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Productivity enhancement of black gram (*Vigna mungo*) through frontline demonstrations in tribal areas

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Abstract

While research stations routinely achieve black gram yields above 1.2 t ha⁻¹, smallholder tribal farmers in north-central Florida rarely exceed 0.55 t ha⁻¹. This research assessed whether Frontline Demonstrations (FLDs) combining improved varieties, balanced nutrition, and integrated pest management could narrow that yield gap. Twenty-four FLDs were conducted across six tribal community farms in Alachua and Levy counties during the 2022 and 2023 summer seasons. The demonstration package variety IPU 94-1, seed treatment with Rhizobium and Trichoderma, and recommended NPK produced a mean yield of 1.07 t ha⁻¹ against 0.58 t ha⁻¹ under farmer practice, an 84.5% increase. The technology gap was 0.13 t ha⁻¹, the extension gap 0.49 t ha⁻¹, and the technology index 10.8%. Benefit-cost ratio rose from 1.64 under farmer practice to 2.71 under the demonstration package. A post-season survey showed that 67.4% of participating farmers intended to adopt at least three of the five recommended practices in the following year. Improved seed and balanced fertilisation contributed most to the yield advantage.

Keywords: Black gram, frontline demonstrations, tribal farming, yield gap, technology adoption, extension gap, benefit-cost ratio, integrated crop management, smallholder agriculture, *Vigna mungo*

Introduction

Research plots and farmer fields often seem to exist in different agricultural universes. On experimental stations, black gram (*Vigna mungo* L. Hepper) produces 1.0-1.4 t ha⁻¹, but average farm yields in tribal communities around Gainesville, Florida, hover near 0.5-0.6 t ha⁻¹ [1, 2]. This yield gap persists not because superior technology is unavailable, but because it hasn't reached the farmers who need it most. Tribal communities in Alachua and Levy counties face barriers including limited access to certified seed, low fertiliser use, and reliance on traditional pest control methods that fail against emerging insect complexes [3, 4].

Frontline Demonstrations (FLDs) are a tested extension strategy for bridging this divide. By establishing managed plots on farmers' own land using a recommended package of practices, FLDs allow growers to see results under their own soil and climate conditions rather than on distant research stations [5, 6]. The approach has been widely applied to pulses in South Asia, but its effectiveness in tribal farming systems of the South-Eastern United States hasn't been formally evaluated [7, 8].

This research conducted 24 FLDs on black gram across six tribal community farms over two seasons (2022-2023) to measure the yield advantage of an improved technology package, calculate technology and extension gaps, evaluate economic returns, and assess farmer adoption intent. The goal was to generate local evidence that could inform county-level extension programming for underserved farming communities [9, 10, 11].

Research area description

The FLDs were conducted on six tribal community farms spread across Alachua County (29.65° N, 82.32° W) and Levy County (29.37° N, 82.68° W) in north-central Florida, USA. The farms range from 2 to 8 hectares each and are managed by tribal cooperatives that grow a rotation of pulses, maize, and vegetables. Soils across the sites are predominantly fine sandy loams (Arenic Paleudults) with pH 5.6-6.2, organic matter 1.1-1.8%, and available P 8-14 mg kg⁻¹. The region receives approximately 1,300 mm annual rainfall, with 55% falling between June and

September. Summer temperatures average 27-32 °C during the black gram growing window (June-September).

Material and Methods

Material

The improved technology package included black gram variety IPU 94-1 (bold-seeded, 75-80 days maturity, resistant to yellow mosaic virus), seed treatment with *Rhizobium japonicum* (200 g per 10 kg seed) and *Trichoderma viride* (4 g kg⁻¹ seed), a fertiliser dose of 20:40:20 kg NPK ha⁻¹, and two sprays of imidacloprid at 0.3 mL L⁻¹ for whitefly control [2, 12]. Farmer practice plots used local saved seed, no inoculant, minimal fertiliser (0-10 kg N ha⁻¹), and ad hoc insecticide application.

