Agric Res J **61** (4): 531-538, *August* 2024
DOI: 10.5958/2395-146X.2024.00066.6

PRODUCTIVITY, PROFITABILITY AND SOIL HEALTH OF *GOBHI SARSON* (*Brassica napus* L.) AS INFLUENCED BY ORGANIC NUTRITION AND PLANTING GEOMETRY

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ABSTRACT

The optimization of agronomy for oilseed crops is crucial for achieving sustainable productivity and effective weed management, particularly in organic agriculture. This three-year study evaluated the impact of organic nutrients and planting geometry on the productivity, profitability, and soil health of *gobhi sarson* (*Brassica napus* L.). The application of 10 t/ha of farmyard manure (FYM) as a basal dose, combined with a top dressing of 1 t/ha FYM at the first irrigation (30 DAS), resulted in a 8.54% and 5.36% higher seed yield compared to treatments with only basal FYM (10 t/ha) and foliar application of 1% seaweed extract at 50, 65, and 80 DAS, respectively. Altering planting geometry did not significantly affect seed yield, though wider row spacing facilitated mechanical weeding. Furthermore, soil organic carbon (SOC) and available nitrogen (N) were significantly enhanced in plots receiving the additional FYM at first irrigation. A significant increase in soil microflora, including bacteria, fungi, and actinomycetes, was observed in all manorial treatments compared to the control. These results highlight the crucial role of organic interventions in enhancing soil health and boosting the productivity of *gobhi sarson* in organic farming systems.

Keywords: FYM, Organic manures, Planting geometry, Seed yield, Soil organic carbon

Oilseed crops play an important role in agricultural diversification and are essential for achieving self-sufficiency in oilseed production in India. Despite being the fourth-largest oilseed producer globally, India remains heavily reliant on imports to meet its demand for edible oils. Among the seven edible oil crops cultivated in the country, rapeseed-mustard contributes approximately 33.24% of total oilseed production (DRMR 2024). This crop is predominantly grown in rain-fed, resource-limited regions of India, and serves as a significant source of income for small and marginal farmers.

Rapeseed-mustard oil is rich in unsaturated fatty acids and low in saturated fatty acids, making it a highly desirable edible oil for human consumption. The oil content in rapeseed-mustard seeds typically ranges from 30% to 45%, depending on the variety and the climatic conditions in which the crop is grown. After oil extraction, the residual cake is often utilized as animal feed or converted into manure.

The concept of sustainable farming is centered around the utilization of natural resources in a manner that does not disrupt the ecological balance. Indigenous agricultural knowledge plays a vital role in ensuring the long-term sustainability of farming systems (Ramprasad *et al.*, 2009). Organic farming, in particular, has emerged as a key strategy for sustaining agriculture in northwest India (Aulakh *et al.*, 2022). Recently, there has been a growing interest in organic farming practices, driven by increasing consumer awareness and a preference for organic food. Traditionally, organic manures such as farmyard manure (FYM), animal manures, sheep manure, poultry manure, green manures, crop residues, and composts were widely used in developing countries up until the 1960s. These inputs not only support the production of safe and nutritious food but also enhance soil fertility (Ramesh *et al.*, 2005).

Soil fertility has declined due to the excessive and imbalanced use of chemical fertilizers and pesticides, with their residues posing health risks to consumers (Follet *et al.*, 1981; Mandal, 2009). The application of organic manures improves soil health by promoting the growth and activity of beneficial microflora, which, in turn, enhances the mineralization of nutrients essential for plant growth. This practice is considered a key component of effective agricultural management (Arancon *et al.*, 2006). For instance, improvements in soil health, such as increased availability of nitrogen, phosphorus, and potassium, higher organic carbon content, and enhanced microbial activity, have been observed in green gram treated with 10% seaweed extract and 5 t/ha farmyard manure (Chaudhary *et al.*, 2021). Gradually replacing chemical fertilizers with organic manures is particularly important for oilseed crops, such as *gobhi sarson* (rapeseed-mustard), which

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Date of receipt: 08.08.2023, Date of acceptance: 17.08.2024

are a staple in Indian households. Substituting chemical inputs with organic alternatives, including farmyard manure (FYM), vermicompost, and bio-fertilizers, is crucial for sustaining yields and promoting long-term soil fertility.

