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RESEARCH ARTICLE

Influence of solid and liquid organic manures on soil properties and quality parameters of summer sesame (*Sesamum indicum* L.) under organic

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Abstract

In recent years, there has been a growing emphasis on organic farming practices due to increasing concerns about soil health, environmental sustainability and consumer demand for chemical-free produce. An experiment was carried out on organic farming to determine the influence of soil - applied solid organic manures and foliar sprays of organic liquids on soil properties, seed quality parameters and yield of sesame under an organic situation. The experiment was laid out in a split plot design with three replications comprising eighteen treatment combinations. Treatments consisted of three sources of solid organic manures *viz.*, 100 % RDN through farmyard manure (M_1), 100 % RDN through poultry manure (M_2) and 100 % RDN through vermicompost (M_3) in main plot and six organic liquid foliar applications *viz.*, Seaweed extract @ 0.3 % (S_1), Egg amino acid @ 1.0 % (S_2), Humic acid @ 0.3 % (S_3), Jeevamrith @ 3.0 % (S_4), Fish amino acid @ 1.0 % (S_5) and Panchgavya @ 3.0 % (S_6) in sub-plot. The results indicated that the soil application of poultry manure and the foliar spray of seaweed extract at 20, 40 and 60 DAS recorded significantly higher nutrient uptake, soil microbial population and lowest post-harvest soil nutrient content in sesame. However, soil application of organic manures and organic foliar spray found to be ineffective in creating a significant change in the soil bulk density, soil water holding capacity, soil pH, soil EC, soil organic carbon, seed oil and protein. Applying poultry manure at 100% recommended dose of nitrogen (RDN) to the soil, combined with spraying 0.3% seaweed extract or 3.0% jeevamrith on the foliage three times at 20, 40 and 60 days after sowing, proven to be the most effective nutrient management practice for summer sesame in the Southern Agro - climatic Zone of Andhra Pradesh.

Keywords: foliar sprays; organic manures; seed quality; sesame; soil parameters

Introduction

Sesame (*Sesamum indicum* L.) is India's oldest oilseed crop. The seeds are composed of around 50-60 percent oil, 18-25 percent crude protein, 14-16 percent carbohydrate and 5-7 percent minerals. Sesame seeds have various industrial uses, *viz.*, food, pharmaceuticals, cosmetics, paints, lubricants, *etc* (1, 2). It has a crucial role in culture, religion and rituals. Sesame cake is a high-grade protein (40 percent) meal for livestock and poultry (3). Sesame seeds are a powerhouse of energy and incredibly rich in minerals, including zinc, iron, phosphorus, calcium, magnesium, potassium and copper, along with vitamins A, E and B complex (4). Sesame is the finest alternative to mother's milk, particularly in allergy cases. Sesame seeds are packed with exceptional amino acids like tryptophan and methionine (5), which have innumerable benefits.

Sesame has earned the title of "Queen of Oil Seeds" since it is the cornerstone of Ayurvedic treatments (6, 2). Scientific studies have found that the lignans present in sesame seeds have a tremendous antioxidant effect on the human body. Sesame oil is anti-cholesterol and extremely useful for cardiac problems (1). It has a high resistance to oxidative rancidity and is known for its durability and purity (7), making it the "poor man's substitute for ghee." Moreover, Sesame is an energy-rich crop cultivated under energy-starved conditions.

The role of organic farming has significantly increased in recent years in promoting a sustainable and healthy food system. Pesticide residues are a significant barrier to the increase of sesame exports since sesame is largely used in food and medicine in developed nations. Therefore, sesame produced organically will satisfy the tailor-made requirements of the purchasers and fetch a premium price on both the national and international markets (8).

Nutrient management is the most critical management strategy for organic growers. Organic manures improve the soil's physicochemical properties, water and nutrient holding capacity, micronutrients and macronutrients and microbial activity (9). Manure application leads to sustainable crop production and quality produce by aiding plant nutrients, growth regulators, organic matter and microorganisms in the soil. Organic foliar nutrition makes plants more efficient in absorbing nutrients through stomata than root uptake. Foliar organic liquid spray is safe for crops, natural resources, land and wildlife (10). Liquid manures having higher beneficial microbes, essential amino acids, macro and micronutrients and promoting substances like auxins, cytokines and gibberellins may greatly help in increasing soil microbial population and soil fertility, further increasing the crop growth, yield and quality (11).

A combination of organic manures, *viz*., FYM, poultry manure and vermicompost, along with foliar feeding of organic liquids, *viz*., panchgavya, jeevamrith, humic acid, fish amino acid (FAA), egg amino acid (EAA) and seaweed extract may result in cost-effective and eco-friendly nutrient management practices. With this in mind, the current research aims to investigate the yield potential of organic sesame through the use of various sources of both liquid and solid organic manure.

