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Enhancing Canola Yield, Quality and Profitability through Organic Soil Amendments: A Sustainable Approach

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ABSTRACT

Sustainable agricultural practices, such as use of organic soil amendments, are gaining attention to enhance productivity of canola while addressing soil health and environmental concerns. Organic amendments viz. farm yard manure (FYM) and sugarcane press mud (PM) could be used for improving yield, quality and profitability of canola on sustained basis. This two-year study was performed to ascertain influence of exclusive addition of FYM (8 and 12 t ha⁻¹) and PM (5 and 7.5 t ha⁻¹) or their combined addition (8 t ha⁻¹ FYM + 5 t ha⁻¹ PM) in soil on yield, quality and profitability of canola. The NPK (90-60-50 kg ha⁻¹) fertilizers were applied for comparison. Organic amendments significantly enhanced canola yield and quality. Addition of 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM in soil exalted number of siliques (10-17%), seeds siliques⁻¹ (12%), 1000-seed weight (3-4%), seed yield (14-27%) and oil content (6-9%) of canola, and succeeded by 12 t ha⁻¹ FYM. Protein content was improved by NPK fertilizers and 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM. Likewise, net benefits and benefit:cost ratio (BCR) were enhanced by application of 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM followed by 12 t ha⁻¹ FYM. In conclusion, addition of 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM in soil enhanced seed yield and quality by improving growth and development of canola; hence, could be employed to enhance profitability. Alternatively, productivity and profitability of canola could be improved by application of 12 t ha⁻¹ FYM.

Keywords: Benefit: cost ratio; Canola; Organic soil amendments; Oil content; Protein content; Sustainability

INTRODUCTION

Canola (*Brassica napus* L.) stands as a vital oilseed crop ranking third in the world. Optimizing its yield through sustainable practices is essential for global food security (Shahzadi et al., 2015). Its cultivation requires a holistic approach to enhance yield and improve sustainability (Dinakaran et al., 2019). Fertilization is a crucial soil and crop management factor which exerts a substantial impact on soil, grain yield and quality of the crops (Kamkar et al., 2011; Mohammadi and Rokhzadi, 2012). Reduced reliance on synthetic fertilizers minimizes environmental impact and improves long-term soil fertility and thus contributes to an environmentally

conscious approach for cultivation of crops (Jan et al., 2011, 2020). Previous research has shown stable soil health and yield improvements by employing FYM along with chemical fertilizers than sole chemical fertilizers (Chandra et al., 2011; Bhadauria et al. 2014; Datta et al. 2018). Exclusive addition of manures in the soil is likely to increase the crop yield on sustained basis via improved organic matter and biological health of soil (Nayak et al., 2007; Mahanta et al., 2013; Dinakaran et al., 2019).

Farmyard manure is a rich source of organic matter and essential nutrients, providing a balanced nutrient profile for crops (Tadesse et al., 2013; Kumar et al., 2021).

Increased organic matter content improves the soil structure, water retention, and microbial activity which lead to better root development, nutrient uptake and plant health (Hatch et al., 2007; Mohammadi and Rokhzadi, 2012; Havlin, 2013). The use of FYM, derived from animal waste, has gained attention for its potential to enhance soil fertility, soil structure and overall crop performance (Awaad et al., 2009; Zhang et al., 2014). Gradual release of nutrients from FYM aligns well with crop nutrient requirements throughout its growth stages positively influencing crop yield (Tadesse et al., 2013). Investigating the role of FYM revealed its capacity to enhance canola yield through improved soil structure, water retention, and microbial activity (Zhang et al., 2014; Kumar et al., 2021). The FYM releases humic substances, which converts the unavailable phosphate to available form in soil and the slow release of nutrients from it, contributes to sustained crop growth (Awaad et al., 2009). When applied appropriately, FYM can positively influence canola yield by providing a balanced nutrient supply and fostering overall soil health (Mohammadi and Rokhzadi, 2012; Mohammadi et al., 2012).