Effective weed management is an important factor for successful adoption of organic farming, second only to nutrient management. To improve the feasibility and sustainability of organic farming, innovative and efficient weed control strategies are essential (Bàrberi, 2002). One such strategy is the manipulation of planting geometry, which can offer significant advantages for weed management in certain crops. Adopting wider row spacing is one such practice that facilitates mechanical inter-row cultivation, enabling effective weed control without the need for herbicides. This approach not only aligns with organic farming principles but also helps reduce machinery costs by decreasing the number of sowing units required for planting. Furthermore, the use of smaller, less powerful machinery for sowing can lead to reduced fuel consumption. In crops like rapeseed and mustard, wider row spacing has been shown to improve plant growth dynamics (Mamun *et al.*, 2014). While this practice reduces plant population density per unit area, it promotes the development of secondary branches and increases the number of pods per plant. The reduced inter-row competition encourages greater vegetative growth and enhances photosynthate production, ultimately improving plant health and productivity. The increased secondary branching and higher pod count per plant can effectively compensate for the yield reduction typically associated with lower plant density.

Among the various agronomic practices, optimizing planting geometry in high-yielding, high-oil-content cultivars is crucial for enhancing both seed yield and oil content. However, the increased use of organic nutrient sources can inadvertently raise the weed seed bank, making effective weed management an essential component of organic farming systems. Mechanical weeding, particularly in crops with wider row spacing, becomes a viable and efficient strategy for controlling weeds. This approach aligns with organic farming principles by reducing dependence on chemical herbicides and fostering more sustainable agricultural practices. By optimizing planting geometry and incorporating organic fertilizers, farmers can enhance plant health and productivity while minimizing the environmental impact. Therefore, this study aims to evaluate the combined effects of planting geometry and organic nutrient sources on the yield, soil health, and economic viability of *gobhi sarson* (rapeseed-mustard), contributing to the development of sustainable and productive farming practices for oilseed crops.

MATERIALS AND METHODS

The experiments were conducted over three consecutive years (2018-2020) at a fixed plot site at the Research Farm, Punjab Agricultural University, Ludhiana, Punjab, India, located at 30°54′N, 75°48′E, and an altitude of 247 meters above sea level. The region is characterized by a subtropical and semi-arid climate. The soil at the experimental site was loamy sand with a pH of 7.2, an electrical conductivity (EC) of 0.26 dS/m, and medium (0.50%) inorganic carbon content, determined using the wet digestion method. The available nitrogen, phosphorus, and potassium were 164.0, 22.4, and 155.5 kg/ha, respectively, as measured by the alkaline permanganate oxidizable method, 0.5 M $NaHCO_3$ extractable method, and 1 M ammonium acetate exchangeable method. The microbial counts for bacteria, fungi, and actinomycetes were 8.152, 4.890, and 6.015 CFU/g, respectively.

The experiment was arranged in a split-plot design with six organic manure treatments in the main plots and two crop geometry treatments in the sub-plots, with three replications. The organic manure treatments included: (1) farmyard manure (FYM) applied alone at 10 t/ha as a basal dose; (2) FYM + Seaweed Extract (SWE), consisting of FYM at 10 t/ha as a basal dose with foliar application of 1% SWE at 50, 65, and 80 days after sowing (DAS); (3) FYM + Microbial Extract (ME), consisting of FYM at 10 t/ha as a basal dose with three foliar sprays of FYM extract at 50, 65, and 80 DAS; (4)

Table 1. Agronomic operations in *gobhi sarson*

Operation	Year		
	2017-18	2018-19	2019-20
Variety		GSC 7	
Sowing	30/10/2017	27/10/2018	25/10/2019
Harvesting	11/04/2018	05/04/2019	08/04/2020
N content (%) of FYM	0.8	0.7	1.0
Seed rate	4.5 kg/ha		
Weed control	Mechanical/Manual		

