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Evaluating the Effect of Farmyard Manure and Green Manure on Soil Physicochemical Traits and Growth Yield of Organic Sesame (*Sesamum indicum* L.)

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ABSTRACT

From 2016 to 2017, an experiment was conducted at Razi University Organic Farming to identify the best organic fertilizers for organic sesame production. The research was carried out in the split-plot design based on a randomized complete block design with three replications. Comparison of soil nitrate in the post-planting stage of sesame with soil before the experiment shows that organic nitrate storage with an application of treatments of 10 and 20 t ha^{-1} of animal manure is 36 and 63% and green manure of fenugreek, berseem clover, and hairy vetch is 63, 54, and 23%, respectively. The reason for improving grain yield is the positive role of animal manure and green manure in the fertility and balance of soil elements. The plant doesn't face a lack of nutrients and increases the concentration of essential growth elements in the leaves, which increases grain yield. Fenugreek and berseem clover were higher than hairy vetch due to higher nitrogen yield. In the post-harvesting stage of sesame, soil experiments revealed that approximately 24% organic carbon, 58% phosphorus, 16% nitrogen, 63% nitrate, and 50% ammonium were stored in the soil. Potassium content was 13% lower than in soil before the experiment. In general, this study showed that the application of animal and green manure by providing physical and chemical properties of soil in organic field conditions leads to improved traits associated with sesame growth and, ultimately, grain yield.

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1. Introduction

Sesame (*Sesamum indicum* L, 2n=26) belongs to the genus Sesamum and the family Pedaliaceae. It is one of the oldest oilseeds with high-quality oil and is widely cultivated in tropical and subtropical regions of Asia, South America, and Africa (Zhang *et al*., 2013; Ganjineh *et al*., 2019). Sesame is one of the most valuable oilseeds due to the special quality of the oil in the seeds for human health. Its seeds are a rich source of calcium, potassium, high in antioxidants such as sesamolin and sesamin, which keep them from becoming rancid (Suddhiyam *et al*., 2009). Cultivation of sesame in poor soil conditions can make it a product that reduces food security in the areas where it is used (Eifediyi *et al*., 2018). Traditional farmers rarely use fertilizers. According to research, using organic or mineral fertilizers improves well performance (Olowe and Busari, 2000; Okpara *et al*., 2007; Haruna *et al*., 2011; Haruna and Abimiku, 2012). The chemical composition of the oil is stable, and it is seldom exposed to oxidation in hot climates (Anilakumar *et al*., 2010).

Nutrient deficiency in calcareous soils is the most important limiting factor to crop production after water shortages (Rahman *et al*., 2022; Akhtar *et al*., 2022). The main factors influencing nutrient bioavailability in calcareous soils are alkaline soil pH, free carbonate, and low organic matter (Ahmad *et al*., 2022). Traditional sources of nutrients were replaced by synthetic and chemical fertilizers. Using inorganic manures is undoubtedly the key to increasing productivity on a larger scale (Fan *et al*., 2021; Alavi, 2017; Dhaliwal *et al*., 2019). However, improper use of chemical or synthetic

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fertilizers, unscientific management, excessive use, etc., cause soil and environmental pollution as well as poor soil quality. In addition, the constant use of these fertilizers causes toxicity as well as a lack of some major and minor nutrients (Verma *et al*., 2020).

Organic farming, which is considered alternative agriculture, provides quality and safe products and benefits the environment (Willer and Lernoud, 2019) because, in organic farming, the use of chemical fertilizers and artificial pesticides is prohibited. In this regard, soil remediation with green manure, animal manure, compost, and pest control with natural methods (biological extracts) are the main operations (Suddhiyam *et al*., 2009; Atkinson and Christine, 2019). According to the standards, the land must not have undergone any chemical treatment for at least one year for annual crops (DOA, 2006). Animal manure (Gatsios *et al*., 2019) and green manure (Denton *et al*., 2017) have traditionally played an important role in organic farming as a source of organic materials and nutrients. Due to the issue of food security, animal manure density is likely to decrease in the future (Ciaccia *et al*., 2017). Feeding the growing world population using sustainable resources is a major challenge in modern agriculture (Schult *et al*., 2013). Consumption of organic fertilizers improves carbon status and soil quality, which helps to improve and decompose carbon (Verma *et al*., 2020). Organic materials are considered soil life as well as a source of nutrient storage. These materials play an important role in maintaining soil fertility and are considered as a source of nitrogen storage, phosphorus, and sulfur in the soil and prevent the leaching of nutrients (Zamil *et al*., 2010). Organic matter prevents the formation of calcium phosphate by complexing dissolved calcium and reducing its concentration in soil solution. Animal manures can be used to increase the level of organic matter in calcareous soils. Animal manures gradually release nutrients and prevent them from being wasted by washing, allowing the plant to absorb them to the maximum extent possible. In addition to being a good source of nutrients, these fertilizers also improve the physical, chemical, and biological properties of the soil (Zamil *et al*., 2004). Therefore, this paper was conducted to investigate the effects of animal and green manures on soil physicochemical properties as well as soil nutrient status and sesame yield under organic conditions.

