

Impact of organic nutrient management and row ratios on the economics and productivity of an Indian mustard (*Brassica juncea*) + chickpea (*Cicer arietinum*) intercropping system

Dharshan, Rohith Kumar

Department of Rural Development and Agricultural Extension,

Article Info

Received: 15-02-2026 Revised: 15-03-2026 Accepted: 02-04-2026 Published: 10-04-2026

ABSTRACT

At the Indian Agricultural Research Institute's research farm in New Delhi, a field experiment was carried out in the winter (rabi) seasons of 2021–2022 and 2022–2023 to determine the best cropping system with the ideal row ratio and nutrient management techniques for Indian mustard [*Brassica juncea* (L.) Czern.] + intercropping strategy for chickpeas (*Cicer arietinum* L.). The major plots were cropping systems such as mustard sole, chickpea sole, mustard + chickpea 2:5, and mustard + chickpea 5:2. Practices for managing nutrients, like as control, 60 kg nitrogen/ha, and 20 kg 20 kg of nitrogen from leaf and farmyard manure To achieve a greater level of accuracy, nitrogen from farmyard manure + leaf manure + microbial consortia was collected as sub-plots. The yield of the intercropping system in terms of mustard equivalent yield was found to be the greatest for mustard + chickpea 5:2 row ratio, despite the fact that the individual crop yields of mustard and chickpea were the highest in the solo crop. Plots treated with a mixture of organic manures and microbial consortia—that is, 20 kg nitrogen via farmyard manure + leaf manure @4 t/ha + microbial consortia—showed the greatest yields of both mustard and chickpea. The mustard + chickpea 5:2 row ratio had the highest gross returns, net returns, and benefit-cost ratio. The mustard + chickpea 5:2 row ratio showed the greatest intercropping benefit when treated with organic manures and microbial consortia, according to an analysis of intercropping indices. The land equivalent ratio of intercropping systems was greater than unity, indicating an advantage. The mustard crop outperformed the chickpea crop according to aggressivity scores.

Keywords: row ratios, equivalent yield, nutrient management, and economics

Introduction

When compared to solitary cropping in a variety of agroecological conditions, intercropping offers substantial benefits in terms of crop yield, land use efficiency, and financial returns due to the efficient use of solar energy and inputs (Mucheru-Muna et al. 2010). In dryland settings with preserved moisture, Indian mustard [*Brassica juncea* (L.) Czern.] and chickpea (*Cicer arietinum* L.) are widely interplanted across the Indian subcontinent. The scientific intercropping approach increases production per unit area per unit time when these two crops are planted in certain proportions and row ratios (Ramaraio et al. 2020). The degree of complementarity between the components must be increased while intercrop competition must be reduced in order to optimize the benefits of intercropping (Willey 1990). In order to reduce the shadowing effect, it is crucial to choose the appropriate row ratio. ICAR (Indian Agricultural Research Institute, New Delhi) and Janta Vedic College (Chaudhary Charan Singh University, Meerut), Bagpat, Uttar Pradesh, are intercropping. *Corresponding author email: sasmitha1995@gmail.com Among the several methods employed to boost the output of oilseed crops, these crops—pulses and oilseed crops—seem to be the most practicable, economically sound, and socially acceptable (Viswanathan et al. 2020). Drought-prone regions can produce chickpeas since they are a climate-resilient and highly water-efficient crop. By fixing nitrogen and encouraging soil microorganisms, it improves soil fertility. Therefore, in order to achieve the dual objectives of profitability and sustainability, it is imperative that we establish intercropping systems, particularly with pulses as component crops in appropriate row ratios. Additionally, organic nutrient management techniques would improve yields, revenue, and soil health due to the decreasing amount of soil organic matter under rainfed conditions. As a result, the current trend is to look at the viability of switching from chemical fertilizers to more affordable and ecologically friendly organic ones (Sarkar et al. 2021). By fixing nitrogen, solubilizing insoluble phosphate, and synthesizing growth hormones and siderophores, biofertilizer inoculation stimulates crop development. Biofertilizers have shown promise in preserving agricultural output and improving soil fertility, according to Ghosh et al. (2009). Combining organic manures with biofertilizers

could turn out to be a useful tactic for preserving crop production. To investigate the impact of cropping methods and organic nutrient management techniques on the economics and yield of a mustard + chickpea intercropping system, an experiment was carried out.

