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Research Paper

Impact of row ratios and nutrient management practices on yield, economics and nutrient uptake of mustard + chickpea intercropping system

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ABSTRACT

A field experiment was undertaken in split plot design at ICAR- Indian Agricultural Research Institute farm, New Delhi during the *rabi* seasons of 2021-22 and 2022-23 determine the impact of different row ratios and nutrient management practices on yield, nutrient uptake and economics of mustard + chickpea intercropping system. Sixteen treatment combinations were taken with four different row ratios as main plots and four nutrient management practices as sub-plots replicated thrice. Though crop yields for individual crops of mustard and chickpea were found to be the highest for sole crop, but yield of intercropping system in terms of mustard equivalent yield was found to be the highest for mustard + chickpea 5:2 row ratio (2.98 t/ha in 2021 and 3.06 t/ha in 2022). Yields of both mustard and chickpea were observed to be the highest in the plots treated with combination of organic manures and microbial consortia i.e., 20 kg nitrogen through farmyard manure + leaf manure @ 4t/ha + microbial consortia (1.38 t/ha for mustard and 1.60 t/ha for chickpea). Highest gross returns (₹84,560), net returns (₹54,040) and benefit-cost ratio (1.77) were found in mustard + chickpea 5:2 row ratio. Analysis of nutrient uptake revealed maximum nutrient uptake in mustard + chickpea 2:5 intercropping system which led to better vegetative growth and higher yields. The above research aptly highlighted the beneficial effects of intercropping mustard with chickpea in dryland areas which helped to generate higher income for the farmers along with maintenance of soil sustainability by application of organic manures in right proportions.

Key words: Economics, Equivalent yield, Intercropping system, Nutrient uptake, Rainfed ecosystem, Row ratios

Intercropping of mustard with chickpea is a widely adopted practice in India, especially in northern and central part of the country. When crops are planted in specific proportions and row ratios, this scientific intercropping technique enhances productivity per unit area and time (Kumar *et al*., 2006). To maximize the benefits of intercropping, it is essential to optimize the complementarity between the crops and minimize competition. This can be achieved by strategically arranging tall plants that require more light at the top and compact chickpea plants at the bottom, allowing for efficient use of light similar to multistorey cropping and resulting in higher yields without excessive shading effects. Intercropping offers significant advantages in terms of land use efficiency, crop productivity, and financial returns as compared to sole cropping, especially in diverse agroecological conditions where solar energy and inputs are utilized effectively (Mucheru-Muna *et al*., 2010). A study conducted at the Indian Agricultural Research Institute farm in New Delhi examined the intercropping of pulses and oilseed crops as a practical and economically viable method to increase oilseed crop yields (Vishwanathan *et al*., 2020). To achieve profitability and sustainability goals, it is essential to develop intercropping systems, particularly with pulses, in appropriate row ratios.

Soil health is a major concern among the various impacts faced. As a result, there is a growing interest in exploring the possibility of replacing chemical fertilizers with organic alternatives that are both cost-effective and environmentally friendly (Sarkar *et al*., 2021). Organic sources of nutrients offer essential nutrients and enhances soil quality by stimulating microorganisms. Biofertilizer inoculation further promotes crop growth through nitrogen fixation, phosphate solubilization, and the synthesis of growth hormones, vitamins, and siderophores. Research has shown that biofertilizers have a positive impact on agricultural

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productivity and soil fertility (Govindan and Thirumurugan, 2005). Combining biofertilizers with organic manures could prove to be a practical approach for maintaining crop yields. Considering the decline in soil organic matter and its implications on soil health and productivity, the integrated application of organic nutrient management practices becomes crucial for enhancing yields and income. Organic manures have more porosity resulting in higher water holding capacity which is of great significance in dryland areas. Further organic manures release both macro and micro nutrients in optimum amounts as required by the plant. Soil physical conditions and fertility levels increase with application of organic manures as they help in increasing microbial diversity and subsequent enzymatic activities in rhizosphere leading to release of nutrients in right proportions. With this in mind, an experiment was conducted to explore the potential of increasing oilseed and pulse production through an intercropping system. The study aimed to determine the feasibility of optimizing crop spatial arrangement and nutrient management practices to maximize productivity while maintaining soil health.