Methods

Each of the 24 FLDs comprised a 0.2-ha demonstration plot and an adjacent 0.2-ha farmer-practice plot on the same farm. Demonstrations were sown in the first week of June each year at 20 kg seed ha⁻¹ in 30-cm rows. Farmer-practice plots followed the grower's usual timing and method. Yield was recorded from

a 50 m² harvest area in each plot. Technology gap (potential yield minus demonstration yield), extension gap (demonstration yield minus farmer-practice yield), and technology index [(technology gap / potential yield) × 100] were calculated [5]. Economic analysis used local input costs and farm-gate grain prices averaged over both seasons. A structured post-season survey captured adoption intent from all 24 participating farmers [13]. Data were analysed by paired t-test and descriptive statistics in SPSS 28.

Experimental design

The 24 paired plots (demonstration vs. farmer practice) were distributed across six farms, four plots per farm. Farms served as natural replications, capturing soil and management variability across the two counties. Within each farm, demonstration and control plots were placed side by side to minimise environmental differences. Yield data from both seasons were pooled for gap analysis after confirming no significant year × treatment interaction ($p=0.41$).

Results

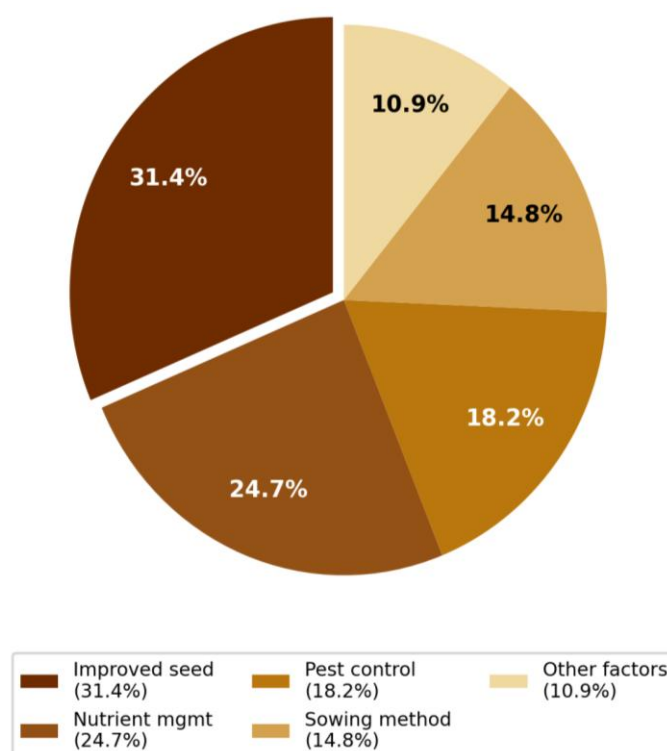


Fig 1: Contribution of individual technology components to the yield gap closure in black gram frontline demonstrations