Materials and Methods

A field experiment was conducted on a dryland farm, S.V. Agricultural College, Tirupati, Andhra Pradesh, during the summer of 2023 to evaluate the effect of organic manures and organic foliar sprays on soil properties, quality parameters, and yield of summer sesame. The soil of the experiment field was sandy loam in texture, neutral in reaction (pH - 6.8), low in organic carbon (0.41%), low in available nitrogen (187 kg ha^{-1}), high in available phosphorus (27 kg ha^{-1}) and medium in potassium (246 kg ha^{-1}). The plots of 4.5 m × 4.2 m were used for each treatment. The experiment was laid out in a split-plot design with three main plots and six subplot treatments, which were replicated thrice. Main plot treatments consisted of three sources of organic manure *viz*., 100 % RDN through farmyard manure (M_1), 100 % RDN through poultry manure (M_2) and 100 % RDN through vermicompost (M_3) and subplot treatments consisted of six organic foliar applications *viz*., Seaweed extract @ 0.3 % (S_1), Egg amino acid @ 1.0 % (S_2), Humic acid @ 0.3 % (S_3), Jeevamrith @ 3.0 % (S_4), Fish amino acid @ 1.0 % (S_5) and Panchgavya @ 3.0 % (S_6) allotted to subplots. The egg amino acid, jeevamrith, fish amino acid and panchgavya were prepared at the greenhouse of the college farm, as mentioned below (Table 1), while seaweed extract and humic acid were purchased from the market. The crop variety Sarada (YLM-66) was sown in the second fortnight of January with a line spacing of 30 cm and 10 cm row-to-row. The recommended dose of nitrogen, *i.e.,* 40 kg ha^{-1}, was supplied through the soil application of organic manures one week before the sowing operation. All organic foliar sprays were applied at 20, 40 and 60 days after sowing. All the weeds were removed by hand weeding twice at 20 and 40 days after sowing and the crop irrigated at regular intervals up to one week before harvesting. The data recorded during the investigation was statistically analyzed following the analysis of variance for split-plot design as suggested by Panse and Sukhatme (12). Statistical significance was tested with an 'F' value at a five percent level of probability by using Microsoft Excel.

Results and Discussion

Soil physicochemical properties

The experimental results revealed that soil application of organic manures and organic foliar sprays could not influence the soil bulk density, water holding capacity, soil pH, soil EC and organic carbon significantly (Table 2). However, the lowest soil bulk density and soil pH were demonstrated with the soil application of 100 % RDN through poultry manure (M_2). Poultry manure is highly porous and contains uric acid which might be the reason for low soil bulk density and soil pH, respectively. Interestingly, the maximum soil bulk density and soil pH were observed with the soil application of 100 % RDN through FYM (M_1). Soil application of 100 % RDN through poultry manure (M_2) had shown maximum soil water holding capacity, soil EC and organic carbon among all the organic manures, followed by 100 % RDN through vermicompost (M_3) and 100 % RDN through FYM (M_1), respectively. The application of poultry manure to soil has been found to increase its capacity to hold water. This is due to the higher water retention properties of poultry manure in comparison to vermicompost and FYM. The use of poultry manure has also been shown to promote greater root and shoot growth, which may contribute to the physical characteristics of the soil and further enhance its water-holding capacity (13). In addition, the higher soil organic carbon levels observed after the

Table 1. Preparation method of liquid organic manures

Liquid organic manures	Preparation method
Panchgavya	The panchgavya was prepared by mixing 7 kg of cow dung, 1 kg of cow ghee, 10 l cow urine, 10 l of water, 2 l cow milk, 2 l cow curd, 3 l coconut water, 250 g jaggery and 12 ripened bananas and kept for 15 days fermentation under shade. The contents were stirred twice a day for about 20 minutes, both in the morning and evening, to facilitate aerobic microbial activity. After fermentation, the content was filtered to get the clear stock solution of panchagavya.
Jeevamrith	For jeevamrith, 1 kg of cow dung, 1 l cow urine, 200 g jaggery, 200 g pulse flour and 20 l water were mixed along with one handful of garden soil in a wide-mouth pot and kept for 10 days of fermentation. The pot mouth was covered with a cloth to facilitate aeration but to avoid contamination. The solution was regularly stirred both morning and evening for 20 minutes to ensure proper aeration. After 10 days, of fermentation solution was filtered to get clear jeevamrith.
Fish amino acid	Fish amino acid was prepared by fermenting fish waste purchased from fish marked with an equal amount of jaggery. Fish waste and jaggery in a 1:1 ratio were kept in a plastic container for 2 months of fermentation. The fish waste and jaggery were kept layer by layer and the uppermost layer was fully covered with jaggery. After 2 months of fermentation, the fish syrup is full of amino acids separated and filtered to get a clear solution.
Egg amino acid	Egg amino acid was prepared by using 10 eggs, 25 lemons and jaggery. Eggs were kept in a plastic container, fully submerged in lemon juice, along with 250 g of jaggery for 10 days of fermentation and smashed into the lemon juice solution along with their shell after 10 days. An equal quantity of jaggery was added after weighing the solution and kept for another 10 days of fermentation. Afterward, the fermentation solution was filtered to get clear egg amino acid and used for foliar spray.

