

**Table S1. List of cowpea genotypes used and their origin/source.**

| <b>Entry</b> | <b>Genotypes</b> | <b>Origin/Source</b> |
|--------------|------------------|----------------------|
| 1            | 24-125B-1        | Cameroon             |
| 2            | 524B             | USA                  |
| 3            | 58-77            | Senegal              |
| 4            | Aloka            | Nigeria              |
| 5            | B301             | Bostwana             |
| 6            | CB27             | USA                  |
| 7            | CB46             | USA                  |
| 8            | Danila           | Nigerian Landrace    |
| 9            | DanMisra         | Nigerian Landrace    |
| 10           | IAR-48           | IAR-Nigeria          |
| 11           | IT00K-1263       | IITA-Nigeria         |
| 12           | IT82E-18         | IITA-Nigeria         |
| 13           | IT84S-2049       | IITA-Nigeria         |
| 14           | IT84S-2246-4     | IITA-Nigeria         |
| 15           | IT86D-1010       | IITA-Nigeria         |
| 16           | IT89KD-288       | IITA-Nigeria         |
| 17           | IT93K-503-1      | IITA-Nigeria         |
| 18           | IT97K-499-35     | IITA-Nigeria         |
| 19           | IT97K-556-6      | IITA-Nigeria         |
| 20           | Kanannado        | Nigeria              |
| 21           | SAMPEA-17        | IAR-Nigeria          |
| 22           | SAMPEA-9         | IAR-Nigeria          |
| 23           | Sanzi            | Ghana                |
| 24           | SuVita2          | Burkina Faso         |
| 25           | Tvu-14676        | IITA-Nigeria         |
| 26           | Tvu-7778         | IITA-Nigeria         |
| 27           | UAM-1055-6       | FUAM-Nigeria         |
| 28           | UCR779           | USA                  |
| 29           | Vita7            | Burkina Faso         |
| 30           | Yacine           | Senegal              |

**Table S2. Formulae used for computation of relative reduction (%), phosphorus concentration, and zinc content of samples.**

$$\begin{aligned} &\text{Phosphorus concentration (mg/kg)} \\ &= \frac{\text{Standard curve factor} \times \text{Volume of solution} \times \text{Dilution factor} \times \text{Absorbent value}}{\text{Weight of sample in grams}} \end{aligned}$$

$$\text{Relative difference (\%)} = \frac{\text{High P value} - \text{Low P value}}{\text{High P value}} \times 100$$

$$\text{Zinc content of samples (ppm)} = \frac{\text{AAS reading} \times \text{Volume of solution} \times \text{Dilution factor}}{\text{Weight of sample in grams}}$$

**Table S3.** Means of genotypes for shoot parameters measured in the screenhouse experiment under three soil phosphorus concentrations.

| Entry | Genotypes    | Pht.HP | Pht.MP | Pht.LP | Sdwt.HP | Sdwt.MP | Sdwt.LP | Shoot.P.HP | Shoot.P.MP | Shoot.P.LP | Shoot.Zn.HP | Shoot.Zn.MP | Shoot.Zn.LP |
|-------|--------------|--------|--------|--------|---------|---------|---------|------------|------------|------------|-------------|-------------|-------------|
| 1     | 24-125B-1    | 19.5   | 12.1   | 13.9   | 2.7     | 0.5     | 0.4     | 1350.0     | 1472.8     | 1254.6     | 70.8        | 50.7        | 74.9        |
| 2     | 524B         | 18.5   | 14.3   | 14.5   | 2.4     | 0.6     | 0.5     | 1663.6     | 1718.2     | 1809.8     | 63.9        | 101.3       | 102.0       |
| 3     | 58-77        | 18.1   | 12.9   | 11.9   | 1.7     | 0.3     | 0.2     | 1377.3     | 886.4      | 709.1      | 70.7        | 55.5        | 69.2        |
| 4     | Aloka        | 24.2   | 15.3   | 15.1   | 2.2     | 0.4     | 0.3     | 1090.9     | 975.0      | 795.5      | 42.7        | 45.1        | 45.4        |
| 5     | B301         | 36.5   | 12.0   | 11.0   | 1.6     | 0.3     | 0.2     | 1377.3     | 954.6      | 722.7      | 51.4        | 53.6        | 27.8        |
| 6     | CB27         | 19.0   | 16.0   | 16.5   | 1.9     | 0.5     | 0.4     | 1390.9     | 927.3      | 763.7      | 99.6        | 89.0        | 79.0        |
| 7     | CB46         | 17.8   | 15.5   | 15.3   | 1.8     | 0.6     | 0.5     | 1077.3     | 940.9      | 722.7      | 101.6       | 65.6        | 66.5        |
| 8     | Danila       | 15.7   | 12.7   | 12.8   | 1.4     | 0.5     | 0.5     | 900.0      | 968.2      | 654.6      | 101.2       | 111.8       | 58.5        |
| 9     | DanMisra     | 15.9   | 10.5   | 10.3   | 2.2     | 0.3     | 0.3     | 1186.4     | 1512.1     | 1363.7     | 78.8        | 64.3        | 58.4        |
| 10    | IAR-48       | 17.8   | 12.7   | 12.8   | 2.4     | 0.4     | 0.4     | 1254.6     | 1322.8     | 1350.0     | 67.4        | 103.2       | 73.4        |
| 11    | IT00K-1263   | 20.1   | 15.4   | 14.3   | 3.4     | 1.0     | 0.6     | 1322.7     | 913.6      | 777.3      | 80.0        | 61.7        | 82.3        |
| 12    | IT82E-18     | 15.9   | 11.3   | 12.1   | 1.8     | 0.3     | 0.3     | 859.1      | 818.2      | 613.6      | 90.3        | 94.1        | 54.9        |
| 13    | IT84S-2049   | 24.1   | 18.0   | 19.0   | 2.3     | 0.4     | 0.4     | 1554.5     | 927.3      | 1036.4     | 42.2        | 34.8        | 54.6        |
| 14    | IT84S-2246-4 | 24.4   | 23.1   | 22.6   | 3.2     | 0.7     | 0.8     | 1200.0     | 954.6      | 968.2      | 41.5        | 36.2        | 41.9        |
| 15    | IT86D-1010   | 32.2   | 16.8   | 16.5   | 2.3     | 0.5     | 0.3     | 1281.8     | 886.4      | 767.1      | 33.5        | 27.5        | 42.8        |
| 16    | IT89KD-288   | 36.7   | 24.9   | 25.7   | 3.0     | 0.9     | 1.0     | 1104.6     | 790.9      | 845.5      | 39.3        | 51.3        | 51.6        |
| 17    | IT93K-503-1  | 33.2   | 20.0   | 20.2   | 2.3     | 0.5     | 0.5     | 1118.2     | 722.7      | 804.5      | 101.3       | 271.6       | 87.9        |
| 18    | IT97K-499-35 | 20.0   | 15.8   | 16.0   | 2.6     | 0.5     | 0.4     | 804.5      | 850.0      | 703.5      | 37.9        | 31.7        | 49.5        |
| 19    | IT97K-556-6  | 21.6   | 14.4   | 19.5   | 2.0     | 0.5     | 0.4     | 1036.4     | 886.4      | 763.6      | 78.2        | 85.9        | 64.9        |
| 20    | Kanannado    | 33.1   | 15.8   | 16.0   | 1.9     | 0.4     | 0.3     | 1718.2     | 886.4      | 790.9      | 49.5        | 54.1        | 42.2        |

