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Research Article

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Evaluation of growth, yield and economics of Okra under different leafy vegetable intercropping systems in Bara, Nepal

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ABSTRACT
The experiment was carried out in the agricultural field of Kalaiya, Bara, from 5 March, 2025 to 5 June, 2025. This study aimed to analyse the effects of intercropping different locally available leafy vegetables on growth and yield parameters and economics of Okra *(Abelmoschus esculentus)*. The experiment was laid out in the Randomized Complete Block Design (RCBD) comprising 5 treatments and four replications. The treatments included Okra + Spinach, Okra + Coriander, Okra + Amaranthus, Okra + Rayo (Mustard leaf) and sole cropping (Okra). Among the given treatments, Okra + spinach raised OEY from 6.65 t ha^{-1} (sole crop) to 37.83 t ha^{-1}, 469% gain, with BCR rising from 1.11 to 4.59, making it the most economically viable treatment. At 30 DAS, plant height was significantly higher in intercropped plots due to a shade-avoidance response; differences disappeared at later stages. At 30, 45 and 60 DAS (0.041, 0.373, and 1.037), respectively, leaf area index was found to be highest in sole cropping (Okra), resulting in superior vegetative performance. Intercropping reflects low additional input cost required for these intercrops (same land, similar cultural operations), combined with the relatively high market value and quick turnover of leafy vegetables. Therefore, Okra + spinach is recommended as the most economically viable intercropping system for smallholder farmers in the Terai region.
Keywords: Okra Equivalent Yield, Benefit Cost Ratio, LAI, Intercropping, Nepal

INTRODUCTION
Okra (*Abelmoschus esculentus* L. Moench) is an economically important vegetable crop widely cultivated in tropical and subtropical regions for its high productivity and market demand. Integrating short-duration leafy vegetables as intercrops in okra-based systems offers an opportunity to improve land-use efficiency, crop diversity, and farm profitability. Leafy vegetables such as spinach (*Spinacia oleracea*), coriander (*Coriandrum sativum*), amaranth (*Amaranthus* spp.), and broadleaf mustard (*Brassica juncea* var. *rugosa*) are nutritionally rich, fast-growing, and well-suited for intercropping due to their early maturity and complementary resource use.

Intercropping enhances overall system productivity by improving utilization of light, nutrients, and space, while reducing weed pressure and production risk (John & Mini, 2005; Begum & Kader, 2018). Intercropping modifies the microclimate and improves canopy light interception, thereby enhancing radiation-use efficiency (Dugassa, 2023). Studies have shown that early-stage intercropping of leafy vegetables such as spinach and coriander does not significantly reduce okra yield and often increases okra equivalent yield (OEY) and economic returns due to early harvest and high market value (Ahmed et al., 2013; Kumar & Kerketta, 2019; Moonmoon, 2025). However, yield response varies with intercrop species, as certain combinations, such as stem amaranth, may reduce okra yield due to interspecific competition (Oseni, 2010; Moonmoon, 2025).

Although okra-based intercropping systems have positive results, comparative evaluation of locally available leafy vegetable intercrops in the central Terai remains limited. Intercropping is one of the inexpensive methods for microclimate modification, restoring biodiversity, affordable, easy and acceptable broadly (Regmi et al., 2020; Bohara et al., 2023). In the Terai, where farming is the dominant livelihood, okra producers face low and volatile market prices (Gurung et al., 2016). On the other hand, intercrops produced earlier than Okra maturation can support farmers in terms of market value and land utilization. Therefore, the present study aims to assess the results of intercropping on different parameters, focusing on the Terai region of Nepal with particular reference to Bara.

MATERIALS AND METHODS

Description of the experimental area

The experiment was conducted in a local farmer's land in Kalaiya, Bara, Nepal. It lies in the latitude of 27° 02' 0'' N, longitude of 85° 0' 0'' E and at an elevation of 97.00m (318.24 ft.). It has a tropical climate with a low temperature of 22.73 °C and a highest average temperature of 28.55 °C during the research period. The relative humidity is 57-71% with an average precipitation of 41.42 mm. The pH of the soil was slightly acidic with medium NPK content.