Sugarcane press mud, a byproduct generated by the sugar industry and commonly referred to as filter cake, improves the organic matter content and nutrient levels in soil (Sarwar et al., 2010). When incorporated into the soil, PM contributes to decreased soil pH, improved soil structure, water infiltration and retention, nutrient-holding capacity and organic matter which fosters the development of beneficial soil microorganisms promoting their activity and creating a more biologically active soil (Rangaraj et al., 2007; Jamil et al., 2008; Sarwar et al., 2010; Sher et al., 2022). Resulting microbiological activity plays a crucial role in nutrient cycling, converting organic matter into readily plant available forms and promoting the soil health (Rangaraj et al., 2007; Kumar and Chopra, 2016; Maçik et al., 2020). Improved soil structure creates an environment conducive for the development of plant roots, facilitating enhanced nutrient absorption and promoting overall plant growth (Basak et al., 2021). Moreover, PM contains essential nutrients viz. N, P, K and micronutrients (Gupta et al., 2011). Its application enriches the soil with these nutrients, providing a balanced and slow-release nutrient source for plants (Dotaniya et al., 2023). Hence, determining the optimum dose of PM for canola cultivation could be useful to improve the NUE and crop yield.

Integrated nutrient management positively influences the yield and yield related traits of crops leading to a more economically and agriculturally valuable crop (Jan et al., 2011; Jalil et al., 2017). Recent trends have shown interest in integrating the use of different sources of organic manures for more beneficial effects on soil health and crop yields than their exclusive use (Du et al., 2020; Jan et al., 2020). Previous research primarily concentrated on revealing the impacts of integrating organic and inorganic fertilizers to enhance soil health, foster plant growth, and promote yield formation ultimately leading to an improved overall crop yield (Abbas et al., 2012; Hlisnikovský et al., 2021). Studies focusing on nutrient availability and uptake in canola cultivation indicate that integrated FYM application improves the utilization of nutrients by the crop (Awaad et al., 2009).

Synthetic fertilizers impact upon long-term soil fertility and health, as well as inducing environmental impacts. Hence, the use of organic fertilizers replenishes the soil nutrient status and soil health which lead to improved crop yield and quality. It was hypothesized that exclusive or integrated use of different organic manures could enhance both yield and quality of canola on sustained basis. This study aimed to ascertain the impact of exclusive or integrated use of FYM or PM at different doses on growth, seed yield and quality, and profitability of canola.

MATERIALS AND METHODS

Experimental details

Two-year study was designed to ascertain impact of various manures on canola yield at Fiber Crops Section, Agronomic Research Institute, Ayub Agricultural Research Institute, Faisalabad (31°23'59"N latitude 73°04'17"E longitude and 184 m above sea level) during 2017-18 and 2018-19. Experimentation was accomplished using randomized complete block design having four replications. Net area of each plot was kept 6 m × 1.8 m. Soil sampling was performed from the experimental area from different depths prior to treatments application. Soil physico-chemical properties were determined and presented in Table 1. The meteorological conditions prevailing during the experimental period during 2017-18 and 2018-19 are presented in Table 2.

Table 1. Soil analysis of experimental site.

Parameters	Depth 0-15 cm		Depth 16-30 cm	
	2017-18	2018-19	2017-18	2018-19
Soil type	Loam			
Soil pH	7.6	8.1	7.9	8.1
Electrical Conductivity (mS/cm)	1.74	1.97	1.83	2.12
Organic matter (%)	0.98	1.08	0.70	0.77
Nitrogen (%)	0.032	0.38	0.031	0.35
Available Phosphorus (ppm)	9.7	10.3	7.8	8.5
Available Potassium (ppm)	200	220	160	180

Table2. Meteorological conditions during experimentation

Month	Temperature (°C)						Total Rainfall (mm)	Relative Humidity (%)		
	Monthly Maximum		Monthly Minimum		Daily Mean			2017-18	2018-19	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18			2018-19
October	35.0	32.6	19.2	18.7	27.1	25.6	0.0	0.0	68.2	64.4
November	24.1	27.0	11.8	12.4	18.0	19.7	1.5	0.6	84.6	74.6
December	22.0	17.0	06.7	6.0	14.4	11.5	4.2	7.0	69.3	77.0
January	21.5	19.2	05.5	07.0	13.5	13.1	0.0	18.0	75.9	80.7
February	24.0	20.3	09.5	09.1	16.7	14.7	9.5	64.2	73.3	79.0
March	31.2	26.1	16.4	13.8	23.8	19.9	12.5	55.7	61.4	68.5
April	36.8	35.0	20.8	20.6	28.8	27.8	7.9	32.2	47.3	42.5

Source: Plant Physiology Section, Agronomic Research Institute, Ayub Agricultural Research Institute, Faisalabad.

