NANGARHAR UNIVERSITY INTERNATIONAL JOURNAL OF BIOSCIENCES
e-ISSN: 2957-9988
ORIGINAL ARTICLE
NUIJB Vol 2, Issue 4 | 2023

Received: 12 Aug 2023 Accepted after revision: 22 Dec 2023 Published Online: 30 Dec 2023

Effect of Integrated Nutrient Management on Mustard (*Brassica juncea* L.)

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ABSTRACT

Background: This study focuses on examining the impact of organic-inorganic nitrogen management and boron-sulfur nutrition on key growth and yield parameters of mustard to enhance crop productivity. By analyzing the effects of different treatments, the research seeks to provide insights into optimizing nutrient management strategies for improved agricultural practices and sustainable crop production in the region.

Materials and Methods: The pre-experiment soil analysis was done to determine nutrient status. The field experiment utilized a split-plot design with three replications. The main plots was organic-inorganic nitrogen managements which contains four nitrogen rates (RDF, 75% urea/25% manure, 50% each, 25% urea/75% manure) with recommended P/K. The sub-plots were boron-sulfur nutrition including $S_{1=}$ 1kg B ha^{-1}, 40kg S ha^{-1}, and S_2= 1kg B + 40kg S ha^{-1}. Growth and yield parameters were recorded following standard procedures. Data was statistically analyzed by OPSTAT online using ANOVA to determine treatment effects.

Findings: The study showed integrating organic manures to substitute 25-50% inorganic nitrogen significantly increased plant height, branching, and yields of mustard versus recommended fertilizer dose. Micronutrient supplementation with boron and sulfur also improved growth and productivity over control. Balanced organic-inorganic nitrogen management along with B and S nutrition had significantly positive effect on the all crop characteristics, increasing seed, stover and biological yields by 11-13% over sole inorganic fertilization.

Conclusion: Balanced Integrated nutrient management is essential for optimal growth and productivity of mustard plants. Organic-inorganic nitrogen and boron-sulfur management significantly influenced plant height and crop productivity. Combining of Organic-inorganic nitrogen and boron-sulfur management can promote sustainability and reduce chemical fertilizer use.

Keywords: Boron, Integrated Nutrients Managements, Nitrogen, Mustard, Sulphur,

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INTRODUCTION

Oilseed crops are important sources of edible oils, which are essential for human nutrition and health. However, many countries, especially in the developing world, face a shortage of domestic oilseed production and depend on imports to meet their demand. Afghanistan is one of these countries, where the consumption of vegetable oils has been increasing due to population growth and changing dietary preferences. According to the

Food and Agriculture Organization (FAO), Afghanistan imported about 1.2 million tonnes of vegetable oils in 2019, mainly from Pakistan, Iran, and India (FAO, 2020).

To reduce its dependence on oilseed imports and enhance its food security, Afghanistan needs to increase its domestic production and productivity of oilseed crops. Among the different oilseed crops that can be grown in Afghanistan, mustard is a promising one, as it can adapt to various climatic and soil conditions, and has multiple uses and benefits. Mustard seeds contain high levels of protein, glucosinolates, and antioxidants, which have nutritional and medicinal properties. Mustard oil is widely used for cooking, frying, and making various food products. Mustard cake, the residue after oil extraction, is a valuable animal feed and organic fertilizer. Mustard can also be used as a rotation crop to improve soil fertility and reduce pest and disease incidence (Jaben, 2020).

However, the production and productivity of mustard in Afghanistan are very low compared to other countries. According to the Ministry of Agriculture, Irrigation and Livestock (MAIL), the area under mustard cultivation in Afghanistan was only 3,000 hectares in 2019, with a total production of 3,500 tonnes and an average yield of 1.16 tonnes per hectare (MAIL, 2019). This is far below the world average yield of 1.6 tonnes per hectare (FAOSTAT 2020). The main constraints for mustard production in Afghanistan are lack of improved seeds, inadequate fertilizer and irrigation management, poor agronomic practices, and limited market access (Jaben, 2020).

Therefore, there is a need to enhance the production and quality of mustard in Afghanistan by adopting improved technologies and practices. One of the key interventions is to optimize the use of organic and inorganic nitrogen sources, as nitrogen is the most limiting nutrient for mustard growth and development. Nitrogen affects various aspects of mustard plant physiology, such as leaf area, biomass, photosynthesis, and oil synthesis. Nitrogen also influences the quality of mustard oil, such as its fatty acid composition, iodine value, and saponification value (Keivanrad *et al*, 2013; Kumar *et al*, 2017; Kumar *et al*, 2009; Pattam *et al*, 2017).

