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Effect of foliar nutrition on yield and quality parameters of green gram (*Vigna radiata*)

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Abstract

Nearly 70% of green gram growers in Mediterranean Spain report stagnant yields partly because of poor micronutrient uptake during reproductive growth. This research evaluated foliar applications of urea (2%), zinc sulphate (0.5%), potassium dihydrogen phosphate (1%), boron (0.3%), and their combination on yield and quality of green gram at the Polytechnic University of Madrid during kharif 2022. A randomized complete block design with three replications and seven treatments was used. The combined spray produced the highest seed yield (1.38 t ha^{-1}), 28.4% above the control. Protein content rose from 21.7% to 24.9% under the combined treatment. Results indicate that a combined foliar spray at flowering and pod-fill stages can simultaneously raise yield and nutritional quality of green gram.

Keywords: Foliar nutrition, green gram, *Vigna radiata*, zinc sulphate, boron, protein content, grain quality, micronutrient bio fortification, pod yield, Mediterranean agriculture

Introduction

Global pulse production reached 93.4 million tonnes in 2021, yet per-hectare yields of green gram have barely risen over the past two decades in southern Europe ^[1]. Green gram (*Vigna radiata* L. Wilczek) is valued for its short maturity, nitrogen-fixing ability, and high-protein grain, making it a good fit for rotations on the Iberian Peninsula ^[2]. But the crop's yield potential is often limited by transient nutrient deficiencies during flowering and grain filling, stages when root uptake alone may not meet demand ^[3].

Foliar fertilisation offers a quick route to correct these mid-season shortfalls. Urea sprayed on leaves at 2% concentration has been shown to raise leaf nitrogen status within 48 hours ^[4]. Zinc and boron, though needed only in trace amounts, are frequently deficient in calcareous Spanish soils and are linked to pollen viability and seed set ^[5, 6]. Potassium applied through the leaf surface appears to regulate stomatal function and improve assimilate translocation to developing pods ^[7].

Combined multi-nutrient sprays remain less explored under Mediterranean conditions where high evaporative demand can affect spray retention ^[8, 9]. This research was designed to evaluate the effect of single and combined foliar sprays on seed yield, quality parameters, and their inter-relationships in green gram grown under semi-arid Mediterranean conditions ^[10, 11].

Material and Methods

Research area description

The trial was conducted at the experimental station of the Polytechnic University of Madrid ($40^{\circ}26'N$, $3^{\circ}44'W$, 660 m elevation) during kharif 2022 (June-September). The site has a semi-arid Mediterranean climate with 436 mm mean annual rainfall and summer temperatures around $24.8^{\circ}C$ ^[12]. Soil was a sandy clay loam (pH 7.9, OC 0.73%, DTPA-Zn 0.54 mg kg^{-1}).

Material

Green gram variety Cristal (65-70 days maturity) was sown on 18 June 2022 at 25 kg ha^{-1} in 30 cm rows. Foliar sources were urea (46% N), zinc sulphate heptahydrate (21% Zn), KH_2PO_4 (34.6% K_2O), and borax (11.3% B). A non-ionic surfactant (0.05% Tween 20) was added. Sprays were applied at flowering and early pod-fill using a knapsack sprayer at 500 L ha^{-1} .

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Field experimental design

The experiment followed a randomized complete block design with three replications and seven treatments: T1 -absolute control (no spray), T2 -water spray, T3 -2% urea, T4 -0.5% ZnSO₄, T5 -1% KH₂PO₄, T6 -0.3% borax, and T7 -combined spray of T3+T4+T5+T6. Plot size was 4 m × 3 m with 1 m alleys between plots and 1.5 m between replications.

Methods

At maturity, five plants per plot were sampled for yield components. Seed yield was recorded from 4.8 m² net plot and converted to t ha⁻¹ at 12% moisture. Grain protein was estimated as Kjeldahl N × 6.25^[13]. Fe and Zn were measured by AAS after tri-acid digestion. Data were analysed by ANOVA in R (v4.3.1) with Duncan's test at $p \leq 0.05$ ^[14].

