

Nano-silicon enhances tomato growth and antioxidant defense under salt stress

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Tomato seed germination experiment (preliminary experiment):

Tomato seeds (*Solanum lycopersicum* L.) were surface-sterilized using 10% NaClO solution for 10 min and subsequently washed several times with sterile water. The seeds under above treatments were placed on a petri dish that was lined two layers of circular filter paper (NaCl 150mM). Then eight doses (0, 5, 50, 100, 200, 300, 400, 500 and 1000 mg·L⁻¹) of Na₂SiO₃·9H₂O (Na₂SiO₃) and silicon nanoparticles (SiNPs) were respectively added for 15 mL, 15 mL 100 mM NaCl solution was set as a control. Each treatment was repeated three times. 20 seeds were placed in each petri dish and incubated in a constant temperature incubator at 25 °C for 10 days, making sure damp filter paper all the time without solution accumulation when tilted. When the length of emergent radicle was ≥ 2 mm, the number of germinated seeds

was recorded every day, and samples collected for determination and calculation at 10 d.

Figures:

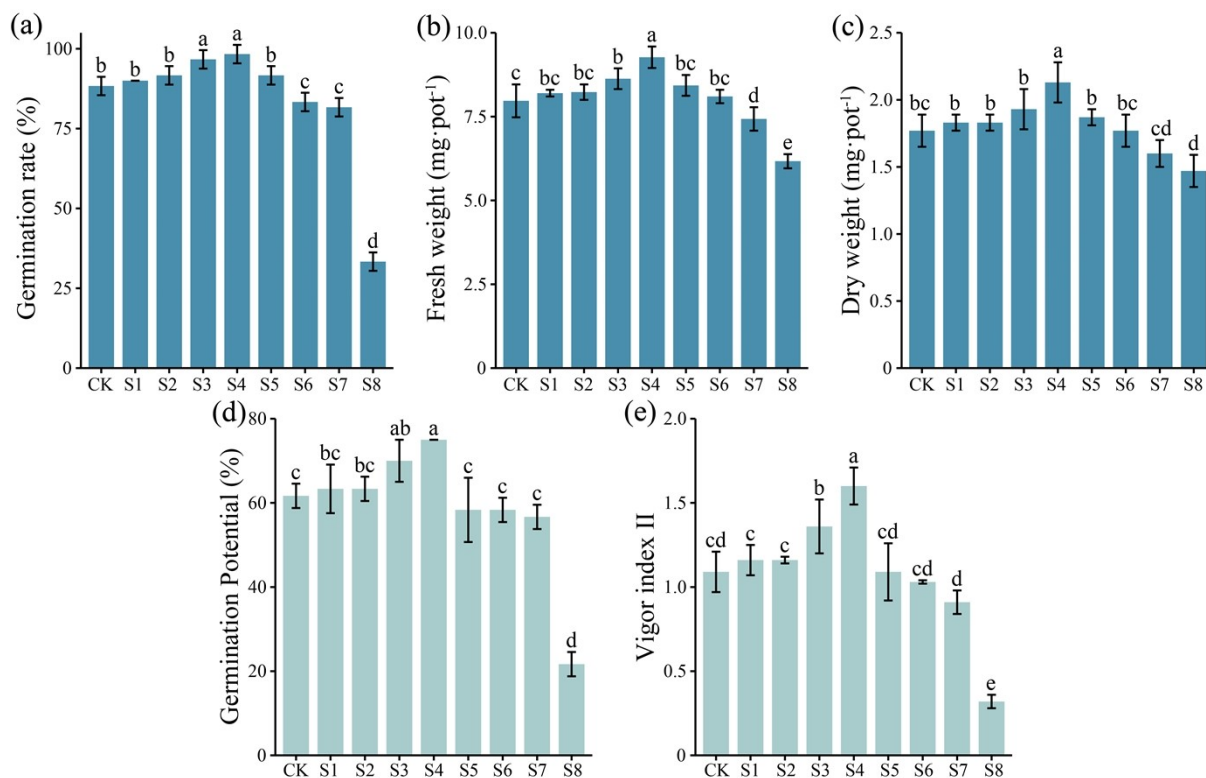


Fig. S1 The effects of different Si doses on germination rate (a), fresh weight (b), dry weight (c), germination potential (d) and vigor index II (e) of tomato seeds. CK, 100 mM NaCl; S1, 5 mg·mL⁻¹ Na₂SiO₃; S2, 50 mg·mL⁻¹ Na₂SiO₃; S3, 100 mg·mL⁻¹ Na₂SiO₃; S4, 200 mg·mL⁻¹ Na₂SiO₃; S5, 300 mg·mL⁻¹ Na₂SiO₃; S6, 400 mg·mL⁻¹ Na₂SiO₃; S7, 500 mg·mL⁻¹ Na₂SiO₃; S8, 1000 mg·mL⁻¹ Na₂SiO₃. The data are the mean values + SD of three individual replications, and different letters show significant differences ($P < 0.05$).

