

**Supplemental information to:**

**Uncoupling proteins 1 and 2 (UCP1 and UCP2) from *Arabidopsis thaliana* are mitochondrial transporters of aspartate, glutamate and dicarboxylates**

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Running title: Transport properties of AtUCP1 and AtUCP2

**Supplemental Tables S1-S4**

**Supplemental Figures S1-S6**

**Supplemental Table S1. Levels of metabolite in AtUCP transgenic plants at the absence of salt.**

Metabolite	with sucrose				without sucrose			
	WT	ucp1	ucp2	dKO	WT	ucp1	ucp2	dKO
phenylalanine	1.0±0.2	0.8±0.1	0.7±0.2	0.8±0.1	1.0±0.1	0.8±0.1	1.6±0.5	1.3±0.1
tryptophan	1.0±0.1	0.7±0.2	1.1±0.1	1.0±0.1	1.0±0.1	0.9±0.1	0.8±0.2	1.1±0.1
asparagine	1.0±0.3	0.9±0.3	0.8±0.5	0.8±0.2	1.0±0.3	0.8±0.2	2.0±0.3	1.6±0.8
lysine	1.0±0.2	0.8±0.1	0.8±0.2	0.9±0.1	1.0±0.1	1.3±0.2	1.6±0.4	2.0±0.1
serine	1.0±0.1	0.9±0.1	0.9±0.1	0.7±0.2	1.0±0.1	1.2±0.1	1.4±0.1	1.3±0.1
threonine	1.0±0.1	1.0±0.1	1.1±0.1	1.0±0.1	1.0±0.1	1.0±0.1	1.1±0.1	1.1±0.1
isoleucine	1.0±0.1	1.1±0.2	1.0±0.1	0.9±0.1	1.0±0.1	1.0±0.1	1.1±0.2	1.2±0.1
methionine	1.0±0.1	0.9±0.1	1.0±0.1	1.0±0.1	1.0±0.1	1.4±0.2	1.2±0.4	1.6±0.2
leucine	1.0±0.1	1.0±0.1	1.0±0.1	0.9±0.2	1.0±0.1	1.1±0.1	1.3±0.3	1.3±0.1
alanine	1.0±0.4	1.2±0.6	1.5±0.3	1.3±0.2	1.0±0.4	1.3±0.5	0.8±0.2	1.5±0.2
beta.alanine	1.0±0.2	0.9±0.1	1.2±0.1	1.0±0.1	1.0±0.1	1.4±0.2	0.8±0.3	1.4±0.1
ornithine	1.0±0.1	1.0±0.3	0.8±0.3	0.9±0.3	1.0±0.1	1.9±0.2	2.3±0.3	<b>3.1±0.3</b>
proline	1.0±0.3	1.1±0.3	1.4±0.4	0.8±0.1	1.0±0.1	1.2±0.2	1.0±0.1	1.5±0.3
valine	1.0±0.1	1.0±0.1	1.0±0.1	0.9±0.1	1.0±0.1	1.2±0.1	1.1±0.1	1.2±0.1
glycine	1.0±0.2	1.0±0.2	0.7±0.1	0.6±0.4	1.0±0.1	1.1±0.2	1.8±0.4	1.6±0.1
glutamine	1.0±0.2	1.3±0.1	0.9±0.1	1.4±0.9	1.0±0.2	1.3±0.2	1.8±0.5	1.8±0.7
aspartate	1.0±0.1	1.1±0.2	1.3±0.3	0.9±0.1	1.0±0.1	1.1±0.1	0.8±0.1	1.0±0.1
glutamate	1.0±0.2	1.0±0.2	1.2±0.1	1.2±0.2	1.0±0.1	0.9±0.1	1.0±0.1	1.1±0.3
arginine	1.0±0.2	0.7±0.1	0.5±0.2	0.7±0.2	1.0±0.2	1.4±0.1	2.6±0.4	2.7±0.1
glucose	1.0±0.2	1.0±0.2	0.9±0.2	0.8±0.1	1.0±0.1	0.8±0.1	0.7±0.2	0.5±0.1
sucrose	1.0±0.1	1.0±0.1	1.0±0.1	1.0±0.1	1.0±0.2	0.9±0.1	0.4±0.1	0.9±0.1
maltose	1.0±0.1	0.9±0.2	0.7±0.1	1.0±0.2	1.0±0.1	1.0±0.2	0.7±0.1	0.9±0.1
raffinose	1.0±0.2	0.8±0.1	1.3±0.2	1.3±0.5	1.0±0.1	0.7±0.2	0.2±0.1	0.6±0.1
glycerol	1.0±0.2	1.0±0.2	0.9±0.1	0.9±0.2	1.0±0.1	0.9±0.1	1.0±0.3	0.7±0.1
erythritol	1.0±0.1	0.9±0.1	1.2±0.1	1.2±0.1	1.0±0.1	1.3±0.2	0.9±0.3	1.2±0.1
myo.inositol	1.0±0.2	1.0±0.1	1.3±0.2	1.1±0.3	1.0±0.1	0.9±0.1	<b>0.5±0.1</b>	0.7±0.1
malate	1.0±0.2	0.9±0.1	1.0±0.1	0.9±0.1	1.0±0.1	0.7±0.1	0.7±0.1	0.7±0.1
fumarate	1.0±0.2	1.0±0.3	0.8±0.1	0.8±0.2	1.0±0.1	0.7±0.1	<b>0.4±0.1</b>	<b>0.5±0.1</b>
citrate	1.0±0.2	0.7±0.1	1.1±0.2	0.9±0.1	1.0±0.1	<b>0.4±0.1</b>	<b>0.4±0.1</b>	<b>0.4±0.1</b>
pyruvate	1.0±0.1	0.9±0.1	1.5±0.2	1.0±0.4	1.0±0.2	1.1±0.1	0.7±0.3	1.0±0.1
glycerate	1.0±0.1	1.0±0.1	1.3±0.2	0.9±0.2	1.0±0.1	0.7±0.1	0.6±0.1	0.5±0.1
succinate	1.0±0.4	0.8±0.2	0.8±0.2	0.6±0.1	1.0±0.1	0.8±0.2	0.7±0.1	0.7±0.1
phosphate	1.0±0.7	1.9±0.6	0.7±0.3	1.4±0.8	1.0±0.1	3.3±0.6	2.9±1.7	5.2±1.1
threonate	1.0±0.4	0.8±0.2	1.0±0.1	1.0±0.4	1.0±0.2	0.8±0.2	0.4±0.1	0.7±0.2
dehydroascorbate	1.0±0.2	1.0±0.1	1.4±0.4	1.2±0.2	1.0±0.2	1.8±0.4	0.9±0.1	2.6±1.7
GABA	1.0±0.3	0.8±0.2	0.7±0.2	0.8±0.4	1.0±0.1	0.6±0.1	1.3±0.2	1.3±0.1
putrescine	1.0±0.3	0.6±0.1	0.8±0.4	1.0±0.2	1.0±0.1	1.2±0.1	1.7±0.2	1.8±0.1
AMP	1.0±0.3	1.3±0.4	1.4±0.6	1.1±0.4	1.0±0.1	1.2±0.2	1.3±0.2	0.8±0.1
benzoate	1.0±0.2	0.7±0.1	0.7±0.1	0.7±0.1	1.0±0.1	0.9±0.1	1.0±0.2	0.8±0.1
sulfate	-	3.5±1.3	-	-	-	-	-	2.3±0.9
nicotinate	1.0±0.1	<b>0.5±0.1</b>	0.7±0.1	0.7±0.1	1.0±0.1	0.7±0.1	0.8±0.3	1.3±0.1
2-oxoglutarate	1.0±0.1	0.9±0.1	0.6±0.2	1.0±0.8	1.0±0.2	0.6±0.1	1.1±0.1	0.9±0.1
fructose	1.0±0.2	0.8±0.1	0.9±0.1	0.7±0.1	1.0±0.1	0.7±0.1	0.8±0.2	0.6±0.1
shikimate	1.0±0.2	0.6±0.1	0.8±0.1	0.7±0.1	1.0±0.1	1.1±0.1	0.8±0.1	0.9±0.1
trehalose	1.0±0.2	0.8±0.3	1.3±0.4	0.9±0.1	1.0±0.1	1.1±0.2	-	0.6±0.1
galactinol	1.0±0.2	0.7±0.1	1.5±0.4	1.6±0.8	1.0±0.1	0.6±0.1	-	-

Values are mean ± SEM (n=3) peak intensities normalized by the mean of those in wild-type (WT) samples in the corresponding sucrose condition at the absence of NaCl. The values in bold are statistically significantly different from those in wild-type plants in each growth condition by ANOVA analysis ( $p < 0.05$ ). Abbreviation: double knockout (dKO).

