AATCC Review

15 January 2025: Received
23 March 2025: Revised
18 April 2025: Accepted
22 April 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article Open Access

Yield and quality of rainfed Indian mustard (*Brassica juncea* L.) as influenced by integrated nutrient management under loamy sand soils

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ABSTRACT

An investigation was undertaken to evaluate the effect of integrated nutrient management on the growth, yield and economics of Indian mustard for three consecutive years (2019-20 to 2021-22) at CCS Haryana Agricultural University, Regional Research Station, Bawal under rainfed condition. Nutrients have paid dividends in yield revolutions in agriculture and will continue to contribute significantly to future food security. Pooled data from three years reveal that different nutrient management treatments had higher growth and yield attributes of Indian mustard over control. Application of 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (through FYM) recorded a significantly higher number of primary branches per plant and siliqua per plant over control. Yield attributes viz. siliqua length, numbers of seeds per siliqua, and 1000-seed weight were not significantly influenced by different nutrient management treatments. Application of 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) recorded significantly higher seed yield (18.74 q/ha) of mustard compared to other treatments except 60:30:15 kg N P K/ha and 25:25:12.5 kg NPK/ha (inorganic) + 25 kg N/ha (FYM). Highest net returns (Rs. (₹) 53,695 /ha), B:C ratio (2.50), and rain-water use efficiency (18.28 kg/ha-mm) were also recorded with the application of 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM). Available NPK kg/ha in soil at harvest were significantly higher under 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) over control. Oil content, nitrogen content and protein content (%) in seed do not differ significantly under various nutrient management treatments but oil yield of mustard was significantly higher with the application of 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) and remained statistically at par with 60:30:15 kg N P K/ha. Our studies suggest a paradigm shift in nutrient management practices and strategies for attaining higher yield, nutrient use efficiency, economic profitability with lower environmental footprints.

Keywords: *Mustard, integrated nutrient management, protein content, oil content, yield and economics.*

Introduction

Indian mustard (*Brassica juncea* L.) is a major oilseed crop in the country. Oilseed crops play an important role in Indian agriculture, industry and trade since edible oils constitute an indispensable component of the Indian diet and have an important role in providing mineral nutrition as oil to human beings and feed to animals. Out of nine important oilseed crops viz. groundnut, rapeseed-mustard, linseed, sunflower, safflower, niger, soybean, sesame and castor grown in the country, rapeseed-mustard ouupies a prestigious position and ranks second after groundnut. India is the second largest producer of rapeseed-mustard in the world, with one-fifth of the world's rapeseed-mustard production next to Canada [16]. The estimated area, production, and yield of rapeseed-mustard in the world were 36.59 million hectares, 72.37 million tones, and 1980 kg/ha, respectively [6] [3]. Mustard production in the country during 2021-22 recorded 11.75 million tones from 8.06 million hectare area and productivity of 1458 kg/ha. Haryana is in second position after Rajasthan with an area of 0.7 million hectares and production of 1.37 million tones [7]. In modern agriculture, production practices mostly emphasize on wide-spread use of chemical fertilizers for realizing higher production but at the same time, evidences reveal deterioration in soil productivity and ecological degradation with their continuous non-judicious use in years to come. The major constraint limiting the productivity of oilseeds is that they are predominantly raised under energy-starved conditions (on poor fertile lands). Mustard responds well to N, P, K and S fertilization depending upon the initial soil fertility status and moisture availability. Application of 10-15 tone/ha farm yard manure with 100 per-cent recommended NPK dose with bio-fertilizers like PSB and *azotobacter* enhances the physical, biological, and chemical properties of the soil [22]. Integration of chemical fertilizers with organic manures has been found quite promising not only in sustaining the soil health and productivity but also in stabilizing the crop production in comparison to the use of each component separately. Farmyard manure (FYM) rich in organic matter can be supplemented with NPK fertilizers. It not only provides most of the essential nutrients but also improves soil structure through a binding effect on soil aggregates. Integrated use of organic and inorganic sources of nutrients can be an effective measure in boosting the average yield of mustard [11]. Keeping in view of declining productivity, it is apparent that there is a need to generate more information on integrated nutrient management for oilseeds especially mustard for sustainable productivity under dryland conditions. Hence, the present investigation was undertaken to evaluate the effect of INM in integration with FYM on the growth and yield of Indian mustard under rainfed conditions.

