# Supplementary Material

**Table S1.** Distribution of soil pH in citrus orchard of Xiangshan County.

| Index | Region（Sample number） | Range | Average | Distribution frequency (%) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | <4.5 | 4.5-5.5 | 5.5-6.5 | 6.5-7.5 | >7.5 |
| pH | Whole county (62) | 3.90-8.60 | 5.46 | 33.87 | 32.26 | 9.68 | 3.23 | 20.97 |
| | Mountain land (32) | 3.90-6.30 | 4.48 | 25.81 | 22.58 | 3.23 | 0.00 | 0.00 |
| | Flat land (14) | 3.90-6.20 | 4.86 | 8.06 | 9.68 | 4.84 | 0.00 | 0.00 |
| | Coastal saline-alkaline land (16) | 6.30-8.60 | 7.96 | 0.00 | 0.00 | 1.61 | 3.23 | 20.97 |

**Table S2.** Distribution of soil organic matter in citrus orchard of Xiangshan County.

| Index | Region（Sample number） | Range ($g \cdot kg^{-1}$) | Average ($g \cdot kg^{-1}$) | Distribution frequency (%) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | <5 | 5-10 | 10-15 | 15-30 | >30 |
| SOM | **Whole county (62)** | 8.98-47.90 | 22.73 | 0.00 | 1.61 | 11.29 | 72.58 | 14.52 |
| | **Mountain land (32)** | 12.20-47.90 | 25.64 | 0.00 | 0.00 | 1.61 | 38.71 | 11.29 |
| | **Flat land (14)** | 14.40-46.90 | 22.47 | 0.00 | 0.00 | 1.61 | 17.74 | 3.23 |
| | **Coastal saline-alkaline land (16)** | 8.98-27.70 | 17.12 | 0.00 | 1.61 | 8.06 | 16.13 | 0.00 |

**Table S3.** Macro-elements (N, P, and K) content and percentage for classification of citrus orchard in Xiangshan County.

| Index | Region（Sample number） | Range (g·kg-1) | Average (g·kg$^{-1}$) | Percentage for classification (%) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Extreme Deficiency | Deficiency | Optimum | High | Excess |
| TN | Whole county (62) | 0.54-2.97 | 1.25 | 11.29 | 25.81 | 37.10 | 17.74 | 8.06 |
| | Mountain land (32) | 0.54-2.97 | 1.33 | 6.45 | 11.29 | 17.74 | 9.68 | 6.45 |
| | Flat land (14) | 0.66-2.14 | 1.34 | 1.61 | 4.84 | 8.06 | 6.45 | 1.61 |
| | Coastal saline-alkaline land (16) | 0.63-1.50 | 1.03 | 3.23 | 9.68 | 11.29 | 1.61 | 0.00 |
| TP | Whole county (62) | 0.11-1.91 | 0.71 | 67.74 | 19.35 | 11.29 | 0.00 | 0.00 |
| | Mountain land (32) | 0.11-1.53 | 0.64 | 37.10 | 6.45 | 8.06 | 0.00 | 0.00 |
| | Flat land (14) | 0.11-1.50 | 0.72 | 12.90 | 6.45 | 3.23 | 0.00 | 0.00 |
| | Coastal saline-alkaline land (16) | 0.56-1.91 | 0.84 | 17.74 | 6.45 | 0.00 | 1.61 | 0.00 |
| TK | Whole county (62) | 12.20-38.60 | 21.37 | 0.00 | 22.58 | 61.29 | 9.68 | 6.45 |
| | Mountain land (32) | 12.20-38.60 | 21.78 | 0.00 | 11.29 | 29.03 | 4.84 | 6.45 |
| | Flat land (14) | 13.30-28.10 | 19.86 | 0.00 | 8.06 | 12.90 | 1.61 | 0.00 |
| | Coastal saline-alkaline land (16) | 17.50-26.20 | 21.84 | 0.00 | 3.23 | 19.35 | 3.23 | 0.00 |