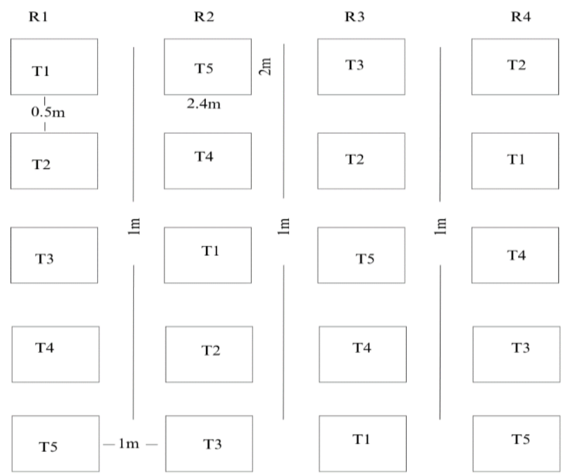

Figure 1. Layout of the Experiment

Experimental materials and design

Arka anamika variety of okra, Spinach seeds (Haripate), Broad leaf mustard green seeds (Khumal Chaudapaat), Coriander seeds (Lotus, OP) and Red amaranthus seeds (Pusa Laal Chaulai) with seed rates of 12 kg ha^{-1}, 10 kg ha^{-1}, 0.3 kg ha^{-1}, 0.5 kg ha^{-1} and 0.3kg ha^{-1}, respectively, were used. Farmyard manure (12-ton ha^{-1}) and Urea (80 kg ha^{-1}), DAP (40 kg ha^{-1}) and MOP (40 kg ha^{-1}) used as recommended on Krishi Diary, 2081 B.S. (2024/25 A.D.) Full dose of Phosphorus and Potassium, and 1/3rd dose of Nitrogen used as Basal dose. Nitrogen was applied at 25 and 35 DAS to complete the dose. The experimental design was a randomised complete block design (RCBD) with five treatments and four replications. The plot size was 2.4 × 2 m. Okra seeds were planted at a spacing of 50 cm × 30 cm, with individual plots consisting of 32 plants. The total area of the field was 176.8 square meters. Intercropped leafy vegetable seeds were sown continuously in line sowing method alternately with Okra with a spacing of 25cm gap, maintaining 1:1 ratio. Irrigation immediately after sowing and at regular intervals of 5 days until flowering, then at10 days interval after flowering. Irrigation was done through a tubewell. Pest and disease incidence were minimal during the cropping period. Minor insect outbreaks were managed using wood-ash spray and farm-prepared Jholmol (a fermented bio-pesticide, cattle urine + dung + plant materials) during infestation with 5 days of reapplication.

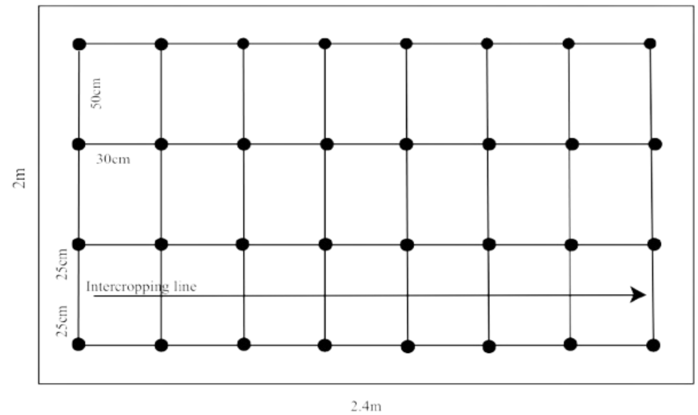

Figure 2. Layout of a single plot

Data collection

Five plants were selected, excluding border plants, for data collection. The growth parameters were measured after 30 DAS at 15 Days interval till 90 Days. Similarly yield parameters were measured after 50 DAS to 90 DAS. Weight of all the intercrops was measured during harvesting from each plot. Fruit weight was measured using electrical weighing balance. Leaf area index (LAI), Okra Equivalent Yield (OEY)and Benefit Cost Ratio (BCR) were calculated using the following formulas:

