



Contemporary nitrogen management in maize (*Zea mays*)–Indian mustard (*Brassica juncea*) cropping system for maximizing yield, water productivity and profitability

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ABSTRACT

A field experiment was conducted during 2018–19 and 2019–20 at the research farm of ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan to evaluate the effect of organic and inorganic nitrogen sources on yield, water productivity, system productivity and economics of maize (*Zea mays* L.)-mustard [*Brassica juncea* (L.) Czern.] cropping system. The experiment was conducted in split-plot design with recommended levels of fertilizers (RDF)/FYM/biofertilizer/mustard straw/Jivamrat in main-plots and recommended doses of nitrogen (RDN) 100, 125 and 150% in sub-plots to maize and Indian mustard and replicated thrice. Application of RDF + FYM @2.5 t/ha + *Azotobacter* + mustard straw @2.5 t/ha recorded highest SCMR (41.2), leaf area index (4.42), number of siliqua/plant (440.7), number of seeds/siliqua (18.4), test weight (5.83 g) and seed yield (3.36 t/ha) of mustard. Application of RDN 150% recorded highest physiological and yield attributes and seed yield (3.22 t/ha) of mustard. Results also showed the highest physiological and yield attributes and grain yield (3.73 t/ha) of maize with RDF+FYM @2.5 t/ha+*Azotobacter*+mustard straw @2.5 t/ha. System productivity (4.84 t/ha) and water productivity (2.14 kg seed/m³) were found higher with RDF+FYM @2.5 t/ha +*Azotobacter*+mustard straw @2.5 t/ha and RDN 150%. The highest net monetary return 51715, 81040 and 132755 ₹/ha and B:C ratio 3.09, 3.22 and 3.15 were recorded for maize, mustard and system with RDF+FYM @2.5 t/ha+*Azotobacter*+mustard straw @2.5 t/ha and RDN 150%, respectively. Thus, integrated use of RDF+FYM @2.5 t/ha+*Azotobacter*+mustard straw @2.5 t/ha with RDN @150% improved maize–mustard system yield and profitability under semi-arid climates.

Keywords: Leaf area index, Maize-mustard cropping system, System productivity, Water productivity

Despite being the third largest producer (11.3%) of rapeseed and Indian mustard [*Brassica juncea* (L.) Czern.] in the world, after Canada and China, India meets 60% of the domestic edible oil requirements through imports and is ranked the 7th largest importer (Jat *et al.* 2021). India imports edible oil worth more than USD 10.0 billion annually to meet the national requirement (Rathore *et al.* 2022). Maize (*Zea mays* L.) is also the third most important food grain crop in India, considered as key option for diversifying agriculture in upland areas of India. Nutrient management is one of the most important agronomic factors that affect the yields of both Indian mustard and maize crops. Among the major nutrients, nitrogen being deficient in most of the Indian soils and its higher requirement by crops is the most limiting element in maize–mustard production system. Both Indian mustard and maize are more responsive to chemical

fertilizers especially nitrogen. Nitrogen is considered as most important nutrient for the crop to activate the metabolic activity and transformation of energy, SCMR and protein synthesis (Singh and Meena 2004). Nitrogen also affects the uptake of other essential nutrients and it helps in the better partitioning of photosynthesis to reproductive parts which increase the seed : stover ratio (Singh and Meena 2004). Under such situation, integrated nutrient management is a practical alternative that holds great promise not only for securing high productivity but also against deterioration of soil environment. So, the current trend is to explore the possibility of supplementing chemical fertilizers with organic ones which are eco-friendly and cost-effective (Datta *et al.* 2009). Integration of chemical fertilizers along with FYM and *Azotobacter* and jivamrat could be serving the purpose, as they are cheap pollution free and renewable.

Therefore, nitrogen management with contemporary alternatives holds great promise not only for securing high productivity but also against deterioration of soil environment. Thus, a field experiment was conducted with the objective to quantify the effects of different sources of

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nitrogen including FYM, *Azotobacter*, mustard straw and jivamrat with graded levels of nitrogen on water productivity, yields and profitability of maize–mustard cropping system.

