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Profitability and Agronomic Performance Assessment of Chickpea and Linseed Intercropping with Different Row Ratios

Md. Jahidul Amin,* A.F.M. Moniruzzaman, Md. Zainul Abedin Tanvir and Md. Rashedur Rahman

Department of Agriculture, Rabindra Maitree University, Kushtia-7000, Bangladesh

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***Corresponding author:**
jahidulamin1963@gmail.com

A b s t r a c t

This study investigates the performance of chickpea (*Cicer arietinum* L.) and linseed (*Linum usitatissimum* L.) intercropping at various row ratios to determine the optimal configuration for maximizing yield and economic returns in Bangladesh. Conducted at the Bangladesh Agricultural Research Institute (BARI) from November 1987 to April 1988, the experiment employed a Randomized Complete Block Design (RCBD) with eight treatments: T_1 (sole chickpea, 100%), T_2 (chickpea 4 rows: linseed 1 row), T_3 (chickpea 1 row: linseed 1 row), T_4 (chickpea 1 row: linseed 4 rows), T_5 (sole linseed, 100%), T_6 (chickpea 2 rows: linseed 3 rows), T_7 (chickpea 3 rows: linseed 2 rows), and T_8 (chickpea 2 rows: linseed 2 rows). The results indicated significant influences of intercropping on agronomic traits, yield attributes, and economic outcomes. The combination of three rows of chickpea with two rows of linseed (T_7) yielded the highest chickpea equivalent yield (1.57 tons/ha) and the highest Land Equivalent Ratio (LER) of 1.38, surpassing sole cropping systems. Economic analysis revealed that T_7 also provided the highest net return (Tk. 11,443.02/ha) and benefit-cost ratio (2.55). These findings demonstrate that intercropping chickpea and linseed can effectively enhance productivity and profitability. Further research is recommended to validate these results across different agroecological zones and cropping seasons.

Keywords: Chickpea, Linseed, Intercropping, Yield optimization and Economic analysis

Introduction

Agriculture has long served as the backbone of Bangladesh's economy, providing livelihood opportunities and ensuring economic stability. In 1987, the country had a total cultivated area of 9.1 million hectares (BBS, 1987). At that time, the agricultural sector contributed about 57% of the gross domestic product (GDP) and supported nearly 80% of the population either directly or indirectly. However, the availability of arable land has been steadily shrinking due to rapid urbanization and industrial expansion. This reduction in cultivable land coincides with a rapidly growing population, creating mounting pressure on food production systems. As a result, Bangladesh faces an annual food deficit estimated between 1.5 and 2.0 million tons (Islam, 1985). Addressing this gap requires strategies to enhance agricultural productivity.

Two approaches can be pursued to increase food production: horizontal expansion, which involves bringing more land under cultivation, and vertical intensification, which focuses on raising yield per unit area per unit time. Given the limitations of land resources, vertical growth is considered more viable. Intercropping—defined as the simultaneous cultivation of two or more crops on the same piece of land—has emerged as a promising strategy to enhance productivity. Studies have shown that intercropping not only increases total production per hectare but also improves economic returns compared to sole cropping (Zandstra, 1979; Willey, 1979; Evans, 1980).

In Bangladesh, the challenge of limited irrigation facilities, particularly for resource-poor and marginal farmers, underscores the importance of efficient and low-input cropping systems. During the winter (rabi) season, crops such as chickpea, lentil, linseed, and mustard are predominantly grown under rainfed conditions. These crops are less input-intensive than rice and wheat, making them suitable for smallholder farmers. However, intercropping is often practiced with higher-than-optimal seed rates for component crops, which may reduce overall efficiency and yields.

Against this backdrop, the present study was undertaken to evaluate the agronomic performance and profitability of chickpea (*Cicer arietinum* L.) and linseed (*Linum usitatissimum* L.) intercropping under different row ratios. The objective is to identify optimal planting arrangements that maximize both yield and economic returns, thereby contributing to sustainable intensification of crop production in Bangladesh.

