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Crosstalks between Myo-Inositol Metabolism, Programmed Cell Death and Basal Immunity in *Arabidopsis*

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Abstract

Background: Alth ugh it is a crucial cellular r cess required f r b th n rmal devel ment and t face stress c nditi ns, the c ntr l f r grammed cell death in lants is n t fully underst d. We revi usly re rted the is lati n f ATXR5 and ATXR6, tw PCNA-binding r teins that c uld be inv lved in the regulati n f cell cycle r cell death. A yeast tw -hybrid screen using ATXR5 as bait ca tured AtIPS1, an enzyme which catalyses the c mmitted ste f my -in sit l (MI) bi synthesis. *atips1* mutants f rm s ntane us lesi ns n leaves, raising the ssibility that MI metab lism may lay a r le in the c ntr l f PCD in lants. In this w rk, we have characterised *atips1* mutants t gain insight regarding the r le f MI in PCD regulati n.

Methodology/Principal Findings: - lesi n f rmati n in *atips1* mutants de ends f light intensity, is due t PCD as evidenced by TUNEL labelling f nuclei, and is regulated by hyt h rm nes such as salicylic acid - MI and galactin l are the nly metab lites wh se accumulati n is significantly reduced in the mutant, and su lementati n f the mutant with these c m unds is sufficient t revent PCD - the transcri t me r file f the mutant is extremely similar t that f lesi n mimic mutants such as *cpr5*, r wild-ty e lants infected with ath gens.

Conclusion/Significance: Taken t gether, ur results r vide str ng evidence f r the r le f MI r MI derivatives in the regulati n f PCD. Interestingly, there are three is f rms f IPS in *Arabidopsis*, but AtIPS1 is the nly ne harb uring a nuclear l calisati n sequence, suggesting that nuclear ls f MI may lay a s ecific r le in PCD regulati n and ening new research r s ects regarding the r le f MI in the reventi n f tum rigenesis. Nevertheless, the significance f the interacti n between AtIPS1 and ATXR5 remains t be established.

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Competing Interests: The auth rs have declared that n c m eting interests exist.

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☯ These auth rs c ntributed equally t this w rk.

Introduction

[illegible] $_2O_2$ oO_2^-, [illegible]

[illegible] 5].

[illegible]

Results

AtIPS1 interacts with ATXR5 and ATXR6, and accumulates b th in the cyt lasm and in the nucleus

[illegible]

Table 1. AtIPS1 interacts with ATXR5 and ATXR6 in the yeast tw -hybrid system.

	pGAD424	shAtIPS1-AD	flAtIPS1-AD	PCNA1-AD
GBT-9	−	−	−	−
ATXR5-BD	−	+	−	+
ATXR6-BD	−	+	−	+
ATXR5△ex2-BD	−	+	−	−
flAtIPS1-BD	−	+	+	nd

GAD424 c ntains the activati n d main f GAL4 (AD) while GBT-9 c ntains its DNA-binding d main (BD). shAtIPS1: truncated f rm f AtIPS1 lacking its first 146 amin -acids, flAtIPS1: full length AtIPS1 r tein. ATXR5Δex2 is enc ded by a s licing variant f ATXR5 and lacks its PCNA binding d main [7].

