Electronic Supplementary Material (ESI) for Environmental Science: Nano.

Selenium nanomaterials induce flower enlargement and improve the nutritional quality of cherry tomatoes: pot and field experiment

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Text S1. Calculation of application amount of Se ENMs in field experiment.

The amounts of ENMs used in the field experiments is determined based on soil mass, which is calculated using the following formula:

$$M=\rho\times A\times h$$

Where M is the mass of soil, ρ is the soil density, A is the application area of Se ENMs, and h is the thickness of the soil. Once the mass of soil has been determined, the amount of Se ENMs applied can be determined.

Text S2. Mobile phase and instrument parameter settings of UPLC-ESI-QE.

Taproot extracts (5 μL, full loop injection) were separated on a Thermo Scientific UPLC Vanquish equipped with an HSS T3 column (100×2.1 mm, particle size 1.8 μm, Waters) at 35 ℃ with a flow rate of 0.35 ml/min and applying the following gradient: 0 min 95% A (0.1% formic acid), 5% B (99.9% Acetonitrile/0.1% formic acid); 1.5min 95% A, 5% B; 14 min 100% B; 15.5 min 100% B; 16 min 95% A, 5% B; 18 min 95% A, 5% B. Eluting compounds were detected from m/z 70 to 1050 using a Thermo Scientific UPLC Vanquish coupled to the Q Exactive Orbitrap (UPLC-ESI-QE) in positive and negative ion mode using the following instrument settings (Table S2). Data analysis was accomplished by using Compound Discoverer software 3.1.

Text S3. Observation of ovary wall.

Cherry tomatoes fruit were fixed in stationary liquid (formalin, acetic acid, and 70% alcohol (V: V: V) = 1:1:16) for at least 48 h. Fruit samples of 0.25 cm^2 were immersed in 70% ethanol overnight under vacuum. Then the samples were processed in the following order: gradient dehydrated in ethanol (85%, 95%, 100%, 2h), and hyalo-cleared (xylene, AR). Subsequently, the wax immersion was performed and the samples were then embedded in paraffin. 15 μm pieces were sectioned off with a Leica RM 2235 (Germany) rotary microtome. Images of cell layers in the ovary wall were captured by a fluorescence microscope (Nikon, Eclipse Ni, Japan).

Text S4. The dissolution experiment of resultant Se ENMs in soil.

The 20 mL soil suspension (water and soil (V/V) = 1:1) and 2 mL (20 $mg\cdot L^{-1}$) of Se ENMs suspension were mixed. Before sampling at 0, 6, 12, 24, 48, and 72 h, 6 mg of poly-aluminum chloride were added to the precipitated Se ENMs in each tube. After

centrifugating at 8000 rpm for 20 min, the supernatant was filtered by a 0.22 μm membrane, diluted 10 times with ultrapure water, and tested by ICP-MS.

Text S5. Measurement of carbohydrate.

The carbohydrate content of the cherry tomatoes plant was measured by the phenol method. Totally dried tomato leaves (0.2 g) and fruits (0.2 g) were ground. After boiling water bath with 5 mL ultrapure water for 15 min, the solutions were filtrated and diluted to 100 mL. H_2SO_4 (5 mL) was slowly added into the mixture (2 mL, 5% phenol solution and 1 mL diluted solution). The absorbance was determined at 490 nm when these solutions cooled to room temperature. Glucose standard curve: a series of concentrations (0, 20, 40, 60, 80 $\mu g \cdot mL^{-1}$) of glucose, and processed in the same way as the samples. $y = 0.0035x + 0.0687$ ($R^2 = 0.9921$), where x is the absorbance at 490 nm and y is the carbohydrates content ($\mu g \cdot g^{-1}$). The final content of carbohydrate is y/0.0002.

Text S6. Measurement of chlorophyll a and chlorophyll b.

Chlorophyll a and chlorophyll b of tomato leaves were measured and calculated as follows. Briefly, 40 mg of fresh leaves were ground into small pieces under liquid nitrogen and extracted with 80% acetone. The leaves were then water bath for 15 min at 68 ℃ and 4000g centrifugation for 15min. Liquid supernatant were measured at 663, 646 nm by a multifunctional microplate reader (Varioskan Lux, Thermo Scientific, Finland). The content of chlorophyll a and chlorophyll b were calculated according to the following equations: $Ca = 12.21A_{663}\text{-}2.81A_{646}$ (chlorophyll a), $Cb = 20.13A_{646}\text{-}5.03A_{663}$ (chlorophyll b).

Text S7. Observation of pollen vigor.

The observation of pollen vigor was carried out by using the fluorescein diacetate (FDA) stain method. Briefly, 2.4 mM FDA was dissolved in acetone and mixed with 0.5 M sucrose solution until the solution turned milky. Fresh pollen and FDA solution were mixed. Bright green fluorescing pollen was observed by using a fluorescence microscope (Nikon, Eclipse Ni, Japan).

Text S8. Economic comparison between Se ENMs and SeO_3^{2-} application.

The potential labor cost was not taken into account for the comparison of investment

between Se ENMs and SeO_3^{2-} application. The investment per hectare (C) of Se ENMs and SeO_3^{2-} fertilizer was calculated by the following equation:

$$C = V*W$$

where V is the price of materials; W is the mass of materials applied to cherry tomatoes; The mass of both Se ENMs and SeO_3^{2-} fertilizer applied to cherry tomatoes was based on the best performance concentration (75 $\mu g \cdot kg^{-1}$) of Se ENMs compared to control. Se ENMs were applied at 100g per hectare and SeO_3^{2-} applied at 200g (Se 100g) per hectare. The C value of Se ENMs and SeO_3^{2-} fertilizer were \$66.61 and \$229.7 per hectare, respectively.

The economic benefit (E) per hectare of Se ENMs and SeO_3^{2-} fertilizer were calculated by the following equation:

$$E = Y*M*R$$

where Y is the yield per hectare of cherry tomatoes in China; M is the average market price of cherry tomatoes in China; R is the production efficiency increase of cherry tomatoes. The yield of cherry tomatoes was 5.42 tons per hectare in this study, the average price of cherry tomatoes is \$393.7/ton. The yield increase rate of cherry tomatoes was 176.9% and 53.8% for Se ENMs and SeO_3^{2-} fertilizer, respectively. The E value for Se ENMs and SeO_3^{2-} fertilizer were \$3774.8 and \$1148.0 per hectare, respectively.