**Table S4.** The Ca and Mg contents of soil in citrus orchard of Xiangshan County.

| Analysis index | Landform | Range ($g \cdot kg^{-1}$) | Mean ($g \cdot kg^{-1}$) | Variation Coefficient % |
|---|---|---|---|---|
| **Ca** | **Whole county** | 0.40-37.80 | 7.68 | 111.20 |
| | **Mountain land** | 0.40-20.00 | 3.14 | 123.44 |
| | **Flat land** | 0.80-7.60 | 4.16 | 48.06 |
| | **Coastal saline-alkaline land** | 7.30-37.80 | 19.81 | 35.20 |
| **Mg** | **Whole county** | 1.10-18.80 | 6.80 | 82.29 |
| | **Mountain land** | 1.10-12.10 | 3.31 | 77.57 |
| | **Flat land** | 2.10-11.90 | 5.21 | 61.24 |
| | **Coastal saline-alkaline land** | 11.80-18.80 | 15.16 | 10.74 |

**Table S5.** Soil available Fe, Mn, B contents and the percentage for classification of citrus orchard in Xiangshan County.

| Index | Region（Sample number） | Range (mg·kg$^{-1}$) | Average (mg·kg$^{-1}$) | Percentage for classification (%) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Extreme Deficiency | Deficiency | Optimum | High | Excess |
| AvFe | Whole county (62) | 10.50-259.00 | 71.75 | 0.00 | 0.00 | 16.13 | 29.03 | 54.84 |
| | Mountain land (32) | 17.30-152.00 | 69.52 | 0.00 | 0.00 | 8.06 | 11.29 | 32.26 |
| | Flat land (14) | 11.00-259.00 | 114.77 | 0.00 | 0.00 | 3.23 | 3.23 | 16.13 |
| | Coastal saline-alkaline land (16) | 10.50-104.00 | 36.23 | 0.00 | 0.00 | 4.84 | 14.52 | 6.45 |
| AvMn | Whole county (62) | 0.60-82.00 | 21.27 | 4.84 | 8.06 | 45.16 | 30.65 | 8.06 |
| | Mountain land (32) | 0.60-82.00 | 24.63 | 3.23 | 3.23 | 20.97 | 17.74 | 6.45 |
| | Flat land (14) | 1.50-88.00 | 20.40 | 1.61 | 4.84 | 4.84 | 9.68 | 1.61 |
| | Coastal saline-alkaline land (16) | 8.80-32.90 | 15.31 | 0.00 | 0.00 | 19.35 | 3.23 | 0.00 |
| AvB | Whole county (62) | 0.03-1.07 | 0.32 | 46.77 | 38.71 | 12.90 | 1.61 | 0.00 |
| | Mountain land (32) | 0.11-0.48 | 0.24 | 33.87 | 17.74 | 0.00 | 0.00 | 0.00 |
| | Flat land (14) | 0.03-0.55 | 0.27 | 11.29 | 9.68 | 1.61 | 0.00 | 0.00 |
| | Coastal saline-alkaline land (16) | 0.19-1.07 | 0.54 | 1.61 | 11.29 | 11.29 | 1.61 | 0.00 |