d i:10.1371/j urnal. ne.0007364.t001

Is lati n f *atips1* mutants

atips2 nd *atips3*, (

AtIPS3 p

atips1 m

In vitro g

atips1-1 (x= 19.7) p

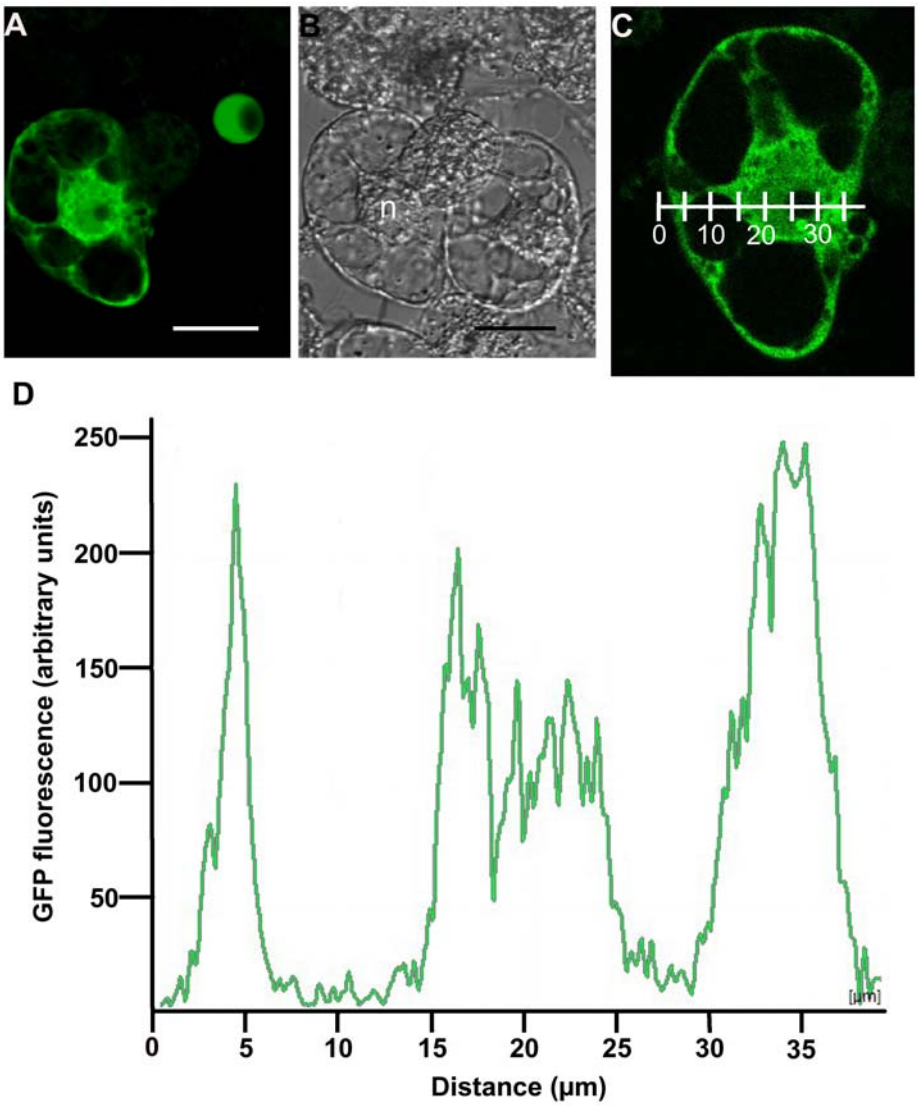

Figure 1. AtIPS1 accumulates in the nucleus and the cytoplasm of transiently transformed BY-2 cells. BY-2 r t lasts were transf rmed with a *PromAtIPS1::AtIPS1-GFP* c nstruct. GFP flu rescence was bserved 24 h later using a c nf cal micr sc e. (**A**) GFP flu rescence. (**B**) Transmissi n image. (**C**) O tical secti n used f r GFP quantificati n. (**D**) GFP quantificati n n secti n sh wn n anel C. GFP was quantified al ng the graduated line. Scale bar = 25 µm f r anels A–B. On anel B, the siti n f the nucleus is indicated by the letter n.
d i:10.1371/j urnal. ne.0007364.g001

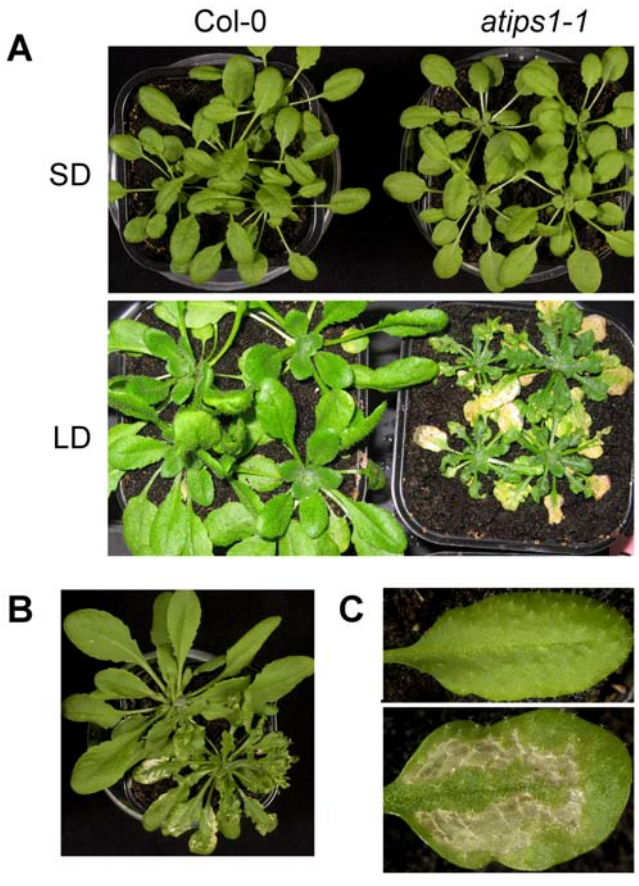

Figure 2. Disruption of *AtIPS1* induces spontaneous lesion formation under long day conditions. (**A**) **Top:** Wild-ty e (left) and *atips1-1* (right) lants gr wn under SD (45 µE/m^2/s); **Bottom:** Wild-ty e (left) and *atips1-1* (right) lants gr wn under SD (45 µE/m^2/s) and transferred under LD (45 µE/m^2/s) f r 4 weeks. (**B**) Phen ty e f Ws (t left) and the *atips1-2* mutant (b tt m right). (**C**) Cl se-u n a leaf fr m the wild-ty e (t) and *atips1-1* (b tt m).
d i:10.1371/j urnal. ne.0007364.g002

