***SUPPLEMENTARY MATERIALS***

**Table S1.** Effects of soil Zn application and source-sink manipulations on single panicle weights and kernel numbers per spike of different wheat cultivars.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Zn application rate**  **(ZnSO4·7H2O kg·ha-1)** | **Treatments** | **Single panicle weight (g)** | |  | **Kernel number per spike** | |
| **Jimai 22** | **Jimai 44** |  | **Jimai 22** | **Jimai 44** |
| 0 | Control | 2.5Aa | 2.0Aa |  | 42.2Aa | 34.5ABa |
|  | Flag leaf removal | 1.7Ba | 1.7Ba |  | 36.0Ba | 31.3BCb |
|  | Half spikelets removal | 1.3Da | 1.2Ca |  | 19.9Da | 17.2Ea |
|  | Spike shading | 1.6BCa | 1.3Ca |  | 31.7Ca | 30.2Ca |
| 30 | Control | 2.4Aa | 2.1Aa |  | 41.9Aa | 35.7Aa |
|  | Flag leaf removal | 1.7Ba | 1.6Ba |  | 35.9Ba | 33.6ABCa |
|  | Half spikelets removal | 1.4Ca | 1.3Cb |  | 21.8Da | 18.6Ea |
|  | Spike shading | 1.4Ca | 1.2Ca |  | 29.9Ca | 25.2Da |

Values followed by different capital letters in the same column are significantly different among treatments at *P* ≤ 0.05. Values followed by different lowercase letters in the same row are significantly different among treatments at *P* ≤ 0.05.

**Table S2.** Effects of soil Zn application and source-sink manipulations on concentrations of Zn, Cu, Ca and K in grains of different wheat cultivars.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Zn application rate**  **(ZnSO4·7H2O kg·ha–1)** | **Treatments** | **Zn (mg·kg-1)** | | **Cu (mg·kg-1)** | | **Ca (mg·kg-1)** | | **K (g·kg-1)** | |
| **Jimai 22** | **Jimai 44** | **Jimai 22** | **Jimai 44** | **Jimai 22** | **Jimai 44** | **Jimai 22** | **Jimai 44** |
| 0 | Control | 29.2Da | 42.2BCa | 4.4Ba | 5.4CDa | 497.4ABCa | 484.5ABa | 3.8BCa | 3.2CDa |
|  | Flag leaf removal | 35.0Ca | 34.3Da | 4.6Bb | 5.7CDa | 473.5Ca | 481.1ABa | 4.0Ba | 3.4Ca |
|  | Half spikelets removal | 55.6Aa | 47.4ABb | 5.9Ab | 6.2Ba | 487.4BCa | 453.9BCa | 3.1Ca | 2.9Da |
|  | Spike shading | 42.4Ba | 42.4BCa | 5.8Aa | 6.9Aa | 416.8Da | 376.3Da | 5.7Aa | 4.6Ba |
| 30 | Control | 32.4CDa | 39.5CDa | 4.3Ba | 5.3DEa | 518.6ABa | 480.3ABa | 3.9BCa | 3.4Ca |
|  | Flag leaf removal | 33.3Cb | 40.8BCDa | 4.7Ba | 4.9Ea | 513.4ABa | 498.8Aa | 3.8BCa | 4.2Ba |
|  | Half spikelets removal | 56.4Aa | 53.4Aa | 5.6Ab | 5.8BCa | 528.8Aa | 439.8Cb | 3.4BCa | 3.4Ca |
|  | Spike shading | 40.2Ba | 49.5Aa | 5.6Aa | 5.8BCa | 361.6Ea | 349.1Da | 6.5Aa | 5.4Aa |

Values followed by different capital letters in the same column are significantly different among treatments at *P* ≤ 0.05. Values followed by different lowercase letters in the same row are significantly different among treatments at *P* ≤ 0.05.