application of poultry manure are likely due to its rich macro and micronutrient content, which promotes steady nutrition of plants, resulting in increased root and shoot biomass and ultimately contributing to higher organic carbon levels. Joshi *et al*. (14) also observed significantly higher water-holding capacity and organic carbon with the soil application of poultry manure followed by the application of vermicompost and farmyard manure, respectively, in finger millet (*Eleusine coracana* L.) and pigeonpea (*Cajanus cajan* L.) intercropping on *alfisols*.

Nutrient dynamics

The detailed analysis of the soil nutrient status revealed a significant improvement in soil fertility status with different organic manures. However, the influence of foliar sprays and their interaction was not statistically measurable (Table 3). Among the soil-applied organic manures, the highest soil-available nitrogen, phosphorus and potassium were observed with the soil application of FYM (M_1), which were 11.8%, 16.03% and 13.7% higher than the soil application of poultry manure (M_2), respectively. However, the soil application of FYM (M_1) was statistically comparable with the soil application of vermicompost (M_3).

Organic manures differ in their source and composition, which affect their nutrient release and mineralization patterns in the soil. These patterns influence the soil nitrogen status and the crop growth performance. Farmyard manure (FYM) and vermicompost are rich in organic matter and microbial biomass, which stimulate the rhizomicroorganisms that mineralize organic nitrogen into inorganic forms such as ammonium and nitrate. These forms are readily available for plant uptake and can improve soil nitrogen fertility. On the other hand, poultry manure has a high content of ammonium, which can provide a quick boost of nitrogen to the crop. However, this also poses a risk of nitrogen loss through the volatilization of ammonia or nitrate leaching, especially in alkaline or sandy soils. This can reduce the soil nitrogen pool after harvest and affect the subsequent crops. In the study conducted by Joshi *et al*. (14), it was observed that the application of farmyard manure (FYM) and vermicompost led to a notable enhancement in post-harvest soil availability of nitrogen, phosphorus and potassium, surpassing the effects of poultry manure application. This outcome aligns with the research findings of Naik *et al.* (15), Parewa *et al*. (16) and Parmar *et al*. (17).

Due to the decomposition of organic manures, various acids are also produced that solubilize phosphate-bearing minerals and incrase phosphatase activity, lower the phosphorus fixation and increase the P-activity. These also help in reducing the K-fixation in soil due to its higher capacity to hold K in available form. Jat *et al*. (18), Singh *et al.* (19) and Mokariya *et al*. (20) also reported similar results in their experiments.

Nutrient uptake by sesame at harvest showed significant variation depending on the use of organic manures and foliar sprays, with significant interactions between these factors (Fig. 1, Fig. 2 and Fig. 3). Among the organic manures applied to the soil, the uptake of nitrogen, phosphorus and potassium was highest with poultry manure (M_2), surpassing that of farmyard manure (M_1) by 51.6%, 43.7% and 48.7%, respectively. The maximum value of nutrient uptake was recorded in poultry manure because it produced more humic acid, which forms water-soluble

Table 2. Soil physicochemical properties of sesame as influenced by organic manures and organic foliar sprays

