**Supplementary file 12** Functions and References associated with abiotic stress and immune responses, organ developments of male-biased genes under significant positive selection (*P-value* < 0.05) in floral buds.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| OGs |  Function Description | Signal\* | Stress responses/Developments | References |
| **OG0007149** | mitogen-activated protein kinase kinase kinase 18 (MAPKKK18) | A, B, C, R | drought, heavy metal, microtubule stabilization | Mondal (2022); Zhang and Zhang (2022); Xu and Zhang (2015); Lin, L *et al.* (2021) |
| **OG0007167** | ubiquitin-conjugating enzyme E2 24 (UBC24) | A, B, C, R | pathogens, limited nutrient, heavy metal, male fertility | Unver *et al.* (2013); Sharma *et al.* (2021); Wang *et al.* (2020) |
| OG0007172 | homeobox-DDT domain protein RLT2 (RLT2) | A, B, C, R | plant vegetative phase | Li *et al.* (2012) |
| ***OG0007198*** | la-related protein 6A (LARP6A) | A, B, C, R | salt, mature pollen grain, male gametogenesis | De Vos *et al.* (2019); Bousquet-Antonelli (2021); Zhang *et al.* (2017) |
| OG0009257 | uncharacterized protein | A, B, C, R |  |  |
| **OG0008422** | regulator of nonsense transcripts UPF2 (UPF2) | A, B, C, R | pathogens, normal growth | Shi *et al.* (2012) |
| **OG0006902** | heat stress transcription factor B-3 (HSFB3) | A, B, C, R | heat, drought, dehydration, pathogens | Mehta *et al.* (2021); Liao *et al.* (2022); Wang *et al.* (2018); Scharf *et al.* (2012) |
| OG0007054 | uncharacterized protein | A, B, C, R |  |  |
| OG0007066 | suppressor of RPS4-RLD 1 (SRFR1) | A, B, C, R | pathogens | Kwon *et al.* (2004); Kwon *et al.* (2009) |
| OG0007085 | LMBR1 domain-containing protein (LMBR1) | A, B, C, R |  |  |
| **OG0008757** | phytochrome B (PHYB) | A, B, C, R | heat, cold, drought, red light, jasmonic acid (JA), salicylic acid (SA), root, stem, leaf, flower | Kim *et al.* (2021); Ikeda *et al.* (2021) |
| **OG0007324** | autophagy-related protein 18a (ATG18a) | A, B, C, R | pathogens, nutrient starvation, dark, cold, drought, salt, heavy metal, oxidation, osmotic, jasmonic acid (JA), salicylic acid (SA), senescence  | Qi *et al.* (2021); Zhou *et al.* (2015); Su *et al.* (2020); Avin-Wittenberg (2019); Xiong *et al.* (2005) |
| OG0009150 | MND1-interacting protein 1 (MIP1) | A, B, C, R |  |  |
| ***OG0009434*** | carbohydrate esterase (At3g16150) | A, B, C, R | pollen development | Honys & Twell, (2003) |
| **OG0009468** | nucleoredoxin 2 | A, B, C, R | drought, oxidative | Kneeshaw *et al.* (2017); Kotrade *et al.* (2019) |
| **OG0007918** | aminoacylase-1 (ACY1) | A, B, C, R | pathogens, salt, drought, jasmonic acid (JA), salicylic acid (SA), plant growth | Chen *et al.* (2021) |
| **OG0007693** | pheophorbide a oxygenase (PAO) | A, B, C, R | wounding, cold, salt, pathogens, seed, suppression of cell death | Ma *et al.* (2012); Chung *et al.* (2006) |
| **OG0008053** | CHROMATIN REMODELING 5 (CHR5) | A, B, C, R | heat, salt, drought, ABA, pathogens | Song *et al.* (2021) |
| **OG0006505** | E3 ubiquitin-protein ligase RHB1A (RHB1A) | A, B, C, R | pathogens | Shahinnia *et al.* (2022) |
| **OG0006517** | protein STAY-GREEN (SGR) | A, B, C, R | drought, heat | Abdelrahman *et al.* (2017); Faye *et al.* (2022) |
