**Impact of Sulphur Sources and Organic Manures on Soil Health in Sesame (Sesamum indicum L.) Cultivation**

**Abstract**

A field experiment was conducted at jobner, rajasthan, during kharif 2022 to study the impact of different sulphur sources and organic manures on soil health in sesame (*sesamum indicum* l.) Cultivation. The experiment was arranged as a factorial in a randomized complete block design with three replications, comprising a total of twenty treatment combinations. One factor consisted of four sulphur sources (control, gypsum, elemental sulphur, and bentonite) while the other factor comprised five organic manure treatments (control, FYM at 5 t/ha, FYM at 10 t/ha, vermicompost at 2.5 t/ha, and vermicompost at 5 t/ha). Results revealed that gypsum improved available sulphur and calcium content and alkaline phosphatase and arylsulphatase enzyme activity in soil, while higher organic manure rates significantly increased soil organic carbon, macronutrient and micronutrient availability, soil microbial biomass and dehydrogenase, alkaline phosphatase and arylsulphatase enzyme activity. Vermicompost at t/ha and FYM at 10 t/ha were particularly effective in enhancing soil fertility and enzyme activity. The study demonstrates the benefit of integrating inorganic sulphur sources with organic manures for improving soil health in sesame production.

**Keywords**

Sesame, sulphur sources, organic manure, soil fertility, enzyme activity

**Introduction**

Sesame (*Sesamum indicum* L.) is one of the oldest cultivated oilseed crops, widely known by regional names such as sesamum, til, gingelly, simsim, and gergelim. It belongs to the family Pedaliaceae (Yadav et al. 2022) and ranks next to groundnut in importance among oilseed crops in India. Sesame is extensively cultivated in tropical and subtropical regions of India due to its adaptability to diverse environmental conditions. Sesame is a hardy crop requiring minimal agronomic inputs, and its extensive root system confers considerable drought tolerance, allowing it to utilize residual soil moisture following the withdrawal of the monsoon. It also exhibits substantial heat tolerance, making it well-suited for semi-arid and arid regions. Sesame seeds are highly valued for their nutritional and medicinal properties, providing quality food and edible oil, and contributing to biomedicine and healthcare. They are rich in oil (48–50%) and protein (18–20%) (Cui et al. 2021). Sesame is cultivated on around 12.82 million hectares worldwide with a production of 6.55 million tonnes and a productivity of 545.85 kg/ha. It is grown on 16.27 lakh hectares in the country with a total yield of 7.8 lakh tonnes with the average productivity of 485 kg/ha (Anonymous, 2021-22a). The total area under sesame crop in Rajasthan in 2021-22 was 290.16 thousand ha with an average productivity of 265.00 kg/ha and a total production of 77.02 thousand tonnes (Anonymous, 2021-22b).

Sulphur (S) is the fourth major plant nutrient after nitrogen, phosphorus, and potassium and is essential for sustainable crop production. It plays a vital role in enhancing the growth, yield, and quality of oilseed crops by improving oil content and promoting seed development (Patel et al. 2019). Among the widely used sulphur sources, gypsum contains approximately 18% sulphur and is abundantly available in Rajasthan. Elemental sulphur (ES), with about 80% sulphur content, is another effective but relatively costlier source, while bentonite sulphur contains approximately 90% sulphur (Parmar et al. 2018).In the current agricultural context, many soils are characterized by low fertility and limited organic matter content, typically ranging from 0.34 to 0.56%. The application of organic manures such as farmyard manure (FYM) and vermicompost (VC) can be effective in improving soil fertility by supplying both macronutrients and micronutrients, as well as beneficial organic matter and enzyme activity. Integrating inorganic sulphur fertilizers with organic manures represents a sustainable nutrient management strategy that can reduce cultivation costs while maintaining or enhancing soil health. Therefore, this study was undertaken to evaluate the effects of different sulphur sources and organic manures on soil health, nutrient availability, and enzyme activity in sesame cultivation under the semi-arid conditions of Rajasthan.

**Materials and methods**

The field experiment was conducted during the *kharif* season of 2022 at the Agronomy Farm, S.K.N. College of Agriculture, Jobner (Rajasthan), India (26°05′ N, 75°28′ E, 427 m above mean sea level). The region belongs to agro-climatic zone IIIA (Semi-arid Eastern Plain Zone), characterized by hot summers (30–46 °C), cold winters (as low as –3 °C), and average annual rainfall of 400–500 mm, most of which occurs between July and September. The experiment was arranged as a factorial in a randomized complete block design with three replications, comprising a total of twenty treatment combinations. One factor consisted of four sulphur sources (control, gypsum, elemental sulphur, and bentonite) while the other factor comprised five organic manure treatments (control, FYM at 5 t/ha, FYM at 10 t/ha, vermicompost at 2.5 t/ha, and vermicompost at 5 t/ha). All sulphur sources and organic manures were applied as basal dressings. Gypsum contains 16% sulphur and 29% calcium. Elemental sulphur has 80% sulphur. Bentonite sulphur contains 90% sulphur and 10% bentonite clay. FYM contains 0.5% N, 0.2% P, and 0.5% K, while vermicompost has 1.5% N, 0.8% P, and 1.0% K. Initial soil properties of the experimental field are given in Table 1.