Treatments	Bulk density (g cm^{-3})	Water holding capacity (%)	Soil pH	Soil electrical conductivity (dSm^{-1})	Soil organic carbon (%)
Soil application of organic manures					
M_1 : 100 % RDN through FYM	1.54	29.2	6.82	0.20	0.39
M_2 : 100 % RDN through poultry manure	1.51	31.8	6.78	0.22	0.43
M_3 : 100 % RDN through vermicompost	1.52	30.7	6.80	0.21	0.40
SEm±	**0.03**	**0.51**	**0.16**	**0.006**	**0.01**
LSD (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**
Organic foliar sprays at 20, 40 and 60 DAS					
S_1 : Seaweed extract @ 0.3 %	1.50	30.9	6.80	0.22	0.42
S_2 : Egg amino acid @ 1.0 %	1.52	29.7	6.81	0.20	0.41
S_3 : Humic acid @ 0.3 %	1.55	28.8	6.79	0.19	0.40
S_4 : Jeevamrith @ 3.0 %	1.50	30.4	6.78	0.22	0.42
S_5 : Fish amino acid @ 1.0 %	1.51	30.2	6.79	0.20	0.41
S_6 : Panchgavya @ 3.0 %	1.53	29.5	6.81	0.22	0.40
SEm±	**0.05**	**0.63**	**0.22**	**0.007**	**0.01**
LSD (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**

Table 3. Post-harvest soil available nutrient status (kg ha^{-1}) of sesame as influenced by organic manures and organic foliar sprays

Treatments	Available N	Available P_2O_5	Available K_2O
Soil application of organic manures			
M_1 : 100 % RDN through FYM	208	30.4	265
M_2 : 100 % RDN through poultry manure	186	26.2	233
M_3 : 100 % RDN through vermicompost	199	28.5	250
SEm±	**3.12**	**0.52**	**3.64**
LSD (P = 0.05)	**12.3**	**2.02**	**14.3**
Organic foliar sprays at 20, 40 and 60 DAS			
S_1 : Seaweed extract @ 0.3 %	190	27.1	247
S_2 : Egg amino acid @ 1.0 %	201	28.4	251
S_3 : Humic acid @ 0.3 %	202	29.1	262
S_4 : Jeevamrith @ 3.0 %	193	27.3	238
S_5 : Fish amino acid @ 1.0 %	199	28.1	247
S_6 : Panchgavya @ 3.0 %	200	28.7	251
SEm±	**5.60**	**0.76**	**6.76**
LSD (P = 0.05)	**NS**	**NS**	**NS**

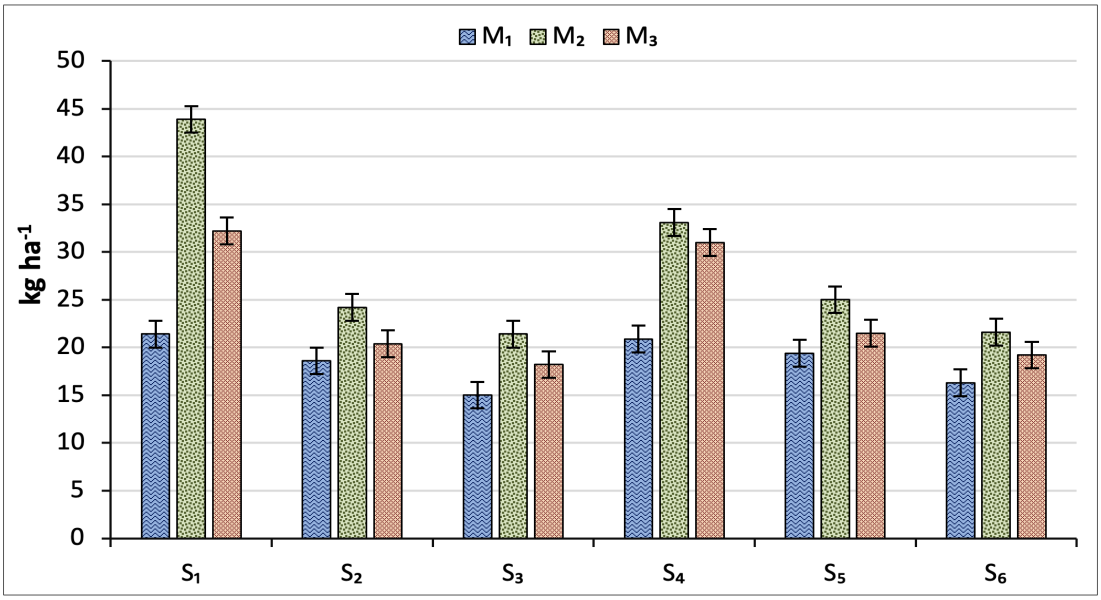

Fig. 1. Nitrogen uptake of sesame as influenced by organic manures and organic foliar sprays.