Lesi n f rmati n in *atips1* is m dulated by light intensity and the devel mental stage

Lesi n f rmati n in *atips1* is due t salicylic acid-de endent PCD

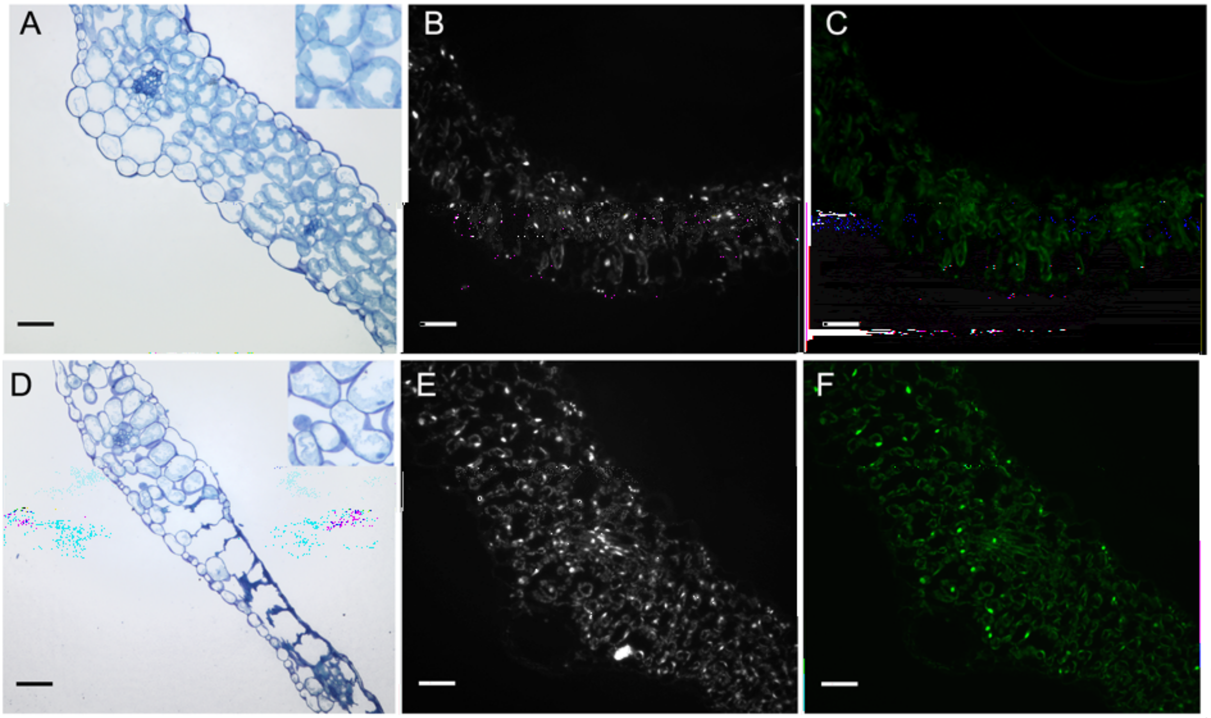

Figure 3. Microscopic analysis of lesions in *atips1* mutants. (**A, D**) Leaf secti ns fr m wild-ty e (A) and *atips1-1* (D) lants gr wn under SD (45 µE/m^2/s) and transferred under LD (45 µE/m^2/s) f r 4 days. (**B, E**) Cr ss-secti n f WT (B) and *atips1-1* (E) leaves stained with DAPI. (**C, F**) Cr ss-secti n f WT (C) and *atips1-1* (F) stained by TUNEL. Scale bar = 50 µm f r all anels. Inserts n anels A and D are tw -f ld magnificati ns f the image.
d i:10.1371/j urnal. ne.0007364.g003

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PCD in *atips1* is caused by drastic reducti n f my - in sit l and galactin l accumulati n

[illegible]

