



RESEARCH ARTICLE

Isolation, characterisation and evaluation of sulfur-oxidising bacteria from rhizospheric soil samples of diverse agronomic crops

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Abstract

Sulfur is a crucial macronutrient that influences plant growth and development. It is considered the sixth major macronutrient after nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Among diverse agronomic crops, pulses and oilseed are more dependent on sulfur than cereals. However, sulfur deficiency is becoming a significant constraint on crop productivity and quality because of the excessive use of fertilisers and continuous cropping. Soil naturally contains sulfur in forms such as elemental sulfur and thiosulfate, which are not readily available to plants. Soil microorganisms, especially bacteria, convert these substances into sulfate, after oxidation, making them accessible to plants. In the present study, effective sulfur-oxidising bacteria (SOBs) were isolated and characterised from rhizospheric soil samples of paddy, black gram and maize fields. The SOB were isolated using modified thiosulfate agar medium and assessed for pH reduction, sulfate ion production, extracellular enzyme production and plant growth-promoting activities (PGPA) using standard methods. A total of 93 SOB isolates were obtained during primary screening. An effective SOB isolate, designated SOB6, exhibited the highest sulfur-oxidising activity, reducing pH to 4.47 and producing 103.7 mg/L sulfate. It was identified and characterised through morphological, biochemical and molecular methods. Molecular analysis based on 16S rRNA gene sequencing identified the isolate SOB6 as *Priestia flexa*, confirming its sulfur-oxidising potential and expanding the known functional diversity of this species. In conclusion, *P. flexa* SOB6 demonstrated efficient sulfur-oxidising activity under laboratory conditions, indicating its potential role in sulfur transformation processes and warranting further investigation for agricultural applications.

Keywords: enzyme production; plant growth-promoting activities; *Priestia flexa*; soil sulfate; sulfur-oxidising bacteria

Introduction

Sulfur is an essential macronutrient that is vital for plant growth. It is essential for the synthesis of proteins, oils and vitamins and its deficiency significantly impacts the quality and yield of oilseeds and legumes (1, 2). Besides, sulfur increases the protein content in legumes, increases the seed oil content and influences the sensory properties of vegetables such as onion and garlic (3, 4). Additionally, sulfur improves plant stress tolerance and soil health (5). Sulfur deficiency can cause chlorosis, stunted growth and decreased crop productivity (3, 4, 6). Bacteria belonging to the genera *Thiomicrospira*, *Acidothiobacillus* and *Thiosphaera*, oxidise soil sulfur, altering soil pH and nutrient availability (7). Sulfur-oxidising bacteria (SOB) can reduce the negative environmental impacts of chemical fertilisers, such as pollution and depletion of soil resources, as reported in Nigeria (8) and India (9). Therefore, the present study aimed to isolate and characterise an effective SOB from the rhizospheric soils of diverse agronomic crops in Tamil Nadu, India.

Materials and Methods

Soil sampling

Root associated soil samples were collected from the rhizospheres of rice (*Oryza sativa*), maize (*Zea mays*) and black gram (*Vigna mungo*) grown in the villages of Pudukkottai District, Tamil Nadu, India, namely Mullur (10.4200174° N, 78.8568569° E), Kottur (10.3222044° N, 78.7394582° E), Peraiyur (10.3783798° N, 78.7851579° E), Arimalam (10.2539772° N, 78.8935756° E), Vellakollai (10.3080160° N, 78.9827866° E), Lekkanappatti (10.6022749° N, 78.7275663° E), Lembalakudi (10.3201732° N, 78.7269032° E) and Manthankudi (10.4659299° N, 78.9189047° E). These locations represent important agricultural regions of Pudukkottai District, characterised by diverse cropping systems and rhizospheric environments (Fig. 1). The collected soil samples were packed in sterilised polythene bags, transported to the laboratory and stored at 4 °C until SOB isolation.

