# 基于全基因组关联分析水稻抗旱相关基因的挖掘

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# Mining of Drought-resistance Related Genes in Rice Based on Genome-Wide Association Study

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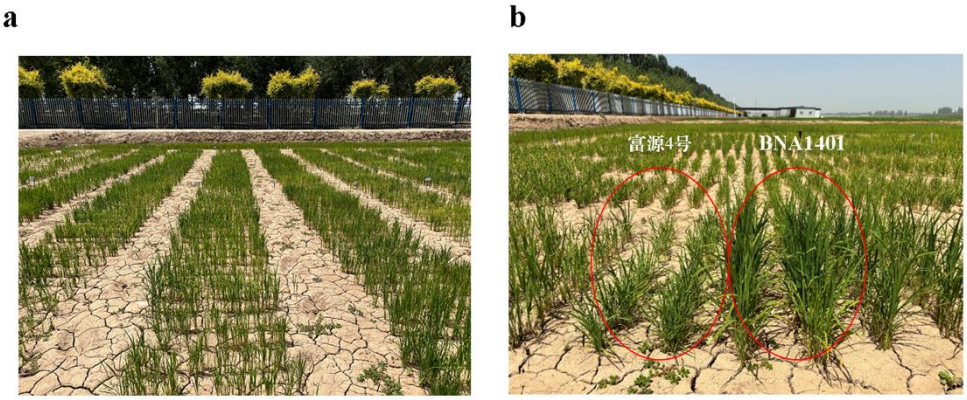



（a）7 月 6 日干旱胁迫下水稻群体整体表型；(b) 耐旱性表现优异的水稻资源 BNA1401（右）和对照品种富源 4 号（左）

(a) Overall phenotype of the rice population under drought stress on July 6； (b) Performance of a drought-tolerant accession, BNA1401 (right), compared with the drought-resistant check variety, Fuyuan 4 (left).

附图 1 大田干旱胁迫下水稻表型展示

Supplementary Fig. 1. Phenotypic performance of rice under field drought stress.

附表 1 定量引物序列

Table S1 Quantitative primer sequence

| 引物名称 Primer name | 正向引物 Forward primer（5′–3′） | 反向引物 Reverse primer（5′–3′） |
|---|---|---|
| qpcr-54360 | GGTGACTGACGAGGTGAATTAT | TGAGCCAAGTGAAATCCTCTAC |
| qpcr-54474 | ATATCCAACAGCTGGAGACAAG | GTTCTCGAAGGCTCCCATTT |
| qpcr-54560 | CACCTTGGCGAGGAGATT | GTGAACCGATTCCGTTGTTC |
| qpcr-54570 | TCGACGCGGGATACTACTT | TCGAGGATCTCTTCCTGTATCG |