2. Materials and methods

2.1. Crop management

During the 2017 growing season, this study was conducted at the Organic Farming Educational and Research Campus of Agriculture and Natural Resources, Razi University, Kermanshah. Sesame seeds (Oltan cultivar) were prepared by the Seed and Plant Research Improvement Institute, Karaj, oilseeds section. The research was performed in a split-plot design based on a randomized complete block design in three replications. Treatments of animal manure at three levels (0, 10, and 20 t ha^{-1}) as the main factor and green manure at four levels (no green manure, berseem clover (*Trifolium alexandrinum*), fenugreek (*Trigonella foenum-graecum*), and hairy vetch (*Vicia villosa*)) as sub-factor were studied. Animal manure is added to the soil at the time of soil preparation to a depth of 30 cm in all stages of the trial. The length of each subplot was 3 m, and its width was 2.5 m. The distance between the main plots from each other and between the sub-plots from each other was considered to be 1.5 and 0.5 m, respectively. The seeds of the desired green manures were planted manually at a suitable depth after preparing the substrate. Seed density was 25 plants per m^2 and plot size was 7.5 m^2 (8 rows, 2.5 m long, 0.375 m row spacing). Planting densities of berseem clover, fenugreek, and hairy vetch were considered to be 30, 50, and 80 kg ha^{-1}, respectively. No field operations were performed for four weeks after the return of green manure species to the soil (Carr *et al*., 2020).

2.2. Basic properties of soil and organic fertilizers used

In order to record the soil properties before applying the treatments, a composite sample of surface soil (depth 0 to 30 cm) was prepared. Soil samples, along with a sample of animal manure used, were sent to the soil and water laboratory to investigate the physical and chemical properties (Table 1). Physical and chemical properties of soil were measured, including soil texture by the hydrometer method (Bouyoucos, 1962) soil pH in saturated soil using a pH meter with a glass electrode (Mclean, 1988) electrical conductivity (EC) using an electrical conductivity device in saturated soil (Page *et al*., 1987) organic carbon by wet oxidation (Walkley and Black, 1934) total nitrogen in soil and plants by Kjeldahl method (Kjeldahl, 1883) phosphorus usable by Olsen et al. (1954) and potassium usable ammonium acetate was measured as normal (Rowell, 1994; Miller *et al*., 2013). Also, at the time of returning the cover plants as green manure to the soil (at the flowering stage), a sample of their aerial organ tissues was prepared and then analyzed (Table 2). Nitrogen yield was obtained from the average biomass of green manures × percentage of nitrogen in their tissues (Ntatsi *et al*., 2018).

Table 1. Physical and chemical properties of soil of the experiment site and animal manure.

Sample	Texture	pH	Electrical conductivity (dS m^{-1})	Organic carbon (%)	Total nitrogen (%)	Carbon to nitrogen ratio	Phosphorus (mg kg^{-1})	Potassium (mg kg^{-1})	Nitrate (mg kg^{-1})	Ammonium (mg kg^{-1})	Sulfur (mg kg^{-1})
Soil	Clay-loam	7.42	4	1.29	0.12	10.75	8.29	312	12.16	13.23	6.68
Animal manure	-	7.76	5	5.96	0.71	8.39	8600	17500	-	-	-

Table 2. Characteristics of green manure when returned to the soil.

Green manure	Total nitrogen (%)	Nitrogen yield (kg ha^{-1})	Organic carbon (%)	Carbon to nitrogen ratio
Hairy vetch	3.25	115.81	34.20	10.52
Berseem clover	2.80	162.37	38.00	13.57
Fenugreek	4.03	290.91	39.40	9.78

2.3. Measuring yield and oil percentage of sesame

The grain yield was measured from 1 m^2 of each plot using the marginal principles at the stage of physiological maturity. So, at this stage, the percentage of seed oil was measured by the Folch method (Folch *et al*., 1957).

2.4. Statistical analysis

Data were analyzed using SAS 9.1 (SAS, 2004) for analysis of variance and interpreting the comparison of its traits.

Table 3. Effect of animal manure and green manure species on green manure biomass.

Sources of variance	df	Mean Square
Block	2	21882091^{**}
Animal manure	2	7853097.2^{*}
Block* Animal manure	4	55383
Green manure species	2	30560153.3^{**}
Animal manure* Green manure species	4	2615493^{ns}
Error	12	-
Total	26	-
CV%	-	25.15

^{ns}, * and **: non-significant and significant at 5 and 1% probability levels, respectively

3. Results

3.1. Green manure biomass

The effects of animal manure (at 5% level) and green manure species (at 1% level) on green manure biomass were significant, but their interactions were not significant (Table 3). With increasing the amount of animal manure, the amount of green manure biomass also increased, so that with the application of 10 and 20 t ha^{-1}, the biomass of green manure compared to the control treatment increased by about 9% and 27%, respectively (Table 4). The highest (7218.7 kg ha^{-1}) and the lowest (3563.6 kg ha^{-1}) green manure biomass produced belonged to fenugreek and hairy vetch, respectively (Table 4).