**Table S3.** Effects of soil Zn application and source-sink manipulations on yields of Zn, Fe, Mn, Cu, N, P, K, Ca, Mg and phytate-P in grains of different wheat cultivars.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Zn (mg)** | **Fe (mg)** | **Mn (mg)** | **Cu (mg)** | **N (mg)** | **P (mg)** | **K (mg)** | **Ca (mg)** | **Mg (mg)** | **Phytate-P (mg)** |
| **Zn application rate (kg·ha–1)** | | | | | | | | | | |
| ZnSO4˙7H2O (0) | 1.5a | 1.9a | 1.7a | 0.21a | 644.4b | 123.4a | 147.1b | 17.7a | 57.6a | 116.4a |
| ZnSO4˙7H2O (30) | 1.6a | 1.6a | 1.8a | 0.20a | 724.3a | 120.0a | 161.0a | 18.2a | 59.8a | 119.3a |
| LSD0.05 | 0.1 | 0.4 | 0.1 | 0.02 | 44.7 | 13.9 | 11.5 | 1.3 | 4.4 | 9.0 |
| **Cultivar (C)** | | | | | | | | | | |
| Jimai 22 | 1.6a | 1.8a | 1.8a | 0.20a | 708.7a | 125.8a | 170.6a | 19.5a | 61.8a | 125.5a |
| Jimai 44 | 1.6a | 1.7a | 1.7a | 0.21a | 660.1b | 117.6a | 137.5b | 16.4b | 55.6b | 110.2b |
| LSD0.05 | 0.1 | 0.4 | 0.1 | 0.02 | 44.7 | 13.9 | 11.5 | 1.3 | 4.4 | 9.0 |
| **Source-sink treatment (SS)** | | | | | | | | | | |
| Control | 1.8a | 2.2a | 2.4a | 0.25a | 882.5a | 135.8a | 187.5a | 25.9a | 74.9a | 143.5a |
| Flag leaf removal | 1.4b | 1.8ab | 1.6b | 0.20b | 642.4b | 111.9b | 153.1b | 19.5b | 60.4b | 115.6b |
| Half spikelets removal | 1.6b | 1.5b | 1.7b | 0.17c | 584.4b | 115.0b | 93.4c | 13.9c | 52.9c | 104.1b |
| Spike shading | 1.4b | 1.5b | 1.3c | 0.20b | 628.1b | 124.3ab | 182.1a | 12.4c | 46.6d | 108.2b |
| LSD0.05 | 0.2 | 0.6 | 0.2 | 0.02 | 63.2 | 19.6 | 18.3 | 1.9 | 6.2 | 12.8 |
| **ANOVA** | | | | | | | | | | |
| Zn | 0.2347 | 0.1907 | 0.6355 | 0.1680 | 0.0010 | 0.6175 | 0.0198 | 0.4889 | 0.3213 | 0.5164 |
| C | 0.7439 | 0.6408 | 0.0753 | 0.6930 | 0.0342 | 0.2355 | <0.0001 | <0.0001 | 0.0067 | 0.0017 |
| SS | 0.0003 | 0.1216 | <0.0001 | <0.0001 | <0.0001 | 0.0782 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Zn × C | 0.3535 | 0.3391 | 0.9158 | 0.4711 | 0.6835 | 0.0534 | 0.2493 | 0.9567 | 0.4253 | 0.6445 |
| Zn × SS | 0.1772 | 0.8502 | 0.0873 | 0.0645 | 0.0628 | 0.6066 | 0.4695 | 0.0209 | 0.0696 | 0.2355 |
| C × SS | 0.0056 | 0.6374 | 0.0257 | 0.1608 | 0.2828 | 0.0641 | 0.0144 | 0.0330 | 0.1193 | 0.1637 |
| Zn × C × SS | 0.5445 | 0.4791 | 0.2593 | 0.2293 | 0.2742 | 0.6632 | 0.1987 | 0.8720 | 0.5871 | 0.0594 |

Values followed by different lowercase letters in the same column are significantly different among treatments at *P* ≤ 0.05. Values under ANOVA are probabilities (*P* values) of the source of variation.