Table 1. Initial soil properties of the experimental field

|  |
| --- |
| **Physical properties** |
| Bulk density (Mg/m3)  | 1.50 |
| Particle density (Mg/m3) | 2.56 |
| **Chemical properties** |
| pH (1:2 Soil: Water) | 8.10 |
| EC (dS/m) (1: 2 Soil: Water)  | 0.390 |
| Organic carbon (%) | 0.185 |
| Available N (kg/ha) | 127.80 |
| Available P (kg/ha) | 18.90 |
| Available K (kg/ha) | 224.32 |
| Available sulphur (mg/kg) | 9.861 |
| Available Ca (cmol(p+)/100 g) | 3.376 |
| Available Mg (cmol(p+)/100 g) | 1.207 |
| Available Fe (ppm) | 4.241 |
| Available Zn (ppm) | 0.442 |
| Available Mn (ppm) | 6.218 |
| Available Cu (ppm) | 1.318 |
| **Biological properties** |
| Microbial biomass carbon (µg/g soil) | 125.21 |
| Dehydrogenase (µg TPF/g soil/24 h) | 17.28 |
| Alkaline phosphatase enzyme (µg pNP produced/ g soil/h) | 8.79 |
| Arylsulphatase (µg pNP produced/g soil/h) | 18.86 |

Soil samples were collected randomly from the experimental plot at the depth of 0 to 15 cm before sowing and after harvesting of crop. These were bulked together to form a composite sample from which a sub-sample was taken into Soil Science laboratory for analysis for physical, chemical and biological properties of the soil. The observation data were analysed statically through analysis of variance (ANOVA) with Factorial concept and significant was tested at the probability level of 0.05. The standard error of the mean and the Critical Difference value were mentioned in tables to compare the difference.

**Experimental results and discussions**

An appraisal of data presented in Table 2 indicates that the application of different sources of sulphur and different organic manures did not bring any significant change in pH, EC, bulk density and particle density of the soil after harvest of sesame. The data indicate that the organic carbon content in soil increased significantly due to application of organic manures as compared to control. Among the organic manures, the application of 10 t/ha FYM recorded highest organic carbon content (0.205%) in soil after harvest. The application of 10 t/ha FYM increased the organic carbon content in soil by 14.53, 6.77, 10.81 and 6.22 % after harvest over control, 5 t/ha FYM, 2.5 t/ha vermicompost and 5 t/ha vermicompost, respectively. Increasing of SOC in soil might be due to the mineralization of applied organic manure. These results are supported with Sheikh and Dwivedi (2017), Singh et al. (2024) and Raj et al. (2024).

Table 2. Effect of sulphur sources and organic manures on soil pH, EC, OC, bulk density and particle density

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Treatment | pH | EC (dS/m) | OC (%) | Bulk density (Mg/M3) | Particle density (Mg/M3) |
| **Sulphur source** |  |  |
| Control | 8.09 | 0.390 | 0.188 | 1.495 | 2.557 |
| Gypsum | 8.02 | 0.403 | 0.194 | 1.474 | 2.536 |
| Element sulphur | 7.97 | 0.393 | 0.192 | 1.479 | 2.549 |
| Bentonite | 7.94 | 0.392 | 0.190 | 1.476 | 2.547 |
| SEm+ | 0.07 | 0.004 | 0.002 | 0.012 | 0.022 |
| CD (P=0.05) | NS | NS | NS | NS | NS |
| **Organic manures** |  |  |
| Control | 8.10 | 0.389 | 0.179 | 1.500 | 2.555 |
| FYM @ 5 t/ha | 8.06 | 0.390 | 0.192 | 1.476 | 2.547 |
| FYM @ 10 t/ha | 7.95 | 0.399 | 0.205 | 1.464 | 2.541 |
| Vermicompost @ 2.5 t/ha | 8.00 | 0.391 | 0.185 | 1.486 | 2.551 |
| Vermicompost @ 5 t/ha | 7.91 | 0.403 | 0.193 | 1.475 | 2.546 |
| SEm+ | 0.08 | 0.004 | 0.002 | 0.014 | 0.025 |
| CD (P=0.05) | NS | NS | 0.005 | NS | NS |

An appraisal of data presented in Table 3,4 and 5 indicates that the effect of different sources of sulphur on available N, P, K, Mg, Fe, Zn, Mn and Cu content in soil after harvest of sesamewas found non-significant. The significant higher available S and Ca content (11.55 mg/kg and 3.880 cmol(p+)/kg) in soil was recorded with the application of gypsum. Due to readily released into the soil solution and onto cation exchange sites, making S and Ca immediately available for plant uptake and detectable in soil tests. These results are supported with Murmu et al. (2015), Jat et al. (2015), Singh et al. (2024) and Mathew et al. (2013).