3.2. Macronutrients' content of soil influenced by co-application of green- and animal manures

3.2.1. Amount of organic carbon

Increasing the amount of animal manure did not have a significant effect on the amount of soil organic carbon (Table 5). In the after returning green manures stage to the soil (pre-planting stage of sesame), the effect of green manure on this trait was significant (P<0.05). At the level of 5%, the interaction of animal manure and green manure did not have a significant effect on this trait (Table 5). The results of comparing the average effect of green manure after the return of green manure to the soil stage showed that the highest amount of organic carbon was obtained if fenugreek green manure was used (1.81%) and the lowest amount was obtained in the control treatment (1.65%). This had a difference of 9.7% from each other (Table 6).

Table 4. Effect of animal manure, green manure species and their interaction on green manure biomass (kg ha^{-1}).

Treatment	Green manure			Average
	Hairy vetch	Berseem clover	Fenugreek	
Control	3666.9^{a}	5235.1^{a}	5413.3^{a}	4771.8^{b}
10 t ha^{-1} of animal manure	2520.2^{a}	5278.4^{a}	7915.3^{a}	5238.0^{a}
20 t ha^{-1} of animal manure	4503.6^{a}	6883.8^{a}	8327.6^{a}	6571.6^{a}
Average (kg ha^{-1})	3563.6^{b}	5799.1^{a}	7218.7^{a}	-

Means within rows followed by the same letter are not significantly different at the 5% level according to the Fishers LSD test

Table 5. Effects of animal and green manures species on chemical properties of soil and micronutrients' content in the pre-planting and post-harvesting stage of sesame.

S.O.V	df	Organic carbon		Phosphorus		Potassium	
		Pre	Post	Pre	Post	Pre	Post
Block	2	0.042^{ns}	0.213886^{ns}	102.8**	0.81^{ns}	1251.2^{ns}	100.028^{ns}
Animal manure	2	0.022^{ns}	0.022566^{ns}	565.1*	24.76*	15091.2*	605.528*
Blocks*animal manure	4	0.024	0.137152	50.7	1.62	6761.9	909.278
Green manure	3	0.047*	0.011340^{ns}	12.4*	0.51^{ns}	2835.5^{ns}	114.620^{ns}
Animal manure* Green manure	6	0.005^{ns}	0.023787^{ns}	3.7^{ns}	1.57^{ns}	1041.3^{ns}	1000.34^{ns}
Error	18	-	-	-	-	-	-
CV%	-	9.20	7.45	16.20	20.41	8.40	10.01

^{ns}, * and **: non-significant and significant at 5 and 1% probability levels, respectively

Table 5 Continued

S.O.V	df	Total nitrogen		Nitrate		Ammonium		Carbon to nitrogen ratio	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Block	2	0.00018^{ns}	0.000302**	133.4*	50.4544*	351.06**	91.8477**	0.0025^{ns}	38.6865**
Animal manure	2	0.006**	0.007186*	87.5*	81.7619*	504.54**	111.1944*	28.0392*	108.2907**
Blocks*animal manure	4	0.0003	0.000469	15.4	7.6552	47.65	36.2711	3.5288	27.5228
Green manure	3	0.0039**	0.000780**	126.9*	62.9074**	376.36**	24.6914*	17.098**	8.5278*
Animal manure* Green manure	6	0.0004^{ns}	0.000019^{ns}	30.7^{ns}	25.7837^{ns}	335.7^{ns}	3.3648^{ns}	2.0701^{ns}	4.1119^{ns}
Error	18	-	-	-	-	-	-	-	-
CV%	-	11.40	13.06	27.76	20.13	16.38	14.78	14.84	8.62

^{ns}, * and **: non-significant and significant at 5 and 1% probability levels, respectively

Analysis of variance of measured soil information in the post-harvest stage of sesame showed that the effect of manure and green manure and their interaction on soil organic carbon was not significant (Table 5). The highest soil organic carbon was observed in the treatment of 20 t ha^{-1} animal manure at a rate of 1.61%, which showed a decrease of about 11% compared to the pre-planting stage of sesame (1.79%) but compared to the pre-test stage (1.29%), it improved on average by about 24% (Table 6).

Table 6. Means comparison of simple effects of animal and green manure species on soil properties and high consumption elements in the pre-planting and post-harvesting stage of sesame.

Treatments	Organic carbon (%)		Phosphorus (mg kg^{-1})		Potassium (mg kg^{-1})	
	Pre	Post	Pre	Post	Pre	Post
0 t ha^{-1} of animal manure	1.70^{a}	1.51^{a}	8.20^{b}	7.10^{b}	381.58^{b}	264.20^{b}
10 t ha^{-1} of animal manure	1.74^{a}	1.56^{a}	16.95^{a}	11.61^{a}	418.00^{a}	275.08^{a}
20 t ha^{-1} of animal manure	1.79^{a}	1.61^{a}	21.72^{a}	13.06^{a}	452.50^{a}	278.00^{a}
LSD 5%	0.17	0.41	8.07	3.11	63.20	12.18
No green manure	1.65^{b}	1.53^{a}	13.99^{b}	9.89^{a}	391.22^{b}	267.33^{a}
Hairy vetch	1.73^{ab}	1.56^{a}	15.72^{ab}	10.52^{a}	421.5^{ab}	274.22^{a}
Berseem clover	1.79^{ab}	1.55^{a}	15.98^{ab}	10.91^{a}	427.00^{a}	273.22^{a}
Fenugreek	1.81^{a}	1.62^{a}	16.77^{a}	11.04^{a}	429.67^{a}	275.33^{a}
LSD 5%	0.13	0.11	2.50	2.14	34.63	27.03

