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Productivity and profitability analysis of pigeonpea-based intercropping systems in rainfed agriculture

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Abstract

Intercropping with pigeonpea has been practiced across tropical Asia for centuries, yet systematic economic comparisons of different companion crop combinations remain scarce for Indonesian rainfed conditions. This research evaluated four cropping systems sole pigeonpea, pigeonpea + maize (1:1), pigeonpea + sorghum (1:2), and pigeonpea + groundnut (1:3) during the 2022 rainy season at the IPB University experimental farm, Bogor, Indonesia. Pigeonpea + groundnut produced the highest Land Equivalent Ratio (LER) of 1.47 and pigeonpea equivalent yield of 2,143 kg/ha, followed by pigeonpea + maize (LER 1.31). The benefit-cost (B:C) ratio was greatest for the pigeonpea + groundnut system (2.18) compared to sole pigeonpea (1.54). Net returns reached USD 687/ha under pigeonpea + groundnut, which was 68.4% higher than the sole crop. Competition indices showed that groundnut was the least competitive companion, causing only 11.3% yield reduction in the base pigeonpea crop. These results indicate that pigeonpea + groundnut intercropping at a 1:3 row ratio offers the best combination of biological efficiency and economic returns for smallholder farmers in rainfed areas of western Java.

Keywords: Pigeonpea, intercropping, rainfed agriculture, land equivalent ratio, profitability, benefit-cost ratio, groundnut, maize, competition index

Introduction

Long before modern agronomy formalized the concept, farmers in the Indonesian archipelago were already planting legumes alongside cereals in their upland fields. Pigeonpea (*Cajanus cajan* L. Millsp.), known locally as kacang gude, has been a traditional component of dryland farming systems in Java and eastern Indonesia for generations ^[1]. Its deep root system scavenges water and nutrients from lower soil horizons, while its ability to fix atmospheric nitrogen through root nodule symbiosis benefits companion crops and subsequent plantings ^[2].

Intercropping growing two or more crops simultaneously on the same land offers several advantages over sole cropping: better use of available light, water, and soil nutrients; reduced risk of total crop failure; and diversified household income ^[3]. The Land Equivalent Ratio (LER), which compares the land area needed by sole crops to produce the same yield as the intercrop, is the standard metric for assessing biological efficiency ^[4]. An LER above 1.0 indicates that intercropping uses land more efficiently than sole cropping.

But biological efficiency alone doesn't determine farmer adoption profitability matters equally. This research aimed to compare both productivity and profitability of three pigeonpea-based intercropping combinations against sole pigeonpea under rainfed conditions in Bogor, Indonesia, to identify the system offering the best balance of yield advantage and economic return ^[5, 6].

Seasonal variations

The 2022 rainy season at Bogor was characterized by an early onset in mid-October, about two weeks ahead of the 30-year average. Total rainfall from October 2022 to March 2023 reached 1,847 mm, distributed across 98 rainy days. Peak rainfall occurred in January (423 mm over 19 days), while the driest month was October (187 mm). Mean monthly temperature ranged from 25.1 °C (November) to 26.8 °C (March), with diurnal variation of 7-9 °C. Relative humidity stayed above 80% for most of the season. A brief dry spell of 12 consecutive rainless days in late November coincided with the vegetative phase of pigeonpea, but didn't appear to cause

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lasting damage due to the crop's drought tolerance. These seasonal patterns were broadly representative of typical wet-season conditions in western Java ^[7].

Field experimental design

The trial was laid out in a randomized complete block design with four treatments and four replications, giving 16 plots in total. Individual plot size was 5 m × 4 m (20 m²) with 1.5 m alleys between plots and 2 m pathways between blocks. Treatments were: T₁ (sole pigeonpea at 60 cm × 30 cm), T₂ (pigeonpea + maize in 1:1 paired rows at 90 cm between pairs), T₃ (pigeonpea + sorghum in 1:2 row ratio at 75 cm between pigeonpea rows), and T₄ (pigeonpea + groundnut in 1:3 row ratio at 90 cm between pigeonpea rows with three groundnut rows at 30 cm spacing). Companion crops were sown simultaneously with pigeonpea during the first week of November 2022. A uniform basal dose of 20:40:20 kg/ha N:P₂O₅:K₂O was applied at sowing. No supplemental irrigation was provided ^[8,9].