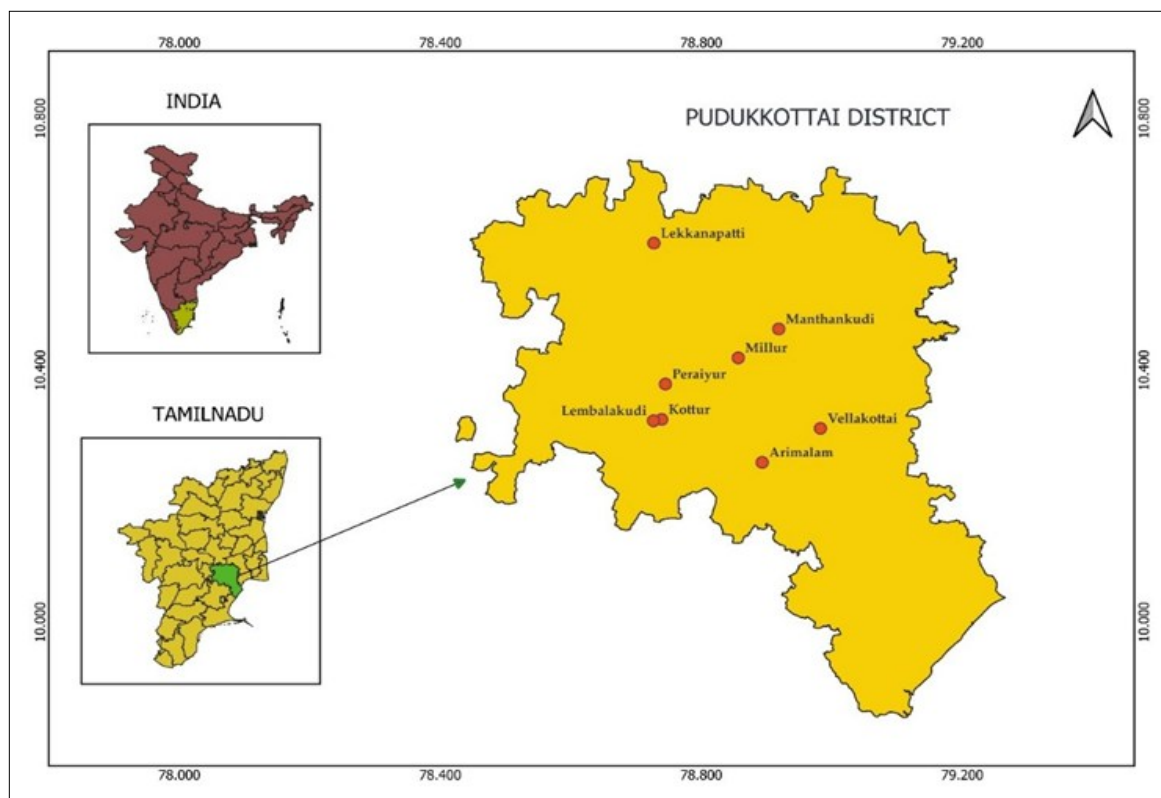


Fig. 1. Sampling sites, Pudukkottai District, Tamil Nadu, India. (Source: QGIS geographic information system.)

Isolation and screening of efficient sulfur-oxidising bacteria

Modified thiosulfate broth containing 5.0 g of $\text{Na}_2\text{S}_2\text{O}_3$, 0.1 g of K_2HPO_4 , 0.2 g of NaHCO_3 , 0.1 g of NH_4Cl , 5.5 g of glucose, 0.015 g of phenol red (pH indicator) and 1000 mL of distilled water, adjusted to pH of 8.0, was used for SOB isolation. The soil samples were enriched in the thiosulfate broth and incubated for 10 days at $32 \pm 2^\circ\text{C}$. After incubation, the soil samples were serially diluted and 1 mL from the appropriate dilutions (10^{-4} , 10^{-5} and 10^{-6}) was spread on modified thiosulfate agar medium in petri plates and incubated at $32 \pm 2^\circ\text{C}$ for 5–7 days. The individual colonies showing a yellow-coloured halo zone were picked and transferred to nutrient agar slants for purification and labelling. Based on halo zone diameter on the modified thiosulfate agar medium, the effective SOB isolates obtained were further assessed for their pH reduction potential in thiosulfate broth.

Selection of sulfur-oxidising bacterial isolates by pH reduction activity

For screening, SOB isolates were inoculated into modified thiosulfate broth and incubated at 32°C for 10 days. The pH of the cultures was measured at two-day intervals and isolates showing rapid pH reduction were selected for further evaluation. The selected isolates were inoculated into three different media: thiosulfate broth, thiosulfate broth without glucose and broth containing glucose but without thiosulfate, to confirm that the observed pH reduction resulted from the oxidation of thiosulfate present in the medium. Appropriate controls were maintained to confirm the pH reduction caused by the SOB isolates.