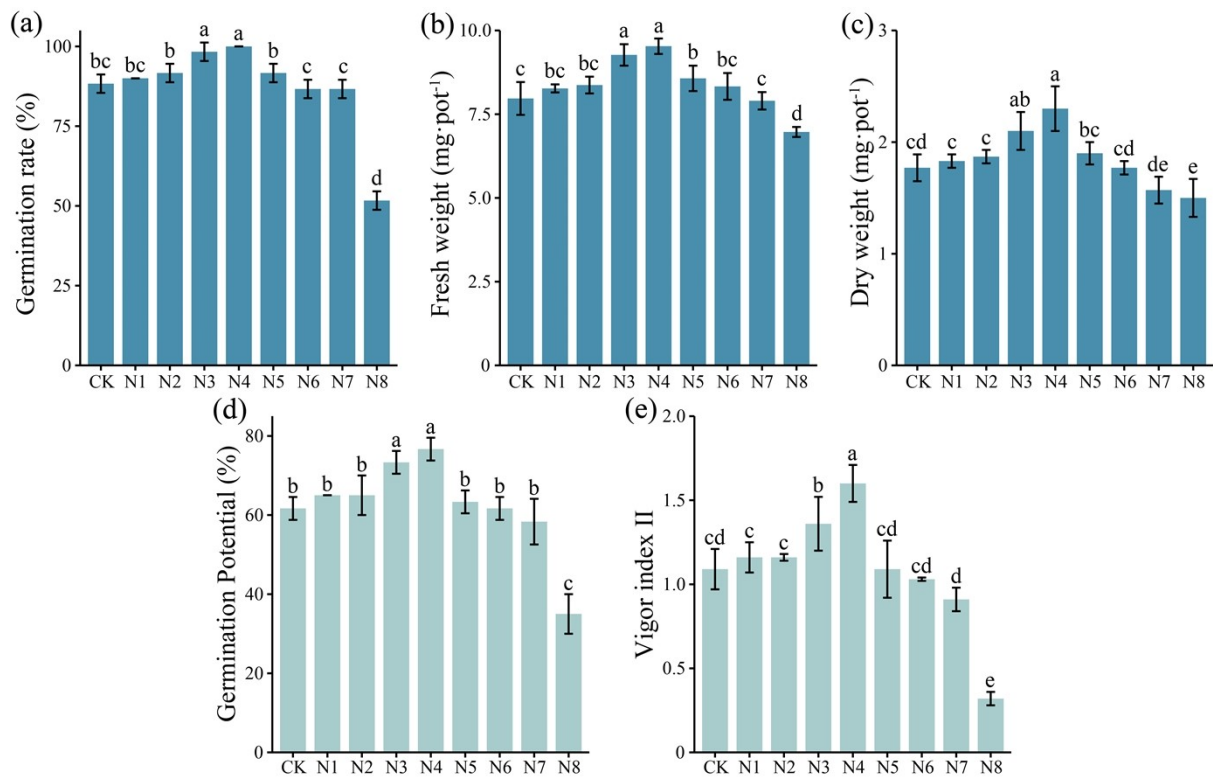


Fig. S2 The effect of different SiNPs doses on germination rate (a), fresh weight (b), dry weight (c), germination potential (d) and vigor index II (e) of tomato seeds. CK, 100 mM NaCl; N1, 5 mg·mL⁻¹ SiNPs; N2, 50 mg·mL⁻¹ SiNPs; N3, 100 mg·mL⁻¹ SiNPs; N4, 200 mg·mL⁻¹ SiNPs; N5, 300 mg·mL⁻¹ SiNPs; N6, 400 mg·mL⁻¹ SiNPs; N7, 500 mg·mL⁻¹ SiNPs; N8, 1000 mg·mL⁻¹ SiNPs. The data are the mean values + SD of three individual replications, and different letters show significant differences ($P < 0.05$).

