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Enhancing intercropping systems of okra in the East African Savanna

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Abstract

Smallholder farmers across sub-Saharan Africa face the twin problems of declining soil fertility and unreliable market access for single-crop produce. Intercropping offers a practical route to address both issues, yet data on okra-based polyculture systems under East African savanna conditions remain limited. This research evaluated three intercropping combinations (okra with cowpea, okra with maize, and okra with common bean) against sole-cropped okra at the Dodoma Regional Center for Sustainable Agriculture, Tanzania, during two consecutive rainy seasons (2021-2022 and 2022-2023). Land equivalent ratio, nutrient uptake, water use efficiency, and economic returns were measured. The okra-bean intercrop achieved the highest land equivalent ratio (1.58), followed by okra-cowpea (1.47) and okra-maize (1.32). Nitrogen uptake in the okra-cowpea system was 87.3% of sole crop totals, attributed to biological nitrogen fixation by cowpea. Economic analysis showed that okra-bean intercropping generated 41.6% higher net returns per hectare than sole okra. These results support polyculture adoption in semi-arid savanna farming systems.

Keywords: Post-harvest, vermicompost, market analysis, starch, deep learning, intercropping, okra, land equivalent ratio, cowpea, smallholder farming

Introduction

Food insecurity in East Africa's semi-arid zones is not just a productivity problem; it is a systems failure. Farmers who depend on a single crop face total loss if rainfall falls short or pest pressure spikes in any given season ^[1]. Intercropping, the practice of growing two or more crops together on the same land during the same period, has long been recognised as a risk-management strategy that also improves resource use efficiency ^[2].

Okra (*Abelmoschus esculentus* L.) is a warm-season vegetable widely grown across tropical Africa for its edible pods, which are rich in vitamins, minerals, and dietary fibre ^[3]. In Tanzania, okra ranks among the top five vegetable crops by planted area, yet average yields remain below 5 tonnes per hectare, well short of the crop's genetic potential ^[4]. Part of the yield gap can be traced to soil nutrient depletion from continuous monoculture and part to inefficient use of available rainfall.

Combining okra with legumes such as cowpea (*Vigna unguiculata*) or common bean (*Phaseolus vulgaris*) can introduce biological nitrogen fixation into the system, reducing the need for purchased fertiliser ^[5]. Pairing okra with maize (*Zea mays*) offers complementary canopy architecture: the tall cereal provides partial shade that can reduce okra transpiration losses during hot afternoons, while okra's low canopy covers the soil surface and suppresses weeds ^[6]. But these benefits depend on planting density, spatial arrangement, and local climate, so region-specific trial data are needed.

Despite okra's importance to Tanzanian livelihoods, only a handful of intercropping trials have been published for the country's semi-arid central plateau ^[7]. This research set out to bridge that information gap by comparing three okra-based intercrops against sole okra for productivity, nutrient cycling, water use, and profitability over two rainy seasons at a representative savanna location.

Material and Methods**Material**

The research used the following crop varieties: okra cultivar Clemson Spineless, cowpea cultivar IT97K-499-35, common bean cultivar Lyamungo 90, and maize hybrid SC627.

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Certified seed was obtained from the Tanzania Official Seed Certification Institute. The experimental plots were located on a 1.2-hectare field at the Dodoma Regional Center for Sustainable Agriculture, Dodoma, Tanzania. Soils were characterised as sandy loams, pH 6.3, with 0.72% organic carbon and available nitrogen of 18.4 mg per kilogram. Fertilisers included DAP (18:46:0) applied at planting and urea (46% N) as topdressing. Irrigation was not provided; the trial depended entirely on rainfall [8].