Table 2. Treatment details

Abbreviation	Treatment details
Main plots (Organic nutrients)	
FYM	FYM @10t/ ha (1.0% N on a dry weight basis) at the time of sowing
FYM + SWE (Sagarika by IFFCO)	FYM @10t/ ha at the time of sowing followed by 3 sprays of 1% SWE at 50, 65 and 80, days after sowing (DAS)
FYM + ME	FYM @10 t/ ha at the time of sowing followed by 3 sprays of 1:2 FYM extract at 50, 65 and 80 DAS
FYM + FYMB	FYM @10t/ ha at the time of sowing followed by Broadcasting 1 t/ha of FYM after 30 DAS
FYMB + ME	FYM @ 1 t/ha after 30 DAS followed by 3 sprays of 1:2 FYM extract at 50, 65, and 80 DAS
Control	Unfertilized
Sub plots (Planting geometry)	
P_1(R×P)	45 × 10 cm
P_2 (R×P)	67.5 × 10 cm

FYM + FYM Broadcast (FYMB), consisting of FYM at 10 t/ha at sowing with broadcasting of 1 t/ha FYM at 30 DAS; and (5) FYMB + ME, involving broadcasting 1 t/ha FYM at 30 DAS with foliar application of 1:2 FYM extract at 50, 65, and 80 DAS. In addition to these five treatments, one unfertilized control was included. The two crop geometry treatments in the sub-plots were row spacings of 45 × 10 cm and 67.5 × 10 cm.

The preparation of the FYM extract involved mixing 30 liters of water in a plastic drum with 10 kg of well-rotted FYM and 3 kg of fresh neem leaves. The mixture was kept under shade for 15-20 days, with stirring every two days. After 15-20 days, the solution was filtered, and the filtrate was used for spraying in a 1:2 extract-to-water ratio. Additionally, a ready-to-use liquid seaweed extract, branded as Sagarika and marketed by IFFCO, was utilized for the treatment. A detailed description of all the treatments is provided in Table 2.

Weeds were managed through mechanical weeding at 25 and 45 days after sowing (DAS) in the 67.5 cm row spacing, and with a wheel hand hoe in the 45 cm row spacing. Any weeds that escaped mechanical control were removed by hand weeding. To manage insect pests, neem-based biopesticides were applied.

The growth and yield parameters from the different treatments were recorded throughout the study. The crop was harvested manually with a sickle when 50% of the pods had reached maturity. For economic analysis, a 25% and 50% premium on organic produce was applied. The pooled data from the three years were analyzed, and the benefit-to-cost (B:C) ratio was calculated by dividing the gross returns by the cost of cultivation.

The microbial populations (bacterial, fungal, and actinomycetes) in the rhizospheric soil were estimated using the serial dilution spread plate technique. The total bacterial count (TBC) was determined on nutrient agar medium (dilutions of 10^{-6} to 10^{-8}), the total fungal count (TFC) was assessed on glucose yeast extract medium (dilutions of 10^{-2} to 10^{-4}), and the total actinomycetes count (TAC) was measured using Kenknight's medium (dilutions of 10^{-3} to 10^{-5}). The Petri plates were incubated in an inverted position at 28 ± 2°C for 2 to 6 days. After the incubation period, the colonies were counted, averaged, and multiplied by the dilution factor to estimate the microbial count per gram of wet soil. To express the microbial counts based on soil dry mass, 10 g of fresh soil (in triplicate) was dried in an oven to a constant weight, and its dry mass was recorded.

$$\text{CFU/g dry soil} = \frac{\text{Number of colonies} \times \text{dilution factor}}{\text{dry weight of 1.0 g moist soil}}$$

(where, dilution factor = reciprocal of the dilution)

The data were analyzed using analysis of variance (ANOVA) in SAS 9.1 software (SAS Institute, Cary, NC) to assess the effects of the treatments. Post-hoc mean separation was conducted using Tukey's Honestly Significant Difference (HSD) test (*p≤0.05*) when ANOVA revealed significant differences.