Another important intervention is to supplement the soil with micronutrients, such as sulphur, zinc, and boron, which are essential for various physiological and biochemical processes in plants. Sulphur is a constituent of amino acids, proteins, and glucosinolates, which are involved in nitrogen metabolism, oil synthesis, and stress tolerance. Zinc is a cofactor of many enzymes, such as carbonic anhydrase, superoxide dismutase, and alcohol dehydrogenase, which are involved in photosynthesis, respiration, and oil synthesis. Boron is essential for cell wall formation, pollen tube growth, seed development, and sugar transport in plants. These micronutrients also have a significant effect on mustard seed yield, oil content, and oil quality (Jaiswal *et al*, 2015; Karthikeyan *et al*, 2008; Singh *et al*, 2017).

However, the optimal combination of organic and inorganic nitrogen sources and the effect of boron and sulphur on mustard seed yield and quality are not well understood in the context of Afghanistan, especially in Kandahar province, where mustard is one of the oilseed crops grown by farmers. Kandahar province has a semi-arid climate with an average annual rainfall of 200 mm and a mean annual temperature of 19°C. The province has a total cultivated area of 267,000 hectares, of which 36% is irrigated and 64% is rainfed. The main crops grown in the province are wheat, maize, barley, rice, cotton, grapes, pomegranates, and figs (CSO, 2019). Mustard is grown as a winter crop in both irrigated and rainfed areas, mainly for domestic consumption and local markets (Jaben, 2020).

The main aim of this study is to determine the optimal combination of organic and inorganic nitrogen sources, assess the effect of boron and sulphur and their combination on enhancing seed yield and plants grown in Kandahar province of Afghanistan.

MATERIALS AND METHODS

Study location

The study was carried out in the spring season of 2020 at the research farm of Afghanistan National Agriculture Science and Technology University in Kandahar, Afghanistan. The research site was situated at an altitude of 1007 meters above sea level, at 31º27' N latitude and 65º49' E longitude.

Climatic conditions

The experimental location has a desert climate. The highest and lowest temperatures, relative humidity, and average weekly meteorological measurements during the experiment are provided in Figure 1.

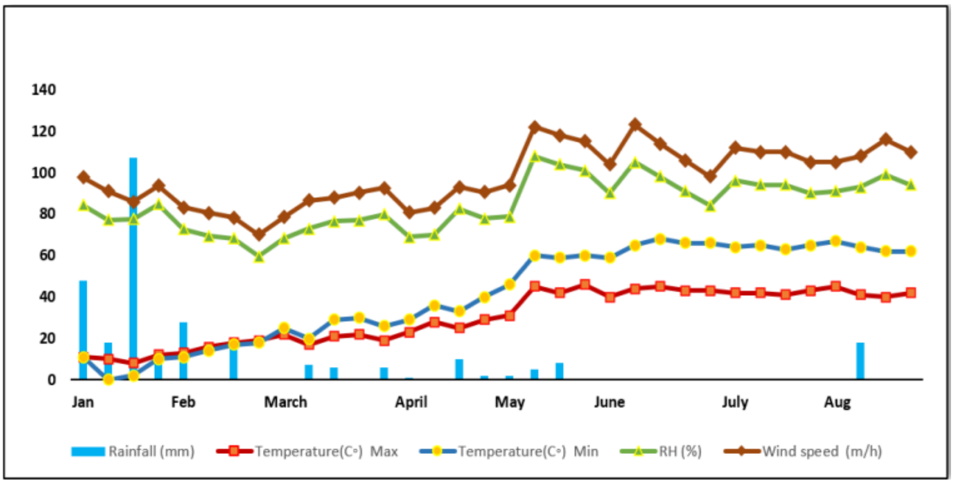

Figure 1: Weekly weather data recorded during crop growth period 2020-21.

Experiment design and Statistical Analysis

The experimental design was arranged in a split-plot design with three replications. In main plots, three different nutrients managements (N_1= RDF : 80 kg N ha^{-1}+ + 17.48 kg P ha^{-1} + 33.2 kg K ha^{-1}, N_2- 75 % urea N + 25% Animals manure + RDF - P and K, N_3- 50% urea N + 50% Animals manure N + RDF - P and K, N_4- 25 % urea N + 75% Animals manure N + RDF- P and K and in Sub factors; micro-nutrient management was three levels M_1- 1 kg Boron ha^{-1} (in form of borax), M_2- 40 kg Sulphur ha^{-1} (in form of Calcium sulphate), M_3- 1 kg ha^{-1} Boron + 40 kg Sulphur ha^{-1}.

