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Comparative assessment of mixed and intercropping of lentil (*Lens culinaris*) and sunflower (*Helianthus annuus*)

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ABSTRACT

An experiment was conducted at Rural Development Academy (RDA) Agricultural Farm, Gopalgonj located in southern area of Bangladesh during 01 November, 2024 to 31 May, 2025 to estimate the impact of mixed cropping and intercropping patterns on yield attributes of lentil and sunflower, to calculate the Gross return (GR), Land equivalent ratio (LER), Monetary advantage and Benefit Cost Ratio (BCR) of mixed and intercropping. BINA Mashur-8 and BARI Sunflower-3 were used for the experiment. There were 11 treatments which consisted of different combinations of mixed cropping, intercropping and sole cropping of lentil and sunflower. The maximum seed yield of lentil was recorded with T_{10} (2078 kg/ha) where 1:0 row system of lentil: sunflower (line sown sole lentil) was applied, and the maximum grain yield was recorded with T_{11} (1885 kg/ha) where 0:1 row system of lentil: Sunflower (Line sown sole sunflower) was applied. The highest monetary advantage was obtained (55%) in treatment T_3, i.e. 100% Lentil+40% sunflower. It was revealed that the treatment lentil 100% + sunflower 40% had the highest land equivalent ratio (1.51) indicating 51% area advantage over sole cropping of lentil. The highest gross return (215700 Tk/ha) was also recorded from the same treatment Moreover; the treatment contributed the highest benefit cost ratio (1.86). The farmers can cultivate lentil and sunflower simultaneously in this combination (100% lentil and 40% sunflower) due to highest monetary advantage, highest land use efficiency and highest economic return.

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INTRODUCTION

Lentil (*Lens culinaris*) also called as "masur" is an important pulse crop of Bangladesh. It is a cheap and vital protein source for low- and medium-income people and so it is often called the poor man's meat. Among the pulses, lentils occupied 40.23% cultivation of pulse crops getting first position in our country (BBS, 2019). The total area covered 308608.85 acre, and the total production of lentil is 184818.8 M tons in 2023-24 in Bangladesh (BBS, 2024). Sunflower (*Helianthus annuus*) is also an important oilseed crop and it provides about 15% of vegetable oil worldwide. The cultivation of sunflower started in Bangladesh in 1975 as a garden plant and has gradually it become a field crop in the coastal area of Bangladesh (Miah, 2014). The total cultivation of the sunflower is 6908.31 acre, and the total production is 3895.16 M tons in 2023-24 in Bangladesh (BBS, 2024). Mixed and intercropping is the process of growing two or more crops at a time. There are some differences in mixed and intercropping in case of cropping arrangement, pattern, management and purposes. Some extra benefits are found in case of mixed and intercropping than the sole cropping such as rational use of growth resources, weed control, pests and diseases control and more stability of yield in case of environmental hazards. In case of intercropping the main objective is to utilize the resource between the rows of the main crop and to increase the yield of the crops. Specific planting design is followed; seeds of two crops are not mixed with each other. In case of mixed cropping the main objective is to reduce the risk of crop failure and to get at least one crop in unfavorable climatic condition. Sometimes the mixed cropping helps to make a symbiotic relationship to each other. The combination of legume and non-legume association helps to biological nitrogen fixation that improves soil fertility.

Although the mixed cropping of lentil with sunflower is a prevailing practice in Bangladesh, the farmers here do not properly follow the principles of mixed cropping. Actually, the small size crop lentil should be taken as a main crop by allowing the full of its optimum plant population to grow and the tall crop sunflower should be incorporated in such a way that its population do not interfere the profitability. The pulse crop cannot compete with the winter vegetable and boro rice. If the researcher can generate a technology of combining cultivation of sunflower and lentil is more profitable compared with their sole cropping, then the farmers of the country might then be interested in growing more lentil crops. It can be a way to grow more pulses in our country to ensure the protein supply for poor people. However, the research about mixed and intercropping is not sufficient in our country. Moreover, most of the land in kotalipara upazila is covered by mono-cropped with rice in this research area. About 6-8 months most of the lands remain under water. Cropping intensity and production levels are much lower in this region than the other parts of the country. Under these circumstances, the present study is aimed at determining the performance and yield advantages and economic gains from the variable seed rate ratio of sunflower as mixed/intercropping within the base crop lentil. Hence, the specific objectives of the present study were- To estimate the impact of mixed cropping and intercropping patterns on yield attributes of lentil, to estimate the impact of mixed cropping and intercropping patterns on yield attributes of sunflower, to calculate the Land equivalent ratio (LER), Gross return (GR), Benefit Cost Ratio (BCR) and monetary advantage of mixed and intercropping of lentil and sunflower.