Table S1. Soil index.

Soil index	
pH	7.6
Redox potential (mV)	310.5
Electrical conductivity ($mS \cdot cm^{-1}$)	0.342
Total nitrogen ($g \cdot kg^{-1}$)	22.1 ± 1.02
Total phosphorus ($g \cdot kg^{-1}$)	0.4 ± 0.05
Total potassium ($g \cdot kg^{-1}$)	11.98 ± 0.38
Total Carbon ($g \cdot kg^{-1}$)	59.03 ± 1.62
Se ($mg \cdot kg^{-1}$)	0.14 ± 0.03
Rapidly available phosphorus ($mg \cdot kg^{-1}$)	130.76 ± 3.23
Rapidly available potassium ($mg \cdot kg^{-1}$)	29.49 ± 1.35
Organic matter ($g \cdot kg^{-1}$)	21.55 ± 1.21

Table S2. Q Exactive Orbitrap (UPLC-ESI-QE) instrument settings.

Parameter	Conditions
Global Settings	User role: Standard
	Use lock mass: off
	Chrom. Peak wi: 5s
Time	Method duration: 18 min
General	Runtime: 0 to 18 min
	Polarity: Positive/negative
	Exclusion: on
	Default charge: 1
Full mass	Resolution: 70,000
	AGC target: 1e6
	Maximum IT: 100ms
	Scan range: 70 to 1050 m/z
dd-MS2/dd-SIM	Resolution: 17500
	Maximum IT: 50ms
	Loop count: 7
	TopN: 8
	Isolation window: 1.5 m/z
	(N) CE/Stepped nce: 20, 40, 60
	AGC target: 5e4
dd setting	Minimum AGC: 8.00e3
	Inetnsity thresh: 1.6e5
	Dynamic exclus: 10.0 s

Table S3. Primer sequences used for the qRT-PCR of selected genes.

Gene name	Forward primer	Reverse primer

SlcodA	ATCGATACGCCGAAGCTGTT	TGGTCCTGCAGGTGCTCGCC
SlSUT1	TTCCATAGCTGCTGGTGTTC	TACCAGAAATGGGTCCACAA
SlCDKA1	AACCCCTGAATAGAACCAAATG	GTATGTGCCGTGATTGTCTG
SlWEE1	TCTTCTTCCGGGTCACTCCT	CAGAAGGACGACGTGTTGGA
SlIAA9	GCGCAGCCTTTGTGAAAGTT	TGCCAAGTGCATCAGAGAGT
SlCTD1	GGAGACTTGCCCTGTGATTTC	CACCTGCTTTCACACCGGA
SlCWINV	GGCAATTAACGACGAGGCAC	TGCCCATACTCCATGCATCC
SUT1;1	GATATTGCGATAGGGCCAGT	GCAAGACGCTGATACTCGTG
Actin	GGAACTTGAGAAGGAGCCTAAG	CAACACCAACAGCAACAGTCT

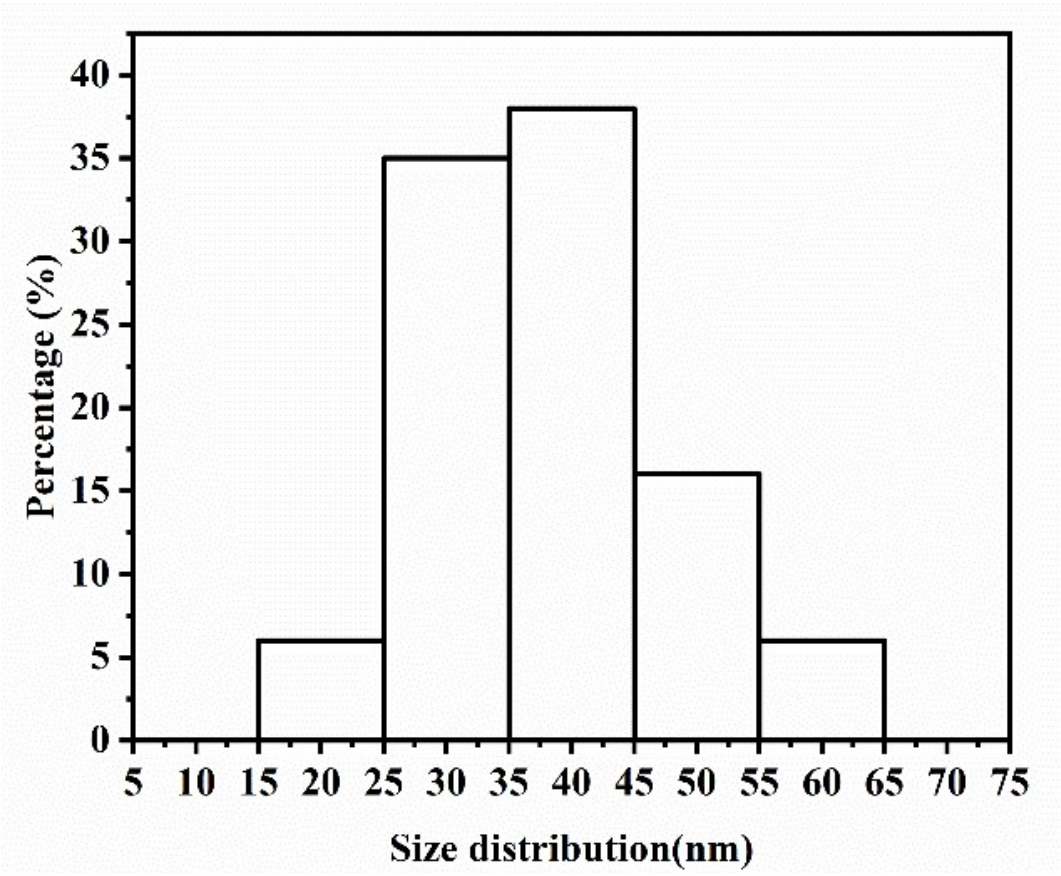

Fig. S1. Size distribution of Se ENMs.