**Table S6.** The correlation between Beni Madonna and *C.unshiu* fruits and soil nutrients in Xiangshan County.

| | | pH | SOM | TN | TP | TK | Ca | Mg | AvFe | AvMn | AvB |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Beni Madonna** | **Ca** | -0.079 | 0.076 | -0.130 | 0.037 | 0.149 | -0.124 | 0.113 | -0.406 | 0.085 | -0.037 |
| | **Mg** | -0.144 | -0.222 | -0.189 | -0.403 | -0.068 | -0.050 | -0.009 | 0.216 | 0.405 | -0.040 |
| | **Zn** | 0.251 | -0.127 | 0.147 | -0.227 | 0.208 | -0.072 | 0.109 | 0.090 | -0.230 | 0.227 |
| | **Fe** | -0.658* | 0.660* | 0.598* | -0.285 | 0.054 | -0.638** | -0.500* | 0.294 | -0.312 | -0.168 |
| | **Mn** | -0.019 | -0.311 | -0.177 | 0.106 | -0.416 | 0.324 | 0.138 | -0.028 | 0.278 | -0.128 |
| | **Cu** | -0.031 | -0.315 | -0.147 | -0.303 | -0.290 | -0.144 | 0.179 | 0.121 | -0.034 | -0.150 |
| | **B** | 0.692** | -0.057 | -0.103 | 0.172 | 0.574* | 0.353 | 0.546* | -0.212 | -0.440 | 0.685** |
| ***C. unshiu*** | **Ca** | 0.437 | -0.444 | -0.290 | -0.032 | 0.104 | 0.447 | 0.385 | -0.311 | 0.043 | 0.179 |
| | **Mg** | -0.535* | 0.107 | -0.016 | 0.122 | -0.199 | -0.351 | -0.173 | 0.204 | -0.165 | -0.152 |
| | **Zn** | -0.237 | 0.401 | 0.010 | -0.137 | 0.513 | -0.205 | -0.465 | -0.112 | 0.178 | -0.169 |
| | **Fe** | 0.283 | 0.0306 | -0.018 | -0.579* | -0.004 | 0.125 | 0.095 | -0.336 | -0.183 | 0.293 |
| | **Mn** | -0.604* | 0.248 | -0.166 | -0.181 | 0.102 | -0.574* | -0.620* | -0.059 | 0.306 | -0.302 |
| | **Cu** | -0.018 | -0.129 | -0.354 | -0.252 | 0.292 | 0.109 | 0.048 | -0.014 | 0.312 | -0.367 |
| | **B** | -0.027 | -0.113 | -0.254 | 0.243 | 0.350 | -0.011 | -0.136 | -0.236 | 0.237 | 0.064 |

The correlation signigicant was indicated with asterisk,(* $P<0.05$,** $P<0.01$).

**Table S7.** The contents of soil total nutrients in different citrus orchards.

| Analysis index | MY | QT | DW | DY | XT |
|---|---|---|---|---|---|
| **TC (%)** | 2.84±0.01 a | 2.14±0.01 ab | 1.43±0.01 bc | 1.18±0.01 c | 1.27±0.01 c |
| **TN (g·kg$^{-1}$)** | 2.37±0.81 a | 1.99±0.26 ab | 1.29±0.17 bc | 1.01±0.17 c | 1.03±0.19 c |
| **K (g·kg$^{-1}$)** | 13.72±0.64 c | 18.70±0.27 a | 13.55±2.05 c | 17.13±0.71 ab | 15.73±0.37 bc |
| **Ca (g·kg$^{-1}$)** | 9.02±0.55 b | 2.10±0.30 c | 12.82±1.38 a | 13.55±1.25 a | 15.63±2.79 a |
| **Mg (g·kg$^{-1}$)** | 4.21±0.36 b | 3.70±0.37 b | 15.16±1.43 a | 14.45±1.51 a | 13.30±1.13 a |
| **Na (g·kg$^{-1}$)** | 2.40±0.34 d | 6.41±0.15 b | 9.62±0.43 a | 5.43±0.21 c | 9.23±0.31 a |
| **Zn (mg·kg$^{-1}$)** | 109.76±7.28 bc | 89.85±11.48 c | 138.95±15.83 a | 95.42±6.00 c | 120.59±16.23 ab |
| **Fe (g·kg$^{-1}$)** | 16.58±0.88 c | 9.22±0.26 d | 25.70±1.15 b | 24.41±0.69 b | 33.80±0.70 a |
| **Mn (mg·kg$^{-1}$)** | 399.12±25.13 b | 255.91±30.09 c | 930.27±95.92 a | 935.21±28.61 a | 913.30±9.42 a |
| **Cu (mg·kg$^{-1}$)** | 51.24±1.67 a | 15.37±0.55 e | 32.69±1.90 c | 26.32±1.11 d | 43.50±5.70 b |

The significant difference of different citrus orchards at $P < 0.05$ was indicated by small letters.

