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ORIGINAL RESEARCH ARTICLE

Optimizing soil quality and mustard (*Brassica juncea*) yield through spacing and sesbania incorporation

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ABSTRACT

Soil fertility is an important variable in achieving higher production scales. Sesbania is frequently utilized as an alternate material for soil fertility improvement since it improves the chemical characteristics of soil and supplies plant nourishment after decomposition. An experiment was conducted at Khulna Agricultural University to investigate the way plant spacing and sesbania incorporation affect mustard yield, yield characteristics, and soil fertility. The study laid out randomized complete block design included six treatments, which consisted of three different spacing's, along with the incorporation of sesbania green manuring crops as a soil fertility improver and using BARI-14 sarisha as the test crop. The findings of the experiment showed that the majority of the yield and yield components notably varied with variation of spacing and sesbania application. Results showed that sesbania incorporated soil with optimum (30 × 20 cm) plant spacing positively impacted highest mustard yield (1.66 t ha^{-1}), 5% more oil content and 2.4% more siliqua plant^{-1} compared to no green manuring plot. On the other hand, plants set up widely (30 × 30 cm) brought in more siliquae plant^{-1}, seeds siliqua^{-1} and 1,000-seed weight than closer spacing. Furthermore, inclusion of sesbania resulted in improvement of organic matter (7%), available nitrogen (30%), phosphorus (30%) and potassium (50%) in soil compared to non-incorporated soil. Therefore, an optimal spacing of 30 × 20, along with the integration of sesbania (5t/ha), is required to achieve enhanced mustard yield and oil content, as well as improved soil fertility.

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INTRODUCTION

Soil degradation and declining fertility pose significant challenges to sustainable agriculture, particularly in mustard (*Brassica juncea*) cultivation. Traditional agronomic practices often overlook the importance of optimizing plant spacing and incorporating organic matter to enhance soil health and maximize yield. Inappropriate spacing can lead to competition for nutrients, water, and sunlight, while a lack of organic amendments results in soil nutrient depletion, reduced microbial activity, and poor crop performance. Addressing these challenges is crucial to improving both soil quality and mustard productivity. Mustard which belongs to the genus Brassica of the family Brassicaceae is one of the most important oil seed crops beside soybean throughout the world (FAO, 2014) is covering above 69.94% of the oil cropped area and producing 38.80% of the total oilseed production in Bangladesh. According to DAE, in the fiscal year 2022-23, the mustard cultivation area expanded to 810,000 hectares, yielding an estimated 1.05 million metric tons. This represents a notable increase from the previous year, where production was reported at 824,000 tons (BBS, 2021). Despite this growth, soil fertility challenges pose significant constraints on mustard yield. The intensification of cropping patterns in Bangladesh has led to the depletion of essential soil nutrients, resulting in diminished soil health and productivity. So soil nutrients need to be replenished after each harvest. Inadequate use of fertilizers, deficiencies of micronutrient exacerbates nutrient deficiencies in the soil (Prasad *et al.*, 2017; Patel *et al.*, 2024). To address these issues, adopting integrated nutrient management practices is essential. This approach involves the combined application of organic manures like use of green manuring crops and inorganic fertilizers, use of biochar, vermicompost, duckweed to replenish depleted nutrients and enhance soil health (Irin & Hasanuzzaman, 2024a) and Irin & Biswas, 2023). These organic fertilizers also provide secondary nutrients and micronutrients which are often absent in synthetic fertilizer. Green manure such as Dhaincha (*Sesbania* spp.) i.e. Sesbania is a fast-growing legume known for its ability to fix nitrogen in the soil (Irin *et al.*, 2019) and improves soil fertility by adding nutrients such as N, phosphorus (P), K (potassium) (Irin *et al.*, 2020). Again, legumes have the potentiality to enhance soil carbon sequestration and could lower soil pH and increase the plant -soil-microbes activity and thus create a favorable environment for crop growth and development. Different soil microbes like P and K solubilizing bacteria are nobly increased by sesbania incorporation in soil and resulting improved crop growth and soil fertility (Irin & Hasanuzzaman, 2024b). It is revealed that, N and K are the key elements that are available in soil through organic manure, which significantly improved seed yield as well as mustard production (Chahal *et al.*, 2020; Turcios *et al.*, 2021).