附表 2 叶枯萎度显著关联的 SNP 信息

Table S2 Significantly associated SNPs for leaf wilting

| Marker | Chr | Pos | p | MarkerR2 | q |
|---|---|---|---|---|---|
| Chr1:15231386 | 1 | 15,231,386 | 9.7367e-06 | 0.01045 | 0.200822111 |
| Chr1:15289931 | 1 | 15,289,931 | 1.7001e-06 | 0.01204 | 0.200822111 |
| Chr1:16255787 | 1 | 16,255,787 | 4.4397e-06 | 0.01119 | 0.139945052 |
| Chr1:19922594 | 1 | 19,922,594 | 6.3334e-06 | 0.01085 | 0.093163892 |
| Chr1:27285252 | 1 | 27,285,252 | 8.8311e-06 | 0.01055 | 0.114621964 |
| Chr1:27285252 | 1 | 27,285,252 | 6.3334e-06 | 0.01087 | 0.349364594 |
| Chr1:33788058 | 1 | 33,788,058 | 7.6095e-06 | 0.01067 | 0.200822111 |
| Chr1:6776916 | 1 | 6,776,916 | 4.7842e-06 | 0.0111 | 0.230706181 |
| Chr12:17219609 | 12 | 17,219,609 | 1.6142e-06 | 0.01209 | 0.220170927 |
| Chr12:18299744 | 12 | 18,299,744 | 5.2279e-06 | 0.01102 | 0.230706181 |
| Chr12:18778781 | 12 | 18,778,781 | 9.6271e-06 | 0.01046 | 0.265526248 |
| Chr12:25599558 | 12 | 25,599,558 | 7.6798e-06 | 0.01068 | 0.105908762 |
| Chr2:13553976 | 2 | 13,553,976 | 8.4787e-06 | 0.0106 | 0.187081668 |
| Chr2:24514016 | 2 | 24,514,016 | 6.7596e-06 | 0.0108 | 0.165722109 |
| Chr3:21445322 | 3 | 21,445,322 | 4.2317e-06 | 0.01122 | 0.071824644 |
| Chr3:21779158 | 3 | 21,779,158 | 5.528e-07 | 0.01309 | 0.060987384 |
| Chr3:28502006 | 3 | 28,502,006 | 3.4656e-06 | 0.01141 | 0.127446862 |
| Chr3:9327945 | 3 | 9,327,945 | 7.8869e-06 | 0.01064 | 0.265526248 |
| Chr4:19298782 | 4 | 19298782 | 5.3007e-06 | 0.01101 | 0.305252131 |
| Chr4:23013303 | 4 | 23,013,303 | 9.4225e-06 | 0.01048 | 0.200822111 |
| Chr4:31991020 | 4 | 31,991,020 | 3.129e-07 | 0.0136 | 0.017260268 |
| Chr4:32033623 | 4 | 32,033,623 | 5.753e-06 | 0.01092 | 0.200822111 |
| Chr4:32033623 | 4 | 32,033,623 | 8.0508e-08 | 0.01484 | 0.008648705 |
| Chr4:32144636 | 4 | 32,144,636 | 1.6585e-06 | 0.01207 | 0.036594637 |
| Chr4:32206745 | 4 | 32,206,745 | 2.7314e-06 | 0.01162 | 0.05022339 |
| Chr4:32233143 | 4 | 32,233,143 | 5.1916e-07 | 0.01313 | 0.021696731 |
| Chr4:32260706 | 4 | 32,260,706 | 5.5895e-06 | 0.01095 | 0.200822111 |
| Chr4:32260706 | 4 | 32,260,706 | 1.1759e-07 | 0.01449 | 0.008648705 |
| Chr4:32299416 | 4 | 32,299,416 | 9.1621e-07 | 0.01261 | 0.022462313 |
| Chr4:32457574 | 4 | 32,457,574 | 9.7488e-06 | 0.01044 | 0.200822111 |
| Chr4:32457574 | 4 | 32,457,574 | 3.3491e-08 | 0.01564 | 0.007389756 |
| Chr4:32668510 | 4 | 32,668,510 | 8.8672e-07 | 0.01264 | 0.022462313 |
| Chr4:32729027 | 4 | 32,729,027 | 1.8594e-06 | 0.01197 | 0.037297705 |
| Chr4:32843337 | 4 | 32,843,337 | 6.5439e-07 | 0.01292 | 0.021696731 |
| Chr4:32990599 | 4 | 32,990,599 | 6.8832e-07 | 0.01288 | 0.021696731 |
| Chr4:4919952 | 4 | 4,919,952 | 9.6747e-06 | 0.01048 | 0.426942576 |
| Chr4:7233461 | 4 | 7,233,461 | 9.751e-06 | 0.01047 | 0.195595309 |
| Chr5:10708018 | 5 | 10,708,018 | 8.6238e-06 | 0.01056 | 0.265526248 |
| Chr5:11168463 | 5 | 11,168,463 | 5.2059e-06 | 0.01104 | 0.143584579 |
| Chr5:19713917 | 5 | 19,713,917 | 2.9743e-06 | 0.01155 | 0.127446862 |
| Chr7:1878281 | 7 | 1,878,281 | 2.1593e-06 | 0.01185 | 0.349364594 |