Materials and Methods

Location and Time: The research was conducted at the experimental farm of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, from November 27, 1987, to April 4, 1988. The experiment took place on high land (Block No. 11) of BARI's Central Research Farm.

Climate of the Area: The experimental site experiences heavy rainfall from April to September, with scant rainfall during the rest of the year. The mean total rainfall recorded from November to April was 318.2 mm. Relative humidity, temperature, and rainfall data during the experiment are detailed in Appendix-1.

Experimental Treatments and design: The experiment was conducted based on the eight treatments viz. T_1=Sole chickpea (100%), 30 cm apart, T_2=Chickpea 4 rows : linseed 1 row. T_3=Chickpea 1 row: linseed 1 row (alternate rows), T_4:=Chickpea 1 row : linseed 4 rows, T_5=Sole linseed (100%), 30 cm apart, T_6= Chickpea 2 rows : linseed 3 rows, T_7=Chickpea 3 rows : linseed 2 rows and T_8= Two rows of chickpea alternated with two rows of linseed. The experiment was laid out in a randomized complete block (RCBD) design with four replications. Each plot measured 5m x 3m.

Agronomic practices for crop production

Land Preparation: The land was initially plowed on November 17, 1987, using a tractor-drawn disc plow, followed by harrowing. A power tiller was used for finer tilth, and the land was leveled using a ladder.

Fertilizer Application: Fertilizers, namely N, P, K, S, and Zn, were applied at rates of 30, 40, 20, 20, and 8 kg/ha respectively, in the forms of urea, triple superphosphate, muriate of potash, gypsum, and zinc sulfate. These were placed in rows adjacent to the seeds during sowing.

Seed Sowing: Seeds of chickpea variety 'Nabin' and linseed variety 'P-14-25' were sown on November 27, 1987. V-shaped furrows, 10 cm deep and 30 cm apart, were made using a country plough. A funnel with a long tube was used to drop seeds uniformly. Chickpea and linseed seeds were sown at rates of 35 kg/ha and 15 kg/ha, respectively. Post-sowing irrigation was applied to ensure uniform germination.

Thinning, Weeding, and Harvesting: Thinning was performed 25 days after sowing to maintain proper spacing. One weeding was done on December 22, 1987. Chickpea was harvested 116 days after sowing, and linseed was harvested after 130 days. The pods were threshed by hand, and grains were cleaned and dried to 12% moisture content.

Data Collection and Analysis: Data on plant height, number of branches per plant, number of pods per plant, number of seeds per pod, and 1000-grain weight were collected from 25 randomly selected plants per plot. The harvested area for both chickpea and linseed was 12 m² per plot. Chickpea equivalent yield was calculated by converting linseed yield to chickpea yield based on market prices. Land equivalent ratio (LER) was determined to assess the yield advantage of intercropping. Economic analysis included gross return, variable costs, net return, and benefit-cost ratio. Statistical analysis was conducted using the F test and Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Dicussions

Agronomic Characters of Chickpea

Plant Height: The height of chickpea plants was also not significantly affected by the different treatments (Figure 1). The tallest plants (47.0 cm) were observed in T_7 (chickpea 3 rows: linseed 2 rows), followed by the sole chickpea (46.7 cm). The shortest plants (42.18 cm) were found in T_4 (chickpea 1 row: linseed 4 rows). The variation in plant height among treatments might be attributed to intra-row competition for light.

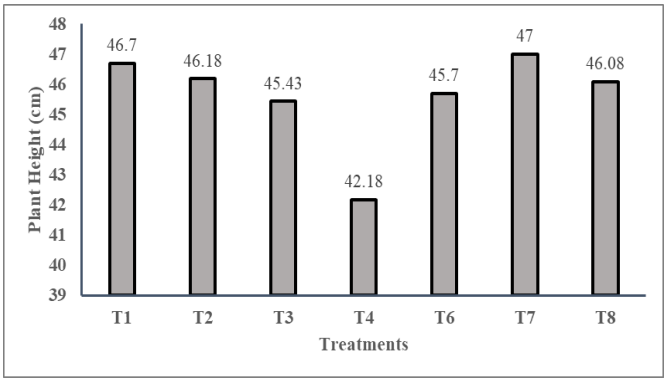

Figure 1: Plant height of chickpea in linseed intercropping

Plant Population: The plant population of chickpea was not significantly affected by the different treatments (Table 1). The highest plant population (278.3 plants per square meter) was recorded in T_1 (sole chickpea), followed by T_2 (chickpea 4 rows: linseed 1 row) with 26.8 plants per square meter. The lowest plant population (25.9 plants per square meter) was observed in T_8 (chickpea 2 rows: linseed 2 rows).