Means within a rows followed by the same letter are not significantly different at the 5% level according to Fishers LSD test

Table 6 Continued

Treatments	Total nitrogen (%)		Nitrate (mg kg^{-1})		Ammonium (mg kg^{-1})		Carbon to nitrogen ratio	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
0 t ha^{-1} of animal manure	0.12^{b}	0.09^{b}	17.83^{b}	14.71^{b}	17.08^{c}	13.88^{b}	14.15^{a}	17.39^{a}
10 t ha^{-1} of animal manure	0.14^{b}	0.12^{a}	20.42^{ab}	16.59^{b}	22.18^{b}	17.13^{a}	13.04^{ab}	13.00^{b}
20 t ha^{-1} of animal manure	0.17^{a}	0.14^{a}	23.23^{a}	19.87^{a}	26.23^{a}	19.97^{a}	11.13^{b}	16.64^{b}
LSD 5%	0.02	0.02	4.450	3.14	3.91	6.02	2.13	4.94
No green manure	0.11^{c}	0.11^{b}	15.40^{b}	14.59^{b}	16.40^{b}	15.13^{c}	14.74^{a}	15.16^{a}
Hairy vetch	0.14^{b}	0.11^{b}	21.44^{a}	15.02^{b}	22.47^{a}	16.13^{bc}	12.60^{b}	14.33^{ab}
Berseem clover	0.15^{ab}	0.12^{ab}	20.71^{ab}	18.74^{a}	23.80^{a}	17.96^{ab}	12.16^{b}	13.70^{bc}
Fenugreek	0.16^{a}	0.13^{a}	24.42a	19.88^{a}	24.67^{a}	18.76^{a}	11.58^{b}	12.86^{c}
LSD 5%	0.02	0.004	5.630	3.39	3.54	2.49	1.88	1.19

Means within a row followed by the same letter are not significantly different at the 5% level according to the Fishers LSD test

3.2.2. Phosphorus content

The results of variance analysis at the pre-planting stage of sesame showed that the application of animal manure and green manure affected the amount of absorbed phosphorus at a level of 5% However, the interaction of animal manure and green manure had no significant effect (Table 5). Animal manure application increased the amount of soil phosphorus compared to the beginning of the experiment. The animal manure used had an absorbable phosphorus level of 8600 mg kg^{-1} (Table 1), which increased the soil phosphorus level. With increasing the application of animal manure, the amount of soil phosphorus increased, so that the highest phosphorus transferred to the soil was at the level of 20 t ha^{-1} of animal manure (21.7 mg kg^{-1}), which was at the level of 10 t ha^{-1} of animal manure (16.9 mg kg^{-1}). The difference was not significant but was about 165% higher compared to control conditions (Table 6).

The effect of green manure in the pre-planting stage of sesame on the amount of soil phosphorus absorbed was significant. Among these, plots with fenugreek treatment had the highest (16.8 mg kg^{-1}) and plots without green manure had the lowest (13.9 mg kg^{-1}) absorbed phosphorus content, which showed a difference of 20% (Table 6). Based on the results of variance analysis, the effect of animal manure on soil phosphorus in the post-sesame stage was significant at the level of 5% (Table 5). The highest amount of soil phosphorus was 20 t ha^{-1} of animal manure (13.1 mg kg^{-1}) which decreased by about 65% compared to the pre-sesame planting stage (Table 6).

3.2.3. Potassium content

The effect of animal manure on the amount of potassium absorbed by the soil in the pre-planting stage of sesame was significant at the level of 5%, but the effect of green manure and their interaction was not significant (Table 5). The highest potassium in the soil was obtained by consuming 20 t ha^{-1} of animal manure (452.5 mg kg^{-1}) which was not significantly different from consuming 10 t ha^{-1} of animal manure (418 mg kg^{-1}) but compared to control (381.6 mg kg^{-1}) increased by about 15% (Table 6).

The results of variance analysis showed a significant effect of animal manure levels on soil potassium in the post-planting stage of sesame, but the effect of green manure on this feature was not significant (Table 5). The highest amount of soil potassium after sesame harvest was obtained by consuming 20 t ha^{-1} of animal manure (278 mg kg^{-1}), which was about 5.1% more than the control treatment (Table 6). Comparison of soil potassium in different stages of measuring soil properties showed that in the pre-planting stage of sesame, the soil potassium amount in the treatments 20 t ha^{-1} of animal manure and fenugreek green manure was 452.5 and 429.67 mg kg^{-1}, respectively. Compared to the soil before the experiment, (312 mg kg^{-1}) showed an increase, but the potassium level of the soil at the end of the growing season of sesame decreased severely and reached less than 275 mg kg^{-1}.

