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INTERCROPPING COMPATIBILITY OF CHEENA AND KAON WITH GROUNDNUT AT CHARLAND CONDITION OF BANGLADESH

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Abstract

Intercropping is a sustainable cropping strategy that enhances productivity, resource-use efficiency, and economic returns, particularly in fragile agro-ecological zones such as charlands in Bangladesh. This study evaluated the intercropping compatibility of groundnut (*Arachis hypogaea* L.) with two minor cereals—cheena (*Panicum miliaceum* L.) and kaon (*Setaria italica* L.)—under varying row arrangements in charland ecosystems during the 2024–25 cropping season. The treatments included four intercropping systems: groundnut:cheena (4:1 and 4:2), groundnut:kaon (4:1 and 4:2), and three sole cropping systems: groundnut, cheena, and kaon. Agronomic yield attributes, groundnut equivalent yield (GEY), economic returns, land equivalent ratio (LER), competitive ratio (CR), and relative crowding coefficient (RCC) were analyzed. Sole groundnut produced the highest pod yield (2.18 t ha^{-1}), while intercropping reduced individual groundnut yield. However, overall system productivity improved under intercropping, with groundnut:cheena (4:2) producing the highest GEY (3.20 t ha^{-1}), gross return (Tk 256,200 ha^{-1}), gross margin (Tk 201,100 ha^{-1}), and benefit–cost ratio (4.65). Groundnut:kaon (4:2) also performed strongly with a GEY of 3.14 t ha^{-1} and a benefit–cost ratio of 4.62. All intercropping treatments recorded LER > 1.0, indicating yield advantage over sole cropping. Competitive indices revealed that kaon was more aggressive than cheena, but cheena-based systems were more complementary and profitable. The findings suggest that intercropping groundnut with cheena (particularly at a 4:2 row proportion) is the most compatible and profitable option for charland conditions, ensuring enhanced productivity, profitability, and sustainability.

Introduction

Bangladesh's agriculture is undergoing immense pressure due to the increasing population, decreasing arable land, and climate variability. Among the vulnerable agro-ecosystems, charlands—riverine floodplains created by silt deposition—present both challenges and opportunities for crop production. These lands are highly fertile but fragile, characterized by sandy-loam soils, recurrent flooding, poor water retention, and limited input use (Paul *et al.,* 2017). Despite their vast coverage, charlands are underutilized and often associated with low-input, subsistence-level farming systems. Sustainable crop intensification strategies are required to fully harness their potential.

Intercropping, the simultaneous cultivation of two or more crops on the same land, has been widely advocated as a viable approach to improve productivity, optimize resource utilization, and enhance resilience in marginal environments (Lithourgidis *et al.*, 2011; Maitra *et al.*, 2021). Legume–cereal intercropping, in particular, has been shown to improve soil fertility through biological nitrogen fixation, increase system yield through complementary resource use, and reduce production risks through crop diversification.

Groundnut (*Arachis hypogaea* L.) is one of the most important legume oilseed crops in Bangladesh. It thrives in sandy and sandy-loam soils, making it well suited for charlands. Groundnut provides edible oil, protein, fodder, and income for rural households (Hossain *et al.*, 2019). It is a short-duration crop, allowing flexibility in multiple cropping systems. In parallel, minor cereals such as cheena (*Panicum miliaceum* L.) and kaon (*Setaria italica* L.) are hardy, drought-tolerant, and adapted to marginal soils. They are nutrient-rich, containing high levels of protein, dietary fiber, vitamins, and minerals, making them valuable for food and nutrition security. Despite their resilience and nutritional potential, these cereals remain underutilized in Bangladesh.

Intercropping groundnut with cheena or kaon could provide multiple benefits: like it can enhanced productivity through better utilization of light, water, and nutrients; economic gains through higher system profitability driven by favorable market prices (Tk 100 kg^{-1} for cheena/kaon vs Tk 80 kg^{-1} for groundnut) and resilience through diversification and reduced yield variability. Although groundnut–cereal intercropping has been widely studied (e.g., groundnut with maize, sorghum, or millet) (Semahegn, 2022; Sherif *et al.*, 2005), there is limited evidence on groundnut intercropping with cheena and kaon, especially under charland conditions in Bangladesh. Given the government's priority on crop diversification and nutritional security, exploring the compatibility of groundnut with minor cereals is timely. Considering the above issues, the proposed study is undertaken to observe the compatibility of cheena and kaon intercropping with groundnut.