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DOI: https://doi.org/10.21276/AATCCReview.2025.13.02.320

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Materials and Methods

A fixed plot field experiment was carried out at CCS Haryana Agricultural University, Regional Research Station, Bawal during *Rabi* 2019-20 to 2021-22 consisting of thirteen treatment combinations *viz.* T_1; Control, T_2; 40:20 kg N P/ha (RDF), T_3; 50:25 kg N P/ha, T_4; 60:30 kg N P/ha, T_5; 40:20:10 kg N P K/ha, T_6; 50:25:12.5 kg N P K/ha, T_7; 60:30:15 kg N P K/ha, T_8; 20:20 kg N P/ha (inorganic) + 20 kg N/ha (FYM), T_9; 25:25 kg N P/ha (inorganic) + 25 kg N/ha (FYM), T_{10}; 30:30 kg N P/ha (inorganic) + 30 kg N/ha (FYM), T_{11}; 20:20:10 kg N P K/ha (inorganic) + 20 kg N/ha (FYM), T_{12}; 25:25:12.5 kg NPK/ha (inorganic) + 25 kg N/ha (FYM), T_{13}; 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) laid out in randomized block design with three replications. The experimental site, located in Haryana's central plains within India's Trans-Gangetic plains agro-climatic zone, has a tropical steppe and semi-arid climate. After the withdrawal of monsoon rains, the experimental field was plowed using a tractor-drawn disc harrow. Two rounds of harrowing were carried out for the preparation of beds and for conventional sowing. This was followed by cultivating the field to incorporate chipped crop residues and weeds, which helped in the breakup of clods and achieved good soil tilth, creating a finely pulverized seedbed ready for sowing during the 42^{nd} standard meteorological week. In 100% (RDF) Recommended Dose of Fertilizer (40 kg N+20 kg P_2O_5 /ha) was applied at the time of sowing. A specific quantity of well-decomposed farmyard manure (FYM) was applied to the designated treatment plots prior to sowing the crop. FYM was thoroughly incorporated into the soil to ensure proper nutrient distribution and to enhance soil fertility. Mustard (*variety* RH 725) was grown as per the recommended package of practices of rainfed condition. After harvest, seed samples were collected for analysis of oil content. At the end of the cropping cycle, the soil samples (0-15 cm) were collected and analyzed for available N, P and K by adopting standard analytical methods [21]. The data recorded on growth, yield attributes and yields were subjected to statistical analysis and the mean differences were evaluated by a critical difference (C.D.) test at 5% level of significance. The 'OPSTAT' software of CCS Haryana Agricultural University, Hisar, India was used for statistical analysis [20]. The economics and benefit-cost (B:C) ratio was worked out by simple tabular analysis. The oil content in mustard seeds produced under various treatments was analyzed as per the method suggested by [26]. Oil yield was calculated by multiplying seed yield and oil content in the seeds. The protein content in the seeds was estimated by multiplying N content with a constant factor of 6.25 and expressed in per-cent. The protein yield was calculated by multiplying seed yield with protein content in seeds.

Experimental site and climatic conditions

Geographically, Bawal is located at 28.07° N and 76.59° E in western Haryana. It is situated in agroclimatic zone II (semi-arid region) of Haryana. The soil of the experimental field was low in organic matter (0.19%) and available nitrogen (105 kg/ha) and medium in available phosphorus (11.2 kg/ha) and available potassium (169 kg/ha) with slightly alkaline in reaction (pH 8.2) at the initiation of the experiment. The crop was grown completely under rainfed conditions. Rainfall during the crop growth period was recorded at RRS, Bawal meteorology unit. The total rainfall received during the crop season of 2019-20 to 2021-22 (October-March) was 106.1, 68.61 and 196.5 mm with 13, 8 and 14 numbers of rainy days, respectively (Table 1). In this study, despite good crop growth yield levels across the treatments in the years 2019-20 and 2020-21 was slightly lower when compared to 2021-22. It was due to the higher amount of rainfall received and more number of rainy days during the year 2021-22.