RESULTS AND DISCUSSION

Effect of organic nutrients on yield attributes and yield

Plant height and test weight did not show significant variation with different nutrient treatments (Table 3). However, the yield-contributing traits, such as the number of primary and secondary branches, number of siliquae per plant, and number of seeds per siliqua, exhibited significant differences across the nutrient treatments. The highest values for primary branches per plant (6.1), siliquae per plant (326.0), and seeds per siliqua (22.6) were recorded when the crop received 1 t/ha FYM at 30 days after sowing (DAS), in addition to

Table 3. Growth and yield attributes of *gobhi sarson* as influenced by organic nutrients and planting geometry (Pooled data of three years)

Treatments	Plant height (cm)	Number of primary branches/ plant	Number of secondary branches/ plant	Number of siliquae/ Plant	Number of seeds / siliqua	Test weight (g)	Seed yield (q/ha)	Stover yield (q/ ha)
Main plots (Organic manures)								
FYM	178.5^{a*}	5.7^{b}	8.0^{b}	317.4^{b}	21.7^{b}	3.42	19.9^{b}	67.3^{a}
FYM + SWE	178.8^{a}	5.8^{b}	8.1^{b}	319.9^{b}	22.0^{b}	3.43	20.5^{b}	67.9^{a}
FYM + ME	180.6^{a}	6.0^{a}	8.2^{b}	322.6^{ab}	22.5^{a}	3.42	21.1^{ab}	68.5^{a}
FYM + FYMB	178.3^{a}	6.1^{a}	8.6^{a}	326.0^{a}	22.6^{a}	3.43	21.6^{a}	68.6^{a}
FYMB + ME	177.3^{a}	5.2^{c}	7.6^{c}	298.0^{c}	20.4^{c}	3.44	14.4^{c}	64.1^{b}
Control	175.0^{a}	4.7^{d}	7.3^{c}	279.7^{d}	19.2^{d}	3.40	11.7^{d}	61.7^{c}
Sub plots (Planting geometry)								
P_1 (R×P)	182.6^{a}	6.3^{b}	8.0^{b}	317.6^{b}	22.0^{a}	3.46^{a}	20.5^{a}	72.1^{a}
P_2 (R×P)	183.2^{a}	6.5^{a}	8.4^{a}	326.2^{a}	22.0^{a}	3.44^{a}	20.4^{a}	71.8^{a}

Within a column, means followed by same alphabet did not differ significantly after Tukey's HSD at $p \leq 0.05$

the basal application of 10 t/ha FYM at sowing. This treatment, FYM + FYMB, was statistically comparable to FYM + ME, where 10 t/ha FYM was applied at sowing, followed by three foliar applications of a 1:2 FYM extract. The enhanced yield attributes observed in the manure treatments compared to the unfertilized control may be attributed to the improved availability of both macro- and micronutrients. Organic manures, such as farmyard manure (FYM), poultry manure, vermicompost, and oilcake, contribute to the improvement of soil structure, aeration, and water-holding capacity. Additionally, they stimulate soil microbial activity, which enhances the plant's ability to access both macro- and micronutrients through increased biological processes, greater nutrient solubility, and alterations in soil properties like sodicity, salinity, and pH (Alabadan *et al.*, 2009). Similar findings have been reported by Hadiyal *et al.* (2017), Kansotia *et al.* (2015), and Rao and Shaktawat (2002), who observed that the application of high doses of nutrients via FYM significantly impacted the growth and development of *gobhi sarson*.