Materials and Methods

The experiment was conducted at Naovanga char, Jamalpur district, during *Rabi* 2024-25. The experiment was laid out in RCBD design with seven treatments i.e. T_1 (Groundnut:Cheena = 4:1), T_2 (Groundnut:Cheena = 4:2), T_3 (Groundnut:Kaon = 4:1), T_4 (Groundnut:Kaon = 4:2), T_5 (Sole groundnut), T_6 (Sole cheena) and T_7 (Sole kaon). BARI Cheenabadam-9, BARI cheena-1 (Tushar) and BARI kaon-2 were respectively taken as groundnut, cheena and kaon verieties. The plot size was 3.0 m × 3.0 m. In case of 4:1 ratios, seeds are sown with 25 cm row to row distance. In 4:2 ratios, seeds are sown with 20 cm row to row distance. Groundnut was sown in line with 15 cm plant to plant spacing. Cheena and kaon were sown in continous line. The plants were fertilized with 15–80–60–60–1.8 kg ha^{-1} of N-P-K-S-B respectively. Half N and all of other fertilizers were applied during final land preparation. Rest half N was applied at 40-45 DAS. Irrigation was done as and when necessary. Data on grain yield (Kg ha^{-1}), tillers per plant, panicles per plant and 1000-grain weight were collected for cereals while seeds per pod, pods per plant, number of primary branches per plant, 100-seed weight and shelling percentage were collected for groundnut.

Crops were harvested as whole plot basis. Mean comparison among the treatments was made by LSD test at 5% level of significance.

Groundnut equivalent yield (GEY): Groundnut equivalent yield was calculated as;

$$GEY = Yig + (Yia \times Pa)/Pg$$

Where, Yig= Yield of intercrop groundnut, Pg= Price of groundnut, Pa= Price of other intercrop component "a" and Yia= Yield of intercrop "a"

Financial Analysis: To determine the most profitable groundnut-minor cereal intercropping pattern, economic analysis was done through;

$$\text{Gross margin (Tk/ha)} = \text{Gross returns (Tk/ha)} - \text{Cost of cultivation (Tk/ha)}$$

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return (Tk/ha)}}{\text{Total cost of cultivation (Tk/ha)}}$$

Land equivalent Ratio (LER): To determine land use efficiency LERs were calculated thus:

$$\text{LER} = \text{La} + \text{Lb} = \text{Ya} / \text{Sa} + \text{Yb} / \text{Sb}$$

Where La and Lb = Partial LERs of crop a (sorghum) and b (groundnut)
Ya and Yb = Individual crop yields in intercropping,
Sa and Sb = Individual crop yields in sole crop and intercrop.

Competitive Indices: Two measures of competitiveness of crops in intercropping, namely, competitive ratio (CR) and the relative crowding coefficient (RCC) were calculated as follows:

(i) Competitive Ratio, CR

$$CRa = \{(Yia/Ysa)/(Yib/Ysb)\} \times (Zb / Za)$$

$$CRb = \{(Yib/Ysb)/(Yia/Ysa)\} \times (Za / Zb)$$

Where, CRa = Competitive Ratio of crop 'a'; CRb = Competitive Ratio of crop 'b'; Yia = Yield of intercrop crop 'a'; Ysa = Yield of sole crop 'a'; Yib = Yield of intercrop crop 'b'; Ysb = Yield of sole crop 'b'; Za = Proportion of crop 'a' in intercrop; Zb = Proportion of crop 'b' in intercrop