Treatments' details

Treatments included exclusive addition of FYM (8 and 12 t ha⁻¹) and PM (5 and 7.5 t ha⁻¹) or their combined addition (8 t ha⁻¹ FYM + 5 t ha⁻¹ PM) in soil. The NPK (90-60-50 kg ha⁻¹) fertilizer was applied for comparison. The organic manures were applied one month before sowing of the crop. Urea, diammonium phosphate (DAP), and sulfate of potash (SOP) were used to apply the NPK fertilizers, respectively. All of the DAP and SOP was employed during sowing, whereas urea was employed in splits at 28 and 70 days after sowing (DAS).

Crop husbandry

Seed of variety Super canola was used for experimentation. Sowing was performed on 3rd and 7th October during 2017-18 and 2018-19, respectively. Drill sowing of crop was performed by maintaining the inter row plant spacing at 45 cm. Crop was sown using 5 kg ha⁻¹ seed after treatment with thiophanate methyl at a rate of one g kg⁻¹ seed. Thinning of crop was performed 25 DAS to maintain the intra row plant spacing at 15 cm. Fertilizers were applied according to the treatments. The crop was irrigated three times during both years

Observations

Plant height was recorded with the help of measuring

rod by randomly selecting the five plants from each replication at maturity and then averaged. At harvesting, number of siliques plant⁻¹ was determined by counting siliques from selected five plants from each plot and averaged. Seeds from selected five siliques were counted to determine the number of seeds silique⁻¹ and averaged. Then, 1000-seeds were counted and weighed to determine the 1000-seed weight using a weighing balance from each plot. Seed yield was determined by manually harvesting and threshing the canola crop from each replication and expressed as t ha⁻¹.

Crude oil content in canola seeds was assessed by grinding the seeds and placing them in an extraction tube. Petroleum ether was continuously added to the extraction tube until it began to siphon into the flask of the Soxhlet apparatus. Subsequently, the ether was heated to facilitate oil extraction. Following 6-7 cycles of siphoning, ether was permitted to collect in the extraction tube whereas the flask was disengaged. Determination of oil content was then conducted according to the AOAC (1990). Seed crude protein contents were determined by grinding the samples and digesting in concentrated sulfuric acid. It was followed by distillation and titration process using Micro

Kjeldahl's method to determine the N content (Estefan et al., 2013). Method of AOAC (1990) was used to determine seed crude protein;

Seed crude protein (%) = N (%) × 6.25

Economic analysis

Total cost, net benefits and BCR were calculated according to the CIMMYT (1988). The fixed cost, variable cost, and gross income were determined using local market prices for inputs and produce, respectively. The total cost was calculated by adding together both fixed and variable costs. Net benefits were computed by deducting total cost from the gross income. The BCR was calculated by using formula [BCR = (Gross income/total cost)].

Statistical analysis

After checking data normality with scatter plot method, the Fisher's analysis of variance procedure was applied to determine significance of data (Steel et al., 1997). Least significant difference test was used at a 5% probability level to assess significance of differences among the means of treatments.

RESULTS

Plant height, seed yield and related attributes of canola

Plant height, siliques plant⁻¹, seeds silique⁻¹ and 1000-seed weight of canola was significantly influenced by the exclusive or combined application of different organic soil amendments at different rates, during both years (Table 3). There was a substantial increase in plant height and yield related attributes of canola by application of sole organic soil amendments at higher rates or in combination at lower rates, in comparison to NPK fertilizers (Table 3). Moreover, the influence of FYM on plant height and yield related attributes was more pronounced as compared to PM (Table 3). The greatest increase in plant height (12-13%), number of siliques (10-17%) and 1000-seed weight (3-4%) of canola was caused by integrated addition of 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM in soil, in comparison to NPK fertilizers; and it was succeeded by treatment of 8 t ha⁻¹ FYM, during both years (Table 3). The seeds silique⁻¹ were increased the most by integrated addition of 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM (12%) during 2017-18 and 8 t ha⁻¹ FYM (12%) during 2018-19 in soil; however, effect of sole treatment of 12 t ha⁻¹ FYM and NPK fertilizers during 2017-18 and integrated treatment of 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM during 2018-19 was statistically similar (Table 3).