3.2.4. Nitrogen content

Levels of animal manure and green manure as green manure in the pre-planting stage of sesame had a significant effect at the 1% level on soil nitrogen content, although their interaction was not significant on the nitrogen content (Table 5). The highest nitrogen transferred to the soil was observed with the use of 20 t ha^{-1} of animal manure (0.17%), which had an increase of about 41% compared to the control, but there wasn't a significant difference between the control treatment and 10 t ha^{-1} of animal manure (0.12 and 0.14%, respectively). The results showed that the return of green manure of flowering hairy vetch, berseem clover, and fenugreek to the soil in the pre-planting stage of sesame compared to control conditions increased the amount of total soil nitrogen by about 27, 36, and 45%, respectively (Table 6). The effect of animal manure ($P<0.05$) and green manure ($P<0.01$) on the amount of soil nitrogen in the post-planting stage of sesame was significant (Table 5). Based on the comparison of the mean, the highest percentage of soil nitrogen was obtained in the treatment of 20 t ha^{-1} of animal manure, which wasn't significantly different from the treatment of 10 t ha^{-1} but showed a difference of 55% with the control (Table 6). The results of this study also showed that the highest soil nitrogen content in the post-planting stage of sesame in the fenugreek treatment was 0.13%, which was about 18% higher than the non-cultivation green manure (Table 6).

3.2.5. Carbon to nitrogen ratio

This feature was affected by animal manure ($P<0.05$) and green manure ($P<0.01$) in the pre-planting stage of sesame, but the interaction between animal manure and green manure was not significant (Table 5). The ratio of carbon to soil nitrogen at levels of 0, 10, and 20 t ha-1 of manure were 14.2, 13.1 and 11.1%, respectively (Table 6). When compared to control conditions, the use of green manure significantly reduced the soil carbon to nitrogen ratio. In the pre-planting stage of sesame, this ratio in control plots (without green manure) was about 14.7% on average. The lowest carbon to nitrogen ratio of 11.6% was obtained by using hairy vetch as green manure. However, there was no significant difference between the levels of berseem clover and fenugreek, at 12.2% and 12.6%, respectively (Table 5).

The ratio of carbon to soil nitrogen in the post-harvesting stage of sesame was affected by animal manure (at a 1% level) and green manure (at a 5% level) (Table 5). The lowest ratio was observed in the treatment of 20 t ha^{-1} (11.6%) of animal manure, which was about 33 and 10% lower than the control treatment and 10 t ha^{-1} of animal manure, respectively (Table 6). The ratio of carbon to soil nitrogen in the pre-testing, pre-planting, and post-planting stages of sesame was 10.7%, 11.1%, and 11.6%, respectively (Tables 1 and 6). In addition, the lowest ratio of carbon to soil nitrogen in fenugreek green manure treatment was 12.8, which was 15% lower than non-cultivation of green manure (Table 6). The experimental results of green manure species also showed that the ratio of carbon to nitrogen in fenugreek plant tissue was lower than in clover flower, hairy vetch, and berseem clover. In the treatment of fenugreek green manure, the ratio of carbon to soil nitrogen at the end of the sesame harvest season was about 19% higher than at the beginning of the experiment, which showed an increase in soil organic carbon.

3.2.6. Nitrate ions' content

The results of the analysis of variance in the pre-planting stage of sesame showed that the effect of animal manure and green manure on soil nitrate was significant at 5% level, while the interaction of animal manure and green manure on this trait was not significant (Table 5). The amounts of soil nitrate in levels of 0, 10, and 20 t ha^{-1} of animal manure were 17.8, 20.4, and 23.2 mg kg^{-1}, respectively (Table 6). Consumption of green manure also increased the amount of nitrate ions in the soil compared to the control conditions, so that the highest amount of nitrate was observed in the treatment of fenugreek green manure and the lowest amount was observed in the treatment without green manure. The difference between them was about 37% (Table 6).

Soil nitrate, as well as total nitrogen, was affected by animal manure levels (at 5% level) and Legum green manure species (at 1% level) in the post-planting stage of sesame (Table 5). A Comparison of means shows that the highest amount of soil nitrate was obtained by consuming 20 t ha^{-1} of animal manure (19.9 mg kg^{-1}) which showed a difference of 19.7 and 35% with 10 t ha^{-1} and control levels, respectively (Table 6). The soil was enriched with the application of 20 t ha^{-1} of animal manure. With the planting and harvesting of sesame, its nitrate content was reduced by about 17%. Also in the post-planting stage of sesame, the highest nitrate ion was obtained in soil enriched with fenugreek green manure (19.9 mg kg^{-1}), which was included in a statistical group with clover treatment (18.7 mg kg^{-1}), but differences of 32% and 36% were observed with control and hairy vetch green manure treatments, respectively (Table 6). Fenugreek-treated soils showed a 23% reduction in soil nitrate compared to the soil at the end of the growing season. Comparison of soil nitrate in the post-planting stage of sesame with soil before the experiment shows that organic nitrate storage with the application of treatments of 10 and 20 t ha^{-1} of animal manure is 36 and 63% and green manure of fenugreek, berseem clover, and hairy vetch is 63, 54, and 23%, respectively (Tables 1 and 6).

