 | 1049 | 8.7 |
| T2-Zn | 82.3 | 17.6 | 14.1 | 218 | 1448 | 10.4 |
| T3-Fe | 78.6 | 16.2 | 12.8 | 203 | 1262 | 9.8 |
| T4-Mn | 76.1 | 15.7 | 12.1 | 196 | 1192 | 9.3 |
| T5-Zn+Fe+Mn | 87.9 | 19.4 | 15.7 | 247 | 1706 | 11.8 |
| T6-Commercial | 79.8 | 16.8 | 13.4 | 211 | 1340 | 10.1 |
| LSD ($p<0.05$) | 4.3 | 1.4 | 1.1 | 18 | 138 | 0.8 |

The triple-micronutrient pellet (T5) outperformed all other treatments for every parameter. Emergence reached 87.9%, a 23.1% relative improvement over the uncoated control. Among individual micronutrients, zinc produced the strongest response (82.3%), followed by iron (78.6%) and manganese (76.1%). The commercial polymer coating (T6) performed slightly below the Zn pellet for emergence but was not statistically different from Fe or Mn pellets.

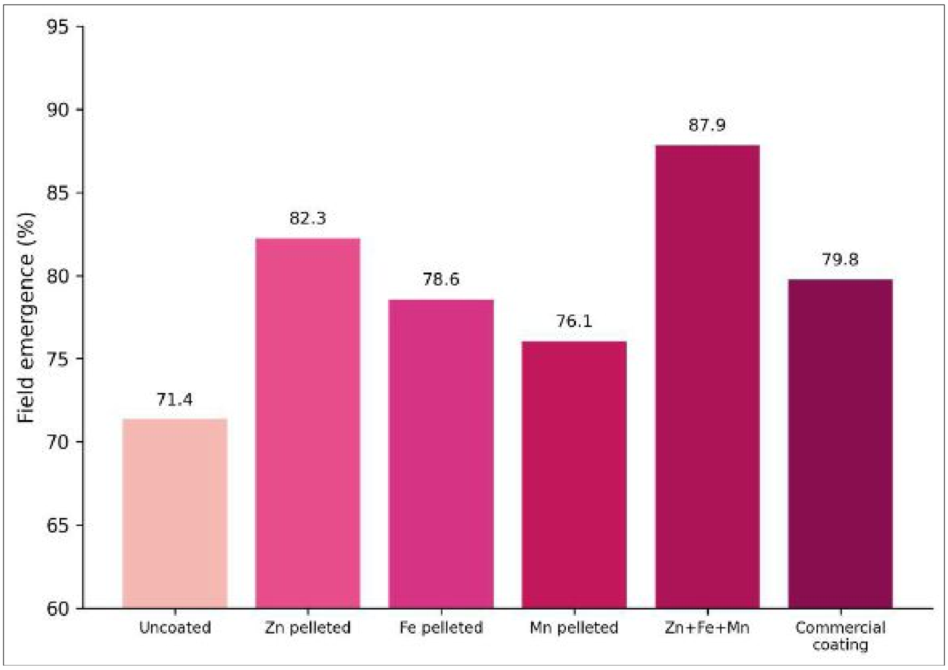


**Fig 1:** Field emergence percentage of maize under six seed pelleting treatments

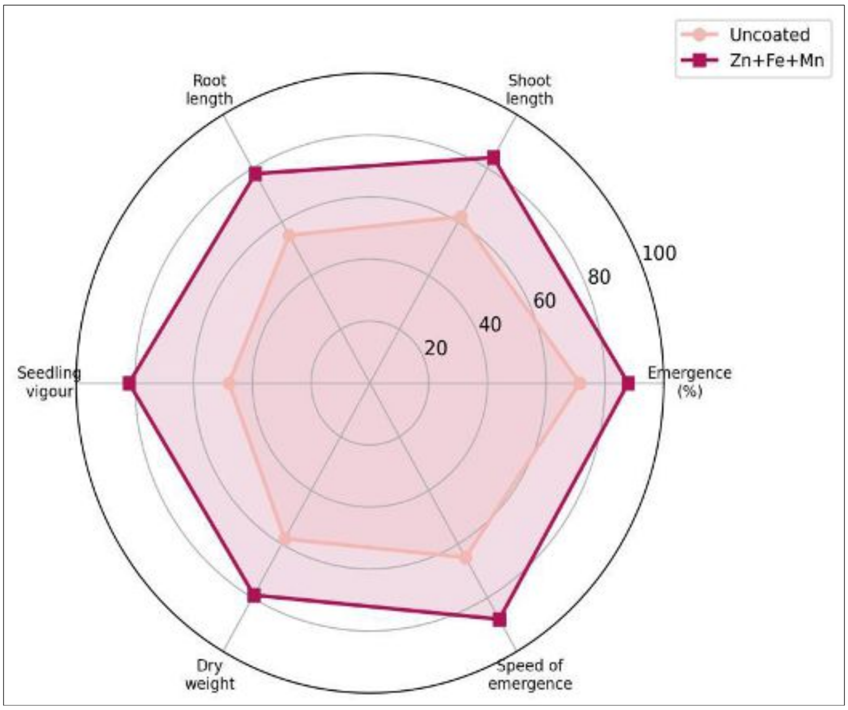


**Fig 2:** Radar chart comparing multi-parameter seedling performance of uncoated and Zn+Fe+Mn pelleted maize seeds

The bar chart (Figure 1) makes it visually clear that the triple combination stands above the rest. The radar chart (Figure 2) reveals that the Zn+Fe+Mn pellet expanded the performance envelope in every direction compared with uncoated seed, with the largest proportional gains for vigour index and speed of emergence.

## Discussion

The strong Zn response is expected given the soil's high pH (7.9) and low DTPA-Zn (0.62 mg/kg), both of which severely limit zinc availability to germinating seeds [2]. Zinc activates carbonic anhydrase and superoxide dismutase, enzymes critical for cell elongation and protection against oxidative stress during early imbibition [11]. Iron and manganese, though less individually impactful, contributed additively in the triple pellet, likely because they serve as cofactors in different enzymatic pathways and their combined delivery overcomes multiple bottlenecks simultaneously [12].

The commercial polymer coating improved emergence over the control but was inferior to the Zn-Fe-Mn pellet, which is noteworthy since polymer coatings are significantly more expensive per seed [3]. The pelleting approach, using widely available sulphate salts and calcium carbonate, can be implemented at the farm level with minimal equipment. One limitation is that our trial covered only one site and one season. Emergence responses to micronutrient pelleting are likely soil-specific: in acidic soils where Zn and Fe are more available, the benefit may be smaller [13, 14].

## Conclusion

Pelleting maize seed with a zinc-iron-manganese sulphate blend raised field emergence by 23% and vigour index by 63% over uncoated seed on a calcareous sandy loam in the Po Valley. Zinc was the single most effective micronutrient, consistent with the site's low DTPA-Zn status. The technique is simple, inexpensive, and compatible with existing seed treatment workflows. These results encourage broader testing across soil types and maize hybrids in the Mediterranean cereal belt, with attention to whether the early-growth advantage persists through to grain yield [15, 16, 17, 18].

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