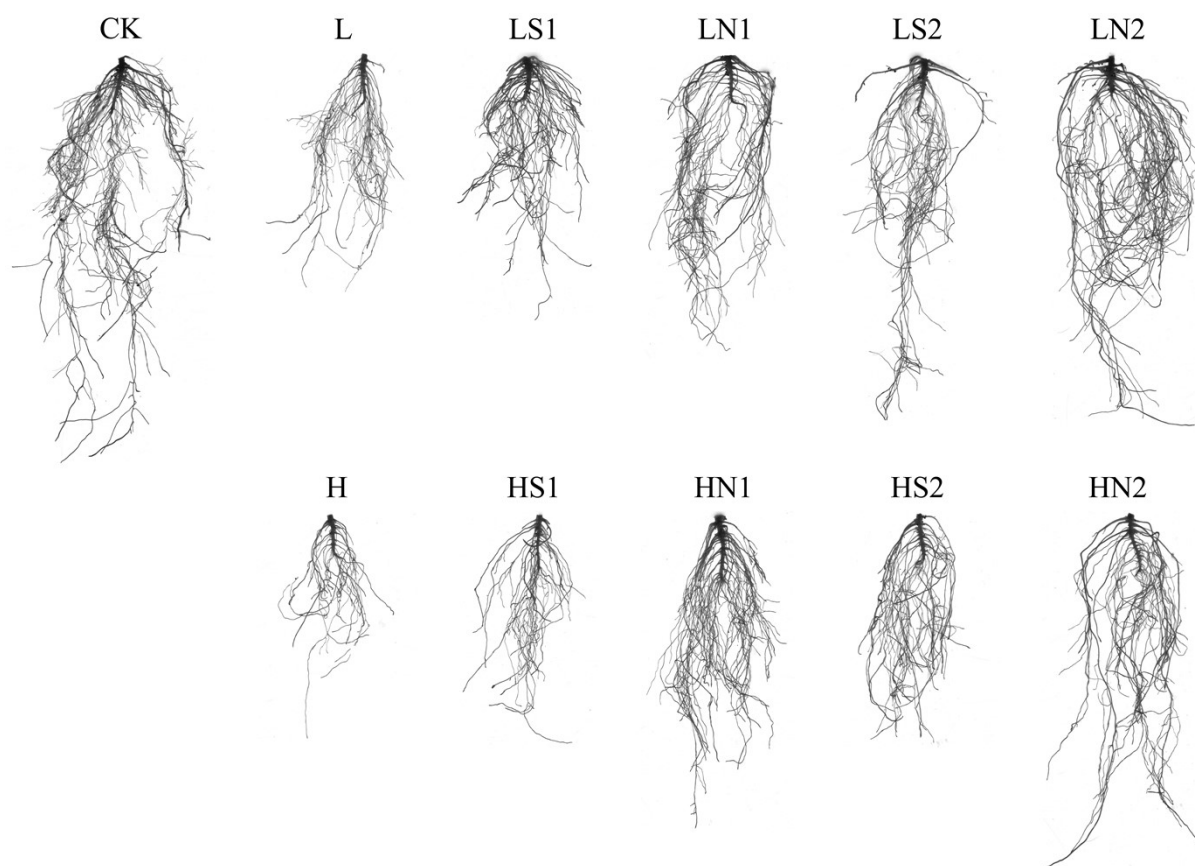


Fig. S3 Effects of Na_2SiO_3 and SiNPs at two different concentrations (100 and 200 $\text{mg}\cdot\text{L}^{-1}$) on root morphology of tomato plants under salt stress.

