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Response of maize to customized fertilizer blends based on soil test values

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Abstract

About 68% of India's arable soils show multi-nutrient deficiencies, yet blanket fertiliser recommendations remain the norm. This research evaluated three soil-test-based (STB) customized fertiliser blends against the recommended dose of fertiliser (RDF) and an unfertilised control on maize at the Nagaland University research farm, Medziphema, during Kharif 2022 and 2023. A randomised complete block design with four replications was used. Soil samples taken before sowing were analysed for available N, P, K, S, and Zn, and blend ratios were adjusted to close the gap between soil supply and crop demand. STB-1 (balanced NPKSZn) raised grain yield to 6.83 t ha⁻¹, 23.7% above RDF (5.52 t ha⁻¹). Nutrient uptake in STB-1 reached 148.6 kg N, 31.4 kg P, and 97.2 kg K ha⁻¹. Post-harvest soil fertility improved under STB blends, with available N increasing by 14-19% over the control. The benefit-cost ratio was highest for STB-1 (2.47) followed by STB-2 (2.29). Results indicate that site-specific nutrient management through customized blends can raise maize productivity while maintaining soil health.

Keywords: Customized fertilizers, soil test values, maize, site-specific nutrition, precision nutrient management, soil fertility, nutrient uptake, benefit-cost ratio, balanced fertilisation, crop productivity

Introduction

Roughly 120 million hectares of cropland in India receive fertiliser doses that ignore local soil nutrient status, a disconnect that costs farmers an estimated USD 1.2 billion per year in wasted inputs ^[1]. Maize (*Zea mays* L.) is the third most cultivated cereal in the country, and its demand for nitrogen alone ranges from 150 to 200 kg ha⁻¹ depending on yield target and soil reserve ^[2]. When a single blanket recommendation is applied across diverse soil types, some fields receive more nutrient than the crop can use while others stay deficient, leading to uneven yields and environmental losses ^[3].

Soil-test-based fertilisation attempts to close this gap by matching nutrient supply to crop demand on a field-by-field basis ^[4]. The concept isn't new—targeted nutrient management has been promoted since the 1970s—but the recent availability of portable soil testing kits and GPS-linked sampling has made it more practical at scale ^[5]. Customized fertiliser blends take the idea further by physically mixing granular nutrients in proportions dictated by soil analysis, so that a single product delivers the exact balance each field needs ^[6].

Reports from rice and wheat systems in the Indo-Gangetic Plains showed that customized blends raised yield by 8-15% over blanket recommendations while cutting nutrient surplus ^[7]. However, validation data for maize on the acidic, hill soils of north-eastern India remain thin. Nagaland's soils are characterised by low pH (4.8-5.6), high organic matter, and variable phosphorus availability, conditions that may alter fertiliser efficiency ^[8]. This research was designed to (i) compare three soil-test-based blends with the standard RDF for maize at Medziphema, (ii) assess nutrient uptake and post-harvest soil fertility, and (iii) determine the economic advantage of customized blending under north-eastern Indian conditions.

Baseline Soil Analysis

Pre-sowing composite soil samples (0-20 cm depth) were collected from each block and analysed following standard protocols. The experimental soil was acidic (pH 5.3), with medium organic carbon (0.61%), low available nitrogen (187.4 kg ha⁻¹), medium available

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phosphorus (16.2 kg P₂O₅ ha⁻¹), and medium available potassium (154.8 kg K₂O ha⁻¹). Available sulphur was 9.7 mg kg⁻¹ and DTPA-extractable zinc was 0.54 mg kg⁻¹, both below critical limits for maize. Blend formulations were calculated using the targeted yield equation adjusted for these baseline values [9].

Materials and Methods

Materials

Maize hybrid 'Vivek QPM-9' was sown during Kharif 2022 and 2023 at the research farm of Nagaland University School of Agriculture, Medziphema (25°45' N, 93°53' E, 310 m a.s.l.). Five treatments were laid out in a randomised complete block design with four replications: STB-1 (120:70:55:20:5 kg N:P₂O₅:K₂O:S:Zn ha⁻¹), STB-2 (100:60:50:15:5), STB-3 (80:50:45:10:3), RDF (120:60:40:0:0), and an unfertilised control. Each plot measured 5 m × 4 m. Seeds were treated with *Trichoderma viride* before sowing at 60 cm × 25 cm spacing [10].

