

Table S1. Physicochemical properties of forest soil used in the study.

<b>pH</b>	<b>Total C</b> (g C kg <sup>-1</sup> )	<b>Total N</b> (g N kg <sup>-1</sup> )	<b>Available S*</b> (mg S kg <sup>-1</sup> )	<b>Soluble P* (mg</b> <b>P<sub>2</sub>O<sub>5</sub> 100 g<sup>-1</sup>)</b>	<b>P adsorption</b> <b>capacity* (mg</b> <b>P<sub>2</sub>O<sub>5</sub> 100 g<sup>-1</sup>)</b>	<b>Fe<sub>o</sub></b> (g kg <sup>-1</sup> )	<b>Fe<sub>d</sub></b> (g kg <sup>-1</sup> )	<b>Al<sub>o</sub></b> (g kg <sup>-1</sup> )	<b>Al<sub>d</sub></b> (g kg <sup>-1</sup> )
5.2 ± 0.1	76.9 ± 1.9	4.9 ± 0.1	21.3 ± 2.6	2.3 ± 0.6	2756.6 ± 17.7	29.2 ± 0.4	43.6 ± 1.0	71.1 ± 0.3	17.4 ± 0.8

\*Lifted from Sugiura et al., 2022

Fe<sub>o</sub> and Al<sub>o</sub> were Fe and Al extractable from acid oxalate method, respectively.

Fe<sub>d</sub> and Al<sub>d</sub> were Fe and Al extractable from dithionite-citrate reduction method, respectively.

Table S2. Chemical reagents as nutrients amended in the soil for soybean pot experiment.

Nutrient	Sulfur treatment (S)		Non-sulfur treatment (NS)	
	Chemical Reagent	(mg/kg)	Chemical Reagent	(mg/kg)
K	K <sub>2</sub> SO <sub>4</sub>	170.0	KCl	145.5
Mg	MgSO <sub>4</sub> ·7H <sub>2</sub> O	389.1	MgCl <sub>2</sub> ·6H <sub>2</sub> O	320.9
N	Urea (CH <sub>4</sub> N <sub>2</sub> O)	214.4	Urea (CH <sub>4</sub> N <sub>2</sub> O)	214.4
Cu	CuCl <sub>2</sub> ·2H <sub>2</sub> O	1.4	CuCl <sub>2</sub> ·2H <sub>2</sub> O	1.4
Mn	MnCl <sub>2</sub> ·4H <sub>2</sub> O	0.5	MnCl <sub>2</sub> ·4H <sub>2</sub> O	0.5
Co	CoCl <sub>2</sub> ·6H <sub>2</sub> O	0.4	CoCl <sub>2</sub> ·6H <sub>2</sub> O	0.4
B	H <sub>3</sub> BO <sub>3</sub>	0.5	H <sub>3</sub> BO <sub>3</sub>	0.5
Mo	Na <sub>2</sub> MnO <sub>4</sub> ·2H <sub>2</sub> O	0.5	Na <sub>2</sub> MnO <sub>4</sub> ·2H <sub>2</sub> O	0.5
Zn	ZnCl <sub>2</sub>	1.1	ZnCl <sub>2</sub>	1.1

Table S3. PERMANOVA on the significance of the influence of soybean cultivation and sulfur fertilization on soil microbial community structure.

	Soybean Cultivation			Sulfur Application		
	F	R <sup>2</sup>	p	F	R <sup>2</sup>	p
Microbial Community Structure	6.8081	0.4050	<0.002	1.0448	0.0946	<0.318

F values indicate the magnitude of change on the microbial community structure. Significance level at  $p<0.05$ .

Table S4. Spearman's rank correlation coefficients of the abundance of microbial community and organic acids from soybean under sulfur applications.