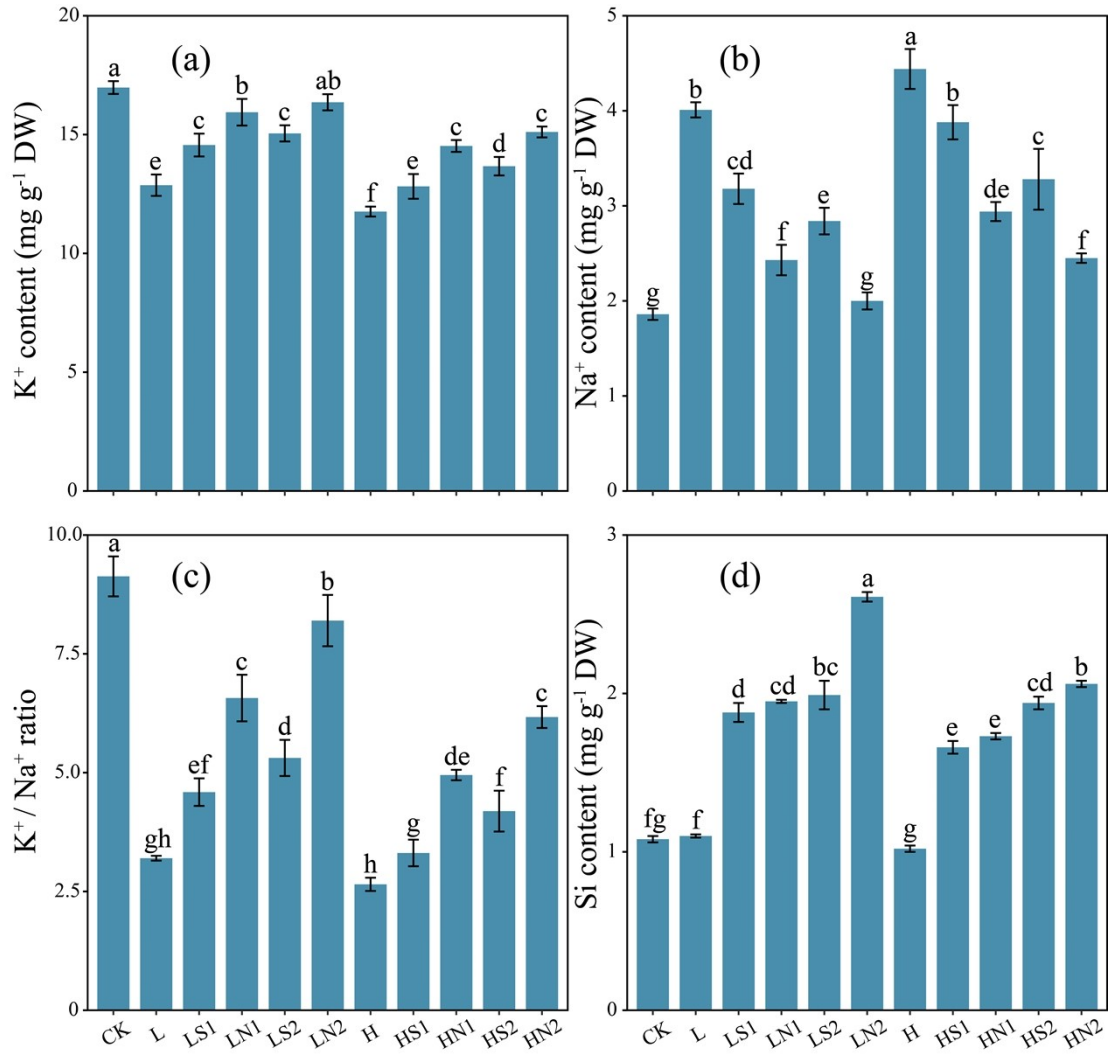


Fig. S4 Effects of Na_2SiO_3 and SiNPs at two different concentrations (100 and 200 $\text{mg}\cdot\text{L}^{-1}$) on the contents of Na^+ , K^+ and Si in tomato seedlings. (a) K^+ content; (b) Na^+ content; (c) K^+ / Na^+ ratio; (d) Silicon content. The data were the mean values + SD of three individual replications, and different letters show significant differences ($P < 0.05$).