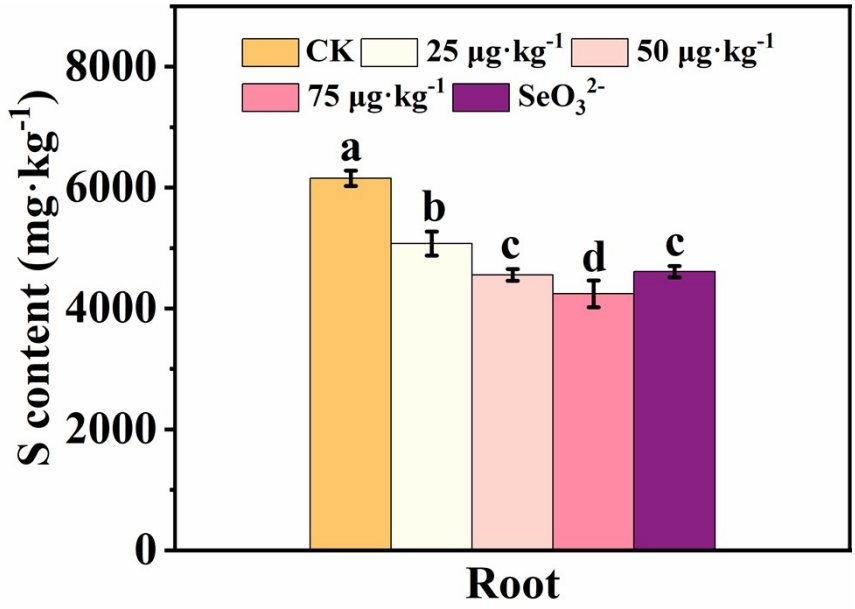

Fig. S2. The content of S in cherry tomatoes root.

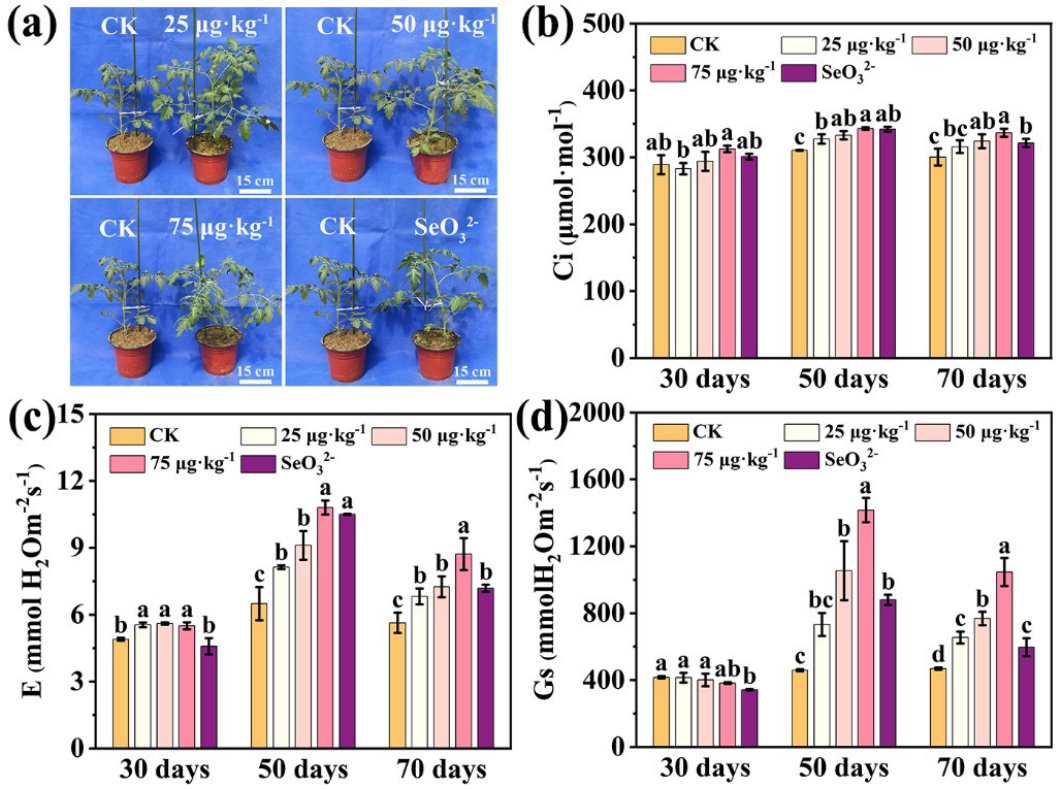

Fig. S3. (a) Flowering period images of cherry tomatoes under different treatment. (b) Intracellular CO_2 concentrations (Ci) of cherry tomatoes leaf; (c) Transpiration rate (E) of cherry tomatoes leaf; (d) Stomatal conductance (Gs) of cherry tomatoes leaf.

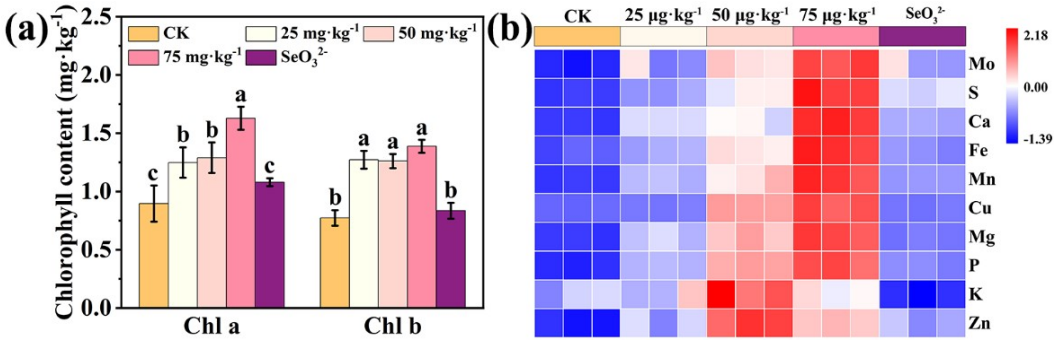

Fig. S4. (a) Chlorophyll a and b content of cherry tomatoes leaves. (b) Heat map of the variation for mineral elements in cherry tomatoes leaves.