**Table S8.** The physical and chemical properties of soil in citrus orchards.

| Analysis index | MY | QT | DW | DY | XT | Suitable range |
|---|---|---|---|---|---|---|
| **pH** | 4.233±0.13 c | 4.46±0.13 b | 7.64±0.14 a | 7.57±0.16 a | 7.48±0.16 a | 5.5-6.5 |
| **EC ($ds \cdot m^{-1}$)** | 0.52±0.12 b | 0.61±0.05 b | 1.70±0.09 a | 1.85±0.42 a | 1.67±0.12 a | 0-2 |
| **SOM ($g \cdot kg^{-1}$)** | 36.39±9.18 b | 34.44±2.22 b | 19.94±2.35 c | 27.14±3.55 bc | 48.33±8.20 a | 15-30 |
| **AN ($mg \cdot kg^{-1}$)** | 255.72±35.02 a | 214.72±28.05 a | 111.009±19.97 b | 73.89±12.14 c | 85.49±15.77 c | 100-200 |
| **OP ($mg \cdot kg^{-1}$)** | 449.32±58.87 a | 120.51±13.32 b | 62.89±7.55 b | 98.90±10.34 b | 80.91±7.99 b | 15-80 |
| **AK ($mg \cdot kg^{-1}$)** | 416.67±41.70 e | 744.82±10.75 b | 511.86±66.14 d | 895.00±32.20 a | 626.72±14.73 c | 100-200 |
| **ExCa ($mg \cdot kg^{-1}$)** | 1015.43±91.35 d | 1033.59±113.44 d | 6113.42±546.77 a | 4156.65±314.96 c | 5565.24±461.41 b | 1000-2000 |
| **ExMg ($mg \cdot kg^{-1}$)** | 125.30±20.11 d | 270.26±26.99 c | 470.38±34.25 a | 450.11±47.98 a | 390.36±31.06 b | 150-300 |
| **AvZn ($mg \cdot kg^{-1}$)** | 6.90±0.57 a | 1.46±0.23 cd | 2.55±0.30 b | 1.40±0.13 d | 1.95±0.17 c | 1.0-5.0 |
| **AvFe ($mg \cdot kg^{-1}$)** | 107.35±11.49 a | 12.33±1.07 b | 9.36±1.1 b | 9.72±1.49 b | 8.38±1.76 b | 10-20 |
| **AvMn ($mg \cdot kg^{-1}$)** | 14.247±1.09 a | 7.72±0.47 b | 5.38±0.66 c | 5.71±0.90 c | 4.52±0.67 c | 5-20 |
| **AvCu ($mg \cdot kg^{-1}$)** | 7.71±0.66 a | 0.22±0.03 d | 1.39±0.15 c | 2.02±0.21 b | 1.78±0.33 bc | 0.5-1.0 |
| **AvB ($mg \cdot kg^{-1}$)** | 0.16±0.04 cd | 0.10±0.03 d | 0.60±0.06 a | 0.30±0.08 b | 0.25±0.05 bc | 0.5-1.0 |

The significant difference of different citrus orchards at $P < 0.05$ was indicated by small letters.

Table S9. The mineral nutrient levels in leaves of Beni Madonna.

| Analysis index | MY | QT | DW | DY | XT | Suitable range |
|---|---|---|---|---|---|---|
| **K (g·kg$^{-1}$)** | 14.02±1.10 bc | 13.04±0.72 c | 16.26±2.14 a | 10.49±1.33 d | 15.45±1.30 ab | 10-15 |
| **Ca (g·kg$^{-1}$)** | 8.52±0.93 c | 16.95±2.67 b | 19.52±2.62 a | 14.97±2.03 b | 21.17±2.80 a | 30-50 |
| **Mg (mg·kg$^{-1}$)** | 2340.30±260.96 ab | 2079.47±167.40 b | 2438.61±296.97 a | 2412.23±249.44 ab | 1731.16±134.04 c | 3000-5000 |
| **Zn (mg·kg$^{-1}$)** | 26.26±2.83 b | 38.16±1.56 a | 25.29±2.78 b | 22.80±2.64 b | 21.74±3.35 b | 25-100 |
| **Fe (mg·kg$^{-1}$)** | 72.25±6.01 a | 61.56±8.61 a | 48.03±6.57 b | 41.25±5.66 b | 46.90±5.30 b | 60-120 |
| **Mn (mg·kg$^{-1}$)** | 124.17±11.21 a | 40.58±0.55 b | 37.23±3.05 b | 37.24±4.87 b | 22.96±3.82 c | 25-100 |
| **Cu (mg·kg$^{-1}$)** | 16.38±1.52 a | 10.45±0.54 b | 10.09±1.32 b | 3.27±0.79 c | 10.69±0.54 b | 6-16 |
| **B (mg·kg$^{-1}$)** | 108.78±12.15 ab | 104.76±11.54 b | 129.74±16.21 a | 117.03±9.46 ab | 105.45±4.85 b | 35-100 |

The significant difference of different citrus orchards at $P < 0.05$ was indicated by small letters.