**Supplemental Table S2. Levels of metabolite in AtUCP transgenic plants at 50 mM NaCl.**

Metabolite	with sucrose				without sucrose			
	WT	ucp1	ucp2	dKO	WT	ucp1	ucp2	dKO
phenylalanine	0.8±0.2	0.6±0.1	0.7±0.1	0.4±0.1	0.9±0.2	0.7±0.1	0.7±0.1	0.7±0.2
tryptophan	0.8±0.1	0.7±0.1	0.8±0.1	0.5±0.1	0.7±0.1	0.7±0.1	0.7±0.1	0.6±0.1
asparagine	0.5±0.1	0.4±0.1	0.5±0.1	0.6±0.1	0.5±0.1	0.5±0.1	0.5±0.1	0.6±0.1
lysine	1.0±0.2	0.7±0.1	0.9±0.1	0.9±0.1	1.2±0.1	1.2±0.1	1.2±0.1	1.6±0.2
serine	1.4±0.2	1.1±0.3	1.2±0.1	1.0±0.1	1.1±0.1	1.1±0.1	1.1±0.1	1.2±0.1
threonine	1.2±0.1	1.3±0.1	1.1±0.1	1.1±0.1	1.2±0.1	1.1±0.1	1.1±0.1	1.0±0.1
isoleucine	1.5±0.3	1.0±0.1	1.5±0.1	0.9±0.1	1.3±0.1	1.2±0.1	1.2±0.1	1.1±0.1
methionine	1.0±0.1	0.9±0.1	0.9±0.1	0.8±0.1	1.0±0.1	1.0±0.1	1.0±0.1	1.0±0.1
leucine	1.5±0.3	1.0±0.2	1.4±0.2	0.8±0.1	1.3±0.1	1.2±0.2	1.2±0.1	1.1±0.1
alanine	1.2±0.4	1.3±0.5	1.0±0.3	1.2±0.7	1.2±0.4	1.4±0.5	1.5±0.6	1.2±0.4
beta.alanine	1.4±0.1	1.1±0.1	1.1±0.1	1.2±0.1	1.5±0.4	1.8±0.3	1.6±0.4	1.6±0.2
ornithine	1.0±0.1	0.6±0.1	1.0±0.2	1.0±0.2	1.0±0.2	1.3±0.5	0.9±0.3	2.3±0.7
proline	2.7±0.2	2.8±0.7	2.4±0.3	2.3±0.3	6.1±1.0	4.5±0.4	5.2±0.8	3.4±0.6
valine	1.3±0.1	1.1±0.1	1.1±0.1	1.0±0.1	1.1±0.1	1.2±0.1	1.2±0.1	1.1±0.1
glycine	0.3±0.1	0.2±0.1	0.3±0.1	0.2±0.1	0.3±0.1	0.2±0.1	0.3±0.1	0.2±0.1
glutamine	1.5±0.3	1.6±0.3	1.4±0.4	1.2±0.3	1.1±0.1	1.3±0.1	1.3±0.2	1.2±0.3
aspartate	1.2±0.1	1.2±0.1	0.9±0.1	0.8±0.1	1.2±0.2	1.1±0.1	1.3±0.2	0.9±0.1
glutamate	1.1±0.1	1.2±0.1	1.0±0.1	1.0±0.2	1.0±0.2	0.9±0.1	1.0±0.2	0.8±0.1
arginine	0.7±0.1	0.4±0.1	0.7±0.1	0.7±0.1	0.6±0.1	0.8±0.2	0.7±0.2	1.1±0.1
glucose	0.8±0.2	0.6±0.1	0.8±0.1	1.2±0.4	0.8±0.2	0.6±0.1	1.5±1.0	0.9±0.5
sucrose	0.8±0.2	0.9±0.1	0.8±0.1	0.8±0.1	0.9±0.4	0.8±0.1	0.7±0.3	0.6±0.3
maltose	0.7±0.1	0.7±0.1	0.8±0.1	1.2±0.1	0.7±0.1	0.9±0.2	0.7±0.1	1.0±0.1
raffinose	1.2±0.3	0.9±0.4	0.9±0.1	0.9±0.3	2.2±0.9	1.5±0.2	1.3±0.3	1.0±0.1
glycerol	1.9±0.8	0.9±0.1	1.0±0.1	1.0±0.1	1.5±0.5	1.3±0.2	2.3±1.3	2.0±1.1
erythritol	1.6±0.1	1.7±0.1	1.5±0.1	1.4±0.1	1.6±0.1	1.7±0.1	1.7±0.1	1.4±0.1
myo.inositol	1.1±0.1	1.3±0.1	0.9±0.1	1.0±0.1	1.6±0.4	1.4±0.1	1.5±0.2	1.0±0.1
malate	0.6±0.1	0.4±0.1	0.4±0.1	<b>0.2±0.1</b>	0.6±0.1	0.4±0.1	0.4±0.1	<b>0.3±0.1</b>
fumarate	0.5±0.1	0.6±0.1	0.4±0.1	0.2±0.1	0.5±0.1	0.4±0.1	0.4±0.1	0.2±0.1
citrate	1.1±0.2	0.7±0.1	0.7±0.1	1.0±0.3	0.9±0.3	0.7±0.1	1.0±0.4	0.7±0.1
pyruvate	1.4±0.2	0.8±0.1	1.0±0.2	-	0.9±0.1	0.8±0.1	0.8±0.1	0.6±0.1
glycerate	0.8±0.1	0.5±0.1	0.4±0.1	0.4±0.1	1.2±0.1	0.9±0.1	1.1±0.2	0.8±0.1
succinate	0.4±0.1	-	0.4±0.1	-	0.3±0.1	-	0.3±0.1	0.3±0.1
phosphate	7.5±5.1	9.7±2.9	3.5±1.3	8.5±0.7	6.4±1.9	9.3±1.1	8.0±0.5	8.5±0.7
threonate	0.7±0.2	0.9±0.1	0.6±0.1	0.6±0.1	1.0±0.4	0.8±0.1	1.0±0.3	0.7±0.2
dehydroascorbate	0.7±0.1	1.1±0.2	0.7±0.1	0.5±0.1	0.7±0.1	0.7±0.1	0.7±0.1	0.5±0.1
GABA	0.4±0.1	0.2±0.1	0.3±0.1	0.2±0.1	0.4±0.1	0.4±0.1	0.5±0.2	0.4±0.1
putrescine	0.3±0.1	0.3±0.1	0.4±0.1	0.3±0.1	0.3±0.1	0.4±0.1	0.3±0.1	0.4±0.1
AMP	3.6±1.2	3.6±0.4	2.6±0.9	3.0±0.7	2.2±0.4	2.2±0.7	3.5±1.9	2.2±1.2
benzoate	0.7±0.1	0.7±0.1	0.7±0.1	0.8±0.1	0.9±0.1	1.0±0.1	0.9±0.1	1.0±0.1
sulfate	10±2	12±2	11±1	13±3	46±14	45±16	40±16	49±17
nicotinate	0.6±0.1	0.4±0.1	0.5±0.1	0.5±0.1	1.0±0.1	0.9±0.2	0.8±0.2	1.0±0.3
2-oxoglutarate	0.5±0.1	0.3±0.2	0.5±0.1	0.2±0.1	0.4±0.1	0.3±0.1	0.3±0.1	0.3±0.1
fructose	0.6±0.1	0.6±0.1	0.6±0.1	1.1±0.3	1.0±0.2	0.7±0.1	1.1±0.4	0.8±0.3
shikimate	0.6±0.1	0.6±0.1	0.6±0.1	0.8±0.1	0.8±0.2	0.8±0.1	0.8±0.1	0.6±0.1
trehalose	0.8±0.1	0.9±0.1	0.5±0.1	0.6±0.1	1.1±0.3	1.0±0.1	1.1±0.2	0.5±0.2
galactinol	0.8±0.3	0.5±0.1	0.5±0.1	0.4±0.1	1.7±0.9	1.0±0.1	1.1±0.4	0.7±0.1

Values are mean ± SEM (n=3) peak intensities normalized by the mean of those in wild-type (WT) samples in the corresponding sucrose condition at the absence of NaCl. The values in bold are statistically significantly different from those in wild-type plants in each growth condition by ANOVA analysis ( $p<0.05$ ). Abbreviation: double knockout (dKO).