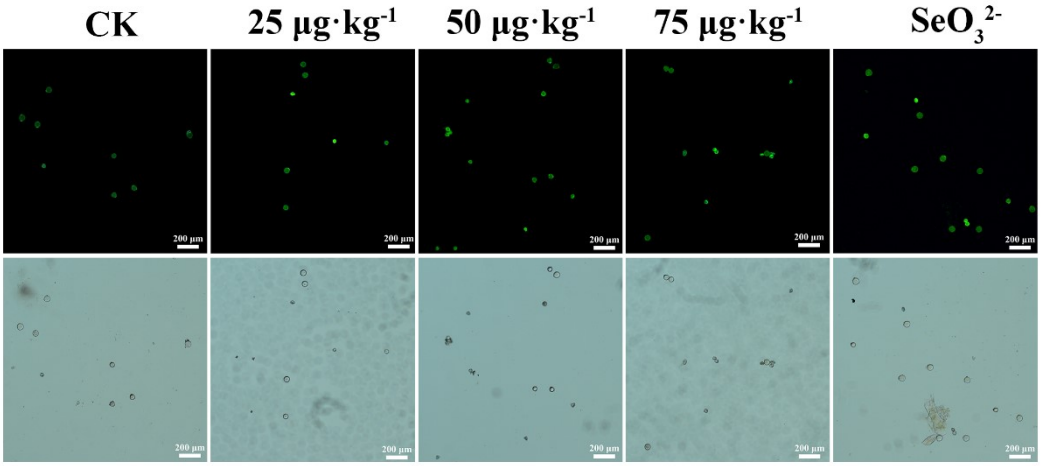

Fig. S5. Pollen vigor of cherry tomatoes upon different treatments.

Fig. S6. Images of cherry tomatoes flower upon different treatments.

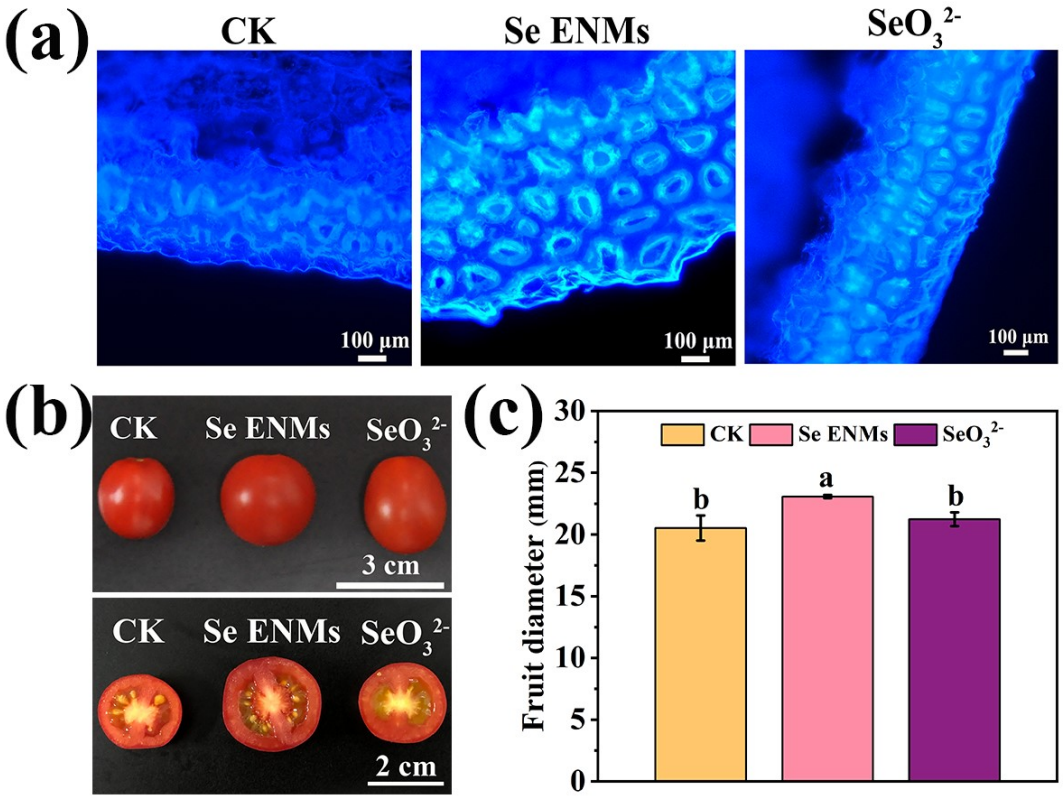

Fig. S7. Effects of Se ENMs (75 μg·kg^{-1}) and SeO_3^{2-} (75 μg·kg^{-1}) on cherry tomatoes fruit. (a) Images of cell layers on the pericarp; (b) Images of cherry tomatoes upon Se ENMs and SeO_3^{2-} exposure; (c) Fruit diameter of cherry tomatoes treated by Se ENMs and SeO_3^{2-}.