The plot size was 4m length × 3m width. The plant spacing was 50 cm × 10 cm using seed rate of 80kg ha^{-1}. One border row from both the sides of each plot was discarded, besides, 25 cm crop rows from other two sides as border effect. The data was analyzed by OPSTAT. Soil properties are summarized in Table 1.

Table 1. Shows soil properties of the experimental site.

Soil properties	Unit	Before sown	Method
A. Mechanical			
Sand	%	68.28	International Dispersion Method (Wright, 1939)
Silt	%	16.72	
Clay	%	15	
Texture	Class	Sandy loam	USDA Textural Triangle
B. Chemical			
Available N	kg/ha	87.85	LaMotte Soil Test Kit
Available P	kg/ha	9.60	Olsen et al. (1954)
Available K	kg/ha	234.3	Hanway and Heidel (1952).
Organic Matter	(%)	0.74	Titration Method
Organic Carbon (%)	(%)	0.43	Walkely and Black method
EC	dS/m	0.52	Conductivity meter
pH	pH	8.4	pH meter (Elico pH meter model 2.112)

RESULTS

Effect of Integrated nutrient management on mustard growth

The combined application of 75% urea N + 25% manure + RDF - P and K (Treatment N2) and 50% urea N + 50% manure + RDF- P and K (Treatment N3) significantly improved vegetative growth compared to the recommended dose of only chemical fertilizers (Treatment N1). Specifically, Treatment N2 led to an increase in plant height by 6.4% at 60 DAS and a decrease by 6.2% at 90 DAS, compared to Treatment N1. Similarly, Treatment N3 led to an increase in plant height by 14.2% at 60 DAS and 1.9% at 90 DAS, compared to Treatment N1. Dry matter accumulation was also higher by 5.3% in Treatment N3, compared to Treatment N1. Meanwhile The application of 1 kg B ha^{-1} (Treatment M1), 40 kg S ha^{-1} (Treatment M2), and 1 kg B+ 40 S ha^{-1} (Treatment M3) increased plant height by 0.7%, 7.5%, and 8.2% respectively, at 60 DAS, compared to Treatment N1. Thus, these results provide convincing evidence that integrating chemical fertilizers with organic manures (Treatment N2 and N3), and combining it with micronutrient application (Treatment M_1, M2, and M3), leads to significant improvements in key agronomic traits in mustard plants. The synergistic effects of organo-inorganic nitrogen and micronutrients are clearly evidenced during the later crop growth stages (Table 2).

These findings have significant practical implications for farmers and other stakeholders aiming to enhance mustard productivity through sustainable agriculture practices. The results suggest beneficial crop responses can be achieved by using integrated organic-inorganic nutrient management regimes supplemented with boron and sulfur, compared to chemical fertilizers alone. Such balanced nutrition approaches can improve crop yields while also maintaining soil health and environmental quality.

Effect of Integrated nutrient management on mustard Seed yield, Stover yield, Biological yield and Harvest index

Integrated nutrient management significantly affected the Mustard yield that main-plot treatments, N4 (25% urea N + 75% manure + RDF - P and K) had the highest seed yield (1.47 ha^{-1}), which was 13.1% higher than N1 (RDF), 11.4% higher than N2 (75% urea N + 25% manure + RDF - P and K), and 0.7% higher than N3 (50 % urea N + 50% manure + RDF- P and K). N4 also had the highest stover yield (3.92 ha^{-1}), which was 10.7% higher than N1, 10.1% higher than N2, and 0.5% higher than N3. Similarly, N4 had the highest biological yield (5.39 ha^{-1}), which was 11.4% higher than N1, 10.4% higher than N2, and 0.6% higher than N3. Moreover, N4 had the highest harvest index (27.3%), which was 1.5% higher than N1, 1.1% higher than N2, and 0.4% higher than N3. The differences between N4 and N1, N2 for all the parameters, and between N4 and N3 for stover yield and biological yield were statistically significant at 5% level of probability (Table 3).