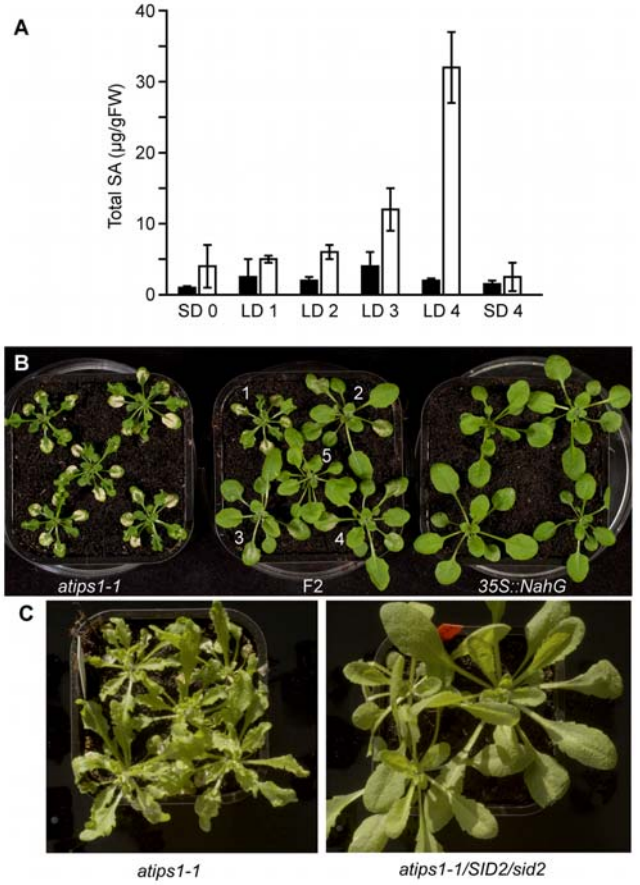

Figure 4. Lesion formation is dependent on salicylic acid accumulation. (**A**) T tal SA c ntent f wild-ty e (black bars) and *atips1-1* (white bars). Plants were gr wn under SD (45 µE/m^2/s) f r ne m nth and transferred under LD (45 µE/m^2/s) f r ne, tw , three r f ur days r maintained under SD f r f ur days. T tal SA was quantified daily after transfer. (**B**) Phen ty e f *atips1-1* (left), *35S::NahG* (right) and F2 lants *atips1-1x35S::NahG* (middle) tw weeks after transfer under LD (45 µE/m^2/s) c nditi ns. In the F2 r geny all lants sh wn are h m zyg us f r the *atips1-1* mutati n. Plant 1 did n t inherit the *35S::NahG* c nstruct. Plants 2–5 c ntain the *35S::NahG* c nstruct but r bably ex ress vari us levels f the r tein resulting in artial (lants 2–4) t c m lete (lant 5) rescue f the hen ty e. (**C**) Phen ty e f *atips1-1* (left) and *atips1-1/SID2/sid2-1* mutants. Inactivati n f nly ne c y f the *ISC1* gene is sufficient t revent lesi n f rmati n in the *atips1-1* backgr und.
d i:10.1371/j urnal. ne.0007364.g004