Agronomic Characters of Linseed

Plant Height: Plant height of linseed was not significantly affected by different treatments (Figure 2). The tallest plants (68.35 cm) were observed in T_3 (chickpea 1 row: linseed 1 row), followed by T_6 (chickpea 2 rows: linseed 3 rows) with 67.28 cm. The shortest plants (63.75 cm) were recorded in T_2 (chickpea 4 rows: linseed 1 row). The variation in plant height might be due to differences in spacing, light, and nutrient availability.

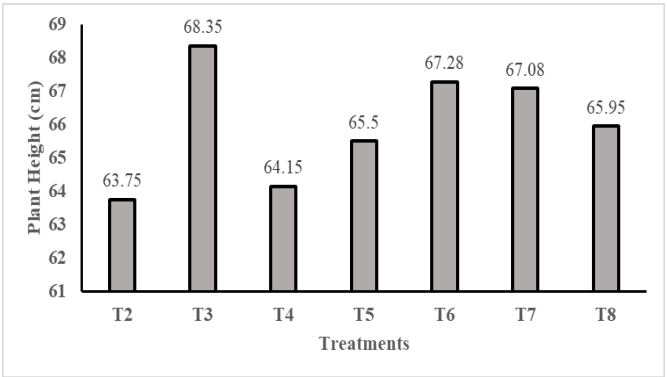

Figure 2: Plant height of linseed in chickpea intercropping

Plant Population: The plant population of linseed was not significantly influenced by the treatments (Table 2). The highest plant population (64.4 plants per square meter) was recorded in T_8 (chickpea 2 rows: linseed 2 rows). The second highest population (62.5 plants per square meter) was in T_7 (chickpea 3 rows: linseed

Table- 1: Yield and yield attributes of chickpea in linseed intercropping

Treatments	Plant population m^{-2}	Number of branches $plant^{-1}$	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})
T_1	28.3	10.40 a	104.2 a	1.5	118.51	1.48 a
T_2	26.8	10.70 a	73.5 b	1.4	117.57	1.25 b
T_3	26.4	10.30 a	68.8 b	1.4	123.79	0.97 d
T_4	27.3	7.30 b	43.8 c	1.4	119.66	0.75 e
T_6	26.7	9.6 ab	64.1 b	1.5	121.56	0.96 d
T_7	26.7	9.6 ab	95.9 a	1.4	125.09	1.38 a
T_8	25.9	9.6 ab	76.8 b	1.4	122.54	1.01 c
CV(%)	0.91	11.69	7.11	4.15	3.81	5.02

Values with different letter (s) are statistically significant as per Duncan Multiple Range Test, T_1=Sole chickpea (100%), 30 cm apart, T_2=Chickpea 4 rows : linseed 1 row. T_3=Chickpea 1 row: linseed 1 row (alternate rows), T_4:=Chickpea 1 row : linseed 4 rows, T_5=Sole linseed (100%), 30 cm apart, T_6= Chickpea 2 rows : linseed 3 rows, T_7=Chickpea 3 rows : linseed 2 rows and T_8= Two rows of chickpea alternated with two rows of linseed. CV= Coefficient of Variation

2 rows), while the lowest (49.8 plants per square meter) was observed in T_4 (chickpea 1 row: linseed 4 rows).