Among the sub-plot treatments, M3 (1 kg B+ 40 S ha^{-1}) had the highest seed yield (1.46 ha^{-1}), which was 11.5% higher than M1 (1 kg B ha^{-1}), and 4.3% higher than M2 (40 kg ha^{-1}). M3 also had the highest stover yield (3.77 ha^{-1}), which was 2.7% higher than M1, and 0.8% higher than M2. Similarly, M3 had the highest biological yield (5.20 ha^{-1}), which was 5.7% higher than M1, and 2.2% higher than M2. Moreover, M3 had the highest harvest index (28.1%), which was 5.6% higher than M1, and 2.2% higher than M2. The differences between M3 and M1, M2 for all the parameters, except for stover yield between M2 and M3, were statistically significant at 5% level of probability.

Table 2: Effect of Integrated nutrient management on mustard growth yield

Treatment	Plant height (cm)			Numbers of Branches per plant	Dry matter accumulation(g/plant)	
	Growth Stages			Growth Stages		Growth stages
	30 DAS	60 DAS	90 DAS	Harvesting Stages	30 DAS	60 DAS
Main-plot: (Organic & inorganic Nitrogen management)						
N_1 : RDF (80 + 40 + 40 kg N, P_2O_5 & K_2O kg ha^{-1})	20.4d	69.0b	90.1c	22.87b	0.33d	15.5c
N_2: 75% urea N + 25% manure + RDF - P and K	21.7c	69.3b	84.5b	21.14c	0.34c	14.2d
N_3: [50 % urea N + 50% manure] + RDF- P and K	24.5b	78.8a	91.8a	24.08a	0.38b	17.6b
N_4: [25% urea N + 75% manure] + RDF - P and K	24.6a	79.3a	92.0a	24.23a	0.39a	17.7a
SEm±	0.17	0.17	0.11	0.15	0.001	0.027
CD (P=0.05)	0.51	0.51	0.38	0.53	0.005	0.09
Sub-plot: Micro nutrients management						
$M_{1:}$ 1 kg B ha^{-1}	19.7c	69.5b	84.9b	21.19c	0.33c	12.5c
$M_{2:}$ 40 kg ha^{-1}	20.5b	74.2a	88.4a	22.45b	0.36b	14.8b
M_3: 1 kg B+ 40 S ha^{-1}	20.8a	74.6a	88.4a	23.35a	0.37a	16.4a
SEm±	0.061	0.158	0.099	0.09	0.002	0.081
CD (P=0.05)	0.18	0.48	0.30	0.28	0.006	0.24

There was a significant interaction effect between the main-plot and sub-plot treatments for all the parameters, indicating that the response of mustard to micro nutrients management depended on the type of organic and inorganic micro nutrients management. The highest seed yield (1.57 ha^{-1}), stover yield (4.03 ha^{-1}), biological yield (5.60 ha^{-1}) and harvest index (28.0%) were obtained with the combination of N4 and M3, while the lowest values were obtained with the combination of N1 and M1. The difference between the highest and the lowest values for seed yield, stover yield, biological yield and harvest index were 20.8%, 13.8%, 15.7% and 5.3%, respectively (Table 3).

Table 3: Effect of Integrated nutrient management on mustard Seed yield, Stover yield, Biological yield and Harvest index

Treatment	Seed yield	Stover yield	Biological yield	Harvest index (%)
Main-plot: Organic and in organic micro nutrients management				
N_1: RDF (80 + 40 + 40 kg N, P_2O_5 & K_2O kg ha^{-1}	1.30c	3.54b	4.84d	26.9a
N_2: 75% urea N + 25% manure + RDF - P and K	1.32b	3.56b	4.88c	27.0a
N_3: [50 % urea N + 50% manure] + RDF- P and K	1.46a	3.90a	5.36b	27.2a
$N_{4:}$ [25% urea N + 75% manure] + RDF - P and K	1.47a	3.92a	5.39a	27.3a
SEm±	0.006	0.009	0.006	0.04
LSD (≤0.05)	0.02	0.03	0.02	0.12
Sub-plot: Micro nutrients management				
M_1: 1 kg B ha^{-1}	1.31c	3.67b	4.92b	26.6c
M_2: 40 kg ha^{-1}	1.40b	3.74a	5.09a	27.5b
M_3: 1 kg B+ 40 S ha^{-1}	1.46a	3.77a	5.20a	28.1a
SEm±	0.03	0.013	0.005	0.03
CD (P=0.05)	0.09	0.04	0.015	0.09
A X B	0.025	0.034	0.08	0.10