MATERIALS AND METHODS

The experiment was conducted during the *Rabi* seasons of 2021-22 and 2022-23 at the Indian Agricultural Research Institute farm in New Delhi located at 28°08' N and 77°12' E at an altitude of 228.61 m above Mean Sea Level. The soil of the experimental plot was sandy loam with a slightly alkaline *p*H of 7.7 and low organic carbon content (0.36%). Medium levels of available nitrogen (256 kg/ha) and potassium (164 kg/ha), along with low available phosphorus (6.3 kg/ha), were observed in the soil. The experiment used a split-plot design, with different row ratios (mustard sole, chickpea sole, mustard + chickpea 2:5, mustard + chickpea 5:2) as the main plots and nutrient management practices (control, 60 kg nitrogen/ha, 20 kg nitrogen through farmyard manure + leaf manure @ 4t/ha, 20 kg nitrogen through farmyard manure + leaf manure @ 4 t/ha + microbial consortia) as the sub-plots, replicated three times. Net plot size taken was 4 m × 3m. Mustard variety 'Pusa Tarak' was sown with a seed rate of 5 kg/ha at 45 cm row spacing, and chickpea variety 'Pusa 1103' was sown with a seed rate of 80 kg/ha at 30 cm row spacing. Sowing took place during the winter season on October 21, 2021, and October 18, 2022. Mustard and chickpea crops were fertilized according to recommended doses. Microbial consortias of *Azotobacter* and *Rhizobium* were taken for mustard and chickpea, respectively. Sole crop of mustard had 100% mustard population and sole crop of chickpea had 100% chickpea population. The intercropping was done using the replacement series method where mustard + chickpea (2:5) had 28.5 % mustard population and 71.5% chickpea population and mustard + chickpea (5:2) had 71.5% mustard population and 28.5% chickpea population. Harvesting occurred in the second fortnight of March for both years. The remaining agronomic practices were followed as per recommendations for the region. Threshing was performed, and seed yields were recorded. The data underwent analysis of variance (ANOVA) in a split plot design, and the results were presented at a significance level of 5% (P=0.05) (Gomez and Gomez, 1984). Critical difference (CD) values were calculated to compare various treatment means accordingly. The calculation of cultivation expenses involved determining the prices of inputs used, given in Indian rupees per hectare. Economic values for seed and straw yield were estimated using the minimum support prices set by the Government of India for mustard and chickpea. Seed yield of chickpea was converted to mustard equivalent yield, based on the prevailing market prices of the commodities by the following formula:

$$\text{Mustard equivalent yield} = \frac{\text{Seed yield of chickpea (t/ha)} \times \text{Price of chickpea (₹/t)}}{\text{Price of mustard (₹/t)}}$$

The nitrogen concentration in seed and straw of both mustard and chickpea samples was determined by modified Kjeldahl's method. The N uptake was calculated by multiplying seed and straw yields with corresponding values of N concentration and expressed in kg/ha as per the standard procedures. Total N uptake was determined by adding the uptake in seed and straw for the individual treatment as per the standard procedures. Percentage of phosphorus (P) in mustard and chickpea seed and straw at harvest was estimated by vando-molybdophosphoric acid yellow colour method (Athokpam *et al*., 2016). P uptake by seed and straw of both the crops was calculated by multiplying the seed and straw yield of crops with their respective concentrations and expressed in kg/ha. Total P uptake was determined by adding the uptake in seed and straw for the individual treatment as per the standard procedures. Percentage of Potassium (K) in mustard and chickpea seed and straw at harvest was estimated by flame photometer method (Wiyantoko *et al*., 2021). Potassium uptake in seed and straw of both the crops was calculated by multiplying the seed and straw yield with their respective concentrations and expressed in kg/ha. Total K uptake was determined by adding the uptake in seed and straw for the individual treatment as per the standard procedures.

RESULTS AND DISCUSSION

Yield of mustard

Yield of sole mustard, both in terms of seed and stover yield was observed to be the highest (1.75 t/ha and 6.38 t/ha respectively) when only mustard crop was considered individually (Table 1). It significantly outperformed mustard + chickpea (5:2) intercropping system by giving 33.5% higher yields in both the years. This can be attributed to the absence of competition and a higher plant population in the sole crop, allowing for better resource utilization. It was followed by mustard + chickpea 5:2 intercropping system due to higher plant population of mustard. Lowest yields were observed in mustard + chickpea 2:5 intercropping system. In terms of mustard equivalent yield, mustard + chickpea 5:2 intercropping system produced the highest yields. This is likely due to the increased availability of light and space when the two plants are closely planted together. The higher availability of photosynthates might have led to more flowers and successful fertilization, resulting in a higher number of siliquae per plant. Among the nutrient management practices, both seed and stover yield of mustard was recorded the highest in the treatment where 20 kg nitrogen was applied through farmyard manure + leaf manure @ 4 t/ha + microbial consortia. This result can be attributed to the organic manures providing a greater availability of macro and micronutrients in appropriate proportions. Additionally, the microbial consortia might have contributed to the solubilization of nutrients, further enhancing plant growth and yield. This was followed by the treatment where 20 kg nitrogen was applied through farmyard manure + leaf manure @ 4 t/ha excluding microbial consortia. Least yields were observed in control plot where no source of organic manure or chemical fertilizer was applied. Second least yields were seen in the plot where fertilization was by inorganic chemical fertilizer i.e., 60 kg nitrogen/ha. A possible reason could be the availability of only a single macronutrient and not other major nutrients. Also, the nutrient availability to the plant from chemical fertilizer gets reduced on account of different losses like leaching and runoff.