The seed and stover yields, recorded at 21.6 q/ha and 68.6 q/ha, respectively, were highest when the crop was supplemented with 1 t/ha FYM broadcasted at 30 days after sowing (DAS), in addition to the basal application of 10 t/ha FYM. This treatment was statistically comparable to the application of 3 foliar sprays of a 1:2 FYM extract, along with the basal dose of FYM (21.1 q/ha and 68.5 q/ha). Both treatments significantly outperformed other nutrient treatments, including the sole application of FYM, foliar application of seaweed extract (SWE) with basal FYM, broadcasting of FYM at 1 t/ha after 30 DAS followed by three foliar applications of 1:2 FYM extract, and the unfertilized control. Among all the manure treatments, the maximum yield reduction was observed when FYM was broadcasted at 30 DAS with foliar applications of 1:2 FYM extract at 50, 65, and 80 DAS. The increase in seed yield can be attributed to the sustained availability of nutrients, which supported crop nourishment and enhanced meristematic activity and cell elongation. Treatments that provided a balanced dose of FYM, including micronutrients, positively influenced metabolic processes, enzymatic activity, and growth hormones, resulting in improved vegetative growth and, ultimately, higher dry matter production. The mineralization and slow release of nutrients throughout the crop's growth period facilitated higher uptake of both macro and micronutrients, leading to increased seed yield under the bulk inoculation of FYM. The initial basal application ensured a nutrient-rich environment for seedling establishment, while the subsequent broadcast supplementation at 30 DAS provided nutrients during critical growth stages, promoting better plant vigour and, consequently, higher seed yield. This dual approach maximized nutrient utilization efficiency and promoted optimal crop development, leading to superior yield compared to other treatments with singular or delayed fertilizer applications. Kumar *et al.* (2019) reported that the application of FYM increased nutrient uptake by the crop as well as the nutrient content of the soil. Similarly, Jat *et al.* (2013) found that the application of organic manures significantly influenced the available nitrogen content in mustard crop, with FYM at 10 t/ha improving available nitrogen by 10.6% compared to the control.

Effect of planting geometry on yield attributes and yield

Planting geometry directly influenced light interception, moisture availability, and wind movement,

Table 4. Economics of *gobhi sarson* as influenced by organic nutrients and planting geometry

Treatments	Cost of cultivation (Rs/ha)	Gross returns (₹/ha)		Net returns (₹/ha)		B:C ratio	
		25% premium	50% premium	25% premium	50% premium	25% premium	50% premium
Main plots (Organic manures)							
FYM	34581	87063	104475	52482	69894	2.51	3.02
FYM + SWE	39381	89688	107625	50307	68244	2.27	2.73
FYM + ME	35631	92444	110933	56813	75302	2.59	3.11
FYM + FYMB	37056	94369	113243	57313	76187	2.54	3.06
FYMB + ME	27356	63131	75758	35775	48402	2.30	2.77
Control	23906	51056	61268	27150	37362	2.14	2.56
Sub plots (Planting geometry)							
P_1 (R×P)	33379	89556	107468	56177	74089	2.68	3.22
P_2 (R×P)	32592	89119	106943	56527	74351	2.73	3.28

Market price of gobhi sarson: ₹3500/qt; Price of FYM: ₹1000/ton dry weight basis

all of which affected photosynthesis, dry matter accumulation, crop maturity, and overall productivity. While most crop growth, yield, and yield attributes did not show significant variation with planting geometry, the number of primary and secondary branches and siliquae per plant were significantly higher with the wider planting geometry of 67.5 cm × 10 cm. The comparable yield observed under this wider spacing could be attributed to the crop's elastic growth nature and the limited nutrient availability under organic farming conditions. Gawariya *et al.* (2015) also reported similar seed yields for *gobhi sarson* under different planting geometries (60 × 15 cm and 45 × 15 cm). The interaction effect between organic manures and planting geometries was non-significant.