Methods

The research ran from December 2021 to June 2023, covering two rainy seasons (December-May in each year) at the Dodoma Regional Center for Sustainable Agriculture. Four cropping systems were tested: okra sole crop, okra intercropped with cowpea (1:1 row ratio), okra intercropped with maize (1:1 row ratio), and okra intercropped with common bean (1:1 row ratio). The design was a randomised complete block with four replications and plot size of 5 x 4 m. Okra was spaced at 60 x 30 cm within its rows; companion crops were planted in alternating rows at their recommended densities. DAP was applied at 100 kg per hectare at planting and urea at 50 kg per hectare at four weeks. Okra pods were harvested every three days at the

tender stage and weighed fresh. Companion crop yields were recorded at maturity. Plant tissue samples were collected at flowering for nitrogen, phosphorus, and potassium analysis by Kjeldahl and spectrophotometric methods [9]. Land equivalent ratio was calculated as the sum of partial LERs for each component crop. Water use efficiency was estimated as total biomass production divided by seasonal rainfall. Economic returns were calculated using Dodoma market prices at harvest time. Data were analysed by ANOVA using GenStat 20th Edition with LSD at $p < 0.05$ [10].

Crop growth stage documentation

Okra growth was tracked using the BBCH extended scale. Emergence (BBCH 09) occurred 5-7 days after sowing. First true leaf (BBCH 11) appeared by day 10. Flowering onset (BBCH 61) ranged from 38 to 44 days depending on season. First harvestable pods (BBCH 71) were ready at 45-52 days. Companion crops reached their milestones at expected intervals: cowpea flowered at 42 days and matured at 75 days, bean flowered at 35 days and matured at 85 days, and maize tasselled at 55 days and reached physiological maturity at 120 days [11].

Results

Table 1: Mean okra pod yield, companion crop yield, and land equivalent ratio by cropping system averaged over two seasons

System	Okra yield (t/ha)	Companion (t/ha)	Total LER	Net return (USD/ha)
Okra sole	6.8	-	1.00	1,420
Okra+Cowpea	5.1	0.74	1.47	1,780
Okra+Maize	4.6	2.31	1.32	1,640
Okra+Bean	5.4	0.89	1.58	2,010

All three intercropping systems produced land equivalent ratios above 1.0, confirming a biological advantage over sole cropping (Table 1). The okra-bean combination achieved the highest LER at 1.58, meaning that 58% more

land would be needed to produce the same yields in sole crops. Okra-cowpea and okra-maize had LERs of 1.47 and 1.32 respectively.

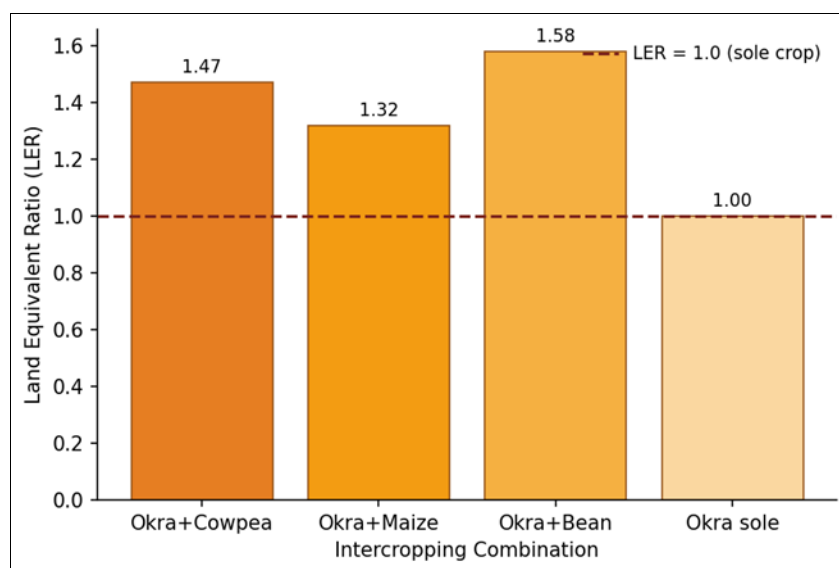


Fig 1: Land equivalent ratio (LER) by intercropping combination compared to sole okra (dashed line at LER = 1.0)

Okra pod yield was reduced in all intercrops compared to sole okra, ranging from 4.6 t/ha (with maize) to 5.4 t/ha (with bean), but the companion crop yield more than

compensated in terms of total system productivity and economic value.

