Extended Table 1 Agronomic traits of generations F1 to F9 derived from the crossing of ‘RD23’ (P1) and *Oryza longistaminata* (P2)*.*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Generation | Rhizome number | Rhizome length (cm) | Pollen fertility (%) | Height (cm) | Tiller number | Grain number | Seed setting rate (%) | Panicle length (cm) | Grain weight (mg) |
| P1 | 0 | 0 | 96.2 | 98 | 42 | 3126 | 74.1 | 30.3 | 24.3 |
| P2 | 14 | 101 | 100 | 181 | 51 | 8543 | 0.0 | 40.1 | 11.9 |
| F1 | 17 | 9.3  | 3.2 | 232 | 132 | 12358 | 4.3 | 42.3 | 22.4 |
| F2 | 13 | 8.3 | 1.2 | 170 | 61 | 2547 | 5.7 | 30.1 | 14.9 |
| F3 | 7 | 6.2 | 3.3 | 170 | 44 | 1614 | 5.2 | 32.7 | 14.9 |
| F4 | 8 | 5.9 | 11.9 | 202 | 68 | 9306 | 12.0 | 31.4 | 16.7 |
| F5 | 7 | 4.3 | 42.6 | 209 | 57 | 8025 | 36.2 | 30.7 | 18.4 |
| F6 | 7 | 5.3 | 70.2 | 161 | 49 | 4372 | 36.3 | 26.9 | 19.2 |
| F7 | 4 | 4.4 | 73.6 | 105 | 26 | 1917 | 29.1 | 25.0 | 16.6 |
| F8 | 5 | 4.0 | 85.3 | 106 | 61 | 2550 | 7.7 | 23.1 | 15.9 |
| F9 | 4 | 3.4 | 90.4 | 114 | 35 | 2040 | 21.4 | 24.8 | 16.2 |

Note: The agronomic traits of P1, P2 and F1-F9 were observed based on the growth stage of ‘RD23’. As *O. longistaminata* was self–incompatible, the seed setting rate is 0. F2-F9, were obtained by selfing.

Extended Table 2 Variance component analysis of genotype by environment interactions in experiment 1, conducted in 2012 and 2013 with 22 genotypes in 12 location-season-year combinations (environments)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variance Components / $σ^{2}$ | GY | RR | Height | Epn | Pl | GN | GW | Gnopm2 | SSR | Duration |
| Environment | 86.15\*\* | 17989.88\*\* | 8377.01\*\* | 1305.08\*\* | 258.59\*\* | 72304.90\*\* | 37.91\*\* | 1628.23\*\* | 0.34\*\* | 31001.85\*\* |
| Genotype | 12.09\*\* | 3127.63\*\* | 3449.55\*\* | 27.10\*\* | 39.96\*\* | 2889.86\*\* | 73.58\*\* | 176.35\*\* | 0.16\*\* | 741.78\*\* |
| G\*E | 1.53\*\* | 330.18\*\* | 203.88\*\* | 13.88\*\* | 7.54\*\* | 1041.80\*\* | 5.17\*\* | 35.22\*\* | 0.03\*\* | 153.70\*\* |
| error | 0.34 | 108.32 | 19.22 | 3.74 | 1.55 | 303.04 | 1.50 | 6.32 | 0.01 | 0.00 |
| Heritability / $h^{2}$ | 0.87 | 0.88 | 0.94 | 0.61 | 0.81 | 0.68 | 0.92 | 0.81 | 0.83 | 0.83 |

Note: GY, grain yield (g/m2). RR, regrowth rate (%). Height, plant height (cm). Epn, effective panicle number per plant. Pl, panicle length (cm). GN, grain number per panicle. GW, grain weight for 1000 grains (g). Gnopm2, filled grain number in one square meter (1000/m2). SSR, seed setting rate (%). Duration, whole growth duration (d), from sowing to harvest for first crop, and from stem cut off to harvest for ratoon crops. \*\**P* < 0.01.