Effect of organic nutrients and planting geometry on soil health

There were no significant effects of planting geometry on the physico-chemical and microbial properties of the soil. However, the soil organic carbon (SOC) and available nitrogen (N) were higher in the treatment where 1 t/ha FYM was broadcasted at 30 days after sowing (DAS) along with the basal application of 10 t/ha FYM (0.56% and 175.3 kg/ha, respectively). These values were statistically comparable to those from the treatment with three foliar applications of a 1:2 FYM extract, following the basal dose of FYM (0.55% and 173.2 kg/ha). Both treatments showed significantly higher SOC and available N compared to the sole application of FYM, three foliar applications of seaweed extract (SWE) with basal FYM, broadcasting of FYM at 1 t/ha followed by three foliar applications of 1:2 FYM extract, and the unfertilized control. The accumulation of organic carbon was highest in treatments where organic manures were applied over the three-year period. No significant differences were observed in soil pH, electrical conductivity (EC), available phosphorus (P), and available potassium (K) across the different organic manure treatments (Table 5). The higher organic matter content can be attributed to the increased microbial activity in the soil, which accelerated the decomposition of organic manures and released weak acids into the soil. Organic manures serve as a direct source of carbon and nutrients for the soil, enhancing microbial activity. Several studies have shown that periodic application of organic amendments in organic farming systems can increase soil macroaggregate proportions (Zhang *et al.*, 2020), as well as soil organic matter and total nitrogen levels (Liu *et al.*, 2016; Guo *et al.*, 2016). Similarly, Mahmood *et al.* (2017) and Brar *et al.* (2013) reported the positive effects of organic manures on the physico-chemical properties of soil in maize and rice-wheat cropping systems, respectively. The increase in soil available nitrogen may be due to the direct addition of nitrogen through organic manures, as well as the increased multiplication of soil microbes that convert organically bound nitrogen into its inorganic form (Panwar, 2008).

Microbial properties

In the third year of the present investigation, soil samples from each treatment were analyzed to assess the presence of total bacterial, actinomycetes, and fungal counts (CFU/g), aimed to determine the impact of organic interventions on soil health. The highest microbial counts for bacteria, fungi, and actinomycetes were observed in the treatment where 1 t/ha of FYM was broadcast at 30 DAS along with a basal dose of 10 t/ha FYM. This was followed by the treatment with three foliar applications of a 1:2 FYM extract after the basal dose of FYM, as well as the foliar application of seaweed extract (SWE) combined with the basal

Table 5. Physico-chemical properties of soil as influenced by organic nutrients and planting geometry (2019-20)

Treatments	pH (1:2)	EC (dSm^{-1})	SOC (%)	Available nutrients		
				N (kg/ha)	P (kg/ha)	K (kg/ha)
Main plots (Organic manures)						
FYM	7.1^{a}	0.46^{a}	0.54^{ab}	168.5^{b}	22.5^{a}	155.4^{a}
FYM + SWE	7.2^{a}	0.47^{a}	0.53^{b}	167.2^{bc}	22.3^{a}	156.4^{a}
FYM + ME	7.3^{a}	0.45^{a}	0.55^{a}	173.2^{a}	22.5^{a}	157.2^{a}
FYM + FYMB	7.2^{a}	0.49^{a}	0.56^{a}	175.3^{a}	22.6^{a}	155.7^{a}
FYMB + ME	7.2^{a}	0.45^{a}	0.52^{bc}	165.0^{c}	22.4^{a}	155.2^{a}
Control	7.2^{a}	0.40^{a}	0.50^{c}	162.5^{d}	22.7^{a}	155.4^{a}
Sub plots (Planting geometry)						
P_1 (R×P)	7.3^{a}	0.46	0.52	168.5	22.5	155.8
P_2 (R×P)	7.2^{a}	0.46	0.53	169.2	22.4	155.6
Initial values	7.4	0.45	0.50	164.0	22.4	155.5

Within a column, means followed by same alphabet did not differ significantly after Tukey's HSD at $p \leq 0.05$

dose of FYM. Other treatments, including the sole application of FYM and the broadcasting of FYM at the first irrigation followed by foliar applications of 1:2 FYM extract, also showed higher microbial counts compared to the unfertilized control. Soil microorganisms play a crucial role in ecological functions such as nutrient cycling and the formation of soil aggregates through the decomposition of organic matter (Stark *et al.*, 2008). Both organic and inorganic amendments significantly influence soil microorganisms (Hu *et al.*, 2011). Keeping in view their importance in ecosystem functions, including the decomposition of organic matter, nutrient cycling, mineralization, and transformation, even small changes in soil microbial biomass can significantly affect soil fertility and ecosystem stability (Babu *et al.*, 2017).