Seed and biological yield of canola was affected significantly by exclusive or combined application of different soil organic amendments at different rates, during 2017-18 and 2018-19 (Figure 1). Application of different organic amendments at varying rates enhanced the canola seed and biological yield in comparison to NPK fertilization (Figure 1). Farm yard manure enhanced the seed yield more than PM, while the effect of PM on biological yield of canola was vice versa, during both years (Figure 1). The seed yield (14-27%) of canola was exalted the most by combined application 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM, in comparison to NPK fertilizers, and the use of 8 t ha⁻¹ FYM as well as NPK fertilizers during 2017-18 and 8 t ha⁻¹ FYM during 2018-19 followed it (Figure 1). However, the greatest increase in biological yield (14-15%) was caused by integrated use of 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM during 2017-18 and exclusive use of 7.5 t ha⁻¹ PM during 2018-19, as compared to NPK fertilizers (Figure 1).

Seed crude protein and oil contents

Seed crude protein and seed crude oil contents of canola were significantly influenced by soil application of various organic amendments at different rates, during both years (Figure 2). Influence of sole applications of FYM or PM on seed crude protein and oil contents was not significantly different; however, there was variation within application rates of FYM and PM (Figure 2). Moreover, the effect of integrated addition of FYM + PM in soil was comparable with NPK fertilizers (Figure 2). Application of NPK exhibited the maximum improvement in seed crude protein content of canola and the effect of 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM application was statistically similar, during 2017-18 and 2018-19 (Figure 2). Nonetheless, seed crude oil content (6-9%) was exalted the most by application of 8 t ha⁻¹.

FYM + 5 t ha⁻¹ PM, in comparison to NPK fertilizers; and it was followed by 7.5 t ha⁻¹ PM during 2017-18 and NPK fertilizers during 2018-19 (Figure 2).

Economic benefits and benefit: cost ratio of canola

Exclusive as well as combined application of organic soil amendments improved the net benefits and BCR of canola, as compared to NPK fertilizers (Table 4). Application of NPK fertilizers was the most expensive while lowest cost was incurred by 5 t ha⁻¹ PM (Table 4). However, the greatest gross income (Rs. 149081), net benefits (Rs. 71081) and BCR (1.91) was obtained by integrated use of 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM and exclusive use of 12 t ha⁻¹ FYM followed it (Table 4).

Conversely, NPK fertilizers exhibited least net benefits (Rs. 35753) and BCR (1.40) (Table 4). Average adjusted seed yield = 10% less than actual seed

yield of canola averaged over two years (2017-18 and 2018-19); Cost and income was averaged over two years (2017-18 and 2018-19).

Table 3. Effect of different organic soil amendments on plant height and yield related attributes of canola

Treatments	Plant height (cm)		No. of siliques plant ⁻¹		1000-seed weight (g)		No. of seeds siliques ⁻¹	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
NPK fertilizers	151.6 bc	158.6 cd	156.8 d	171.6 bc	3.83 b	3.78 bcd	21.6 ab	19.0 b
8 t ha ⁻¹ FYM	149.5 bc	150.1 d	156.0 d	160.5 d	3.71 c	3.68 d	18.6 c	17.1 c
12 t ha ⁻¹ FYM	162.7 ab	169.1 ab	174.4 b	181.5 ab	3.87 b	3.88 ab	21.1 b	21.7 a
5 t ha ⁻¹ PM	146.9 c	154.5 d	147.6 e	164.0 cd	3.63 c	3.76 cd	18.6 c	19.0 b
7.5 t ha ⁻¹ PM	158.7 abc	164.9 bc	165.0 c	165.0 cd	3.80 b	3.81 bc	20.3 b	19.4 b
8 t ha ⁻¹ FYM + 5 t ha ⁻¹ PM	171.5 a	177.7 a	183.2 a	188.0 a	3.96 a	3.94 a	22.8 a	21.3 a

Means in a column followed by different letters are significantly different at P ≤ 0.05.