By improving nutrient availability, and plant productivity, this study contributes to enhanced agricultural sustainability, reduced dependency on chemical fertilizers, and improved farmer profitability. The findings will provide valuable insights for agronomists, farmers, and policymakers aiming to promote eco-friendly agricultural practices. Therefore, legumes such as sesbania green manure incorporation is necessary to rejuvenate soil fertility without further depletion. Along with soil fertility, proper spacing is crucial for increasing mustard yield (Alam *et al.*, 2015). Despite existing studies on mustard spacing and soil amendments, there is limited research on the synergistic effects of different spacing regimes and sesbania incorporation on soil quality and mustard yield. This study uniquely bridges this research gap by evaluating how these two factors interact to enhance soil health and optimize plant performance. Hence the present experiment was undertaken to assess the effects of different plant spacing and sesbania incorporation on soil quality parameters and mustard yield. Specifically, it seeks to determine the optimal combination of these factors to maximize mustard productivity while improving soil fertility and sustainability.

MATERIALS AND METHODS

Experimental area, design and treatments

The field experiment was conducted at Khulna Agricultural University Utilized during the rabi season in 2022 -2023. The soil of the experimental plot was sandy loam, having pH 6.2, organic matter 0.8%, available N, P, and K was .08%, 13.31 ppm and 0.19 mev/100g soil. The treatment comprises three different spacing such as D_1=30 cm x15, D_2=30 cm x20, D_3= 30 x30 cm and two levels of green manure (no green manure=NGM) and 5 kg ha^{-1} (GM). Thus, six treatment combination was laid at RCRD design with 3 replications and BARI -14 sarisha used as a research material. BARI-14 sarisha was collected from Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. *Sesbania rostrata* plants were collected and chopped into pieces, then mixed with soil and left for decomposition for 40 days. After decomposition, mustard seeds were sown in October, 2022. and recommended fertilizers were used @ 250, 180, 90 150 kg and 6 kg per hectare of Urea, TSP, MoP, Gypsum and Zinc sulphate, respectively. Intercultural operations were done as and when necessary. The crop was harvested at proper maturity. Before harvesting, 10 plants were randomly selected from each plot for collecting data on yield attributes. The quantitative parameters like, plant height (distance from soil surface to top of plant at maturity), no. of filled siliqua $plant^{-1}$, no. of seed siliqua-1, 1000 seed wt. (dried seeds was calculated and then converted to1000-seed weight by multiplying by 10), seed yield $plot^{-1}$and seed yield ha^{-1} and oil%, days to 50% flowering: (number of days from seed sowing until 50% of plants showed at least flower $plant^{-1}$,) days to harvest (number of days from seed sowing until 75% of plants of the genotype had dried or turned yellow before seed maturation) were measured. The harvest index was calculated on the ratio of seed yield to biological yield (seed yield straw yield) and expressed in percentage. It was calculated by using the following formula:

$$\text{Harvest index (\%)} = \text{Seed yield/Biological yield} \times 100$$

The oil content of the oven dried seeds was estimated by extracting oil using petroleum ether (60-80°C) as solvent and Soxhlet apparatus x. The oil yield (kg ha^{-1}) was calculated using following formula:

$$\text{Oil yield (kg ha}^{-1}) = \text{Seed oil content (\%)} \times \text{Seed yield (kg ha}^{-1})$$

Chemical analysis of soil

Before setting up the experiment, soil samples were collected from 0-15 cm depth and were dried under shade, powdered with wooden pestle and mortar, passed through 2 mm sieve and were analyzed for organic matter by rapid titration method by Nelson (1975). Available nitrogen was estimated by alkaline permanganate method by Subbiah & Asija (1956), available phosphorus by Olsen's method as outlined by Jackson (1967), available potassium was determined by using the flame photometer (Chesnin & Yien, 1951). After harvesting the crops, the same procedure was followed to analyze soil chemical properties such as organic matter, soil total N%, soil available P (ppm) and exchangeable K ($mev100g^1$ soil) and compared to the initial soil chemical properties which were presented in Table 1.