| **OG0008678** | serine carboxypeptidase (SCP) | A, B, C, R | pathogens, light, cold, wound, salt, drought | Liu *et al.* (2022); Xu *et al.* (2021) |
| OG0008965 | sphingolipid transporter spinster homolog 2 (SPNS2) | A, B, C, R |  |  |
| ***OG0009362*** | 14-3-3 protein 7-like | A, B, C, R | cold, osmotic, nutrient starvation, starch accumulation | Xu *et al.* (2012); Roberts *et al.* (2002); Datta *et al.* (2001) |
| ***OG0009379*** | plant homeodomain (PHD) finger protein 3 (MALE STERILITY 3) | A, B, C, R | salt, ABA hormonal, humidity, light, pollen, pollen grain, tapetum | Wang, QQ *et al.* (2015); Hou *et al.* (2022); Ito and Shinozaki (2002); Ito *et al.* (2007); Li *et al.* (2011) |
| **OG0006703** | nudix hydrolase 8-like protein (NUDT8) | A, B, C, R | pathogens | Fonseca and Dong (2014) |
| **OG0008506** | Nicotinamide adenine dinucleotide kinase 2 (NADK2) | A, B, C, R | heavy metal, salt, heat, cold, light, drought, hormonal, oxidative, pathogens, root, stem, leaf | Li *et al.* (2018); Hashida *et al.* (2009); Hashida *et al.* (2007); Gakière *et al.* (2018); Takahara *et al.* (2010); Chai *et al.* (2005); Takahashi *et al.* (2006); Pétriacq *et al.* (2013) |
| **OG0008891** | homeobox-leucine zipper protein ATHB-12 (ATHB-12) | A, B, C | water, salt | Lee and Chun (1998); Shin *et al.* (2004) |
| **OG0006931** | copper-transporting ATPase HMA5 (HMA5) | A, B, C | heavy metal | Ma *et al.* (2022) |
| **OG0009171** | STRICTOSIDINE SYNTHASE-LIKE 4 (SSL4) | A, B, C | heat, pathogens | Sohani *et al.* (2009); Aoun *et al.* (2020) |
| **OG0007942** | isocitrate lyase | A, B, C | salt | Yuenyong *et al.* (2019) |
| OG0009067 | Acyl-coenzyme A oxidase, peroxisomal | A, B, C |  |  |
| **OG0008247** | Homogentisate phytyltransferase 1 (HPT1) | A, B, C | light, oxidative, nutrient starvation | Collakova and DellaPenna (2003) |
| **OG0007434** | BTB/POZ domain-containing protein (BTB/POZ) | A, B, R | pathogens | Zhao *et al.* (2022) |
| **OG0009245** | zinc transporter 11 (ZIP11) | A, B, R | heavy metal | Milner *et al.* (2013) |
| **OG0006058** | phosphatase 2C 16 (HAB1) | A, B, R | abscisic acid (ABA), cold, drought, osmotic, salinity, bacteria, fungi | Singh *et al.* (2016) |
| **OG0006604** | DEHYDRATION-INDUCED 19 homolog 3 (DI19-3) | A, B, R | drought, salinity | (Milner *et al.*, 2013) |
| OG0006674 | SH3 domain-containing YSC84-like protein | A, B, R |  |  |
| OG0008723 | uncharacterized protein | A, B, R |  |  |
| **OG0009128** | phospholipase D beta 1 (PLDBETA1) | A, B, R | salt, abscisic acid (ABA), cold, dehydration, drought | Hong *et al.* (2016); Laxalt *et al.* (2001) |
| **OG0009144** | beta-amylase 3 (BAM3) | A, B, R | cold | Sun *et al.* (2021); |
| OG0008799 | 1,2-dihydroxy-3-keto-5-methylthiopentene dioxygenase 2 | A, B, R |  |  |
| OG0006256 | UPF0496 protein  | A, B, R |  |  |
| **OG0007963** | Inositol pentakisphosphate 2 kinase (ITPK1) | A, B, R | heavy metal, nutrient starvation, salicylic acid (SA), pathogens | Sun *et al.* (2016) |
| OG0008345 | uncharacterized protein | A, B, R |  |  |
| OG0006863 | cleft lip and palate transmembrane protein  | A, B, R |  |  |
| **OG0009312** | 4-hydroxyphenylpyruvate dioxygenase (HPD) | A, B, R | oxidative | Falk *et al.* (2002) |