|    |             |             |             |             |            |            |            |               |               |              |             |             |             |
|----|-------------|-------------|-------------|-------------|------------|------------|------------|---------------|---------------|--------------|-------------|-------------|-------------|
| 21 | SAMPEA-17   | 17.7        | 12.9        | 10.8        | 3.1        | 0.5        | 0.4        | 1527.3        | 1090.9        | 1104.6       | 70.5        | 105.6       | 84.8        |
| 22 | SAMPEA-9    | 17.9        | 10.0        | 11.3        | 2.4        | 0.3        | 0.3        | 1418.2        | 1322.7        | 1133.8       | 71.0        | 85.8        | 67.9        |
| 23 | Sanzi       | 45.4        | 14.9        | 14.6        | 2.4        | 0.4        | 0.3        | 1240.9        | 995.5         | 958.0        | 52.9        | 43.9        | 55.9        |
| 24 | SuVita2     | 15.1        | 12.6        | 11.5        | 2.6        | 0.5        | 0.5        | 1322.7        | 1186.4        | 1133.8       | 81.3        | 69.2        | 158.5       |
| 25 | Tvu-14676   | 22.0        | 8.9         | 9.0         | 2.1        | 0.3        | 0.2        | 1540.9        | 1227.3        | 950.6        | 45.1        | 37.7        | 37.4        |
| 26 | Tvu-7778    | 14.5        | 12.2        | 11.8        | 1.3        | 0.3        | 0.1        | 1363.7        | 831.8         | 791.1        | 101.1       | 82.7        | 157.0       |
| 27 | UAM-1055-6  | 15.6        | 12.2        | 12.4        | 1.6        | 0.4        | 0.4        | 1459.1        | 1393.4        | 1363.7       | 80.3        | 54.5        | 65.1        |
| 28 | UCR779      | 14.1        | 10.0        | 9.6         | 1.6        | 0.5        | 0.3        | 1131.8        | 804.6         | 831.8        | 80.7        | 88.3        | 72.8        |
| 29 | Vita7       | 21.6        | 11.5        | 13.9        | 3.0        | 0.6        | 0.4        | 1363.7        | 1527.3        | 1050.0       | 53.1        | 76.7        | 157.0       |
| 30 | Yacine      | 17.4        | 14.2        | 14.4        | 1.6        | 0.5        | 0.4        | 1240.9        | 927.3         | 736.4        | 70.5        | 68.5        | 37.5        |
|    | <b>Mean</b> | <b>22.2</b> | <b>14.3</b> | <b>14.5</b> | <b>2.2</b> | <b>0.5</b> | <b>0.4</b> | <b>1275.9</b> | <b>1054.1</b> | <b>942.4</b> | <b>68.3</b> | <b>73.4</b> | <b>70.7</b> |

See Table 1 in the main text for list and abbreviations of the traits

**Table S4.** Means of cowpea genotypes for shoot parameters measured in the field experiment under three soil phosphorus concentrations.