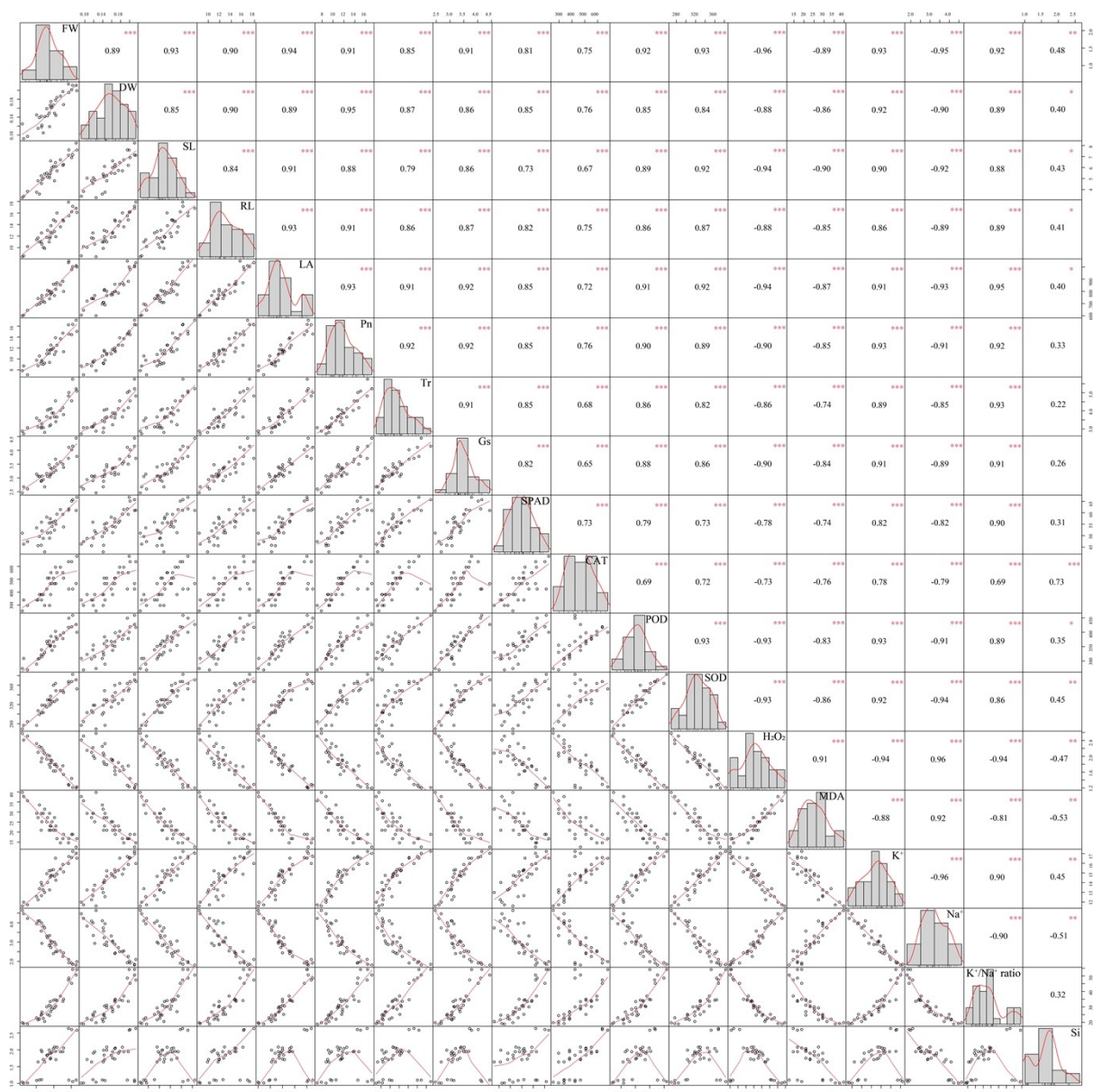


Fig. S5 Correlation analysis between tomato growth parameters, antioxidant system and the contents of Na⁺, K⁺, Si. FW, fresh weight; DW, dry weight; SL, shoot length; RL, root length; LA, leaf area; Pn, net photosynthetic rate; Tr, transpiration rate; Gs, stomatal conductance; SPAD, chlorophyll content (SPAD); CAT, catalase activity; POD, peroxidase activity; SOD, superoxide dismutase activity; H₂O₂, hydrogen peroxide content; MDA, malondialdehyde content. The number in the figure represent the correlation coefficients, *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Tables:

Table S1. Calculation method of tomato seed germination parameters.

Germination character	Unit	Formula	Description
Germination rate	%	$\frac{G_{10}}{TNP} * 100$	G_{10} = 10 d number of germinated seeds TNP = total number of planted seeds
Germination potential	%	$\frac{G_3}{TNP} * 100$	G_3 = 3 d number of germinated seeds TNP= total number of planted seeds
Vigor index II	-	$\frac{SDM * GP}{100}$	SDM=seedling dry mass (g) GP = Germination Potential (%).

Table S2. Primers used for qRT-PCR analysis in the present study.