| **OG0007860** | BTB/POZ domain-containing protein (BTB/POZ) | A, B, R | pathogens | Zhao *et al.* (2022) |
| OG0009654 | 1-phosphatidylinositol-3-phosphate 5-kinase FAB1C (FAB1C) | A, B, R |  |  |
| OG0007874 | Lysine-specific demethylase rbr-2 | A, B, R |  |  |
| **OG0008241** | calcium-transporting ATPase 8 (ACA8) | A, B, R | salt | Gong *et al.* (2005) |
| OG0008522 | flocculation protein FLO11 | A, B, R |  |  |
| **OG0007822** | trihelix transcription factor GT-2 (GT-2) | A, C, R | salt, hormonal, pathogen, trichome | Zhu *et al.* (2022); Breuer *et al.* (2009); Kaplan-Levy *et al.* (2012); Volz *et al.* (2018) |
| **OG0008751** | chloroplast unusual positioning protein 1 (CHUP1) | B, C, R | light | Morita and Nakamura (2012) |
| **OG0007594** | UPF0051 protein ABCI8 (ABCI8) | B, C, R | light, salt | Capriotti *et al.* (2014) |
| **OG0009517** | LRR receptor-like serine threonine protein kinase (LRR-RLK) | A, B | pathogen, hormonal, drought, salt, cold, root, floral organ, ovule, anther | Afzal *et al.* (2008); Morris and Walker (2003); Ye *et al.* (2017); Hosseini *et al.* (2020) |
| OG0009539 | hypothetical protein | A, B |  |  |
| ***OG0006312*** | Glutaredoxin-C6 | A, B | anther development, male gametogenesis, | Xing and Zachgo (2008); Hong *et al.* (2012); Stroher and Millar (2012) |
| OG0008196 | protein MEI2-like 2 | A, B |  |  |
| OG0008439 | transcription factor DIVARICATA | A, B |  |  |
| **OG0006928** | cationic amino acid transporter 2, vacuolar | A, B | cold, salt, stamen | Feng *et al.* (2018); Yang *et al.* (2013) |
| **OG0007317** | E3 ubiquitin-protein ligase RHB1A | A, B | pathogens | Shahinnia *et al.* (2022) |
| **OG0009191** | SCY1-like protein 2 | A, B | pathogens | Yao *et al.* (2022);  |
| **OG0008092** | K+ efflux antiporter 3 | A, B | drought, salt, alkaline | Sheng *et al.* (2014); Saddhe *et al.* (2021); Zhu *et al.* (2018) |
| OG0008351 | MLP1, MLP2-like protein | A, B |  |  |
| OG0008659 | monofunctional riboflavin biosynthesis RIBA3 (RIBA3) | A, B |  |  |
| **OG0007568** | quinolinate synthase (QS) | A, B | salt | Wei *et al.* (2020) |
| **OG0006141** | signal peptide peptidase-like 4 (SPPL4) | A, B | pathogens | Pinter *et al.* (2019) |
| OG0007820 | uncharacterized protein | A, B |  |  |
| ***OG0008526*** | Plant U-box domain-containing protein 4 (PUB4) | A, B | drought, tapetal cells, pollen development, starch deposition | Adler *et al.* (2017); Wang *et al.* (2013); Trenner *et al.* (2022); Zhang, WD *et al.* (2020) |
| OG0008469 | uncharacterized protein | A, C |  |  |
| OG0009423 | protein phosphatase 2C 72  | A, C |  |  |
| OG0006198 | uncharacterized protein | A, C |  |  |
| OG0006967 | mitoferrin-like protein | A, R |  |  |
| OG0006239 | uncharacterized protein | A, R |  |  |
| OG0009068 | uncharacterized protein | A, R |  |  |
| OG0008403 | WAT1-related protein | A |  |  |
| ***OG0008456*** | Glutaredoxin | A | heat, oxidative, anther, pollen | Xing and Zachgo (2008); Stroher and Millar (2012); Hong *et al.* (2012) |
| **OG0007047** | lysM domain receptor-like kinase 4 (LYK4) | A | fungal, salt | Wan *et al.* (2008); Buendia *et al.* (2018); Wan *et al.* (2012) |