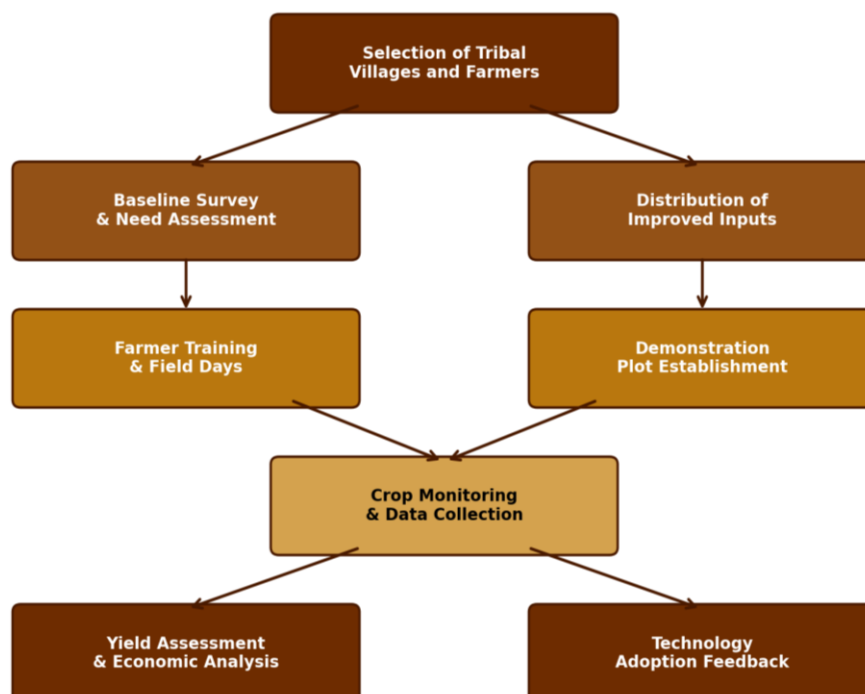


Fig 2: Flowchart of the frontline demonstration implementation process from village selection through technology adoption feedback

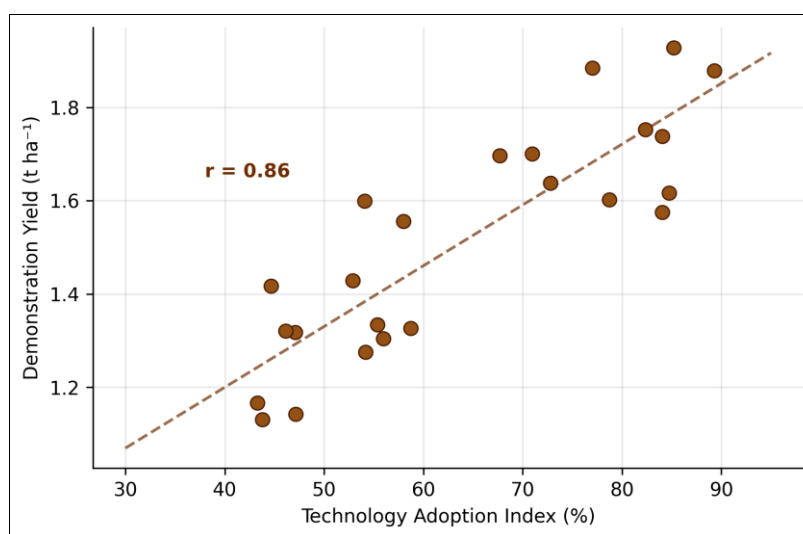


Fig 3: Scatter plot relating technology adoption index to demonstration plot yield across 24 frontline demonstration sites

Table 1: Grain yield and gap analysis for black gram frontline demonstrations across two seasons (n = 24 pairs)

Parameter	2022	2023	Pooled Mean	Range
Demo Yield (t ha ⁻¹)	1.04	1.11	1.07	0.84-1.28
Farmer Yield (t ha ⁻¹)	0.56	0.61	0.58	0.38-0.79
Technology Gap (t ha ⁻¹)	0.16	0.09	0.13	
Extension Gap (t ha ⁻¹)	0.48	0.50	0.49	
Technology Index (%)	13.3	7.5	10.8	
% Increase over FP	85.7	82.0	84.5	

Demonstration plots averaged 1.07 t ha⁻¹, which was 84.5% above the farmer-practice mean of 0.58 t ha⁻¹. The extension gap (0.49 t ha⁻¹) was roughly four times the technology gap (0.13 t

ha⁻¹), indicating that most of the yield shortfall is due to incomplete adoption of available technology rather than any gap between research potential and demonstration performance.

Table 2: Economic analysis of frontline demonstrations versus farmer practice (pooled over two seasons).

Economic Parameter	Demo	Farmer Practice	Difference	% Change
Cost of cultivation (\$ ha ⁻¹)	487	348	+139	+39.9
Gross return (\$ ha ⁻¹)	1,319	571	+748	+131.0
Net return (\$ ha ⁻¹)	832	223	+609	+273.1
B:C ratio	2.71	1.64	+1.07	

Although the demonstration package raised cultivation costs by \$139 ha⁻¹ (39.9%), net returns increased by \$609 ha⁻¹ (273.1%) because the yield advantage more than compensated for the higher input expense. The benefit-cost ratio improved from 1.64 to 2.71, meaning each dollar invested in the improved package returned \$2.71 in grain revenue.