MATERIALS AND METHODS

The field experiment was conducted at Rural Development Academy (RDA) Agricultural Farm, Kotalipara, Gopalgonj during 01 November 2024 to 31 May, 2025. The location of the site is between 21°51´and 23°10´ north latitude and between 89°56´ and 90°10´ east longitude. The topography of the farm area is medium high land and the soil is sandy loam type. The average temperature of this location varies from 12.1 °C to 36.1 °C. Heavy rainfall occurs during rainy season.

BINA Mashur-8 and BARI Sunflower-3 were used for the experiment. BINA Mashur-8 was collected from the Bangladesh Institute of Nuclear Agriculture (BINA) regional sub-station, Gopalganj. BARI Sunflower-3 was collected from the On-Farm Research Division, Bangladesh Agriculture Research Institute (BARI), Gopalganj. The four cross ploughing was done by a rotary plough by four times and raised plot was prepared. The plot size was (4m×2m). Total number of plot was 33 and about 50 cm drain was kept between two plots. The seed was sown during 03 November 2024. Seed was sown according to the treatments. Before sowing the plot was prepared by cleaning the waste from the field. Randomized Completely Block Design (RCBD) was used with 3 replications of mixed cropping, intercropping and sole cropping. Treatments were- T_1=100% Lentil + 0% Sunflower (Broadcasting), T_2=100% Lentil + 20% Sunflower (Mixed cropping), T_3=100% Lentil + 40% Sunflower (Mixed cropping), T_4:100% Lentil + 60% Sunflower (Mixed cropping), T_5=100% Lentil + 80% Sunflower (Mixed cropping), T_6=0% Lentil + 100% Sunflower (Broadcasting), T_7=Row system of lentil: Sunflower (1:1) (Intercropping), T_8=Row system of lentil: Sunflower (2:1) (Intercropping), T_9=Row system of lentil: Sunflower (3:1) (Intercropping), T_{10}=Row system of lentil: Sunflower (1:0) (Line sowing of sole lentil) T_{11}=Row system of lentil: Sunflower (0:1) (Line sowing of sole sunflower).

Fertilizer was used as the recommendation of Bangladesh Institute of Nuclear Agriculture (BINA). Urea 35 kg/ha, TSP 90 kg/ha, MoP 35 kg/ha, Zypsum 30 kg/ha, Zinc Sulphate 3 kg/ha was the fertilizer dose. The cowdung was used at 10 ton/ha. All fertilizers and ½ of Urea was applaied as a basal dose during land preparation. Rest of Urea was splited in two parts. One was applied after 30 days of seed sowing and another was applied after 60 days of seed sowing. Thinning and weeding were done to maintain the optimum population. Irrigation and drainage were done at proper time. The crop was attacked by fungal disease which was controlled by spraying proper fungicide. Harvesting of the crop was done at appropriate time.

Data collection was very important for a research work. In case of the present study data was recorded on the following parameters in case of lentil: Plant height (cm), Branches per plant, Fertile pods per plant, Infertile pods per plant, Seeds per plant, 1000 seeds weight (g) and Seed yield (kg/ ha). In case of sunflower, the data was collected on the following parameters: Plant height (cm) during harvesting, Head diameter (cm), Thousand Seed weight (g) and Seed yield (Kg/ha). Then the Gross return (GR), Land equivalent ratio (LER), monetary advantage and Benefit Cost Ratio (BCR) of mixed and intercropping were calculated.