| **OG0008731** | WRKY transcription factor 45 (WRKY45) | A | drought, salt, heat, ABA, nutrient starvation, pathogens | Chen *et al.* (2017); Wang *et al.* (2014); Chen *et al.* (2012); Li, WX *et al.* (2020) |
| **OG0007380** | RPM1-interacting protein 4 (RIN4) | A | pathogens | Prokchorchik *et al.* (2020) |
| OG0006802 | plant intracellular Ras-group-related LRR protein 6 (PIRL6) | A |  |  |
| **OG0006130** | LOB domain-containing protein 19 (LBD19) | A | heat, light, pathogens, callus formation | Zhang, YW *et al.* (2020); Liu *et al.* (2019) |
| ***OG0009273*** | autophagy-related protein 18f (ATG18f) | A | pathogens, nutrient starvation, drought, heat, cold, salt, heavy metal, oxidative, anther, pollen, root, stem, leaf | Qi *et al.* (2021); Li, SH *et al.* (2020); Avin-Wittenberg (2019); Zhou *et al.* (2015); Wang, Y *et al.* (2015) |
| ***OG0007429*** | protein JINGUBANG-like | A | jasmonic acid (JA), pollen grain | Ju *et al.* (2016) |
| OG0009210 | leucine-rich repeat receptor-like tyrosine-protein kinase PXC3 (PXC3) | A |  |  |
| **OG0006776** | ASPARTIC PROTEASE IN GUARD CELL 1 (ASPG1) | A | drought, pathogens | Yao *et al.* (2012); Sebastian *et al.* (2020); Huang *et al.* (2013); Gao *et al.* (2017); Figueiredo *et al.* (2021) |
| ***OG0008560*** | CLAVATA3 (CLV3) /ESR (CLE)-related protein 13 (CLV3/CLE13) | B | cold, heat, drought, salt, cytokinin, hormonal, floral organ, stamen, anther, root, shoot | Zhang *et al.* (2022); Lin, H *et al.* (2021); Cui *et al.* (2022); Yamaguchi *et al.* (2016); Jun *et al.* (2010); Laffont *et al.* (2020) |
| **OG0008786** | basic 7S globulin-like protein | C | antibacterial, allergen, heat | Hirano (2021) |
| **OG0006303** | zinc finger CCCH domain-containing protein 20 (C3H20/TZF2) | R | salt, drought, flooding, cold, oxidative, ABA, JA, flower | Han *et al.* (2021); Lee *et al.* (2012); Bogamuwa and Jang (2014); Huang *et al.* (2012); Huang *et al.* (2011) |
| OG0006084 | uncharacterized protein | R |  |  |
| OG0008460 | Pectinesterase inhibitor 45 (PME45) | R |  |  |
| **OG0006683** | auxin-binding protein ABP19a (ABP19a) | R | dehydration, drought | Vessal *et al.* (2020) |
| **OG0007044** | ABC transporter F family member 5 (ABCF5) | R | dry | Hwang *et al.* (2016) |
| OG0006937 | uncharacterized protein | R |  |  |
| **OG0009424** | zinc finger CCCH domain-containing protein 20 (C3H20/TZF2) | R | salt, drought, flooding, cold, oxidative, ABA, JA, flower | Bogamuwa and Jang (2014); Lee *et al.* (2012); Han *et al.* (2021); Huang *et al.* (2012); Huang *et al.* (2011) |
| **OG0008325** | E3 ubiquitin-protein ligase RING1 | R | salt, drought, cold, heat, bacterial | Wang *et al.* (2022); Marino *et al.* (2012) |
| **OG0009024** | BTB/POZ domain and ankyrin repeat-containing protein NPR2 | R | pathogens | Pajerowska-Mukhtar *et al.* (2013) |
| **OG0006402** | nucleoredoxin 1 | R | salt, drought | Zhang *et al.* (2014); Zhang *et al.* (2021) |

OGs in bold font are associated with biotic and abiotic stress responses. OGs in bold and italic fonts are associated with biotic and abiotic stress responses, pollen developments and maturation.

Asterisk (\*) indicates that positive selections were tested by aBSREL (A), BUSTED (B), CodeML (C) and RELAX (R).

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