| | | | | | |
|---|---|---|---|---|---|
| Chr7:27978534 | 7 | 27,978,534 | 3.0953e-07 | 0.01362 | 0.060987384 |
| Chr8:17403818 | 8 | 17,403,818 | 2.9935e-06 | 0.01152 | 0.220170927 |
| Chr8:7093584 | 8 | 7093584 | 7.689e-06 | 0.01067 | 0.305252131 |
| Chr10:15229404 | 10 | 15,229,404 | 5.2344e-06 | 0.0094 | 0.082497509 |
| Chr10:3169064 | 10 | 3,169,064 | 2.3761e-06 | 0.01176 | 0.127446862 |
| Chr11:12295393 | 11 | 12,295,393 | 4.0332e-06 | 0.01128 | 0.349364594 |
| Chr11:22934789 | 11 | 22,934,789 | 2.8648e-06 | 0.01156 | 0.220170927 |
| Chr11:23861379 | 11 | 23,861,379 | 5.0204e-06 | 0.01108 | 0.349364594 |
| Chr11:2888595 | 11 | 2,888,595 | 2.1295e-06 | 0.01183 | 0.200822111 |
| Chr11:6795367 | 11 | 6,795,367 | 1.1887e-06 | 0.01239 | 0.087428489 |

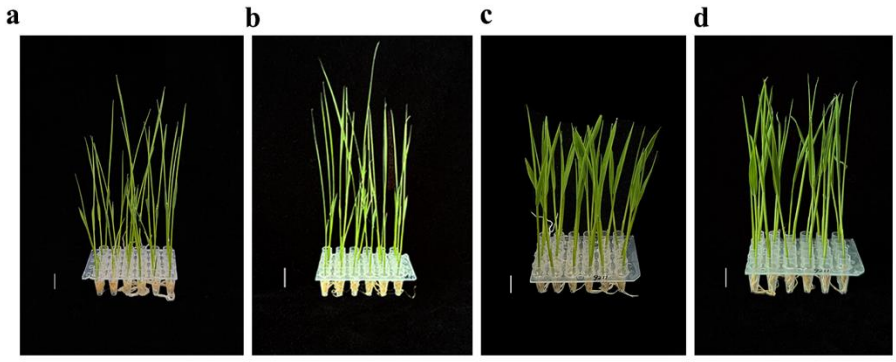
**附表 3 *qLWD4-1* 位点候选基因**

Table S3 Candidate genes for the *qLWD4-1* locus

| 候选基因<br>Candidate gene | 基因注释<br>Gene annotation | 起始位置<br>Start position | 结束位置<br>End position |
|---|---|---|---|
| *LOC_Os04g53800* | leucoanthocyanidin reductase putative expressed | 32059521 | 32062391 |
| *LOC_Os04g53810* | leucoanthocyanidin reductase putative expressed | 32063705 | 32065859 |
| *LOC_Os04g53820* | transposon protein putative unclassified expressed | 32068442 | 32076123 |
| *LOC_Os04g53830* | 3-beta hydroxysteroid dehydrogenase isomerase family protein putative expressed | 32078551 | 32081906 |
| *LOC_Os04g53850* | leucoanthocyanidin reductase putative expressed | 32085528 | 32088329 |
| *LOC_Os04g53860* | reductase putative expressed | 32090821 | 32093093 |
| *LOC_Os04g53890* | retrotransposon protein putative Ty3-gypsy subclass expressed | 32113064 | 32117614 |
| *LOC_Os04g53920* | leucoanthocyanidin reductase putative expressed | 32131999 | 32135388 |
| *LOC_Os04g53930* | organic cation transporter protein putative expressed | 32137818 | 32141183 |
| *LOC_Os04g53950* | glycosyl hydrolases family 16 protein protein expressed | 32145679 | 32147540 |
| *LOC_Os04g53960* | retrotransposon protein putative Ty1-copia subclass expressed | 32151331 | 32152103 |
| *LOC_Os04g53990* | ethylene-responsive protein related putative expressed | 32166724 | 32169604 |
| *LOC_Os04g53994* | kinase putative expressed | 32173554 | 32177365 |
| *LOC_Os04g53996* | protein kinase putative expressed | 32183781 | 32184551 |
| *LOC_Os04g53998* | kinase putative expressed | 32178133 | 32182246 |
| *LOC_Os04g54002* | serine threonine-protein kinase receptor precursor putative expressed | 32189405 | 32193189 |
| *LOC_Os04g54010* | serine threonine-protein kinase receptor precursor putative expressed | 32193893 | 32196603 |
| *LOC_Os04g54020* | receptor-like kinase putative expressed | 32197592 | 32202721 |
| *LOC_Os04g54040* | expressed protein | 32206661 | 32207610 |
| *LOC_Os04g54070* | receptor-like kinase putative expressed | 32223116 | 32226952 |
| *LOC_Os04g54080* | serine threonine-protein kinase receptor precursor putative expressed | 32229075 | 32233640 |
| *LOC_Os04g54090* | RALFL18 - Rapid ALkalinization Factor RALF family protein precursor expressed | 32234697 | 32235021 |