The increase in productivity per unit area of mixed and intercrops was calculated in terms of land equivalent ratio (LER) using the following formula (Willey, 1979):

LER= (Intercrop yield of lentil/ Sole crop yield of lentil) + (Intercrop yield of sunflower/ Sole crop yield of sunflower)

Monetary advantage was used for economic performance of the mixed intercrops. It was calculated using formula (Willey, 1979):

Monetary advantage= GR x [(LER-1)/ LER]
Where, GR= Gross return and LER = Land equivalent ratio.

Benefit cost ratio was calculated as, BCR = (Gross margin/Cost of cultivation)

All data was taken carefully at proper time. Data was collected from the experimental plot and the mean values for all the parameters were calculated and the analysis of variance was performed. The significance of the difference among the treatment means was estimated by the at 5 % levels of probability.

RESULTS AND DISCUSSION

Plant height during harvesting (cm) in lentil

The plant height during harvesting (cm) in lentil was observed from 35.13cm to 37.73cm (Table 1).

The maximum plant height during harvesting was recorded with T_{10} (37.73cm) and the minimum plant height during harvesting was recorded in T_5 (35.13cm) which was statistically similar with each other. There was no significant difference among the treatments in case of plant height during harvesting in lentil. Plant height during harvesting was not significantly affected by the mixed and intercropping in comparison with sole cropping (Broadcast and line sowing) treatment. Sunflower is deeper rooted than the lentil and the canopy structure of lentil is short and compact. As a result, plant height was not significantly varied among the treatments.

Table 1. Impact of mixed cropping and intercropping patterns on yield attributes of lentil

Treatments	Plant height (cm)	Branches per plant	Fertile pods per plant	Infertile pods per plant	Seeds per plant	Thousand seed weight (g)	Seed yield (kg/ha)
T1	37.43	2.53	34.60a	3.07	50.27a	23.25	1901a
T2	36.53	2.47	30.2b	3.13	46.47b	22.86	1775b
T3	36.20	2.47	28.6cd	2.93	44.60b	23.04	1570c
T4	36.40	2.33	27.07d	2.90	41.87c	23.08	1395cd
T5	35.13	2.33	27.73d	2.87	38.47d	23.16	1180d
T6	Data of sunflower was shown in Table 2						
T7	36.97	2.47	28.93cd	2.87	39.14cd	23.10	1205d
T8	36.73	2.33	29.40bc	3.00	41.73c	22.99	1339cd
T9	37.13	2.47	34.40a	3.13	43.53bc	23.15	1564c
T10	37.73	2.53	34.67a	3.00	52.60a	23.15	2078a
T11	Data of sunflower was shown in Table 2						
CV (%)	6.66	16.91	16.64	7.88	6.23	5.34	9.34
F-test	NS	NS	*	NS	*	NS	*

T_1= 100% Lentil + 0% Sunflower (Broadcasting), T_2= 100% Lentil + 20% Sunflower (Mixed cropping), T_3= 100% Lentil + 40% Sunflower (Mixed cropping), T_4:100% Lentil + 60% Sunflower (Mixed cropping), T_5=100% Lentil + 80% Sunflower (Mixed cropping), T_6=0% Lentil + 100% Sunflower (Broadcasting), T_7=Row system of lentil: Sunflower (1:1) (Intercropping), T_8=Row system of lentil: Sunflower (2:1) (Intercropping), T_9= Row system of lentil: Sunflower (3:1) (Intercropping), T_{10}=Row system of lentil: Sunflower (1:0) (Line sowing of sole lentil) T_{11}=Row system of lentil: Sunflower (0:1) (Line sowing of sole sunflower). In a column, figure with same letter do not differ significantly; *Significant at 5% level of significance; NS= Non Significant.