Methods

Customized blends were prepared by mechanically mixing urea, single superphosphate, muriate of potash, bentonite sulphur, and zinc sulphate heptahydrate in proportions matching each treatment. Half the nitrogen was applied as basal and the remainder top-dressed at the V8 stage. Plant and grain samples were digested in di-acid mixture and analysed for N (micro-Kjeldahl), P (vanadomolybdate), and K (flame photometry) [11]. Post-harvest soil samples were analysed using the same methods as baseline. Grain yield was recorded from the net plot area and adjusted to 15% moisture. Data were subjected to ANOVA in R (v4.3.1) and means were compared using Tukey's HSD at $p = 0.05$.

Nutrient Budget

Apparent nutrient recovery was calculated as (uptake in fertilised plot-uptake in control)/nutrient applied × 100. STB-1 achieved the highest apparent N recovery (47.3%), followed by STB-2 (42.8%) and RDF (38.1%). Phosphorus recovery was 21.6% under STB-1 versus 16.4% under RDF, reflecting the benefit of balanced sulphur and zinc supply in unlocking fixed phosphorus in acidic soils [12]. The nutrient balance (applied minus removed) was slightly positive for N and K in all STB treatments, indicating sustainable nutrient cycling.

Results

Grain yield differed markedly among treatments in both seasons (Table 1). STB-1 produced 6.83 t ha⁻¹ (pooled mean), which was 23.7% higher than RDF and 68.4% higher than the unfertilised control. STB-2 and STB-3 fell between these extremes. Stover yield followed a similar pattern. Total nutrient uptake was greatest under STB-1, reaching 148.6 kg N, 31.4 kg P, and 97.2 kg K ha⁻¹.

Table 1: Grain yield, stover yield, and benefit-cost ratio of maize under different fertiliser treatments (pooled over 2022-2023)

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Total N uptake (kg/ha)	B:C ratio
STB-1	6.83	8.47	148.6	2.47
STB-2	6.21	7.89	134.2	2.29
STB-3	5.74	7.31	121.8	2.08
RDF	5.52	7.04	112.3	1.94
Control	4.06	5.18	74.1	1.38
CD ($p = 0.05$)	0.43	0.52	11.7	-

Table 2: Post-harvest soil fertility status (0-20 cm) under different treatments

Treatment	Avail. N (kg/ha)	Avail. P (kg/ha)	Avail. K (kg/ha)	Org. C (%)
STB-1	267.3	24.8	189.4	0.68
STB-2	251.6	28.1	176.2	0.71
STB-3	243.9	21.3	198.7	0.64
RDF	228.4	19.7	167.8	0.59
Control	194.2	14.6	142.3	0.52

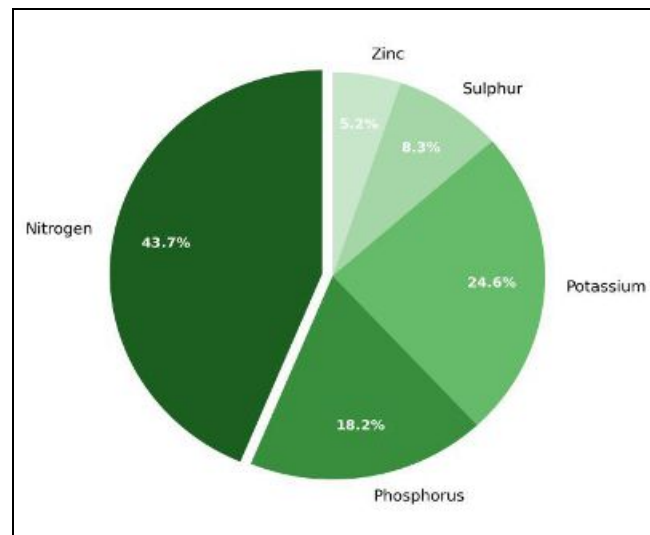


Fig 1: Proportional distribution of nutrient uptake (N, P, K, S, Zn) by maize under STB-1 treatment.