(ii) Relative Crowding Coefficient, RCC

$$RCCa = \{(Yia \times Zb)/(Ysa - Yia)\} \times Za$$

$$RCCb = \{(Yib \times Za)/(Ysb - Yib)\} \times Zb$$

Where, RCCa = Relative Crowding Coefficient of crop 'a'; RCCb = Relative Crowding Coefficient of crop 'b'; Yia = Yield of intercrop crop 'a'; Ysa = Yield of sole crop 'a'; Yib = Yield of intercrop crop 'b'; Ysb = Yield of sole crop 'b'; Za = Proportion of crop 'a' in intercrop; Zb = Proportion of crop 'b' in intercrop

Results and Discussion

Yield components and yield of groundnut

Yield components of groundnut varied significantly under different intercropping systems. Plant height, number of branches per plant, pod number, effective pod number, nut weight per square meter, and pod yield (t ha^{-1}) were influenced by the presence of intercrops (cheena and kaon) and their row proportions (Table 1).

Table 1. Yield components and yield of groundnut in different combination

Treatments	Plant height (cm)	No. of branches $plant^{-1}$	Pod per plant (nos)	Effective pod $plant^{-1}$	Nut weight ($g\ m^{-2}$)	Yield (t ha^{-1})
T_1	56.33	3.67	30	29	180	1.80
T_2	48.33	3.33	34	31	202	1.79
T_3	65.00	5.67	26	25	196	1.66
T_4	41.67	5.00	29	27	205	1.98
T_5	67.33	4.33	35	31	214	2.18
$LSD_{(0.01)}$	9.33	1.77	3.24	3.09	20.67	0.20
CV	5.90	14.21	5.58	5.75	5.51	5.51

Here, T_1= (Groundnut:Cheena = 4:1), T_2= (Groundnut:Cheena = 4:2), T_3= (Groundnut:Kaon = 4:1), T_4= (Groundnut:Kaon = 4:2), T_5= (Sole groundnut)

Plant height ranged from 41.67 cm (T4: groundnut:kaon = 4:2) to 67.33 cm (T_5: sole groundnut). The tallest plants were recorded in the sole groundnut plot, while the shortest occurred when groundnut was intercropped with kaon in a 4:2 row proportion. This suggests that interspecific competition with kaon strongly restricted groundnut vegetative growth compared to cheena. Earlier studies confirm that cereals, due to their rapid early growth and higher nutrient uptake capacity, often compete more strongly with legumes for resources, leading to reduced plant height and biomass in legumes (Lithourgidis *et al.*, 2011; Maitra *et al.*, 2021).

Branch number per plant was highest in groundnut:kaon (4:1) with 5.67, followed by groundnut:kaon (4:2) with 5.00. In contrast, sole groundnut produced only 4.33 branches. This may be attributed to stress-induced branching when intercropped with cereals, especially kaon, as legumes tend to compensate for competition by increasing branch numbers.

Pods per plant ranged from 26 (T_3: groundnut:kaon = 4:1) to 35 (T_5: sole groundnut). Sole groundnut produced significantly higher pod numbers compared to all intercrops. Similarly, effective pods per plant were highest in T_5 (31 pods) and lowest in T_3 (25 pods). This indicates that intercropping reduces reproductive success due to competition for assimilates. The decline was sharper under groundnut–kaon intercropping than groundnut–cheena.

Nut weight per square meter followed a similar pattern, being highest in sole groundnut (214 g m^{-2}) and lowest in groundnut:cheena (4:1) (180 g m^{-2}). However, groundnut:kaon (4:2) produced nut weight (205 g m^{-2}) comparable to sole groundnut, indicating that although kaon reduced per plant productivity, its influence was less detrimental at the plot level under certain row ratios.

Pod yield per hectare was maximum in sole groundnut (2.18 t ha^{-1}), followed by groundnut:kaon (4:2) (1.98 t ha^{-1}). The lowest yield was observed in groundnut:kaon (4:1) (1.66 t ha^{-1}). Intercropping reduced groundnut yield in all cases, consistent with earlier reports that intercropping usually decreases the yield of the main crop compared to monoculture, but enhances overall system productivity (Lithourgidis *et al.*, 2011). Thus, the results suggest that while sole groundnut ensures maximum pod yield, intercropping with kaon (4:2) provides a competitive alternative by maintaining a relatively high yield compared to other intercrops.