Estimation of sulfate ion production

The amount of sulfate ions produced during the growth of SOB isolates in modified thiosulfate broth was determined using a digital spectrophotometer. The selected SOB isolates were cultured individually in modified thiosulfate broth and after 7 days, the broth cultures and controls were centrifuged at 8000 rpm for

30 min to obtain the supernatant, with slight modifications to the referenced method. The supernatant was mixed with barium chloride solution (1 : 1 w/v) and the suspension was mixed thoroughly. The formation of white turbidity in the culture supernatant was measured by recording the optical density (OD) at 420 nm using a digital visible spectrophotometer (10). Sulfate concentrations were calculated using a standard curve prepared with 0–10 mM K_2SO_4 (11).

Extra-cellular enzymatic activities

Catalase activity

The efficient SOB isolate was grown on trypticase soya agar medium and after 48 hr of incubation, 3–4 drops of hydrogen peroxide (H_2O_2) were added. Foam formation was observed to confirm catalase activity (12).

Protease activity

The selected efficient SOB was spot inoculated onto skim milk agar plates and incubated at 30°C for 24 hr. The formation of a clear zone around the colony was considered a positive result for protease activity (13).

Amylase activity

Amylase activity of the selected SOB isolate was assessed using starch agar plates. The isolate was inoculated on starch agar medium plates and incubated at 30°C for 48 hr. At the end of the incubation period, the plates were flooded with iodine solution, allowed to stand for 1 min and then the excess solution was poured off. The formation of a colourless zone around the colony was considered a positive result for amylase production (14).

Qualitative screening of plant growth-promoting activities

Ammonia production

Ammonia production assay was performed using peptone water. The freshly grown culture was inoculated in 10 mL of peptone water and incubated for 48–72 hr at 30°C . After incubation, 0.5 mL

of Nessler's reagent was directly added to the broth and the development of a brown to yellow colour was observed to confirm ammonia production (15).

Indole-3-acetic acid production

The selected SOB was inoculated in Luria Bertani broth medium (25 mL) amended with 50 µg/mL of tryptophan and incubated for 24 hr at 28 °C on rotary shaker. The incubated culture was centrifuged at 10000 rpm for 15 min and the supernatant was collected in a test tube. To 2 mL of the supernatant, 2–3 drops of orthophosphoric acid and 4 mL of Salkowski reagent were added, followed by incubation for 25 min at room temperature. Indole-3-acetic acid (IAA) production was confirmed by observing pink colour development in the solution (16).

Phenotypic and biochemical identification of sulfur-oxidising bacterial isolate

The selected efficient SOB isolate was identified preliminarily based on morphological and biochemical characterisation using standard methods. The phenotypic characteristics of the isolate, such as cell morphology, Gram staining, shape and motility, were determined according to Bergey's Manual of Determinative Bacteriology (17). The biochemical characteristics of the isolate, such as Indole production, methyl red, Vogas's Proskauer, citrate utilisation, catalase and oxidase, tests were examined (18).

Molecular characterisation and phylogenetic analysis of sulfur-oxidising bacterial isolate

Genomic DNA was extracted using the HiPurA® Multi-Sample DNA Purification Kit, standardised by PAR Life Sciences and Research Pvt Ltd., Trichy. The 16S rRNA gene was amplified with primers 27F (AGAGTTTGATCMTGGCTCAG) and 1492R (TACGGYTACCTTGTACGACTT). The PCR products were purified, sequenced using the Big Dye® Terminator 3.1 method and analysed using MEGA11 (19). The Neighbour-Joining method was used to infer evolutionary relationships (20).

Statistical analysis

All experimental data were subjected to statistical analysis using IBM SPSS statistics version 21 (IBM Corp., Armonk, NY, USA). The data were analysed using one-way analysis of variance (ANOVA) and significant differences among treatments was determined at $p < 0.05$. Data are presented as mean $\pm$ standard deviation (SD) of 3 replicates.

Results

A total of 93 SOB colonies were isolated from the rhizospheric soil samples of rice, maize and black gram. Among these, 8 isolates (4 from rice, 3 from maize and 1 from black gram) were selected based on their ability to reduce the initial pH of 8. Rapid halo zone formation, indicated by a colour change from pink to yellow on thiosulfate agar medium, confirmed their sulfur-oxidising activity. The selected isolates were designated SOB1 to SOB8 and were compared with the control.