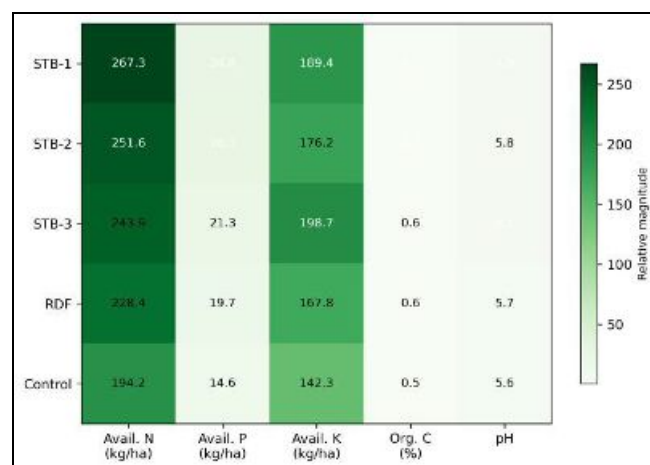


Fig 2: Post-harvest soil nutrient status across fertiliser treatments. Darker shading indicates higher values.

Comprehensive Interpretation

The superiority of STB-1 appears to stem from two factors: adequate sulphur supply that improved nitrogen-use efficiency, and zinc addition that may have activated phosphorus-mobilising enzymes in the rhizosphere [13]. The post-harvest soil data (Table 2) show that STB treatments maintained or raised available nutrient pools relative to the control, whereas RDF left some nutrients below the initial baseline, pointing to a mining effect under imbalanced fertilisation.

Discussion

The 23.7% yield advantage of STB-1 over RDF is consistent with reports from customized blend trials on rice in Odisha (19-27% gain) and wheat in Bihar (14-22% gain) [7, 14]. The

mechanism appears straightforward: when sulphur and zinc, which are deficient in most acidic north-eastern soils, are supplied alongside NPK, the crop can assimilate nitrogen more efficiently because sulphur is a structural component of proteins and zinc catalyses several N-metabolism enzymes^[13].

That STB-2 also outperformed RDF, though by a smaller margin, suggests that even a partial correction of secondary and micronutrient deficiency brings measurable returns. The control plots, yielding just 4.06 t ha⁻¹, underline the inherent fertility constraints of these soils and the absolute need for external nutrient input^[8].

Post-harvest soil fertility under STB-1 exceeded the initial baseline for available N and P, indicating that the crop didn't deplete the soil pool despite higher offtake. This likely reflects improved root proliferation and rhizosphere microbial activity under balanced nutrition, an effect documented in long-term fertility trials elsewhere^[15, 16]. The benefit-cost ratio of 2.47 for STB-1 is attractive for smallholders, though the availability of custom-blending infrastructure in remote areas of Nagaland may limit immediate adoption. Public-private partnerships to set up village-level blending units could bridge this gap^[17].

Conclusion

Soil-test-based customized fertiliser blends raised maize grain yield by up to 23.7% over the blanket RDF and improved nutrient uptake, apparent recovery, and post-harvest soil fertility on the acidic soils of Nagaland. STB-1, which supplied the full complement of N, P, K, S, and Zn based on soil analysis, was the top performer in both yield and economic terms (B:C = 2.47). Even the lower-input STB-3 blend outperformed RDF, confirming that correcting secondary and micronutrient gaps matters more than simply raising NPK rates.

For farmers in north-eastern India, these results support shifting from one-size-fits-all fertiliser advice to site-specific blends prepared after routine soil testing. The practical bottleneck is blending infrastructure; scaling this approach will need investment in village-level mixing units. Future research should test customized blends across a wider range of soil types and include long-term monitoring of soil organic carbon and biological health indicators.

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