Yield Attributes of Chickpea

Number of Branches per Plant: The highest number of branches per plant (10.7) was found in T_2 (chickpea 4 rows: linseed 1 row), followed by the sole chickpea and T_3 (chickpea 1 row: linseed 1 row). The lowest number of branches per plant (7.3) was observed in T_4 (chickpea 1 row: linseed 4 rows). The number of branches per plant was significantly influenced by the different treatments at the 5% level of probability (Table 1).

Number of Pods per Plant: The sole chickpea had the highest number of pods per plant (104.2), followed by T_7 (chickpea 3 rows: linseed 2 rows) with 95.9 pods. The lowest number of pods per plant (43.8) was recorded in T_4 (chickpea 1 row: linseed 4 rows). The number of pods per plant was significantly affected by the different treatments at the 1% level of statistical probability (Table 1).

Number of Seeds per Pod: The number of seeds per pod was not significantly affected by the different treatments (Table 1). The highest number of seeds per pod (1.5) was recorded in the sole chickpea and T_6 (chickpea 2 rows: linseed 3 rows).

1000 Grain Weight: There was no significant difference in the 1000 grain weight among the treatments (Table 1). The highest 1000 grain weight (125.09 g) was recorded in T_7 (chickpea 3 rows: linseed 2 rows), while the lowest (117.57 g) was observed in T_2 (chickpea 4 rows: linseed 1 row).

Table-2: Yield and yield attributes of linseed in chickpea intercropping

Treatments	Plant population m^{-2}	Number of branches $plant^{-1}$	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})
T_2	56.5	5.4	69.4 b	9.3	5.18	0.24 e
T_3	59.3	5.5	101.2 a	9.3	5.49	0.57 c
T_4	49.8	5.2	75.5 b	9.3	5.52	0.86 b
T_5	50.5	4.9	64.4 b	9.4	5.51	1.01 a
T_6	56.2	5.7	83.8 ab	9.3	5.39	0.60 c
T_7	62.5	4.9	79.6 b	9.2	5.56	0.45 d
T_8	64.4	4.7	69.3 b	9.4	5.54	0.57 c
CV(%)	16.84	9.15	11.25	2.05	3.22	4.34

Values with different letter (s) are statistically significant as per Duncan Multiple Range Test, T_1=Sole chickpea (100%), 30 cm apart, T_2=Chickpea 4 rows : linseed 1 row. T_3=Chickpea 1 row: linseed 1 row (alternate rows), T_4:=Chickpea 1 row : linseed 4 rows, T_5=Sole linseed (100%), 30 cm apart, T_6= Chickpea (chickpea 4 rows: linseed 1 row).

Yield Attributes of Linseed

Number of Branches per Plant: The number of branches per plant in linseed was not significantly affected by the treatments (Table 2). The highest number of branches per plant (5.7) was recorded in T_6 (chickpea 2 rows: linseed 3 rows), while the lowest (4.7) was observed in T_8 (chickpea 2 rows: linseed 2 rows).

Number of Pods per Plant: The highest number of pods per plant (101.2) was observed in T_3 (chickpea 1 row: linseed 1 row), followed by T_6 (chickpea 2 rows: linseed 3 rows) with 83.8 pods. The lowest number of pods per plant (64.4) was recorded in the sole linseed. The number of pods per plant was significantly

Table-3: Relative yield, land equivalent ratio, chickpea equivalent yield and linseed equivalent yield

Treatments	Chickpea		Linseed		Land Equivalent Ratio	Chickpea equivalent yield (t ha^{-1})	Linseed equivalent yield (t ha^{-1})
	Grain yield (t ha^{-1})	Relative yield (t ha^{-1})	Grain yield (t ha^{-1})	Relative yield (t ha^{-1})			
T_1	1.48	1	-	-	1	1.48	3.55
T_2	1.25	0.84	0.24	0.24	1.08	1.35	3.24
T_3	0.97	0.66	0.57	0.56	1.22	1.21	2.9
T_4	0.75	0.51	0.86	0.85	1.36	1.1	2.66
T_5	-	-	1.01	1	1	0.42	1.01
T_6	0.96	0.65	0.6	0.59	1.24	1.21	2.9
T_7	1.38	0.93	0.45	0.45	1.38	1.57	3.76
T_8	1.01	0.68	0.57	0.56	1.24	1.24	2.99