Table 4. Effect of soil organic amendments on the economic benefits and benefit:cost ratio of canola

Treatments	Adjusted seed yield (t ha ⁻¹)	Gross income (Rs. ha ⁻¹)	Fixed cost (Rs. ha ⁻¹)	Variable cost (Rs. ha ⁻¹)	Total cost (Rs. ha ⁻¹)	Net benefits (Rs. ha ⁻¹)	BCR
NPK fertilizers	1.39	125186	65000	24433	89433	35753	1.40
8 t ha ⁻¹ FYM	1.30	117167	65000	8000	73000	44167	1.61
12 t ha ⁻¹ FYM	1.55	139077	65000	12000	77000	62077	1.81
5 t ha ⁻¹ PM	1.35	121136	65000	5000	70000	51136	1.73
7.5 t ha ⁻¹ PM	1.41	126603	65000	7500	72500	54103	1.75
8 t ha ⁻¹ FYM + 5 t ha ⁻¹ PM	1.66	149081	65000	13000	78000	71081	1.91

Average adjusted seed yield = 10% less than actual seed yield of canola averaged over two years (2017-18 and 2018-19); Cost and income was averaged over two years (2017-18 and 2018-19).

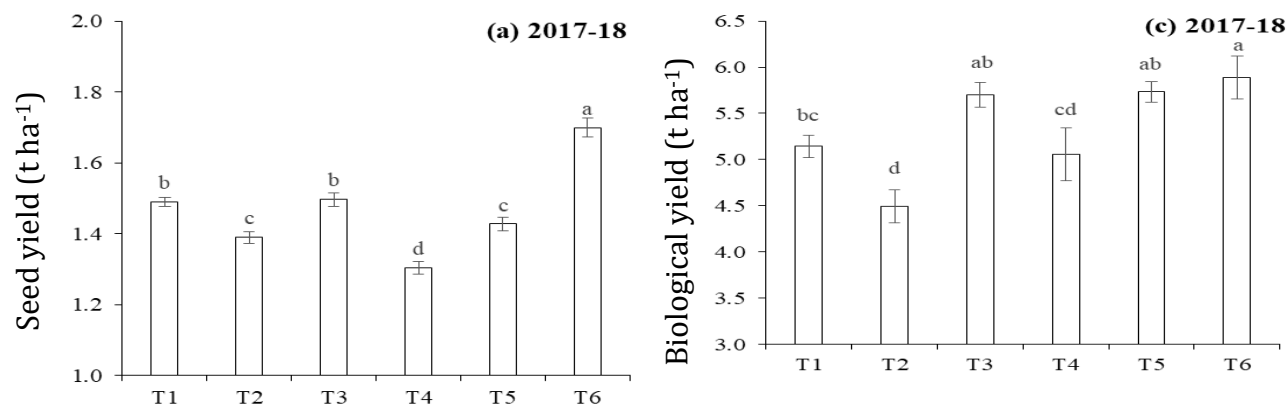


Figure 1 (a). Effect of different organic amendments on grain yield (t ha⁻¹) and (c and d) biological yield (t ha⁻¹) of canola. Bars are mean ± SE of four replications. Bars sharing the different letters differ significantly at P < 0.05.