Extended Table 3 Variance component analysis of genotype by environment interactions in experiment 2, conducted in 2014-2017 with nine genotypes in 19 location-season-year combinations (environments)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variance Components / $σ^{2}$ | GY | RR | Height | Epn | Pl | GN | GW | Gnopm2 | SSR | Duration |
| Environment | 52.99\*\* | 7321.94\*\* | 3420.75\*\* | 67.46\*\* | 49.41\*\* | 9849.74\*\* | 59.99\*\* | 715.59\*\* | 0.25\*\* | 1887.00\*\* |
| Genotype | 180.50\*\* | 20512.28\*\* | 5430.80\*\* | 304.07\*\* | 117.00\*\* | 1756.68\*\* | 484.18\*\* | 667.94\*\* | 0.30\*\* | 2077.47\*\* |
| G\*E | 11.54\*\* | 610.10\*\* | 190.37\*\* | 29.46\*\* | 9.88\*\* | 1419.55\*\* | 10.20\*\* | 124.76\*\* | 0.07\*\* | 502.50\*\* |
| error | 0.38 | 135.34 | 33.13 | 2.61 | 2.76 | 568.04 | 3.10 | 9.53 | 0.00 | 1.45 |
| Heritability / $h^{2}$ | 0.94 | 0.96 | 0.96 | 0.90 | 0.90 | 0.47 | 0.97 | 0.83 | 0.81 | 0.80 |

Note: GY, grain yield (g/m2). RR, regrowth rate (%). Height, plant height (cm). Epn, effective panicle number per plant. Pl, panicle length (cm). GN, grain number per panicle. GW, grain weight for 1000 grains (g). Gnopm2, filled grain number in one square meter (1000/m2). SSR, seed setting rate (%). Duration, whole growth duration (d), from sowing to harvest for first crops, and from stem cut off to harvest for ratoon crops. \*\**P* < 0.01.

Extended Table 4 Number and cumulative area of perennial rice cultivation locations from 2011 to 2020 in China.

|  |  |  |
| --- | --- | --- |
| Year | Locations  | Cumulative Area (ha) |
| 2011 | 2 | 30 |
| 2012 | 2 | 30 |
| 2013 | 2 | 50 |
| 2014 | 2 | 50 |
| 2015 | 2 | 120 |
| 2016 | 9 | 493 |
| 2017 | 21 | 916 |
| 2018 | 43 | 2884 |
| 2019 | 64 | 4582 |
| 2020 | 82 | 8400 |

Note: As PR017 and PR25 were released in 2020, the data of the cultivation area was mostly for PR23.

Extended Table 5 Grain yield (Mg ha-1) of perennial rice PR23 and replanted annual rice over five years with ten seasons at three locations in Yunnan, China between 2016 and 2020

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Cropping system | F1 | S1 | F2 | S2 | F3 | S3 | F4 | S4 | F5 | S5 | Mean grain yield (Mg ha-1) |
| Mengzhe | Perennial rice | 10.9 | 6.6 | 8.7 | 6.4 | 8.2 | 6.2 | 8.1 | 6.0 | 5.3 | 3.1 | 6.9 |
| Annual rice | 8.0 | 5.7 | 7.7 | 6.2 | 7.8 | 6.5 | 7.9 | 6.3 | 7.7 | 6.0 | 7.0 |
| Xinping | Perennial rice |  | 6.1 | 6.6 | 5.4 | 5.3 | 3.5 | 3.3 | 3.6 | 3.7 | 3.8 | 4.6 |
| Annual rice |  | 6.5 | 6.4 | 5.3 | 6.9 | 5.5 | 6.8 | 4.7 | 6.9 | 4.8 | 6.0 |
| Menglian | Perennial rice | 9.8 | 6.9 | 9.5 | 6.4 | 9.8 | 5.7 | 8.5 | 5.1 |  |  | 7.7 |
| Annual rice | 8.0 | 6.2 | 7.9 | 6.2 | 8.2 | 6.0 | 8.0 | 6.3 |  |  | 7.1 |
| Total number | Perennial rice | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 27 |
| Annual rice | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 27 |
| Mean grain yield (Mg ha-1) | Perennial rice | 10.3 | 6.5 | 8.2 | 6.1 | 7.8 | 5.1 | 6.7 | 4.9 | 4.5 | 3.5 | 6.4 |
| Annual rice | 8.0 | 6.2 | 7.3 | 5.9 | 7.6 | 6.0 | 7.6 | 5.8 | 7.3 | 5.4 | 6.7 |