3.2.7. Ammonium content of the soil

The results showed that ammonium was affected by different levels of animal manure and green manure in the pre-planting stage of sesame at a level of 1%. However, the interaction of animal manure and green manure had no significant effect on the amount of ammonium ions (Table 5). The soil ammonium content of 10 t ha^{-1} (22.2 mg kg^{-1}) and 20 t ha^{-1} (26.2 mg kg^{-1}) animal manure differed from the control conditions by 29.8% and 53.5%, respectively (Table 6).

Planting legumes and returning them to the soil as green manure significantly increased the amount of ammonium ions in the soil compared to the control conditions. However, there was no significant difference between green manure species in terms of ammonium in the soil. Planting fenugreek as green manure yielded the highest amount of ammonium ion (24.7 mg kg-1) with a 50% difference from the control (16.4 mg kg^{-1}). Soil ammonium ion content in the post-planting stage of sesame was affected by the use of animal and green manures at a level of 5% (Table 5). The highest soil ammonium content was obtained in the application of 20 t ha^{-1} of animal manure (19.9 mg kg^{-1}) which was about 30.5% higher compared to the control treatment (Table 6). In addition, the highest amount of soil ammonium ion was in the cultivation conditions of fenugreek green manure (18.8 mg kg^{-1}), which was about 23% higher compared to the control treatment (Table 6). Although most of the soil ammonium was harvested by sesame, in general, the effect of organic fertilizers on the preservation and storage of ammonium was positive, and in all treatments, some ammonium was stored for subsequent cultivation. The amount of ammonium ion in the post-harvesting stage of sesame improved by 50% compared to the pre-test stage in the treatment of 20 t ha^{-1} of animal manure (Tables 1 and 6).

3.3. Yield and oil percentage of sesame

3.3.1. Grain yield

Grain yield was significantly (P<0.01) affected by the animal and green manure. The interaction of the animal and green manure at a level of 5% was also significant (Table 7). The interaction between green manure and animal manure was statistically significant at the 1% level (Table 7). The highest grain yield was obtained in the treatment of 20 t ha^{-1} of animal manure and the treatment of fenugreek green manure. The lowest grain yield was observed in the control treatment with a difference of about 42% (Fig. 1). At each level of animal manure, the effect of green manure on increasing grain yield was obtained under control, hairy vetch, berseem clover, and fenugreek treatments, respectively (Fig. 1). This trend can be attributed to the nitrogen yield, which was about 115, 162, and 290 kg ha^{-1}, respectively, for hairy vetch, berseem clover, and fenugreek.

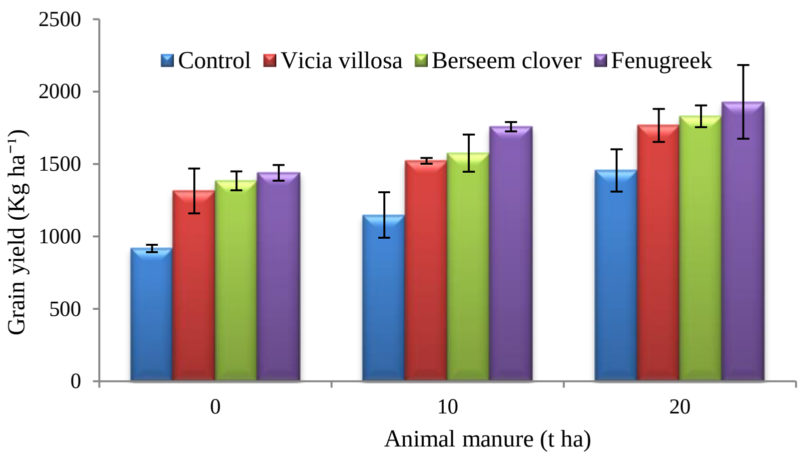

Figure 1. Interaction of animal manure and green manure application on grain yield of sesame.

Table 7. Effects of animal and green manures species on yield and oil percentages of Sesame

S.O.V	df	Mean Square	
		Grain yield	Oil percentages
Block	2	12827.37^{ns}	0.14^{ns}
Animal manure	2	696818.78**	0.17^{ns}
Blocks*animal manure	4	25506.64	0.009
Green manure	3	480501.50**	0.065^{ns}
Animal manure* Green manure	6	4138.94*	0.14^{ns}
Error	18	-	-
CV%	-	17.95	2.33

^{ns}, * and **: non-significant and significant at 5 and 1% probability levels, respectively

3.3.2. Oil percentage

The results of the analysis of variance showed that the effects of animal manure and green manure application and their interaction on oil percentage weren't significant (Table 7).