Table 1. Chemical properties of the after- harvest soil along with percent increase of nutrient of the experimental plot.

Treatments		OM%	%OM increased in soil	N%	%N increased in soil	P (ppm)	%P increased in soil	K (mev100g^{-1})	%K increased in soil
	30 x15	0.80		0.12		14.01		0.17	
NGM	30 x20	0.82	-	0.15	-	10.13	-	0.16	-
	30 x30	0.78		0.12		15.02		0.16	
	30 x15	0.89		0.16		17.21		0.22	
GM	30 x20	0.90	7.5%	0.19	30%	18	30%	0.26	50%
	30 x30	0.87		0.16		16		0.24	

Data analysis

The collected data were analyzed using computer package STATIC-10 package and mean differences were adjudged by using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Plant growth characteristics

Significant variation was observed in plant height owing to plant spacing and sesbania application (Figure 1). The highest plant height was recorded from sesbania incorporated plot with D_2 spacing whereas lowest was observed from non- green manure (NGM) plot. The significant increase in plant height was observed owing to the supply of a profuse amount of sesbania decomposed nitrogen fertilizer along with recommended fertilizer throughout the growing phase. Furthermore, decomposition ensures the deposition of different micro and macro nutrients to the soil (Irin & Biswas, 2023) and enhances plant root growth with profuse spreading and eventually increased plant height in the present experiment. Similar results were observed by Reza *et al.* (2022). Among the three -row spacing the highest number of branches plant^{-1} was obtained from D_3 followed by D_2 and D_1 and it showed significant difference with each other. The highest no. of siliqua plant^{-1} (29.00) and length of siliqua was observed at the spacing of wider rows (D_3) followed by D_2 and D_1. Proper spacing ensures sufficient oxygen supply to the plant root and leads to increase the growth of vigorous root system resulting in uptake more nutrients instead of formation of aerenchyma tissue. Proper spacing also reduces inter and intraspecific competition between plants and notably increased plant growth. This study was agreed with Mevada *et al.* (2017) who stated that proper spacing also ensures sufficient sunlight and increased leaf chlorophyll formation which ultimately promote plant growth and development This also facilitated higher siliqua production, siliqua length, seeds siliqua^{-1}, 1000 seed weight and ultimately better yields in present research, which was agreed by Gupta *et al.* (2018).