LAI = (0.62 × leaf length × leaf breadth × total leaves in plot) /Area of spacing

k = 0.62 for okra (Tanko & Hassan, 2016)

OEY = (Yield of Okra + Market price of intercrops ×Yield of intercrops)/ Market price of Okra

BCR = Gross of produce /Total cost of produce

Market prices used for OEY and BCR computation were collected from the Kalaiya local wholesale market during the harvesting period (May–June 2025). Okra NPR 50/kg, spinach NPR 70/kg, coriander NPR 200/kg, amaranthus NPR 70/kg, and rayo NPR 50/kg.

Data analysis

Data analysis was carried out by one-way ANOVA as a randomized complete block design using the agricolae package in R-Studio 4.4.2. Duncan's Multiple Range Test (DMRT) for mean separation was done at 5% level of significance, a widely used method for comparing treatment means in field experiments.

RESULTS AND DISCUSSION

Morphological Parameters

Plant height (cm)

Okra plant height differed significantly ($p < 0.05$) among treatments at 30 DAS, with the highest height observed in okra + coriander (T_2), statistically similar to okra + amaranthus (T_3).

The increased plant height at 30 DAS in intercropped treatments is due to shade avoidance response, leading to enhanced vertical growth of the dominant crop

(Muoneke & Mbah, 2007; Regmi et al., 2020). This advantage disappeared after 30 DAS, as leafy vegetables have a short duration; once the okra canopy overtopped them, the elongation signal was removed (Brooker et al., 2015; Moonmoon, 2025)

Table 1. Effect of intercropping different leafy vegetables on the plant height (cm) of okra

Treatment	Plant height (cm)				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Okra + Spinach	11.59^{ab}	25.25	26.71	40.65	51.85
Okra + Coriander	12.09^{a}	26.30	31.53	42.10	56.77
Okra + Amaranthus	12.06^{a}	22.71	22.79	39.80	53.35
Okra + Rayo	10.87^{bc}	23.71	23.09	42.80	58.12
Sole crop (Okra)	10.26^{c}	22.82	29.12	54.15	73.20
SEm (±)	0.35	0.70	1.86	2.62	3.80
F probability	*	Ns	Ns	Ns	Ns
LSD (=0.05)	1.10	-	-	-	-
CV (%)	6.29	10.00	37.12	17.17	20.35
Grand Mean	11.37	24.15	25.85	43.9	58.66

Note: DAS = Days after sowing, Ns = Non-significant, SEM = Standard Error of Mean, LSD = Least Significant Difference, CV(%)= Coefficient of Variation, treatment means sharing common letter (s) within each column are not statistically differ among each other at 5% level by Duncan Multiple Range Test (DMRT), * Significant at 5%.

Leaf Area Index (LAI)

The leaf area index varied significantly at 30, 45 and 60 DAS. The highest LAI was found in sole crop (T5), followed by okra + rayo (T4) and the lowest was found in okra + Spinach (T1).

Greater leaf area index in the control is a result of more photosynthetically active leaf area and higher leaf area per unit ground area. This helped assimilate translocation from source to sink, eventually increasing yield (Kumar & Kerketta, 2019). Comparable suppression has been documented with cassava at Umudike, where Okra LAI declined relative to sole crop within 10 weeks after planting (Muoneke & Mbah, 2007).