| | | | |
|---|---|---|---|
| *LOC_Os04g54100* | exostosin family protein putative expressed | 32235313 | 32235699 |
| *LOC_Os04g54110* | ARK3 putative expressed | 32238374 | 32242528 |
| *LOC_Os04g54120* | serine threonine-protein kinase receptor precursor putative expressed | 32244877 | 32248178 |
| *LOC_Os04g54130* | TKL_IRAK_DUF26-ld.1 - DUF26 kinases have homology to DUF26 containing loci expressed | 32248949 | 32253028 |
| *LOC_Os04g54140* | receptor-like kinase putative expressed | 32254120 | 32258262 |
| *LOC_Os04g54180* | serine threonine-protein kinase receptor precursor putative expressed | 32273357 | 32276952 |
| *LOC_Os04g54190* | cysteine-rich receptor-like protein kinase 8 precursor putative expressed | 32278147 | 32281447 |
| *LOC_Os04g54200* | diacylglycerol kinase putative expressed | 32286661 | 32291459 |
| *LOC_Os04g54210* | expressed protein | 32295071 | 32295355 |
| *LOC_Os04g54220* | expressed protein | 32296089 | 32296600 |
| *LOC_Os04g54230* | wound induced protein putative expressed | 32297556 | 32298132 |
| *LOC_Os04g54240* | wound induced protein putative expressed | 32301622 | 32302456 |
| *LOC_Os04g54250* | retrotransposon protein putative Ty1-copia subclass expressed | 32304817 | 32306616 |
| *LOC_Os04g54280* | retrotransposon protein putative Ty1-copia subclass expressed | 32319644 | 32323748 |
| *LOC_Os04g54300* | wound induced protein putative expressed | 32333335 | 32333993 |
| *LOC_Os04g54310* | expressed protein | 32336347 | 32337872 |
| *LOC_Os04g54320* | expressed protein | 32338417 | 32339536 |
| *LOC_Os04g54330* | acetyltransferase GNAT family putative expressed | 32339069 | 32342426 |
| *LOC_Os04g54340* | double-strand break repair protein MRE11 putative expressed | 32342580 | 32348446 |
| *LOC_Os04g54350* | SPRY-domain containing protein putative expressed | 32348410 | 32351851 |
| *LOC_Os04g54360* | glycosyl transferase 8 domain containing protein putative expressed | 32353487 | 32356043 |
| *LOC_Os04g54370* | expressed protein | 32356158 | 32358757 |
| *LOC_Os04g54380* | aluminum resistance protein putative expressed | 32359202 | 32362652 |
| *LOC_Os04g54390* | nuclease PA3 putative expressed | 32362968 | 32365039 |
| *LOC_Os04g54400* | BTBN12 - Bric-a-Brac Tramtrack Broad Complex BTB domain with non-phototropic hypocotyl 3 NPH3 and coiled-coil domains expressed | 32365684 | 32369961 |
| *LOC_Os04g54410* | expressed protein | 32370810 | 32378071 |
| *LOC_Os04g54420* | protein of unknown function DUF618 domain containing protein expressed | 32378706 | 32382044 |
| *LOC_Os04g54430* | immediate-early protein RSP40 putative expressed | 32383898 | 32387161 |
| *LOC_Os04g54440* | RNA binding protein putative expressed | 32388440 | 32392487 |
| *LOC_Os04g54490* | expressed protein | 32414780 | 32415613 |
| *LOC_Os04g54500* | POLGAMMA2 putative expressed | 32418363 | 32423997 |
| *LOC_Os04g54510* | mTERF family protein expressed | 32424166 | 32425618 |
| *LOC_Os04g54520* | retrotransposon protein putative Ty3-gypsy subclass | 32430029 | 32432681 |
| *LOC_Os04g54530* | retrotransposon protein putative unclassified | 32435980 | 32437552 |