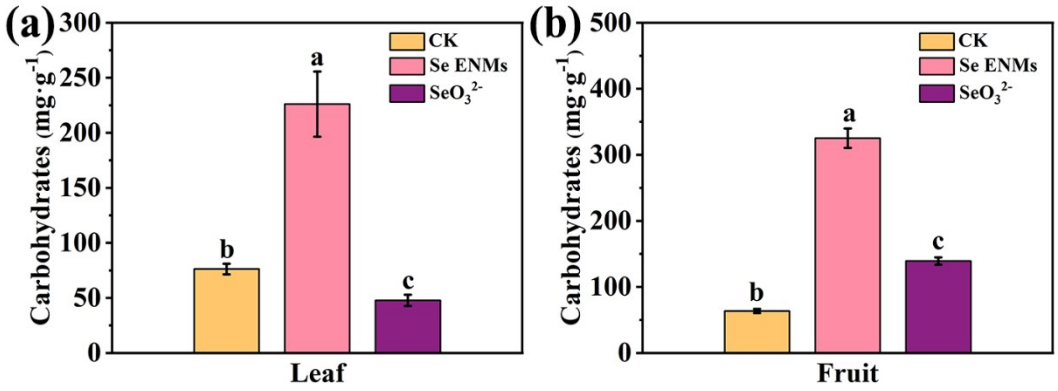

Fig. S8. Carbohydrate content in different plant tissues of cherry tomatoes upon different treatments. (a) Leaf carbohydrates; (b) Fruit carbohydrates.

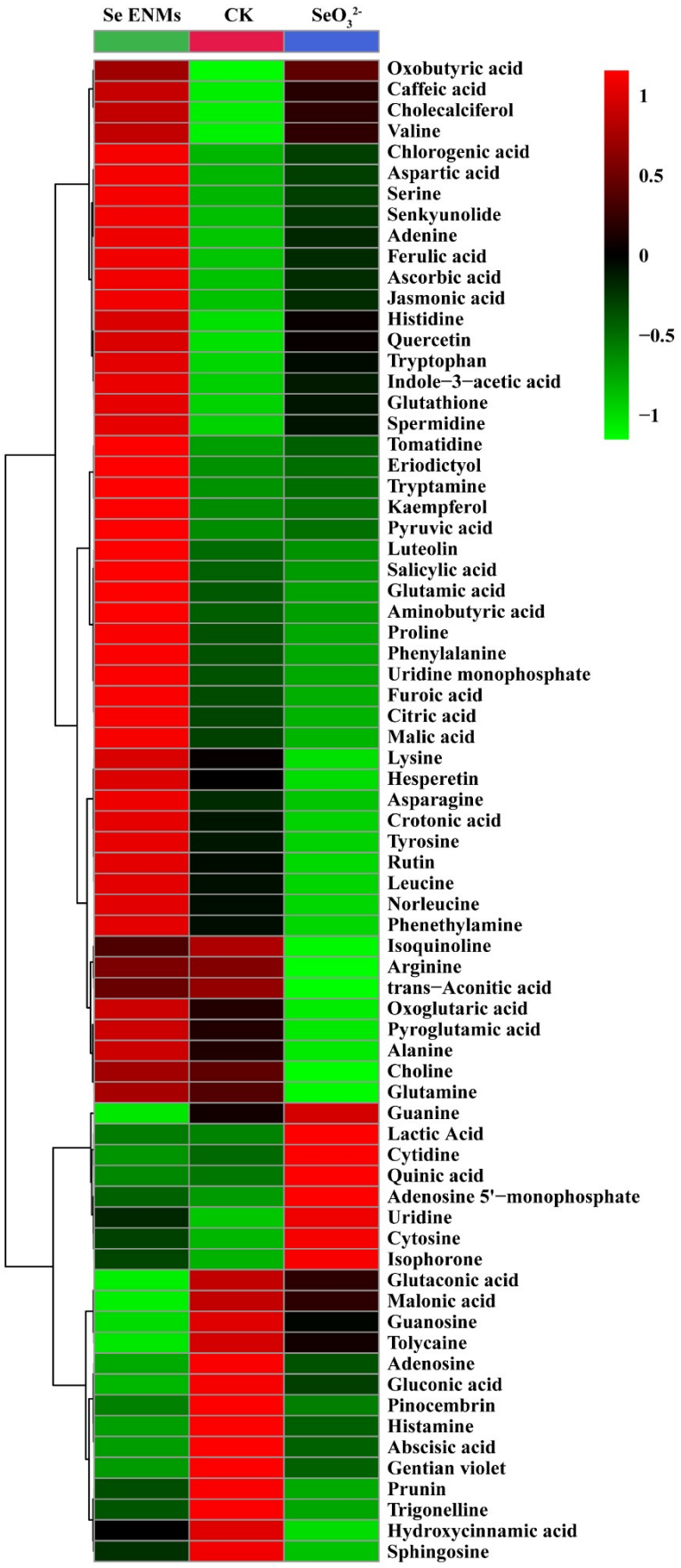

Fig. S9. Heat map of cherry tomatoes fruit metabolites.