The data presented in Table 3,4 and 5 reveals that application of organic manures exerted significant effect on available N, P, K, S, Ca, Mg, Fe, Zn, Mn and Cu content in soil after harvest of sesame. The significant higher available N, P, K, S, Ca, Mg, Fe, Zn, Mn and Cu content (133.67, 19.82, 229.40 kg/ha, 11.49 mg/kg, 3.775, 1.398 cmol(p+)/kg, 4.327, 0.457, 6.438, 1.373 ppm) in soil was recorded with the application of 5 t/ha vermicompost, which was found statistically at par with 10 t/ha FYM after harvest. Organic manures such as farmyard manure (FYM) and vermicompost play a crucial role in improving soil fertility and nutrient availability in sesamum cultivation. Their application increases the content of available macronutrients and micronutrients by enhancing mineralization of organic matter and improving soil microbial activity. The slow and sustained release of nutrients from organic sources helps maintain soil fertility over time while reducing nutrient losses. These results are supported with Elayaraja et al. (2020), Choudhary et al. (2017), Gaddi et al. (2020), Singh et al. (2024) and Rodrigues et al. (2016).

Table 3 Effect of sulphur sources and organic manures on available nitrogen, phosphorus and potassium in soil

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Available N (kg/ha) | Available P (kg/ha) | Available K (kg/ha) |
| **Sulphur source** |
| Control | 123.97 | 18.54 | 222.31 |
| Gypsum | 128.09 | 19.08 | 225.27 |
| Element sulphur | 127.11 | 18.94 | 224.65 |
| Bentonite | 126.58 | 18.80 | 224.14 |
| SEm+ | 1.09 | 0.16 | 1.23 |
| CD (P=0.05) | NS | NS | NS |
| **Organic manures** |
| Control | 116.57 | 17.57 | 216.01 |
| FYM @ 5 t/ha | 125.62 | 18.56 | 223.26 |
| FYM @ 10 t/ha | 130.30 | 19.54 | 228.10 |
| Vermicompost @ 2.5 t/ha | 126.02 | 18.70 | 223.69 |
| Vermicompost @ 5 t/ha | 133.67 | 19.82 | 229.40 |
| SEm+ | 1.22 | 0.18 | 1.38 |
| CD (P=0.05) | 3.49 | 0.52 | 3.95 |

Table 4 Effect of sulphur sources and organic manures on available sulphur, calcium and magnesium in soil

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Available S (mg/kg) | Available Ca (cmol(p+)/kg) | Available Mg (cmol(p+)/kg) |
| **Sulphur source** |
| Control | 9.52 | 3.330 | 1.200 |
| Gypsum | 11.55 | 3.880 | 1.215 |
| Element sulphur | 11.02 | 3.410 | 1.205 |
| Bentonite | 10.97 | 3.380 | 1.210 |
| SEm+ | 0.09 | 0.031 | 0.011 |
| CD (P=0.05) | 0.27 | 0.087 | NS |
| **Organic manures** |
| Control | 9.39 | 3.175 | 0.998 |
| FYM @ 5 t/ha | 10.74 | 3.425 | 1.148 |
| FYM @ 10 t/ha | 11.39 | 3.675 | 1.298 |
| Vermicompost @ 2.5 t/ha | 10.79 | 3.475 | 1.198 |
| Vermicompost @ 5 t/ha | 11.49 | 3.775 | 1.398 |
| SEm+ | 0.10 | 0.034 | 0.012 |
| CD (P=0.05) | 0.30 | 0.098 | 0.034 |

Table 5 Effect of sulphur sources and organic manures on available Fe, Zn, Mn and Cu in soil