**Supplemental Table S3. Levels of metabolite in AtUCP transgenic plants at 75 mM NaCl.**

Metabolite	with sucrose				without sucrose			
	WT	ucp1	ucp2	dKO	WT	ucp1	ucp2	dKO
phenylalanine	0.9±0.2	0.6±0.2	0.5±0.1	0.4±0.1	1.2±0.3	0.6±0.1	0.8±0.1	0.6±0.1
tryptophan	0.8±0.1	0.7±0.1	0.7±0.1	0.6±0.1	0.7±0.1	0.6±0.1	0.6±0.1	0.6±0.1
asparagine	0.4±0.1	0.4±0.1	0.4±0.1	0.4±0.1	0.5±0.1	0.5±0.2	0.5±0.1	0.4±0.1
lysine	1.1±0.2	0.9±0.1	1.1±0.1	1.1±0.1	1.5±0.1	1.4±0.2	1.3±0.2	1.4±0.1
serine	1.4±0.2	1.1±0.2	1.3±0.1	1.1±0.1	1.4±0.1	1.0±0.2	1.3±0.2	1.0±0.1
threonine	1.7±0.1	1.8±0.1	1.4±0.1	1.3±0.1	1.6±0.1	1.3±0.2	1.5±0.2	1.4±0.2
isoleucine	1.6±0.4	1.3±0.3	1.3±0.2	1.0±0.1	1.7±0.2	1.0±0.1	1.3±0.1	1.2±0.1
methionine	1.2±0.1	1.2±0.1	1.1±0.1	1.0±0.1	1.2±0.1	1.1±0.1	1.2±0.1	1.1±0.1
leucine	1.8±0.4	1.2±0.4	1.2±0.1	0.9±0.1	1.8±0.2	1.0±0.1	1.4±0.1	1.1±0.1
alanine	1.3±0.5	1.5±0.5	1.4±0.5	1.4±0.5	1.4±0.5	1.3±0.5	1.5±0.5	1.5±0.5
beta.alanine	1.4±0.2	1.5±0.2	1.6±0.2	1.5±0.1	1.9±0.1	1.7±0.3	1.8±0.3	1.8±0.2
ornithine	0.5±0.2	0.5±0.1	1.1±0.3	1.1±0.3	1.4±0.3	1.8±0.6	1.4±0.5	1.3±0.1
proline	5.3±1.5	4.3±1.0	3.8±0.7	3.5±0.9	12±2	7.4±0.9	12±2	7±2
valine	1.4±0.2	1.2±0.1	1.2±0.1	1.1±0.1	1.3±0.1	1.0±0.1	1.3±0.1	1.2±0.1
glycine	0.2±0.1	0.1±0.1	0.1±0.1	0.1±0.1	0.2±0.1	0.1±0.1	0.2±0.1	0.1±0.1
glutamine	1.8±0.3	1.8±0.3	2.0±0.6	1.6±0.3	1.3±0.3	1.1±0.2	1.6±0.3	1.2±0.4
aspartate	1.2±0.1	1.1±0.1	0.9±0.2	0.7±0.1	1.0±0.2	0.7±0.1	1.1±0.1	0.7±0.1
glutamate	1.2±0.1	1.3±0.1	1.0±0.1	1.0±0.1	1.2±0.1	0.9±0.2	1.1±0.1	0.9±0.1
arginine	0.4±0.1	0.3±0.1	0.7±0.1	0.7±0.1	0.9±0.1	0.9±0.2	0.8±0.2	0.7±0.1
glucose	0.6±0.1	0.6±0.1	0.6±0.1	0.7±0.1	1.5±0.3	1.9±0.2	0.6±0.1	0.6±0.1
sucrose	1.0±0.1	1.0±0.1	0.9±0.1	0.8±0.1	1.0±0.1	0.5±0.2	1.3±0.3	1.3±0.3
maltose	0.5±0.1	0.5±0.1	0.5±0.1	0.6±0.1	0.6±0.1	1.1±0.3	0.6±0.1	1.0±0.2
raffinose	1.8±0.7	1.6±0.8	1.1±0.6	1.1±0.6	5.1±3.1	1.8±0.7	3.3±1.6	3.2±0.3
glycerol	1.6±0.6	1.5±0.5	1.6±0.6	1.3±0.5	1.9±0.6	1.8±0.4	1.6±0.7	1.3±0.3
erythritol	2.1±0.1	2.1±0.2	2.0±0.2	1.6±0.1	2.0±0.2	1.6±0.2	2.0±0.1	1.9±0.3
myo.inositol	1.5±0.1	1.5±0.1	1.2±0.2	1.1±0.1	2.1±0.2	1.7±0.5	2.1±0.5	2.0±0.5
malate	0.6±0.1	0.3±0.1	0.3±0.1	<b>0.2±0.1</b>	0.5±0.1	<b>0.2±0.1</b>	0.4±0.1	<b>0.2±0.1</b>
fumarate	0.5±0.1	0.4±0.1	0.2±0.1	<b>0.1±0.1</b>	0.5±0.1	<b>0.2±0.1</b>	0.4±0.1	<b>0.2±0.1</b>
citrate	0.9±0.2	0.7±0.1	0.8±0.3	0.7±0.1	0.6±0.1	<b>0.4±0.1</b>	0.7±0.1	0.5±0.1
pyruvate	1.1±0.1	0.9±0.1	0.8±0.1	0.9±0.1	1.0±0.1	0.7±0.1	0.9±0.1	<b>0.7±0.1</b>
glycerate	0.8±0.1	0.7±0.1	0.5±0.1	0.5±0.1	2.1±0.3	1.3±0.2	1.1±0.2	<b>0.7±0.1</b>
succinate	-	-	-	-	-	-	-	-
phosphate	9.4±1.4	11.0±2.2	13.5±4.1	12.0±2.4	7.8±2.7	9.1±0.5	7.0±1.7	9.5±3.1
threonate	0.9±0.2	0.7±0.1	0.5±0.1	0.4±0.1	0.8±0.2	0.4±0.1	0.8±0.1	0.6±0.1
dehydroascorbate	0.7±0.1	0.6±0.1	0.7±0.1	0.5±0.1	0.5±0.1	0.5±0.1	0.7±0.1	0.6±0.1
GABA	0.2±0.1	0.1±0.1	0.2±0.1	0.2±0.1	0.5±0.2	0.6±0.1	0.3±0.1	0.2±0.1
putrescine	0.2±0.1	0.2±0.1	0.3±0.1	0.3±0.1	0.3±0.1	0.3±0.1	0.4±0.1	0.4±0.1
AMP	5.1±1.1	4.8±1.1	4.6±1.2	4.4±1.6	3.1±0.7	3.3±0.5	2.8±1.0	2.2±0.7
benzoate	0.9±0.2	0.8±0.1	0.8±0.1	0.6±0.1	1.0±0.2	0.8±0.1	1.0±0.1	1.0±0.1
sulfate	20±4	25±8	21±7	19±5	45±15	30±10	46±23	49±15
nicotinate	0.5±0.1	0.4±0.1	0.5±0.1	0.5±0.1	0.9±0.2	0.8±0.2	1.0±0.2	0.9±0.1
2-oxoglutarate	0.2±0.1	0.2±0.1	0.2±0.1	0.1±0.1	0.3±0.1	0.2±0.1	0.2±0.1	<b>0.1±0.1</b>
fructose	0.5±0.1	0.5±0.1	0.5±0.1	0.6±0.1	1.7±0.1	1.9±0.1	0.8±0.2	0.7±0.2
shikimate	0.6±0.1	0.6±0.1	0.5±0.1	0.5±0.1	0.9±0.1	0.8±0.1	0.9±0.1	0.8±0.1
trehalose	1.2±0.1	1.0±0.1	<b>0.7±0.1</b>	<b>0.6±0.1</b>	1.2±0.2	1.0±0.2	1.1±0.3	1.4±0.3
galactinol	1.0±0.2	0.7±0.2	0.5±0.1	0.4±0.2	2.5±1.0	1.7±0.8	2.0±0.8	1.8±0.3

Values are mean ± SEM (n=3) peak intensities normalized by the mean of those in wild-type (WT) samples in the corresponding sucrose condition at the absence of NaCl. The values in bold are statistically significantly different from those in wild-type plants in each growth condition by ANOVA analysis ( $p<0.05$ ). Abbreviation: double knockout (dKO).

**Supplemental Table S4. Primer sequences used in this study**

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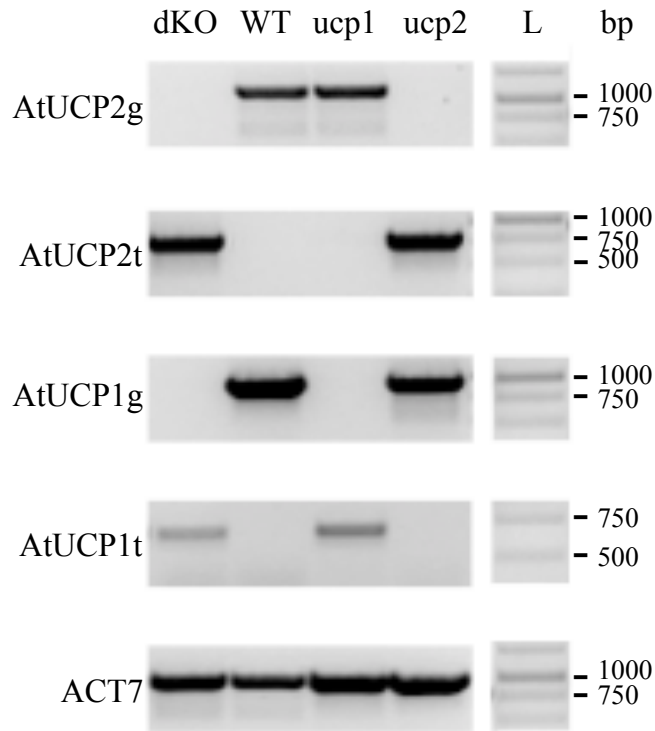
Name	Sequence (5'-3')
BH254	cgagtgcgggatcctctagaggccATGGTGGCGGCTGGTAAATC
BH255	cttgctcacgccgctccctccccgcCCGTTTCTTTGGACGCATC
DG5	AAACAACCACCAGTAGAAGCC
DG6	TCGATCAATCACTGTCACTGG
DG8	TTCTAGCCACAGATCTGACCG
DG9	TTTATCATCGAGGGCACTCTG
DG23	CGAGGATTGTTGGGAACTGT
DG24	AAAGAGCTCGGACTCCTTCC
DG25	ATGGTGAGAATTTGCCCAAG
DG26	GCCGGTAACTTTCCTTCTGA
SALK- LBa1	TGGTTCACGTAGTGGGCCATCG
SAIL-Lba	TTCATAACCAATCTCGATACAC
UCP2_BPF	ggggacaagttgtacaaaaagcaggctccaccATGGCGGATTTCAAACCAAG
UCP2_BPR-s	ggggaccactttgtacaagaagctgggtcATCGTACAAGACTTCTCTTAGAAACACTT