4. Discussion

"Green manure" means the cultivation of plant species in order to produce biomass. Therefore, after harvesting plant species to increase the content of organic matter, soil protection and nutrient recycling are returned to the soil (Souza *et al*., 2013). This method can increase soil fertility (Fageria and Baligar, 2005) reduce fertilizer costs (Teixeira *et al*., 2006), weed control (Recalde *et al*., 2015), and reduce erosion (Cardoso *et al*., 2012). Despite its many benefits, green manure is currently rarely used. According to the studies by Dourado et al. (2001), one of the reasons for this is the lack of immediate economic return and occupation of land space, which is usually used for the main crop. Gatsios et al. (2021) reported that less Faba bean biomass was limited compared to other treatments due to sunlight, short days, and cloudy skies in autumn and winter.

The increase in soil organic carbon, if fenugreek green manure is used, can be attributed to the higher biomass and its high carbon content (39.4%) compared to other legumes (Table 2). In the experiment of Carvalho et al. (2015), by combining green manure for 30 and 60 days after its application, they did not show any change in soil organic carbon in terms of statistics. Dou and Hons (2006) and Huang et al. (2010) reported that soil organic carbon usually increases in the medium and long term. The increase in soil organic matter is mostly affected by the amount of biomass returned to the soil and the percentage of organic carbon in plant residues (Gatsios *et al*., 2019). The results of this study showed that the highest rate of biomass production was in the treatment of fenugreek (Table 6). Therefore, in the post-sesame stage, the highest soil organic carbon content of 1.62% was related to the treatment of fenugreek, which decreased by about 12% compared to the pre- planting stage of sesame, but on average, 26% compared to the stage before the start of the experiment showed an increase. According to studies by Pour et al. (2013), the growth, yield, and quality of vegetable leaves are affected by organic and inorganic nutrients. The increase in soil organic matter is mostly affected by the amount of biomass returned to the soil and the percentage of organic carbon in manure and plant residues (Yuan *et al*., 2021; Liu *et al*., 2014).

Organic fertilizers significantly increased all forms of organic phosphorus compared to the control treatment and, regardless of the amount used, the effects of organic fertilizers on all forms of organic phosphorus were significant. Due to microbial activity, after adding organic fertilizers to the soil, organic phosphorus is gradually absorbed by the plant. Oberson et al. (2001) stated that microorganisms cause the mineralization of phosphorus in the soil by secreting the enzyme phosphatase. With the addition of organic matter to the soil, the population of soil microorganisms increases, followed by faster nutrient circulation and their ability to absorb, especially the ability to absorb phosphorus. In the study by Carvalho et al. (2015), for 60 days after combining *Crotalaria cunninghamii* green manure with soil, the amount of phosphorus measured in the soil was 62.4 mg kg^{-1}, which showed a 67% increase compared to the control treatment. A comparison of available soil phosphorus in the post-sesame stage with the pre-research stage also showed that about 58% of soil phosphorus reserves were improved. Girdharbhai (2016) showed that the absorbed phosphorus content of the soil in the treatment of compost and animal manure was 36 kg ha^{-1}, which has improved by about 9% compared to the base soil.

Adding organic residues to land in organic agriculture can change the potassium status of the soil and thus change the usability of this element and its cycle in the soil. Girdharbhai (2016) reported that a 2.5

unit increase in the amount of potassium oxide remaining in the organic fertilizer treatment showed an increase in potassium storage compared to the soil sample. They also stated that although this increase was small, it can be increased by applying other management methods such as the use of green manure. Zamil et al. (2004) investigated the effects of poultry and cow manure on yield and nutrient uptake by mustard. They found that the application of 20 t ha^{-1} of fertilizer had a significant effect on phosphorus uptake. Available phosphorus and exchangeable potassium had the highest values in *Crotalaria cunninghamii* green manure treatment (Carvalho *et al*., 2015). Jalali (2011) showed that the addition of plant residues to calcareous soils in Iran causes a change in the rate of release of potassium from the non-exchange phase and its conversion into the usable form.