METHODS AND MATERIALS

An experiment was carried out at the Indian Agricultural Research Institute farm in New Delhi during the winter (rabi) seasons of 2021–2022 and 2022–2023 (28°08' N and 77°12' E at an altitude of 228.61 m amsl). The sandy loam soil used in the experiment had a pH of 7.7, which is somewhat alkaline, and a low amount of organic carbon (0.36%). It had low available P (6.3 kg/ha), medium available K (164 kg/ha), and medium available N (256 kg/ha). The experiment was carried out using a split-plot design with cropping systems such as mustard sole, chickpea sole, mustard + chickpea 2:5, and mustard + chickpea 5:2 as the main plots and nutrient management techniques such as control, 60 kg nitrogen/ha, 20 kg nitrogen through farmyard manure + leaf manure @4 t/ha, and 20 kg nitrogen through farmyard manure + leaf manure @4 t/ha + microbial consortia as sub-plots with three replications. Pusa Tarak, a mustard variety, was seeded with a seed rate of 5 kg/ha at 45 cm row spacing, whereas Pusa 1103, a chickpea variety, was sown with a seed rate of 80 kg/ha at 30 cm row spacing. In the winter, on October 21, 2021, and October 18, 2022, seeds were sown. The recommended fertilizer dosage for mustard crops was 60-40-40 kg of N, P₂O₅, and K₂O/ha, whereas the recommended dosage for chickpea crops was 20-60-40 kg of N, P₂O₅, and K₂O/ha. Rows of component crops were altered in accordance with the intercropping system, which was implemented in accordance with replacement series. In both years, crop harvesting took place during the second two weeks of March, when leaves were seen to be drying up and dropping off, indicating senescence. Chickpeas were collected one week after mustard. Seed yields were measured after threshing.

Analysis of variance (ANOVA) was performed on the data using a split-plot design for different observations (Gomez and Gomez 1984). Critical difference (CD) values were computed to compare the different treatment means, and the findings were shown at the 5% level of significance (P=0.05). The intercropping indices and additional production potential metrics were computed as follows:

Mustard equivalent yield: Based on the current market values of the commodities, the chickpea seed yield was converted to mustard equivalent yield as follows:

$$\frac{\text{Seed yield of chickpea (q/ha)} \times \text{Price of chickpea (₹/q)}}{\text{Price of mustard (₹/q)}}$$

Equivalent yield of mustard equals

The land equivalent ratio (LER) is calculated as follows: $L_i + L_j = (Y_{ij}/Y_{ii}) + (Y_{ji}/Y_{jj})$, where Y is the yield per unit area, Y_{ii} and Y_{jj} are the single crop yields of the component crops, i (mustard) and j (chickpea), and Y_{ij} and Y_{ji} are the intercrop yields. The values of the partial LER

The ratios of crop I and crop J's yields when cultivated as intercrops to single crops are represented by L_i and L_j . The yield of a component crop in a mixture divided by the yield of its solitary crops is the relative crowding coefficient, or RCC.

Aggressivity (A): When two crops are seeded together, the aggressivity indicates how dominant one crop is over the other.

A_{ij} is the aggressivity value for the component crop, while i, Z_{ij} , and Z_{ji} are the proportions of the component crops. $A_{ij} = (Y_{ij}/Y_{ii} \times Z_{ij}) - (Y_{ji}/Y_{jj} \times Z_{ji})$.

The cost of agriculture, expressed in rupees (₹) per hectare, was calculated using the prices of the inputs utilized for cultivation. Based on the current minimum support prices for mustard and chickpeas declared by the Indian government, economic values of seed and straw output were calculated.