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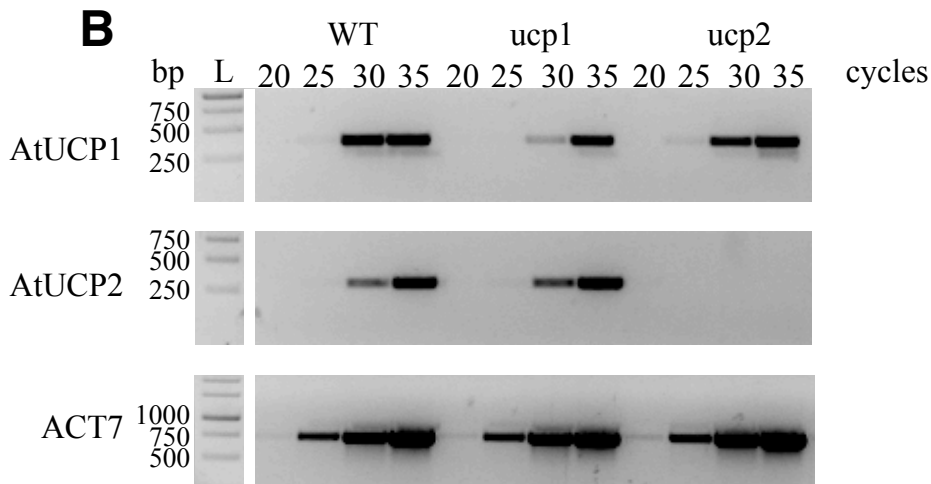
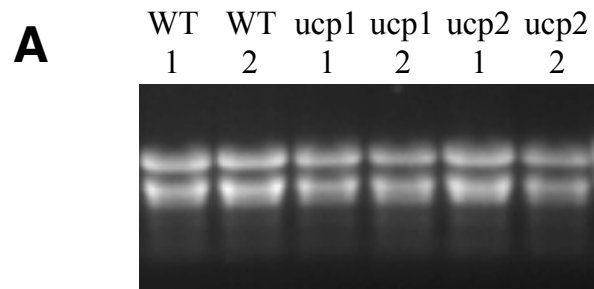
PUMP1\_ARATH 1 MVAAGK..SDLS..LPKTFACSAFAACVGEVCTIPLD<sup>1</sup>TAKVRLQ<sup>2</sup>LQKSA.....LAGD.....VTL<sup>3</sup>PKYRG....LLGT<sup>4</sup>VTG<sup>5</sup>TIAREEGLRSLWK  
 PUMP2\_ARATH 1 MADFKPRIEIS..FLETFICSAFAACFAELCTIPLD<sup>1</sup>TAKVRLQ<sup>2</sup>LQKRI.....PTGDG.....ENL<sup>3</sup>PKYRG....SIG<sup>4</sup>TLAT<sup>5</sup>IAREEGISGLWK  
 UCP2\_HUMAN 1 MVGFKATDVPTT..ATVFLGAGTAACTADLI<sup>1</sup>TFPLD<sup>2</sup>TAKVRLQ<sup>3</sup>LQGESQ.....GPVRA.....TASAQ<sup>4</sup>YRG....VMG<sup>5</sup>TIL<sup>6</sup>TMVTEGPRSLYN  
 DIC1\_YEAST 1 MSTNAKESAGKN..IKYPWVYGGAGIFATMV<sup>1</sup>THPLD<sup>2</sup>LAKVRLQ<sup>3</sup>AAMPKPT.....LFRMLE<sup>4</sup>SILANE<sup>5</sup>EGVVGGLYS  
 DIC\_HUMAN 1 MAAEARVSR.....WYFGGLASC<sup>1</sup>GAACCTH<sup>2</sup>PLDLLK<sup>3</sup>VHLQ<sup>4</sup>TQEQEVKLR.....MTGMAL<sup>5</sup>RVV<sup>6</sup>TDGILALYS  
 DIC2\_ARATH 1 MGDHGKVKSDIS...FAGTFASSAFAACFAE<sup>1</sup>VTIPLD<sup>2</sup>TAKVRLQ<sup>3</sup>LQKKA.....PSTTT<sup>4</sup>VTL<sup>5</sup>LRPALAFP...NSSPA<sup>6</sup>AFL<sup>7</sup>ETTSSV<sup>8</sup>PKVG...PISL<sup>9</sup>GINIVK<sup>10</sup>SEG<sup>11</sup>AALF<sup>12</sup>S  
 DIC1\_ARATH 1 MG.....LKGFAE<sup>1</sup>GGIASIVAGCSTH<sup>2</sup>PLDLI<sup>3</sup>KV<sup>4</sup>RMQLQ<sup>5</sup>GES.....APIQ<sup>6</sup>TN..LRPALAFQ...TST...TVNAP<sup>7</sup>PLRVG...VIG<sup>8</sup>VGSRLI<sup>9</sup>RE<sup>10</sup>GMRALF<sup>11</sup>S  
 DIC3\_ARATH 1 MG.....FKP<sup>1</sup>FLEGGIAAI<sup>2</sup>IAGAL<sup>3</sup>TH<sup>4</sup>PLDLI<sup>5</sup>KV<sup>6</sup>RMQLQ<sup>7</sup>GEHSFSLDQNP<sup>8</sup>PNLSLDH<sup>9</sup>NLPV<sup>10</sup>KYPR<sup>11</sup>VPV<sup>12</sup>FALDSLIG<sup>13</sup>ISL<sup>14</sup>PLPHI<sup>15</sup>HAPSS<sup>16</sup>STRSV<sup>17</sup>MTP<sup>18</sup>FAVGAH<sup>19</sup>IVK<sup>20</sup>TEG<sup>21</sup>PAALF<sup>22</sup>S  
 A0A077DCK6\_TOBAC 1 MGDHGKVKSDIS...FAGTFASSAFAACFAE<sup>1</sup>VTIPLD<sup>2</sup>TAKVRLQ<sup>3</sup>LQKKA.....VEGD.....L<sup>4</sup>SLPKYRG....LLG<sup>5</sup>TVG<sup>6</sup>TIAREE<sup>7</sup>GVASLWK  
 Q2Q212\_ORYSJ 1 MP.EHGSKPDIS...FAGRFTA<sup>1</sup>SAIAACFAE<sup>2</sup>VCTIPLD<sup>3</sup>TAKVRLQ<sup>4</sup>LQKNV.....AADA...PKYRG....LLG<sup>5</sup>TAAT<sup>6</sup>IAREE<sup>7</sup>GAAALWK  
 Q8S4C4\_MAIZE 1 MPGDHSGKDIS...FAGRFTA<sup>1</sup>SAIAACFAE<sup>2</sup>ICTIPLD<sup>3</sup>TAKVRLQ<sup>4</sup>LQKNV.....VAAA<sup>5</sup>SGDAAPAL<sup>6</sup>PKYRG....LLG<sup>7</sup>TAAT<sup>8</sup>IAREE<sup>9</sup>GAAALWK  
 C6T891\_SOYBN 1 MVADSKNSDLS...FGKIFASSAFSACFAE<sup>1</sup>VCTIPLD<sup>2</sup>TAKVRLQ<sup>3</sup>LQKKA.....VAGDV.....V<sup>4</sup>SLPKYRG....MLG<sup>5</sup>TVG<sup>6</sup>TIAREE<sup>7</sup>GLSALWK  
 B9GIV8\_POPTR 1 MADLKPSSDIS...FVEIFLCSAFAACFAE<sup>1</sup>CTIPLD<sup>2</sup>TAKVRLQ<sup>3</sup>LQKRT.....FASEG...V<sup>4</sup>SLPKYRG....LLG<sup>5</sup>TVAT<sup>6</sup>IAREE<sup>7</sup>GLAALWK  
 A9PAU0\_POPTR 1 MVADSKGSDIS...FAGTFASSAFAACFAE<sup>1</sup>ICTIPLD<sup>2</sup>TAKVRLQ<sup>3</sup>LQKSA.....VAGDG...LAL<sup>4</sup>PKYRG....MLG<sup>5</sup>TVAT<sup>6</sup>IAREE<sup>7</sup>GLSALWK  
 I3ST66\_LOTJA 1 MVADSKNSDLS...FAKTFASSAFSACFAE<sup>1</sup>VCTIPLD<sup>2</sup>TAKVRLQ<sup>3</sup>LQKQG.....IAGDV.....ASL<sup>4</sup>PKYRG....MLG<sup>5</sup>TIAT<sup>6</sup>IAREE<sup>7</sup>GASALWK  
 A8J1X0\_CHLRE 1 MVASSSSQPLS...FPRTFLASAIACFAE<sup>1</sup>AL<sup>2</sup>TPLD<sup>3</sup>TAKVRLQ<sup>4</sup>LQAGGN.....K<sup>5</sup>YKG....MLG<sup>6</sup>TVAT<sup>7</sup>IAREE<sup>8</sup>PASLWK  
 A4S0P6\_OSTLU 1 MAREGDATATRTKTKT<sup>1</sup>PLVNPFL<sup>2</sup>GLG<sup>3</sup>LAASAF<sup>4</sup>SASFAE<sup>5</sup>FCTIPLD<sup>6</sup>TVK<sup>7</sup>VLQ<sup>8</sup>LRGASA.....TATAT...TRGRGAG...MLG<sup>9</sup>TMRAVAE<sup>10</sup>EIG<sup>11</sup>ALWK

