JEB®

Journal of Environmental Biology

p-ISSN: 0254-8704 • e-ISSN: 2394-0379 • CODEN: JEBIDP

Journal website : www.jeb.co.in ★ **E-mail :** editor@jeb.co.in

Triveni Enterprises (Educational Services Set-up)

Original Research

DOI : http://doi.org/10.22438/jeb/44/2/MRN-3087

Productivity and profitability of Indian mustard under nutrient management and different sowing method in lateritic soil of West Bengal

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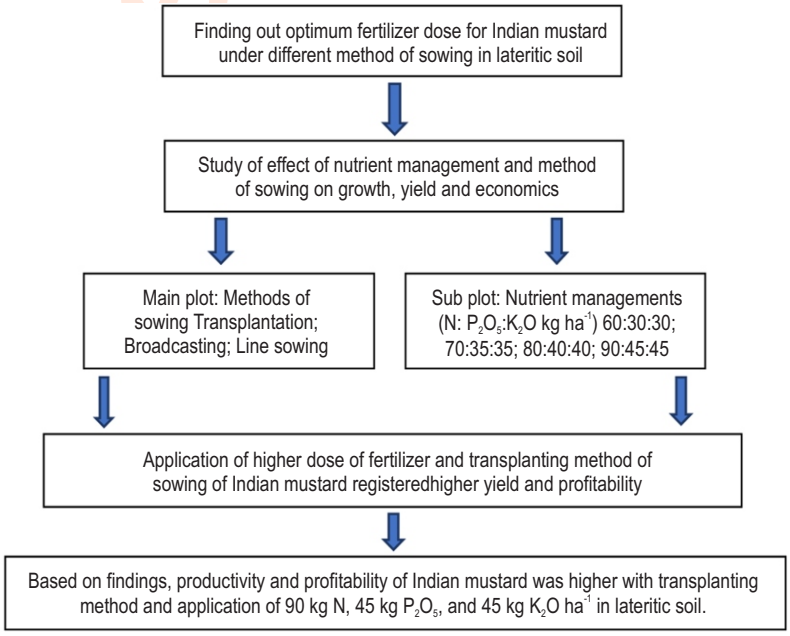
Received: 14.10.2021 *Revised*: 18.03.2022 *Accepted*: 16.08.2022

Abstract

Aim: This study was carried out to find the optimum fertilizer requirement and best planting method for higher productivity and profitability of Indian mustard.

Methodology: A field trial was performed during the *rabi* season of 2019-20 on a sandy-loam soil at Agricultural Farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, Birbhum, West Bengal. The treatments comprised of three methods of sowing, *i.e.,* transplantation, broadcasting, and line sowing in the main plot and four nutrient managements, *i.e.,* 60:30:30, 70:35:35, 80:40:40, and 90:45:45 (N: P_2O_5:K_2O kg ha^{-1}) in a subplot and replicated thrice in a split-plot design. Growth economics parameters were evaluated.



Results: Transplanting method with the nutrient management 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} was significantly superior in terms of growth attributes, yield parameters, productivity, and profitability over other methods of sowing and nutrient management in lateritic soil of West Bengal. The transplanted mustard crop produced higher yield because it got the longest reproductive period and required nutrient level, *i.e.,* 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1}.

Interpretation: Finding appropriate method of sowing under different nutrient levels can be done using growth, yield attributes, and yield. Yield and profitability were found maximum under 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} over other nutrient levels and transplanting method of sowing of Indian mustard was better than broadcasting, and line sowing method in the present experiment under the lateritic soil of West Bengal.

Key words: Indian mustard, Laterite soil, Nutrient management

How to cite : Biswas, C., K. Pramanik and S. Kumar De: Productivity and profitability of Indian mustard under nutrient management and different sowing method in lateritic soil of West Bengal. *J. Environ. Biol.*, **44**, 250-258 (2023).

Introduction

Indian agriculture has made significant improvement, particularly with respect to food crops such as wheat and rice in irrigated areas; however, the performance has not been satisfactory in the case of other crops especially oilseeds, pulses and coarse cereals. Therefore, after attaining self-sufficiency in food grains, the government is concentrating on these agricultural commodities. The oilseed sector has been a crucial area of concern and intervention for Indian policymakers in the post-reforms era when India became one of the largest importers of edible oils in the world, importing about half of the domestic requirement. With 21 per cent of the world's area and 15 per cent of the world's production, India is the fourth largest oilseed producing state in the world, next to the USA, China, and Brazil. Rapeseed and mustard comes under major edible oilseeds in India. Rapeseed and mustard oil is consumed in India as an edible oil and the meal cake left after the extraction of oil forms important cattle feed. It can also be used as manure for various grain crops.