Yield of chickpea

Here, if chickpea crop was considered individually, both grain and straw yield of sole chickpea plot recorded the highest yields (1.99 t/ha and 1.58 t/ha respectively) due to the efficient utilization of both above and below-ground resources. It was followed by mustard + chickpea 2:5 plot (1.50 t/ha and 1.24 t/ha respectively) on account of higher plant population of chickpea. An increment of 33% grain yield and 28% straw yield was marked in sole chickpea over mustard + chickpea (2:5) intercropping system. More rows of chickpea fix a higher amount of atmospheric nitrogen and make it available for plant uptake increasing yields. Also, plants being more photosynthetically efficient, led to higher assimilate and dry matter production, resulting in better vegetative growth. The reduction in seed, straw, and biological yields of chickpea under the intercropping system was significantly higher than mustard, indicating more competition and shading effects caused by the taller mustard plants. Similar findings were reported by Singh and Rana in 2006. Among the nutrient management practices, both grain and straw yield of chickpea was recorded the highest in the treatment where 20 kg nitrogen was applied through farmyard manure + leaf manure @ 4t/ha + microbial consortia. The microbial consortia Rhizobium used in chickpea helps in better nitrogen availability to the plant on account of symbiotic relationship between

Table 1. Effect of cropping systems and nutrient management practices on yield of mustard, chickpea and mustard equivalent yield (data mean of 2 years)

Treatment	Yield of mustard		Yield of chickpea		Mustard equivalent yield (t/ha)
Cropping systems	Seed yield (t/ha)	Stover yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	
Mustard sole	1.75	6.38	–	–	1.75
Chickpea sole	–	–	1.99	1.58	1.94
Mustard + Chickpea (2:5)	0.80	2.35	1.50	1.24	2.27
Mustard + Chickpea (5:2)	1.31	4.77	0.85	0.67	2.34
SEm±	0.09	0.22	0.04	0.05	0.10
CD (P=0.05)	0.29	0.68	0.15	0.16	0.28
Nutrient management practices					
Control	1.16	4.27	1.27	1.05	2.42
60 kg Nitrogen/ha	1.29	4.51	1.35	1.18	2.62
20 kg Nitrogen through FYM + Leaf Manure	1.31	4.58	1.56	1.21	2.86
20 kg Nitrogen through FYM + Leaf Manure + Microbial Consortia	1.38	4.66	1.60	1.22	2.95
SEm±	0.07	0.12	0.05	0.05	0.14
CD (P=0.05)	0.20	0.37	0.16	0.15	0.41

Rhizobium and host plant. Also, organic manures enhance root development and chickpea plant can extract nutrients from deeper layers of soil profile due to its deep root system.

Mustard equivalent yield

Both intercropping systems and nutrient management practices significantly influenced mustard equivalent yield. The highest mustard equivalent yield was recorded in the mustard + chickpea 5:2 row ratio (2.34 t/ha) which was almost 3% higher yield compared to mustard + chickpea 2:5 row ratio (2.27 t/ha), highlighting the advantage of intercropping (Table 1). Regarding nutrient management practices, the integrated application of farmyard manure, leaf manure, and microbial consortia resulted in the highest mustard equivalent yield (2.95 t/ha) which was 21% higher than control plot. This can possibly be attributed to the secretion of growth-promoting substances by microbial inoculants, which contributed to improved root development, nutrient uptake, and ultimately higher yields.