| Entry | Genotype     | pht.HP | pht.MP | pht.LP | sdwt.HP | sdwt.MP | sdwt.LP | Yield.HP | Yield.MP | Yield.LP | shootP.HP | shootP.MP | shootP.LP | shootZn.HP | shootZn.MP | shootZn.LP | GrainP.HP | GrainP.MP | GrainP.LP | GrainZn.HP | GrainZn.MP | GrainZn.LP |
|-------|--------------|--------|--------|--------|---------|---------|---------|----------|----------|----------|-----------|-----------|-----------|------------|------------|------------|-----------|-----------|-----------|------------|------------|------------|
| 1     | 24-125B-1    | 26.0   | 21.4   | 16.8   | 81.4    | 33.5    | 21.1    | 1098.4   | 375.3    | 297.3    | 1079.6    | 1335.2    | 909.1     | 85.5       | 123.8      | 84.7       | 2965.9    | 2420.5    | 2522.8    | 47.0       | 62.8       | 48.5       |
| 2     | 524B         | 44.8   | 22.9   | 15.5   | 61.0    | 23.7    | 19.3    | 569.2    | 385.9    | 112.0    | 1590.9    | 1306.8    | 1108.0    | 76.1       | 93.1       | 97.2       | 3068.2    | 2454.6    | 2215.9    | 22.1       | 17.6       | 34.5       |
| 3     | 58-77        | 34.5   | 22.9   | 16.0   | 85.2    | 22.1    | 20.1    | 1137.7   | 152.0    | 209.3    | 1051.1    | 1363.7    | 1420.5    | 107.6      | 80.3       | 75.6       | 2318.2    | 2420.5    | 2250.0    | 20.9       | 30.4       | 36.4       |
| 4     | Aloka        | 28.9   | 21.7   | 15.4   | 73.7    | 30.5    | 19.5    | 943.1    | 534.5    | 238.0    | 1051.1    | 1335.2    | 1420.5    | 77.9       | 92.1       | 79.9       | 2488.7    | 2181.8    | 2079.6    | 17.9       | 32.3       | 16.4       |
| 5     | B301         | 22.6   | 20.8   | 13.2   | 80.2    | 62.3    | 20.9    | 1295.6   | 1135.1   | 371.3    | 880.7     | 738.6     | 681.8     | 61.4       | 93.4       | 106.1      | 2079.6    | 2250.0    | 2011.4    | 15.5       | 9.0        | 20.4       |
| 6     | CB27         | 37.1   | 23.0   | 20.1   | 64.5    | 20.1    | 19.8    | 605.9    | 314.9    | 146.4    | 1448.9    | 1278.4    | 1306.8    | 94.2       | 99.2       | 100.7      | 3000.0    | 2863.7    | 2318.2    | 37.1       | 70.2       | 37.5       |
| 7     | CB46         | 54.7   | 24.9   | 16.6   | 71.7    | 31.7    | 19.9    | 736.8    | 396.2    | 162.0    | 1534.1    | 1221.6    | 1448.9    | 107.9      | 82.0       | 121.1      | 2625.0    | 3170.5    | 2352.3    | 27.0       | 35.0       | 23.4       |
| 8     | Danila       | 27.2   | 21.0   | 13.3   | 119.1   | 61.7    | 20.2    | 1639.6   | 627.3    | 140.0    | 994.3     | 1335.2    | 1079.6    | 93.7       | 5          | 122.5      | 1772.8    | 1704.6    | 1363.7    | 32.5       | 38.2       | 36.2       |
| 9     | DanMisra     | 27.3   | 22.2   | 16.7   | 127.6   | 27.3    | 22.1    | 2105.4   | 459.9    | 571.9    | 1278.4    | 1306.8    | 1164.8    | 57.8       | 1          | 136.4      | 1977.3    | 2965.9    | 1909.1    | 31.1       | 24.2       | 39.4       |
| 10    | IAR-48       | 35.0   | 22.5   | 15.3   | 116.5   | 32.2    | 21.9    | 1547.1   | 421.9    | 388.7    | 1022.7    | 1136.4    | 994.3     | 75.5       | 3          | 103.4      | 1602.3    | 1670.5    | 1636.4    | 41.1       | 22.6       | 26.3       |
| 11    | IT00K-1263   | 29.4   | 21.1   | 15.8   | 135.2   | 40.4    | 19.6    | 2070.8   | 321.9    | 212.0    | 1022.7    | 994.3     | 852.3     | 78.8       | 7          | 82.8       | 2522.8    | 2863.7    | 2386.4    | 26.2       | 24.0       | 39.2       |
| 12    | IT82E-18     | 24.5   | 20.9   | 15.8   | 90.8    | 49.2    | 21.3    | 1171.0   | 643.9    | 519.2    | 1534.1    | 1306.8    | 1534.1    | 116.0      | 93.7       | 100.7      | 2761.4    | 2761.4    | 2284.1    | 40.7       | 37.2       | 31.7       |
| 13    | IT84S-2049   | 33.7   | 22.4   | 16.0   | 91.5    | 42.3    | 19.5    | 1560.9   | 595.2    | 188.7    | 1335.2    | 1363.7    | 1335.2    | 96.0       | 72.2       | 97.1       | 3170.5    | 2659.1    | 2454.6    | 31.1       | 38.2       | 43.1       |
| 14    | IT84S-2246-4 | 26.3   | 21.6   | 15.7   | 85.4    | 34.2    | 20.5    | 1296.3   | 324.6    | 447.2    | 937.5     | 1108.0    | 965.9     | 80.0       | 86.7       | 100.1      | 2522.8    | 2420.5    | 2522.8    | 15.4       | 18.7       | 21.6       |