Note: The data was from experiment 3 from 2016 to 2020. The elite annual rice for Mengzhe, Xinping and Menglian were Diantun502, Wenfu6 and Yunhui290, respectively and all of these three locations are double cropping paddy area. F1 to F5 represent the first season of year 1 to year 5, S1 to S5 represent the second season of year 1 to year 5.

Extended Table 6 Grain yield (Mg ha-1) of perennial rice PR25 and PR107 over three years and two seasons per year at seven locations in Yunnan, China between 2018 and 2020

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cultivar | Location | F1 | S1 | F2 | S2 | F3 | S3 | Mean grain yield (Mg ha-1) |
| PR25 | Jinghong  |  | 4.8  | 5.8  | 5.4  |  |  | 5.3  |
| Xinping  |  | 6.7  | 8.58  | 6.4  | 5.7  | 4.8 | 6.4  |
| Menglian  |  | 6.3  | 8.70  | 7.1  | 8.7  |  | 7.7  |
| Mengzhe  |  | 6.4  | 9.48  | 7.0  | 8.5 | 5.2 | 7.3  |
| Wenshan | 9.3  |  | 7.6  |  |  |  | 8.4  |
| Yiliang  | 10.4  |  | 9.0  |  |  |  | 9.7  |
| PR107 | Jinghong  |  | 4.8  | 6.0  | 4.8  |  |  | 5.2  |
| Xinping |  | 6.8  | 7.7  | 7.1  |  |  | 7.2  |
| Menglian  |  | 6.0  | 8.9  | 6.8  |  |  | 7.2  |
| Lancang  | 8.7  |  | 7.9  |  |  |  | 8.3  |
| Mengzhe  |  | 6.4  | 8.6  | 6.5  |  |  | 7.2  |
| Total number | PR25 | 2  | 4  | 6  | 4  | 3  | 2 | 21 |
| PR107 | 1  | 4  | 5  | 4  |  |  | 14 |
| Mean grain yield (Mg ha-1) | PR25 | 9.8  | 6.1  | 8.2  | 6.5  | 7.6  | 5.0 | 7.2  |
| PR107 | 8.7 | 6.0  | 7.8  | 6.3  |  |  | 6.9 |

Note: The data of PR25 was from experiment 4 with 6 locations contains 12.5 years with 21 seasons. Jinghong, Xinping, Menglian and Mengzhe are double cropping paddy area, while Wenshan, Yiliang and Lancang are single cropping paddy area. The data of PR107 was from experiment 4 with 5 locations contains 8 years with 14 seasons. F1 to F3 represent the first season of year 1 to year 3, S1 to S3 represent the second season of year 1 to year 3.

Extended Table 7 Comparisons of social-economic benefits between perennial rice (PR) and annual rice (AR) cropping systems over five years with ten seasons at three locations in Yunnan, China between 2016 and 2020