Screening of effective sulfur-oxidising bacteria

The pH of the culture medium and control broths were measured at 2-days intervals over a 10-day incubation period to assess the pH reduction ability of the SOB isolates, which indicates sulfur oxidation activity (Table 1). Among the eight isolates, SOB6 isolated from rice rhizosphere, showed the greatest pH reduction in thiosulfate medium without glucose, with a steady decline from 5.5 on the 2nd day to 4.5 by the 10th day. However, a moderate pH reduction ranging from 6.0 to 6.5 was observed on the 10th day with the other SOB isolates. In contrast, SOB4 and SOB8 maintained relatively high pH levels throughout the incubation period, indicating weak sulfur oxidation. This suggests that pH reduction occurred only in the presence of thiosulfate, indicating sulfur oxidation-associated activity by SOB isolates. Among the isolates, SOB6 exhibited the strongest sulfur-oxidising ability, followed by SOB7, as evidenced by the significant reduction in pH compared with the uninoculated controls. Based on their pH reduction ability, three isolates (SOB6, SOB7 and SOB3) were selected for the further analysis.

Estimation of sulfate ion production

The sulfate ion production activity of the bacterial isolates is shown in Table 2. This experiment revealed that the SOB-6 isolate (103.7 mg/L) produced the maximum sulfate ion concentration, followed by the SOB-7 isolate (99.9 mg/L), whereas the minimum sulfate ion concentration was produced by the SOB-3 isolate (98.94 mg/L). Based on sulfate ion production, SOB6 was identified as an efficient SOB and stored for further studies.

Extra-cellular enzymatic activities

The efficient isolate SOB6 exhibited strong catalase activity, indicating its ability to decompose hydrogen peroxide into water and oxygen, a key role associated with oxidative stress tolerance.

Table 1. pH reduction (initial pH 8.0) by sulfur-oxidising bacterial isolates in thiosulfate medium with and without glucose

Isolate	Medium	2 nd DAI	4 th DAI	6 th DAI	8 th DAI	10 th DAI
SOB1	With glucose	7.50 $\pm$ 0.06 ^d	6.47 $\pm$ 0.03 ^c	5.97 $\pm$ 0.03 ^c	5.67 $\pm$ 0.09 ^c	6.03 $\pm$ 0.03 ^c
	Without glucose	7.37 $\pm$ 0.06 ^d	6.43 $\pm$ 0.09 ^c	5.97 $\pm$ 0.03 ^c	5.63 $\pm$ 0.06 ^c	5.93 $\pm$ 0.03 ^c
SOB2	With glucose	7.43 $\pm$ 0.07 ^d	7.43 $\pm$ 0.07 ^d	6.97 $\pm$ 0.03 ^d	6.53 $\pm$ 0.03 ^d	6.03 $\pm$ 0.03 ^c
	Without glucose	7.33 $\pm$ 0.03 ^d	7.37 $\pm$ 0.03 ^d	6.90 $\pm$ 0.06 ^d	6.50 $\pm$ 0.06 ^d	5.93 $\pm$ 0.03 ^c
SOB3	With glucose	6.57 $\pm$ 0.07 ^c	5.97 $\pm$ 0.03 ^b	6.03 $\pm$ 0.03 ^c	5.90 $\pm$ 0.06 ^c	5.97 $\pm$ 0.09 ^c
	Without glucose	6.50 $\pm$ 0.06 ^c	5.87 $\pm$ 0.03 ^b	5.93 $\pm$ 0.03 ^c	5.83 $\pm$ 0.06 ^c	5.90 $\pm$ 0.06 ^c
SOB4	With glucose	7.53 $\pm$ 0.09 ^d	7.43 $\pm$ 0.07 ^d	6.97 $\pm$ 0.03 ^d	6.50 $\pm$ 0.06 ^d	7.43 $\pm$ 0.03 ^d
	Without glucose	7.43 $\pm$ 0.03 ^d	7.43 $\pm$ 0.03 ^d	6.87 $\pm$ 0.03 ^d	6.47 $\pm$ 0.03 ^d	7.33 $\pm$ 0.03 ^d
SOB5	With glucose	7.47 $\pm$ 0.03 ^d	6.97 $\pm$ 0.03 ^c	5.97 $\pm$ 0.03 ^c	6.00 $\pm$ 0.06 ^c	5.97 $\pm$ 0.03 ^c
	Without glucose	7.37 $\pm$ 0.03 ^d	6.87 $\pm$ 0.03 ^c	5.93 $\pm$ 0.03 ^c	5.93 $\pm$ 0.03 ^c	5.93 $\pm$ 0.03 ^c
SOB6	With glucose	5.47 $\pm$ 0.03 ^a	5.10 $\pm$ 0.06 ^a	5.00 $\pm$ 0.06 ^a	4.87 $\pm$ 0.03 ^a	4.50 $\pm$ 0.06 ^a
	Without glucose	5.43 $\pm$ 0.03 ^a	5.00 $\pm$ 0.06 ^a	4.93 $\pm$ 0.03 ^a	4.80 $\pm$ 0.06 ^a	4.47 $\pm$ 0.03 ^a
SOB7	With glucose	6.97 $\pm$ 0.03 ^c	5.03 $\pm$ 0.03 ^a	4.97 $\pm$ 0.03 ^a	4.90 $\pm$ 0.06 ^a	4.97 $\pm$ 0.03 ^b
	Without glucose	6.93 $\pm$ 0.03 ^c	4.97 $\pm$ 0.03 ^a	4.90 $\pm$ 0.06 ^a	4.83 $\pm$ 0.06 ^a	4.93 $\pm$ 0.03 ^b
SOB8	With glucose	7.93 $\pm$ 0.03 ^e	7.87 $\pm$ 0.04 ^e	7.83 $\pm$ 0.03 ^e	7.77 $\pm$ 0.03 ^e	7.57 $\pm$ 0.03 ^e
	Without glucose	7.87 $\pm$ 0.03 ^e	7.84 $\pm$ 0.03 ^e	7.80 $\pm$ 0.06 ^e	7.77 $\pm$ 0.03 ^e	7.63 $\pm$ 0.03 ^e