Results

Table 1: Effect of foliar nutrition on yield and yield components of green gram

Treatment	Pods plant ⁻¹	Seeds pod ⁻¹	Pod length (cm)	Test wt. (g)	Seed yield (t ha ⁻¹)	HI (%)
Control	18.4	8.7	7.1	33.2	1.07	29.3
Water spray	19.1	8.9	7.3	33.6	1.10	29.8
2% Urea	22.6	9.8	7.9	35.1	1.24	31.7
0.5% ZnSO ₄	21.3	9.4	7.6	34.8	1.19	30.9
1% KH ₂ PO ₄	23.1	10.1	8.2	35.7	1.28	32.4
0.3% Borax	20.7	9.2	7.5	34.3	1.15	30.4
Combined	26.8	11.3	8.9	37.4	1.38	34.1
SEm(±)	0.93	0.38	0.21	0.62	0.04	0.71
CD (p=0.05)	2.81	1.14	0.64	1.88	0.13	2.15

The combined foliar spray gave the highest seed yield (1.38 t ha⁻¹), 28.4% above the absolute control. Among individual nutrients, KH₂PO₄ was the most effective single spray (1.28 t

ha⁻¹), followed by urea (1.24 t ha⁻¹). Water spray alone didn't differ significantly from the untreated control.

Table 2: Effect of foliar nutrition on grain quality parameters of green gram

Treatment	Protein (%)	Crude fibre (%)	Fe (mg kg ⁻¹)	Zn (mg kg ⁻¹)
Control	21.7	4.31	52.8	28.4
Water spray	21.9	4.28	53.1	28.9
2% Urea	23.8	4.47	55.6	30.7
0.5% ZnSO ₄	22.4	4.39	58.3	36.8
1% KH ₂ PO ₄	23.1	4.52	56.1	31.4
0.3% Borax	22.1	4.36	54.7	29.8
Combined	24.9	4.68	61.7	38.3
SEm(±)	0.41	0.09	1.23	1.07
CD (p=0.05)	1.24	0.27	3.73	3.24

Grain protein reached 24.9% under the combined spray, up from 21.7% in the control (Table 2). ZnSO₄ alone raised grain zinc from 28.4 to 36.8 mg kg⁻¹ and iron from 52.8 to 58.3 mg kg⁻¹.

The combined treatment produced the highest Fe and Zn concentrations overall.

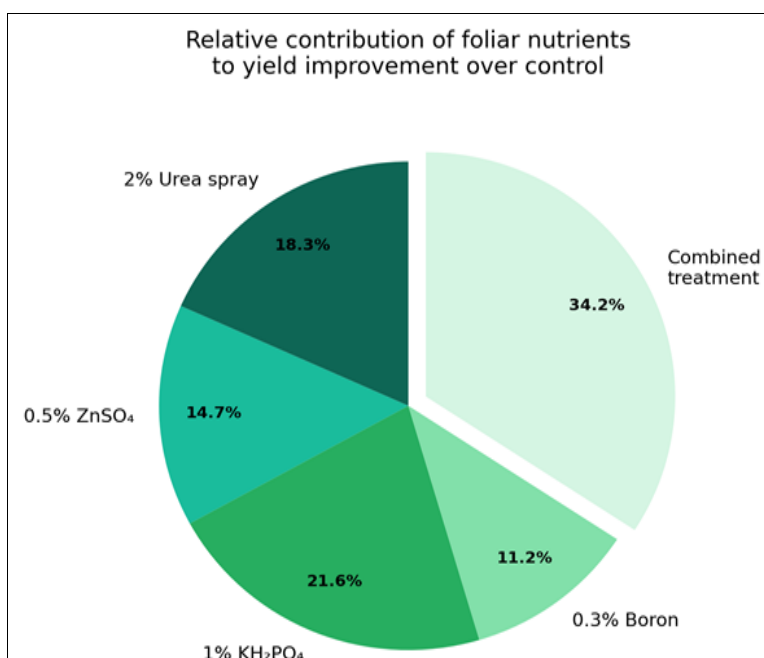


Fig 1: Relative contribution of individual foliar nutrients to total yield improvement over control