Soil N is mainly present in soil organic matter. The nitrogen content of the whole soil also increases under the influence of organic matter (Stockdale *et al*., 2019; Bustamante and Hartz, 2015). Nitrogen as an essential nutrient is an important component of most organic fertilizers. In such fertilizers, the main part of the nitrogen is located in the structure of organic molecules (Stockdale *et al*., 2019). Soil biological activities produce carbon dioxide, ammonium, nitrate, and simple acids. For these reasons, soil nitrogen is significantly influenced by animal manure. Cherr et al. (2006) introduced green manure as a source of nitrogen for the corn plant. According to a study that compared legumes in terms of nutrient content, mung bean nitrogen was 30% higher than Black-eyed pea nitrogen and was similar in percentages of phosphorus and potassium. While the percentage of nitrogen in Crotalaria was 2.3% and in Asian beans, it was 3.5%. Ross et al. (2009) concluded that crop residue management improved about 44% of organic nitrogen in long-term ecological culture systems in soil. Before planting potatoes, cultivating clover as green manure adds approximately 20 kg ha^{-1} nitrogen to the soil (Canali *et al*., 2010). Sesame absorbs an average of 32 kg ha^{-1} of nitrogen, of which 56% is transferred to seed and the other 44% to straw (Girdharbhai, 2016). Nitrogen deficiency in sesame causes plant yellowing, thinning of stems, less branching, and leaf fall, which will ultimately lead to reduced yield (Weiss, 2000). Canali et al. (2010) in an experiment with soil improvers, potato tuber yield was more affected by animal manure than compost. This could be due to the ability to simultaneously release mineral nitrogen from animal manure with the plant life cycle and the lower carbon to nitrogen ratio of animal manure compared to compost. High NO3-N concentrations in the treatments reflect high levels of total nitrogen and a low C/N ratio in the soil (Bonanomi *et al*., 2019). Animal manure provided sufficient nitrate levels for tomato cultivation during the first sampling. In the next sampling (75 days after transplanting), the NO3-N concentration decreased to insufficient levels (Nair and Delate, 2016). Nitrate levels in compost treatment were lower compared to legume and manure because compost mineralization is much less than manure and green manure (Gatsios *et al*., 2021). In organic farming, the availability of nitrogen depends not only on the total nitrogen in the soil but also on the rate of nitrogen mineralization, that provides nitrogen to plants (Li *et al*., 2020). The ammonium concentration in manure treatment was higher than in other treatments and all sampling dates of mineralization rate. However, the concentration of ammonium was always less than 10 mg/kg because, in soils with good aeration, neutral pH, and sufficient microbial activity, the nitrification process is rapid (Pandey *et al*., 2018).

In the study by Ross et al. (2009), soil nitrate levels were increased by green manure compared to the control (without green manure). They reported an increase in soil nitrate under the influence of white clover and Crimson clover manure compared to rye green manure. Berseem clover and alfalfa as a green manure by Westcott et al. (1995) showed that the higher amount of soil nitrogen using alfalfa is higher than using berseem clover due to higher aerial biomass nitrogen. The effect of animal manure on increasing soil exchange capacity prevents the loss of nutrients due to leaching. Most of the plant's absorbable nutrients are stored in the soil in the form of exchange. Despite the organic compounds in the soil that are absorbable by the plant, they are also prevented from leaching. It seems that with the use of organic fertilizers, especially animal manures and green manures, which increase organic matter and provide nitrogen, the formation of nitrogenous precursors increases, the formation of protein increases, and finally the amount of substances needed to convert into oil decreases. The yield of the sesame harvest index was less than 20%, which does not seem to be desirable. This is due to the genotype, high height, and multi-branched plants, which cause more vegetative growth and a lower harvest index. Adding organic matter to the soil not only provides the nutrients needed by the plant and improves the physical condition and vital processes of the soil, but also provides a suitable substrate for root growth, increases shoot growth and dry matter production, and ultimately improves yield. Singh et al. (2008) reported that when nitrogen fertilizer was not applied, legume green manure increased potato tuber yield by 35% compared to potatoes grown after winter wheat.

Nitrogen increases plant height, growth rate, ease of respiration, plant freshness, and increases root growth and leaf area, which ultimately improves grain yield. In most processes related to the activity of enzymes, photosynthesis, sugar transport, protein synthesis, starch, the further establishment of the plant in conditions of moisture stress by adjusting the speed and rate of opening and closing of pores, improving resistance to weeds, pests, and diseases (which is important in organic farming), potassium plays an essential role. Phosphorus deficiency in sesame inhibits branching, causes leaf deformation, necrosis of lower leaves and petals, and reduces yield (Weiss, 2000).

It seems that with the use of organic fertilizers, especially animal and green manure, which increase organic matter and cause nitrogen availability, the formation of nitrogenous precursors and protein formation increase, thus reducing the amount of material needed to convert into oil.

5. Conclusion

Application of 10 and 20 tons of manure per hectare increased the growth of plants grown as green manure compared to control conditions (without the use of manure) by 9 and 27%, respectively. Among the green manures studied, biomass and nitrogen yield of fenugreek and the lowest carbon to nitrogen ratio (7219 and 291 kg/ha and 9.8, respectively) were higher than clover (5799 and 162 kg/ha, and 13.6) and vetch was clustered (3564 and 116 kg/ha and 10.5). The results of this study showed that the application of animal manure increased the amount of organic carbon, total nitrogen, nitrate and ammonium by about 3.5, 41, 30.2 and 53.5%, respectively, compared to the control. Phosphorus was also strongly affected by animal manure and increased by 165% and potassium by 15% at the level of 20 t ha^{-1} of animal manure. The findings of this study suggest that the manure requirements of a sesame field can be effectively managed by organic manure management strategies. The measured soil parameters were also strongly affected by green manure species, and fenugreek green manure was the most effective due to its higher biomass and lower carbon to nitrogen ratio. In general, the results of this study showed that the application of livestock manure and selection of suitable plant species as green manure in organic farm conditions improves soil quality characteristics that in the long run will have positive effects on the growth and yield of crops. According to these results, it can be recommended to use 20 tons of animal manure along with fenugreek green manure to improve crop yield in organic farming conditions.

Conflict of Interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

All authors had an equal role in study design, work, statistical analysis and manuscript writing.

Informed Consent

The authors declare not to use any patients in this research.

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