Economics analysis

The economic analysis revealed that the treatment with the highest cost of cultivation (₹39,381/ha) was the one where the basal dose of FYM was supplemented with three foliar applications of seaweed extract (SWE). This increased cost was attributed to the higher purchase cost of the SWE. In contrast, the treatment where FYM was broadcasted at 1 t/ha at 30 DAS, accompanied by three foliar applications of a 1:2 FYM extract, recorded the lowest cost of cultivation (₹27,356/ha), which was also lower than the unfertilized control. This reduction in cost was due to the relatively lower expense involved in preparing the FYM extract. The highest gross and net returns were observed in the treatment where the crop was supplemented with 1 t/ha FYM at the first irrigation,

Table 6. Microbial properties of soil as influenced by organic nutrients and planting geometry (2019-20)

Treatments	Bacteria (cfu/g)	Fungi (cfu/g)	Actinomycetes (cfu/g)
Main Plots (Organic manures)			
FYM	8.245^{d}	4.920^{d}	6.095^{d}
FYM + SWE	8.249^{c}	4.958^{c}	6.123^{c}
FYM + ME	8.255^{b}	5.003^{b}	6.138^{b}
FYM + FYMB	8.274^{a}	5.032^{a}	6.188^{a}
FYMB + ME	8.242^{d}	4.909^{d}	6.045^{e}
Control	8.222^{e}	4.909^{d}	6.019^{f}
Sub Plots (Planting geometry)			
P_1 (R×P)	8.253^{a}	4.979^{a}	6.123^{a}
P_2 (R×P)	8.243^{a}	4.930^{a}	6.079^{a}
Initial status	8.152	4.890	6.015

Within a column, means followed by same alphabet did not differ significantly after Tukey's HSD at $p \leq 0.05$

in addition to the basal application of 10 t/ha FYM, at both 25% and 50% premiums. This was attributed to the higher seed yield in this treatment. It was followed by the treatment with three foliar applications of a 1:2 FYM extract after the basal dose of FYM, and yielded better returns than treatments involving the sole application of FYM, foliar application of 1% SWE with basal FYM, broadcasting of FYM at first irrigation followed by foliar applications of 1:2 FYM extract, and the unfertilized control. The highest benefit-cost (B:C) ratio at both premium levels was recorded in the treatment where the basal dose of FYM was followed by three foliar applications of a 1:2 FYM extract. This treatment's favorable B:C ratio was attributed to its relatively lower cost of cultivation.

Under different plant geometries, the treatment with a 45 × 10 cm plant spacing resulted in a higher cost of cultivation (₹33,379/ha) and gross returns (₹89,556/ha). However, the 67.5 × 10 cm plant geometry yielded higher net returns (₹56,527/ha) and a better benefit-cost (B:C) ratio of 2.73. This suggests that while the 45 × 10 cm spacing led to higher gross returns, the wider spacing of 67.5 × 10 cm provided a more favourable economic outcome due to its lower associated costs.

CONCLUSION

The application of 10 t/ha FYM (1.0% N) at the time of sowing, followed by broadcasting 1 t/ha of FYM at 30 DAS, and the application of 10 t/ha FYM at sowing with three sprays of 1:2 FYM extract at 50, 65, and 80 DAS, resulted in significantly higher seed yield compared to other organic manure treatments applied at different times. However, the latter treatment, which involved the 1:2 FYM extract, recorded a higher benefit-cost (B:C) ratio due to the lower cost of preparing the extract, which enhances nutrient supply to the crop. While both planting geometries did not show significant differences in seed yield and other attributes, the 67.5 cm × 10 cm planting geometry should be preferred for organic cultivation of *gobhi sarson* as it facilitates easier weed control.

Authors' contribution

Conceptualization of research work (ASS, CSA, AS); Execution of field experiments (ASS, SS, AS); Preparation of manuscript (ASS, SS); Manuscript proofreading (ASS, CSA); Soil Analysis (NR); Microbial analysis (GP).

Acknowledgement

Authors are grateful to the Punjab Agricultural University, Ludhiana, India, for providing the necessary financial support for conducting this study.

Conflicts of interest

Authors declare that they have no conflicts of interest.

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