MATERIALS AND METHODS

Experimental site and climate characteristics: An experiment was conducted at the research farm of ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur (77°30' E, 27°15' N and at an altitude of 178.37 m amsl) Rajasthan during 2018–19 and 2019–20. The mean monthly meteorological observations recorded at ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur during the crop growth period. The experimental soil was silty clay loam in texture (21.3% sand, 50.3% silt and 28.4% clay), pH (1:2 soil water suspension) 8.3, bulk density 1.52 g/cm³, field capacity (by weight) 12.5% and permanent wilting point 2.35% were observed. The nutrient concentration in soil was also measured 0.27%, 128.6 kg/ha, 15.31 kg/ha, 270.4 kg/ha organic C, available N, available P and available K, respectively.

Treatment details and preparation of field: The experiment consisted of 5 main plot treatments, viz. RDF (T₁), RDF+FYM @ 2.5 t/ha (T₂), RDF+FYM @ 2.5 t/ha + *Azotobacter* (T₃), RDF+FYM @ 2.5 t/ha+*Azotobacter*+mustard straw @ 2.5 t/ha (T₄), RDF+FYM @ 2.5 t/ha+*Azotobacter* + mustard straw @ 2.5 t/ha+Jivamrat @ 500 l/ha (T₅) and 3 sub plot treatments including RDN 100% (N₁), RDN 125% (N₂) and RDN 150% (N₃) with 3 replications. RDF for mustard was used 80:40:40:20:5:1 (N:P:K:S:Zn:B) and for maize, 100:60:40:5:1 (N:P:K:Zn:B). Well-decomposed FYM which has been stored for a sufficient period of time to allow its decomposition and apply in the field before 15 days of sowing. Jivamrat ingredients, viz. cow dung : 10 kg, jaggery : 2 kg, chickpea flour : 2 kg, cow urine : 10 l, soil : 500 g were put into a drum containing 200 l water. After a week, the jivamrat was ready and was used for soil application. Jivamrat (500 l/ha) was applied as per the treatments at the time of irrigation. The seeds were inoculated by *Azotobacter* species as per the treatment. Date of sowing of mustard were 18 October 2018 and 17 October 2019 and harvesting dates were 9 March 2019 and 7 March 2020. Variety DRMRIJ 31 was used for sowing purpose with row to row distance 45 cm.

Observation recorded: Observations on physiological parameters, yield and yield attributing characters were recorded. The SCMR content was measured with SPAD SCMR meter reading (SCMR) and LAI after 30, 60 and 90 DAS. SCMR data were recorded. In maize crop various observations were recorded [SCMR (SPAD chlorophyll meter reading) and LAI at 30, 60 and 90 DAS; cob length, number of grains/ear, 100-grain weight, grain and stalk yield] on physiological parameters, yield components and yield by tagging five plants in each plot. After harvest maize stalks were removed from the field to facilitate the sowing of the succeeding mustard crop. In mustard, harvested length of randomly tagged plants length of 5 siliqua/plant was measured with a scale and expressed

as mean length of siliqua (cm). While reported the average number of seeds per siliqua, the number of seeds per siliqua of respective branches has been averaged.

Mustard equivalent yield was obtained by separating the economic value of the produce [Yield of produce (tonnes/ha) × Price of produce (₹/tonne)] with the price of the mustard (₹/tonne). Total productivity of the system in mustard equivalent yield was calculated on the basis of support price for the main produce during study period and prevailing market prices for the inputs. The input water productivity was computed as the ratio of grain yield to the total water input (irrigation+rainfall) from sowing to harvesting of the crop and expressed as kg seed/m³. The net monetary return (NMR), gross monetary returns (GMR) and B:C ratio were calculated as per the standard formula.

The data obtained on various observations were tabulated and analyzed split-plot design with three replications by using the techniques of the analysis of variance (ANOVA) as suggested by Panse and Sukhatme (1967) and the treatment was tested by F test shown their significance where critical difference (CD) at 5% level of significance was determined for each character to compared the differences among treatment means.

RESULTS AND DISCUSSION

SCMR: SCMR value increased till 60 DAS and marginally reduction was observed at 90 DAS in both maize and mustard crop (Table 1). The highest SCMR was recorded at 60 DAS in both crops. Treatment T₄ recorded highest SCMR (40.26) in maize crop. In mustard crop, the highest SCMR was recorded in treatment T₄ (41.19). In N levels treatments, the highest SCMR for maize (38.43) and mustard (39.51) were recorded in N₃ treatment. The present work is supported by the reports of earlier work done by Kadam *et al.* (2022).