No pH reduction was observed in glucose-only medium (without thiosulfate), confirming that acidification resulted from thiosulfate oxidation rather than glucose metabolism. DAI: days after inoculation.

Table 2. Sulfate ion production efficiency of sulfur-oxidising bacterial isolates

Sl. No.	Isolates	Sulfate production (mg/L)
1	SOB6	103.7
2	SOB7	99.9
3	SOB3	98.94

The isolate also showed positive results for protease and amylase activities, confirming its capacity to hydrolyse extracellular proteins and degrade starch under the tested conditions.

Qualitative screening of plant growth-promoting activities

The culture exhibited ammonia production activity, indicating its capacity to release ammonia during nitrogen (N) metabolism. However, IAA production was negative, demonstrating that the strain does not produce auxin-type phytohormones under evaluated culture conditions.

Phenotypic and biochemical characterisation of SOB6

SOB6 was characterised on the basis of phenotypic and biochemical tests. Microscopic observation revealed Gram-positive, rod-shaped bacilli that formed white, circular, flat, opaque and colonies (Fig. 2 and 3). The isolate was motile. Biochemical tests revealed positive reactions for methyl red, catalase and citrate utilisation reactions and utilise citrate as the only carbon source. However, isolate had negative results for indole production, the Vogas's Proskauer reaction and oxidase test. SOB6 grew optimally at neutral to alkaline pH, it tolerated and acidified the medium during sulfur oxidation. These features provide insights into the metabolic capabilities and environmental adaptability of SOB6 and results are shown in Table 3.

Table 3. Morphological and biochemical characterisation of sulfur-oxidising bacteria (SOB6) isolate

Sl. No.	Tests	Characters
1	Morphology	Rod - Bacillus
2	Gram reaction	Gram positive
3	Colony characters	White, circular, flat and opaque
4	Motility	Positive
5	Initial growth pH	8
6	Indole production	-
7	Methyl red	+
8	Vogas's Proskauer	-
9	Citrate utilisation	+
10	Catalase	+
11	Oxidase	-