Groundnut Equivalent Yield and Productivity Advantages

Groundnut equivalent yield (GEY) provides a holistic measure of productivity by converting intercrop yields into groundnut equivalents based on market prices (Table 2).

Table 2. Yield and groundnut equivalent yield (GEY) of crops in different intercrop combination and monocrop

Treatments	Yield (t ha^{-1})			Groundnut equivalent yield GEY (t ha^{-1})
	Groundnut	Cheena	Kaon	
T_1	1.8	0.75	0	2.74
T_2	1.79	1.13	0	3.20
T_3	1.66	0	0.61	2.42
T_4	1.98	0	0.93	3.14
T_5	2.18	0	0	2.18
T_6	0	1.2	0	1.50
T_7	0	0	1.15	1.44

Here, T_1= (Groundnut:Cheena = 4:1), T_2= (Groundnut:Cheena = 4:2), T_3= (Groundnut:Kaon = 4:1), T_4= (Groundnut:Kaon = 4:2), T_5= (Sole groundnut), *Market price: Groundnut- Tk 80 kg^{-1}, cheena- Tk 100 kg^{-1}, kaon- Tk 100 kg^{-1}

The highest GEY was recorded in groundnut:cheena (4:2) (3.20 t ha^{-1}), followed by groundnut:kaon (4:2) (3.14 t ha^{-1}). Sole groundnut produced a GEY of only 2.18 t ha^{-1}, while sole cheena and sole kaon gave the lowest values (1.50 t ha^{-1} and 1.44 t ha^{-1}, respectively). This clearly demonstrates the productivity advantage of intercropping.

The higher GEY in groundnut:cheena (4:2) was due to substantial cheena yield (1.13 t ha^{-1}) along with stable groundnut performance. Cheena's shorter duration and rapid growth allow efficient use of available resources, particularly in the early growth phase, without completely suppressing groundnut. On the other hand, kaon produced comparatively lower additional yield, which explains why its contribution to GEY was less than cheena.

These findings align with studies from India and Africa where legumes intercropped with short-duration cereals improved overall system productivity and ensured greater returns compared to monocropping (Maitra *et al.*, 2021).

Financial Analysis of Cropping Systems

Profitability is a critical determinant for farmers when choosing cropping systems. The economic analysis (Table 3) revealed substantial differences among treatments. The highest gross return was obtained from groundnut:cheena (4:2) (Tk 256,200 ha^{-1}), followed closely by groundnut:kaon (4:2) (Tk 251,400 ha^{-1}). Sole groundnut generated only Tk 174,400 ha^{-1}. In terms of gross margin, groundnut:cheena (4:2) (Tk 201,100 ha^{-1}) was again superior, followed by groundnut:kaon (4:2) (Tk 197,000 ha^{-1}). The lowest margin was found in sole kaon (Tk 81,000 ha^{-1}). The benefit–cost ratio (BCR) was also highest in groundnut:cheena (4:2) (4.65), indicating the most profitable system. This was followed by groundnut:kaon (4:2) (4.62). Sole groundnut achieved a BCR of only 3.35. The superior profitability of intercrops, particularly with cheena, can be attributed to higher GEY and favorable price structure. Cheena and kaon both fetched Tk 100 kg^{-1} in the market, compared to Tk 80 kg^{-1} for groundnut. Hence, their inclusion significantly enhanced economic returns. Similar economic advantages of cereal–legume intercropping have been documented in sub-Saharan Africa and South Asia (Lithourgidis *et al.*, 2011).