|    |              |      |      |      |      |      |      |        |       |      |       |       |       |      |      |      |       |        |       |      |      |      |
|----|--------------|------|------|------|------|------|------|--------|-------|------|-------|-------|-------|------|------|------|-------|--------|-------|------|------|------|
| 15 | IT86D-1010   | 65.0 | 25.3 | 23.2 | 113. | 56   | 21.5 | 2357.4 | 1037. | 484. | 880.7 | 965.9 | 1022. | 78.8 | 116. | 90.8 | 2488. | 2181.8 | 2250. | 31.1 | 40.7 | 42.8 |
|    |              |      |      |      | 4    |      |      |        | 8     | 6    |       |       | 7     |      | 6    |      | 7     |        | 0     |      |      |      |
| 16 | IT89KD-288   | 24.2 | 20.8 | 12.6 | 98.6 | 33.5 | 19.0 | 1475   | 599.2 | 99.9 | 1448. | 1392. | 1448. | 103. | 123. | 132. | 1977. | 1670.5 | 1840. | 43.7 | 39.2 | 36.2 |
|    |              |      |      |      |      |      |      |        |       |      | 9     | 1     | 9     | 7    | 2    | 8    | 3     |        | 9     |      |      |      |
| 17 | IT93K-503-1  | 36.9 | 21.1 | 14.6 | 97.3 | 30   | 19.8 | 1482.9 | 344.3 | 288. | 1164. | 1221. | 1278. | 96.2 | 107. | 132. | 1977. | 1840.9 | 1704. | 13.7 | 8.0  | 14.6 |
|    |              |      |      |      |      |      |      |        |       | 8    | 8     | 6     | 4     |      | 1    | 1    | 3     |        | 6     |      |      |      |
| 18 | IT97K-499-35 | 27.1 | 22.2 | 17.2 | 80.3 | 48.2 | 20.2 | 1261.0 | 925.1 | 289. | 965.9 | 994.3 | 1079. | 80.0 | 88.9 | 117. | 2556. | 1772.8 | 1875. | 39.5 | 34.6 | 30.3 |
|    |              |      |      |      |      |      |      | 5      |       | 3    |       |       | 6     |      |      |      | 8     |        | 8     |      |      |      |
| 19 | IT97K-556-6  | 30.1 | 21.3 | 15.7 | 76.4 | 19.6 | 22.2 | 913.3  | 283.8 | 550. | 1619. | 965.9 | 1278. | 125. | 68.2 | 93.5 | 2420. | 2454.6 | 2284. | 23.6 | 20.9 | 47.9 |
|    |              |      |      |      |      |      |      |        |       | 7    | 3     |       | 4     | 3    |      |      | 5     |        | 1     |      |      |      |
| 20 | Kanannado    | 31.7 | 22.0 | 15.4 | 81.9 | 78.8 | 22.7 | 1375.7 | 1577. | 329. | 1079. | 1136. | 1079. | 79.9 | 89.2 | 117. | 1943. | 2284.1 | 2488. | 23.5 | 20.9 | 45.7 |
|    |              |      |      |      |      |      |      |        | 0     | 3    | 6     | 4     | 6     |      |      |      | 2     |        | 7     |      |      |      |
| 21 | SAMPEA-17    | 30.4 | 22.8 | 14.6 | 105. | 48.8 | 19.8 | 1661.6 | 427.2 | 177. | 1306. | 1392. | 1193. | 101. | 88.1 | 118. | 2284. | 2113.7 | 1977. | 26.5 | 32.7 | 29.7 |
|    |              |      |      |      | 3    |      |      |        |       | 8    | 1     | 2     | 9     | 1    |      | 1    | 3     |        | 26.5  |      |      |      |
| 22 | SAMPEA-9     | 29.7 | 21.5 | 15.2 | 143. | 70.3 | 24.8 | 1644.2 | 921.1 | 672. | 1079. | 1136. | 1022. | 83.2 | 77.6 | 115. | 1772. | 2011.4 | 1772. | 32.0 | 36.9 | 37.8 |
|    |              |      |      |      | 3    |      |      | 5      |       | 6    | 4     | 7     | 4     |      |      |      | 7     |        | 32.0  |      |      |      |
| 23 | Sanzi        | 29.9 | 24.6 | 15.7 | 84.0 | 26   | 20.9 | 1994.8 | 547.2 | 409. | 1221. | 909.1 | 1051. | 69.9 | 75.5 | 95.6 | 2454. | 2181.8 | 2284. | 27.2 | 31.0 | 34.2 |
|    |              |      |      |      |      |      |      | 5      |       | 9    | 6     |       | 2     |      |      |      | 6     |        | 1     |      |      |      |
| 24 | SuVita2      | 25.3 | 21.8 | 14.3 | 90.6 | 36.8 | 19.5 | 1400.3 | 633.2 | 148. | 1363. | 1221. | 994.3 | 86.0 | 129. | 109. | 2863. | 2488.7 | 2454. | 24.7 | 26.6 | 33.5 |
|    |              |      |      |      |      |      |      |        |       | 0    | 7     | 6     |       |      |      |      | 6     |        | 3     |      |      |      |
| 25 | Tvu-14676    | 28.3 | 21.1 | 13.6 | 64.2 | 16.7 | 19.8 | 575.9  | 233.6 | 256. | 1164. | 1448. | 1278. | 83.8 | 84.9 | 113. | 1806. | 2147.8 | 2181. | 28.4 | 32.6 | 60.6 |
|    |              |      |      |      |      |      |      |        |       | 1    | 8     | 9     | 4     |      |      |      | 8     |        | 3     |      |      |      |
| 26 | Tvu-7778     | 35.3 | 22.2 | 17.0 | 108. | 45.5 | 19.1 | 1650.9 | 676.1 | 154. | 1278. | 1079. | 795.5 | 117. | 117. | 136. | 2522. | 2352.3 | 1943. | 26.1 | 29.3 | 19.4 |
|    |              |      |      |      | 8    |      |      | 6      |       | 4    | 6     | 8     |       |      |      |      | 7     |        | 4     |      |      |      |
| 27 | UAM-1055-6   | 32.2 | 20.3 | 14.7 | 93.4 | 26.8 | 20.6 | 1898.3 | 327.1 | 334. | 937.5 | 767.1 | 1108. | 74.0 | 86.4 | 85.1 | 2522. | 2284.1 | 1568. | 31.6 | 31.2 | 40.7 |
|    |              |      |      |      |      |      |      | 5      |       | 9    |       |       | 0     |      |      |      | 8     |        | 8     |      |      |      |
| 28 | UCR779       | 23.7 | 20.2 | 12.5 | 93.6 | 12.9 | 19.5 | 1197.0 | 232.0 | 22.2 | 1022. | 937.5 | 789.6 | 104. | 100. | 70.4 | 2284. | 2250.0 | 2045. | 31.4 | 19.0 | 21.1 |
|    |              |      |      |      |      |      |      | 5      |       |      | 7     |       |       |      |      |      | 9     |        | 1     |      |      |      |
| 29 | Vita7        | 32.9 | 22.2 | 15.7 | 142. | 69.3 | 22.8 | 2006.8 | 619.9 | 409. | 1108. | 1022. | 994.3 | 87.3 | 80.7 | 96.2 | 2079. | 1704.6 | 1738. | 41.9 | 48.7 | 55.4 |
|    |              |      |      |      | 9    |      |      | 5      |       | 9    | 0     | 7     |       |      |      |      | 6     |        | 7     |      |      |      |
| 30 | Yacine       | 23.4 | 20.6 | 14.1 | 76.3 | 36.6 | 20.4 | 1524.9 | 695.2 | 191. | 1108. | 1164. | 1335. | 79.2 | 99.6 | 86.3 | 2215. | 2045.5 | 2488. | 30.0 | 33.1 | 23.6 |
|    |              |      |      |      |      |      |      | 5      |       | 3    | 0     | 8     | 2     |      |      |      | 9     |        | 7     |      |      |      |