Branches per plant in lentil

Branches per plant in lentil were observed from 2.33 to 2.53 (Table 1). The maximum branches per plant were recorded with T_{10} (2.53) and T_1 (2.53). The minimum branches per plant were recorded in T_4 (2.33), T_5 (2.33) and T_8 (2.33). There was no significant difference among the treatments in case of branches per plant in lentil. Branches per plant were not significantly affected by the mixed and intercropping in comparison with sole cropping (Broadcast and line sowing) treatment.

Fertile pods per plant in lentil

Fertile pods per plant varied from 34.67 to 27.07 (Table 1). The maximum fertile pods per plant was recorded with T_{10} (34.67) which was statistically similar with T_1 (34.60) and T_9 (34.40). The minimum fertile pods per plant were found in T_4 (27.07) which were statistically similar with T_5 (27.73). In case of T_{10} the line sowing of sole lentil got maximum favorable microenvironment for reproductive development. There was no competition between lentil and sunflower for air, light and nutrient.

Infertile pods per plant in lentil

The number of Infertile pods per plant in lentil was varied from 2.87 to 3.13 (Table 1). The maximum infertile pods per plant were recorded with T_2 (3.13) and T_9 (3.13). The minimum infertile pods per plant were recorded in T_5 (2.87) and T_7 (2.87).

There was no significant difference among the treatments in case of infertile pods per plant in lentil. Infertile pods per plant were not significantly affected by the mixed and intercropping in comparison with sole cropping (Broadcast and line sowing) treatment.

Table 2. Impact of mixed cropping and intercropping patterns on yield attributes of sunflower

Treatments	Plant height during harvesting (cm)	Number of seed per head	Thousand Seed weight (g)	Seed yield (kg/ha)
T1	Data of lentil was shown in table-1			
T2	76.50	462c	62.50bc	678d
T3	76.10	490b	62.68bc	1058c
T4	74.75	465c	63.88b	767cd
T5	73.50	472c	61.57c	850cd
T6	73.00	529a	63.23b	1560b
T7	72.00	470c	61.55c	832cd
T8	73.25	468c	61.88c	784cd
T9	73.50	460c	63.20b	623d
T10	Data of lentil was shown in table-1			
T11	77.50	573a	68.85a	1885a
CV (%)	6.66	16.91	16.64	12.88
F-test	NS	*	*	*

T_1=100% Lentil + 0% Sunflower (Broadcasting), T_2=100% Lentil + 20% Sunflower (Mixed cropping), T_3=100% Lentil + 40% Sunflower (Mixed cropping), T_4:100% Lentil + 60% Sunflower (Mixed cropping), T_5=100% Lentil + 80% Sunflower (Mixed cropping), T_6=0% Lentil + 100% Sunflower (Broadcasting), T_7=Row system of lentil: Sunflower (1:1) (Intercropping), T_8=Row system of lentil: Sunflower (2:1) (Intercropping), T_9=Row system of lentil: Sunflower (3:1) (Intercropping), T_{10}=Row system of lentil: Sunflower (1:0) (Line sowing of sole lentil) T_{11}=Row system of lentil: Sunflower (0:1) (Line sowing of sole sunflower). In a column, figure with same letter do not differ significantly; *Significant at 5% level of significance; NS= Non Significant.

Number of seeds per plant in lentil

The number of seeds per plant in lentil was identified from 52.60 to 38.47 (Table 1). The maximum number of seeds per plant was recorded at T_{10} (52.60) which was statistically similar with T_1 (50.27). The minimum number of seeds per plant was recorded in T_5 (38.47) which was statistically similar with T_7 (39.14). As the number of fertile pods has a relationship with the number of seeds per plant, the T_{10} gave maximum performance. In case of T_5 and T_7 the plant population was higher, and the lentil and sunflower made a maximum competition for space, sunlight as well as nutrient.

Thousand seed weight (g) of lentil

The thousand seed weight of lentils varied from 22.86g to 23.25g (Table 1). The maximum thousand seed weight was recorded with T_1 (23.25g) and the minimum thousand seed weight was found in T_2 (22.86g) which was statistically similar with each other. So, there was no significant difference among the treatments in case of thousand seed weight in lentil. Thousand seed weight was not significantly affected by the mixed and intercropping in comparison with sole cropping (Broadcast and line sowing) treatment.