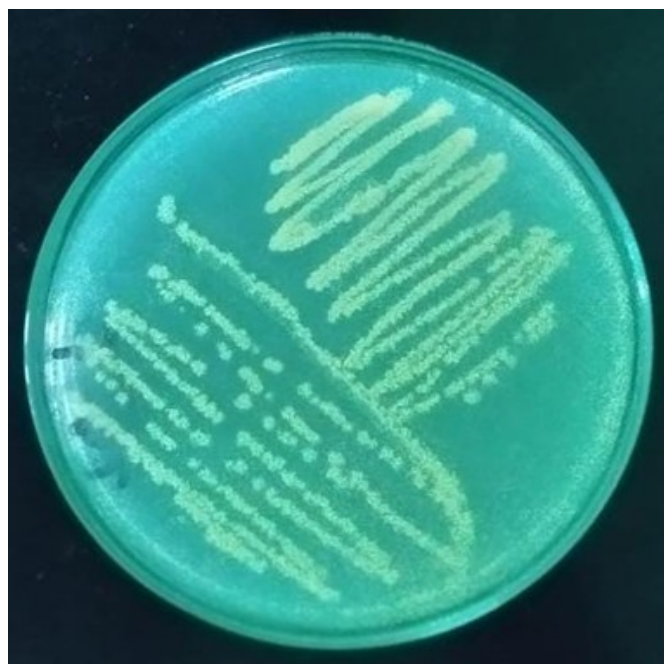
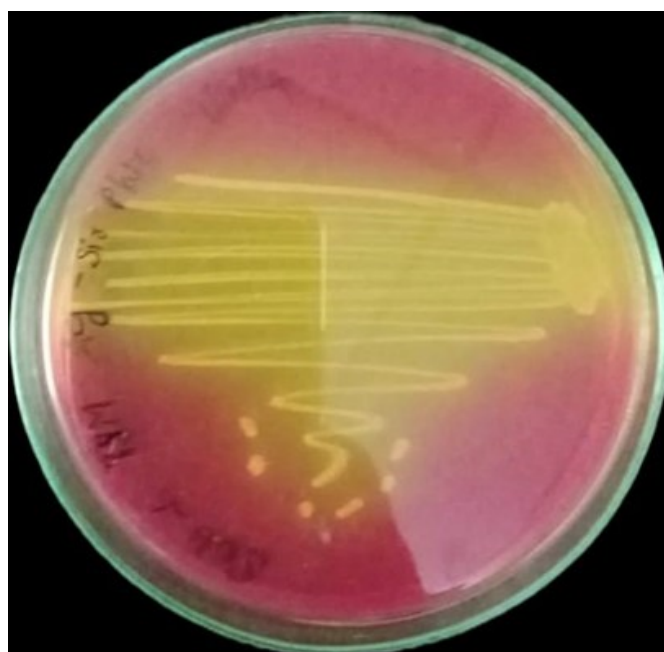
(+): Positive; (-): Negative.

Molecular identification of SOB6

To confirm its taxonomic identity, the 16S rRNA gene of SOB6 was amplified by PCR and sequenced. The obtained sequence was analysed and compared with the NCBI GenBank database, which identified the isolate as *Priestia flexa*. The 16S rRNA gene sequence of SOB6 was deposited in the NCBI GenBank database under the accession number PQ152230. Combined with the morphological and biochemical characteristics, these molecular data confirmed that SOB6 is *P. flexa* (Fig. 4).

Discussion

In this study, 93 SOB isolates were obtained; among them, SOB6, isolated from rice rhizospheric soil, demonstrated the most promising results. Several researchers have isolated SOB from various environments, including agricultural fields, rhizospheres

**Fig. 2.** Sulfur-oxidising bacteria (SOB6) growth on nutrient agar plate.**Fig. 3.** Growth of sulfur-oxidising bacteria (SOB6) on modified thiosulfate agar.

(root zones), dumpsites, abattoirs and automobile workshops, where organic matter and sulfur compounds support their growth (8, 21–23). The SOB have also been isolated from aquatic and sediment environments, including shrimp ponds, coastal sediments and fish farm sediments (9, 24–26). These isolates are valuable for environmental management and plant nutrition. Common SOB genera include *Bacillus*, *Paenibacillus*, *Staphylococcus*, *Sulfurovum*, *Pseudomonas* and *Acidithiobacillus* (8, 9). Most of these studies revealed that paddy fields contained a higher population of SOB than over ecosystems. In this present study, the efficient SOB6 was isolated from paddy fields soil because flooded soil conditions, sulfur availability and active rhizosphere microbial communities provide a favourable environment for the growth of SOB. This finding aligns with previous studies highlighting the abundance and activity of SOB in similar environments, where they contribute to nutrient cycling and soil health. Furthermore, the isolation of SOB from a variety of