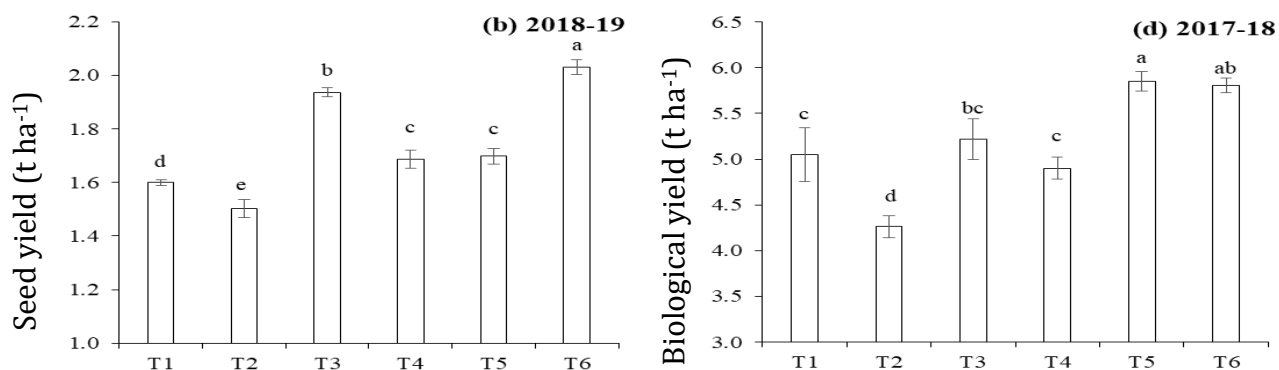


Figure 1 (b). Effect of different organic amendments on grain yield (t ha⁻¹) and (c and d) biological yield (t ha⁻¹) of canola. Bars are mean ± SE of four replications. Bars sharing the different letters differ significantly at P < 0.05.

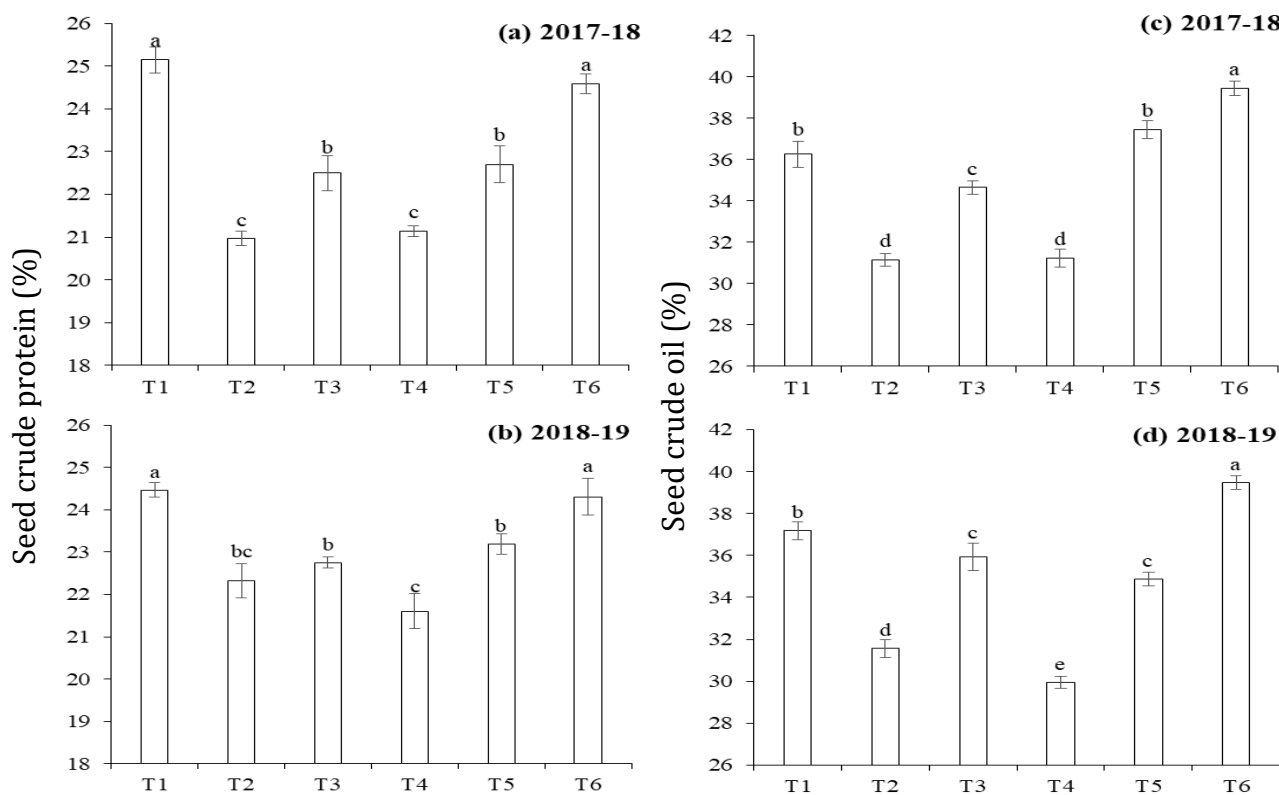


Figure 2. Effect of different organic amendments on (a and b) seed crude protein (%) and (c and d) seed crude oil (%) of canola. Bars are mean ± SE of four replications. Bars sharing the different letters differ significantly at P < 0.05.