Seed yield of lentil (kg/ha)

The seed yield of lentils varied from 1180 kg/ha to 2078 kg/ha (Table 1). The maximum seed yield was recorded with T_{10} (2078 kg/ha) where 1:0 row system of lentil: sunflower (line sown sole lentil) was applied and that was statistically similar with the T_1 (1901 kg/ha). The minimum seed yield was found in T_5 (1180 kg/ha) which was statistically identical with T_7 (1205 kg/ha). In case of lentil the higher yield was achieved in line sowing than broadcast sowing. This may be due to higher aeration and desirable spread of canopy for efficient utilization of solar energy for photosynthesis (Choudhury, 1962). Here we observed that the sole cropping performed higher yield than the mixed and intercropping. The yield reduction in mixed cropping might be due to shading effect of the taller sunflower and higher competition for moisture, space and light and nutrition among the crop plants (Mojibul *et al.*, 1992; Hussain *et al.*, 1995).

Plant height during harvesting (cm) in sunflower

The plant height during harvesting (cm) in sunflower was observed from 72cm to 77.50cm (Table 2). The maximum plant height during harvesting was recorded with T_{11} (77.50cm) and the minimum plant

height during harvesting was recorded in T_7 (72.00cm) which was statistically similar to each other. There was no significant difference among the treatments in case of plant height harvesting in sunflower. Plant height during harvesting was not significantly affected by the mixed and intercropping in comparison with sole cropping (Broadcast and line sowing) treatment.

Number of seeds per head in sunflower

The number of seeds per head was identified from 460 to 573 (Table 2). The maximum number of seeds per head was recorded with T_{11} (573) which were statistically similar with T_6 (529). The minimum number of seeds per head was recorded in T_9 (460) which was statistically similar to T_2 (462), T_4 (465), T_7 (470) and T_8 (468). In case of T_{11} the line sowing of sole sunflower got maximum air, light and nutrient for reproductive growth and so performed better than the other combination of mixed and sole cropping.

Thousand seed weight (g) of sunflower

The thousand seed weight of sunflower was varied from 61.57g to 68.85g (Table 2). The maximum thousand seed weight was recorded with T_{11} (68.85g).

The minimum thousand seed weight was found in T_5 (61.57g) which was statistically similar with T_8 (61.88g), T_2 (62.50g) and T_3 (62.68g). In case of line sowing of sole sunflower, the plant got maximum light and spacing and so produced more food that increased the thousand seed weight.

Table 3. Gross return (GR), land equivalent ratio (LER), monetary advantage and benefit cost ratio (BCR)

Treatments	Gross return (GR)	Land equivalent ratio (LER)	Monetary advantage	Benefit cost ratio (BCR)
T1	133070.00	1.00	-	1.30
T2	192050.00	1.37	51867.50 (39%)	1.63
T3	215700.00	1.51	72852.0 (55%)	1.86
T4	174350.00	1.23	32602.0 (25%)	1.36
T5	167600.00	1.17	24352.0 (18%)	1.19
T6	156000.00	1.00	-	1.12
T7	167550.00	1.02	3285.0 (3%)	1.14
T8	172130.0	1.06	9743.0 (7%)	1.17
T9	171780.00	1.09	14184.0 (10%)	1.25
T10	145460.00	1.00	-	1.34
T11	188500.00	1.00	-	1.18

T_1=100% Lentil + 0% Sunflower (Broadcasting), T_2=100% Lentil + 20% Sunflower (Mixed cropping), T_3=100% Lentil + 40% Sunflower (Mixed cropping), T_4:100% Lentil + 60% Sunflower (Mixed cropping), T_5=100% Lentil + 80% Sunflower (Mixed cropping), T_6=0% Lentil + 100% Sunflower (Broadcasting), T_7=Row system of lentil: Sunflower (1:1) (Intercropping), T_8=Row system of lentil: Sunflower (2:1) (Intercropping), T_9=Row system of lentil: Sunflower (3:1) (Intercropping), T_{10}=Row system of lentil: Sunflower (1:0) (Line sowing of sole lentil) T_{11}=Row system of lentil: Sunflower (0:1) (Line sowing of sole sunflower).

