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Performance of maize-legume intercropping systems under varying fertility levels in sub-humid tropics

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Abstract

A farmer in the Colombian Andes plants maize between rows of climbing bean and wonders whether adding fertiliser helps or hurts the partnership. This research tested three maize–legume intercropping combinations (maize + common bean, maize + soybean, maize + cowpea) against sole maize at four nitrogen fertility levels (0, 40, 80, and 120 kg N ha⁻¹) at the National University of Colombia's La Selva research station, Rionegro, Antioquia (6°08'N, 75°25'W, 2,120 m a.s.l.) during two cropping seasons (2020A and 2020B). Land equivalent ratio (LER) exceeded 1.0 in all intercropping treatments, peaking at 1.52 for maize + cowpea at 40 kg N ha⁻¹. But LER declined at 120 kg N, suggesting that high nitrogen favours the cereal at the expense of the legume partner. Net returns were highest for maize + bean at 40 kg N (USD 1,847 ha⁻¹ vs. USD 1,412 for sole maize). These results indicate that moderate nitrogen inputs optimise the biological and economic advantages of intercropping in sub-humid tropical highlands.

Keywords: Intercropping, maize-legume, land equivalent ratio, nitrogen fertility, cowpea, common bean, soybean, sub-humid tropics, weed suppression, net returns

Introduction

Intercropping-growing two or more crops simultaneously in the same field-is among the oldest agronomic strategies on Earth, yet it still lacks a firm evidence base under modern fertility management ^[1]. Smallholder farmers across tropical America have intercropped maize with beans for centuries, relying on the legume's nitrogen fixation to supplement soil fertility ^[2]. But as mineral fertilisers become more accessible, the question shifts: does adding nitrogen strengthen or weaken the intercrop advantage?

The land equivalent ratio (LER) captures this trade-off by comparing the total land needed by sole crops to match the output of an intercrop ^[3]. An LER above 1.0 signals a biological advantage. Published LER values for maize–legume combinations range from 1.1 to 1.8, but most trials use a single nitrogen rate, making it impossible to assess how fertility interacts with the competitive balance between species ^[4, 5]. Colombia's sub-humid highland zone (1,800–2,400 m), where moderate temperatures extend the growing season and rainfall is bimodal, is well suited to intercropping but has produced little controlled data on nitrogen × cropping-system interactions ^[6]. This research filled that gap using three legume species and four nitrogen levels over two consecutive seasons.

Climatic conditions

La Selva station experiences a sub-humid tropical highland climate with bimodal rainfall peaking in April–May and September–October. Total rainfall during the research period was 2,148 mm (2020A: 1,087 mm; 2020B: 1,061 mm). Mean temperature was 17.4 °C with a narrow diurnal range of 8–24 °C. Relative humidity averaged 78%. Soils are Andisols (Typic Hapludands) with pH 5.3, organic matter 8.7%, and available P (Bray II) 12.4 mg kg⁻¹.

Material and methods

Material

Maize (cv. ICA V-305), common bean (*Phaseolus vulgaris* cv. Cargamanto), soybean (*Glycine max* cv. Soyica P-34), and cowpea (*Vigna unguiculata* cv. IT97K-499-35) were sown in plots of

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6 × 5 m. Nitrogen was applied as urea (46% N) at 0, 40, 80, and 120 kg N ha⁻¹, split between sowing and 30 days after emergence. Basal phosphorus (40 kg P₂O₅ ha⁻¹ as triple superphosphate) and potassium (30 kg K₂O ha⁻¹ as KCl) were uniform across treatments.

Methods

The trial was a factorial split-plot in a randomised complete block design with three replications. Cropping system (sole maize, maize + bean, maize + soy, maize + cowpea) was the main plot; nitrogen level was the subplot. Maize was planted at 75 × 25 cm; legumes were sown in the inter-row space at 37.5 cm from the maize row. Grain yields of both components were measured at maturity from the central 3 × 4 m harvest area. LER

was calculated as (intercrop maize yield / sole maize yield) + (intercrop legume yield / sole legume yield). Weed biomass was assessed at 45 days after sowing by quadrat sampling (0.5 m², four per plot). Net returns were computed using local market prices. Data were analysed by split-plot ANOVA with Tukey's HSD ($\alpha = 0.05$) in SAS v9.4.

Field experimental design

Plots were arranged on a gentle slope (< 3%) with main plots running perpendicular to the gradient. A 1.5 m alley separated main plots and a 1 m path separated subplots. Planting dates were staggered by one week between the two seasons to align with the onset of effective rains confirmed by the on-site weather station.

Results

Table 1: Land equivalent ratio (LER) of three intercropping systems at four nitrogen levels (pooled over two seasons)

System	0 kg N	40 kg N	80 kg N	120 kg N
Maize + bean	1.31	1.47	1.42	1.34
Maize + soybean	1.24	1.38	1.36	1.29
Maize + cowpea	1.37	1.52	1.48	1.39

All intercropping combinations achieved LER above 1.0 at every nitrogen level (Table 1). Peak LER occurred at 40 kg N ha⁻¹ for all three systems. Maize + cowpea consistently produced

the highest LER, reaching 1.52. At 120 kg N, LER declined toward the unfertilised level, indicating that high nitrogen suppressed legume contribution.