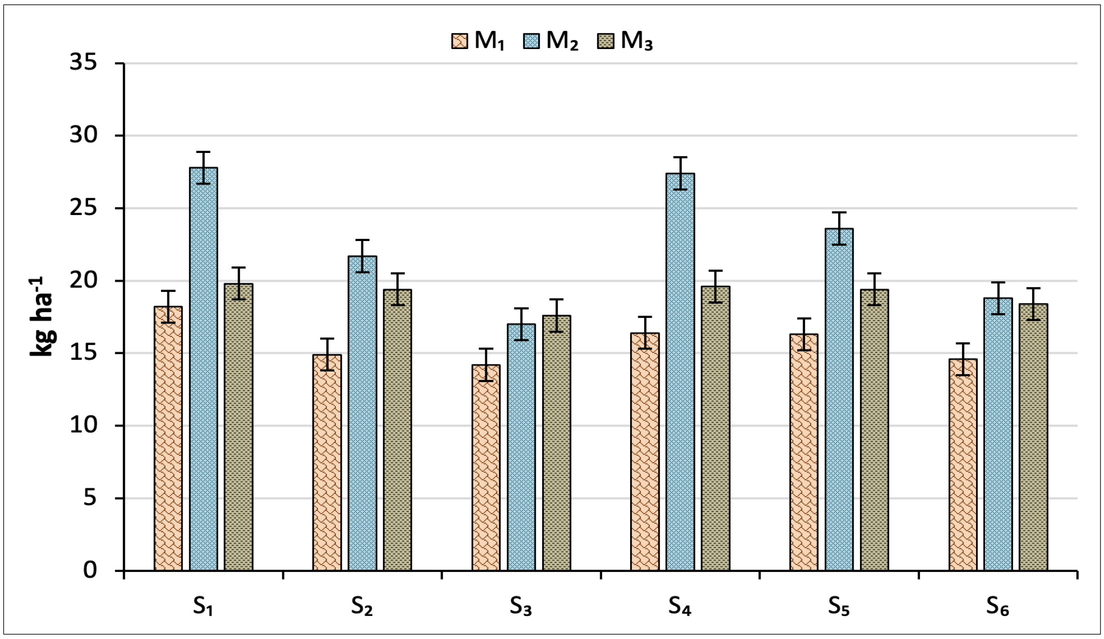

Fig. 2. Phosphorus uptake of sesame as influenced by organic manures and organic foliar sprays.

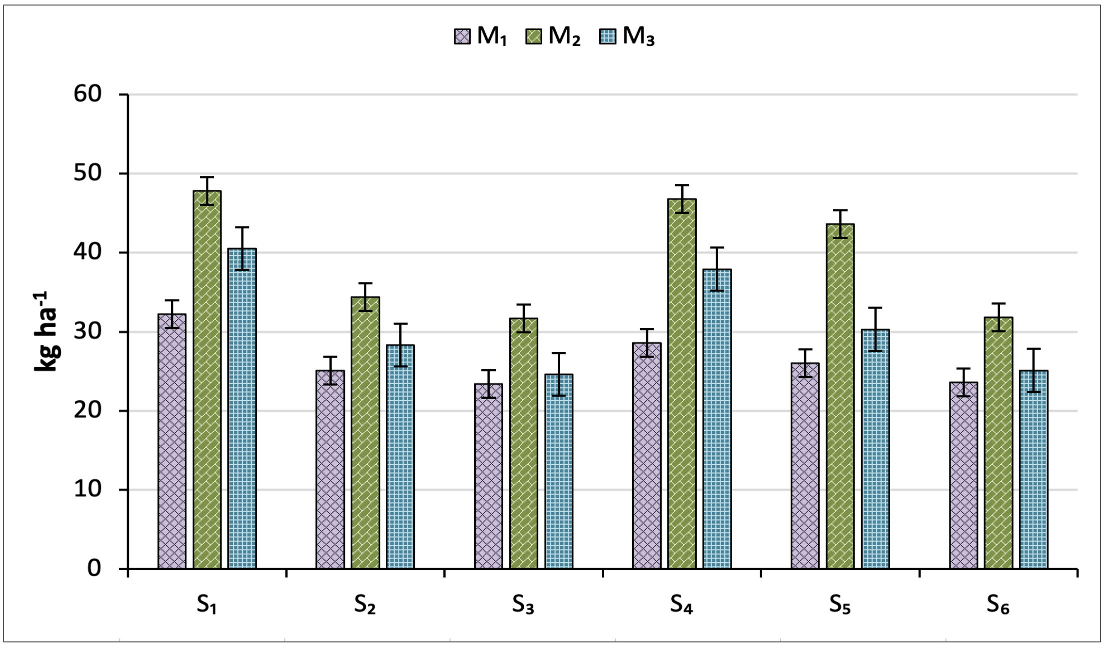

Fig. 3. Potassium uptake of sesame as influenced by organic manures and organic foliar sprays.

