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O.sativa_ZEBRA3 1 MALAISKVVLGCVARSIHWLAVFVPEFMPVGRTAGSLGAMLMVLRVISEDAYAA
O.brachyantha 1 MALAISKVVLGCVARSIHWLAVFVPEFMPVGRTAGSLGAMLMVLRVISEDAYAA
Z.mays_1 1 MALAISKVVLGCVARSIHWLAVFVPEFMPVGRTAGSLGAMLMVLRVISEDAYAA
Z.mays_2 1 MALAISKVVLGCVARSIHWLAVFVPEFMPVGRTAGSLGAMLMVLRVISEDAYAA
H.vulgare 1 MALAISKVVLGCVARSIHWLAVFVPEFMPVGRTAGSLGAMLMVLRVISEDAYAA
S.bicolor 1 MALAISKVVLGCVARSIHWLAVFVPEFMPVGRTAGSLGAMLMVLRVISEDAYAA
S.tuberosum 1 MALAISKVVLGCVARSIHWLAVFVPEFMPVGRTAGSLGAMLMVLRVISEDAYAA
G.max 1 MALAISKVVLGCVARSIHWLAVFVPEFMPVGRTAGSLGAMLMVLRVISEDAYAA
A.thaliana 1 MALAISKVVLGCVARSIHWLAVFVPEFMPVGRTAGSLGAMLMVLRVISEDAYAA

O.sativa_ZEBRA3 61 DLPFLGGLFGTMVVSIFLERADMEKYLGNLLSKSRGSKDLEFRVCSVAASALFTND
O.brachyantha 61 DLPFLGGLFGTMVVSIFLERADMEKYLGNLLSKSRGSKDLEFRVCSVAASALFTND
Z.mays_1 61 DLPFLGGLFGTMVVSIFLERADMEKYLGNLLSKSRGSKDLEFRVCSVAASALFTND
Z.mays_2 61 DLPFLGGLFGTMVVSIFLERADMEKYLGNLLSKSRGSKDLEFRVCSVAASALFTND
H.vulgare 61 DLPFLGGLFGTMVVSIFLERADMEKYLGNLLSKSRGSKDLEFRVCSVAASALFTND
S.bicolor 61 DLPFLGGLFGTMVVSIFLERADMEKYLGNLLSKSRGSKDLEFRVCSVAASALFTND
S.tuberosum 61 DLPFLGGLFGTMVVSIFLERADMEKYLGNLLSKSRGSKDLEFRVCSVAASALFTND
G.max 61 DLPFLGGLFGTMVVSIFLERADMEKYLGNLLSKSRGSKDLEFRVCSVAASALFTND
A.thaliana 61 DLPFLGGLFGTMVVSIFLERADMEKYLGNLLSKSRGSKDLEFRVCSVAASALFTND

O.sativa_ZEBRA3 121 CCVVLTEFLKVARQNNLPPOPFLLALASSNIGSAATPIGNQNLVAVESGISFGQF
O.brachyantha 121 CCVVLTEFLKVARQNNLPPOPFLLALASSNIGSAATPIGNQNLVAVESGISFGQF
Z.mays_1 121 CCVVLTEFLKVARQNNLPPOPFLLALASSNIGSAATPIGNQNLVAVESGISFGQF
Z.mays_2 121 CCVVLTEFLKVARQNNLPPOPFLLALASSNIGSAATPIGNQNLVAVESGISFGQF
H.vulgare 121 CCVVLTEFLKVARQNNLPPOPFLLALASSNIGSAATPIGNQNLVAVESGISFGQF
S.bicolor 121 CCVVLTEFLKVARQNNLPPOPFLLALASSNIGSAATPIGNQNLVAVESGISFGQF
S.tuberosum 121 CCVVLTEFLKVARQNNLPPOPFLLALASSNIGSAATPIGNQNLVAVESGISFGQF
G.max 121 CCVVLTEFLKVARQNNLPPOPFLLALASSNIGSAATPIGNQNLVAVESGISFGQF
A.thaliana 121 CCVVLTEFLKVARQNNLPPOPFLLALASSNIGSAATPIGNQNLVAVESGISFGQF

O.sativa_ZEBRA3 181 LGGVFAMIVGVLINAAILLVFWKYLSEKDEKSGSGSGSGSGSGSGSGSGSGSGSG
O.brachyantha 181 LGGVFAMIVGVLINAAILLVFWKYLSEKDEKSGSGSGSGSGSGSGSGSGSGSGSG
Z.mays_1 181 LGGVFAMIVGVLINAAILLVFWKYLSEKDEKSGSGSGSGSGSGSGSGSGSGSGSG
Z.mays_2 181 LGGVFAMIVGVLINAAILLVFWKYLSEKDEKSGSGSGSGSGSGSGSGSGSGSGSG
H.vulgare 181 LGGVFAMIVGVLINAAILLVFWKYLSEKDEKSGSGSGSGSGSGSGSGSGSGSGSG
S.bicolor 181 LGGVFAMIVGVLINAAILLVFWKYLSEKDEKSGSGSGSGSGSGSGSGSGSGSGSG
S.tuberosum 181 LGGVFAMIVGVLINAAILLVFWKYLSEKDEKSGSGSGSGSGSGSGSGSGSGSGSG
G.max 181 LGGVFAMIVGVLINAAILLVFWKYLSEKDEKSGSGSGSGSGSGSGSGSGSGSGSG
A.thaliana 181 LGGVFAMIVGVLINAAILLVFWKYLSEKDEKSGSGSGSGSGSGSGSGSGSGSGSG