PUMP1\_ARATH 77 GVVEGLHRQCLF<sup>1</sup>GGLRIGLYE<sup>2</sup>FPVKNLYV<sup>3</sup>GKDFV<sup>4</sup>GV<sup>5</sup>DV<sup>6</sup>PLS<sup>7</sup>KKILAGL<sup>8</sup>TTGALGIMVAN<sup>9</sup>PTD<sup>10</sup>LK<sup>11</sup>VRLQ<sup>12</sup>AEG<sup>13</sup>KLAA<sup>14</sup>GAPRRY<sup>15</sup>SGALNAY<sup>16</sup>STIV<sup>17</sup>RQEG.VRAL<sup>18</sup>WTGLG<sup>19</sup>PNVARN<sup>20</sup>AINAA<sup>21</sup>ELAS<sup>22</sup>YD<sup>23</sup>VQ<sup>24</sup>KE<sup>25</sup>TIL  
 PUMP2\_ARATH 79 GVVIAGLHRQCIY<sup>1</sup>GGLRIGLYE<sup>2</sup>FPVKTLLV<sup>3</sup>GSDFIG<sup>4</sup>DI<sup>5</sup>PLY<sup>6</sup>QKILAA<sup>7</sup>LLTGAIAI<sup>8</sup>IVAN<sup>9</sup>PTD<sup>10</sup>LK<sup>11</sup>VRLQ<sup>12</sup>SEG<sup>13</sup>KLPA<sup>14</sup>GV<sup>15</sup>PRRY<sup>16</sup>AGAV<sup>17</sup>DAY<sup>18</sup>FTIV<sup>19</sup>KLEG.VSAL<sup>20</sup>WTGLG<sup>21</sup>PNIARN<sup>22</sup>AINAA<sup>23</sup>ELAS<sup>24</sup>YD<sup>25</sup>QI<sup>26</sup>KETIM  
 UCP2\_HUMAN 81 GLVAGLQRQMSFASV<sup>1</sup>RIGLYDSVK<sup>2</sup>QFYTKGSE..HASIGSRLLAG<sup>3</sup>STYGALAVAV<sup>4</sup>QPTD<sup>5</sup>VV<sup>6</sup>KV<sup>7</sup>RFOA<sup>8</sup>QAR..AGGGRY<sup>9</sup>QSTVNAY<sup>10</sup>KTIAREEG.FRGL<sup>11</sup>WK<sup>12</sup>GTSP<sup>13</sup>NVARN<sup>14</sup>AINAA<sup>15</sup>ELV<sup>16</sup>YD<sup>17</sup>LLK<sup>18</sup>DALL  
 DIC1\_YEAST 70 GLSAAVLRQCTY<sup>1</sup>TTV<sup>2</sup>RFGAY<sup>3</sup>DLLEN<sup>4</sup>VI<sup>5</sup>PREQ..LTN<sup>6</sup>MAYLL<sup>7</sup>PCSM<sup>8</sup>FSGAIG<sup>9</sup>L<sup>10</sup>AGN<sup>11</sup>FAD<sup>12</sup>VVNI<sup>13</sup>RMQ<sup>14</sup>NSDALEAA<sup>15</sup>KRN<sup>16</sup>YKNA<sup>17</sup>ID<sup>18</sup>GVY<sup>19</sup>KI<sup>20</sup>RYE<sup>21</sup>GGL<sup>22</sup>KT<sup>23</sup>FTG<sup>24</sup>WK<sup>25</sup>P<sup>26</sup>N<sup>27</sup>VRG<sup>28</sup>ILMTAS<sup>29</sup>QV<sup>30</sup>TV<sup>31</sup>YD<sup>32</sup>V<sup>33</sup>FK<sup>34</sup>NYL<sup>35</sup>V  
 DIC\_HUMAN 63 GLSASLCRQMTY<sup>1</sup>SLRFAI<sup>2</sup>YET<sup>3</sup>VRDRVAK<sup>4</sup>GSQ<sup>5</sup>PLPF<sup>6</sup>HE<sup>7</sup>KVLLGS.VSGLAG<sup>8</sup>GFV<sup>9</sup>GT<sup>10</sup>PAD<sup>11</sup>L<sup>12</sup>VN<sup>13</sup>RMQ<sup>14</sup>ND<sup>15</sup>VL<sup>16</sup>PQ<sup>17</sup>QR<sup>18</sup>RNYA<sup>19</sup>HALD<sup>20</sup>GLY<sup>21</sup>RVAREEG.LRR<sup>22</sup>LF<sup>23</sup>SGAT<sup>24</sup>MASS<sup>25</sup>RGAL<sup>26</sup>V<sup>27</sup>TG<sup>28</sup>QL<sup>29</sup>SCYD<sup>30</sup>QAK<sup>31</sup>QLV  
 DIC2\_ARATH 90 GVSATLLRQTLYST<sup>1</sup>TRMGLYEV<sup>2</sup>LKNKWT.DPESGKLNLSR<sup>3</sup>KI<sup>4</sup>AGLVAGG<sup>5</sup>IAA<sup>6</sup>VN<sup>7</sup>PAD<sup>8</sup>VAM<sup>9</sup>VRM<sup>10</sup>QAD<sup>11</sup>GR<sup>12</sup>LPLA<sup>13</sup>QR<sup>14</sup>RNYA<sup>15</sup>GVGD<sup>16</sup>AI<sup>17</sup>RS<sup>18</sup>MV<sup>19</sup>KGEG.VTSL<sup>20</sup>WR<sup>21</sup>GSAL<sup>22</sup>TNR<sup>23</sup>AM<sup>24</sup>IV<sup>25</sup>TAQ<sup>26</sup>LA<sup>27</sup>SYD<sup>28</sup>Q<sup>29</sup>KEG<sup>30</sup>IL  
 DIC1\_ARATH 83 GVSATVLRQTLYST<sup>1</sup>TRMGLYDI<sup>2</sup>IKGEWT.DPETK<sup>3</sup>TM<sup>4</sup>PL<sup>5</sup>M<sup>6</sup>KKI<sup>7</sup>GAGAI<sup>8</sup>AGA<sup>9</sup>IAA<sup>10</sup>AV<sup>11</sup>GN<sup>12</sup>PAD<sup>13</sup>VAM<sup>14</sup>VRM<sup>15</sup>QAD<sup>16</sup>GR<sup>17</sup>LPL<sup>18</sup>DR<sup>19</sup>NY<sup>20</sup>KS<sup>21</sup>VLD<sup>22</sup>AIT<sup>23</sup>QMI<sup>24</sup>R<sup>25</sup>REG.VTSL<sup>26</sup>WR<sup>27</sup>GS<sup>28</sup>SL<sup>29</sup>TNR<sup>30</sup>AM<sup>31</sup>LV<sup>32</sup>TSS<sup>33</sup>QLA<sup>34</sup>SYD<sup>35</sup>S<sup>36</sup>VE<sup>37</sup>KE<sup>38</sup>TIL  
 DIC3\_ARATH 111 GVSATILRQMLYSAT<sup>1</sup>RMGI<sup>2</sup>YDFL<sup>3</sup>KRRWT.DQLT<sup>4</sup>GN<sup>5</sup>F<sup>6</sup>LV<sup>7</sup>TKITAG<sup>8</sup>LIAG<sup>9</sup>AV<sup>10</sup>VGN<sup>11</sup>PAD<sup>12</sup>VAM<sup>13</sup>VRM<sup>14</sup>QD<sup>15</sup>GS<sup>16</sup>LPL<sup>17</sup>NRR<sup>18</sup>NY<sup>19</sup>KS<sup>20</sup>VVD<sup>21</sup>AI<sup>22</sup>DR<sup>23</sup>ARQEG.VSSL<sup>24</sup>WR<sup>25</sup>GS<sup>26</sup>WLT<sup>27</sup>VNR<sup>28</sup>AM<sup>29</sup>IV<sup>30</sup>TAS<sup>31</sup>QLAT<sup>32</sup>YD<sup>33</sup>H<sup>34</sup>VE<sup>35</sup>ILV  
 A0A077DCK6\_TOBAC 79 GIVPGLHRQCLF<sup>1</sup>GGLRIGLYE<sup>2</sup>FPVKNLYV<sup>3</sup>GKDFV<sup>4</sup>GV<sup>5</sup>DV<sup>6</sup>PLS<sup>7</sup>KKILAA<sup>8</sup>LLTGAIAI<sup>9</sup>IVAN<sup>10</sup>PTD<sup>11</sup>LK<sup>12</sup>VRLQ<sup>13</sup>AEG<sup>14</sup>KLAA<sup>15</sup>GAPRRY<sup>16</sup>SGALNAY<sup>17</sup>STIV<sup>18</sup>RQEG.VAKL<sup>19</sup>WTGLG<sup>20</sup>PNIARN<sup>21</sup>AINAA<sup>22</sup>ELAS<sup>23</sup>YD<sup>24</sup>VQ<sup>25</sup>KE<sup>26</sup>TIL  
 Q2Q212\_ORYSJ 76 GIVPGLHRQCIY<sup>1</sup>GGLRIGLYE<sup>2</sup>FPVKNLYV<sup>3</sup>GKDFV<sup>4</sup>GV<sup>5</sup>DV<sup>6</sup>PLS<sup>7</sup>KKILAA<sup>8</sup>LLTGAIAI<sup>9</sup>IVAN<sup>10</sup>PTD<sup>11</sup>LK<sup>12</sup>VRLQ<sup>13</sup>AEG<sup>14</sup>KLAA<sup>15</sup>GAPRRY<sup>16</sup>SGALNAY<sup>17</sup>STIV<sup>18</sup>RQEG.FAAL<sup>19</sup>WTGLG<sup>20</sup>PNVARN<sup>21</sup>AINAA<sup>22</sup>ELAS<sup>23</sup>YD<sup>24</sup>VQ<sup>25</sup>KE<sup>26</sup>TIL  
 Q8S4C4\_MAIZE 85 GIVPGLHRQCIY<sup>1</sup>GGLRIGLYE<sup>2</sup>FPVKNLYV<sup>3</sup>GKDFV<sup>4</sup>GV<sup>5</sup>DV<sup>6</sup>PLS<sup>7</sup>KKILAA<sup>8</sup>LLTGAIAI<sup>9</sup>IVAN<sup>10</sup>PTD<sup>11</sup>LK<sup>12</sup>VRLQ<sup>13</sup>AEG<sup>14</sup>KLAA<sup>15</sup>GAPRRY<sup>16</sup>SGALNAY<sup>17</sup>STIV<sup>18</sup>RQEG.VAAL<sup>19</sup>WTGLG<sup>20</sup>PNVARN<sup>21</sup>AINAA<sup>22</sup>ELAS<sup>23</sup>YD<sup>24</sup>VQ<sup>25</sup>KE<sup>26</sup>TIL  