Table 2. Effect of intercropping different leafy vegetables on Leaf Area Index of Okra

Treatment	Leaf Area Index				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Okra + Spinach	0.028^{b}	0.139^{b}	0.428^{b}	0.920	0.664
Okra + Coriander	0.029^{b}	0.152^{b}	0.548^{b}	1.028	0.729
Okra + Amaranthus	0.033^{b}	0.153^{b}	0.556^{b}	1.094	0.746
Okra + Rayo	0.029^{b}	0.217^{ab}	0.706^{b}	1.263	0.771
Sole crop (Okra)	0.041^{a}	0.373^{a}	1.037^{a}	1.466	0.844
SEm (±)	0.008	0.161	0.319	-	-
F probability	*	*	*	NS	NS
LSD (=0.05)	0.002	0.043	0.105	0.095	0.029
CV (%)	15.476	50.807	31.649	22.726	26.435
Grand Mean	0.032	0.206	0.655	1.154	0.751

Note: DAS = Days after sowing, Ns = Non-significant, SEM = Standard Error of Mean, LSD= Least Significant Difference, CV(%)= Coefficient of Variation, treatment means sharing common letter (s) within each column are not statistically different from each other at 5% level by Duncan Multiple Range Test (DMRT),* Significant at 5%.

Yield Parameters

The leaf area index varied significantly at 30, 45 and 60 DAS. The highest LAI was found in sole crop (T_5), followed by okra + rayo (T_4) and the lowest was found in okra + Spinach (T_1).

Fruit weight (g)

Fruit weight varied significantly at 80 and 90 DAS, where the highest fruit weight was found in sole cropping (T_5) compared to intercropping treatments.

Leafy intercrops form a dense ground cover once established. This cover competes with okra for soil water and nutrients. The reduced resource supply per plant shows up most clearly in fruit-filling traits, not in vegetative growth (Muoneke & Mbah, 2007; Moonmoon, 2025).The effect appeared only after 80 DAS. This timing fits a known pattern that reproductive sinks are more sensitive to resource limitation than early vegetative growth. Fruit dry-matter accumulation depends on current photosynthate supply rather than on stored reserves (Lithourgidis et al., 2011).

Table 3. Effect of intercropping different leafy vegetables on the fruit weight (g) of Okra

Treatment	Fruit weight (g)				
	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Okra + Spinach	12.42	16.23	14.71	15.31^{b}	14.18^{b}
Okra + Coriander	14.06	16.85	14.14	15.07^{b}	15.61^{b}
Okra + Amaranthus	12.02	15.82	14.76	16.20^{b}	14.24^{b}
Okra + Rayo	14.17	14.87	14.48	15.11^{b}	15.96^{b}
Sole crop (Okra)	16.18	19.34	16.51	18.53^{a}	18.88^{a}
SEm (±)	0.74	0.75	0.41	0.65	0.85
F probability	Ns	Ns	Ns	*	*
LSD (=0.05)	-	-	-	1.96	2.74
CV (%)	14.17	14.33	13.87	7.94	11.30
Grand Mean	13.77	16.62	14.92	16.04	15.77

Note: DAS = Days after sowing, Ns = Non-significant, SEM = Standard Error of Mean, LSD = Least Significant Difference, CV(%)= Coefficient of Variation, treatment means sharing common letter (s) within each column are not statistically differ among each other at 5% level by Duncan Multiple Range Test (DMRT), * Significant at 5%.

Total yield (t ha^{-1})

Total yield in plots varied significantly at 60 and 70 DAS, where the highest value was found in sole cropping (T_5). All four intercrops produced lower per-harvest okra yield. Sole cropping okra had no interspecific competitor, leaving more soil moisture, nutrients and light available per okra plant, and consequently higher per-plant fruit yield. Similar findings have been reported by Ahmed et al. (2013).

Table 4. Effect of intercropping different leafy vegetables on total yield (t ha^{-1}) of Okra

Treatment	Yield (t ha^{-1})				
	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Okra + Spinach	0.56	0.42^{b}	0.27^{b}	0.38	0.39
Okra + Coriander	0.57	0.48^{b}	0.24^{b}	0.42	0.44
Okra + Amaranthus	0.41	0.42^{b}	0.31^{b}	0.48	0.35
Okra + Rayo	0.46	0.32^{b}	0.27^{b}	0.46	0.40
Sole crop (Okra)	0.74	0.87^{a}	0.52^{a}	0.58	0.60
SEm (±)	0.05	0.09	0.05	0.03	0.04
F probability	Ns	**	*	Ns	Ns
LSD (=0.05)	-	0.25	0.17	-	-
CV (%)	42.97	32.16	35.53	28.23	36.47
Grand Mean	0.55	0.51	0.32	0.46	0.44