LAI: Among different sources treatment T₄ recorded highest leaf area index (4.74) at 60 DAS (Table 1). In mustard crop, the highest leaf area index (4.42) was recorded in T₄. 150% RDN recorded significantly higher leaf area index in both maize (4.33) and mustard (4.14). The highest LAI was recorded at 60 DAS in both maize and mustard crops and a reduction in LAI was observed at 90 DAS due to shrinkage in leaves at this stage. Similar results were also reported by Hashim *et al.* (2015) and Kadam *et al.* (2022).

Post-harvest observations in maize: Among different sources treatment T₄ recorded highest cob length (15.81) (Table 2). 150% RDN recorded highest cob length (15.02) followed by RDN 125% (13.84) and RDN 100% (12.82). The highest number of grains/cob was found in the T₄ treatment (323.9). Among N levels, RDN 150% recorded highest number of grains (322). Among N levels, N₃ recorded highest 100-grain weight (24.40 g) and least 100-grain weight was recorded in the treatment N₁ (22.41). Similar results were also reported by Sarkar *et al.* (2018) and Kolhapure *et al.* (2013).

Table 1 Effect of different nutrient sources and N levels on SCMR and LAI of maize and mustard (pooled data of two years)

Treatment	Maize						Mustard					
	SCMR			LAI			SCMR			LAI		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
<i>Sources of Nutrient</i>												
T ₁	22.90	33.88	31.56	1.66	3.45	3.24	21.90	33.94	31.31	0.94	3.17	2.67
T ₂	23.39	34.71	31.78	1.94	3.77	3.45	22.54	36.10	32.92	1.09	3.47	2.84
T ₃	24.32	36.60	32.55	2.20	4.16	3.65	23.81	37.39	34.01	1.20	3.89	3.06
T ₄	25.76	40.26	35.02	2.68	4.74	3.98	25.91	41.19	36.12	1.42	4.42	3.45
T ₅	25.15	38.82	35.53	2.40	4.56	3.79	24.36	38.48	33.82	1.33	4.19	3.16
SEm±	0.33	0.56	0.63	0.06	0.08	0.11	0.53	0.60	0.55	0.05	0.09	0.09
CD (P=0.05)	1.08	1.82	2.04	0.20	0.25	0.35	1.73	1.95	1.79	0.17	0.29	0.29
<i>N levels</i>												
N ₁	23.78	35.18	32.56	2.03	3.91	3.45	22.48	36.22	32.89	1.09	3.43	2.82
N ₂	23.90	36.95	33.22	2.09	4.17	3.63	23.49	36.52	33.59	1.16	3.91	3.06
N ₃	25.23	38.43	34.09	2.41	4.33	3.79	25.14	39.51	34.42	1.34	4.14	3.23
SEm±	0.45	0.51	0.52	0.05	0.03	0.07	0.47	0.56	0.71	0.03	0.06	0.03
CD (P=0.05)	NS	1.49	NS	0.14	0.10	0.21	1.39	1.64	NS	0.08	0.17	0.10

Treatment details are given under Materials and Methods.

Post-harvest observations in mustard

Length of siliqua (cm): The length of siliqua was significantly (P=0.05) higher under T₄ treatment (4.49 cm) as compared to other treatments (Table 2). RDN 150% recorded highest siliqua length (4.14 cm). Similar results were also reported by Singh *et al.* (2014) and Singh *et al.* (2018).

Number of siliqua/plant: The treatment T₄ recorded highest number of siliqua/plant (440) followed by T₅ treatment (418) and least number of siliqua was recorded under treatment T₁ (261) (Table 2). RDN 150% recorded more number of siliqua/plant (383) followed by RDN 125% and 100%. Similar results were also reported by Singh *et al.* (2018).

Number of seeds/siliqua: The number of seeds/siliqua was significantly (P=0.05) higher under T₄ treatment (18.39) (Table 2). RDN 150% recorded highest number of seeds/siliqua (17.23), whereas treatment N₁ recorded least number of seeds/siliqua (15.77). Similar results were also reported by Singh *et al.* (2014) and Singh *et al.* (2018).

1000-seed weight (g): Significantly higher 1000-seed weight of mustard was recorded in T₄ treatment (5.83) (Table 2). Treatment N₃ (RDN 150%) recorded highest test weight (5.23) followed by N₂ (4.95) and N₁ (4.63). Similar results were also reported by Singh *et al.* (2014).