 C6T891\_SOYBN 80 GIVPGLHRQCLY<sup>1</sup>GGLRIGLYE<sup>2</sup>FPVKNLYV<sup>3</sup>GKDFV<sup>4</sup>GV<sup>5</sup>DV<sup>6</sup>PLS<sup>7</sup>KKILAA<sup>8</sup>LLTGAIAI<sup>9</sup>IVAN<sup>10</sup>PTD<sup>11</sup>LK<sup>12</sup>VRLQ<sup>13</sup>AEG<sup>14</sup>KLAA<sup>15</sup>GAPRRY<sup>16</sup>SGALNAY<sup>17</sup>STIV<sup>18</sup>RQEG.VGAL<sup>19</sup>WTGLG<sup>20</sup>PNIARN<sup>21</sup>AINAA<sup>22</sup>ELAS<sup>23</sup>YD<sup>24</sup>VQ<sup>25</sup>KE<sup>26</sup>TIL  
 B9GIV8\_POPTR 79 GITAGLHRQFIY<sup>1</sup>GGLRIGLYE<sup>2</sup>FPVKNLYV<sup>3</sup>GKDFV<sup>4</sup>GV<sup>5</sup>DV<sup>6</sup>PLS<sup>7</sup>KKILAA<sup>8</sup>LLTGAIAI<sup>9</sup>IVAN<sup>10</sup>PTD<sup>11</sup>LK<sup>12</sup>VRLQ<sup>13</sup>AEG<sup>14</sup>KLAA<sup>15</sup>GAPRRY<sup>16</sup>SGALNAY<sup>17</sup>STIV<sup>18</sup>RQEG.LGAL<sup>19</sup>WTGLG<sup>20</sup>PNIARN<sup>21</sup>AINAA<sup>22</sup>ELAS<sup>23</sup>YD<sup>24</sup>VQ<sup>25</sup>KE<sup>26</sup>TIL  
 A9PAU0\_POPTR 80 GIVPGLHRQCVF<sup>1</sup>GGLRIGLYE<sup>2</sup>FPVKNLYV<sup>3</sup>GKDFV<sup>4</sup>GV<sup>5</sup>DV<sup>6</sup>PLS<sup>7</sup>KKILAA<sup>8</sup>LLTGAIAI<sup>9</sup>IVAN<sup>10</sup>PTD<sup>11</sup>LK<sup>12</sup>VRLQ<sup>13</sup>AEG<sup>14</sup>KLAA<sup>15</sup>GAPRRY<sup>16</sup>SGALNAY<sup>17</sup>STIV<sup>18</sup>RQEG.VRAL<sup>19</sup>WTGLG<sup>20</sup>PNVARN<sup>21</sup>AINAA<sup>22</sup>ELAS<sup>23</sup>YD<sup>24</sup>VQ<sup>25</sup>KE<sup>26</sup>TIL  
 I3ST66\_LOTJA 80 GIVPGLHRQCLY<sup>1</sup>GGLRIGLYE<sup>2</sup>FPVKNLYV<sup>3</sup>GKDFV<sup>4</sup>GV<sup>5</sup>DV<sup>6</sup>PLS<sup>7</sup>KKILAA<sup>8</sup>LLTGAIAI<sup>9</sup>IVAN<sup>10</sup>PTD<sup>11</sup>LK<sup>12</sup>VRLQ<sup>13</sup>AEG<sup>14</sup>KLAA<sup>15</sup>GAPRRY<sup>16</sup>SGALNAY<sup>17</sup>STIV<sup>18</sup>RQEG.VGAL<sup>19</sup>WTGLG<sup>20</sup>PNIARN<sup>21</sup>AINAA<sup>22</sup>ELAS<sup>23</sup>YD<sup>24</sup>VQ<sup>25</sup>KE<sup>26</sup>TIL  
 A8J1X0\_CHLRE 72 GIEPGLHRQCLF<sup>1</sup>GGLRIGLYE<sup>2</sup>FPVKNLYV<sup>3</sup>GKDFV<sup>4</sup>GV<sup>5</sup>DV<sup>6</sup>PLS<sup>7</sup>KKILAA<sup>8</sup>LLTGAIAI<sup>9</sup>IVAN<sup>10</sup>PTD<sup>11</sup>LK<sup>12</sup>VRLQ<sup>13</sup>AEG<sup>14</sup>KLAA<sup>15</sup>GAPRRY<sup>16</sup>SGALNAY<sup>17</sup>STIV<sup>18</sup>RQEG.IGL<sup>19</sup>L<sup>20</sup>WK<sup>21</sup>GLG<sup>22</sup>PNIARN<sup>23</sup>AINAA<sup>24</sup>ELAS<sup>25</sup>YD<sup>26</sup>VQ<sup>27</sup>KE<sup>28</sup>Q<sup>29</sup>SLL  
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PUMP1\_ARATH 206 KIPGFTDN.VV<sup>1</sup>THLSGLGAG<sup>2</sup>FFAV<sup>3</sup>IC<sup>4</sup>SP<sup>5</sup>DV<sup>6</sup>V<sup>7</sup>KSR<sup>8</sup>MMG<sup>9</sup>DSG.A....YK<sup>10</sup>GT<sup>11</sup>ID<sup>12</sup>CF<sup>13</sup>V<sup>14</sup>KT<sup>15</sup>KS<sup>16</sup>DG<sup>17</sup>PM<sup>18</sup>AFY<sup>19</sup>K<sup>20</sup>GF<sup>21</sup>IP<sup>22</sup>N<sup>23</sup>FR<sup>24</sup>LG<sup>25</sup>SN<sup>26</sup>VIM<sup>27</sup>FL<sup>28</sup>TLE<sup>29</sup>QAK<sup>30</sup>KY<sup>31</sup>VELDASKRN  
 PUMP2\_ARATH 208 KIPFFRDS.VL<sup>1</sup>THLLAGLAG<sup>2</sup>FFAV<sup>3</sup>IC<sup>4</sup>SP<sup>5</sup>DV<sup>6</sup>V<sup>7</sup>KSR<sup>8</sup>MMG<sup>9</sup>DS..T....YRN<sup>10</sup>TV<sup>11</sup>DC<sup>12</sup>F<sup>13</sup>IK<sup>14</sup>TK<sup>15</sup>TE<sup>16</sup>GI<sup>17</sup>MA<sup>18</sup>FY<sup>19</sup>K<sup>20</sup>GF<sup>21</sup>LP<sup>22</sup>N<sup>23</sup>FR<sup>24</sup>LG<sup>25</sup>TN<sup>26</sup>AIM<sup>27</sup>FL<sup>28</sup>TLE<sup>29</sup>QV<sup>30</sup>KK<sup>31</sup>VFLREVLYD  
 UCP2\_HUMAN 206 KANLMTDD.LP<sup>1</sup>CHFTSAFGAG<sup>2</sup>FFAV<sup>3</sup>IC<sup>4</sup>SP<sup>5</sup>DV<sup>6</sup>V<sup>7</sup>KSR<sup>8</sup>MMG<sup>9</sup>DS....YSSAG<sup>10</sup>HCAL<sup>11</sup>MLQ<sup>12</sup>KE<sup>13</sup>GF<sup>14</sup>MP<sup>15</sup>SP<sup>16</sup>FL<sup>17</sup>RL<sup>18</sup>GS<sup>19</sup>SN<sup>20</sup>V<sup>21</sup>MFV<sup>22</sup>TYE<sup>23</sup>QL<sup>24</sup>KRALMAACTSREAPF  
 DIC1\_YEAST 198 TKLDFDASKNY<sup>1</sup>THLTASLLAGLVA<sup>2</sup>ITVCS<sup>3</sup>PAD<sup>4</sup>VM<sup>5</sup>KTR<sup>6</sup>IM<sup>7</sup>NGSG..A....DHQ<sup>8</sup>PALK<sup>9</sup>ILADAV<sup>10</sup>RK<sup>11</sup>EG<sup>12</sup>SP<sup>13</sup>FM<sup>14</sup>RG<sup>15</sup>WL<sup>16</sup>PS<sup>17</sup>FR<sup>18</sup>LG<sup>19</sup>P<sup>20</sup>TM<sup>21</sup>LIF<sup>22</sup>FAI<sup>23</sup>E<sup>24</sup>QL<sup>25</sup>KK<sup>26</sup>HRVGM<sup>27</sup>PKEDK  
 DIC\_HUMAN 190 LSTGYLSDNIF<sup>1</sup>THFVAS<sup>2</sup>FAGG<sup>3</sup>AT<sup>4</sup>FLCQ<sup>5</sup>PLD<sup>6</sup>VL<sup>7</sup>KTR<sup>8</sup>LM<sup>9</sup>NSKG....EY<sup>10</sup>QGV<sup>11</sup>HC<sup>12</sup>AVETA.KLG<sup>13</sup>PLA<sup>14</sup>FY<sup>15</sup>K<sup>16</sup>GLV<sup>17</sup>PAGI<sup>18</sup>RL<sup>19</sup>PH<sup>20</sup>VT<sup>21</sup>LF<sup>22</sup>V<sup>23</sup>FE<sup>24</sup>QL<sup>25</sup>RKN.FGI<sup>26</sup>KVPS  
 DIC2\_ARATH 218 ENGVMNDG.LG<sup>1</sup>THVVASFAAG<sup>2</sup>FVAS<sup>3</sup>VASN<sup>4</sup>PVD<sup>5</sup>V<sup>6</sup>IK<sup>7</sup>TRV<sup>8</sup>NM<sup>9</sup>KVGA....YD<sup>10</sup>GA<sup>11</sup>W<sup>12</sup>DC<sup>13</sup>AV<sup>14</sup>TK<sup>15</sup>V<sup>16</sup>K<sup>17</sup>EG<sup>18</sup>AM<sup>19</sup>ALY<sup>20</sup>K<sup>21</sup>GF<sup>22</sup>V<sup>23</sup>TV<sup>24</sup>CR<sup>25</sup>Q<sup>26</sup>GP<sup>27</sup>TV<sup>28</sup>V<sup>29</sup>LF<sup>30</sup>V<sup>31</sup>TLE<sup>32</sup>Q<sup>33</sup>V<sup>34</sup>K<sup>35</sup>LLRDF  
 DIC1\_ARATH 211 EKGLKDG.LG<sup>1</sup>THVSASFAAG<sup>2</sup>FVAS<sup>3</sup>VASN<sup>4</sup>PVD<sup>5</sup>V<sup>6</sup>IK<sup>7</sup>TRV<sup>8</sup>NM<sup>9</sup>KVAGVAPPYK<sup>10</sup>GA<sup>11</sup>VD<sup>12</sup>CA<sup>13</sup>L<sup>14</sup>TK<sup>15</sup>V<sup>16</sup>K<sup>17</sup>EG<sup>18</sup>AM<sup>19</sup>ALY<sup>20</sup>K<sup>21</sup>GF<sup>22</sup>IP<sup>23</sup>TV<sup>24</sup>SR<sup>25</sup>Q<sup>26</sup>AP<sup>27</sup>TV<sup>28</sup>V<sup>29</sup>LF<sup>30</sup>V<sup>31</sup>TLE<sup>32</sup>Q<sup>33</sup>V<sup>34</sup>K<sup>35</sup>LLKDYDF  