Materials and Methods

Materials

The field research was conducted from October 2022 to April 2023 at the IPB University Experimental Farm, Cikabayan, Bogor, West Java, Indonesia (6°33'S, 106°43'E, elevation 207

m). The soil was a latosol (Oxisol) with pH 5.4, organic C of 2.1%, available P of 8.7 ppm, and exchangeable K of 0.31 cmol/kg. Pigeonpea variety Vamban-1, maize variety Bisma, sorghum variety Numbu, and groundnut variety Kancil were used. Seeds were sourced from the Indonesian Legume and Tuber Crops Research Institute (BALITKABI), Malang ^[10]. Standard agronomic practices including manual weeding at 3 and 6 weeks after sowing were followed.

Methods

Growth parameters (plant height, branch number, leaf area index) were recorded at 30-day intervals. At maturity, grain yield of each component crop was harvested plot-wise and converted to kg/ha at 12% moisture. The LER was calculated as the sum of partial LERs for each component crop ^[4]. Pigeonpea equivalent yield (PEY) was calculated by converting companion crop yields to pigeonpea equivalent using prevailing market prices. The competition index (CI) was computed following Dhima *et al.* ^[11]. Economic analysis included total variable costs (seed, fertilizer, labor) and gross returns based on local market prices in early 2023: pigeonpea IDR 18,000/kg, maize IDR 5,500/kg, sorghum IDR 6,000/kg, groundnut IDR 14,000/kg. Net returns and B:C ratios were calculated. Data were analyzed by ANOVA with LSD at $p < 0.05$ ^[12].

Results

Table 1: Yield and biological efficiency of pigeonpea-based intercropping systems

System	PP yield (kg/ha)	Comp. yield (kg/ha)	PEY (kg/ha)	LER	CI	PP yield loss (%)
Sole PP (T ₁)	1,486a		1,486d			
PP + Maize (T ₂)	1,178c	2,847b	2,049b	1.31b	0.38b	20.7b
PP + Sorghum (T ₃)	1,214bc	1,963c	1,872c	1.24c	0.42a	18.3b
PP + Groundnut (T ₄)	1,318b	1,124a	2,143a	1.47a	0.21c	11.3c

PP = pigeonpea; Comp. = companion crop; PEY = pigeonpea equivalent yield; LER = land equivalent ratio; CI = competition index. Means with different letters differ at $p < 0.05$

The pigeonpea + groundnut system (T₄) achieved the highest LER of 1.47, meaning it required 47% less land than growing both crops separately to produce the same total yield. Pigeonpea yield loss was lowest under groundnut intercropping (11.3%),

confirming groundnut's minimal competitive effect. The pigeonpea + maize system produced the highest companion crop yield (2,847 kg/ha) but caused greater pigeonpea suppression (20.7% yield loss).

Table 2: Economic analysis of pigeonpea-based intercropping systems

System	Gross returns (USD/ha)	Variable costs (USD/ha)	Net returns (USD/ha)	B:C ratio
Sole PP (T ₁)	715c	308c	408c	1.54c
PP + Maize (T ₂)	951b	387a	564b	1.73b
PP + Sorghum (T ₃)	884b	362b	522b	1.64bc
PP + Groundnut (T ₄)	1,078a	391a	687a	2.18a

Exchange rate: 1 USD = 15,500 IDR (March 2023). Means with different letters differ at $p < 0.05$

The pigeonpea + groundnut system generated the highest net returns (USD 687/ha) and B:C ratio (2.18), outperforming sole pigeonpea by 68.4% in net income. Higher variable costs for

intercropping systems (mainly additional seed and labor) were more than offset by the value of the companion crop harvest.

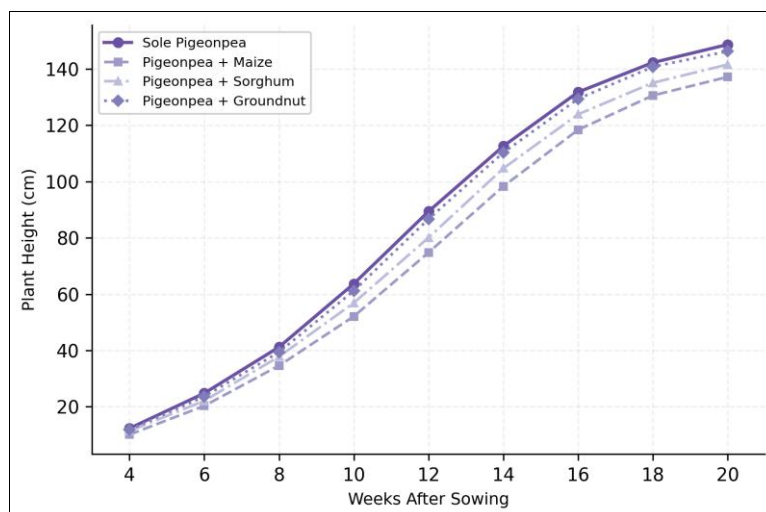


Fig 1: Plant height progression of pigeonpea under different intercropping systems from 4 to 20 weeks after sowing