India occupies 5.06 mha area, and the production is 5.83 mt and 1,152 kg ha^{-1} productivity (Shukla, 2020). *Brassica juncea* belongs to the family Brassicaceae is popularly called mustard. The mustard oil comprises a low proportion of saturated fatty acids (palmitic acid and stearic acid) (8%) and a high amount of monounsaturated fatty acids (oleic, eicosenoic, and erucic acids) (70%), and polyunsaturated fatty acids linoleic and linolenic acids (22%) (Kumar, 2015). However, the yield obtained from mustard is low due to the adoption of poor agronomic practices, of which nutrient management and planting methods are most influential. Other factors responsible for low productivity of mustard are, growing in residual moisture condition, photo-thermosensitive nature, non-adoption of good agronomic practices like optimum date of sowing. The plant population and date of sowing affects the yield and yield parameters. Repeatedly the farmers have to sow crop late due to delay sowing and harvesting of *Kharif* paddy concluding in poor yield because of its depressing effect on the plant growth, flowering duration, seed formation, and productivity. Under timely sown conditions, seed yield per plant showed significant and positive correlations with plant height, primary branches, and test weight (Sharma *et al.,* 2022).

The late sown mustard has a shorter growing period due to high temperature during the reproductive phase which leads to a concomitant reduction in yield. In general, has been found that the mustard crop sown after October 30th resulted in lower yields due to congenital potential restriction. The forceful late sowing circumstances of crop are mainly due to delayed harvesting of *Kharif* crops. Hence, an early method of sowing through transplanting technique could be a satisfactorily alternative to minimize yield loss in mustard (De *et al*., 2021). The transplantation method can also improve the crop intensity as the interval of crop in the field is reduced by at least a fortnight without impeding productivity. It is also beneficial to the farmers who take second crop as mustard just after harvesting paddy or other *Kharif* crops. Farmers can adopt this technique to take a second crop where time is limited for sowing mustard to indemnify 12-15 days' nursery period (Hedayetullah *et al.,* 2016). The transplanted crop has the exact plant population with mathematical precision, and there is also some time benefit after harvest of the *Kharif* crops (Singh *et al.,* 2019). However, yield obtained from mustard is low due to poor agronomic practices, of which nutrient management is most influential. Deteriorating soil fertility is one of the factors of low productivity in cultivated soils. The ample and harmonious supply of plant nutrients assist in better yield and quality seed production.

Nitrogen is the most important nutrient, which determines the growth of mustard crop and improves the amount of protein, methionine dry matter and yield. Phosphorus and potassium facilitates flowering, setting of siliqua and increases the size of siliqua and yield (Singh *et al.,* 2012). Keeping in view the importance particularly adopting of transplanting of mustard of nutrient management along with different sowing method in changing climate for optimum yield, and profitability, the present study was carried out to study the influence of nutrient management on growth, productivity and profitability in different sowing techniques in lateritic soil.

Materials and Methods

Study area: The experiment was conducted at Agricultural Farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, Birbhum, West Bengal the during *rabi* season of 2019-20. The experiment site (Sriniketan) is located in the western part of West Bengal under the sub-humid tropical zone of Eastern India. The soil was slightly acidic in nature (6.18), electrical conductivity (0.21 dSm^{-1}), low in organic carbon (5.0 g kg^{-1} of soil), available nitrogen (135.5 kg ha^{-1}), available P (11.9 kg ha^{-1}) and medium in available K (161.5 kg ha^{-1}).

Experimental setup: The field experiment was carried out in a split-plot design with three replications of three methods of sowing, *i.e.,* transplantation, broadcasting, and line sowing in the main plot and four nutrient managements, *i.e.,* 60:30:30, 70:35:35, 80:40:40, and 90:45:45 (N: P_2O_5:K_2O kg ha^{-1}) in a subplot. There were twelve treatments combination and a total of 36 plots, each measuring 4.5 m x 4.5 m area. The treatments were allotted randomly. The Indian mustard variety Kesari Gold was used as experimental material. The seed rate for transplanted mustard was 300 g ha^{-1}, whereas, it was 4 kg ha^{-1} and 6 kg ha^{-1} for line and broadcasting method of sowing, respectively.