Seed yield of sunflower (kg/ha)

Yield is an important factor in crop cultivation. The seed yield of sunflower varied from 623 kg/ha to 1885 kg/ha (Table 2). The maximum grain yield was recorded with T_{11} (1885 kg/ha) where 0:1 row system of lentil: Sunflower (Line sown sole sunflower) was applied and that was statistically dissimilar with the others treatment. The minimum seed yield was found in T_9 (623 kg/ha) which was statistically identical with T_2 (678 kg/ha), T_4 (767 kg/ha) and T_8 (784 kg/ha). In case of sunflower the higher yield was achieved in line sowing than broadcast sowing. This may be due to higher aeration and desirable spread of canopy for efficient utilization of solar energy for photosynthesis (Choudhury, 1962).

Land equivalent ratio (LER), gross return (GR), monetary advantage and benefit cost ratio (BCR)

In the mixed cropping treatments, the different percentage of land equivalent ratio (1.17 to 1.37) (Table 3) indicated that the mixed cropping increased

the productivity per unit area in comparison with the sole cropping of lentil. In intercropping treatments, the percentage of land equivalent ratio (1.02 to 1.09) (Table 3) indicates the increased productivity but it was not identical with mixed cropping. The performance of sunflowers in mixed cropping was higher than that of intercropping. This might be beneficial action from the associated legumes. Some early pot studies suggested that legumes could excrete nitrogen from root nodules and thus benefit the associated crops (Nicol, 1935; Agboola and Fayemi, 1972; Remison, 1978). In the different treatments it was clear that the lentil and sunflower yield decreased due to mixed or intercropping (Table 1 and Table 2) but its land equivalent ratio increased in all the mixed/intercropping in relation to their sole crop (Table 3). The pattern of yield reduction collaborates with the results in other experiments of lentil mixed and intercropped with mustard (Iqbal, 1989) and lentil intercropped with wheat (Ahmed *et al.*, 1987). The highest monetary advantage was obtained (55%) in the treatment T_3, where 100%Lentil +40% sunflower was sown as a mixed crop. It found that the treatment lentil 100% + sunflower 40% had the highest land equivalent ratio (1.51) indicating 51% area advantage over sole cropping of lentil.

The results showed that the highest gross return (215700 Tk/ha) was also recorded from the same treatment followed by lentil 100+20% sunflower (i.e. in the treatment T_2 scoring 192050 Tk/ha). Moreover, the treatment contributed to the highest benefit cost ratio (1.86) which was followed by lentil 100+20% sunflower (1.63) (Table 3). Mozibul Islam *et al.* (1992) reported similar results from lentil intercropping with jute. Gangwar and Karla (1982) and Quayum (1987) obtained the highest net income by intercropping of maize with legumes and maize with chickpea, respectively.

CONCLUSION

The result of the study showed that the highest land equivalent ratio (1.17 to 1.51) was found in mixed cropping. It indicated that the mixed cropping increased the productivity per unit area in comparison with the sole cropping of lentil.

The performance of sunflower in mixed cropping was higher than that of intercropping. This might be beneficial action from the associated legumes. The individual yield of lentil and sunflower was decreased due to mixed or intercropping than the sole cropping, but its land equivalent ratio increased in all the mixed/intercropping in relation to their sole crop. The highest monetary advantage (55%) and the highest land equivalent ratio (1.51) were obtained when used 100% lentil +40% sunflower that indicating 51% area advantage over sole cropping of lentil. The results showed that the highest gross return (215700 Tk/ha) was also recorded from the same treatment. Moreover, the treatment (100% lentil +40% sunflower) contributed to the highest benefit cost ratio (1.86). In conclusion, the mixed cropping of lentil with 40% sunflower seed rate would be the appropriate seed rate with base crop lentil for higher total production and income. It can be highly beneficial for the farmers.

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