Economics

Upon inspecting the data, it became evident that the applied treatments resulted in significant variations in economic parameters (Table 2). The mustard + chickpea 2:5 row ratio intercropping system incurred the highest cost of cultivation (₹ 30610/ha), considering both seed rate and seed cost. This was ₹500 extra than mustard sole crop. Additionally, the organically treated plots incurred higher costs due to the need for applying bulk amounts of organic materials with lower nutrient concentration. Maximum cost of cultivation was incurred for the plot treated with 20 kg nitrogen + leaf manure @ 4 t/ha + microbial consortia (₹32,670/ha). Despite the higher cost of cultivation, the mustard and chickpea 5:2 intercropping system provided the highest gross returns (₹84,560/ha), net returns (₹ 54040/ha), and benefit-cost ratio (1.77), compared to the sole cropping system due to higher yields. This system gave 47% higher gross returns over sole chickpea crop making it remunerative for farmers. These findings align with the results reported by Neupane *et al*., 1997.

Nutrient uptake

Total nutrient uptake by both mustard + chickpea was recorded the highest in mustard + chickpea 2:5 row ratio (182.93 kg/ha) (Table 3) which was 3% higher over chickpea sole plot (176.77 kg/ha). Chickpea has deep root system and by virtue of this trait, it extracts nutrients from deeper soil layers and makes them available for plant uptake. Also, Rhizobium present in the root nodules of chickpea fix atmospheric nitrogen by utilizing the symbiotic relationship between the bacteria and host plant. Considering mustard plant individually, nitrogen uptake by seed and stover was found to be the highest in mustard sole crop as mustard is a heavy feeder of nutrients and it requires nitrogen for its robust growth. It was followed by mustard + chickpea (5:2) ratio which was significantly lower than mustard sole crop. Similarly, nitrogen uptake by grain and straw for chickpea was found the highest in chickpea sole crop considering uptake for chickpea crop individually. It was significantly higher than uptake of intercropping systems due to higher plant population of chickpea. Also, this may be attributed to deep roots of chickpea which go to deeper layer and utilize nutrients effectively. Among the nutrient management practices, 20 kg nitrogen through farmyard manure + leaf manure + microbial consortia gave the highest nitrogen uptake as application of microbial consortia helps increase enzymatic activ-

Table 2. Effect of cropping systems and nutrient management practices on economic parameters (mean data of 2 years)

Treatment	Cost of cultivation (₹ × 10^3/ha)	Gross returns (₹ × 10^3/ha)	Net returns (₹ × 10^3/ha)	Net Benefit: cost
Cropping systems				
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 practices				
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

Table 3. Effect of cropping systems and nutrient management practices on total nutrient uptake of mustard and chickpea (mean data of 2 years)

Treatments	Mustard			Chickpea			Mustard + Chickpea
	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)	Total uptake (kg/ha)
Cropping systems							
Mustard sole	53.99	19.87	97.10	–	–	–	170.96
Chickpea sole	–	–	–	97.75	11.76	67.26	176.77
Mustard + Chickpea (2:5)	12.29	4.48	23.64	84.18	10.24	57.87	182.93
Mustard + Chickpea (5:2)	27.59	10.43	56.00	32.53	3.95	22.81	141.61
SEm±	0.48	0.17	0.85	3.04	0.35	1.96	6.49
CD (P=0.05)	1.55	0.56	2.74	9.08	1.07	5.89	19.65
Nutrient management practices							
Control	11.46	11.46	20.52	78.97	8.97	49.93	172.37
60 kg Nitrogen/ha	13.74	13.74	24.42	86.03	10.08	55.24	190.88
20 kg Nitrogen through FYM + Leaf Manure	14.45	14.42	24.87	86.06	10.07	55.43	194.50
20 kg Nitrogen through FYM + Leaf Manure + Microbial Consortia	15.27	15.27	26.72	86.77	10.26	55.83	198.03
SEm±	0.59	0.21	1.05	2.63	0.30	1.69	6.13
CD (P=0.05)	1.89	0.69	3.36	7.40	0.92	5.05	18.22

ity in soil thus solubilizing nutrients and making them available for plant uptake. This similar trend was observed both for phosphorus and potassium uptake in mustard as well. Among the nutrient management practices, integrated application of farmyard manure, leaf manure and microbial consortia gave highest nitrogen, phosphorus, potassium and total uptake. The reason could be the secretion of growth promoting substances by microbial inoculants, which in turn led to better root development and enhanced uptake of nutrients.

Thus, it may be concluded that yield of cropping system in terms of mustard equivalent yield based on price of produce was recorded the highest in mustard + chickpea (5:2) intercropping system. Gross returns, net returns, net B:C was also found the highest in this treatment. Total nutrient uptake was recorded the highest in mustard + chickpea 2:5 intercropping system with integrated application of organic manures and microbial consortia (20 kg N through FYM + leaf manure + microbial consortia).

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