**Figure S1.** Geographical location of Beni Madonna (BM) citrus orchards.

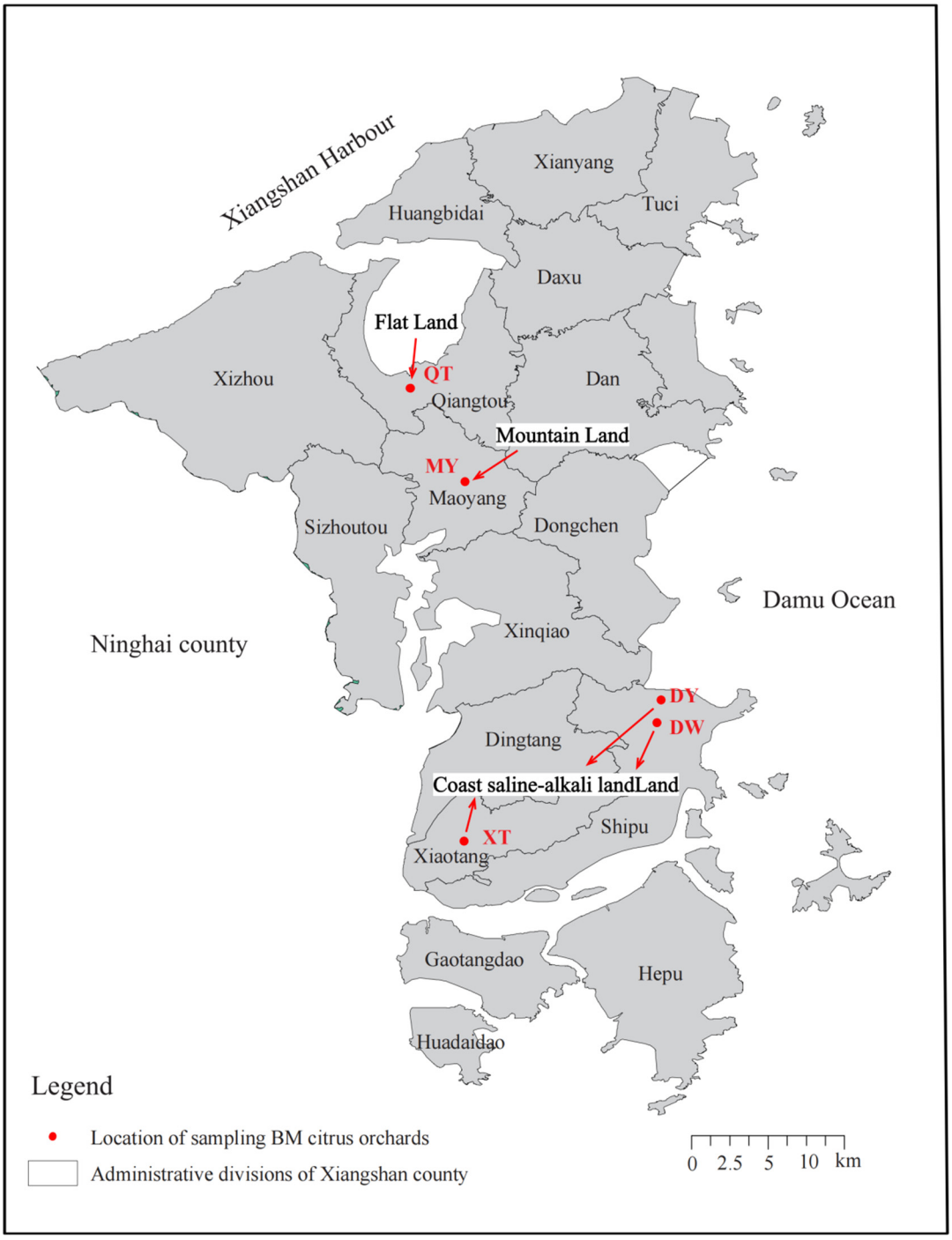