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|      |      |      |      |      |      |      |        |       |   |      |       |       |       |      |   |      |        |   |       |      |      |  |  |
|------|------|------|------|------|------|------|--------|-------|---|------|-------|-------|-------|------|---|------|--------|---|-------|------|------|--|--|
|      |      |      |      |      |      |      |        |       |   | 293. | 1150. | 1100. | 1083. |      |   | 104. | 2276.  |   | 2081. |      |      |  |  |
| Mean | 30.9 | 21.8 | 15.2 | 96.1 | 38.9 | 20.7 | 1495.2 | 590.9 | 8 | 6    | 1     | 6     | 90.9  | 95.6 | 5 | 5    | 2136.4 | 5 | 29.0  | 29.0 | 34.2 |  |  |

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See Table 1 in the main text for list and abbreviations of the traits

**Table S5. Trait correlations between dry biomass yield, P and Zn content of shoot and root of genotypes evaluated in the screenhouse under varying soil P rates, \* denotes significance at  $p \leq 0.05$ , \*\* denotes significant at  $p \leq 0.01$ , \*\*\* denotes significance at  $p < 0.01$  and metrics without significant correlations are without an asterisk.**

|             | Sdwt.LP | Rdwt.LP | Shoot.P.LP | Shoot.Zn.LP | Root.P.Lp | Root.Zn.Lp | Pht.Mp  | Sdwt.Mp | Rdwt.Mp | Shoot.P.Mp | Shoot.Zn.Mp | Rootp.Mp | Root.Zn.Mp | Sdwt.Hp | Rdwt.Hp | Shoot.P.Hp | Shoot.Zn.Hp |
|-------------|---------|---------|------------|-------------|-----------|------------|---------|---------|---------|------------|-------------|----------|------------|---------|---------|------------|-------------|
| Rdwt.LP     | 0.53**  |         |            |             |           |            |         |         |         |            |             |          |            |         |         |            |             |
| Shoot.P.LP  | -0.01   | -0.02   |            |             |           |            |         |         |         |            |             |          |            |         |         |            |             |
| Shoot.Zn.LP | 0.02    | 0.01    | -0.06      |             |           |            |         |         |         |            |             |          |            |         |         |            |             |
| Root.P.LP   | -0.09   | -0.24   | 0.34*      | -0.06       |           |            |         |         |         |            |             |          |            |         |         |            |             |
| Root.Zn.LP  | 0.14    | 0.14    | -0.12      | 0.05        | -0.14     |            |         |         |         |            |             |          |            |         |         |            |             |
| Sdwt.MP     | 0.60**  | 0.37*   | -0.14      | 0.27*       | -0.05     | 0.12       | 0.12    |         |         |            |             |          |            |         |         |            |             |
| Rdwt.MP     | 0.38*   | 0.59**  | -0.14      | 0.30*       | -0.16     | 0.21       | -0.08   | 0.72*** |         |            |             |          |            |         |         |            |             |
| Shoot.P.MP  | -0.09   | -0.01   | 0.58**     | -0.07       | 0.30*     | 0.00       | -0.08   | -0.19*  | -0.15   |            |             |          |            |         |         |            |             |
| Shoot.Zn.MP | 0.01    | 0.08    | -0.15      | 0.14        | -0.18*    | 0.15       | -0.02   | 0.10    | 0.17    | -0.09      |             |          |            |         |         |            |             |
| Root.P.MP   | -0.01   | -0.10   | 0.26*      | -0.03       | 0.70***   | -0.12      | -0.12   | -0.01   | -0.12   | 0.30*      | -0.13       |          |            |         |         |            |             |
| Root.Zn.MP  | -0.06   | 0.05    | -0.20      | 0.02        | -0.12     | 0.25*      | -0.12   | 0.10    | 0.21    | -0.10      | 0.36*       | -0.11    |            |         |         |            |             |
| Sdwt.HP     | 0.28**  | 0.18*   | 0.00       | 0.16        | 0.01      | 0.01       | 0.25**  | 0.39*   | 0.29    | 0.11       | -0.02       | 0.10     | -0.13      |         |         |            |             |
| Rdwt.HP     | 0.07    | 0.34*   | -0.04      | 0.17        | -0.08     | 0.08       | 0.01    | 0.27*   | 0.46*   | 0.16       | 0.06        | 0.03     | -0.01      | 0.68*** |         |            |             |
| Shoot.P.HP  | -0.11   | -0.09   | 0.51**     | 0.02        | 0.39*     | -0.07      | 0.06    | -0.15   | -0.16   | 0.46*      | -0.10       | 0.31*    | -0.07      | -0.02   | -0.07   |            |             |
| Shoot.Zn.HP | -0.08   | 0.06    | -0.13      | 0.16        | -0.17     | 0.33*      | -0.22** | -0.02   | 0.13    | -0.01      | 0.27**      | -0.11    | 0.28**     | -0.13   | 0.01    | 0.04       |             |
| Root.P.HP   | -0.08   | 0.02    | 0.00       | 0.03        | 0.18*     | 0.00       | 0.05    | -0.06   | -0.01   | 0.18*      | -0.03       | 0.19*    | -0.01      | 0.15    | 0.17    | 0.22       | 0.01        |
| Root.Zn.HP  | -0.06   | 0.05    | -0.24      | -0.12       | -0.23*    | 0.29*      | -0.12   | -0.08   | -0.01   | -0.09      | 0.25*       | -0.19    | 0.26*      | -0.20   | -0.19   | -0.08      | 0.35*       |