chelated phosphorus, which helped in the easy release of phosphorus to the crop. It helped in supplying the nutrients in soluble form for a quite longer period by not allowing the entire soluble form in solution, to come in contact with soil and other inorganic constituents, thereby minimizing fixation and precipitation from the manures, so that the plant roots can very well compete with loss mechanisms and absorb more nutrients as a result of increased cation exchange capacity with increased organic matter content leading to better yield. Anguria *et al*. (21) reported a significant increase in nitrogen, phosphorus and potassium uptake with the application of poultry manure over cattle manure and control in organic sesame cultivation. Changkija and Gohain (22) also observed similar results where soil application of poultry manure @ 6 t ha^{-1} inoculated with *Rhizobium* and *Phosphatica* resulted in maximum uptake of nitrogen, phosphorus and potassium followed by vermicompost and farmyard manure, respectively, over control in *kharif* soybean.

Among the organic foliar sprays, the significantly highest nutrient uptake was observed with the foliar application of seaweed extract @ 0.3% (S_1), which was statistically comparable to jeevamrith @ 3% (S_4). Both treatments demonstrated superior nutrient uptake, with 78.6% and 55.5% higher nitrogen uptake, 34.3% and 29.4% higher phosphorus uptake and 51.1% and 42.1% higher potassium uptake, respectively, compared to the application of humic acid @ 0.3% (S_3). Higher nutrient uptake observed with seaweed extracts can be attributed to the presence of numerous enzymes and hormones within the extracts, which actively facilitate cellular processes such as division and elongation. These biochemical components play a pivotal role in augmenting root and shoot growth in plants. Consequently, the heightened development of plant structures contributes to an overall enhancement in nutrient uptake. Our findings confirm the results of Ghosh *et al*. (23), who recorded 76.61 % increase in nitrogen uptake, 185.7 % increase in phosphorus uptake and 88.3 % increase in potassium uptake with foliar application of 15% seaweed (*Kappaphycus*) extract + RDF over alone RDF in black gram (*Vigna mungo* L.). Similar results were reported by Patra *et al*. (24), Shekh *et al.* (25) and Kiruthika *et al*. (26).

The interaction effect between organic manures and foliar sprays was found significant and it was concluded that organic foliar spray of seaweed extract @ 0.3 % (S_1) had shown significant maximum nitrogen absorption by sesame, which was significantly superior over all other treatments with soil application of poultry manure (M_2) and it was at par with jeevamrith @ 3 % (S_4) with soil application of vermicompost (M_3) and FYM (M_1) and the lowest nitrogen uptake was observed with the foliar spray of humic acid @ 0.3 % (S_3). Significantly, the highest phosphorus and potassium uptake was recorded with the organic foliar spray of seaweed extract @ 0.3 % (S_1), which was on par with jeevamrith @ 3 % (S_4) concerning all organic manures. Humic acid @ 0.3 % (S_3) noticed significantly lower phosphorus and potassium uptake as an organic foliar spray along with all organic manures (M_1, M_2 & M_3). Naik *et al.* (27) and Sharma *et al.* (28) also reported similar results.

Soil microbial population

The soil microbial population was significantly influenced by soil application of organic manures. However, the effect of organic foliar sprays and the interaction between organic manures and foliar sprays on soil microbial population were not statistically comparable (Fig. 4 and Fig. 5). Significantly higher soil microbial population, *i.e*., total count of bacteria, fungi and actinomycetes were noticed with the soil application of 100 % RDN through poultry manure (M_2), which were 19.2%, 32.03% and 14.6% higher, respectively compared to the soil application of FYM (M_1). Whereas lower microbial count was noticed with soil application of 100 % RDN through FYM (M_1), which was comparable with vermicompost (M_3). A significant increase in the soil microbial population was observed with soil application of organic manures and organic foliar sprays relative to the initial microbial population. The composition and density of microbial populations constitute crucial determinants of soil organic matter quality, serving as key indicators of the soil's proficiency in nutrient and energy storage and recycling. Additionally, these microbial attributes play a pivotal role in signalling alterations in organic matter content. Poultry manure, characterized by its high nitrogen content and low carbon-to-nitrogen ratio, creates a favourable environment for microbial colonization within the soil rhizosphere. These results are in correlation with the findings of Patra *et al*. (24) and Yan *et al*. (29).