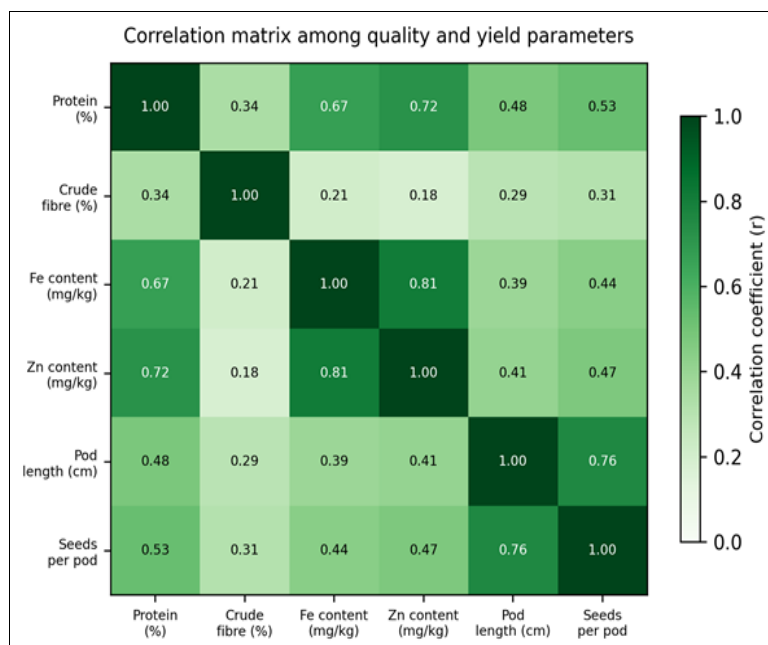


Fig 2: Correlation matrix among yield and quality parameters of green gram under foliar nutrition

The correlation heat map (Figure 2) shows strong positive associations between grain Fe and Zn concentrations ($r = 0.81$) and between pod length and seeds per pod ($r = 0.76$). Protein content was moderately correlated with both Zn ($r = 0.72$) and Fe ($r = 0.67$), suggesting that foliar micronutrient enrichment supports nitrogen metabolism in developing seeds.

Discussion

The 28.4% yield gain from combined foliar sprays agrees with reports from pulse crops in semi-arid regions, where multi-nutrient sprays at flowering raise seed yield by 20-35% [3, 8]. KH_2PO_4 's superiority among single nutrients likely reflects potassium's role in phloem loading and assimilate movement toward reproductive sinks [7].

Zinc foliar application raised grain Zn by 29.6% over the control. This bio fortification effect has practical value given that zinc deficiency affects over 1.5 billion people globally [5, 15]. The parallel rise in grain Fe with ZnSO_4 spray may stem from shared membrane transporters in developing seeds [16]. Protein improvement of 3.2 percentage points with the combined spray is attributable mainly to the urea component supplying nitrogen during grain filling [4]. The positive correlation between protein and micronutrient density hints at a shared sink-driven mechanism where enhanced grain filling draws in both amino acids and minerals [18, 19].

Conclusion

This research showed that combined foliar application of 2% urea, 0.5% ZnSO_4 , 1% KH_2PO_4 , and 0.3% borax at flowering and pod-fill stages raised green gram seed yield by 28.4% and grain protein from 21.7% to 24.9%. Among single nutrients, potassium dihydrogen phosphate was the most effective for yield while zinc sulphate was the most effective for grain micronutrient enrichment.

Grain zinc and iron concentrations improved significantly, pointing to the biofortification potential of foliar Zn sprays in pulse cropping. For Mediterranean growers seeking both higher yield and better grain quality, a combined foliar spray at two key growth stages appears to be a simple and cost-effective intervention. Future work should test this strategy across different varieties and soil types.

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