 DIC3\_ARATH 239 AGGRTPGGIG<sup>1</sup>THVVAASFAAG<sup>2</sup>I<sup>3</sup>VAAV<sup>4</sup>ASN<sup>5</sup>P<sup>6</sup>D<sup>7</sup>V<sup>8</sup>V<sup>9</sup>KTR<sup>10</sup>MM<sup>11</sup>NADKEI....YGG<sup>12</sup>PLD<sup>13</sup>CA<sup>14</sup>V<sup>15</sup>K<sup>16</sup>MA<sup>17</sup>VE<sup>18</sup>GP<sup>19</sup>MA<sup>20</sup>LY<sup>21</sup>K<sup>22</sup>GLV<sup>23</sup>PTAT<sup>24</sup>RQ<sup>25</sup>GP<sup>26</sup>TM<sup>27</sup>L<sup>28</sup>FL<sup>29</sup>TLE<sup>30</sup>Q<sup>31</sup>VR<sup>32</sup>GLLKDVKF  
 A0A077DCK6\_TOBAC 208 KIPGFTDN.VV<sup>1</sup>THLFAG<sup>2</sup>FGAG<sup>3</sup>FFAV<sup>4</sup>IC<sup>5</sup>SP<sup>6</sup>DV<sup>7</sup>V<sup>8</sup>KSR<sup>9</sup>MMG<sup>10</sup>DS..T....YK<sup>11</sup>N<sup>12</sup>T<sup>13</sup>DC<sup>14</sup>F<sup>15</sup>V<sup>16</sup>KT<sup>17</sup>L<sup>18</sup>K<sup>19</sup>ND<sup>20</sup>G<sup>21</sup>PLA<sup>22</sup>FY<sup>23</sup>K<sup>24</sup>GF<sup>25</sup>IP<sup>26</sup>N<sup>27</sup>FR<sup>28</sup>LG<sup>29</sup>SN<sup>30</sup>VIM<sup>31</sup>FL<sup>32</sup>TLE<sup>33</sup>QAK<sup>34</sup>K<sup>35</sup>FVKNLESA  
 Q2Q212\_ORYSJ 205 KLPGFKDD.VV<sup>1</sup>THLLSGLGAG<sup>2</sup>FFAV<sup>3</sup>IC<sup>4</sup>SP<sup>5</sup>DV<sup>6</sup>V<sup>7</sup>KSR<sup>8</sup>MMG<sup>9</sup>DS..A....YTS<sup>10</sup>T<sup>11</sup>DC<sup>12</sup>F<sup>13</sup>V<sup>14</sup>KT<sup>15</sup>L<sup>16</sup>K<sup>17</sup>ND<sup>18</sup>G<sup>19</sup>PLA<sup>20</sup>FY<sup>21</sup>K<sup>22</sup>GF<sup>23</sup>LP<sup>24</sup>N<sup>25</sup>FR<sup>26</sup>LG<sup>27</sup>SN<sup>28</sup>VIM<sup>29</sup>FL<sup>30</sup>TLE<sup>31</sup>Q<sup>32</sup>V<sup>33</sup>Q<sup>34</sup>K<sup>35</sup>LV<sup>36</sup>FRKPGS  
 Q8S4C4\_MAIZE 214 KLPGFKDD.VV<sup>1</sup>THLFAGL<sup>2</sup>GAG<sup>3</sup>FFAV<sup>4</sup>IC<sup>5</sup>SP<sup>6</sup>DV<sup>7</sup>V<sup>8</sup>KSR<sup>9</sup>MMG<sup>10</sup>DS..A....YK<sup>11</sup>ST<sup>12</sup>DC<sup>13</sup>F<sup>14</sup>V<sup>15</sup>KT<sup>16</sup>L<sup>17</sup>K<sup>18</sup>ND<sup>19</sup>G<sup>20</sup>PLA<sup>21</sup>FY<sup>22</sup>K<sup>23</sup>GF<sup>24</sup>LP<sup>25</sup>N<sup>26</sup>FR<sup>27</sup>LG<sup>28</sup>SN<sup>29</sup>VIM<sup>30</sup>FL<sup>31</sup>TLE<sup>32</sup>Q<sup>33</sup>V<sup>34</sup>Q<sup>35</sup>K<sup>36</sup>LV<sup>37</sup>FRKATS  
 C6T891\_SOYBN 209 KIPGFTDN.VV<sup>1</sup>THLLAGL<sup>2</sup>GAG<sup>3</sup>FFAV<sup>4</sup>IC<sup>5</sup>SP<sup>6</sup>DV<sup>7</sup>V<sup>8</sup>KSR<sup>9</sup>MMG<sup>10</sup>DS..S....YK<sup>11</sup>N<sup>12</sup>T<sup>13</sup>DC<sup>14</sup>F<sup>15</sup>IK<sup>16</sup>L<sup>17</sup>K<sup>18</sup>ND<sup>19</sup>G<sup>20</sup>PLA<sup>21</sup>FY<sup>22</sup>K<sup>23</sup>GF<sup>24</sup>LP<sup>25</sup>N<sup>26</sup>FR<sup>27</sup>LG<sup>28</sup>SN<sup>29</sup>VIM<sup>30</sup>FL<sup>31</sup>TLE<sup>32</sup>Q<sup>33</sup>V<sup>34</sup>Q<sup>35</sup>K<sup>36</sup>LV<sup>37</sup>FRKATS  
 B9GIV8\_POPTR 208 QIPGFTDS.AF<sup>1</sup>THVL<sup>2</sup>AGL<sup>3</sup>GAG<sup>4</sup>FFAV<sup>5</sup>IC<sup>6</sup>SP<sup>7</sup>DV<sup>8</sup>V<sup>9</sup>KSR<sup>10</sup>MMG<sup>11</sup>DS..S....YK<sup>12</sup>N<sup>13</sup>TV<sup>14</sup>DC<sup>15</sup>F<sup>16</sup>IK<sup>17</sup>L<sup>18</sup>K<sup>19</sup>NE<sup>20</sup>G<sup>21</sup>ILAFY<sup>22</sup>K<sup>23</sup>GF<sup>24</sup>LP<sup>25</sup>N<sup>26</sup>FR<sup>27</sup>LG<sup>28</sup>SN<sup>29</sup>VIM<sup>30</sup>FL<sup>31</sup>TLE<sup>32</sup>Q<sup>33</sup>V<sup>34</sup>Q<sup>35</sup>K<sup>36</sup>LV<sup>37</sup>TGAYYD  
 A9PAU0\_POPTR 209 KIPGFTDN.IV<sup>1</sup>THLFAGL<sup>2</sup>GAG<sup>3</sup>FFAV<sup>4</sup>IC<sup>5</sup>SP<sup>6</sup>DV<sup>7</sup>V<sup>8</sup>KSR<sup>9</sup>MMG<sup>10</sup>DS..A....YK<sup>11</sup>ST<sup>12</sup>DC<sup>13</sup>F<sup>14</sup>IK<sup>15</sup>L<sup>16</sup>K<sup>17</sup>ND<sup>18</sup>G<sup>19</sup>PLA<sup>20</sup>FY<sup>21</sup>K<sup>22</sup>GF<sup>23</sup>IP<sup>24</sup>N<sup>25</sup>FR<sup>26</sup>LG<sup>27</sup>SN<sup>28</sup>VIM<sup>29</sup>FL<sup>30</sup>TLE<sup>31</sup>QAK<sup>32</sup>K<sup>33</sup>FVRNLESS  
 I3ST66\_LOTJA 209 KIPGFTDN.VV<sup>1</sup>THLLSGLGAG<sup>2</sup>FFAV<sup>3</sup>IC<sup>4</sup>SP<sup>5</sup>DV<sup>6</sup>V<sup>7</sup>KSR<sup>8</sup>MMG<sup>9</sup>DS..T....YK<sup>10</sup>ST<sup>11</sup>DC<sup>12</sup>F<sup>13</sup>V<sup>14</sup>KT<sup>15</sup>L<sup>16</sup>K<sup>17</sup>ND<sup>18</sup>G<sup>19</sup>PLA<sup>20</sup>FY<sup>21</sup>K<sup>22</sup>GF<sup>23</sup>IP<sup>24</sup>N<sup>25</sup>FR<sup>26</sup>LG<sup>27</sup>SN<sup>28</sup>VIM<sup>29</sup>FL<sup>30</sup>TLE<sup>31</sup>Q<sup>32</sup>V<sup>33</sup>Q<sup>34</sup>K<sup>35</sup>LV<sup>36</sup>FRKATS  
 A8J1X0\_CHLRE 201 GIG.MKDN.VG<sup>1</sup>THLAAGL<sup>2</sup>GAG<sup>3</sup>FFAV<sup>4</sup>IC<sup>5</sup>SP<sup>6</sup>DV<sup>7</sup>V<sup>8</sup>KSR<sup>9</sup>MMG<sup>10</sup>DREG....FK<sup>11</sup>GL<sup>12</sup>DC<sup>13</sup>F<sup>14</sup>V<sup>15</sup>KT<sup>16</sup>AR<sup>17</sup>NE<sup>18</sup>GPLA<sup>19</sup>FY<sup>20</sup>K<sup>21</sup>GF<sup>22</sup>IP<sup>23</sup>N<sup>24</sup>FR<sup>25</sup>LG<sup>26</sup>SN<sup>27</sup>VAM<sup>28</sup>FL<sup>29</sup>TLE<sup>30</sup>Q<sup>31</sup>V<sup>32</sup>Q<sup>33</sup>K<sup>34</sup>LLTPAPSH  
 A4S0P6\_OSTLU 218 GVG.MKDD.VV<sup>1</sup>THIASALGAG<sup>2</sup>FFAV<sup>3</sup>IC<sup>4</sup>SP<sup>5</sup>DV<sup>6</sup>V<sup>7</sup>KSR<sup>8</sup>MMG<sup>9</sup>DTGK....YK<sup>10</sup>GF<sup>11</sup>DC<sup>12</sup>V<sup>13</sup>KT<sup>14</sup>LANE<sup>1</sup>