Table 1. Actual rainfall (mm) and rainy days during crop growth period (2019-2022)

Month	2019-20		2020-21		2021-22	
	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days
October	0.0	0	0.0	0	33.5	3
November	5.0	1	1.4	0	0.0	0
December	13.9	1	0.0	0	1.1	0
January	17.0	4	33.41	4	152.4	9
February	1.4	0	0.0	0	9.5	2
March	68.8	7	33.8	4	0.0	0
Total	106.1	13	68.61	8	196.5	14

Results and Discussion

Yield attributes

The perusal of pooled data (2019-20 to 2021-22) in Table 2 depicted that a significant difference was observed among different nutrient management treatments regarding yield attributes in mustard. Critical examination of data indicates that application of T_{13}; 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) recorded a significantly higher number of primary branches per plant over T_8; 20:20 kg N P/ha (inorganic) + 20 kg N/ha (FYM) and all the inorganic nutrient treatments; except T_7; 60:30:15 kg N P K/ha, where it remained at par. The number of siliquae/plant were significantly higher under T_{13}; 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) over rest of the treatments but remained at with T_{10}; 30:30 kg N P/ha (inorganic) + 30 kg N/ha (FYM) and T_{12}; 25:25:12.5 kg NPK/ha (inorganic) + 25 kg N/ha (FYM). The number of primary branches per plant and number of siliquae/plant under T_{13}; 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) were higher to the tune of 22.9 and 116.7 percent over control, respectively. No significant difference was found among various nutrient treatments in respect of siliqua length, no. of seeds per siliqua and 1000-seed weight. Because, nitrogen is considered as a growth element, thus improved meristematic activities coupled with sufficient availability of photosynthates on account of efficient physiological processes altogether led to increased growth and its attributes. The results are in close conformity with those of [12] and [18].

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Table 2. Effect of Effect of integrated nutrient management on yield attributes of Indian mustard (pooled mean of 3 years)

Treatment	No.of primary branches/ plant	Number of iliquae/ plant	Siliqua length (cm)	Number of seeds/ siliqua	1000-seed wt. (g)
T_1: Control	3.71	132	3.83	10.98	4.74
T_2 : 40:20 kg NP/ha (RDF)	4.09	192	3.87	11.27	4.74
T_3: 50:25 kg NP/ha	4.09	201	3.91	11.51	4.79
T_4: 60:30 kg NP/ha	4.18	217	3.93	11.46	4.82
T_5: 40:20:10 kg NPK/ha	4.22	213	3.97	11.67	4.77
T_6: 50:25:12.5 kg NPK/ha	4.28	224	3.97	11.74	4.82
T_7: 60:30:15 kg NPK/ha	4.43	241	4.00	11.69	4.93
T_8: 20:20 kg NP/ha (inorganic) + 20 kg N/ha (FYM)	4.30	221	4.00	11.60	4.85
T_9: 25:25 kg NP/ha (inorganic) + 25 kg N/ha (FYM)	4.40	241	4.05	11.77	4.86
T_{10}: 30:30 kg NP/ha (inorganic) + 30 kg N/ha (FYM)	4.47	268	4.06	11.77	4.94
T_{11}: 20:20:10 kg NPK/ha (inorganic) + 20 kg N/ha (FYM)	4.44	262	4.06	11.74	4.95
T_{12}: 25:25:12.5 kg NPK/ha (inorganic)+25 kg N/ha (FYM)	4.52	276	4.06	11.80	4.99
T_{13}: 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM)	4.56	286	4.07	11.63	5.02
CD (p=0.05)	0.18	23	NS	NS	NS
CV (%)	6.41	5.85	9.97	8.14	6.81

Cumulative effect of improved growth parameter (dry matter accumulation) through efficient metabolic activity, increased photosynthetic rate and supply of photosynthates from source to sink had accommodated more number of siliquae/plant under 125% RDF. These results are in line with those of [4].