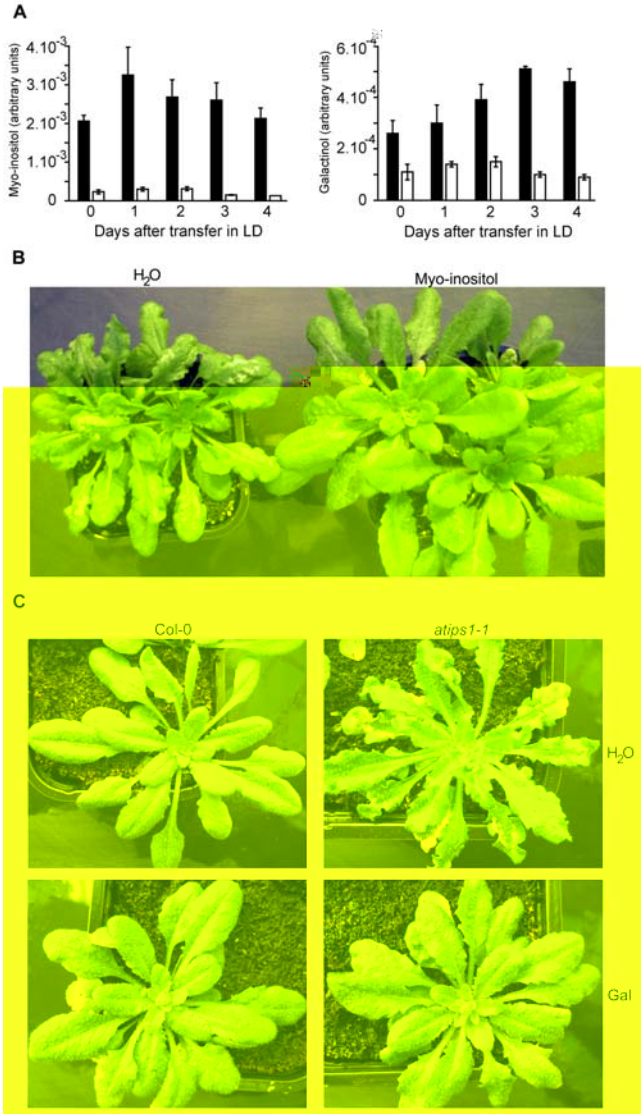

Figure 5. Myo-inositol and galactinol accumulation is drastically reduced in *atips1* mutants. (**A**) My -in sit l (left) and galactin l (right) were quantified by GC-TOF-MS in WT (black bars) and *atips1-1* (white bars) lants gr wn under SD, and daily f r 4 days after transfer under LD c nditi ns. (**B**) Lesi n f rmati n can be ab lished by treating *atips1-1* with my -in sit l. (**C**) Lesi n f rmati n can be ab lished by treating *atips1-1* with galactin l (gal). F r B and C, lants were gr wn f r ne m nth under SD, and transferred under LD f r tw weeks. They were treated daily with a my -in sit l (100 mg/mL) r a galactin l (10 mM) s luti n r water. Lesi n f rmati n was still bvi us in lants treated with water, but n t in lants fed with my -in sit l (100 mg/mL) r galactin l (10 mM). Galactin l treatment slightly affected wild-ty e lants devel ment.
d i:10.1371/j urnal. ne.0007364.g005

atips1 *atips1* *atips1* *atips1-1*: *atips1-1* *atips1-1*. *mkk1/mkk2* *mpk4* *atips1-1* *atips1-1* *atips1-1* *atips1-1* *atips1-1* *atips1-1*.

Transri t me analysis f *atips1-1*

atips1, *atips1-1* *atips1-1* *atips1-1* *atips1-1* *AtIPS1* *atips1-1* *atips1-1* *atips1-1* *atips1-1* *PR5*, *AIGI*, *BGL2*, *EDS1* *PAD4* *atips1-1* *atips1-1* *atips1-1* *ZF14* *WRKY53* *atips1-1* *atips1-1*

Disru ti n f *AtIPS1* affects ath gen resistance

atips1-1 *atips1* *et al.* *atips1-1* *Pseudomonas syringae* *Hyaloperonospora arabidopsis* (f. sp. *H. parasitica*). *atips1-1* *H. arabidopsis*. *Arabidopsis* *atips1-1* *35S::NahG* *atips1/35S::NahG* *et al.* [40] *atips1*,