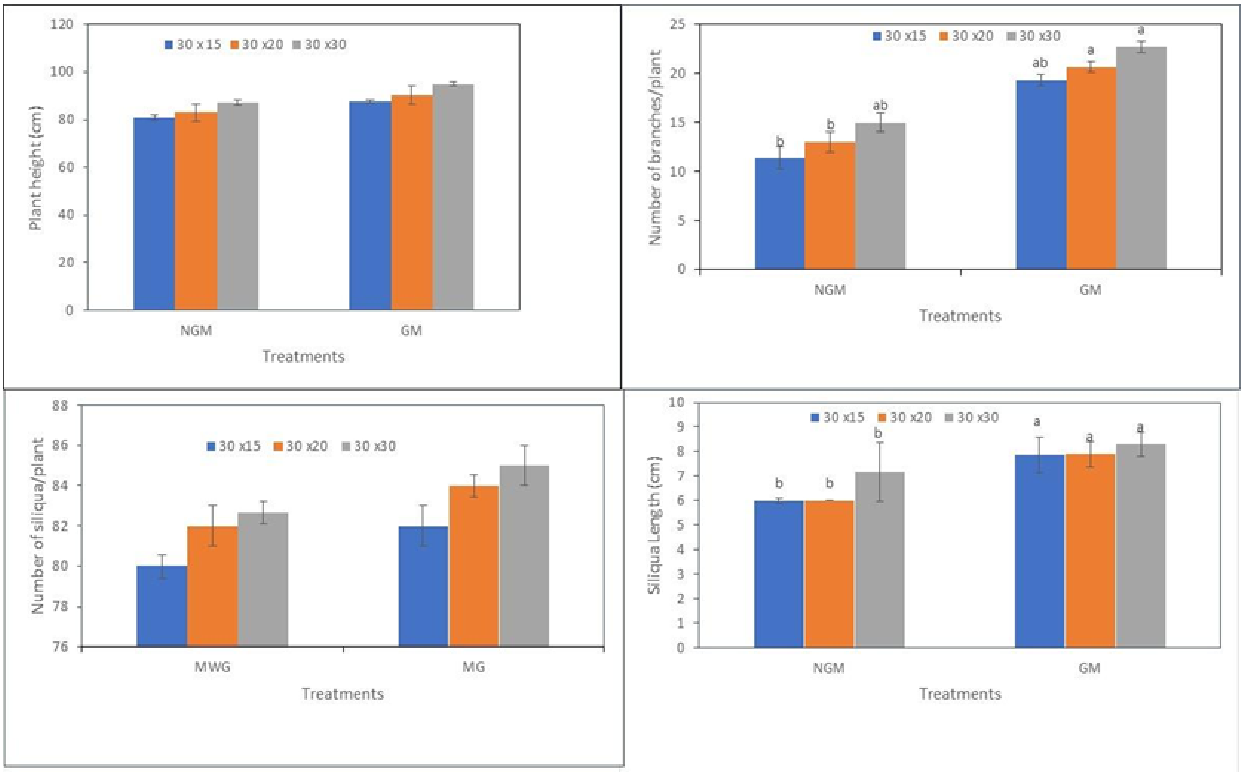

Figure 1. *Effect of treatments on the plant height^{-1} (a), number of branches plant^{-1} (b), number of siliqua plants^{-1} (c) and siliqua length (d) of mustard.*

Yield contributing Parameter

There was significant variation observed in seed siliqua^{-1}seed yield, days of 50% flowering and weight of thousands of mustard seeds in relation to spacing and sesbania incorporation (Figure 2). The highest mustard seed siliqua^{-1}and seed yield (1.6 tha^{1}) was observed from D_2 spacing followed by D_3 (1.60 tha^{1}) and $D_{1,}$ whereas, NGM plot showed 1.33 tha^{1} at D_2 spacing. Nitrogen is a vital nutrient for mustard and its availability through Sesbania incorporation can directly impact mustard vegetative growth, flower and pod formation resulting, higher yields in my studies. Additionally, mustard plants generated more siliqua plant^{1} due to the availability of plant-needed nutrients through sesbania and appropriate spacing, which ultimately resulted in profitable output in the experiment. Seed yield was found 25% higher in GM incorporated plot compared to NGM plot owing to application of higher doses of nitrogen through sesbania incorporation. This study was agreed with Priyanka *et al.* (2020). Furthermore, wide spacing (30 cm × 20 cm) also increased light interception leading to prolonged photosynthetic activity and speeding up cell activity and allow the crops to take in more accessible nutrients, which in turn led to exuberant vegetative growth and grain yield (Keivanrad & Zandi, 2012). Proper spacing also facilitated higher root shoot ratio and increased more branches and eventually higher mustard production (Mahto *et al.*, 2024). Again, sesbania incorporation showed delayed flowering compared to the NGM plot. It was agreed with Turcios *et al.* (2021).