Grain and stover yield

The results related to seed and stover yield of mustard showed significant differences between different treatment combinations. A quick view of the pooled data of three years in Table 3 reveals that seed yield was significantly higher (18.74 q/ha) in T_{13} treatment and significantly lower in control (12.49 q/ha) which was statistically at par with T_7 (17.47 q/ha) and T_{12} (17.26 q/ha). The stover yield was significantly higher in T_{13} (41.12 q/ha) over the rest of the treatments but remained at par with T_{12} (40.98 q/ha) and T_{10} treatments. It is evident from the data that seed and stover yield in T_{13} were higher to the tune of 50.0 and 23.5 % over control, respectively (Table 3).

Table 3. Effect of integrated nutrient management on yield and economics of Indian mustard (pooled mean of 3 years)

Treatment	Seed yield (q/ha)	Stover yield (q/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
T_1: Control	12.49	33.30	61017	28978	1.95
T_2 : 40:20 kg NP/ha (RDF)	14.33	36.41	69700	36307	2.13
T_3: 50:25 kg NP/ha	14.92	36.85	72560	38830	2.20
T_4: 60:30 kg NP/ha	16.40	38.70	79469	45401	2.38
T_5: 40:20:10 kg NPK/ha	15.50	38.14	75166	41480	2.27
T_6: 50:25:12.5 kg NPK/ha	16.26	38.11	78836	44738	2.36
T_7: 60:30:15 kg NPK/ha	17.47	37.44	84608	50099	2.50

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T_8: 20:20 kg NP/ha (inorganic) + 20 kg N/ha (FYM)	14.63	35.85	71073	36081	2.06
T_9: 25:25 kg NP/ha (inorganic) + 25 kg N/ha (FYM)	15.75	37.77	76333	40604	2.17
T_{10}: 30:30 kg NP/ha (inorganic) + 30 kg N/ha (FYM)	16.72	40.03	81034	44550	2.26
T_{11}: 20:20:10 kg NPK/ha (inorganic) + 20 kg N/ha (FYM)	16.71	38.91	80873	45589	2.33
T_{12}: 25:25:12.5 kg NPK/ha (inorganic)+25 kg N/ha (FYM)	17.26	40.98	83585	47489	2.36
T_{13}: 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM)	18.74	41.12	90619	53695	2.50
CD (p=0.05)	1.65	1.96	--	--	--
CV (%)	6.09	6.77	--	--	--

The cultivation of mustard responds favorably to this combined application of organic and inorganic fertilizer which exhibits higher root growth. This robust root system facilitates optimal absorption of moisture and nutrients from the soil, contributing to superior dry matter production. The consequential translocation of photosynthates from leaves to the siliquae further ensures the development of high-quality seeds. The seed size must have risen because to additional carbohydrates, synthesis process, etc. under integrated nutrition supply. Due to synergy relation between organic and inorganic fertilizers has proven pivotal in achieving higher seed yield. Significant growth and yield response to higher levels of fertilizer application might be attributed to increased availability and uptake of nutrients by crop plants which takes part in the metabolism of plant as an activator of several enzymes and in turn may directly or indirectly affect the synthesis of carbohydrate and protein [25] [24] [14].

Economics

A thorough understanding of the data pertaining to economics presented in Table 3 reveal that application of 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) (T_{13}) recorded the maximum gross return of Rs. (₹) 90,619/ha and net returns of ₹ 53,695/ha for mustard. This was followed by treatment T_7 (60:30:15 kg N P K/ha) and T_{12} (25:25:12.5 kg NPK/ha (inorganic) + 25 kg N/ha (FYM). Net return in T_{13} and T_7 was higher to the tune of 85.3 and 72.9 % over control, respectively (Fig. 1). The benefit: cost ratio of 2.50 was recorded under T_{13} (30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM), which is at par with T_7 (60:30:15 kg N P K/ha). This might be due to the higher yield of crops with this treatment. Gross return values are attributed to seed and stover yields while net return values are affected by both gross return and total cost of crop cultivation with different nutrient management. It is in conformity with the results reported by [19] [23] [1] [25] [17].