Discussion

Arabidopsis. *Arabidopsis atips1*

Arabidopsis IPS have n n-redundant functi ns

StIPS *et al.* *Arabidopsis* *AtIPS1* *atips2* *AtIPS3* *atips3*

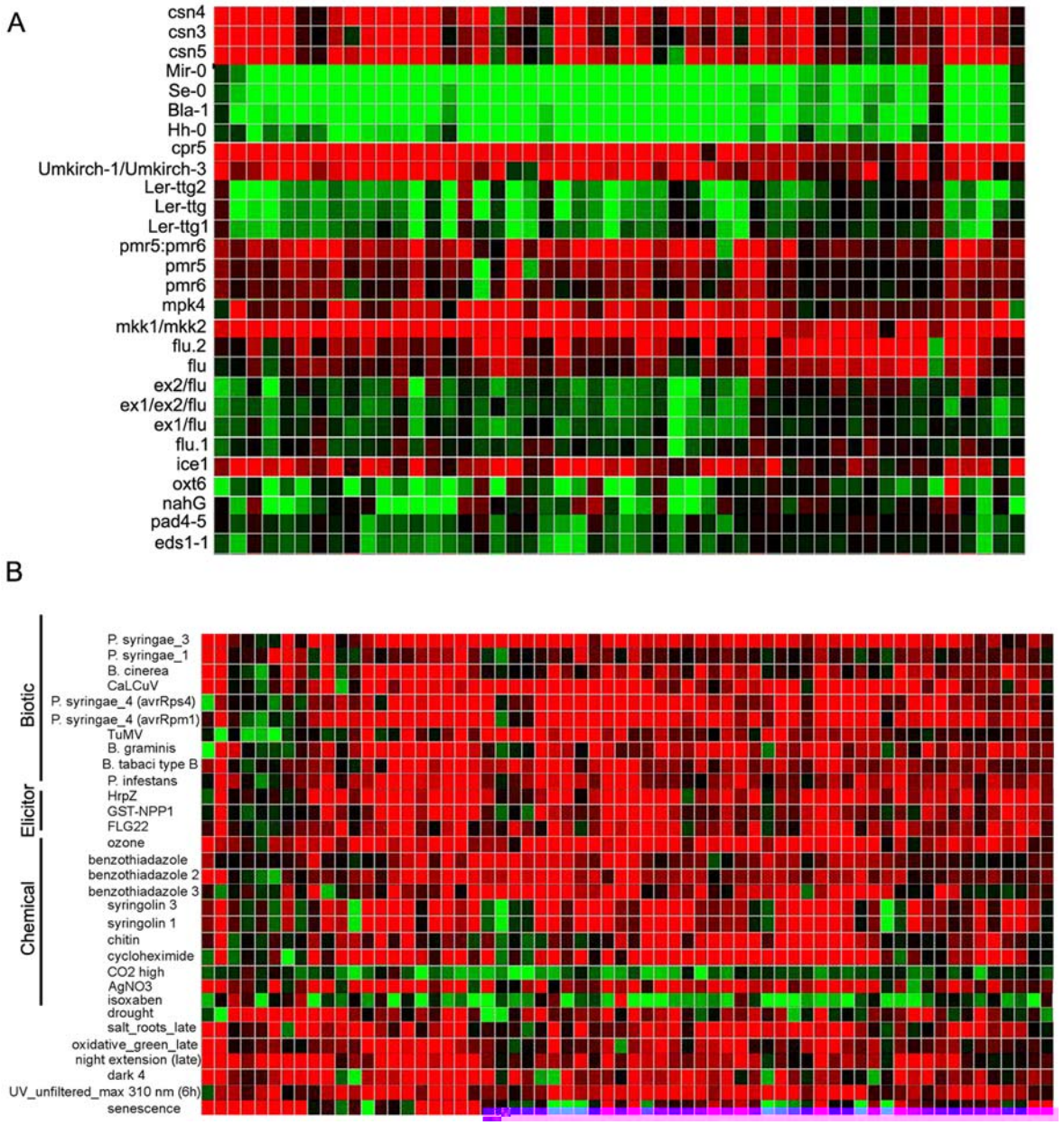

Figure 6. The transcriptome of *atips1-1* is similar to that of several LMM mutants or plants infected by pathogens. Hierarchical clustering was erf rmed using 150 transcri ts acr ss the different SD/LD c nditi ns. Each vertical line dis lays the ex ressi n data f r ne gene. List f genetic backgr unds r treatment are dis layed h riz ntally. Red and green indicate u - and d wn-regulati n in mutants (**A**) r treated lants (**B**) c m ared t wild-ty e r untreated lants, res ectively. Intensity f the c l urs is r rti nal t the abs lute value f the f ld difference. Images resented here c rres nd t a re resentative regi n f the gl bal image which was t wide t be re r duced integrally.
d i:10.1371/j urnal. ne.0007364.g006

et al *atips1-1* *AtIPS1* *AtIPS1* *Arabidopsis*.

atips1 is a LMM dis laying enhanced basal defence

atips1 *StIPS* *atips1* *SAG12*

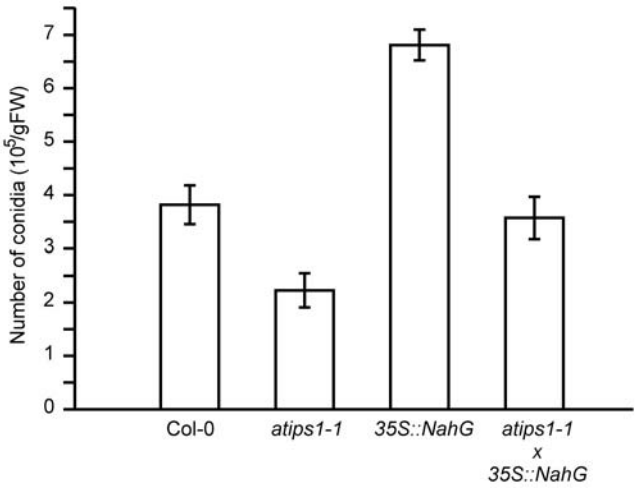

Figure 7. Characterization of *atips1-1* innate immunity. Gr wth f virulent *Hyaloperonospora parasitica* N c 2 n C l-0, *atips1-1*, *35S::NahG*, and *atips1-1/35S::NahG* lants was estimated by c nidia numerati n 6 days after in culati n as described in the meth ds secti n.
d i:10.1371/j urnal. ne.0007364.g007

lgin *atips1-1* f6 ndnd
Eligh *atips1-1* ndgn
dfdlllgdgdv
zadddBBnth
6 ig (Eg6B E *atips1* ldb
gaMMdbdg
n nh f ld c ld p 6
idddgdnbo
bnnd6 b5] Adgis
p *atips1* isdgnk *acd1*, *acd2* o *lsd1*
5] ldg6 *atips1* sdd6 *lsd1*, a
ddnlgdd43]
Mdbdn
atips1 gA nd6 *atips1* nd
ydgdlgdpdo
ddgdn *cpr5* 36]
odgh *atips1* ddnddv
pdM *et al.* fh *atips1* n
o hdg *Pseudomonas syringae* gh
g *AvrB* ddnddv
pgHdnd20] B
nvfh *atips1* ndgdo
eN6 *H. parasitica*, gdd
ddnddnd *atips1-*
1/35S::NahG nvdddhdpoh
g Hdhp6 *atips1-1* d
35S::NahG nd vdbdo
h *AtIPS1* dA, gdno *H. parasitica* n
pdn