<b>Genus</b>	<b>Malonic</b>	<b>Malic</b>	<b>Tartaric</b>	<b>Citric</b>
<i>Aquicella</i>	0.41	0.57 <sup>+</sup>	0.46	0.46
<i>Arthrobacter</i>	-0.41	-0.53 <sup>+</sup>	-0.32	-0.44
<i>Bacillus</i>	-0.75**	-0.86**	-0.80**	-0.77**
<i>Burkholderia</i>	0.82**	0.92**	0.91**	0.84**
<i>Catenulispora</i>	0.48	0.64*	0.80**	0.49
<i>Chthoniobacter</i>	-0.62*	-0.70*	-0.64*	-0.57 <sup>+</sup>
<i>Dyella</i>	0.72**	0.54 <sup>+</sup>	0.68*	0.78**
<i>Edaphobacter</i>	-0.65*	-0.68*	-0.68*	-0.69*
<i>Flavisolibacter</i>	-0.82**	-0.89**	-0.85**	-0.82**
<i>Ideonella</i>	-0.76**	-0.82**	-0.75**	-0.78**
<i>Labilithrix</i>	0.43	0.63*	0.54 <sup>+</sup>	0.45
<i>Mesorhizobium</i>	0.82**	0.84**	0.95**	0.83**
<i>Mycobacterium</i>	-0.30	-0.54 <sup>+</sup>	-0.34	-0.27
<i>Nitrospira</i>	0.59*	0.63*	0.60*	0.60*
<i>Paraburkholderia</i>	0.80**	0.90**	0.89**	0.78**
<i>Polaromonas</i>	0.39	0.52 <sup>+</sup>	0.46	0.33
<i>Rhizobium</i>	0.53 <sup>+</sup>	0.53 <sup>+</sup>	0.73**	0.54 <sup>+</sup>
<i>Sphingomonas</i>	-0.89**	-0.86**	-0.84**	-0.88**
<i>Streptomyces</i>	0.79**	0.72**	0.85**	0.81**
<i>Undibacterium</i>	0.58*	0.78**	0.66*	0.55 <sup>+</sup>

Significant relationships at \*\*  $p < 0.01$ ; \*  $p < 0.05$ ; +  $p < 0.10$ .

Table S5. Characteristics and identity of cultivable bacteria from rhizospheres of NS and S applied soybean.

Isolate	Source	Type of Isolation*	% Identity	16S rRNA	Gram Reaction <sup>a</sup>	Cellular morphology <sup>b</sup>	Colony morphology <sup>c</sup>
JSC1	S	Ca-PSB	93.8	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, translucent, convex, moist, punctiform
JSC2	S	Ca-PSB	97.1	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC4	S	Ca-PSB	93.1	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC5 <sup>+</sup>	S	Ca-PSB	94.9	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC6	S	Ca-PSB	97.3	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, cream, convex, shiny, punctiform
JSC7	S	Ca-PSB	94.3	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC9	S	Ca-PSB	98.9	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC10 <sup>+</sup>	S	Ca-PSB	99.7	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC11	S	Ca-PSB	99.1	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC12	S	Ca-PSB	99.6	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC13 <sup>+</sup>	NS	Ca-PSB	99.8	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC14	NS	Ca-PSB	87.2	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, translucent, convex, shiny, punctiform
JSC15	NS	Ca-PSB	95.9	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC16	NS	Ca-PSB	99.8	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC17	NS	Ca-PSB	99.2	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC18	NS	Ca-PSB	87.6	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform

JSC19	NS	Ca-PSB	97.0	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC20	NS	Ca-PSB	97.9	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, iridescent, convex, moist, punctiform
JSC21	NS	Ca-PSB	95.9	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSC22 <sup>+</sup>	NS	Ca-PSB	99.9	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSA1 <sup>+</sup>	S	Al-PSB	98.9	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSA2	S	Al-PSB	99.1	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSA3	S	Al-PSB	99.8	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSA5 <sup>+</sup>	S	Al-PSB	99.9	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSA6	S	Al-PSB	98.9	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSA8	NS	Al-PSB	99.8	<i>Burkholderia</i> sp.	-	coccobacilli	entire, opaque, convex, moist, punctiform
JSA9	NS	Al-PSB	99.8	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSA10 <sup>+</sup>	NS	Al-PSB	98.6	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, iridescent, convex, shiny, punctiform
JSA12 <sup>+</sup>	NS	Al-PSB	99.9	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSA13	NS	Al-PSB	99.1	<i>Paraburkholderia</i> sp.	-	coccobacilli	entire, translucent, convex, shiny, punctiform
JSF7	S	SPB	99.9	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, translucent, convex, moist, round
JSF8 <sup>+</sup>	S	SPB	92.9	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, iridescent, convex, moist, round
JSF9	S	SPB	98.3	<i>Burkholderia</i> sp.	-	coccobacilli	entire, translucent, convex, moist, punctiform
JSF10 <sup>+</sup>	S	SPB	99.9	<i>Burkholderia</i> sp.	-	coccobacilli	entire, translucent, convex, shiny, punctiform
JSF11	NS	SPB	99.7	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, translucent, convex, moist, round