RESULTS AND DISCUSSION

Impact on mustard seed and stover yield, growth parameters: As crop age increased, mustard plant height gradually increased. In both years, mustard + chickpea 2:5 (159.9 cm) had the maximum plant height at maturity,

followed by mustard + chickpea 5:2 (156.7 cm) (Table 1). This might be the result of the plants' tendency to grow vertically and increased competition for light and space when they were planted closer together in the mustard + chickpea intercropping system. Sunlight interception increased as the percentage of intercrops in the cropping system increased. Through increased photosynthetic activity and the buildup of dry matter throughout both the vegetative and reproductive phases, this increased exposure to light enabled the mustard plants to develop quickly. However, plant height at maturity was not significantly affected by intercropping techniques. The plot treated with 20 kg N using FYM + leaf manure + microbial consortia had the highest plant height (165.8 cm) among the nutrient management techniques. Because there was more effective rainfall in 2022–2023 than in 2021–2022, the plants were taller. The crop may reach its maximum production potential when dry matter accumulates optimally and assimilates are adequately partitioned to growing sinks. The mustard + chickpea 2:5 plot had the greatest total dry matter accumulation at maturity (227.5 g/m row length), followed by the mustard + chickpea 5:2 cropping system. When compared to other treatments over both seasons, the integrated application of organic manures that provided sufficient levels of both macro and micronutrients showed noticeably greater dry matter buildup at maturity. When looking at individual mustard crops, mustard sole had the highest seed and stover yields (1.75 t/ha and 6.38 t/ha, respectively), which were significantly higher than intercropping systems in both years. This is likely because there was less competition and a larger plant population. Population expansion per unit area boosts dry matter production and vegetative growth, which is reflected in mustard seed output.

by the chickpea solo crop and the mustard + chickpea 5:2 farming scheme. The mustard + chickpea 5:2 intercropping system produced the highest yield when both crops were considered as a system. This might be because there were more photosynthates available, which would have produced more flowers. When those flowers were fertilized, more siliquae/plants were produced, leading to bigger yields. Similar to this, the plot that received a combination of leaf manure, farmyard manure, and microbial consortia had the highest mustard seed and stover output because of improved nutrient absorption and increased dry matter buildup. This is due to the fact that organic manures guaranty that plants get all macro and micronutrients in the proper amounts for improved growth and development. Additionally, they assist in the rapid decomposition, mineralization, and solubilization of nutrients in the soil by increasing the number of beneficial bacteria that produce organic acids (Paramesh et al. 2020).

Impact on chickpea growth metrics, grain, and straw yield: From 30 days following seeding to harvest, plant height exhibited a progressive tendency. The mustard + chickpea 2:5 plot had the maximum plant height at maturity of any individual chickpea crop (38.5 cm) (Table 1). Better use of resources, particularly solar radiation and temperature, was the cause of this. Due to improved nutrient availability at the appropriate crop stage, 20 kg N via farmyard manure + leaf manure + microbial consortia produced the tallest plants among the sub-plots (40.7 cm). Dry matter buildup showed a similar tendency, with highest values being reported in a 2:5 intercropping system of mustard and chickpeas (156.9 g/m row length). This might be explained by the plants' increased photosynthetic efficiency, which produces more assimilate and dry matter and improves vegetative growth. Due to more effective use of both above-ground and below-ground resources, the chickpea single plot produced the highest grain production (1.99 t/ha) and straw yield (1.58 t/ha) when considering individual chickpea plants. This might be the result of reduced intercrop competition, increased photosynthetic active radiation, and latent heat that the crop can use to produce more photosynthates, all of which positively affected the yield-attributing factors. Compared to mustard, which exhibited more competitiveness and the shadowing impact of tall mustard, the decline in the grain and straw production of chickpeas under an intercropping system was much greater. Chickpeas treated with farmyard manure + leaf manure @4 t/ha + microbial consortia had the maximum grain yield (1.60 t/ha) and straw yield (1.22 t/ha) in 20 kg of nitrogen. This might be due to microbial consortia further solubilizing nutrients and increased availability of both macro and micronutrients in appropriate amounts via organic manures. Additionally, Rhizobium and chickpea root had a symbiotic connection that improved air nitrogen fixation, improving nutrient absorption and leading to greater yields. By altering the physical and chemical characteristics of soil, the application of leaf manure and farmyard manure reduces nutrient losses (Bhattacharjee and Dey 2012). The low C:N ratio of organic manures leads to