T_1=Sole chickpea (100%), 30 cm apart, T_2=Chickpea 4 rows : linseed 1 row. T_3=Chickpea 1 row: linseed 1 row (alternate rows), T_4:=Chickpea 1 row : linseed 4 rows, T_5=Sole linseed (100%), 30 cm apart, T_6= Chickpea 2 rows : linseed 3 rows, T_7=Chickpea 3 rows : linseed 2 rows and T_8= Two rows of chickpea alternated with two rows of linseed.

affected by the different treatments at the 1% level of statistical probability (Table 2).

Number of Seeds per Pod: There was no significant difference in the number of seeds per pod among the treatments (Table 2). The highest number of seeds per pod (9.4) was recorded in the sole linseed and T_8 (chickpea 2 rows: linseed 2 rows).

1000 Grain Weight: The 1000 grain weight of linseed did not show significant differences among the treatments (Table 2). The highest 1000 grain weight (5.56 g) was recorded in T_7 (chickpea 3 rows: linseed 2 rows), while the lowest (5.18 g) was observed in T_2 (chickpea 4 rows: linseed 1 row).

Evaluation of Intercropping System

Relative Yield of Chickpea: In all intercrop treatments, the relative yield of chickpea was reduced compared to the sole crop (Table 3). The highest relative yield of chickpea (0.93) was obtained in T_7 (chickpea 3 rows: linseed 2 rows), while the lowest (0.51) was recorded in T_4 (chickpea 1 row: linseed 4 rows).

Relative Yield of Linseed: The relative yield of linseed varied significantly among the treatments (Table 3). The highest relative yield (1.0) was observed in the sole linseed, while the lowest (0.24) was recorded in T_2 (chickpea 4 rows: linseed 1 row).

Land Equivalent Ratio (LER): The LER was greater than 1 in all intercrop treatments, indicating a yield advantage from intercropping (Table 3). The highest LER (1.38) was obtained in T_7 (chickpea 3 rows: linseed 2 rows), followed by T_4 (chickpea 1 row.

Grain Yield of Chickpea per Hectare: The grain yield of chickpea varied significantly across different treatments (Table 4). The highest grain yield of 1.48 tons per hectare was recorded for the sole chickpea (T_1), which was notably higher than the yields obtained from intercropped treatments. This superior yield was

Table-3: Relative yield, land equivalent ratio, chickpea equivalent yield and linseed equivalent yield

Treatments	Chickpea		Linseed		Land Equivalent Ratio	Chickpea equivalent yield (t ha^{-1})	Linseed equivalent yield (t ha^{-1})
	Grain yield (t ha^{-1})	Relative yield (t ha^{-1})	Grain yield (t ha^{-1})	Relative yield (t ha^{-1})			
T_1	1.48	1	-	-	1	1.48	3.55
T_2	1.25	0.84	0.24	0.24	1.08	1.35	3.24
T_3	0.97	0.66	0.57	0.56	1.22	1.21	2.9
T_4	0.75	0.51	0.86	0.85	1.36	1.1	2.66
T_5	-	-	1.01	1	1	0.42	1.01
T_6	0.96	0.65	0.6	0.59	1.24	1.21	2.9
T_7	1.38	0.93	0.45	0.45	1.38	1.57	3.76
T_8	1.01	0.68	0.57	0.56	1.24	1.24	2.99

T_1=Sole chickpea (100%), 30 cm apart, T_2=Chickpea 4 rows : linseed 1 row. T_3=Chickpea 1 row: linseed 1 row (alternate rows), T_4:=Chickpea 1 row : linseed 4 rows, T_5=Sole linseed (100%), 30 cm apart, T_6= Chickpea 2 rows : linseed 3 rows, T_7=Chickpea 3 rows : linseed 2 rows and T_8= Two rows of chickpea alternated with two rows of linseed.