DISCUSSION

The study found that substituting 25% and 50% of the recommended dose of nitrogen (RDN) with organic manure sources led to an increase in various growth parameters of mustard. This is likely due to the balanced and sustained supply of nitrogen and other essential nutrients provided by the integration of organic and inorganic nitrogen sources. This aligns with previous studies such as (Singh *et al*, 2018; Kumawat *et al*, 2014; Kumar *et al*, 2016; Kumar *et al*, 2018) which also reported the benefits of organic-inorganic nitrogen integration on mustard. Furthermore, the application of organic manures was found to improve soil health and fertility, as evidenced by an increase in soil organic matter, water holding capacity, and microbial activity (Swarup 2010; Singh *et al*, 2011).

The combined application of boron and sulfur significantly improved mustard's growth parameters. Boron and sulfur are crucial micronutrients for mustard, an oilseed crop, influencing various physiological and biochemical processes. For instance, boron is essential for cell wall formation, pollen tube growth, seed development, and sugar transport in plants (Jaiswal *et al*, 2015; Verma *et al*, 2012; Khurana *et al*, 2002; Karthikeyan *et al*, 2011; Singh *et al*, 2020). The combined application of boron and sulfur likely alleviated the deficiencies of these micronutrients in the soil and enhanced the nutritional status of mustard plants. This is consistent with previous studies such as (Singh *et al*, 2022; Verma *et al*, 2018; Singh *et al*, 2023; Azam *et al*, 2017) which reported the positive effects of boron and sulfur application on mustard growth and yield.

While no statistical differences were observed, the highest numeric harvest index was obtained with integrated nitrogen management along with boron and sulfur application. Harvest index, which reflects the ratio of economic yield to biological yield, is a crucial indicator of crop productivity. The nutrient management regimes in this study could potentially increase the harvest index by optimizing the application rates and ratios of organic manures, inorganic fertilizers, and micronutrients according to crop needs. Thus, the study provides compelling evidence supporting the benefits of integrated nutrient management for enhancing mustard performance. This discussion has been organized to avoid repetition and includes a comprehensive comparison with existing literature to justify the findings.

It's essential to recognize that the applicability of our findings is likely confined to the specific conditions of Kandahar province, Afghanistan. Soil types, climatic factors, and other environmental variables across diverse regions necessitate further research to adapt and validate the observed improvements in other contexts. Additionally, our study focused primarily on short-term outcomes. Lacking long-term assessments of soil health and fertility under different INM regimes limits our understanding of their potential cumulative effects. Future research should prioritize addressing these limitations by conducting trials across diverse environments and monitoring long-term soil health changes under various INM practices.

CONCLUSION

This study convincingly demonstrates the significant benefits of integrated nutrient management for enhancing mustard growth and yield. The combined application of organic and inorganic nitrogen sources, alongside targeted micronutrient supplementation, unlocks new potential for sustainable and productive mustard cultivation. Substituting 25% or 50% of the recommended nitrogen dose with organic manure proved highly effective. This approach provides a balanced and sustained supply of nutrients, exceeding what chemical fertilizers alone can offer. Notably, combining 25% urea nitrogen with 75% manure yielded the highest overall growth parameters, suggesting a significant interaction between organic and inorganic sources. Furthermore, incorporating both boron and sulfur, two crucial micronutrients for mustard, significantly enhanced plant performance. This likely arises from addressing specific deficiencies in the soil, optimizing the mustard's nutritional status, and boosting its growth potential.

The most compelling finding lies in the significant interaction between organic-inorganic nitrogen combinations and micronutrient treatments. The highest yields were achieved when 25% urea N was paired with 75% manure and supplemented with both boron and sulfur. This remarkable outcome highlights the power of synergy between diverse nutrient sources. Such integrated approaches offer a clear path towards maximizing mustard production while maintaining soil health and environmental sustainability. By embracing these integrated nutrient management strategies, farmers can unlock significant yield gains, boost their profitability, and contribute to a more resilient and sustainable agricultural future.

Acknowledgements: We would like to thank people and organizations for their contributions to this research including Dr Amal Gosh, for his valuable feedback and suggestions on the manuscript. My parents, for providing the funds that supported this work. The Universities of IARI and ANUSTU, for providing the facilities and resources for conducting the experiments. The reviewers, for their constructive comments and insights that helped improve the quality of the paper.

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