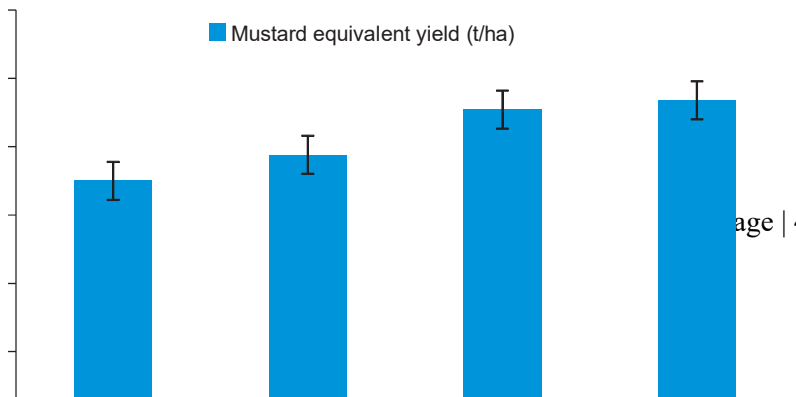
Table 1: Impact of cropping system and nutrient management techniques on mustard and chickpea growth parameters and production (mean data from 2021–2022 and 2022–2023)

Treatment	Mustard	Chickpea
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	Plant height maturity (cm)	Dry matter accumulation (g/m ² /row length)	Seed yield (t/ha)	Stover yield (t/ha)	Plant height maturity (cm)	Dry matter accumulation (g/m ² /row length)	Grain yield (t/ha)	Straw yield (t/ha)
Cropping system								
Mustard sole	154.6	218.9	1.75	6.38	—	—	—	—
Chickpea sole	—	—	—	—	37.6	152.9	1.99	1.58
Mustard + Chickpea (2:5)	159.9	227.5	0.80	2.35	38.5	156.9	1.50	1.24
Mustard + Chickpea (5:2)	156.7	222.6	1.31	4.77	37.8	154.8	0.85	0.67
SEm±	2.70	4.00	0.09	0.23	0.67	2.69	0.04	0.05
CD (P=0.05)	NS	NS	0.29	0.68	NS	NS	0.15	0.16
Nutrient management practice								
Control	143.5	188.8	1.16	4.27	34.5	71.6	1.27	1.05
60 kg Nitrogen/ha	151.7	216.9	1.29	4.51	37.3	76.4	1.35	1.18
20 kg Nitrogen through FYM + leaf manure	161.3	238.8	1.31	4.58	40.4	80.5	1.56	1.21
20 kg Nitrogen through FYM + leaf manure + microbial consortia	165.8	245.5	1.38	4.66	40.7	81.7	1.60	1.22
SEm±	2.60	4.09	0.07	0.12	0.63	2.59	0.05	0.05
CD (P=0.05)	7.80	12.16	0.20	0.37	1.86	7.60	0.16	0.15