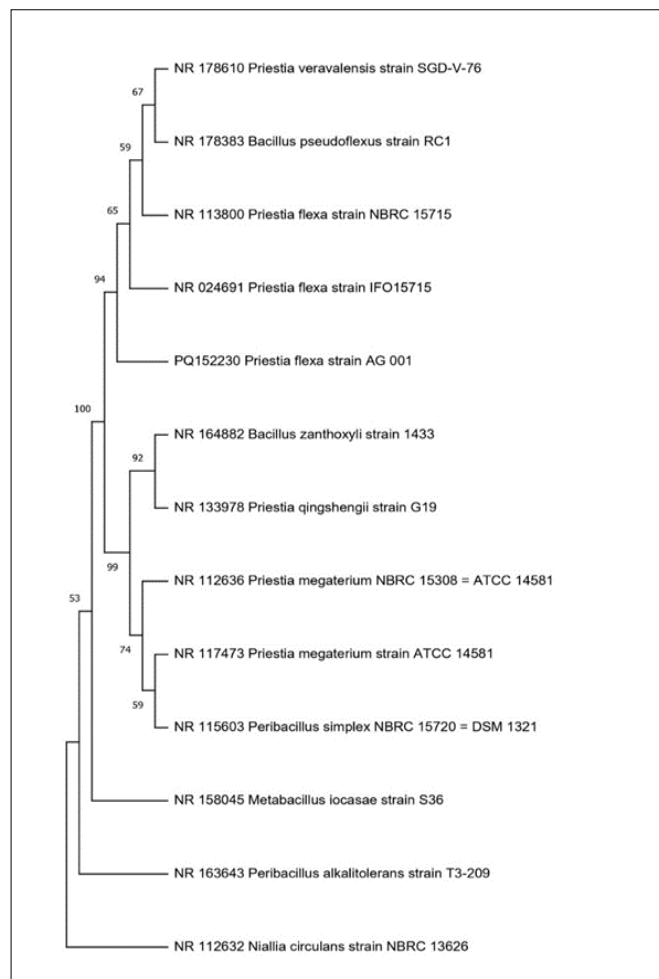


Fig. 4. Phylogenetic analysis of sulfur-oxidising bacteria (SOB6) (AG001).

samples, including shrimp ponds and rubber factory waste, shows their ecological adaptability and underscores their potential participation in environmental management. Interestingly, SOB observed under industrial effluents plays a crucial role in the bioremediation and detoxification of contaminated environments (26).

On the basis of its ability to reduce pH and produce sulfate ion in the growth medium, SOB6 was identified as the most promising isolate among the 93 SOB isolates. In the present investigation, a greater reduction in pH was observed with SOB6 in thiosulfate medium without glucose on the 10th day of incubation, indicating active thiosulfate oxidation and subsequent production of acidic compounds that lowered the medium pH. However, previous studies have reported consistently reduced pH values ranging from 5.69 to 6.03 on the 6th day of incubation in thiosulfate medium (8, 22, 27). Similarly, earlier studies have shown that the SOB *Pantoea dispersa*, isolated from the mustard rhizosphere, reduced the pH to 3.93 through sulfur oxidation, thereby enhancing nutrient availability and supporting healthy crop growth, making SOB valuable for sustainable soil management in agriculture (27–29). During acidification by SOB, phosphates and other minerals are solubilised, making them more readily available to plants. The SOB also plays a crucial role in the biogeochemical cycle, particularly in sulfur cycling, by converting sulfur into forms that are readily available to plants (24). Previous researchers have further reported that SOB effectively reduced soil pH from 7.5 to 4.8 and increased the availability of micronutrients such as iron

and zinc, which are often deficient in alkaline soils. These findings further support the beneficial role of these microorganisms in promoting plant growth (30).