DISCUSSION

In present study, seed yield of canola was improved by the application of organic amendments in soil, especially combined application of FYM and PM, (Table 3; Figure 1) which was associated with enhanced siliques plant⁻¹, seeds silique⁻¹ and seed weight (Table 3). The observed enhancement in growth and yield of canola (Table 3;

Figure 1) could be attributed to improved soil fertility, balanced nutrient availability and better moisture retention provided by different organic amendments especially their combined use, ultimately promoting canola growth and dry matter accumulation (Kazemeini et al., 2010; Soliman et al., 2024). In current study, the enhanced plant height and biological yield in response to

organic amendments (Table 3; Figure 1) indicate better growth and development, reflecting positive influence of organic amendments on overall plant vigor and performance (Sher et al., 2022; Shehzad et al., 2023; Soliman et al., 2024). Moreover, in present study, increased seed number and weight (Table 3) is indicative of improved seed setting and filling, possibly due to better soil structure, nutrient uptake and utilization facilitated by organic amendments (Banerjee et al., 2010; Kheir et al., 2021). Previous research has exhibited similar enhancement in the crop growth and yield by addition of organic amendments in soil (Banerjee et al., 2010; Samreen et al., 2022; Shehzad et al., 2023).

In current study, influence of FYM on canola growth and yield was more pronounced in comparison to PM (Table 2; Figure 1). This comparatively better influence of FYM on canola growth and seed yield could be attributed to longer residual effect and slow release of nutrients due to continuous decline in soil pH by released organic acids from it than PM, which met the crop nutrient requirements throughout the growing season (Singh et al., 2015). Moreover, FYM enhances soil structure, nutrient recovery and reduces the nutrient losses from the soil better than other organic sources thereby resulting in improved crop growth, yield and nutrient use efficiency (Yaduvanshi, 2003; Jan et al., 2020). In this study, more prominent effect of FYM than PM was observed at higher rate (12 t ha⁻¹) in comparison to lower rate (8 t ha⁻¹), which shows that application of FYM is more effective only when applied at higher rates (Figure 1). Sher et al. (2022) described that growth and yield of triticale was increased more by PM when its dose was kept equal to the FYM.

Increased seed protein content is necessary as it enhances the nutritional value of canola seeds, making it more suitable for various applications in food and feed industries (Bhat et al., 2007). Similarly, higher oil content is desirable as it enhances the economic value of canola seeds for oil extraction and biodiesel production (Bhat et al., 2007; Raboanatahiry et al., 2021). In present study, addition of FYM and PM alone as well as in combination enhanced protein and oil contents in canola seed (Figure 2). However, the effect of NPK fertilizers and combined effect of FYM and PM on protein and oil contents in canola seed was comparable (Figure 2) which indicates that increased protein and oil contents in response to organic amendments was due to availability of balanced soil nutrients. The increase in protein and oil contents in

canola seed could be attributed to enhanced N and P concentrations in soil in response to FYM and PM (Yaduvanshi, 2003; Singh et al., 2015; Ashraf et al., 2021). Previous studies have demonstrated an increase in protein and oil contents in canola seed by use of different manures including FYM and composts (Banerjee et al., 2010; Mohammadi and Rokhzadi, 2012).

Economic analysis exhibited that net benefits and BCR of canola were enhanced by exclusive as well as combined application of organic soil amendments, as compared to NPK fertilizers (Table 4). Lowest net benefits and BCR by NPK fertilizers is attributed to highest total cost (Table 4). In contrast, low cost and high yield was associated with exclusive or combined treatment of various organic amendments which resulted in high net benefits and BCR (Table 4). Previous research has also reported similar improvement in economic benefits and profitability of crops due to application of organic amendments in soil (Ali and Jan, 2016; Khan et al., 2022).

CONCLUSION

Application of organic soil amendments enhanced the seed yield and profitability of canola by improving the plant growth and yield related attributes. Moreover, the protein and oil contents in canola seed were also enhanced by the use of organic soil amendments. In conclusion, combined application of 8 t ha⁻¹ FYM + 5 t ha⁻¹ PM most effectively improved seed yield, quality and profitability of canola; hence, could be employed for better productivity and profitability of canola. Alternatively, 12 t ha⁻¹ FYM could be used to enhance the yield, quality and profitability of canola.

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