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Cropping system | Season | Labour cost (US$ ha-1) | 　 | Non-labour cost (US$ ha-1) | 　 | Total cost(US$ ha-1) | Labournumber | Output(US$ ha-1) | Net economic gain(US$ ha-1) |
| Seedling | Plowing | Transplanting  | Crop management | Harvest | Total | 　 | Seed | Pesticide | Herbicide | Fertilizer | Total | 　 |
| Mengzhe | PR | First season | 329  | 415  | 564  | 470  | 235  | 2012  |  | 94  | 164  | 63  | 489  | 810  |  | 2822  | 129  | 4758  | 1935  |
| Regrowth | 0  | 0  | 0  | 556  | 235  | 791  |  | 0  | 168  | 69  | 360  | 597  |  | 1389  | 51  | 2775  | 1386  |
| AR | First season | 329  | 415  | 564  | 470  | 235  | 2012  |  | 70  | 164  | 63  | 489  | 787  |  | 2799  | 129  | 3253  | 454  |
|  |  | Regrowth | 282  | 415  | 564  | 470  | 235  | 1965  |  | 70  | 176  | 63  | 489  | 798  |  | 2764  | 126 | 3269  | 505  |
| Xinping | PR | First season | 258  | 485  | 470  | 470  | 313  | 1997  |  | 94  | 125  | 35  | 282  | 536  |  | 2533  | 128  | 2861  | 328  |
| Regrowth | 0  | 0  | 0  | 626  | 313  | 940  |  | 0  | 141  | 47  | 212  | 399  |  | 1339  | 60  | 2073  | 734  |
| AR | First season | 258  | 485  | 470  | 470  | 313  | 1997  |  | 70  | 125  | 35  | 284  | 515  |  | 2511  | 128  | 3059  | 548  |
|  |  | Regrowth | 258  | 485  | 470  | 470  | 313  | 1997  |  | 70  | 129  | 35  | 284  | 519  |  | 2515  | 128 | 3140  | 625  |
| Menglian | PR | First season | 235  | 470  | 564  | 376  | 282  | 1926  |  | 94  | 176  | 47  | 331  | 648  |  | 2574  | 123  | 4139  | 1565  |
| Regrowth | 0  | 0  | 0  | 438  | 282  | 720  |  | 0  | 235  | 56  | 239  | 530  |  | 1250  | 46  | 3138  | 1888  |
| AR | First season | 235  | 470  | 564  | 376  | 282  | 1926  | 　 | 70  | 176  | 47  | 336  | 629  | 　 | 2556  | 123  | 3750  | 1195  |
|  |  | Regrowth | 235  | 470  | 564  | 376  | 282  | 1926  |  | 70  | 176  | 47  | 332  | 626  |  | 2552  | 123 | 3276  | 723  |

Note: PR, perennial rice cropping system. AR, annual rice cropping system. In rice production, the economic cost includes labour and non-labour cost. Labour cost mainly includes seedling, plowing, transplanting, crop management and harvest. Non-labour cost includes mainly seed, pesticide, herbicide and fertilizer. The output refers to the gross income from grain sales. The net economic gain equals output minus cost. For annual rice, seeds, plowing, seedling, transplanting, crop management and harvest are all needed in each season. For perennial rice, seeds, plowing, seedling, transplanting, crop management and harvest are all needed in the first season; however, in the subsequent seasons, tillers of the plants is accomplished by regrowth, and thus seed, seedling, plowing and transplanting are not performed, resulting in considerable savings of money and labour. 1 US$ =6.4 China Yuan, the date for exchange was due to the rate of 4 Nov 2021. The data were from experiment 3.