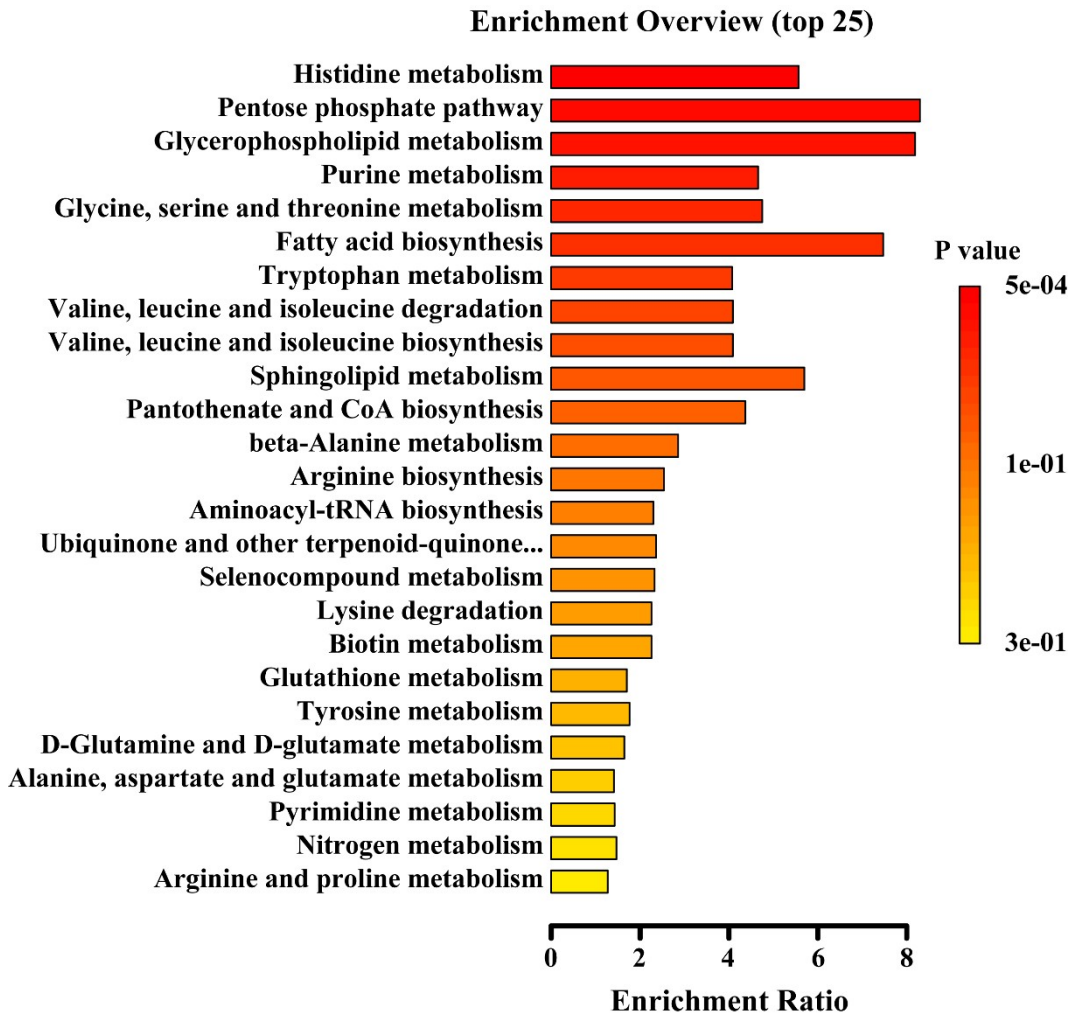

Fig. S10. Pathway enrichment analysis of cherry tomatoes metabolites.

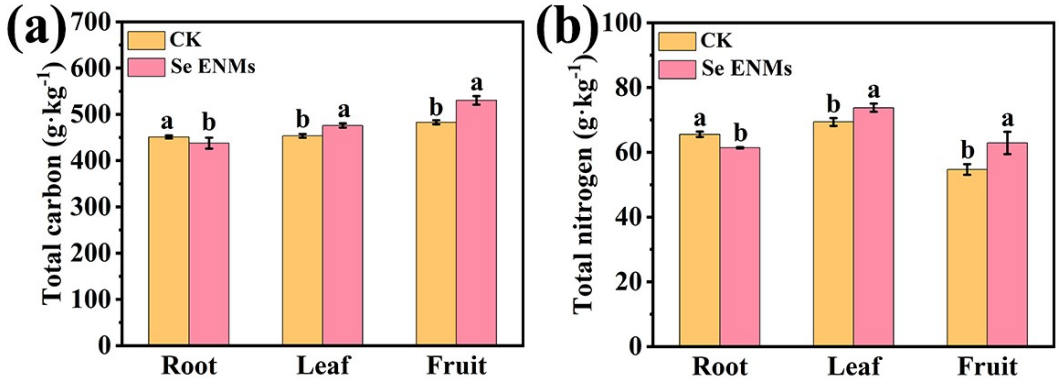

Fig. S11. C and N content of different cherry tomatoes tissues. (a)Total carbon; (b) Total nitrogen

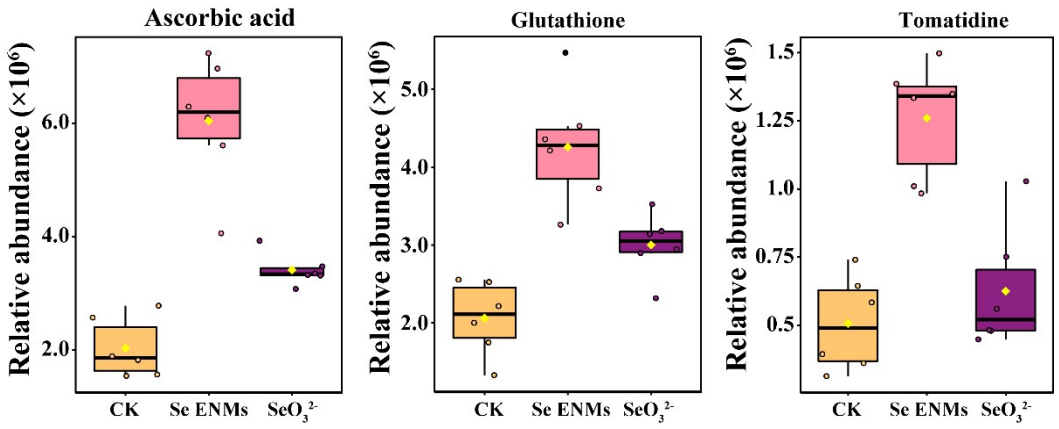

Fig. S12. Ascorbic acid, glutathione and tomatidine content of cherry tomatoes fruit.