| | | | |
|---|---|---|---|
| *LOC_Os04g54540* | expressed protein | 32438583 | 32439478 |
| *LOC_Os04g54550* | AT5MAT putative expressed | 32445398 | 32445928 |
| *LOC_Os04g54560* | transferase family protein putative expressed | 32448490 | 32450325 |
| *LOC_Os04g54564* | expressed protein | 32450512 | 32451874 |
| *LOC_Os04g54570* | transferase family protein putative expressed | 32453265 | 32455214 |
| *LOC_Os04g54580* | expressed protein | 32457056 | 32457668 |
| *LOC_Os04g54590* | expressed protein | 32459573 | 32460498 |
| *LOC_Os04g54600* | DUF617 domain containing protein expressed | 32464933 | 32466074 |
| *LOC_Os04g54610* | expressed protein | 32476612 | 32477579 |
| *LOC_Os04g54620* | expressed protein | 32478832 | 32479294 |
| *LOC_Os04g54630* | expressed protein | 32481117 | 32481777 |
| *LOC_Os04g54640* | peptidase cysteine peptidase active site putative expressed | 32483013 | 32485554 |
| *LOC_Os04g54650* | retrotransposon protein putative Ty3-gypsy subclass expressed | 32495675 | 32503544 |
| *LOC_Os04g54680* | ulp1 protease family protein putative expressed | 32531424 | 32537198 |
| *LOC_Os04g54720* | expressed protein | 32545515 | 32547299 |
| *LOC_Os04g54730* | expressed protein | 32549152 | 32550018 |
| *LOC_Os04g54740* | expressed protein | 32552399 | 32556341 |
| *LOC_Os04g54759* | expressed protein | 32556873 | 32565405 |
| *LOC_Os04g54780* | retrotransposon protein putative Ty3-gypsy subclass expressed | 32569746 | 32572598 |
| *LOC_Os04g54790* | ELMO CED-12 family protein putative expressed | 32574405 | 32581684 |
| *LOC_Os04g54800* | shikimate kinase putative expressed | 32582126 | 32585724 |
| *LOC_Os04g54810* | beta-D-xylosidase putative expressed | 32588940 | 32595893 |
| *LOC_Os04g54820* | programmed cell death 2 C-terminal domain-containing protein putative expressed | 32600309 | 32603388 |
| *LOC_Os04g54830* | expressed protein | 32605092 | 32608651 |
| *LOC_Os04g54840* | DNA-directed RNA polymerase subunit putative expressed | 32609882 | 32618950 |
| *LOC_Os04g54850* | pectinesterase putative expressed | 32625802 | 32629134 |
| *LOC_Os04g54860* | glutaredoxin putative expressed | 32632277 | 32634821 |
| *LOC_Os04g54870* | RNA recognition motif containing protein putative expressed | 32633163 | 32637837 |
| *LOC_Os04g54890* | expressed protein | 32648181 | 32652728 |



（a）水稻‘Nip’三叶期，20% PEG-6000 处理 0 h 表型（对照）；(b) 水稻‘Nip’三叶期，20% PEG-6000 处理 24 h 表型（干旱胁迫）（c）水稻‘9311’三叶期，20% PEG-6000 处理 0 h 表型（对照）；(d) 水稻‘9311’三叶期，20% PEG-6000 处理 24 h 表型（干旱胁迫）

(a) Phenotype of rice cultivar 'Nip' at the three-leaf stage under 0 h treatment with 20% PEG-6000 (control);

(b) Phenotype of rice cultivar 'Nip' at the three-leaf stage under 24 h treatment with 20% PEG-6000 (drought stress);

(c) Phenotype of rice cultivar '9311' at the three-leaf stage under 0 h treatment with 20% PEG-6000 (control);

(d) Phenotype of rice cultivar '9311' at the three-leaf stage under 24 h treatment with 20% PEG-6000 (drought stress).

**附图 2 水稻‘Nip’及‘9311’对 PEG-6000 模拟干旱胁迫的表型响应**

Supplementary Fig 2.Phenotypic Responses of Rice Cultivars 'Nip' and '9311' to PEG-6000 Simulated Drought Stress