Extended Table 8 Differences in soil structure and nutrients between annual rice (AR) and perennial rice (PR) cropping systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Indicator | Soil depth (cm) | AR | PR-2y | PR-3y | PR-4y | Standard error |
| pH  | 0-10 | 5.2 | 5.2 | 5.4 | 5.5 | 0.15 |
| 10-20 | 5.7 | 5.6 | 5.9 | 5.9 | 0.14 |
| 20-30 | 5.9 | 6.1 | 6.1 | 6.3 | 0.15 |
| 30-40 | 5.9 | 6.0 | 6.2 | 6.4 | 0.21 |
| Soil bulk density(g cm-3) | 0-10 | 1.26 | 1.30 | 1.29 | 1.31 | 0.02 |
| 10-20 | 1.31 | 1.33 | 1.33 | 1.34 | 0.01 |
| 20-30 | 1.39 | 1.37 | 1.37 | 1.36 | 0.01 |
| 30-40 | 1.46 | 1.43 | 1.41 | 1.39 | 0.03 |
| Soil porosity(%)  | 0-10 | 52.6 | 50.9 | 51.3 | 50.7 | 0.85 |
| 10-20 | 50.5 | 49.7 | 49.7 | 49.6 | 0.41 |
| 20-30 | 47.5 | 48.5 | 48.4 | 48.7 | 0.54 |
| 30-40 | 45.1 | 46.2 | 46.6 | 47.5 | 1.00 |
| Capillary porosity(%) | 0-10 | 27.6 | 30.7 | 30.3 | 30.6 | 1.45 |
| 10-20 | 30.6 | 33.4 | 33.5 | 34.4 | 1.65 |
| 20-30 | 35.2 | 36.9 | 36.5 | 38.9 | 1.51 |
| 30-40 | 39.3 | 40.1 | 40.5 | 40.9 | 0.69 |
| Noncapillary porosity(%) | 0-10 | 25.0 | 20.2 | 21.0 | 20.2 | 2.29 |
| 10-20 | 19.9 | 16.4 | 16.1 | 15.2 | 2.06 |
| 20-30 | 12.3 | 11.5 | 11.9 | 9.9 | 1.06 |
| 30-40 | 5.8 | 6.1 | 6.1 | 6.6 | 0.33 |
| Porosity ratio | 0-10 | 0.90 | 0.66 | 0.69 | 0.66 | 0.12 |
| 10-20 | 0.65 | 0.49 | 0.48 | 0.44 | 0.09 |
| 20-30 | 0.35 | 0.31 | 0.32 | 0.25 | 0.04 |
| 30-40 | 0.15 | 0.15 | 0.15 | 0.16 | 0.01 |
| Soil water capacity (%) | 0-10 | 22.0 | 23.6 | 23.4 | 23.4 | 0.75 |
| 10-20 | 23.3 | 25.1 | 25.2 | 25.7 | 1.05 |
| 20-30 | 25.3 | 27.0 | 26.7 | 28.6 | 1.36 |
| 30-40 | 27.0 | 28.1 | 28.7 | 29.4 | 1.01 |
| Available soil statured water (%) | 0-10 | 17.4 | 18.9 | 18.7 | 18.8 | 0.69 |
| 10-20 | 18.5 | 20.1 | 20.1 | 20.8 | 0.98 |
| 20-30 | 20.1 | 21.6 | 21.2 | 23.3 | 1.35 |
| 30-40 | 21.6 | 22.5 | 22.9 | 23.9 | 0.96 |
| Wilting soil water (%) | 0-10 | 4.6 | 4.7 | 4.7 | 4.6 | 0.08 |
| 10-20 | 4.8 | 5.0 | 5.1 | 4.9 | 0.10 |
| 20-30 | 5.2 | 5.4 | 5.5 | 5.3 | 0.13 |
| 30-40 | 5.4 | 5.6 | 5.8 | 5.5 | 0.14 |
| SOC(g kg-1) | 0-10 | 14.2 | 15.1 | 15.4 | 16.4 | 0.92 |
| 10-20 | 12.4 | 12.6 | 12.9 | 13.0 | 0.28 |
| 20-30 | 9.7 | 9.7 | 9.6 | 9.6 | 0.06 |
| 30-40 | 7.9 | 7.9 | 7.8 | 7.8 | 0.05 |
| TN(g kg-1) | 0-10 | 1.5 | 1.6 | 1.7 | 1.8 | 0.11 |
| 10-20 | 1.3 | 1.4 | 1.4 | 1.5 | 0.05 |
| 20-30 | 1.1 | 1.1 | 1.1 | 1.1 | 0.01 |
| 30-40 | 1.0 | 1.0 | 0.9 | 0.9 | 0.00 |
| C/N　 | 0-10 | 9.4 | 9.3 | 9.1 | 9.2 | 0.13 |
| 10-20 | 9.2 | 9.2 | 9.0 | 9.0 | 0.11 |
| 20-30 | 8.8 | 8.7 | 8.8 | 8.8 | 0.03 |
| 30-40 | 8.4 | 8.3 | 8.3 | 8.3 | 0.03 |

Note: AR, annual rice. PR-2y, PR-3y and PR-4y are perennial rice year 2, perennial rice year 3 and perennial rice year 4, respectively. The data was from experiment 3. SE represent the standard error of different treatments.