primarily attributed to a higher number of pods per plant. The second highest yield was observed in the T_7 treatment (chickpea 3 rows: linseed 2 rows), producing 1.38 tons per hectare, followed by T_2 (chickpea 4 rows: linseed 1 row) with a yield of 1.25 tons per hectare. The T_8 treatment (chickpea 2 rows: linseed 2 rows) yielded 1.01 tons per hectare, with one row of chickpea on one side and one row of linseed on the other side. The yields of T_3 (chickpea 1 row: linseed 1 row) and T_6 (chickpea 2 rows: linseed 3 rows) were similar, both at 0.97 tons per hectare, though these differences were not statistically significant. The lowest yield was recorded in T_4 (chickpea 1 row: linseed 4 rows) with 0.75 tons per hectare. These yield variations were mainly influenced by the differences in the number of branches per plant and the number of pods per plant. The effect of different row ratios on chickpea yield was statistically significant at the 1% probability level.

Grain Yield of Linseed per Hectare: The grain yield of linseed also showed significant variation among the different treatments (Table 4). The highest yield of 1.01 tons per hectare was obtained from the sole linseed (T_5), which was significantly higher than the yields from intercropped treatments. The second highest yield of 0.86 tons per hectare was recorded in T_4 (chickpea 1 row: linseed 4 rows). Significant differences were also observed among T_3 (chickpea 1 row: linseed 1 row), T6 (chickpea 2 rows: linseed 3 rows), and T_8 (chickpea 2 rows: linseed 2 rows), with T_8 having one row of chickpea on one side and one row of linseed on the other side. The yield of linseed in T_7 (chickpea 3 rows: linseed 2 rows) was 0.45 tons per hectare, while the lowest yield of 0.24 tons per hectare was recorded in T_2 (chickpea 4 rows: linseed 1 row). These yield differences were primarily due to variations in the number of pods per plant. Different row ratios significantly affected the grain yield of linseed at the 1% probability level.

Economical Analysis

Gross return: Total gross return was highest (Tk. 18810/ha) in T_7 (chickpea 3: linseed 2) followed by (Tk. 17760/ha) T_1 (sole chickpea. The lowest total gross return (Tk. 5050/ha) was obtained from the T_5 (sole linseed). Other treatments conditions were found lower gross return the sole chickpea but higher than the sole linseed (Table 4).

Total variable cost: The highest total variable cost (Tk. 7742.80/ha) was found from sole chickpea followed by T_2 (chickpea 4: linseed 1) (Tk. 7554.82/ha). The lowest total variable cost of (tk. 6800.80/ha) was recorded from sole linseed (Table 4).

Net return: The highest net return over total variable cost (Tk.11443.02/ha) was found in T_7 (chickpea3: linseed 2) followed by (Tk. 10017.20/ha) sole chickpea. The lowest net return over total variable cost (Tk. 6309.18/ha) was obtained from T_4 (chickpea 1: linseed 4). Net loss (Tk. 1750.80/ha) was recorded from the sole linseed (Table 4).

Benefit cost ratio: The highest B/C ratio (2.55) was obtained from treatment T_7 (chickpea 3: linseed 2 rows) followed by (2.29) treatment T_1 (sole chickpea). The lowest B/C ratio (0.74) was obtained from T_5 (sole linseed) Table 4. This clearly shows that net return can be increased considerably if chickpea is intercropped with linseed. Similar results were also obtained by Tarhalker and Rao (1979), Rahman *et. Al.,* (1982), from the intercrop combination of different crops.

Conclusions

The intercropping of chickpea and linseed in a 3:2 row ratio (T_7) proved most effective, producing a higher chickpea equivalent yield (1.57 t/ha) than sole chickpea (T_1). All intercropping systems demonstrated land-use advantages, with Land Equivalent Ratios (LER) exceeding those of monocropping. Notably, T_7 achieved the highest LER alongside the greatest net monetary return, underscoring its superiority in both productivity and profitability. These results indicate that chickpea–linseed intercropping can enhance yield and economic returns compared to monoculture systems. Nonetheless, further multi-location and multi-season studies are recommended to confirm the stability and broader applicability of these findings.

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