Transplanting method: The transplanting method of sowing seedling trays or seed trays was made up of foldable plastic material. Consisting of cells (holes) throughout the trays. Soil and vermicompost in 1:1 ratio was thoroughly mixed with each other. These cells were filled with a mixture of soil and vermicompost. One seed was sown in each cell and covered the seeds with vermicompost. Trays were watered regularly in the morning and evening until seeds germinated. Seedlings were raised in trays for 15 days and 15-days-old seedling of mustard was

transplanted on 13th November, 2019 in a previously made small hole at 7.5 cm depth with a square planting with row to row, and plant to plant distance was 45 cm, and 45 cm, respectively in zero tillage. Only one time watering was done in the pits manually with a sprayer for the first 3-5 days.

Line and broadcasting method: The land was ploughed thoroughly with soil turning plough and two cross wise harrowing were done followed by one laddering to make the soil free of clods, weeds, and well pulverized. For the line sowing method, the row to row spacing was taken as 45 cm and plant to plant distance was taken as 15 cm; line sowing and broadcasting was done on 22nd November, 2019.

Fertilizer management: According to the treatment of nutrient management, fertilizer was applied. A full dose of P_2O_5 and 3/4th of K_2O and 1/4th N were applied as basal. The first top dressing at 40 days after transplanting (DAT) in case of transplanted mustard, and 40 days after sowing (DAS) for line and broadcasting method of sowing @ 1/2 of N and the second top dressing at 60 DAT and 60 DAS @ 1/4 of N + 1/4 K_2O were applied. Nitrogen in the form of Urea, phosphorus in the form of Single Super Phosphate (SSP), and potassium in the form of Muriate of Potash (MOP) was used in this experiment.

Sampling and measurement: Five plants from each plot were randomly selected and marked by labeling for recording their plant height, dry matter accumulation, leaf area at 40 and 60 DAT/DAS, and an average of the values for each plot were determined. Leaf area was measured by Leaf Area Meter instrument (Systronic). Crop growth rates during the period of 20- 40 and 40-60 DAT/DAS were determined with the following formula:

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} (g\ m^2\ d^{-1})$$

Where, W_2 and W_1 were the final and initial dry weights of all plant parts per unit land area at times t_2 and t_1, respectively.

The crop from each plot was harvested when 90% of the siliquae turned yellow to avoid shattering. 10 plants were randomly selected from each plot for collecting data on yield attributes such as number of primary branches plant^{-1}, number of siliqua plant^{-1}, length of siliqua (cm), number of seeds siliqua^{-1}, and test weight (g) before harvesting the whole plot. The sample plants were harvested with sickle and dried properly in the sun, and collected data from these plants. The seed and stover yields were measured from the plot after harvesting, cleaning, and drying the plants from the whole plot. To assess the economic suitability of each treatment, the gross return (₹ha^{-1}) and net return (₹ha^{-1}) were worked out.

Statistical analyses: Data recorded were compiled and tabulated for statistical analysis. Analysis of variance was evaluated by MS Office Excel 2016 and the mean differences were adjusted by multiple comparison test (Gomez and Gomez, 1984).

Results and Discussion

Plant height is one of the important growth parameters of any crop, which affects the yield attributing characters. The observations on plant height were recorded (Table 1) at 40- and 60-days interval. The results showed that the method of sowing exerted a significant effect on the plant height of mustard. The maximum plant height was recorded when mustard grown with the transplanting method (114.7 and 136.4) and it was significantly higher than broadcasting (99.3 and 126.8 cm) and line sowing method (98.7 and 128.8) at 40 and 60 days. The higher plant height under transplanting method might be due to early transplanting of mustard seedling (15 days early than broadcasting and line sowing) coupled with congenial weather condition. The plant height (Table 1) was differed significantly due to nutrient management at 40 and 60 days. At 40 and 60 days interval, mustard crop receiving 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} recorded significantly tallest plant (115.8 and 141.4 cm) over 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (110 and 133.6cm), 70 kg N, 35 kg P_2O_5 and 35 kg K_2O ha^{-1} (97.8 and 126.9 cm) and 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} (93.3 and 120.6 cm).