Extended Table 9 Latitude, longitude and elevation for each of the field trial locations used to evaluate perennial rice in this study

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment | Location | Latitude | Longitude | Elevation | Year |
| Experiment 1 | Na Pok | 17°57′N | 104°34′E | 171 m | 2012-2013 |
| Jinghong#1 | 21°59′N | 100°44′E | 611 m | 2012-2013 |
| Simao | 22°79′N | 100°96′E | 1340 m | 2012-2013 |
| Menglian#1 | 22°33′N | 99°59′E | 955 m | 2012-2013 |
| Experiment 2 | Jinghong#2 | 21°59′N | 100°44′E | 550 m | 2014-2016 |
| Puer | 22°45′N | 100°51′E | 1305 m | 2014-2016 |
| Hongta | 24°24′N | 102°32′E | 1630 m | 2014-2015 |
| Wenshan | 23°23′N | 104°13′E | 1260 m | 2015-2016 |
| Yuanyang | 23°8′N | 102°40′E | 1034 m | 2015-2016 |
| Lancang#1 | 22°26′N | 99°58′E | 1150 m | 2015-2016 |
| Dehong | 24°26′N | 98°35′E | 900 m | 2016-2017 |
| Experiment 3 | Mengzhe | 21°57′N | 100°14′E | 1255 m | 2016-2020 |
| Menglian | 22°33′N | 99°59′E | 980 m | 2017-2020 |
| Xinping#1 | 24°02′N | 101°34′E | 760 m | 2016-2020 |
| Experiment 4 | Mengzhe | 21°57′N | 100°14′E | 1255 m | 2018-2020 |
| Menglian#2 | 22°33′N | 99°59′E | 960 m | 2018-2020 |
| Jinghong#2 | 21°59′N | 100°44′E | 550 m | 2018-2019 |
| Xinping#2 | 24°02′N | 101°34′E | 600 m | 2018-2020 |
| Lancang#2 | 22°26′N | 99°58′E | 1020 m | 2018-2019 |
| Yiliang | 24°54′N | 103°09′E | 1600 m | 2018-2020 |

Extended Table 10 The effect of low temperature on the regrowth of perennial rice in field trials at 16 locations in Yunnan, China

|  |  |  |  |
| --- | --- | --- | --- |
| Location | Altitude (m) | Average monthly temperature in January (℃) | Regrowth (%) |
| Baoshan | 1670 | 11.4 | 0.0 |
| Wenshan | 1260 | 13.2 | 68.4 |
| Yiliang | 1600 | 15.5 | 80.3 |
| Jinghong | 550 | 19.4 | 92.0 |
| Lancang | 1150 | 15.7 | 96.1 |
| Puer | 1305 | 15.5 | 85.0 |
| Yuanjiang | 580 | 17.5 | 98.8 |
| Dehong | 900 | 14.6 | 90.0 |
| Xinping | 600 | 15.2 | 85.3 |
| Menglian | 980 | 12.5 | 94.5 |
| Honghe | 1300 | 15.2 | 92.0 |
| Mengzhe | 1255 | 14.2 | 93.3 |
| Congjiang | 430 | 15.4 | 93.7 |
| Shangsi | 190 | 14.9 | 97.0 |
| Guanyang | 260 | 16.4 | 84.0 |
| Yudu | 318 | 13.0 | 92.0 |

Note: The temperature was investigated when the experiment was performed.

Extended Table 11 The effect of low temperature duration on the regrowth of perennial rice.

|  |  |  |  |
| --- | --- | --- | --- |
| Temperature（℃） | Duration (d) | Regrowth rate (%) | SE |
| 0 | 3 | 92.0 | 0.25 |
| 0 | 5 | 82.8 | 0.75 |
| 0 | 7 | 22.4 | 0.85 |
| 4 | 3 | 93.4 | 0.78 |
| 4 | 5 | 91.0 | 0.44 |
| 4 | 7 | 55.4 | 1.06 |

Note: Each of the treatment was with three replicates.