JSF12 <sup>+</sup>	NS	SPB	98.4	<i>Burkholderia</i> sp.	-	coccobacilli	entire, opaque, convex, moist, punctiform
JSF14	NS	SPB	83.6	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, brown, convex, shiny, punctiform
JSF15 <sup>+</sup>	NS	SPB	97.4	<i>Burkholderia</i> sp.	-	coccobacilli	entire, opaque, convex, shiny, punctiform
JSS1	S	APB	95.0	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, opaque, convex, moist, round
JSS2	S	APB	90.8	<i>Burkholderia</i> sp.	-	coccobacilli	entire, opaque, convex, shiny, punctiform
JSS3 <sup>+</sup>	S	APB	96.0	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, opaque, convex, moist, round
JSS4 <sup>+</sup>	S	APB	90.0	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, opaque, convex, moist, round
JSS5	S	APB	99.0	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, opaque, convex, moist, round
JSS6	S	APB	94.0	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, opaque, convex, moist, round
JSS7	NS	APB	100.0	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform
JSS8	NS	APB	96.6	<i>Burkholderia</i> sp.	-	coccobacilli	entire, translucent, convex, shiny, punctiform
JSS9	NS	APB	97.2	<i>Burkholderia</i> sp.	-	coccobacilli	entire, translucent, convex, moist, punctiform
JSS10	NS	APB	91.0	<i>Pseudomonas</i> sp.	-	coccobacilli	entire, translucent, convex, moist, round
JSS11 <sup>+</sup>	NS	APB	93.0	<i>Pseudomonas</i> sp.	-	coccobacilli	wavy, translucent, flat, shiny, irregular
JSS12	NS	APB	99.7	<i>Burkholderia</i> sp.	-	coccobacilli	entire, cream, convex, moist, punctiform

\*Ca-PSB: phosphate solubilization from tricalcium phosphate; Al-PSB: phosphate solubilization from aluminum phosphate; SPB: siderophore production based from yellow to orange halo zones; APB: arylsulfatase-producing bacteria observed based on the formation of blue colony

<sup>a</sup>Gregersen's method

<sup>b</sup>Observed in oil immersion objective

<sup>c</sup>Grown on Luria-Bertani agar and observed after 24 hours

<sup>+</sup>Isolates selected for multiple nutrient mobilization traits

Table S6. Characterization of top fifteen isolates with multiple nutrients mobilizing traits.

Isolate	Source	Bacterial Identity	Ca-PS	Al-PS	Siderophore	Arylsulfatase
JSC5	S	<i>Burkholderia</i> sp.	2.39±0.06	3.04±0.03	1.02±0.02	+
JSC10	S	<i>Burkholderia</i> sp.	2.55±0.07	3.79±0.09	1.00±0.00	+
JSC13	NS	<i>Burkholderia</i> sp.	2.90±0.08	3.71±0.09	1.49±0.02	+
JSC22	NS	<i>Burkholderia</i> sp.	2.38±0.04	3.31±0.08	1.00±0.00	+
JSA1	S	<i>Burkholderia</i> sp.	2.74±0.04	4.42±0.08	1.51±0.02	++
JSA5	S	<i>Burkholderia</i> sp.	2.00±0.06	4.06±0.05	2.19±0.04	+
JSA10	NS	<i>Paraburkholderia</i> sp.	1.88±0.16	2.94±0.10	1.58±0.15	+
JSA12	NS	<i>Burkholderia</i> sp.	2.50±0.03	4.27±0.09	2.63±0.06	+
JSF8	S	<i>Pseudomonas</i> sp.	1.11±0.05	1.00±0.00	1.95±0.02	+
JSF10	S	<i>Burkholderia</i> sp.	1.06±0.05	1.00±0.00	2.70±0.04	+
JSF12	NS	<i>Burkholderia</i> sp.	2.25±0.03	3.64±0.06	2.06±0.06	+
JSF15	NS	<i>Burkholderia</i> sp.	1.00±0.00	2.78±0.04	2.42±0.02	+
JSS3	S	<i>Pseudomonas</i> sp.	1.15±0.01	1.00±0.00	1.69±0.04	++
JSS4	S	<i>Pseudomonas</i> sp.	1.06±0.05	1.00±0.00	1.59±0.02	++
JSS11	NS	<i>Pseudomonas</i> sp.	1.72±0.24	1.32±0.01	2.13±0.09	++

Ca-PS: phosphate solubilization index from tricalcium phosphate; Al-PS: phosphate solubilization index from aluminum phosphate; Siderophore: siderophore production index based from yellow to orange halo zones; Arylsulfatase: observed based on the formation of blue colony