See Table 1 in the main text for list and abbreviations of the traits

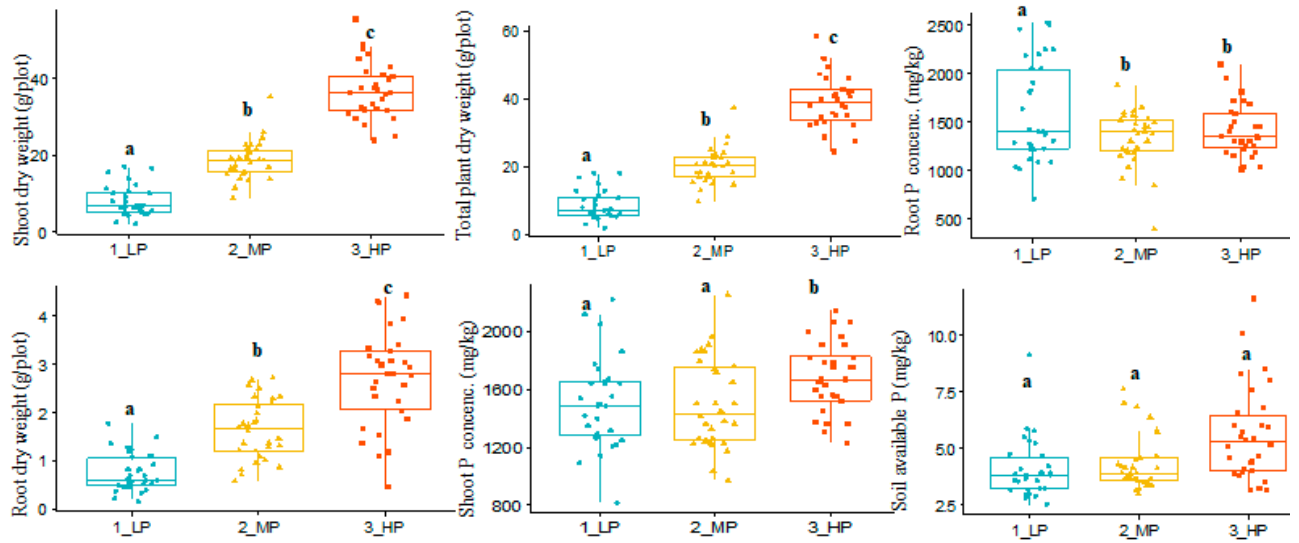


**Table S6. Trait correlations between grain yield, Zn content of shoot and grain of genotypes evaluated in the field under varying soil P rates, \* denotes significance at  $p \leq 0.05$ , \*\* denotes significant at  $p \leq 0.01$ , \*\*\* denotes significance at  $p < 0.01$  and metrics without significant correlations are without an asterisk.**