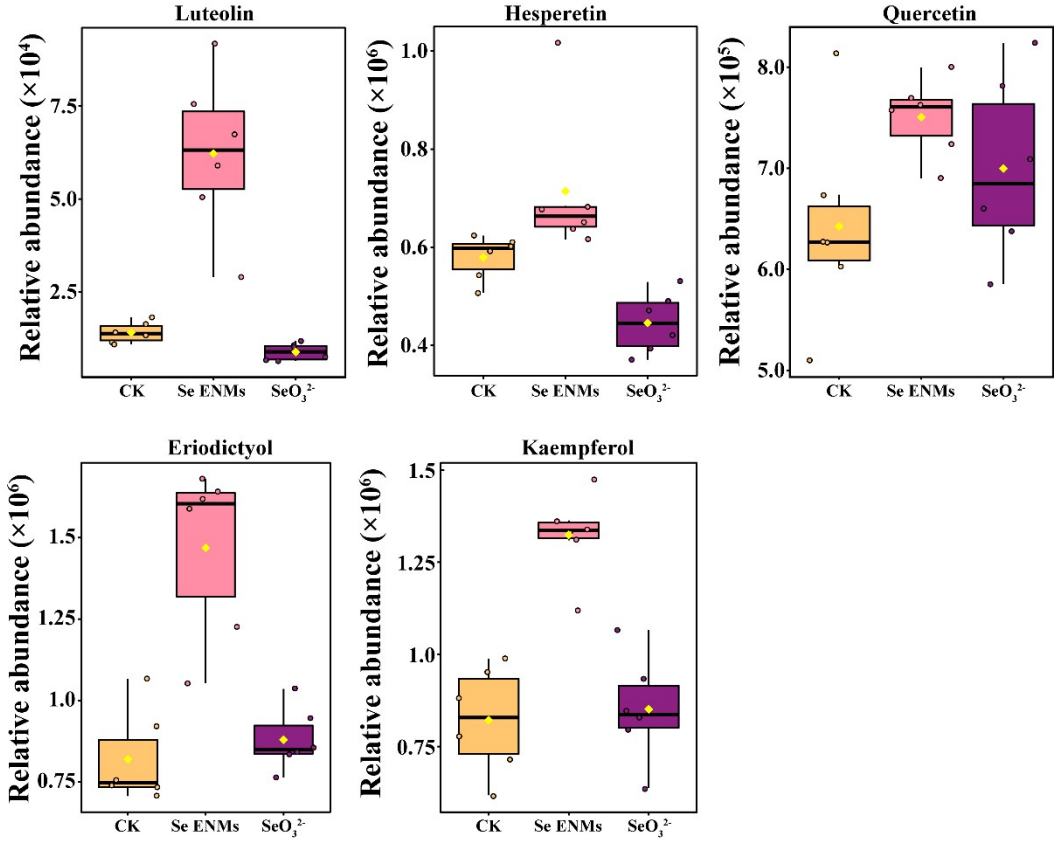

Fig. S13. Change of flavonoids in cherry tomatoes fruit.

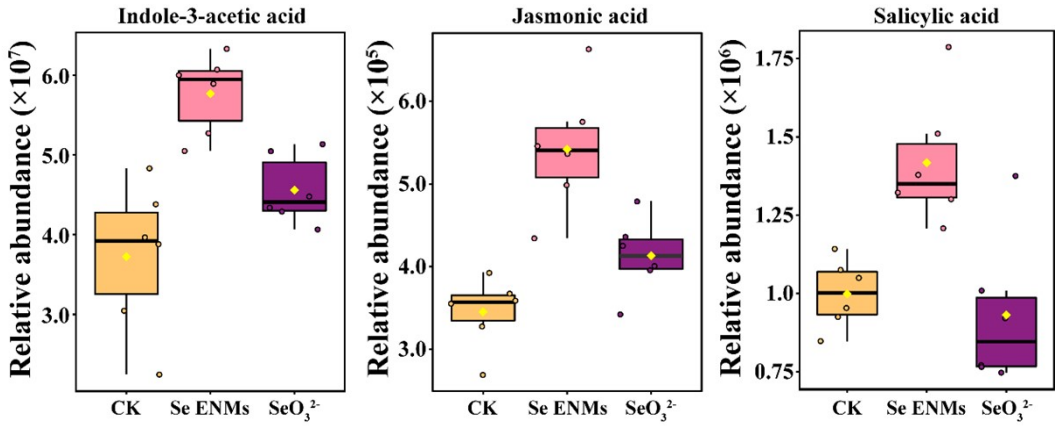

Fig. S14. IAA (indole-3-acetic acid), jasmonic acid and salicylic acid content of cherry tomatoes fruit.

Fig. S15. (a)Field experiment scene and (b) cherry tomatoes fruit image.

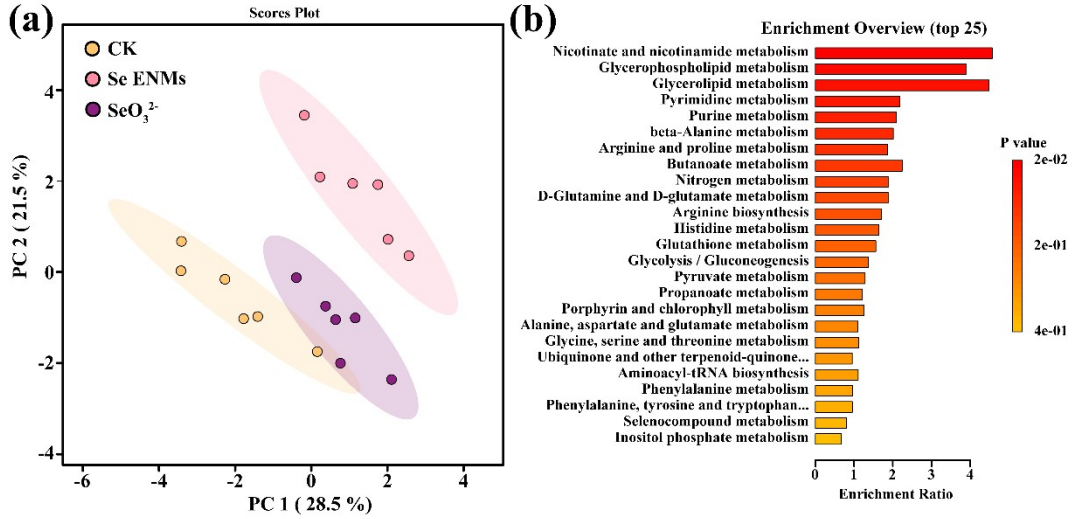

Fig. S16. (a) PCA analysis; (b) KEGG pathway enrichment results.