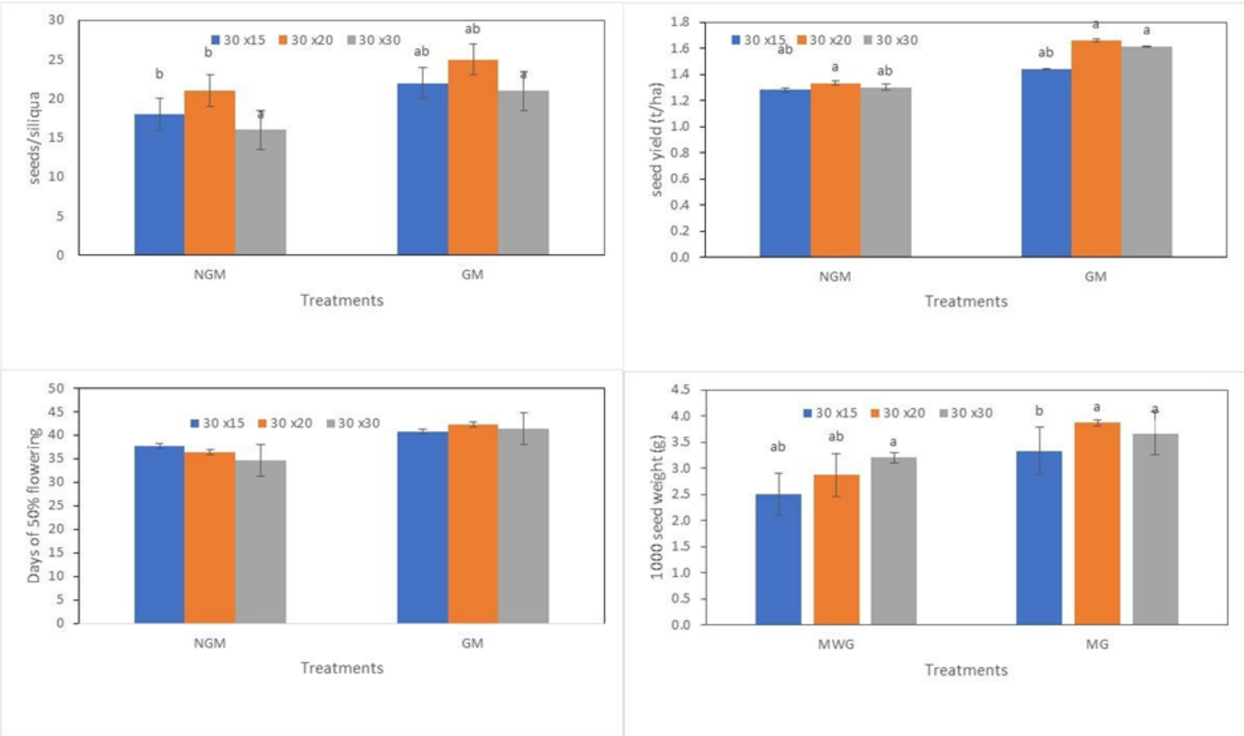

Figure 2. *Effect of treatments on the seed siliqua^{-1} (a), seed yield (b), days of 50% flower emergence (c) and 1000 seed weight (d) of mustard.*