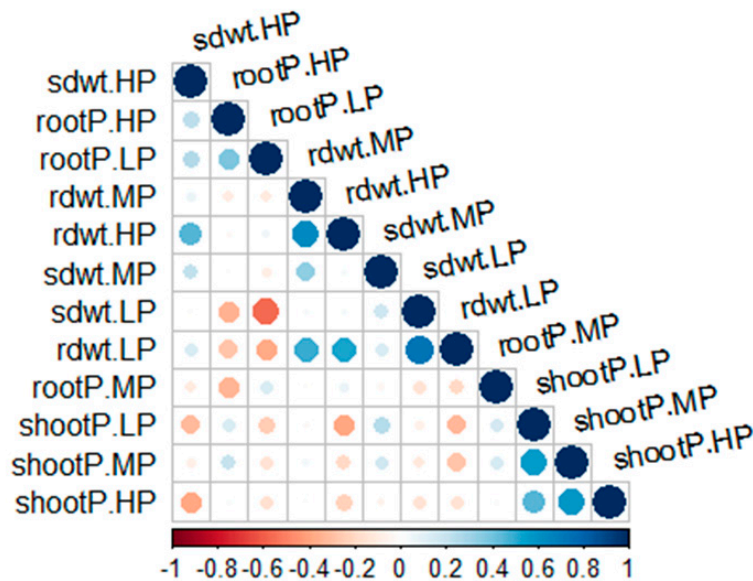
|            | Sdwt.Lp | Grain.LP | ShootP.LP | ShootZn.LP | GrainP.LP | GrainZn.LP | Sdwt.MP | Yield.MP | ShootP.MP | ShootZn.MP | GrainP.MP | GrainZn.MP | Sdwt.HP | Yield.HP | ShootP.HP | ShootZn.HP |
|------------|---------|----------|-----------|------------|-----------|------------|---------|----------|-----------|------------|-----------|------------|---------|----------|-----------|------------|
| Yield.LP   | 0.85*** |          |           |            |           |            |         |          |           |            |           |            |         |          |           |            |
| ShootP.LP  | -0.16   | -0.09    |           |            |           |            |         |          |           |            |           |            |         |          |           |            |
| ShootZn.LP | 0.11    | 0.14     | 0.11      |            |           |            |         |          |           |            |           |            |         |          |           |            |
| GrainP.LP  | 0.08    | 0.12     | 0.11      | -0.25      |           |            |         |          |           |            |           |            |         |          |           |            |
| GrainZn.LP | 0.38*   | 0.34*    | 0.04      | 0.01       | 0.23      |            |         |          |           |            |           |            |         |          |           |            |
| Sdwt.MP    | 0.38*   | 0.31*    | -0.19     | 0.17       | -0.04     | 0.18       |         |          |           |            |           |            |         |          |           |            |
| Yield.MP   | 0.38*   | 0.33*    | -0.16     | 0.17       | 0.12      | 0.16       | 0.86*** |          |           |            |           |            |         |          |           |            |
| ShootP.MP  | -0.04   | -0.07    | 0.38*     | 0.23       | 0.0       | 0.0        | -0.1    | -0.2     |           |            |           |            |         |          |           |            |
| ShootZn.MP | -0.06   | 0.00     | -0.24     | 0.13       | 0.0       | -0.1       | 0.0     | 0.10     | 0.10      |            |           |            |         |          |           |            |
| GrainP.MP  | -0.14   | -0.06    | 0.13      | -0.13      | 0.31*     | 0.05       | -0.10   | -0.16    | 0.15      | -0.20      |           |            |         |          |           |            |
| GrainZn.MP | 0.12    | 0.06     | 0.14      | -0.05      | 0.21      | 0.59***    | 0.14    | 0.05     | 0.13      | -0.07      | 0.07      |            |         |          |           |            |
| Sdwt.HP    | 0.47**  | 0.33*    | -0.20     | 0.15       | -0.29*    | 0.21287    | 0.36*   | 0.13     | -0.11     | 0.05       | -0.16     | 0.11       |         |          |           |            |
| Yield.HP   | 0.31*   | 0.21     | -0.20     | 0.07       | -0.14     | 0.12       | 0.27*   | 0.18     | -0.25     | 0.03       | -0.17     | -0.01      | 0.81*** |          |           |            |
|            |         | -        |           |            |           |            |         |          |           |            |           |            |         |          |           |            |
| ShootP.HP  | -0.29*  | 0.28*    | 0.42**    | 0.21       | 0.04      | -0.09      | -0.16   | -0.17    | 0.34*     | -0.17      | 0.35*     | -0.04      | -0.24   | -0.24    |           |            |
|            |         |          |           |            |           |            |         |          |           |            |           |            |         | -        |           |            |
| ShootZn.HP | -0.10   | -0.07    | 0.24      | -0.01      | -0.01     | -0.25      | -0.09   | -0.13    | 0.18      | 0.25       | 0.01      | -0.15      | -0.16   | 0.31*    | 0.26*     |            |
| GrainP.HP  | -0.29*  | -0.16    | 0.09      | -0.26      | 0.42**    | 0.06       | -0.12   | -0.12    | 0.05      | -0.14      | 0.46**    | 0.34*      | -0.25   | -0.13    | 0.24      | -0.09      |
|            |         |          |           |            |           |            |         |          |           |            |           |            |         |          |           | -          |
| GrainZn.HP | 0.18    | 0.24     | 0.08      | 0.06       | 0.08      | 0.60***    | 0.21    | 0.16     | 0.05      | -0.03      | -0.11     | 0.78***    | 0.23    | 0.10     | -0.14     | 0.26*      |