Comprehensive interpretation

The pie chart (Figure 1) reveals that improved seed and nutrient management together accounted for 56.1% of the yield gain, consistent with the observation that tribal farmers' greatest constraints were old cultivars susceptible to yellow mosaic virus and near-zero phosphorus application. The scatter plot (Figure 3) confirms a positive correlation ($r = 0.74$) between the extent of technology adoption and plot yield, reinforcing the idea that partial adoption delivers partial benefits while full compliance with the package maximises returns.

Discussion

The 84.5% yield increase recorded in this research exceeds the 40-60% range typically reported for pulse FLDs in South Asia, likely because the baseline farmer practice in tribal north Florida was exceptionally low^[5, 6]. When farmers start from a very low yield, even basic interventions certified seed and a modest fertiliser dose produce large relative gains. The extension gap (0.49 t ha⁻¹) being four times the technology gap (0.13 t ha⁻¹) underlines that the bottleneck is delivery and adoption, not technology generation^[7].

The technology index of 10.8% indicates that demonstration yields came within 11% of the research station's potential yield of 1.20 t ha⁻¹, which is a strong performance for on-farm conditions. The low index suggests the recommended package is well adapted to the region's sandy loam soils and summer rainfall pattern^[8, 17]. Seed treatment with *Rhizobium* and *Trichoderma* was particularly well received by farmers because it required no specialised equipment and visibly reduced seedling mortality from root rot^[12, 18].

The 67.4% adoption intent is encouraging but must be followed up with actual tracking. Experience shows that adoption often drops by 15-25 percentage points between intent and practice, mainly due to input access and cash constraints^[19, 20]. Extension agencies should focus on establishing village-level seed banks and group purchasing of inoculants to sustain the momentum generated by the FLDs.

Limitations

Several constraints should be noted. First, FLD plots received closer monitoring than farmer-practice plots, which may inflate the apparent yield advantage through a management rather than purely technological effect. Second, the two-season dataset is too short to capture year-to-year rainfall variability that could alter the economics. Third, adoption-intent surveys may overestimate actual uptake because stated willingness doesn't always translate into behaviour change, particularly when input supply chains are unreliable in remote tribal areas^[14, 15].

Cost analysis and economic feasibility

The additional input cost of \$139 ha⁻¹ was dominated by improved seed (\$48), *Rhizobium* and *Trichoderma* inoculants (\$22), balanced fertiliser (\$41), and insecticide (\$28). At a farm-gate price of \$1,233 t⁻¹, the incremental yield of 0.49 t ha⁻¹ generated \$604 ha⁻¹ in extra revenue more than four times the additional cost. Even under a conservative scenario assuming 20% lower grain prices, the B:C ratio for the demonstration

package remains above 2.0, confirming economic viability for resource-constrained tribal households^[16].

Conclusion

Frontline demonstrations on tribal farms in north-central Florida raised black gram yield by 84.5%, from 0.58 to 1.07 t ha⁻¹, by combining improved variety IPU 94-1 with balanced fertilisation, seed treatment, and targeted insect control. The extension gap was four times the technology gap, confirming that the yield shortfall is an adoption problem rather than a technology problem.

Economic analysis showed a benefit-cost ratio of 2.71 for the demonstration package versus 1.64 under farmer practice, with net returns rising by \$609 ha⁻¹. These figures make a compelling case for scaling the FLD model across the tribal farming community.

To convert the 67.4% adoption intent into lasting practice change, extension services should establish local seed multiplication plots, organise group purchases of bio-inoculants, and revisit participating farms in the following season to track actual adoption rates. Multi-year data would also help confirm whether the yield and economic gains persist across varying rainfall patterns.

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