O.sativa_ZEBRA3 234 FTARMSSHVSSLNDDDDSEPTLRSSSVR-SRSHNLSRNSNS--RADIQAI
O.brachyantha 234 FTARMSSHVSSLNDDDDSEPTLRSSSVR-SRSHNLSRNSNS--RADIQAI
Z.mays_1 234 FTARMSSHVSSLNDDDDSEPTLRSSSVR-SRSHNLSRNSNS--RADIQAI
Z.mays_2 234 FTARMSSHVSSLNDDDDSEPTLRSSSVR-SRSHNLSRNSNS--RADIQAI
H.vulgare 241 FTARMSSHVSSLNDDDDSEPTLRSSSVR-SRSHNLSRNSNS--RADIQAI
S.bicolor 236 FTARMSSHVSSLNDDDDSEPTLRSSSVR-SRSHNLSRNSNS--RADIQAI
S.tuberosum 231 FTARMSSHVSSLNDDDDSEPTLRSSSVR-SRSHNLSRNSNS--RADIQAI
G.max 231 FTARMSSHVSSLNDDDDSEPTLRSSSVR-SRSHNLSRNSNS--RADIQAI
A.thaliana 235 FTARMSSHVSSLNDDDDSEPTLRSSSVR-SRSHNLSRNSNS--RADIQAI

O.sativa_ZEBRA3 288 SLRASSMHEMVEVSTVDRRDG---ASSRKFTRPASQORSVIEE--SPSPAS-NH
O.brachyantha 288 SLRASSMHEMVEVSTVDRRDG---ASSRKFTRPASQORSVIEE--SPSPAS-NH
Z.mays_1 288 SLRASSMHEMVEVSTVDRRDG---ASSRKFTRPASQORSVIEE--SPSPAS-NH
Z.mays_2 288 SLRASSMHEMVEVSTVDRRDG---ASSRKFTRPASQORSVIEE--SPSPAS-NH
H.vulgare 295 SLRASSMHEMVEVSTVDRRDG---ASSRKFTRPASQORSVIEE--SPSPAS-NH
S.bicolor 290 SLRASSMHEMVEVSTVDRRDG---ASSRKFTRPASQORSVIEE--SPSPAS-NH
S.tuberosum 288 SLRASSMHEMVEVSTVDRRDG---ASSRKFTRPASQORSVIEE--SPSPAS-NH
G.max 281 SLRASSMHEMVEVSTVDRRDG---ASSRKFTRPASQORSVIEE--SPSPAS-NH
A.thaliana 271 SLRASSMHEMVEVSTVDRRDG---ASSRKFTRPASQORSVIEE--SPSPAS-NH

O.sativa_ZEBRA3 343 -----SRERSRERKRWVWKTAVALITLGMILLMGLNMSWTAITAAVLVLI
O.brachyantha 343 -----SRERSRERKRWVWKTAVALITLGMILLMGLNMSWTAITAAVLVLI
Z.mays_1 342 -----SRERSRERKRWVWKTAVALITLGMILLMGLNMSWTAITAAVLVLI
Z.mays_2 342 -----SRERSRERKRWVWKTAVALITLGMILLMGLNMSWTAITAAVLVLI
H.vulgare 350 DRANGDMSSEIPEERKRWVWKTAVALITLGMILLMGLNMSWTAITAAVLVLI
S.bicolor 312 EYEDNTYIPEWYFTEERKRWVWKTAVALITLGMILLMGLNMSWTAITAAVLVLI
S.tuberosum 349 RARVATYIPEWYFTEERKRWVWKTAVALITLGMILLMGLNMSWTAITAAVLVLI
G.max 318 PVEADLLITSEKLYRSRWVWKTAVALITLGMILLMGLNMSWTAITAAVLVLI
A.thaliana 290 -----ESNNTNMFQTEERKRWVWKTAVALITLGMILLMGLNMSWTAITAAVLVLI