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Fe (ppm) | Zn (ppm) | Mn (ppm) | Cu (ppm) |
| **Sulphur source** |
| Control | 4.171 | 0.432 | 6.220 | 1.310 |
| Gypsum | 4.251 | 0.437 | 6.246 | 1.339 |
| Element sulphur | 4.231 | 0.436 | 6.234 | 1.329 |
| Bentonite | 4.217 | 0.435 | 6.229 | 1.324 |
| SEm+ | 0.036 | 0.004 | 0.053 | 0.013 |
| CD (P=0.05) | NS | NS | NS | NS |
| **Organic manures** |
| Control | 4.043 | 0.409 | 5.975 | 1.272 |
| FYM @ 5 t/ha | 4.203 | 0.429 | 6.175 | 1.314 |
| FYM @ 10 t/ha | 4.323 | 0.447 | 6.375 | 1.356 |
| Vermicompost @ 2.5 t/ha | 4.218 | 0.434 | 6.198 | 1.314 |
| Vermicompost @ 5 t/ha | 4.327 | 0.457 | 6.438 | 1.373 |
| SEm+ | 0.040 | 0.004 | 0.060 | 0.014 |
| CD (P=0.05) | 0.115 | 0.012 | 0.170 | 0.040 |

An appraisal of data presented in Table 6 indicates that the application of different sources of sulphur did not bring any significant change in microbial biomass carbon and dehydrogenase enzyme activity in soil after harvest of sesame. But bring significant change in alkaline phosphatase and arylsulphatase enzyme activity in soil after harvest of sesame. The maximum alkaline phosphatase and arylsulphatase enzyme activity (11.04 µg pNP produced/ g soil/h, 21.34 µg pNP produced/g soil/h) in soil was observed with the application of gypsum as compare to elemental sulphur and bentonite. Due to its supply of calcium and sulphate, which improve soil structure and support beneficial microbial activity. Calcium enhances enzyme stability, while sulphate stimulates sulphur-cycling microbes. Better root growth and microbial activity lead to greater enzyme production. These results are supported with Malik et al. (2021), Khalili et al. (2024) and Tang et al. (2016).

It is evident from the data presented in Table 6 that the microbial biomass carbon and dehydrogenase, alkaline phosphatase and arylsulphatase enzyme activity in soil was noted to be significantly enhanced due to application of different organic manures as compared to control after harvest of sesame. The maximum microbial biomass carbon and dehydrogenase, alkaline phosphatase and arylsulphatase enzyme activity (132.75 µg/g soil, 18.71 µg TPF/g soil/24h, 11.30 µg pNP produced/ g soil/h, 21.68 µg pNP produced/g soil/h, respectively) in soil was recorded with the application 10 t/ha FYM at harvest. The increase in the soil phosphatase activity with the addition of organics could have been due to the soil substrate enrichment caused by the addition of mineral fertilizers. The phosphates added through organics and fertilizer improved the phosphatase activity, which may be ascribed to the stabilized extra cellular fraction of enzyme. The increased dehydrogenase activity might be due to the incorporation of organics, owing to increase in microbial activity of the soil. Similar results were reported by Malik et al. (2020), Dotaniya et al. (2025), Parham et al. (2002) and Borase et al. (2020).

Table 6 Effect of sulphur sources and organic manures on soil microbial biomass carbon and enzymatic activity of dehydrogenase, alkaline phosphatase and arylsulfatase in soil

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Microbial biomass carbon (µg/g soil) | Dehydrogenase (µg TPF/g soil/24h) | Alkaline phosphatase (µg pNP produced/ g soil/h) | Arylsulphatase (µg pNP produced/g soil/h) |
| **Sulphur source** |
| Control | 125.40 | 17.16 | 8.74 | 18.81 |
| Gypsum | 127.03 | 17.66 | 11.04 | 21.34 |
| Element sulphur | 126.62 | 17.41 | 10.39 | 20.81 |
| Bentonite | 126.07 | 17.26 | 10.34 | 20.71 |
| SEm+ | 1.08 | 0.15 | 0.09 | 0.18 |
| CD (P=0.05) | NS | NS | 0.27 | 0.51 |
| **Organic manures** |
| Control | 120.25 | 16.21 | 8.85 | 18.89 |
| FYM @ 5 t/ha | 127.29 | 17.51 | 10.40 | 20.80 |
| FYM @ 10 t/ha | 132.75 | 18.71 | 11.30 | 21.68 |
| Vermicompost @ 2.5 t/ha | 123.75 | 16.84 | 9.63 | 19.88 |
| Vermicompost @ 5 t/ha | 127.35 | 17.56 | 10.45 | 20.83 |
| SEm+ | 1.20 | 0.17 | 0.10 | 0.20 |
| CD (P=0.05) | 3.45 | 0.48 | 0.30 | 0.57 |

**Conclusion**

Integrating sulphur sources and organic manures significantly improved soil health in sesame cultivation. Gypsum effectively increased available sulphur and calcium, and alkaline phosphatase and arylsulphatase enzyme activity while higher rates of FYM and vermicompost enhanced organic carbon, macronutrient and micronutrient availability, and soil enzyme activity. This integrated nutrient management approach offers a sustainable strategy for improving soil fertility and soil enzyme activity under semi-arid conditions.

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