Gene name	Forward primer (5' to 3')	Reverse primer (5' to 3')
<i>SlActin</i>	GGGATGGAGAAGTTTGGTGGTG G	CTTCGACCAAGGGATGGTGTAGC
<i>SICAT</i>	CGCATACGACACCCCTTTC	CGGAGAAAATCAGCACAAGTAA G
<i>SIPOD</i>	CTTGCCCTAATGCTCTCACC	GCATCACAACCCTGAACAAA
<i>SISOD</i>	TCACCACAACCAGCACTACCA	AGTGACAACCCCTCAACATTAG
<i>SISPDS2</i>	CTTTGGCCTGGGGAAGCAC	ATCCAAAACAAGCACCTTCCCA
<i>SINHXI</i>	GGATGGGAAGGAGAATAATG	TGATGTAGGAGGTTGAGAG

<i>SINHX2</i>	ATACAGAAACCAGCATTAGGGC	CAAGGTAAACCAGAATGCCAGT
<i>SILsi1</i>	ATGGAGTTTTTGAGTCTTCTGC	GCTGCGTTTCTGGCTTAGG

Table S3. The effects of Na₂SiO₃ and SiNPs on root basic indicators of tomato seedlings.

Treatments	Total root length (cm)	Root surface area (cm ²)	Root volume (cm ³)	Mean root diameter (mm)
CK	982.72 ± 29.00 b	355.48 ± 13.31 b	10.94 ± 0.36 b	1.01 ± 0.06 bc
L	546.33 ± 30.87 f	187.50 ± 8.24 f	4.67 ± 0.16 g	0.68 ± 0.02 g
LS1	625.02 ± 26.37 e	224.99 ± 12.35 e	5.47 ± 0.18 ef	0.97 ± 0.01 cd
LN1	841.35 ± 36.40 a	280.71 ± 9.90 c	6.28 ± 0.10 d	1.04 ± 0.02 b
LS2	702.55 ± 19.63 d	248.14 ± 9.00 d	5.63 ± 0.21 e	0.99 ± 0.01 cd
LN2	1168.55 ± 27.24 a	391.36 ± 12.61 a	12.20 ± 0.57 a	1.10 ± 0.03 a
H	399.15 ± 15.20 g	150.69 ± 10.72 g	3.68 ± 0.30 h	0.60 ± 0.03 h
HS1	512.33 ± 23.75 f	175.87 ± 7.98 f	4.77 ± 0.28 g	0.89 ± 0.02 f
HN1	677.64 ± 29.21 d	214.07 ± 15.70 e	6.17 ± 0.34 d	0.95 ± 0.01 de
HS2	609.53 ± 10.96 e	186.42 ± 10.03 f	5.08 ± 0.20 fg	0.91 ± 0.04 ef
HN2	876.81 ± 20.56 c	261.65 ± 7.81 d	8.18 ± 0.34 c	1.00 ± 0.01 bcd

The data were the mean values + SD of three individual replications, and different letters showed significant differences ($P < 0.05$).

Table S4. The effects of Na₂SiO₃ and SiNPs on root architecture parameters of tomato seedlings.

Treatments	Root links	Root tips	Root forks	Fractal dimension
CK	4521.67 ± 106.81 b	726.33 ± 31.26 b	2584.67 ± 73.10 b	1.72 ± 0.02 b
L	3062.67 ± 159.52 f	403.33 ± 27.57 f	1466.00 ± 57.38 f	1.48 ± 0.02 f
LS1	3477.00 ± 169.50 e	451.00 ± 14.42 de	1814.33 ± 58.07 d	1.59 ± 0.03 d
LN1	4368.00 ± 107.09 bc	584.33 ± 21.59 c	1978.67 ± 71.22 c	1.66 ± 0.02 c
LS2	3618.67 ± 205.95 e	479.00 ± 18.25 d	1922.33 ± 68.07 c	1.60 ± 0.02 d
LN2	5729.33 ± 195.59 a	900.00 ± 41.94 a	2710.33 ± 28.75 a	1.76 ± 0.01 a
H	2682.00 ± 149.90 g	341.00 ± 20.66 g	1334.33 ± 47.86 g	1.40 ± 0.03 g
HS1	3084.00 ± 139.54 f	416.00 ± 32.60 ef	1662.67 ± 46.92 e	1.52 ± 0.03 e
HN1	4040.00 ± 97.53 d	485.67 ± 13.32 d	1807.67 ± 47.35 d	1.60 ± 0.02 d
HS2	3422.67 ± 222.32 e	432.00 ± 18.36 ef	1717.00 ± 59.86 de	1.57 ± 0.02 d
HN2	4114.67 ± 118.60 cd	595.00 ± 18.25 c	1984.67 ± 49.24 c	1.64 ± 0.02 c

The data are the mean values + SD of three individual replications, and different letters show significant differences ($P < 0.05$).