The initial soil N status being low, the addition of supplementary N which is constituent of amino acids, and chlorophyll would directly enhance the meristematic activity leading to cell multiplication, cell elongation and ultimately, increased the plant height. A significant effect of nitrogen on mustard was also reported by Bhari *et al.* (2007) and Biswas *et al.* (2022) because P status of experimental soil is low, therefore addition of P helps to stem elongation through supply of adequate energy to plant. The same finding was observed in the case of P and K. With increasing levels of P, the plant height increased significantly. These results corroborate the findings of Kumar and Yadav (2007) and Cheema *et al.* (2012). Dry matter accumulation at different growth stages varied significantly due to sowing method (Table 1). However, dry matter accumulation at 40 days intransplanting method of sowing was statistically at par with broadcasting and line sowing methods. The maximum dry matter accumulation was recorded with transplanting method of sowing (232.1 g m^{-2}) at 60 days over line sowing method (168.8 g m^{-2}) and broadcasting method of sowing (213.8 g m^{-2}).

The transplanted method recorded higher dry matter accumulation over line sowing and broadcasting method. The transplanted crop took significantly more time to mature as compared to conventional crop which could be due to more dry matter production and more vigorous growth of transplanted crop (Chaudhary *et al.,* 2017). At 40- and 60-days interval, mustard crop receiving 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} recorded significantly higher dry matter accumulation (115 and 231.7 g m^{-2}) over 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (95.7 and 212.3 g m^{-2}), 70 kg N, 35 kg P_2O_5 and 35 kg K_2O ha^{-1} (79.9 and 195.3 g m^{-2}) and 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} (64.7 and 180.2 g m^{-2}), respectively. This increase in dry matter might be due to balance

Table 1: Effect of method of sowing and nutrient management on plant height and dry matter accumulation of mustard at different growth stages

Plant height (cm)										
	40 DAS/DAT					60 DAS/DAT				
Method of sowing	Nutrient management (N: P_2O_5: K_2O kg ha^{-1})					Nutrient management (N: P_2O_5: K_2O kg ha^{-1})				
	60:30:30	70:35:35	80:40:40	90:45:45	Mean	60:30:30	70:35:35	80:40:40	90:45:45	Mean
Transplanting	105.3	108.9	118.8	125.7	114.7	123	134.3	137.8	150.7	136.4
Broadcasting	85.7	93.2	109.3	109	99.3	119	122.9	129.7	135.6	126.8
Line sowing	88.9	91.3	102	112.5	98.7	119.8	123.6	133.8	137.9	128.8
Mean	93.3	97.8	110	115.8	104.2	120.6	126.9	133.6	141.4	130.7
LSD (P=0.05)	Method of sowing				6.87					7.27
	Nutrient management				2.67					6.04
	MS x NM				9.11					NS
	NM x MS				4.63					NS
Dry matter accumulation (g m^{-2})										
	40 DAS/DAT					60 DAS/DAT				
Method of sowing	Nutrient management (N: P_2O_5: K_2O kg ha^{-1})					Nutrient management (N: P_2O_5: K_2O kg ha^{-1})				
	60:30:30	70:35:35	80:40:40	90:45:45	Mean	60:30:30	70:35:35	80:40:40	90:45:45	Mean
Transplanting	63	79.6	104.1	126.2	93.2	191.8	213.9	246.6	276	232.1
Broadcasting	53.7	70.2	81.5	96.1	75.4	151.4	164.6	173.6	185.4	168.8
Line sowing	77.5	90	101.6	122.9	98	197.4	207.4	216.7	233.7	213.8
Mean	64.7	79.9	95.7	115	88.9	180.2	195.3	212.3	231.7	204.9
LSD (P=0.05)	Method of sowing				15.43					8.63
	Nutrient management				11.38					6.37
	MS x NM				26.32					14.73
	NM x MS				19.71					11.02

application of NPK that enhance the effectiveness of photosynthesis of crop, leading to more production and accumulation of photosynthates. Kumar *et al.* (2007) also observed similar results in Indian mustard with regards to dry matter production. The increase in dry matter accumulation was found to be significant with different levels of P and K might be due to higher plant height. Similar types of results also indicated by Kumar and Yadav (2007), , (Chhaba *et al*., 2017) in mustard. The crop growth rates estimated during the period of 20-40 and 40-60 days interval during the experiment, were statistically analyzed and is presented in Table 2. The results suggested that the method of sowing had a significant role in influencing the crop growth rate throughout the growth periods of mustard crop.