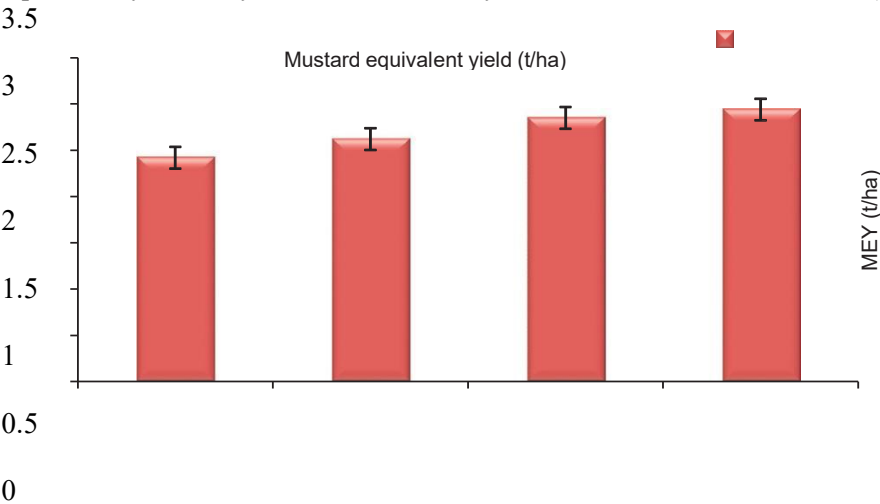
faster rates of breakdown, giving the plant enough nutrients. N, P, and K are more readily accessible when organic nutrition sources are applied. Additionally, it raises the amount of organic carbon in the soil, improving its fertility. It enhances the structure of the soil and facilitates the release of secondary nutrients into the soil solution, such as calcium and magnesium.

Impact on intercropping indices and mustard equivalent yield: By calculating the mustard equivalent yield while taking into account the prices of both crops, the yield of the component crop, chickpeas, was converted to the output of the major crop, mustard. Both planting types and nutrient management techniques have a major impact on mustard equivalent production. The benefit of intercropping was shown by the mustard + chickpea 5:2 row ratio, which recorded the greatest value of mustard equivalent yield (2.34 t/ha), followed by mustard solo crop (Fig 1). Two rows of chickpeas and five rows of mustard planted closely together make efficient use of space, nutrients, and sun radiation to increase biomass and yields. Interestingly, it was found that there was a significant reciprocal advantage in terms of resource availability, especially in the nitrogen economy, as the percentage of pulses like chickpeas grew in the intercropping system.



demonstrating the complementing interaction that gives them a yield advantage over their monocultures. In the mustard + chickpea 5:2 row ratio, the system's greatest relative crowding coefficient value (7.25) showed that it produced a higher yield than anticipated. The combined application of 20 kg N using leaf manure, farmyard manure, and microbial consortia produced the greatest values of all intercropping indicators among nitrogen management techniques. Among the nutrient-management techniques, it had the greatest LER (1.56) and relative crowding coefficient of system (13.62) (Table 2). The control plot and the plot that was chemically fertilized with 60 kg N/ha showed less competition. The use of organic manures has been shown to boost fertility, which may have contributed to increased vegetative growth and the formation of a large root system that can draw moisture from deeper soil layers, ultimately increasing yields. Similar findings regarding aggressivity and relative crowding coefficient values in the linseed + gram intercropping system were also reported by Lal et al. (2019). Consequently, the and the mustard crop's total yield output. The combined application of leaf manure, farmyard manure, and microbial consortia produced the greatest mustard equivalent yield (2.94 t/ha) among the nutrient management techniques (Fig 2). The release of growth-promoting compounds by microbial inoculants, which improved root development, nutrient absorption, and increased yields, may be the likely cause. To ascertain the benefit of intercropping, intercropping indices were computed.

illustrating the benefits of intercropping. The mustard + chickpea 5:2 row ratio with integrated application of organic manures and microbial consortia produced the highest value of 1.54 when the land equivalent ratio was calculated (Table 2). The mustard + chickpea 2:5 farming method came next (1.34). In every cropping scheme, mustard's aggressivity ratings were positive, demonstrating its superiority over chickpeas. The yield benefit of intercropping was shown by aggressivity values greater than zero (Fig. 1 Effect of cropping system on mustard equivalent yield of system; mean data of years 2021–2022 and 2022–2023).



choosing intercropping over single-crop farming. The relative crowding coefficient was greater for each intercropping condition.

Control 20 kg N (FYM) + LM 60 kg N/ha

Methods for managing nutrients

20 kg N (FYM) + MC + LM

values, and the relative crowding coefficient product was greater than unity,

Figure 2 shows the impact of nutrient management techniques on the system's mustard equivalent yield (mean data from 2021–2022 and 2022–2023).