**Figure S2.** Pictures of plastic shed BM orchards in Xiangshan county.

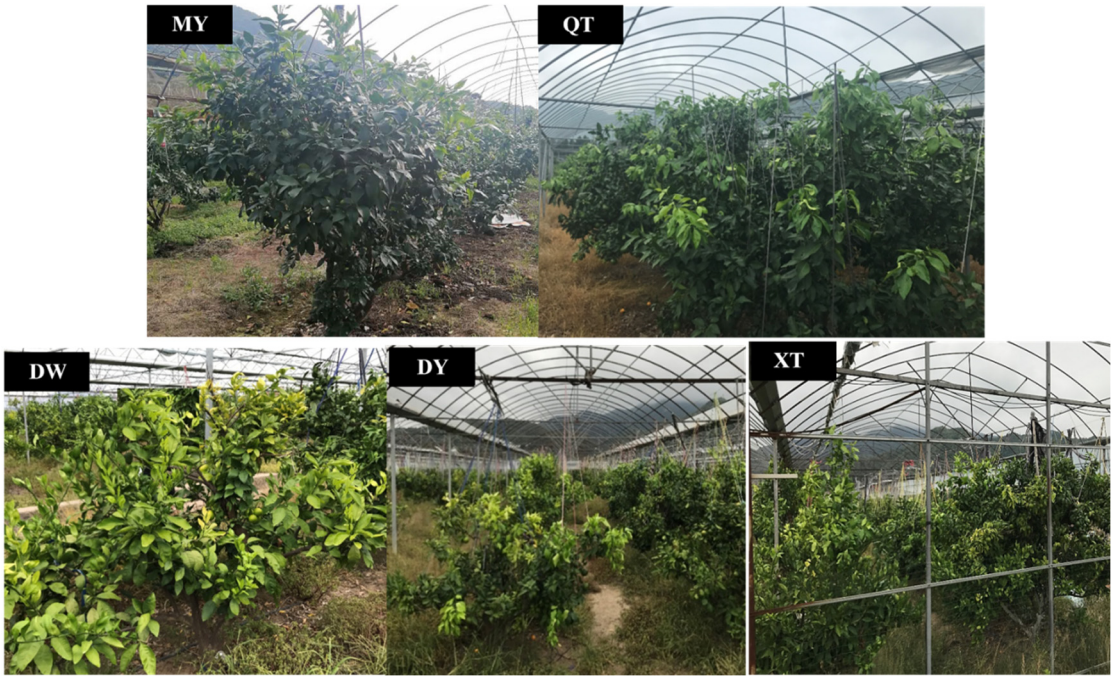
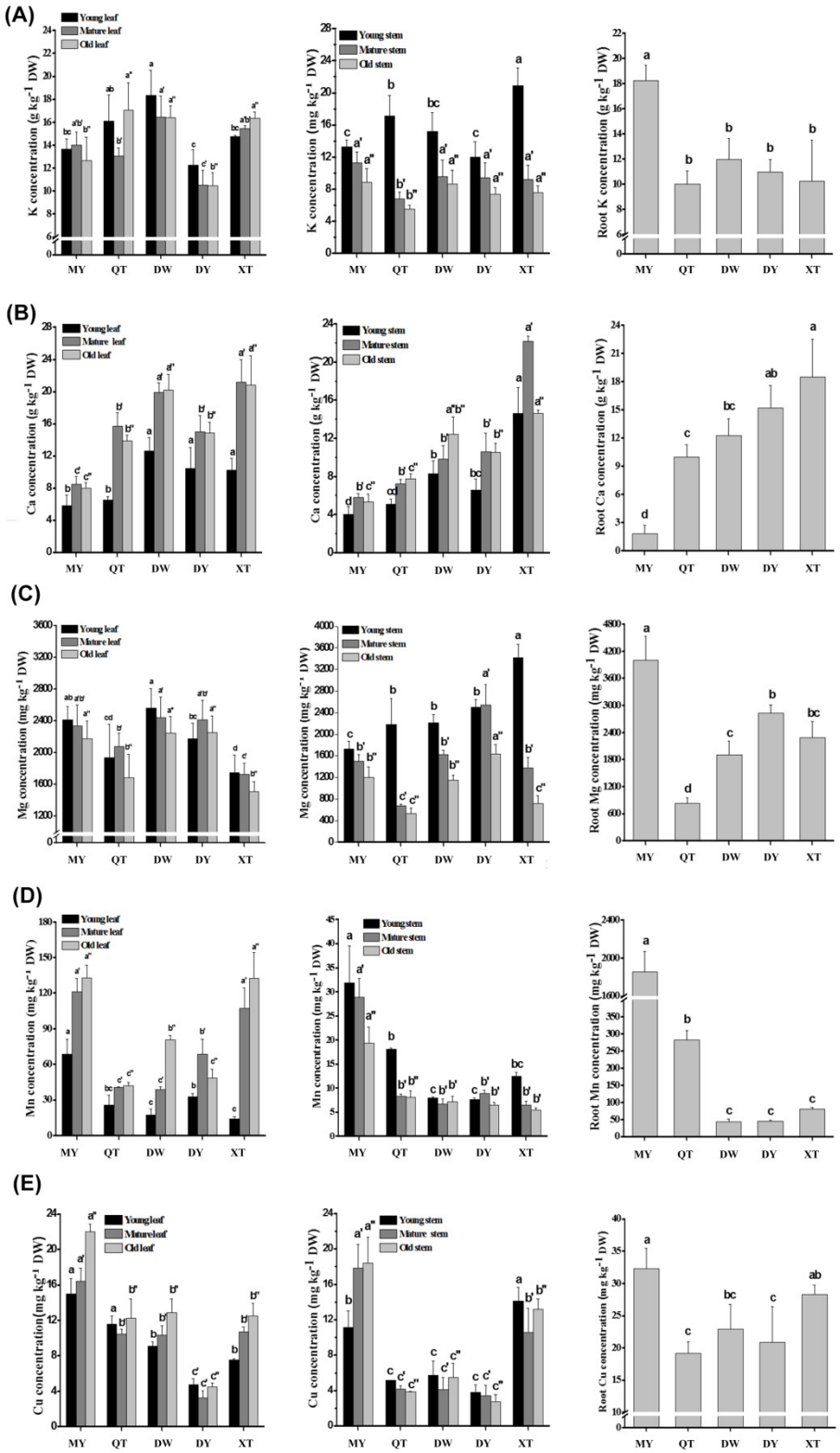