Maize grain and stover yield (t/ha): The highest grain yield was recorded in the treatment T₄ treatment (3.73 t/

Table 2 Effect of different nutrient sources and N levels on post-harvest observations of maize and mustard (2 years pooled data)

Treatment	Maize			Mustard			
	Cob length (cm)	Number of grains/cob	100-grains weight (g)	Siliqua length (cm)	Number of siliqua/plant	Number of seeds/siliqua	1000-seed weight (g)
<i>Sources of nutrient</i>							
T ₁	11.83	277.72	21.56	3.36	261.11	14.39	3.69
T ₂	12.59	293.78	21.99	3.54	287.72	15.39	4.46
T ₃	13.70	303.11	23.32	3.79	354.22	16.89	5.11
T ₄	15.81	323.94	25.09	4.49	440.67	18.39	5.83
T ₅	15.55	316.78	24.83	4.22	418.67	17.50	5.61
SEm±	0.08	2.29	0.04	0.07	5.45	0.35	0.11
CD (P=0.05)	0.27	7.47	0.14	0.24	17.76	1.15	0.34
<i>N levels</i>							
N ₁	12.82	281.90	22.41	3.64	322.97	15.77	4.63
N ₂	13.84	305.30	23.26	3.87	351.43	16.53	4.95
N ₃	15.02	322.00	24.40	4.14	383.03	17.23	5.23
SEm±	0.07	2.07	0.07	0.05	4.00	0.20	0.06
CD (P=0.05)	0.20	6.10	0.20	0.15	11.79	0.60	0.17

Treatment details are given under Materials and Methods.

ha) (Table 3). RDN 150% recorded highest grain yield (3.67 t/ha) of maize. Choudhary and Behera (2019) also reported significantly higher values of most of the growth and yield parameters with 120 kg N/ha as compared to 0 and 60 kg N/ha levels in a conservation agriculture-based maize production system. Highest stover yield of maize was recorded in treatment T₄ (6.52 t/ha) followed by T₅ treatment (6.36 t/ha). Treatment N₃ recorded more stalk yield (6.35 t/ha). Similar results were also reported by Saha *et al.* (2010), Hashim *et al.* (2015), Sarkar *et al.* (2018) and Parihar *et al.* (2018).

Mustard seed and stover yield (t/ha): The highest seed yield was produced under the treatment T₄ (3.36 t/ha) which was closely at par with treatment T₅ (3.32 t/ha) (Table 3). However, the least seed yield was found in the T₁ (RDF) treatment (2.76 t/ha). 150% RDN gave highest seed yield (3.22 t/ha). Stover yield of mustard recorded highest under the treatment T₄ (6.57 t/ha). Among N levels, the highest stover yield was reported in the treatment N₃ (6.18 t/ha). Similar results were also reported by Singh *et al.* (2014), Singh *et al.* (2018) and Kadam *et al.* (2022).

Mustard equivalent yield (MEY) of maize (t/ha): The mustard equivalent yield of maize recorded highest in the treatment T₄ (1.48) followed by T₅ (1.45) treatment. The highest MEY was reported under the N level treatment RDN 150% (1.46) and least MEY was reported in RDN 100% treatment (1.31). Similar results were also reported by Das *et al.* (2010).

System productivity (t/ha): The highest

system productivity was recorded with T₄ treatment (4.84) followed by T₅>T₃>T₂ and T₁. Among N level treatments, the highest system productivity was recorded in RDN 150% treatment (4.68) treatment. However, least system productivity was observed in 100% RDN treatment (4.32). Similar results were also reported by Hashim *et al.* (2015).

Water productivity (kg seed/m³): The water productivity (WP) of mustard was recorded highest in the treatment T₄ (2.14) while least WP was recorded in the treatment T₁ (1.76) (Fig 1). Among N level, the highest water productivity was recorded with treatment N₃ (2.05) which was closely followed by N₂ (1.99) and N₁ (1.92).

Economics of maize crop: The common cost of cultivation for maize was ₹24750/ha (Table 3). The highest NMR was calculated in the T₄ treatment (51715 ₹/ha). The B : C ratio was maximum (3.09) under the

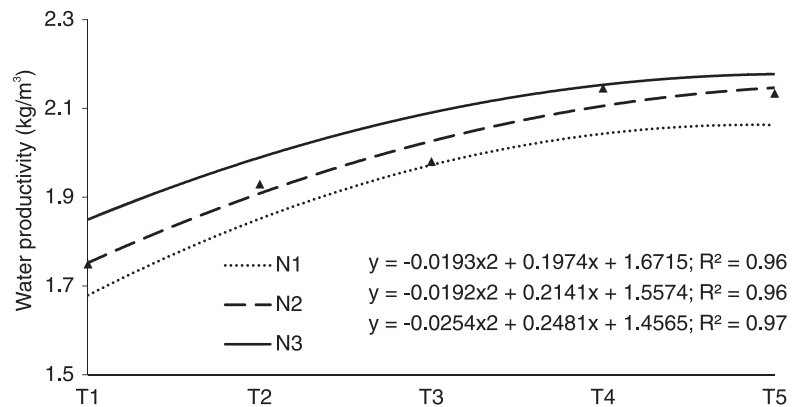


Fig 1 Effect of nutrient management practices and N levels on water productivity of mustard.