Mustard crop establishing through line sowing recorded maximum crop growth rate (4.65 g m^{-2} d^{-1}), however, it was statistically at par with the transplanting method (4.42 g m^{-2} d^{-1}). The lowest crop growth rate was recorded with the broadcasting method (3.57 g m^{-2} d^{-1}) at 20-40 days interval. At 40-60 days interval, the transplanting method recorded a significantly maximum crop growth rate (6.94 g m^{-2} d^{-1}) over the broadcasting method (4.67 g m^{-2} d^{-1}) and line sowing method (5.79 g m^{-2} d^{-1}). The increase in crop growth rate could be due to longer period of vegetative growth under transplanted conditions and effective uptake of water and nutrients increasing the number of leaves, leaf area per plant, and dry matter accumulation. At 20-40 days, mustard crop receiving 90 kg N, 45 kg P^2O^5, and 45 kg K_2O ha^{-1} recorded significantly more crop growth rate (5.43 g m^{-2} d^{-1}) over 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (4.53 g m^{-2} d^{-1}) and 70 kg N, 35 kg P_2O_5, 35 kg K_2O ha^{-1} (3.80 g m^{-2} d^{-1}) and 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} (3.09 g m^{-2} d^{-1}). There is no significant difference between mustard crop receiving 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} (5.83 g m^{-2} d^{-1}) and 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (5.83 g m^{-2} d^{-1}) at 40-60 days. A higher crop growth rate with a higher dose of N, P, and K might be due to greater dry matter production. Observation on leaf area per plant recorded at 40 and 60 days interval during the experiment, has been statistically analyzed and is presented in Table 2.

The observation showed that the leaf area per plant of the mustard crop increased steadily from 20 to 40 and 40-60 days interval. At 40 and 60 days interval, the transplanting method recorded significantly maximum leaf area per plant (642.7 cm^2, 786.8 cm^2) over that of the broad casting method (423.3 cm^2, 573.4 cm^2) and line sowing method (416.1 cm^2, 529.5 cm^2),

Table 2: Effect of method of sowing and nutrient management on crop growth rate and leaf area plant^{-1} of mustard at different growth stages

Method of sowing	Crop growth rate (g m^{-2} d^{-1})									
	20-40 DAS/DAT					40-60 DAS/DAT				
	Nutrient management (N: P_2O_5: K_2O kg ha^{-1})					Nutrient management (N: P_2O_5: K_2O kg ha^{-1})				
	60:30:30	70:35:35	80:40:40	90:45:45	Mean	60:30:30	70:35:35	80:40:40	90:45:45	Mean
Transplanting	2.96	3.77	4.96	6.00	4.42	6.44	6.72	7.13	7.49	6.94
Broadcasting	2.56	3.36	3.86	4.50	3.57	4.89	4.72	4.61	4.46	4.67
Line sowing	3.74	4.29	4.78	5.79	4.65	6.00	5.87	5.76	5.54	5.79
Mean	3.09	3.80	4.53	5.43	4.21	5.77	5.77	5.83	5.83	5.80
LSD (P=0.05)	Method of sowing				0.50					0.11
	Nutrient management				0.38					0.08
	MS x NM				NS					0.19
	NM x MS				NS					0.14
	Leaf area per plant (cm^2)									
Method of sowing	40 DAS/DAT					60 DAS/DAT				
	Nutrient management (N: P_2O_5: K_2O kg ha^{-1})					Nutrient management (N: P_2O_5: K_2O kg ha^{-1})				
	60:30:30	70:35:35	80:40:40	90:45:45	Mean	60:30:30	70:35:35	80:40:40	90:45:45	Mean
Transplanting	525.9	590.2	732.2	722.3	642.7	610	770.6	838.6	927.8	786.8
Broadcasting	345.8	402.5	389.9	555.0	423.3	474.8	545.4	573.8	699.4	573.4
Line sowing	333.2	338.8	400.6	591.8	416.1	522.5	475.9	489.2	630.3	529.5
Mean	401.6	443.8	507.6	623.0	494.0	535.8	597.3	633.9	752.5	629.9
LSD (P=0.05)	Method of sowing				49.87					81.10
	Nutrient management				39.61					45.04
	MS x NM				88.78					120.72
	NM x MS				68.60					78.02

respectively. higher leaf area per plant was recorded under transplanted crop due to higher number of leaves per plant. This could be due to early sowing of mustard crops under optimum weather conditions resulting in a higher number of leaves coupled with a higher number of primary branches per plant that led to higher leaf area per plant. The reduction in leaf area per plant at broadcasting and line sowing method might be due to delay sowing of crop and shorter duration of crop due to increase temperature during the latter phase of crop growth.