Table 2 Effect of cropping system and nutrient management practices on intercropping indices of system (mean data of years 2021–22 and 2022–23)

Treatment	Land equivalent ratio	Aggressivity of mustard	Aggressivity of chickpea	Relative crowding coefficient of system
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Cropping system				
Mustard + Chickpea (2:5)	1.34	0.18	(-) 0.18	5.74
Mustard + Chickpea (5:2)	1.54	0.28	(-) 0.28	7.25
Nutrient management practice				
Control	1.37	0.33	(-) 0.33	2.03
60 kg Nitrogen/ha	1.39	0.24	(-) 0.24	4.63
20 kg Nitrogen through FYM + leaf manure	1.45	0.20	(-) 0.20	8.30
20 kg Nitrogen through FYM + leaf manure + microbial consortia	1.56	0.15	(-) 0.15	13.62

The optimum way to attain potential yields and revenue under rainfed conditions is to intercrop mustard and chickpeas in a 5:2 row ratio and apply organic manures, according to the data.

Intercropping systems and nutrient management techniques' effects on the economy: Data analysis showed that the applied treatments resulted in significant differences in economic indicators (Table 3). Cropping strategies had little effect on production costs, while nutrient management techniques had a big impact. The plot mustard + chickpea 2:5 row ratio had the highest cultivation cost (\$30,610), accounting for both seed rate and seed cost. Additionally, organically treated plots cost extra (\$32,670) because the poor nutrient content in them required mass application. Although the pace of production and the minimal support price were taken into account when calculating gross returns and net returns, mustard + The chickpea 5:2 intercropping system had the greatest cultivation costs, but because of its greater yields, it produced the highest gross returns (\$84,560), net returns (\$54,040), and B:C ratio (1.77) for both years when compared to the solitary cropping system. The mustard solitary crop and the mustard + chickpea 2:5 farming pattern came next. Singh et al. (2019) also observed similar findings. Maximum gross returns, net returns, and B:C were noted among nutrient management techniques for the treatment in which the plot underwent integrated application of leaf manure, farmyard manure, and microbial consortia. This was due to the fact that using organic nutrition sources produced better yields than using inorganic chemical fertilizers.

According to the results of the experimental study, the mustard + chickpea (5:2) intercropping system had the greatest yield of the cropping system overall in terms of mustard equivalent yield based on the price of output. net returns, gross returns

Table 3 Effect of cropping system and nutrient management practices on economics of system (mean data of years 2021–22 and 2022–23)

Treatment	Cost of cultivation (103/ha)	Gross returns (× 103/ha)	Net returns (103/ha)	Net B:C
Cropping system				
Mustard sole	30.11	81.90	51.78	1.72
Chickpea sole	30.28	55.72	25.44	0.84
Mustard + Chickpea (2:5)	30.61	79.24	48.63	1.59
Mustard + Chickpea (5:2)	30.51	84.56	54.04	1.77
SEm±	0.56	1.14	0.92	0.02
CD (P=0.05)	NS	3.38	2.73	0.07
Nutrient management practice				
Control	28.49	89.60	61.10	2.14
60 kg Nitrogen/ha	29.17	97.86	68.69	2.33
20 kg Nitrogen through FYM + leaf manure	32.36	104.10	71.79	2.21
20 kg Nitrogen through FYM + leaf manure + microbial consortia	32.67	108.70	76.10	2.35
SEm±	0.62	1.37	1.29	0.03
CD (P=0.05)	1.86	4.09	3.82	0.10

returns, this therapy was also shown to have the greatest net B:C. The combined application of organic manures and microbial consortia (20 kg N via FYM+ Leaf manure+ Microbial consortia) produced the greatest mustard equivalent yield and economic characteristics among the nutrient management techniques. The mustard + chickpea 5:2 intercropping system was shown to be superior than the solitary cropping system based on the values of intercropping indices such as land equivalent ratio, aggressivity, and relative crowding coefficient. Therefore, using a 5:2 row ratio for mustard and chickpeas in conjunction with the integrated application of organic nitrogen sources such as leaf manure, farmyard manure, and microbial consortia has the potential to increase farmers' revenue and yields under rainfed conditions.

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