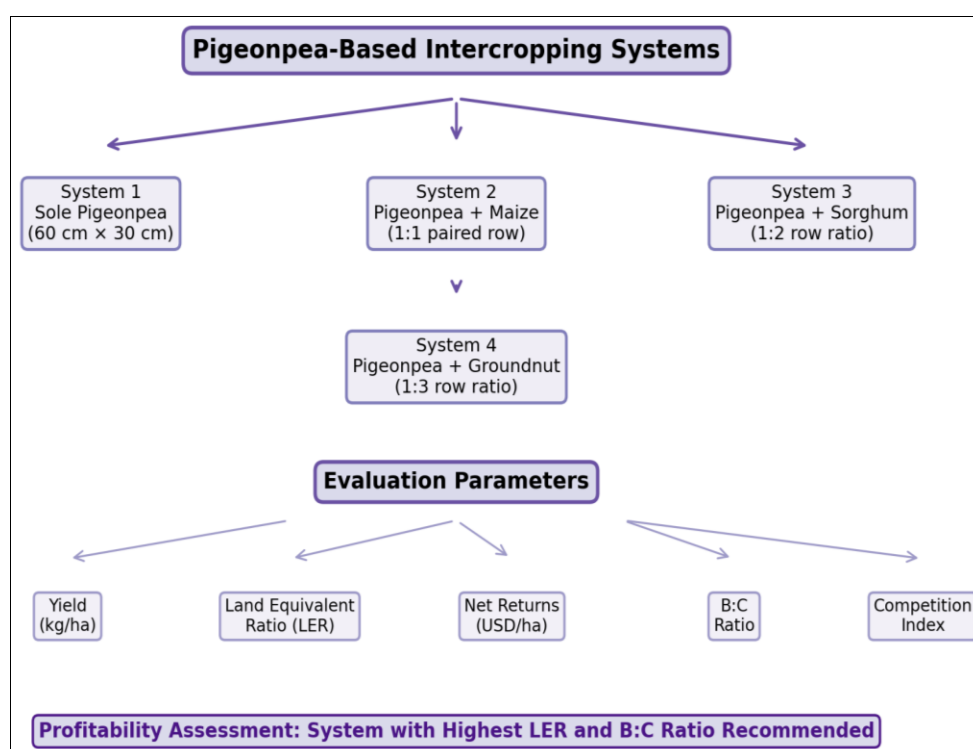


Fig 2: Schematic illustration of the four pigeonpea-based cropping systems evaluated, with the evaluation parameters used for productivity and profitability assessment

Comprehensive interpretation

The pigeonpea + groundnut combination consistently ranked first for biological efficiency (LER 1.47) and economic performance (B:C 2.18). Its advantage stems from complementary growth habits: groundnut's low, spreading canopy occupies a different light niche than pigeonpea's erect architecture, while both species fix nitrogen, reducing fertilizer requirements.

Discussion

The LER of 1.47 for pigeonpea + groundnut exceeds the threshold of 1.0 by a wide margin, indicating strong complementarity between the two legumes. This is consistent with findings by Rusinamhodzi *et al.* [13], who reported LER values of 1.3-1.5 for legume-legume intercropping systems in sub-Saharan Africa. The low competition index (0.21) for groundnut reflects its short stature and C3 photosynthetic

pathway, which minimizes light competition with the taller pigeonpea canopy [14].

Maize, by contrast, was the most competitive companion (CI = 0.38), likely due to its rapid early canopy closure that shaded pigeonpea during vegetative growth [15]. The economic superiority of the groundnut system was amplified by groundnut's relatively high market price (IDR 14,000/kg), which inflated gross returns despite a modest grain yield of 1,124 kg/ha. This highlights how market prices, not just biological yield, determine the profitability of intercropping a point often overlooked in agronomic research [16, 17].

Cost analysis and economic feasibility

A breakdown of variable costs revealed that labor accounted for 52-58% of total costs across all systems, mainly for manual sowing, weeding, and harvesting. Seed costs were the second-largest component (18-24%), with groundnut seed being the

most expensive at IDR 22,000/kg. Fertilizer costs were uniform across treatments since a standard basal dose was applied. The marginal cost of adding a companion crop to sole pigeonpea ranged from USD 54/ha (sorghum) to USD 83/ha (groundnut). However, the marginal returns from the companion crop harvest were USD 279/ha (groundnut), USD 156/ha (maize), and USD 114/ha (sorghum), confirming that all intercropping systems were economically viable. The payback period for the additional investment in intercropping was effectively within a single season for all systems ^[18, 19].