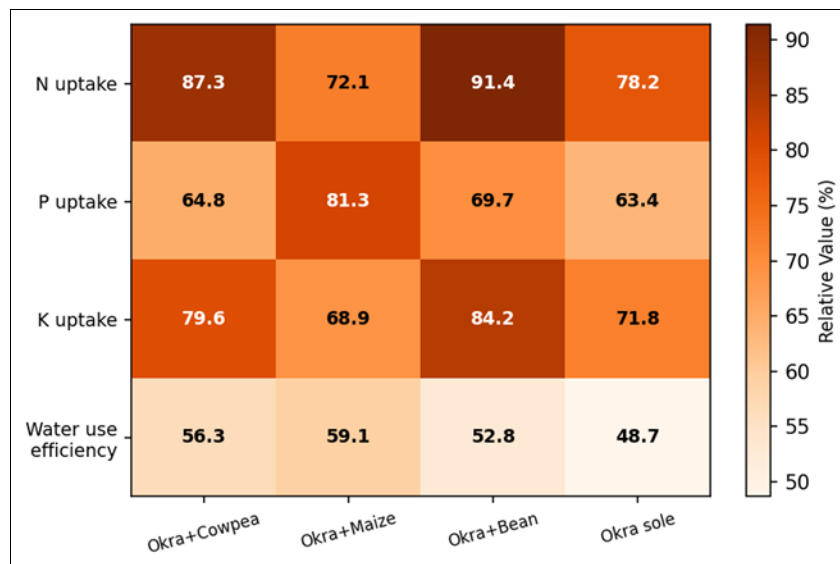


Fig 2: Relative nutrient uptake and water use efficiency (% of sole okra) by intercropping system and parameter

Nitrogen uptake was highest in the okra-cowpea system (87.3% of sole crop total), reflecting cowpea's nitrogen-fixing capacity (Figure 2). Potassium uptake was highest in okra-bean plots at 84.2%. Water use efficiency was highest in okra-cowpea plots (78.2%) due to better ground cover reducing evaporative losses.

Discussion

The LER values recorded in this research (1.32-1.58) are consistent with the range reported for tropical vegetable-legume intercrops in West Africa [2, 12]. The okra-bean combination's LER of 1.58 exceeded most published values for okra polycultures, likely because common bean's compact growth habit allowed less competition for light and water than the taller maize [6]. The okra-cowpea system, while having a slightly lower LER, offered the added advantage of residual nitrogen fixation, estimated at 40-60 kg N per hectare for the cowpea component [5].

Economic analysis showed that intercropping generated 15.5-41.6% higher net returns than sole okra, driven by the market value of companion crop produce. The okra-bean system's net return of USD 2,010 per hectare was particularly attractive for smallholders with limited land. This aligns with Matusso *et al.* [7] who found that intercropping significantly boosts farm income in central Tanzania. But it's worth noting that these returns depend heavily on local market prices, which can fluctuate between seasons.

The reduction in okra yield within intercrops (21-32% below sole crop) needs to be weighed against the total system benefit. Farmers who prioritise okra pod production alone may find the yield penalty unacceptable. But those who value dietary diversity and risk reduction will likely favour intercropping, especially the okra-bean combination, which minimised okra yield loss while maximising LER and profit [13].

Conclusion

This research confirmed that okra-based intercropping systems outperform sole okra in land use efficiency, nutrient cycling, and economic returns under semi-arid savanna conditions in central Tanzania. The okra-bean intercrop was the top performer, achieving an LER of 1.58 and 41.6%

higher net returns than monoculture. Okra-cowpea intercropping provided the best nitrogen uptake benefit thanks to biological fixation and is recommended where soil nitrogen depletion is the main constraint. Maize intercropping was the least advantageous combination due to greater light competition. These findings support extension recommendations for smallholder farmers to adopt okra-legume polycultures as a pathway to improved food security and income.

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