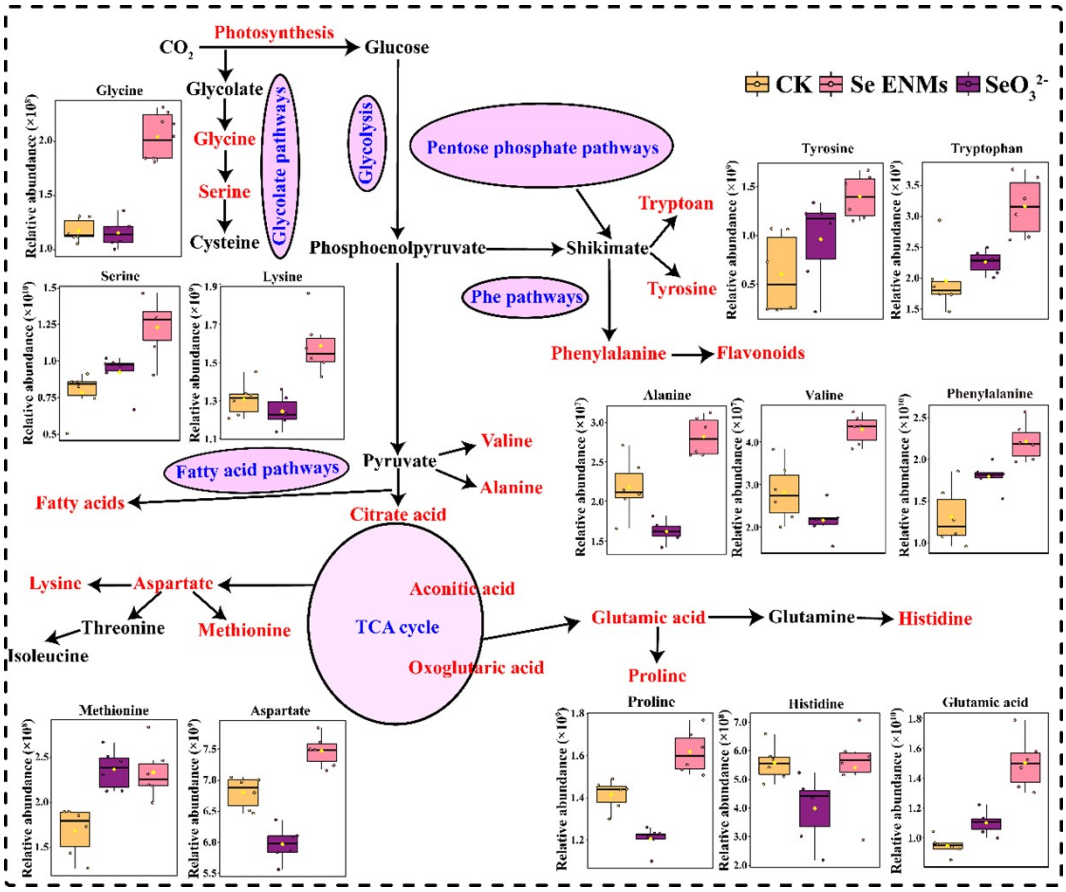

Fig. S17. Changes in metabolism pathways of cherry tomatoes fruit under Se ENMs treatment.

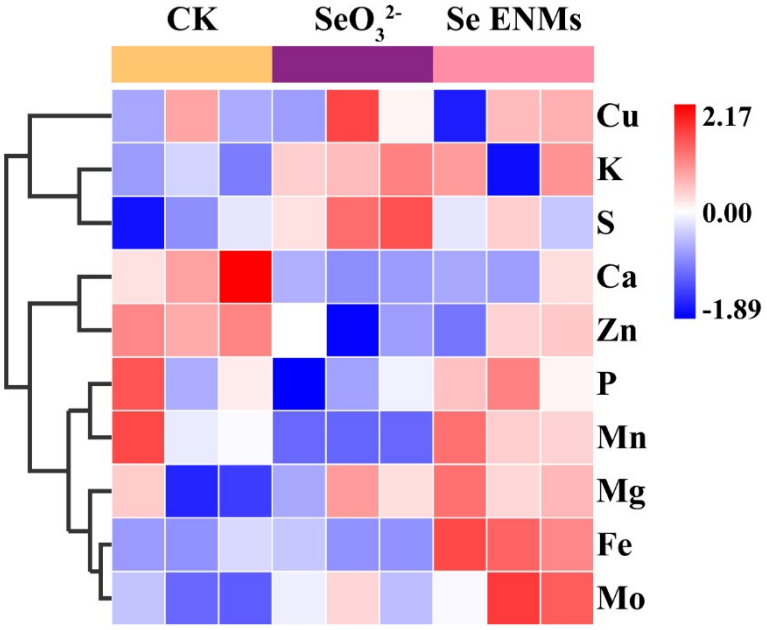

Fig. S18. The relative abundance of macronutrients and micronutrients in cherry tomatoes fruit (field experiment).

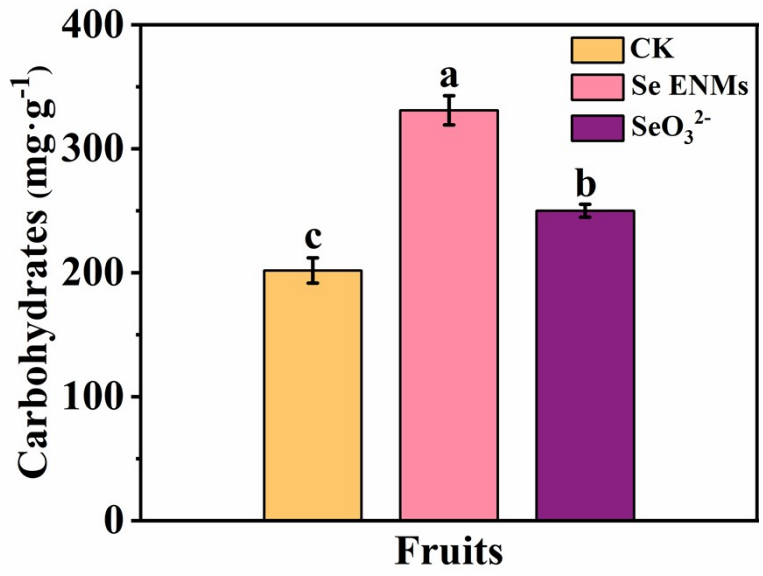

Fig. S19. Carbohydrate content in cherry tomato fruits upon different treatments.