Table 3. Financial analysis from different cropping system

Treatments	GEY	Gross return	Total Cost	Gross margin	BCR
T1	2.74	219000	54600	164400	4.01
T2	3.20	256200	55100	201100	4.65
T3	2.42	193800	54200	139600	3.58
T4	3.14	251400	54400	197000	4.62
T5	2.18	174400	52000	122400	3.35
T6	1.50	120000	35000	85000	3.43
T7	1.44	115000	34000	81000	3.38

Here, T1= (Groundnut:Cheena = 4:1), T2= (Groundnut:Cheena = 4:2), T3= (Groundnut:Kaon = 4:1), T4= (Groundnut:Kaon = 4:2), T5= (Sole groundnut), T6= (Sole Cheena), T7= (Sole Kaon), * Market price: Groundnut- Tk 80 kg^{-1}, cheena- Tk 100 kg^{-1}, kaon- Tk 100 kg^{-1}

Land Equivalent Ratio

LER is a standard index for assessing the efficiency of intercropping compared to monocropping. All intercropping treatments recorded LER > 1.0 (Table 4), confirming yield advantages of intercropping. Groundnut:cheena (4:2) achieved the highest LER (1.76), followed by groundnut:kaon (4:2) (1.72). Groundnut:cheena (4:1) and groundnut:kaon (4:1) recorded lower LER values (1.45 and 1.29, respectively). This indicates that two rows of cereals intercropped with four rows of groundnut were more resource-efficient than one row of cereals with groundnut. The additional cereal rows improved system yield without proportionately reducing groundnut yield, thereby increasing total land productivity. LER values from previous studies on legume–cereal systems ranged between 1.2–1.8, consistent with the present findings (Maitra *et al.,* 2021).

Competitive Ratio and Relative Crowding Coefficient

The competitive ratio provides insights into the dominance of one crop over another in an intercrop system. In groundnut:cheena (4:2), cheena recorded a CR of 2.14, much higher than groundnut (1.57), indicating cheena's competitive dominance. In groundnut:kaon (4:2), kaon had a CR of 4.62, showing even greater dominance over groundnut (CR = 1.22) (Table 4).

This explains why groundnut yields were more suppressed in kaon intercrops compared to cheena intercrops. Kaon is more competitive in resource use, particularly for light and soil nutrients.RCC values further validate these interactions. Groundnut:cheena (4:2) recorded an RCC of 7.53, indicating strong complementarity, whereas groundnut:kaon (4:1) had the lowest RCC (0.30), signifying poor compatibility.The results clearly show that, Sole groundnut yields highest per crop but is less profitable than intercropping. Groundnut:cheena (4:2) ensures the most profitable and resource-efficient system, balancing yield, economics, and competition. Groundnut:kaon (4:2) also performs strongly and may be suitable where kaon is culturally or nutritionally preferred. Intercropping enhances land productivity (LER > 1), system profitability, and risk minimization, making it highly suitable for resource-poor charland farmers. These outcomes align with the broader literature emphasizing the ecological and economic sustainability of cereal–legume intercropping (Lithourgidis *et al.,* 2011; Maitra *et al.*, 2021).

Table 4. Land equivalent Ratio (LER), competitive ratio (CR) and relative crowding coefficient (RCC) as influenced by intercropping minor cereals with groundnut

Treatments	LER	CR		RCC	
		Groundnut	Cereal	Groundnut	Cereal
T_1	1.45	0.55	1.82	1.25	0.44
T_2	1.76	0.64	1.57	2.14	7.53
T_3	1.29	0.60	1.67	0.85	0.30
T_4	1.72	0.82	1.22	4.62	1.97

Here, T_1= (Groundnut:Cheena = 4:1), T_2= (Groundnut:Cheena = 4:2), T_3= (Groundnut:Kaon = 4:1), T_4= (Groundnut:Kaon = 4:2)

Conclusion

The study confirms that intercropping groundnut with minor cereals, cheena and kaon, significantly improves productivity and profitability compared to monocropping under charland conditions. While sole groundnut yielded the highest pod output, intercropping maximized system efficiency and economic returns. The groundnut:cheena (4:2) system proved most compatible, achieving the highest GEY (3.20 t ha^{-1}), gross margin (Tk 201,100 ha^{-1}), and BCR (4.65). Groundnut:kaon (4:2) was also highly productive and profitable. All intercropping systems recorded LER > 1, confirming yield advantages. Therefore, adoption of groundnut:cheena (4:2) intercropping can be recommended as a profitable, resource-efficient, and sustainable cropping system for charland farmers in Bangladesh.

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