At 40 and 60 days, mustard crop receiving 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} recorded significantly higher leaf area per plant (623 and 752.5 cm^2) over 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (507.6 and 633.9 cm^2), 70 kg N, 35 kg P_2O_5 and 35 kg K_2O ha^{-1} (443.8,597.3 cm^2) and 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} (401.6, 535.8 cm^2), respectively. The balanced application of higher dose of NPK accelerates higher photosynthetic rates resulted in stem elongation and leaf area expansion. Kuai *et al.* (2020) also reported that increase in the number of leaves and leaf area of crops with increasing nitrogen application. The combined and balanced application of N and K was essential for increasing photosynthetic area and rate of oil seed crop (Li *et al.,* 2022). The results showed (Table 3) that the transplanting method had a significant effect on primary branches per plant. The highest number of primary branches per plant (7.8) was recorded in transplanting method. The lowest number of primary branches plant^{-1} (4.0) was obtained from the line sowing method. This could be ascribed due to early sowing of seedlings in micro pot and branching taking place from the basal part of the main shoot in the transplanted crop. Similar findings were reported by Chaudhary *et al.* (2016) and Tyagi *et al.* (2017). Nutrient management showed a significant effect on primary branches of per plant at harvesting. The nutrient level of 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} recorded a significantly higher number of primary branches per plant (8.1) than other nutrient management. The number of primary branches per plant increased with increasing levels of N, P, and K. The positive effects of higher dose of N might be attributed to their direct role in the formation of protoplasm and chlorophyll molecule in the leaf cells resulting in increased photosynthetically active leaf area.

Availability of these photosynthates was reflected in profuse branching. Similar findings were obtained by Tripathi and Tripathi (2003) and Sah *et al.* (2006). The findings indicated that the transplanting method had a significant effect on the production of many siliquae per plant (Table 3). The highest

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Table 3: Effect of method of sowing and nutrient management on yield attributes of mustard

Method of sowing	Yield parameters									
	Number of primary branches per plant					Number of siliquae per plant				
	Nutrient management (N: P_2O_5: K_2O kg ha^{-1})					Nutrient management (N: P_2O_5: K_2O kg ha^{-1})				
	60:30:30	70:35:35	80:40:40	90:45:45	Mean	60:30:30	70:35:35	80:40:40	90:45:45	Mean
Transplanting	4.33	6.67	8.00	12.00	7.75	430.2	560	639.2	825.3	613.7
Broadcasting	4.33	5.33	6.00	7.00	5.67	209.3	246	258.9	284	249.6
Line sowing	2.67	3.67	4.33	5.33	4.00	227.7	277.8	315	337	289.4
Mean	3.78	5.22	6.11	8.11	5.81	289	361.3	404.4	482.1	384.2
LSD (P=0.05)	Method of sowing				1.53					30.72
	Nutrient management				1.04					24.75
	MS x NM				2.49					55.16
	NM x MS				1.79					42.87

Method of sowing	Yield parameters									
	Length of siliqua (cm)					Number of seeds per siliqua				
	Nutrient management (N: P_2O_5: K_2O kg ha^{-1})					Nutrient management (N: P_2O_5: K_2O kg ha^{-1})				
	60:30:30	70:35:35	80:40:40	90:45:45	Mean	60:30:30	70:35:35	80:40:40	90:45:45	Mean
Transplanting	4.84	5.18	5.28	5.62	5.23	11.93	13.08	13.77	14.90	13.42
Broadcasting	4.60	4.82	4.79	4.95	4.79	9.25	11.33	11.83	12.33	11.19
Line sowing	4.18	4.35	4.31	4.59	4.36	10.05	11.35	10.90	11.90	11.05
Mean	4.54	4.78	4.79	5.05	4.79	10.41	11.92	12.17	13.04	11.89
LSD (P=0.05)	Method of sowing				0.31					1.07
	Nutrient management				0.24					0.79
	MS x NM				NS					NS
	NM x MS				NS					NS

number of siliquae per plant (614) was recorded from a crop grown under transplanting method. The lowest number of siliquae per plant (250) was obtained in broadcasting method. The number of siliquae per plant was significantly more in the transplanted crop over conventionally sown crop through broad casting and line sowing to a greater number of primary branches in the transplanted crop, which was largely attributed due to more branching taking place from the basal part of the main shoot in the transplanted crop. The number of siliquae per plant is a function and resultant of the number of primary branches per plant. The application of 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} recorded a significantly higher number of siliquae per plant (482) over 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (404), 70 kg N, 35 kg P_2O_5 and 35 kg K_2O ha^{-1} (361). The significantly lowest number of siliquae per plant was recorded with crops receiving 60 kg N, 30 kg P_2O_5, and 30 kg K_2O ha^{-1} (289). The outcomes displayed that the transplanting method had a significant effect on the length of siliqua (Table 3). The longest siliqua (5.2 cm) was recorded from a crop grown under transplanting method.