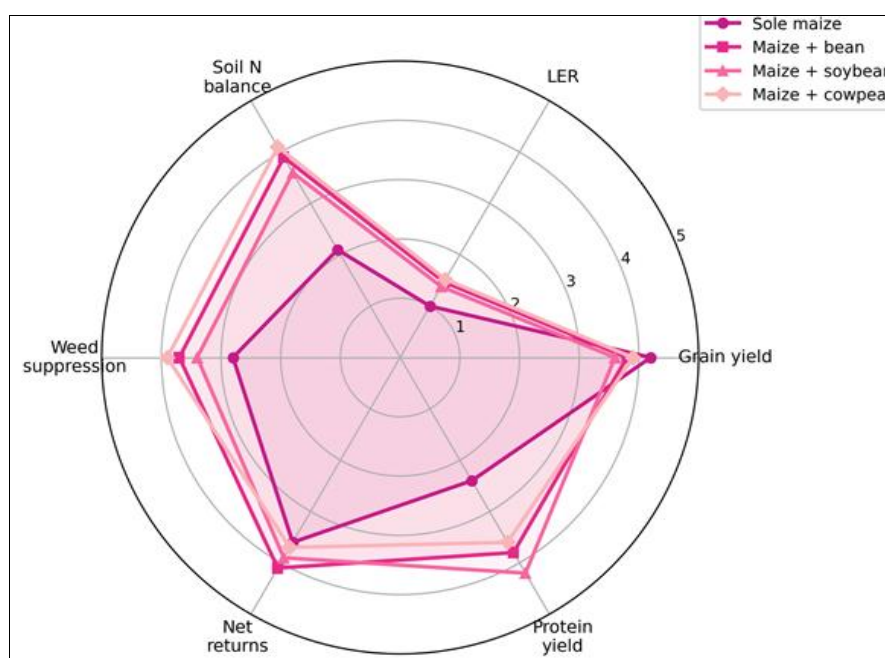


Fig 1: Multi-attribute performance comparison of sole maize and three maize-legume intercropping systems at 40 kg N ha⁻¹

Table 2: Net economic returns (USD ha⁻¹) at 40 kg N ha⁻¹ and weed biomass at 45 DAS

System	Net returns	Weed biomass (g m ⁻²)	Weed reduction (%)
Sole maize	1,412	187.3	-
Maize + bean	1,847	74.6	60.2
Maize + soybean	1,723	89.1	52.4
Maize + cowpea	1,681	63.8	65.9

Maize + bean at 40 kg N generated the highest net returns (USD 1,847 ha⁻¹), 30.8% above sole maize (Table 2). All intercropping systems reduced weed biomass by 52–66%, with cowpea

providing the strongest suppression due to its rapid ground coverage.

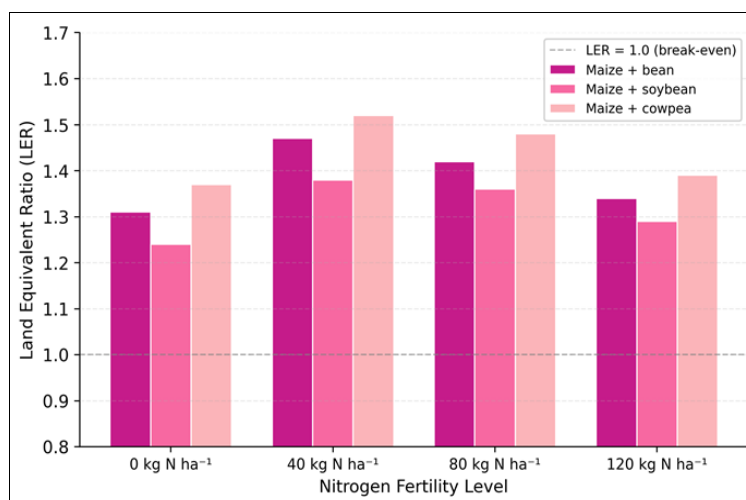


Fig 2: Land equivalent ratio of three maize-legume intercropping systems across four nitrogen fertility levels

Comprehensive interpretation

The parabolic LER response to nitrogen-rising from 0 to 40 kg N then declining toward 120 kg N-suggests that moderate fertilisation supports the cereal component without overshadowing the legume, whereas heavy nitrogen tips the competitive balance toward maize and reduces symbiotic N fixation [7].

Discussion

The LER peak at 40 kg N aligns with theoretical models predicting that intercrop advantage is greatest when resource supply is moderate [3, 8]. At zero nitrogen, maize growth was too weak to provide the structural support that climbing bean requires, depressing the bean partial LER. At 120 kg N, vigorous maize canopy growth shaded the shorter legumes, reducing their photosynthesis and pod set-a pattern well documented in East African maize-bean systems [9]. Cowpea's consistently higher LER reflects its prostrate canopy that captures light missed by the erect maize, combined with aggressive nodulation even under modest nitrogen [10].

The 52–66% weed suppression is an important non-yield benefit that reduces herbicide costs and manual weeding labour, particularly relevant for smallholders who face labour constraints during peak season [11]. Net returns favoured maize + bean because common bean commands a higher market price per kilogram than soybean or cowpea in Colombian highland markets [12].

Conclusion

All three maize-legume intercropping systems outperformed sole maize in land productivity (LER 1.24–1.52), weed suppression (52–66%), and net economic returns at the optimal nitrogen rate of 40 kg N ha⁻¹. Maize + cowpea achieved the highest biological efficiency, while maize + bean delivered the best economic returns. Nitrogen beyond 80 kg ha⁻¹ eroded the intercrop advantage. Extension programmes in Colombia's sub-humid highlands should promote moderate-input intercropping as a practical intensification strategy.

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