**Table S4.** Effects of soil Zn application and source-sink manipulations on yields of ABA and ACC in grains of different wheat cultivars.

|  |  |  |
| --- | --- | --- |
| **Treatments** | **ABA (ng)** | **ACC (ng)** |
| **Zn application rate (kg·ha–1)** | | |
| ZnSO4˙7H2O (0) | 961.6a | 1529.6a |
| ZnSO4˙7H2O (30) | 1182.3a | 1322.2b |
| LSD0.05 | 254.2 | 185.7 |
| **Cultivar (C)** | | |
| Jimai 22 | 1256.8a | 1290.6b |
| Jimai 44 | 887.2b | 1561.2a |
| LSD0.05 | 254.2 | 185.7 |
| **Source-sink treatment (T)** | | |
| Control | 1485.8a | 1741.7a |
| Flag leaf removal | 1031.2b | 1355.3b |
| Half spikelets removal | 1260.1ab | 875.5c |
| Spike shading | 510.8c | 1731.0a |
| LSD0.05 | 359.5 | 262.7 |
| **ANOVA** | | |
| Zn | 0.0863 | 0.0299 |
| C | 0.0058 | 0.0057 |
| SS | <0.0001 | <0.0001 |
| Zn × C | 0.2961 | 0.0139 |
| Zn × SS | 0.2433 | 0.5183 |
| C × SS | 0.0233 | 0.3574 |
| Zn × C × SS | 0.6095 | 0.1047 |

Values followed by different lowercase letters in the same column are significantly different among treatments at *P* ≤ 0.05. Values under ANOVA are probabilities (*P* values) of the source of variation.

**Table S5.** Pearson correlation coefficients among single panicle weight (SPW), kernel number per spike (KNPS), thousand kernel weight (TKW), total grain weight (TGW), yields/accumulation of Zn, Fe, Mn, Cu, N, P, K, Ca, Mg and phytate-P, C/N ratio, and molar ratios of PA/Zn, PA × Ca/Zn, PA/Fe and PA × Ca/Fe in wheat grains as affected by soil Zn applications, cultivars and source-sink treatments (*n* = 48).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Zn** | **Fe** | **Mn** | **Cu** | **N** | **P** | **K** | **Ca** | **Mg** | **C/N** | **Phytate-P** | **PA/Zn** | **PA × Ca/Zn** | **PA/Fe** | **PA × Ca/Fe** |
| **SPW** | 0.416\*\* | 0.393\*\* | 0.756\*\* | 0.706\*\* | 0.808\*\* | 0.375\*\* | 0.602\*\* | 0.919\*\* | 0.823\*\* | 0.465\*\* | 0.757\*\* | + | + | + | + |
| **KNPS** | 0.303\* | 0.400\*\* | 0.488\*\* | 0.690\*\* | 0.716\*\* | 0.340\* | 0.808\*\* | 0.802\*\* | 0.687\*\* | 0.412\*\* | 0.696\*\* | + | + | + | + |
| **TKW** | 0.507\*\* | ns | 0.551\*\* | ns | ns | ns | -0.415\*\* | ns | 0.354\* | ns | ns | + | + | + | + |
| **TGW** | 0.577\*\* | 0.475\*\* | 0.794\*\* | 0.831\*\* | 0.894\*\* | 0.437\*\* | 0.668\*\* | 0.959\*\* | 0.907\*\* | 0.395\*\* | 0.840\*\* | + | + | + | + |
| **Zn** | - | 0.459\*\* | 0.678\*\* | 0.656\*\* | 0.743\*\* | 0.289\* | ns | 0.578\*\* | 0.662\*\* | ns | 0.631\*\* | -0.354\* | ns | ns | ns |
| **Fe** | - | - | 0.484\*\* | 0.486\*\* | 0.362\* | ns | ns | 0.426\*\* | 0.506\*\* | ns | 0.450\*\* | ns | ns | -0.672\*\* | -0.493\*\* |
| **Mn** | - | - | - | 0.728\*\* | 0.796\*\* | 0.349\* | ns | 0.848\*\* | 0.928\*\* | 0.290\* | 0.739\*\* | ns | 0.467\*\* | ns | ns |
| **Cu** | - | - | - | - | 0.822\*\* | 0.396\*\* | 0.559\*\* | 0.738\*\* | 0.784\*\* | ns | 0.736\*\* | ns | ns | ns | ns |
| **N** | - | - | - | - | - | 0.447\*\* | 0.640\*\* | 0.851\*\* | 0.856\*\* | ns | 0.818\*\* | ns | 0.342\* | ns | ns |
| **P** | - | - | - | - | - | - | 0.517\*\* | 0.372\*\* | 0.386\*\* | ns | 0.478\*\* | ns | ns | ns | ns |
| **K** | - | - | - | - | - | - | - | 0.519\*\* | 0.429\*\* | ns | 0.584\*\* | 0.426\*\* | ns | ns | ns |
| **Ca** | - | - | - | - | - | - | - | - | 0.939\*\* | 0.432\*\* | 0.799\*\* | 0.310\* | 0.653\*\* | ns | 0.352\* |
| **Mg** | - | - | - | - | - | - | - | - | - | 0.339\* | 0.820\*\* | ns | 0.559\*\* | ns | ns |
| **C/N** | - | - | - | - | - | - | - | - | - | - | ns | 0.412\*\* | 0.515\*\* | ns | ns |
| **Phytate-P** | - | - | - | - | - | - | - | - | - | - | - | 0.478\*\* | 0.611\*\* | ns | 0.373\*\* |