The shortest siliqua (4.4 cm) was obtained from a crop grown under the line sowing method. The nutrient dose of 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} recorded significantly longer length of siliqua (5.1 cm) over 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (4.8 cm), 70 kg N, 35 kg P_2O_5 and 35 kg K_2O ha^{-1} (4.8 cm) and the significantly shortest length of siliqua (4.5 cm) was recorded with crop receiving 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}. The highest number of seeds per siliqua (13.4) was recorded (Table 3) in transplanting method. The lowest number of seeds per siliqua (11.1) was obtained from a crop grown under the line sowing method. Application of 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} was recorded a significantly higher number of seeds $siliqua^{-1}$ (13.0) over 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (12.2), 70 kg N, 35 kg P_2O_5 and 35 kg K_2O ha^{-1} (11.9) and 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} (10.4). The result showed that the transplanting method had a significant effect on the test weight (Table 4).

The highest test weight (4.4 g) was found from a crop grown under the transplanting method. The lowest test weight (4.1 g) was obtained from a crop grown under the broadcasting and line sowing method. The nutrient level of 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} registered significantly higher test weight (4.5 g) over 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (4.2 g), 70 kg N, 35 kg P_2O_5 and 35 kg K_2O ha^{-1} (4.2 g). The significantly lowest test weight (4 g) was recorded with crops

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Table 4: Effect of method of sowing and nutrient management on test weight, seed yield, stover yield and harvest index of mustard

Yield parameters and yield										
	Test weight (g)					Seed yield (kg ha^{-1})				
Method of sowing	Nutrient management (N: P_2O_5: K_2O kg ha^{-1})					Nutrient management (N: P_2O_5: K_2O kg ha^{-1})				
	60:30:30	70:35:35	80:40:40	90:45:45	Mean	60:30:30	70:35:35	80:40:40	90:45:45	Mean
Transplanting	4.22	4.45	4.75	4.40	4.22	912	1370	1741	2320	1586
Broadcasting	4.16	4.18	4.27	4.12	4.16	830	1272	1453	1618	1294
Line sowing	4.10	4.11	4.36	4.13	4.10	810	1363	1477	1710	1340
Mean	4.16	4.24	4.46	4.22	4.16	851	1335	1557	1883	1406
LSD (P=0.05)	Method of sowing				0.24					122.7
	Nutrient management				0.15					107
	MS x NM				NS					231.4
	NM x MS				NS					185.4
Yield and harvest index										
	Stover yield (kg ha^{-1})					Harvest index (%)				
Method of sowing	Nutrient management (N: P_2O_5: K_2O kg ha^{-1})					Nutrient management (N: P_2O_5: K_2O kg ha^{-1})				
	60:30:30	70:35:35	80:40:40	90:45:45	Mean	60:30:30	70:35:35	80:40:40	90:45:45	Mean
Transplanting	2081	2953	3376	4383	3198	30.5	31.7	34.0	34.6	32.7
Broadcasting	2190	2792	3270	3562	2953	27.5	31.3	30.8	31.2	30.2
Line sowing	2037	2783	3204	4135	3040	28.5	32.9	31.6	29.2	30.6
Mean	2103	2842	3283	4026	3064	28.8	32.0	32.1	31.7	31.2
LSD (P=0.05)	Method of sowing				161.4					1.72
	Nutrient management				168.9					1.93
	MS x NM				344.4					NS
	NM x MS				292.5					NS

Table 5: Effect of method of sowing and nutrient management on economics of mustard

Economics										
	Gross return (₹ ha^{-1})					Net return (₹ ha^{-1})				
Method of sowing	Nutrient management (N: P_2O_5: K_2O kg ha^{-1})					Nutrient management (N: P_2O_5: K_2O kg ha^{-1})				
	60:30:30	70:35:35	80:40:40	90:45:45	Mean	60:30:30	70:35:35	80:40:40	90:45:45	Mean
Transplanting	43957	65914	83474	111154	76125	21614	43093	60176	87379	53066
Broadcasting	40259	61259	70029	77920	62367	17416	37938	46231	53644	38807
Line sowing	39193	65450	71077	82629	64587	14930	40709	45859	56934	39608
Mean	41137	64208	74860	90568	76125	17986	40580	50756	65986	53066
LSD (P=0.05)	Method of sowing				5701					5701
	Nutrient management				4973					4973
	MS x NM				10751					10751
	NM x MS				8613					8613