Note: DAS = Days after sowing, Ns = Non-significant, SEM = Standard Error of Mean, LSD = Least Significant Difference, CV(%)= Coefficient of Variation, treatment means sharing common letter (s) within each column are not
statistically differ from each other at 5% level by Duncan Multiple Range Test (DMRT),** Significant at 1%, * Significant at 5%.

Okra Equivalent Yield and Benefit Cost Ratio (BCR)

Both Okra Equivalent Yield varied significantly (P<0.001). It was found to be highest at okra + spinach (T_1), followed by okra + coriander (T_2).

Okra + spinach treatment followed by okra + coriander combination achieved more efficient use of growth resources (light, nutrients and soil moisture) and better temporal complementarity than other treatments (Willey, 1979; Lithourgidis et al., 2011). Ahmed et al.,(2013) also recorded the highest okra-equivalent yield in okra + red-amaranth and okra + leaf-amaranth combinations and the highest BCR (5.66) in okra + red-amaranth, with the additional vegetable yield offsetting the reduction in sole-okra yield. The lower OEY and BCR of okra + rayo (12.41 t ha⁻¹; BCR 1.78) are consistent with rayo's lower local market price and lower marketable biomass relative to spinach and coriander.

The higher benefit-cost ratio in both reflects low additional input cost required for these intercrops (same land, similar cultural operations), combined with the relatively high market value and quick turnover of leafy vegetables.

Table 5. Effect of intercropping different leafy vegetables on okra equivalent yield and benefit-cost ratio of okra

Treatment	OEY (t ha^{-1})	B : C ratio
Okra + Spinach	37.833^{a}	4.593^{a}
Okra + Coriander	29.111^{b}	3.725^{b}
Okra + Amaranthus	22.178^{c}	3.089^{b}
Okra + Rayo	12.418^{d}	1.784^{c}
Sole crop (Okra)	6.648^{d}	1.108^{c}
SEm (±)	6.162	0.797
F probability	***	***
LSD (=0.05)	5.604	0.633
CV (%)	18.486	18.106
Grand Mean	21.637	2.860

Note: DAS= Days after sowing, SEM= Standard Error of Mean, LSD= Least Significance Difference, CV(%)= Coefficient of Variation, treatment means sharing common letter (s) within each column are not statistically differ among each other at 5% level by Duncan Multiple Range Test (DMRT);***Significant at 0.1%.

CONCLUSION

Okra yield, fruit weight, and leaf area index were highest under sole cropping, showing the absence of interspecific competition for light, water, and nutrients. However, in terms of okra-equivalent yield (OEY) and benefit–cost ratio (BCR), every intercropping treatment outperformed the sole crop. Okra + spinach gave the highest OEY (37.83 t ha⁻¹) and BCR (4.59), 469% gain in OEY over sole okra (6.65 t ha⁻¹; BCR 1.11), followed by okra + coriander (29.11 t ha⁻¹; BCR 3.73) and okra + amaranthus (22.18 t ha⁻¹; BCR 3.09). The early plant-height advantage of intercropped okra at 30 DAS, attributable to a shade-avoidance response, did not persist beyond canopy closure of the leafy intercrops, indicating only a transient morphological influence on the main crop.

Therefore, intercropping okra with spinach (and secondarily coriander) is recommended for smallholder farmers in the Terai region of Nepal as a low-input strategy to diversify production, improve land-use efficiency, and substantially raise farm-level economic returns. Future studies should examine multi-season performance, soil-nutrient dynamics, and additional leafy-vegetable cultivars to validate these findings across the wider mid-Terai zone.

CONFLICT OF INTEREST

The author here declares there is no conflict of interest in the publication of this article.

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