O.sativa_ZEBRA3 395 DFTDAQCLEKVSYSLLIFFCGMPITVDGNKGTGINTLWELVPEYPSRIDSAGVALLAV
O.brachyantha 395 DFTDAQCLEKVSYSLLIFFCGMPITVDGNKGTGINTLWELVPEYPSRIDSAGVALLAV
Z.mays_1 394 DFTDAQCLEKVSYSLLIFFCGMPITVDGNKGTGINTLWELVPEYPSRIDSAGVALLAV
Z.mays_2 394 DFTDAQCLEKVSYSLLIFFCGMPITVDGNKGTGINTLWELVPEYPSRIDSAGVALLAV
H.vulgare 410 DFTDAQCLEKVSYSLLIFFCGMPITVDGNKGTGINTLWELVPEYPSRIDSAGVALLAV
S.bicolor 356 DFTDAQCLEKVSYSLLIFFCGMPITVDGNKGTGINTLWELVPEYPSRIDSAGVALLAV
S.tuberosum 372 DFTDAQCLEKVSYSLLIFFCGMPITVDGNKGTGINTLWELVPEYPSRIDSAGVALLAV
G.max 378 DFTDAQCLEKVSYSLLIFFCGMPITVDGNKGTGINTLWELVPEYPSRIDSAGVALLAV
A.thaliana 344 DFTDAQCLEKVSYSLLIFFCGMPITVDGNKGTGINTLWELVPEYPSRIDSAGVALLAV

O.sativa_ZEBRA3 450 VILLSNVSNVPTVLLGTRVAASAATISGSRERAWLLAWVSTVAGNLTLLGSAANI
O.brachyantha 450 VILLSNVSNVPTVLLGTRVAASAATISGSRERAWLLAWVSTVAGNLTLLGSAANI
Z.mays_1 454 VILLSNVSNVPTVLLGTRVAASAATISGSRERAWLLAWVSTVAGNLTLLGSAANI
Z.mays_2 454 VILLSNVSNVPTVLLGTRVAASAATISGSRERAWLLAWVSTVAGNLTLLGSAANI
H.vulgare 470 VILLSNVSNVPTVLLGTRVAASAATISGSRERAWLLAWVSTVAGNLTLLGSAANI
S.bicolor 414 VILLSNVSNVPTVLLGTRVAASAATISGSRERAWLLAWVSTVAGNLTLLGSAANI
S.tuberosum 432 VILLSNVSNVPTVLLGTRVAASAATISGSRERAWLLAWVSTVAGNLTLLGSAANI
G.max 438 VILLSNVSNVPTVLLGTRVAASAATISGSRERAWLLAWVSTVAGNLTLLGSAANI
A.thaliana 404 VILLSNVSNVPTVLLGTRVAASAATISGSRERAWLLAWVSTVAGNLTLLGSAANI

O.sativa_ZEBRA3 515 IVCQARRAQFFQYNIWFSHRFGVSTIIIVTAIGLLIVS
O.brachyantha 515 IVCQARRAQFFQYNIWFSHRFGVSTIIIVTAIGLLIVS
Z.mays_1 514 IVCQARRAQFFQYNIWFSHRFGVSTIIIVTAIGLLIVS
Z.mays_2 514 IVCQARRAQFFQYNIWFSHRFGVSTIIIVTAIGLLIVS
H.vulgare 530 IVCQARRAQFFQYNIWFSHRFGVSTIIIVTAIGLLIVS
S.bicolor 474 IVCQARRAQFFQYNIWFSHRFGVSTIIIVTAIGLLIVS
S.tuberosum 492 IVCQARRAQFFQYNIWFSHRFGVSTIIIVTAIGLLIVS
G.max 498 IVCQARRAQFFQYNIWFSHRFGVSTIIIVTAIGLLIVS
A.thaliana 462 IVCQARRAQFFQYNIWFSHRFGVSTIIIVTAIGLLIVS

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**Additional File 3: Fig. S3** Amino acid alignment of Z3 homologs in higher plants. The amino acid sequences of Z3 homologs in higher plants were acquired from NCBI (<http://www.ncbi.nlm.nih.gov/>), and the amino acid alignment was obtained using the Clustal Omega EMBL-EBI (<http://www.ebi.ac.uk/Tools/mba/clustalo/>) and BoxShade 3.21 Server ([http://www.ch.embnet.org/software/BOX\\_form.html](http://www.ch.embnet.org/software/BOX_form.html)). *O. brachyantha*, *Z. mays\_1*, *Z. mays\_2*, *H. vulgare*, *S. bicolor*, *S. tuberosum*, *G. max*, and *A. thaliana* have 99, 96, 95, 87, 72, 65, 64, and 62% sequence similarity to Z3, respectively. The mutated residue (S542P in z3) is indicated by a red arrowhead. *O. sativa\_ZEBRA3* (*Oryza sativa* ZEBRA3, LOC\_Os03g05390, NP\_001048962.1); *O. brachyantha* (*Oryza brachyantha*, XP\_006649400.1); *Z. mays\_1* (*Zea mays*, NP\_001151517.1); *Z. mays\_2* (*Zea mays*, ACG43196.1); *H. vulgare* (*Hordeum vulgare*, BAK05230.1); *S. bicolor* (*Sorghum bicolor*, XP\_002467148.1); *S. tuberosum* (*Solanum tuberosum*, XP\_00636328.1); *G. max* (*Glycine max*, XP\_003533988.1); *A. thaliana* (*Arabidopsis thaliana*, NP\_171728.2).