receiving 60 kg N, 30 kg P_2O_5, and 30 kg K_2O ha^{-1}. Seed yield from each plot recorded after threshing and drying, was statistically analyzed and presented in Table 4. The result showed that the transplanting method had a significant effect on seed yield. Significant higher seed yield (1586 kg ha^{-1}) was obtained in transplanting method than in line sowing method (1340 kg ha^{-1}). The lowest seed yield (1294 kg ha^{-1}) was obtained from a crop grown under the broadcasting method. There is no significant difference between broadcasting and the line sowing method. The transplanted crop registered the longest reproductive period and resulted in better yield of early crop, while in delayed sowing there was a drastic reduction in yield due to a shorter reproductive

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period (Bala *et al.,* 2011). Higher seed yield under transplanting system in mustard was also reported by Singh *et al.* (2006); Chaudhary *et al.* (2017); Singh *et al.* (2019).

The application of 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} to crop recorded significantly higher seed yield (1883 kg ha^{-1}) than 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (1557 kg ha^{-1}), 70 kg N, 35 kg P_2O_5 and 35 kg K_2O ha^{-1} (1335 kg ha^{-1}). The significantly lower seed yield (851 kg ha^{-1}) was recorded due to application of 60 kg N, 30 kg P_2O_5, and 30 kg K_2O ha^{-1}. The maximum seed yield in 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} is attributable to maximum number of siliquae per plant, siliqua length, seeds per siliqua, and 1000-seed weight. The positive effect of N, P, and K application on mustard seed yield has been reported by Jat *et al.* (2005); Mir *et al.* (2010); Mozaffari *et al.* (2012), and Kumar *et al.* (2016). The positive response in higher fertilizer dose may be due to low to medium nutrient status of the experimental soil *i.e.,* low in organic carbon (5.0 g kg^{-1} of soil), available nitrogen (135.5 kg ha^{-1}), available P (11.9 kg ha^{-1}), medium in available K (161.5 kg ha^{-1}).

The results showed that the transplanting method had a significant effect on stover yield (Table 4). The highest stover yield (3198 kg ha^{-1}) was recorded from a crop grown under the transplanting method. The addition of 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} to crop recorded a significantly highest stover yield (4026 kg ha^{-1}). The highest harvest index (32.7%) was recorded from a crop grown under the transplanting method. Application of 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} recorded a significantly higher harvest index (32.1%). The significantly lowest harvest index (28.8%) was recorded due to application of 60 kg N, 30 kg P_2O_5, and 30 kg K_2O ha^{-1}. The nutrient level of 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} was statistically at par with nutrient levels of 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} and 70 kg N, 35 kg P_2O_5, and 35 kg K_2O ha^{-1} with respect to harvest index.

The crop grown following transplanting method of sowing recorded maximum gross return of ₹76125 ha^{-1}. The crop grown with 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} recorded the highest gross return of ₹90568 ha^{-1} over other nutrient management. Similarly, the transplanting method recorded a maximum net return of ₹53066 ha^{-1} and the nutrient level of 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} recorded the maximum net return of ₹65986 ha^{-1} over 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1} (₹50756 ha^{-1}), 70 kg N, 35 kg P_2O_5 and 35 kg K_2O ha^{-1} (₹40580 ha^{-1}) and 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} (₹17987 ha^{-1}), respectively.

In conclusion, the findings of this study showed that application of 90 kg N, 45 kg P_2O_5, and 45 kg K_2O ha^{-1} along with transplanting method of mustard obtained maximum growth attributes, and recorded maximum yield as well as net return. However, further re-validation is needed for optimization of nutrient levels and transplanting method in Indian mustard.

Acknowledgment

The authors are thankful to Agricultural Farm, Palli Siksha Bhavana, Visva-Bharati, Sriniketan for providing necessary field and laboratory facilities during the course of investigation.

Authors' contribution: C. Biswas: Conceptualization, investigation, methodology, data collection, writing-original draft preparation; **K. Pramanik:** Conceptualization, methodology, software, validation, data curation, writing-review and editing; **S. Kumar De:** Methodology, data collection, writing-review.

Funding: Not applicable.

Research content: The research content of manuscript is original and has not been published elsewhere.

Ethical approval: Not applicable.

Conflict of interest: The authors declare that there is no conflict of interest.

Data availability: Not applicable.

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology.*

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