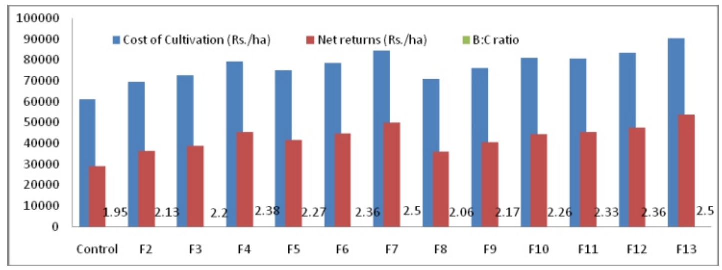

Fig.1. Economics of Indian mustard as influenced by different treatments

Soil nutrient status and water use efficiency

A thoughtful perception of the reveals that different integrated nutrient management treatments show significant differences in respect of available NPK in the soil at harvest. In pooled data analysis available NPK in the soil were significantly higher in T_{13} treatment and minimum were recorded under control which remained at par with T_{12}. Critical examination of data indicates that available NPK in the soil were significantly higher in T_{13} (combination of organic and inorganic sources) which were found at par with T_7 treatment (inorganic sources), which could be attributed to thape plication of higher doses of fertilizers. Application of a higher dose of phosphorus recorded a higher available N, P and K in the soil. The treatment where inorganic fertilizers were applied in conjunction with FYM analyzed higher available NPK in soil. It was due to the reason that incorporation of organic manures and chemical fertilizers generally affects the physical, chemical and biological properties of the soil [10]. The increase in variables N, P and K might be due to the addition of FYM. Organic manure plays a key role in the transformation, cycling and availability of nutrients to the crops, thus conjoint use of organic manure and chemical fertilizer helped in maintaining stability in production and improved chemical and physical properties of soil [2] [9]. Rain-water use efficiency (RWUE) (18.28 kg/ha-mm) was recorded highest in T_{13} (30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) followed by treatment T_7 (60:30:15 kg N P K/ha) as compared to other treatments (Table 4). It might be attributed to the improved growth of plants and significantly higher seed yield of mustard under this treatments. Similar results have also been reported by [8] and [15].

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Table 4. Effect of integrated nutrient management on available N P K and water use efficiency of soil at harvest

Treatment	N (kg/ha)	P (kg/ha)	K (kg/ha)	RWUE (kg/ha-mm)
T_1: Control	104.58	10.07	165.53	12.10
T_2 : 40:20 kg NP/ha (RDF)	104.58	12.93	169.02	13.94
T_3: 50:25 kg NP/ha	106.11	13.24	169.28	14.52
T_4: 60:30 kg NP/ha	106.47	14.69	171.70	15.97
T_5: 40:20:10 kg NPK/ha	108.37	13.88	174.37	15.08
T_6: 50:25:12.5 kg NPK/ha	106.86	14.41	174.51	15.83
T_7: 60:30:15 kg NPK/ha	108.11	15.07	176.80	17.03
T_8: 20:20 kg NP/ha (inorganic) + 20 kg N/ha (FYM)	109.35	13.38	173.37	14.23
T_9: 25:25 kg NP/ha (inorganic) + 25 kg N/ha (FYM)	107.40	14.50	173.86	15.33
T_{10}: 30:30 kg NP/ha (inorganic) + 30 kg N/ha (FYM)	109.30	14.77	174.39	16.37
T_{11}: 20:20:10 kg NPK/ha (inorganic) + 20 kg N/ha (FYM)	109.88	15.12	174.30	16.30
T_{12}: 25:25:12.5 kg NPK/ha (inorganic)+25 kg N/ha (FYM)	110.77	15.18	177.52	16.82
T_{13}: 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM)	110.87	15.88	178.26	18.28
CD (p=0.05)	1.95	1.35	2.32	--
CV (%)	6.06	5.64	7.79	--
Initial soil fertility	105.0	11.2	169.0	--

Quality parameters

After a careful glance of the data, it was observed that nitrogen content and protein content (%) in seed does not differ significantly under various nutrient management treatments. Protein yield (kg/ha) was significantly higher (411.28 kg/ha) in T_{13} treatment and significantly lower in control (232.32 kg/ha) which was statistically at par with T_7 (17.47 q/ha), T_{10}, T_{11} and T_{12}, which could be attributed to higher seed yield of mustard (Table 5). Various treatments of integrated nutrient management imposed in mustard indicated that there was not any significant effect of any treatment on oil content in mustard but oil yield of mustard was significantly higher with the application of T_{13} (30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) and remained statistically at par with T_7 (60:30:15 kg N P K/ha). Oil yield of mustard is increased due to the synergetic effect of seed yield. The results were in harmony with results recorded by [13] [5] [14].