Seed quality parameters

The impact of soil application of various organic manures and foliar sprays, as well as their interactions, did not yield significant effects on the oil and protein content of sesame seeds (as depicted in Fig. 6 and Fig. 7). Notably, the highest oil and protein content was observed when poultry manure (M_2) was applied to the soil, while the lowest levels were associated with farmyard manure (M_1). These findings align with the research findings of Naik *et al.* (30). The increased oil and protein content observed following poultry manure application may be attributed to the nutrient-rich composition of poultry manure, which serves as a significant source of macro and micronutrients essential for plant growth and metabolic processes. Poultry manure is known to contain significant amounts of nitrogen, phosphorus and potassium, as well as micronutrients such as zinc, copper and manganese (31). These nutrients play crucial roles as precursors and cofactors in various biochemical pathways, including those involved in oil and protein synthesis in plants.

Specifically, nitrogen is a vital component of amino acids, the building blocks of proteins, while phosphorus is essential for ATP synthesis, a key energy molecule involved in various metabolic processes, including protein synthesis (32). Furthermore, potassium serves as a cofactor for enzymes involved in protein synthesis and plays a crucial role in maintaining cellular osmotic balance, which is essential for proper nutrient uptake and utilization. Additionally, micronutrients such as zinc, copper and manganese act as cofactors for enzymes involved in various metabolic pathways, including those related to oil synthesis (33, 34).

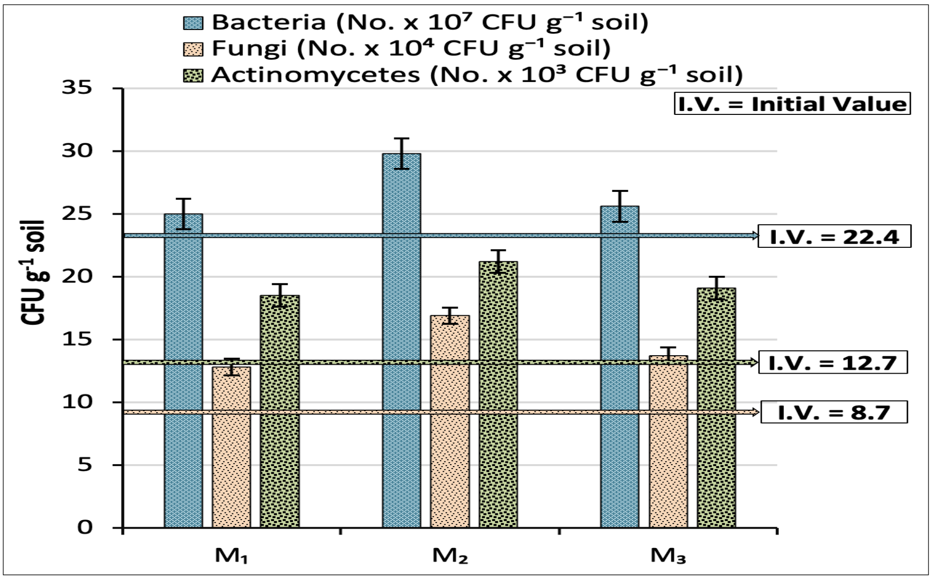

Fig. 4. Soil microbial population at sesame harvest as influenced by organic manures.

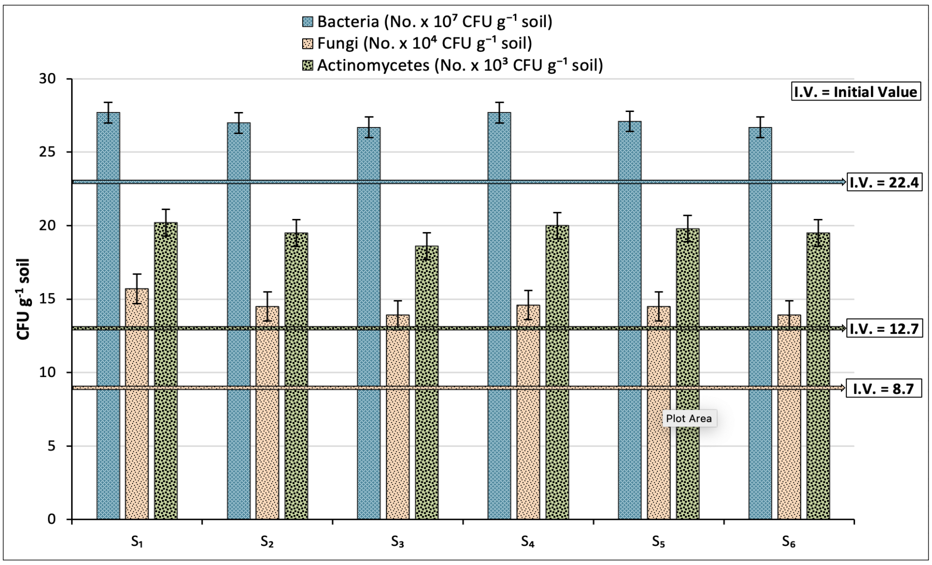

Fig. 5. Soil microbial population at sesame harvest as influenced by organic foliar sprays.