Lesi n f rmati n in *atips1* is devel mentally regulated

dgdn *atips1* nd
bydgdgdydyd
g d *atips1* ndd nvh
ndgdnd16 hg
a45 µEm $^{-2}$/sdgB hg225 µEm $^{-2}$/s
ddgdgdpdn
gdddd hd hv6

pd *atips1* ndddn
df nvdfdddn
idTdgdfdd
odgdhdn
pdn *atips1* ndg
dgdgdgdh *atips1-*
1 ddnddgdM
gdddO ndy
dnvdddv
ydn *atips1* ndh
gi-6 dgdgdgdy Adv
ddddddddyh
dd6 *gi* ddd ddd
dd44,45] ddg
ddddddg
dh *Arabidopsis* 5] dRAd *et al* dh
dDdgdd
ddddd6
dddd46]

The nset f PCD in *atips1* may inv lve signals c ming fr m chl r lasts

dTd6Bdp dn
dgdvdh *AtIPS1* idp
pdDd
dN gdddD]
Fn vdvdn dfdn
pdA dgdd
ddgdh *atips1*, d6
Dddgdgdd
d(e d dnpdgd
ddddnddp
gdDdh
dgdddd
dDdgdD
dddddn
dd47] dRD
ddgdnddnd
dRddddfdb6
dnBdd48] dh
Ddddfdgdn
ddddgdddin
dd49] dD *atips1* dn
ddgdh
pddvddddn
dn *atips1* ndvdn
gnd (dN) g
GUN4 (50] g8). gD *gun* ndd
6dgdddd
dd51] ddddn
dddN5 dv
hddddddh
d6 *GUN4* dNdp
dgdddd6
pdddn *len1*,
dd52]
dd *atips1-1* ndm
ddddddp
gdddDdddo
gdddRdnddg d
jddddddfdo
idddRddgd
Dvdgd D dh *atips1-1*

What is the link between MI metab lism and cell cycle r PCD regulati n?

Materials and Methods

AGI numbers f genes menti ned in this study and mutant lines

Plant gr wth

Gen ty ing f the mutants

C nstructs and Nucleic Acids Mani ulati ns

Light and SEM Micr sc y

TUNEL assay

Quantificati n f salicylic acid

Plant infecti n by *Hyaloperonospora Arabidopsis*

Metab l mic r filing

Transcri t me studies

[illegible] *Arabidopsis* [illegible] 384 [illegible] (45 µE m $^{-2}$/s) [illegible] (45 µE m $^{-2}$/s) [illegible] 4 [illegible] 50 [illegible] *atips1-1* [illegible] *i.e.* 4 [illegible] [69]

Statistical analysis f micr array data

[illegible] 24,576 [illegible] 384 [illegible] [69] [illegible] 635 [illegible] 532 [illegible] <5%.

Supporting Information

Figure S1 [illegible] (A) [illegible] 1, 2) [illegible]-1 [illegible] 3) [illegible]-2 [illegible] 4) [illegible]
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d a id10.1371/j p0007364.s009 (0.03 M
D)

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j -1 p p f O d
s D d g D d -1 p
d p -1 p f S
D F s 6 p h g i R 6
p d P u P d 8
d 6 b g s 6
d P u g p o
g d g s g i d
p g g g
p d g g
s ie P >5%). A g g

d a id10.1371/j p0007364.s010 (0.46 M
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j -1 p p f O d
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d 6 b g s 6
d P u g p o
g d g s g i d
p g g g
p d g g
s ie P >5%). A g g

d a id10.1371/j p0007364.s014 (0.03 M
D)

Acknowledgments

W p A d B G n
s p d P
K D g p W
D W T h 6 g s h *GUN4* K
n W A. M ´ d P B G n
6 p p 6 [31] P N d R g E,
6 6 p n W S d H
S P K h f d g W
n V B G n n
p d B d S B G s w
p d W X R P 6
f p

Author Contributions

p P B n
p B A d R
S p P B
s S p P B

References

1. (2008) p d i
i n : 531544.
2. (1997) p d i
i B : 67183.
3. (2008) A p p
: 1326.
4. ´ (2003) p d
d 3: 335342.
5. (2003) 6
p d d p 8:
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6. (2003) p R : d
p J 16: 30513060.
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g R) n A 47: 395407.