See Table 1 in the main text for list and abbreviations of the traits

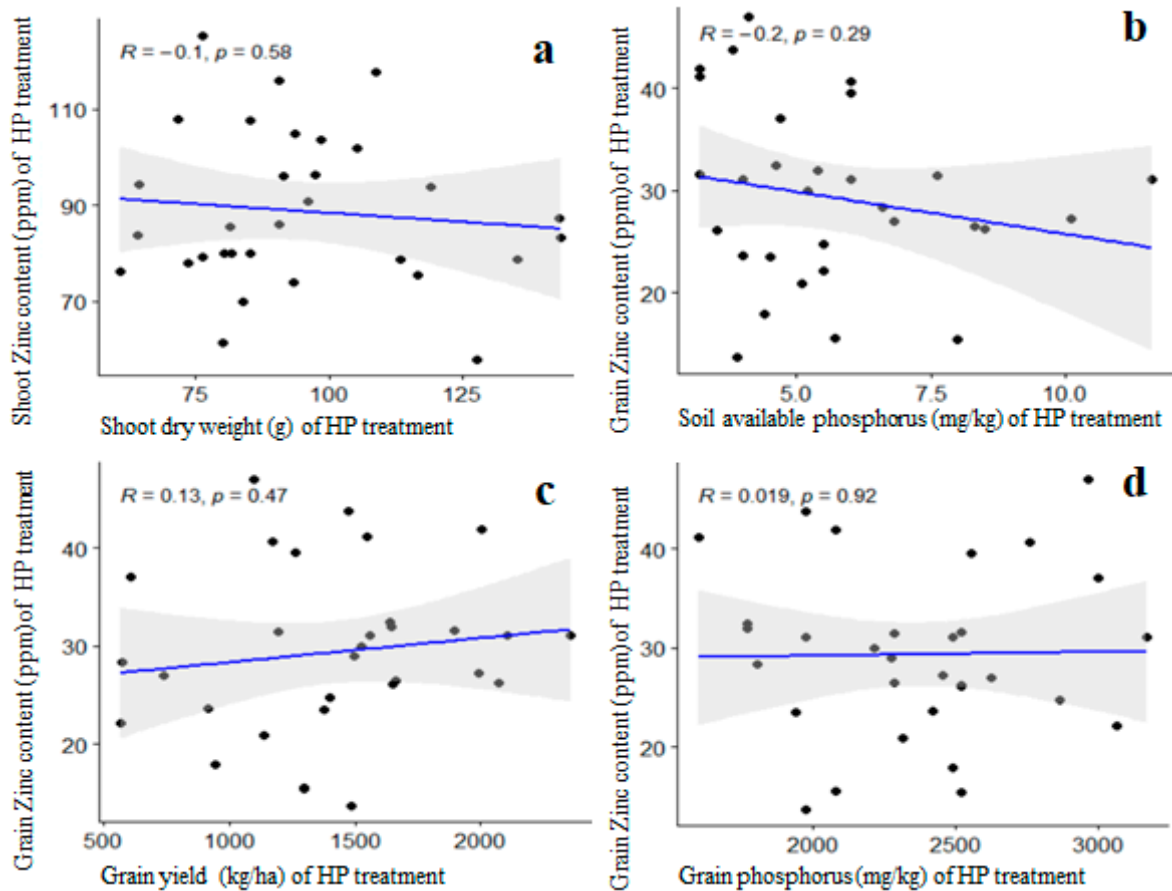
## Supplementary Figures



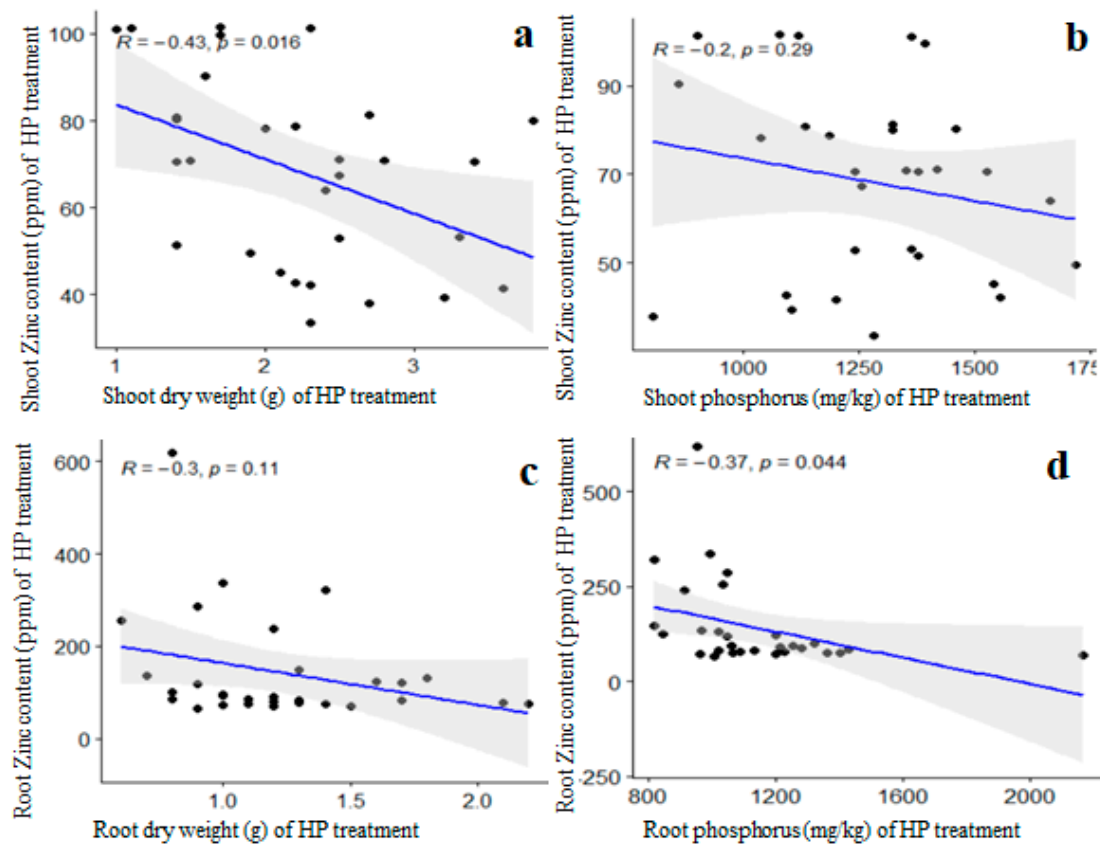
Supplementary Figure 1. Phenotypic distribution of traits measured in the field experiment at the vegetative stage under varying soil phosphorus levels. Box plot displays the median of each group bounded by the first and third quartile, with 1\_LP = no-P application, 2\_MP = 10 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> & 3\_HP = 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>



Supplementary Figure 2. Correlation matrices for traits measured across varying soil phosphorus concentrations in the field experiment at the vegetative stage (n = 30 genotypes). See Table 1 for list and abbreviations of the traits. Positive and negative associations between given traits are in blue and red, respectively. The color intensity and the size of the circle are proportional to the correlation coefficients. On the X-axis of the correlogram, the legend color shows the correlation coefficients and the corresponding colors.



Supplementary Figure 3. Scatterplot showing weak correlations between pairs of traits from the field evaluation (a) Shoot dry weight (g) and shoot Zinc content (ppm) of high phosphorus treatment,  $R = -0.10$ ;  $P = 0.58$ , (b) Soil available phosphorus (mg/kg) and grain Zinc content (ppm),  $R = -0.20$ ,  $P = 0.29$ , (c) Grain yield (kg/ha) and grain Zinc content (ppm),  $R = 0.13$ ,  $P = 0.47$ , (d) Grain phosphorus (mg/kg) and grain Zinc content (ppm),  $R = 0.02$ ,  $P = 0.92$ . HP = high phosphorus (HP = 60 kg  $P_2O_5$  ha $^{-1}$ ). Each point represents an average of a genotype.



Supplementary Figure 4. Scatterplot showing weak correlations between pairs of traits from the screenhouse evaluation (a) Shoot dry weight (g) and shoot Zinc content (ppm) of high phosphorus treatment,  $R = -0.43$ ;  $P = 0.02$ , (b) Shoot phosphorus (mg/kg) and shoot Zinc content (ppm) of high phosphorus treatment,  $R = -0.20$ ,  $P = 0.29$ , (c) Root dry weight (g) and root Zinc content (ppm) of high phosphorus treatment,  $R = -0.30$ ,  $P = 0.11$ , and (d) Root phosphorus (mg/kg) and root Zinc content (ppm) of high phosphorus treatment,  $R = -0.37$ ,  $P = 0.04$ . HP = high phosphorus (HP = 60 kg  $P_2O_5$  ha $^{-1}$ ). Each point represents an average of a genotype.