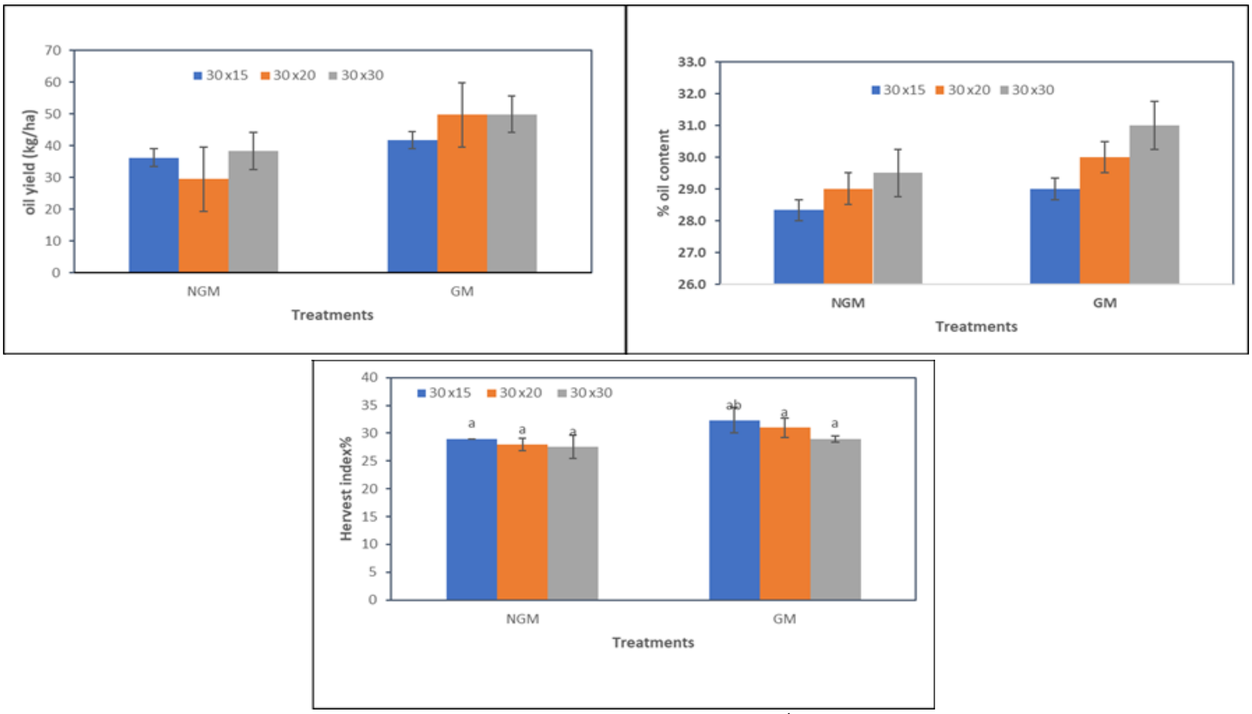

Figure 3. *Combined effect of treatments on oil content% (a), oil yield (t ha^{-1}) (b) and harvest index(c) of mustard.*

Harvest index and oil content of mustard

Sesbania-incorporated soil with greater spacing produced a maximum harvest index over two spacing's. For example, D_1 spacing produced a maximum harvest index of 32%, which was close to D_2, while D_3 spacing produced the lowest harvest index. The close spacing and growth in plant population per unit area were the primary causes of the harvest index increase. The maximum weight of 1000-seed was obtained from D_1(4 g) which was at par of D_2(3 g) plots and the minimum weight was found in D_3. It may be the transfer of nutrients from the source to the sink was impeded by intra-competition in closer spacing, which led to a diminished seed weight in D_1 spacing. Highest oil content and oil yield was observed from D_3 which was at par to D_2 and lowest oil content was observed in D_1. The increase in Seed oil% and seed oil yield due to the wider spacing and GM application were ranged up to 5% to 9% (Figure 3). The result was agreed by Baranwal *et al.* (2017) and Zangani (2021), who stated that increased levels of organic fertilizer have a positive correlation with increased seed production, oil output, and seed filling time of mustard by promoting gas exchange. Again, sesbania decomposition promotes the growth of P solubilizing bacteria in soil along with N (Irin & Hasanuzzaman, 2024b), thus P availability increases better root growth and absorption of N and Sulphur. Additionally, wider spacing's aided in the synthesis of fatty acids and their ester formation by speeding up the glyoxylate cycle's metabolic activities (Dwivedi & Bapat, 1998).

Soil chemical properties upgraded

There was a notable difference observed between the NGM and GM incorporated soil Following harvest, the maximum OM buildup was seen in D_2 spacing with GM introduced soil, compared to D_3 and D_1. The increased soil organic matter, soil nitrogen, phosphorus and potassium was ranged between 7% to 29% compared to non -green manuring plots in the present study (Table 1). The study was agreed by Irin & Biswas, (2023) who mentioned that organic fertilizer through sesbania significantly increased soil N, P and K availability. Thus, these nutrients have a considerable effect on quality, quantity of seed and finally crop yield (Chahal *et al.*, 2020; Turcios *et al.*, 2021).

Conclusion

Wider plant spacing results in less plants per unit area, which is insufficient to offset the yields of closer plant spacing, which results in more plants per unit area. In the current study, optimal spacing consistently guaranteed correct growth and output of mustard, while a larger plant population did not guarantee a greater yield due to intra-competition. Integrated Effect of Spacing and Sesbania Incorporation has a synergistic effect on crop yield. The combination of appropriate spacing and the incorporation of Sesbania can create a more favorable growth environment for mustard. The spacing ensures better plant growth, while sesbania provides the necessary nutrients and organic matter to support that growth. Therefore, proper spacing (30 ×20) and Sesbania incorporation are both effective strategies for improving soil fertility and increasing mustard yield.

DECLARATIONS

Author's contribution: Conceptualization: I.J.I; Methodology: I.J.I..; Software and validation: I.J.I.; Formal analysis: I.J.I.; Resources: I.J.I; Data curation: I.J.I. and L.D.; Writing—original draft preparation: I.J.I; Writing—review and editing: I.J.I and S.R.; Visualization: I.J.I; Supervision: I.J.I. and S.K.P. All authors have read and agreed to the published version of the manuscript.

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