Sulfur-oxidising bacterial isolates evaluated in this study demonstrated distinct abilities for sulfate ion production, highlighting their different metabolic potentials. Among the isolates, SOB6 presented the highest sulfate production (103.7 mg/L) after 7 days of incubation, making it the most efficient strain. Earlier investigations reported that the isolate *P. dispersa*, originating from the mustard rhizosphere, produced 173.6 mg/L sulfate and exhibited high sulfur oxidation activity (22, 23). Compared with previous findings, the present isolate showed moderate sulfate production. Previous research has also reported that SOB from crop rhizospheres, such as mustard, rice and *Vigna*, are highly efficient at converting sulfur into sulfate (22, 23, 31). Some strains produce approximately 170 mg/L sulfate *in vitro*, although these values are moderately higher than those obtained in the present study. Related studies have shown that SOB from rhizospheres effectively oxidise sulfide to sulfate, thereby supporting plant nutrition and improving soil fertility (32). Therefore, this study revealed that all SOB isolates produced significant amounts of sulfate ions from thiosulfate-glucose medium. Notably, the selected SOB6 isolate showed moderate sulfate ion production compared with previous reports (22, 23).

To determine the extracellular enzymatic activity and plant growth-promoting rhizobacteria (PGPR) traits, including ammonia and IAA production abilities, of SOB6, analyses were carried out. The results showed positive activities for protease, amylase, catalase and ammonia production. Several studies have reported that *P. flexa* obtained from organically enriched, contaminated or waste-associated soils possess amylase and protease production ability (33, 34). Some studies have further revealed that the co-occurrence of multiple extracellular hydrolytic enzymes, including protease, had also been reported in *P. flexa* and related *Bacillus*-like genera, facilitating the degradation of complex organic substrates and contributing to nutrient mineralisation in soil and rhizosphere environments (33, 35, 36). Earlier investigations have frequently reported ammonia production by plant-associated bacteria as a common plant growth-promoting trait, particularly among phosphate-solubilising and endophytic isolates (35, 36). In the present isolate, ammonia production together with sulfur oxidation, suggests a role in nitrogen and sulfur cycling, thereby contributing indirectly to plant nutrition. In contrast, no IAA production was detected in the *P. flexa* isolate. Overall, the enzymatic activities and qualitative plant growth-promoting traits observed in this sulfur-oxidising *P. flexa* isolate support its interpretation as a metabolically versatile decomposer and nutrient cyler. Similar functional profiles have been reported for *P. flexa* in this study highlight its potential for plant growth and development.

Although the phenotypic and biochemical characteristics of SOB6 resembled those of *Bacillus* or *Thiobacillus*, molecular identification through 16S rRNA gene sequencing revealed that SOB6 belongs as *P. flexa*, supporting its reclassification into the genus *Priestia* (37). Some researchers have indicated that genomic analysis of *P. flexa* TBS3110 revealed the presence of genes related to sulfur and iron homeostasis (38–40). In rice plants, *P. flexa*, as part of a bacterial consortium, has been reported to stimulate sulfur metabolism, which may enhance plant health and stress

tolerance (39, 40). In the present investigation, *P. flexa* was identified as an SOB.

The novelty of the present study lies in the isolation and characterisation of *P. flexa* (SOB6), from agronomic rhizosphere soils of Pudukkottai district, Tamil Nadu, India and the demonstration of its sulfur-oxidising capability under laboratory conditions. The isolate exhibited efficient sulfur-oxidation, as evidenced by significant pH reduction and sulfate production in thiosulfate-containing media. To the best of our knowledge, reports on *P. flexa* as a SOB isolated from agricultural rhizosphere soils are limited, highlighting its potential significance in sulfur biogeochemistry.

Conclusion

In the present study, among the 93 sulfur-oxidising bacterial (SOB) isolates obtained from rhizospheric soils of various agronomic crops, the SOB6 isolate from rice rhizosphere soil demonstrated superior performance in terms of pH reduction, sulfate production, enzyme production and plant growth promoting activity. This study highlights the role and importance of SOB in sulfur oxidation and cycling in soil. Additionally, the pH-reducing ability of sulfur-oxidising bacteria can be utilised for the reclamation of alkaline soils. However, further research is required to explore the functional genes and metabolic pathways involved in sulfur oxidation by *P. flexa*. Comprehensive field trials are also needed to validate its effectiveness and consistency under real agricultural conditions. These studies will pave way for its potential application as a promising biofertiliser for sustainable agriculture.

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Authors' contributions

VP contributed to conceptualisation, methodology, investigation, data curation, formal analysis and writing of the original draft. GA contributed to conceptualisation, data curation, supervision, project administration, validation and writing through review and editing. Both authors have read and approved the final manuscript.

Compliance with ethical standards

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

Ethical issues: None

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