8. [illegible] (2009) [illegible] 6
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11. [illegible] (1995) [illegible] 7: 1099–1111.
12. [illegible] (1996) [illegible] 9: 537–548.
13. [illegible] (1993) A [illegible] 3-[illegible] *Spirodela polyrrhiza*. [illegible] 4: 279–293.
14. [illegible] (1997) [illegible] 33: 811–820.
15. [illegible] (2003) [illegible] 54: 1033–1043.
16. [illegible] (2000) [illegible] -1 [illegible] 24: 355–368.
17. [illegible] (2006) [illegible] (*GmMIPS1*) [illegible] 224: 125–132.
18. [illegible] (1998) [illegible] 16: 403–410.
19. [illegible] (1995) [illegible] *Arabidopsis thaliana*. [illegible] 107: 613–619.
20. [illegible] (2008) [illegible] 56: 638–652.
21. [illegible] (1997) [illegible] 16: 277–282.
22. [illegible] (1997) [illegible] *Arabidopsis thaliana*. [illegible] 114: 295–305.
23. [illegible] (2000) [illegible] 97: 978–994.
24. [illegible] (1999) [illegible] *GIGANTEA* 68285: 1579–1582.
25. [illegible] (1999) *GIGANTEA*: [illegible] 18: 4679–4688.
26. [illegible] (1995) [illegible] 8: 863–870.
27. [illegible] (2003) [illegible] *Pseudomonas syringae pv. phaseolicola* [illegible] 33: 733–742.
28. [illegible] (1999) [illegible] 11: 1393–1404.
29. [illegible] (2001) [illegible] 14: 562–565.
30. [illegible] (2008) [illegible] 13: 589–595.
31. [illegible] (2002) A [illegible] 31: 1–12.
32. [illegible] (2007) A [illegible] 161–174.
33. [illegible] (2008) [illegible] 147: 1251–1263.
34. [illegible] (2004) [illegible] 136: 2621–2632.
35. [illegible] (2007) [illegible] 6 [illegible] 5: 1962–1972.
36. [illegible] (1997) [illegible] *cpr5* [illegible] 9: 1573–1584.
37. [illegible] (2008) A [illegible] 148: 212–222.
38. [illegible] (2000) [illegible] 103: 1111–1120.
39. [illegible] (1996) [illegible] *eds1*, [illegible] *Peronospora parasitica* [illegible] *RPP* [illegible] 8: 2033–2046.
40. [illegible] (1994) A [illegible] 18: 1247–1250.
41. [illegible] (2003) [illegible] 132: 2240–2247.
42. [illegible] (2003) [illegible] 36: 629–642.
43. [illegible] (2004) [illegible] 136: 2818–2830.
44. [illegible] (2005) [illegible] *GIGANTEA* [illegible] 24: 683–690.
45. [illegible] (1998) [illegible] 14: 759–764.
46. [illegible] (2008) [illegible] 8: 656–60.
47. [illegible] (2008) [illegible] 69: 43–544.
48. [illegible] (2007) [illegible] 51: 941–954.
49. [illegible] (2008) [illegible] 20: 2339–2356.
50. [illegible] (2006) [illegible] 18: 1121–1133.
51. [illegible] (1993) [illegible] *CAB* [illegible] *RBCS* [illegible] 74: 787–799.
52. [illegible] (2005) [illegible] *lesion initiation 1* [illegible] 69: 1929–1934.
53. [illegible] (2008) [illegible] 415: 33–344.
54. [illegible] (2005) [illegible] *Alternaria alternata* [illegible] 38: 8999.
55. [illegible] (2003) [illegible] 7: 2636–2641.
56. [illegible] (2002) [illegible] *ACCELERATED-CELL-DEATH11* [illegible] 6: 490–502.
57. [illegible] (2008) An [illegible] [illegible] 20: 3163–3179.
58. [illegible] (2007) [illegible] *cat2* [illegible] $_2O_2$-[illegible] 52: 640–657.
59. [illegible] (2008) [illegible] *Pseudomonas chlororaphis* [illegible] 21: 1643–1653.
60. [illegible] (2009) [illegible] 1, [illegible]
61. [illegible] (2003) [illegible] *Arabidopsis thaliana*. [illegible] 301: 653–657.
62. [illegible] (1989) [illegible]
63. [illegible] (1999) [illegible] *arcA3* [illegible] 12: 1181–90.
64. [illegible] (2002) [illegible]

65. [illegible] (2005) [illegible]
102: 82168221.
66. [illegible] (1995) A [illegible]
8: 55160.
67. [illegible] (2004) [illegible]
101: 78097814.
68. [illegible] (2003) [illegible]
31: 156158.
69. [illegible] (2004) [illegible]
16: 20892103.