“-” indicates no this value, “ns” indicates not significant, “+” indicates the value has been presented in TABLE 5, “\*” and “\*\*” indicate significant correlations at *P* ≤ 0.05 and *P* ≤ 0.01, respectively.

**Table S6.** Pearson correlation coefficients between grain phytohormones (yields of ABA, ACC and ratios of ABA/ACC) and grain yield traits or nutritional parameters (yields or ratios), and among different phytohormones across different soil Zn applications, cultivars and source-sink treatments (*n* = 48).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **SPW** | **KNPS** | **TKW** | **TGW** | **Zn** | **Fe** | **Mn** | **Cu** | **N** | **P** | **K** | **Ca** | **Mg** | **C/N** | **Phytate-P** | **PA/Zn** | **PA × Ca/Zn** | **PA/Fe** | **PA × Ca/Fe** | **ABA** | **ACC** | **ABA/ACC** |
| **ABA** | 0.466\*\* | ns | 0.428\*\* | 0.437\*\* | 0.363\* | ns | 0.584\*\* | ns | 0.434\*\* | 0.286\* | ns | 0.554\*\* | 0.502\*\* | ns | 0.444\*\* | ns | 0.431\*\* | ns | 0.332\* | - | -0.288\* | 0.869\*\* |
| **ACC** | 0.326\* | 0.473\*\* | -0.324\* | 0.379\*\* | ns | ns | ns | 0.614\*\* | 0.312\* | ns | 0.422\*\* | ns | ns | ns | ns | ns | ns | ns | ns | - | - | -0.613\*\* |
| **ABA/ACC** | + | + | + | + | ns | ns | 0.359\* | ns | ns | ns | ns | ns | ns | + | ns | + | + | + | + | - | - | - |

“SPW”: single panicle weight, KNPS: “kernel number per spike”, “TKW”: thousand kernel weight, “TGW”: total grain weight. “-” indicates no this value, “ns” indicates not significant, “+” indicates the value has been presented in Table 6, “\*” and “\*\*” indicate significant correlations at *P* ≤ 0.05 and *P* ≤ 0.01, respectively.