**Figure S3.** K (**A**), Ca (**B**), Mg (**C**), Mn (**D**), Cu (**E**) concentration in citrus leaves, stems, and roots in different orchards.



## Supplementary methods

Soil samples were mixed with ultrapure water in the ratio of 1:2.5 and shaken at 220 rpm for 30 min. After 2 h, they were measured by pH meter (PB-10, Sartorius, Germany). Soil conductivity was measured by electrode method (HJ 802-2016). Soil organic matter was determined by the potassium dichromate volumetric method and the measured value was the soil organic carbon content, multiplied by a correction factor of 1.724 to be the soil organic matter content. The total amount of N was determined by modified kjeldahl method (HJ 717-2014). The total amount of P, K, Ca, Mn, Cu was measured by $HNO_3$-$HClO_4$-HF digestion. Soil samples (0.1 g) were digested with 7 mL $HNO_3$, 1 mL $HClO_4$, 1 mL HF for 10 h at 180°C. The concentrations were determined using iCAP6300 ICP-MS (Thermo Fisher Scientific Inc., Waltham, MA, USA). Certified reference materials (GBW07405) and reagent blanks were used for quality control in every batch of digestion procedures. Available Fe, Mn, Cu, Zn were determined using buffered DTPA solution extraction and inductively coupled plasma optical emission spectrometry (HJ 804-2016). Available B was determined by curcumin－spectrophotometric method (HJ/T 49-1999). Available P, i.e. Olsen-P was determined by sodium hydrogen carbonate solution-Mo-Sb anti spectrophotometric method (HJ 704-201). Available N, i.e. alkali-hydrolysable N, was determined by alkaline diffusion method (DB51/T 1875-2014). Available K, Ca, Mg was determined by $NH_4OAc$ extraction method (NY/T 889-2004, NY/T 1121.13-2006).