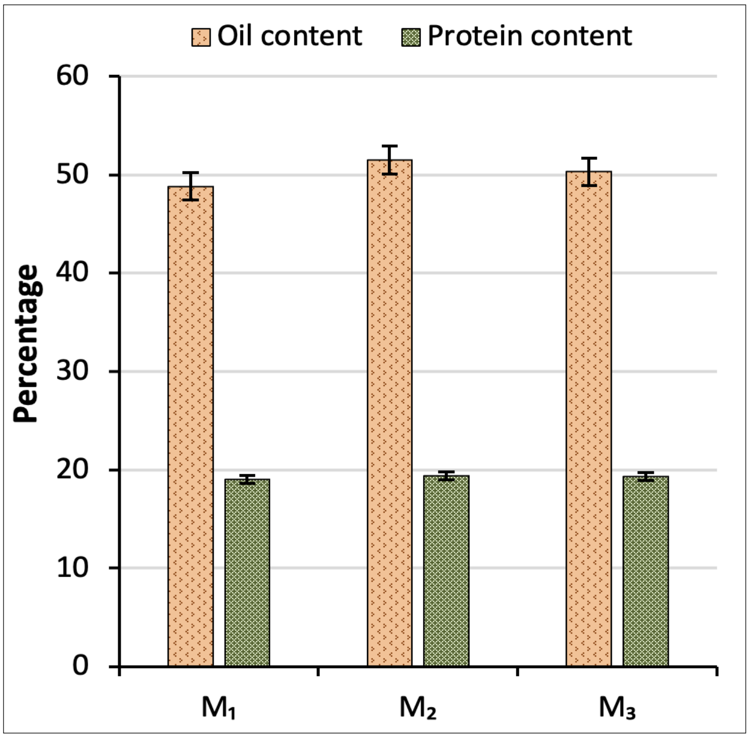

Fig. 6. Oil and protein content of sesame as influenced by organic manures.

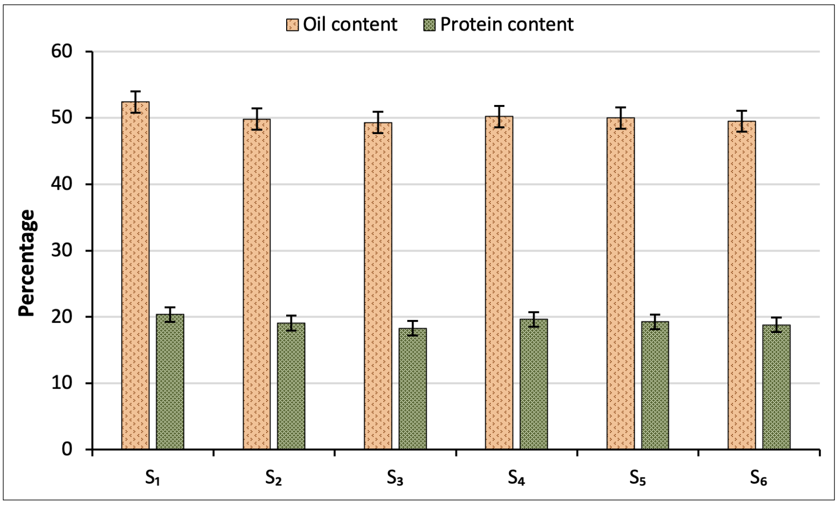

Fig. 7. Oil and protein content of sesame as influenced by organic foliar sprays.

Conclusion

The current era of global warming calls for sustainable and eco-friendly farming practices. Organic farming may be an optimal solution in this regard. The present study found that applying poultry manure @ 100 % RDN to the soil along with spraying seaweed extract (0.3 %) or jeevamrith (3.0 %) on the foliage three times at 20, 40 and 60 days after sowing improved the soil physical, chemical and biological properties and the seed quality of summer sesame under organic management system in the Southern Agro - climatic Zone of Andhra Pradesh. These findings underscore the viability and benefits of organic farming for sustainable agriculture in the face of environmental challenges.

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Authors' contributions

Keshav conducted field experiments, laboratory work, data analysis and wrote the manuscript. GK designed the experiment and drafted the manuscript. KN participated in writing the manuscript and in data analysis. PL was involved in designing the experiment and in data analysis. V contributed to the study's design. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflicts of interest to declare.

Ethical issues: None

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