Table 3 Effect of different nutrient sources and N levels on yield and economics of maize and mustard (2 years pooled data)

Treatment	Maize				Mustard				System (Pooled)			
	Grain yield (t/ha)	Stover yield (t/ha)	NMR (₹/ha)	B:C ratio	Seed yield (t/ha)	Stover yield (t/ha)	NMR (₹/ha)	B:C ratio	Mustard equivalent yield of maize (t/ha)	System productivity (t/ha)	NMR (₹/ha)	B:C ratio
<i>Sources of nutrient</i>												
T ₁	3.26	5.49	42121	2.70	2.76	5.15	63315	2.89	1.30	4.06	105436	2.80
T ₂	3.34	5.70	43679	2.76	3.03	5.30	70590	2.99	1.33	4.36	114269	2.88
T ₃	3.48	5.97	46590	2.88	3.13	5.50	73685	3.06	1.38	4.51	120275	2.97
T ₄	3.73	6.53	51715	3.09	3.36	6.57	81040	3.22	1.48	4.84	132755	3.15
T ₅	3.65	6.37	49993	3.02	3.32	6.19	78645	3.09	1.45	4.77	128638	3.06
SEm±	0.02	0.15			0.03	0.12			0.01	0.03		
CD (P=0.05)	0.08	0.49			0.10	0.38			0.03	0.09		
<i>N levels</i>												
N ₁	3.30	5.70	42879	2.73	3.02	5.44	72170	3.16	1.31	4.33	115049	2.95
N ₂	3.50	5.97	46822	2.87	3.12	5.61	75550	3.24	1.39	4.52	122372	3.06
N ₃	3.67	6.36	49965	2.98	3.22	6.19	78825	3.32	1.46	4.68	128790	3.15
SEm±	0.02	0.06			0.02	0.07			0.01	0.02		
CD (P=0.05)	0.06	0.18			0.04	0.21			0.02	0.06		

Treatment details are given under Materials and Methods.

treatment T₄ while, least was recorded in T₁ (2.70) for maize crop. Among N level, the highest NMR and B:C ratio was recorded with treatment RDN 150% which was 49965 ₹/ha and 2.98. Similar results were also reported by Hashim *et al.* (2015), Singh *et al.* (2018) and Kadam *et al.* (2022).

Economics of mustard crop: The common cost of cultivation for mustard was ₹33425/ha (Table 3). The highest NMR was accrued in the T₄ (81040 ₹/ha). The B:C ratio was maximum (3.22) under the treatment T₄ while, least was recorded in T₁ (2.89). Among N level, the highest NMR and B:C ratio was recorded with treatment RDN 150% which was 78825 ₹/ha and 3.32, respectively. Application of 120 kg N/ha has been reported economically most profitable in addition to other benefits of improved produce quality and soil health in maize-based cropping system (Choudhary and Behera 2019; 2021). Similar results were also reported by Singh *et al.* (2014) and Kadam *et al.* (2022).

System economics: The treatment T₄ treatment and 150% RDN recorded highest system economics including NMR and B:C ratio (Table 3). The highest NMR was accrued in the treatment T₄ (132755 ₹/ha). Maximum B:C ratio was recorded with treatment T₄ (3.15). Among N levels, the highest NMR and B:C ratio was recorded in N₃ which was 128790 ₹/ha and 3.15, respectively. However, lowest B:C ratio was recorded under treatment T₁ (2.95).

This study highlighted the standardization of various nutrient sources with nitrogen levels in mustard and maize crops. Overall, the integrated use of RDF+FYM @2.5 t/ha+*Azotobacter*+ mustard straw @2.5 t/ha and RDN @150% improved the water productivity, system productivity and profitability of maize–mustard cropping system which could be recommended for use in Rajasthan and similar ecological conditions for maximizing the income of the farmers.

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