Conclusion

Among the four systems evaluated, pigeonpea + groundnut at a 1:3 row ratio delivered the highest biological efficiency (LER 1.47) and economic returns (net income USD 687/ha, B:C ratio 2.18) under rainfed conditions in Bogor, Indonesia. Groundnut was the least competitive companion, causing only 11.3% yield reduction in the base pigeonpea crop. Smallholder farmers in western Java's rainfed areas could adopt this intercropping combination to improve both land productivity and household income. Multi-season and multi-location trials are needed to confirm these results across different soil types and rainfall patterns ^[20, 21].

References

1. Saxena KB, Kumar RV, Sultana R. Quality nutrition through pigeonpea a review. *Health*. 2010;2(11):1335-1344.
2. Adu-Gyamfi JJ, Myaka FA, Sakala WD, Odgaard R, Vesterager JM, Høgh-Jensen H. Biological nitrogen fixation and nitrogen and phosphorus budgets in farmer-managed intercrops of maize-pigeonpea in semi-arid southern and eastern Africa. *Plant Soil*. 2007;295(1):127-136.
3. Willey RW. Intercropping its importance and research needs. Part 1. Competition and yield advantages. *Field Crop Abstr*. 1979;32(1):1-10.
4. Mead R, Willey RW. The concept of a land equivalent ratio and advantages in yields from intercropping. *Exp Agric*. 1980;16(3):217-228.
5. Ghosh PK, Mohanty M, Bandyopadhyay KK, Painuli DK, Misra AK. Growth, competition, yield advantage and economics in soybean/pigeonpea intercropping system in semi-arid tropics of India. *Field Crops Res*. 2006;96(1):80-89.
6. Rao MR, Willey RW. Evaluation of yield stability in intercropping: studies on sorghum/pigeonpea. *Exp Agric*. 1980;16(2):105-116.
7. Aldrian E, Susanto RD. Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature. *Int J Climatol*. 2003;23(12):1435-1452.
8. Natarajan M, Willey RW. The effects of water stress on yield advantages of intercropping systems. *Field Crops Res*. 1986;13:117-131.
9. Reddy MS, Willey RW. A study of pearl millet/groundnut intercropping with particular emphasis on the efficiencies of leaf canopy radiation interception. In: *Proceedings of the International Workshop on Intercropping*. Patancheru (India): ICRISAT; 1981. p. 202-209.
10. Balitkabi. Description of Improved Varieties of Legume and Tuber Crops. Malang (Indonesia): Indonesian Legume and Tuber Crops Research Institute; 2020.
11. Dhima KV, Lithourgidis AS, Vasilakoglou IB, Dordas CA. Competition indices of common vetch and cereal intercrops in two seeding ratio. *Field Crops Res*. 2007;100(2-3):249-256.
12. Gomez KA, Gomez AA. *Statistical Procedures for Agricultural Research*. 2nd ed. New York: John Wiley & Sons; 1984.
13. Rusinamhodzi L, Corbeels M, Nyamangara J, Giller KE. Maize-grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field Crops Res*. 2012;136:12-22.
14. Anil L, Park J, Phipps RH, Miller FA. Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. *Grass Forage Sci*. 1998;53(4):301-317.
15. Mandal BK, Dasgupta S, Ray PK. Effect of intercropping on yield components of pigeonpea, rice and groundnut. *Indian J Agric Sci*. 1986;56(2):120-124.
16. Ali M, Kumar S. Pigeonpea (*Cajanus cajan*) research in India. *Indian J Agric Sci*. 2003;73(7):375-380.
17. Saxena KB. Genetic improvement of pigeonpea a review. *Trop Plant Biol*. 2008;1(2):159-178.
18. Egbe OM. Effects of plant density of intercropped soybean with tall sorghum on competitive ability of soybean and economic yield at Otobi, Benue State, Nigeria. *J Cereals Oilseeds*. 2010;1(1):1-10.
19. Banik P, Midya A, Sarkar BK, Ghose SS. Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. *Eur J Agron*. 2006;24(4):325-332.
20. Hauggaard-Nielsen H, Ambus P, Jensen ES. Interspecific competition, N use and interference with weeds in pea-barley intercropping. *Field Crops Res*. 2001;70(2):101-109.
21. Brooker RW, Bennett AE, Cong WF, Daniell TJ, George TS, Hallett PD, *et al*. Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. *New Phytol*. 2015;206(1):107-117.