Table 5: Effect of integrated nutrient management on quality of Indian mustard (pooled mean of 3 years)

Treatment	N content in grain (%)	Protein content (%)	Protein yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
T_1: Control	2.97	18.54	232.32	37.51	468.07
T_2 : 40:20 kg NP/ha (RDF)	3.15	19.67	281.61	38.11	546.18
T_3: 50:25 kg NP/ha	3.15	19.69	294.60	38.32	571.40
T_4: 60:30 kg NP/ha	3.21	20.07	330.04	38.56	632.18
T_5: 40:20:10 kg NPK/ha	3.21	20.04	311.42	38.43	595.21
T_6: 50:25:12.5 kg NPK/ha	3.26	20.38	332.24	38.62	627.77
T_7: 60:30:15 kg NPK/ha	3.40	21.25	372.50	38.87	678.87
T_8: 20:20 kg NP/ha (inorganic) + 20 kg N/ha (FYM)	3.32	20.73	304.11	38.27	559.55
T_9: 25:25 kg NP/ha (inorganic) + 25 kg N/ha (FYM)	3.33	20.81	328.79	38.37	604.15
T_{10}: 30:30 kg NP/ha (inorganic) + 30 kg N/ha (FYM)	3.38	21.13	253.61	38.43	642.63
T_{11}: 20:20:10 kg NPK/ha (inorganic) + 20 kg N/ha (FYM)	3.45	21.56	361.73	38.94	650.12
T_{12}: 25:25:12.5 kg NPK/ha (inorganic)+25 kg N/ha (FYM)	3.48	21.73	376.22	38.91	671.06

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T_{13}: 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM)	3.50	21.88	411.28	38.96	729.46
CD (p=0.05)	NS	NS	76.29	NS	51.52
CV (%)	7.72	7.73	13.67	4.14	4.95

Conclusion

Based on three years of study, it can be concluded that the application of 30:30:15 kg NPK/ha (inorganic) + 30 kg N/ha (FYM) in Indian mustard produced significantly higher seed yield; and fetched the highest net returns and benefit: cost ratio over other nutrient combinations; but it was statistically at par with 60:30:15 kg NPK/ha and 25:25:12.5 kg NPK/ha (inorganic) + 25 kg N/ha (FYM). The integrated nutrient supply system concept needs a relook for rainfed areas, especially in low and medium rainfall zones.

Future scope of the study

In modern agriculture, production practices mostly emphasized on wide-spread use of chemical fertilizers for realizing higher production but at the same time, evidences reveal deterioration in soil productivity and ecological degradation with their continuous non-judicious use in years to come. The role of soil organic carbon in maintaining soil fertility and productivity is well recognized. It increases water-holding capacity, soil microbiological activities, play key role in the transformation, recycling, and availability of nutrients to the crop. Therefore, to minimize the dependence on chemical fertilizers, recycling of organic sources is necessary, as these are environmentally friendly. The integrated nutrient supply system (INSS) helps to produce higher yields and improve soil fertility. Moreover, for higher fertilizer use efficiency and sustainability of cropping systems, there is a need to recommend and develop site-specific nutrient management strategies considering the cropping system as a whole, instead of component crops in isolation. To achieve this goal, we have to take into account the direct as well as residual effects of fertilizer to different crops in the system, particularly under rainfed conditions. Thus, we must better target nutrients for contrasting management scenarios so that farmers in emerging economies can balance risk and fertilizer application while expanding the use of nutrients beyond nitrogen, phosphorus, and potassium to a balanced approach that improves yields, use efficiency, and preserve our soils for the future.

Declaration of competing interest

The author declares that they have no conflict of interest.

Acknowledgement

The authors are highly thankful to Chaudhary Charan Singh Haryana Agricultural University, Hisar for providing funds and facilities that were essential for doing these research activities and completing of objectives.

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