**Supplemental Fig. S2. Isolation of *ucp1* and *ucp2* T-DNA homozygous insertion lines and *ucp1/ucp2* double mutants.** Genomic DNA PCR analysis of wild-type *A. thaliana* Col-0 plants (WT), *ucp1*, *ucp2* and double knockout (dKO). A DNA ladder (L) with the number of base pairs (bp) is shown to the right. The g letter (in AtUCP1g and AtUCP2g) indicates PCR reaction with primers surrounding the T-DNA insertion and the letter t (in AtUCP1t and AtUCP2t ) indicates PCR reaction with primers specific for T-DNA/gene flanking region. ACT7 refers to ACT7 control gene amplification.



**Supplemental Fig. S3. Semiquantitative RT-PCR in wild-type (WT), ucp1 single mutant and ucp2 single mutant.** A: Agarose gel of total RNA for qualitative and quantitative assessments. Total RNA extractions have been done on 2 independent plants (WT1 and 2, ucp1-1 and 2 and ucp2-1 and 2). B: RT-PCR with AtUCP1 specific primer pair, AtUCP2 specific primer pair or Act7 specific primer pair as a control. A DNA ladder (L) with the number of base pairs (bp) is shown to the left. Note: All reactions have been done at the same time and loaded on the same gel.



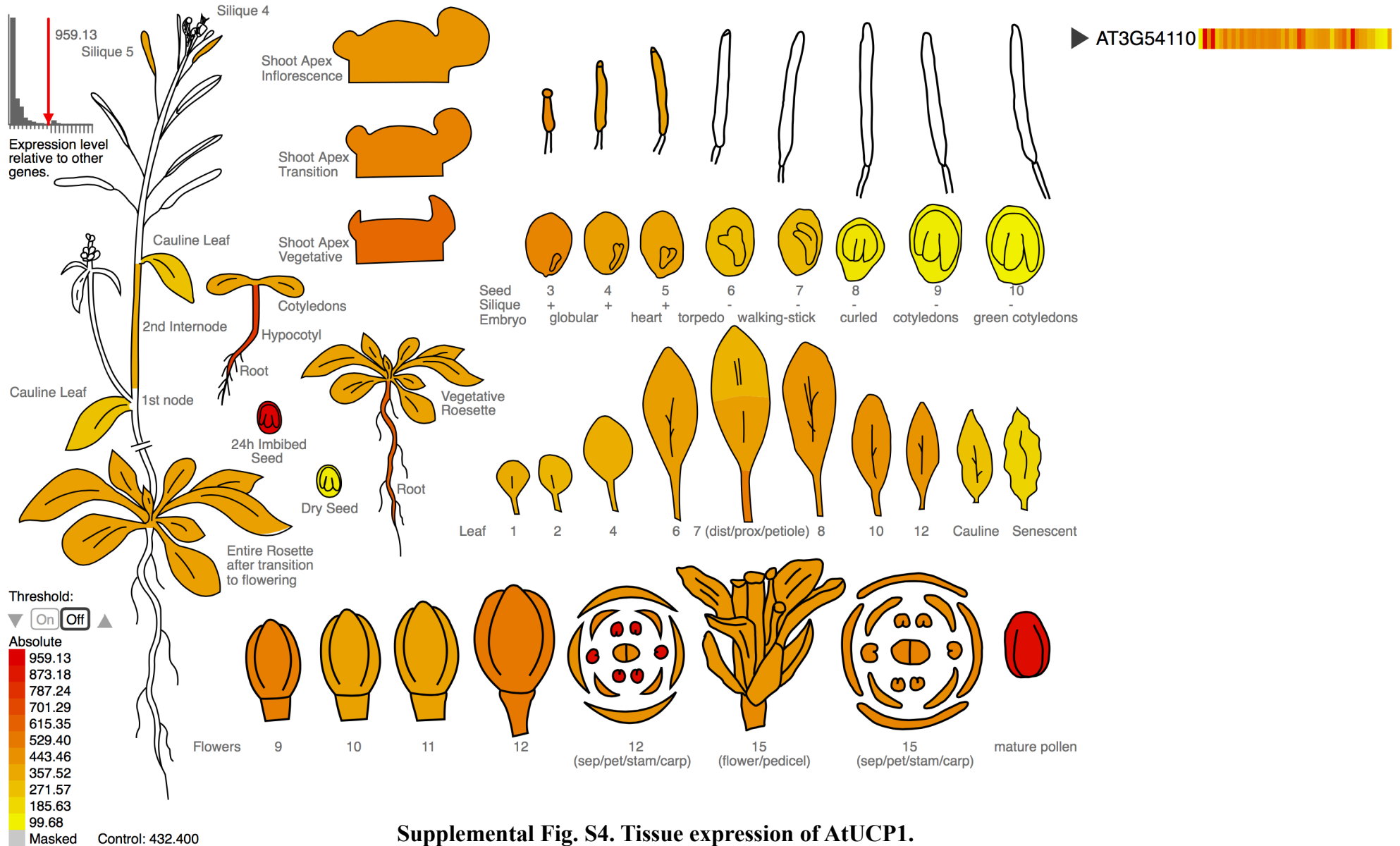
AT3G54110(probe set 251902\_at)

ATPUMP1\_ATUCP1\_PUMP1\_UCP1\_UCP1\_\_plant uncoupling mitochondrial protein 1



Arabidopsis eFP Browser 2.0

<http://bar.utoronto.ca>



Supplemental Fig. S4. Tissue expression of AtUCP1.

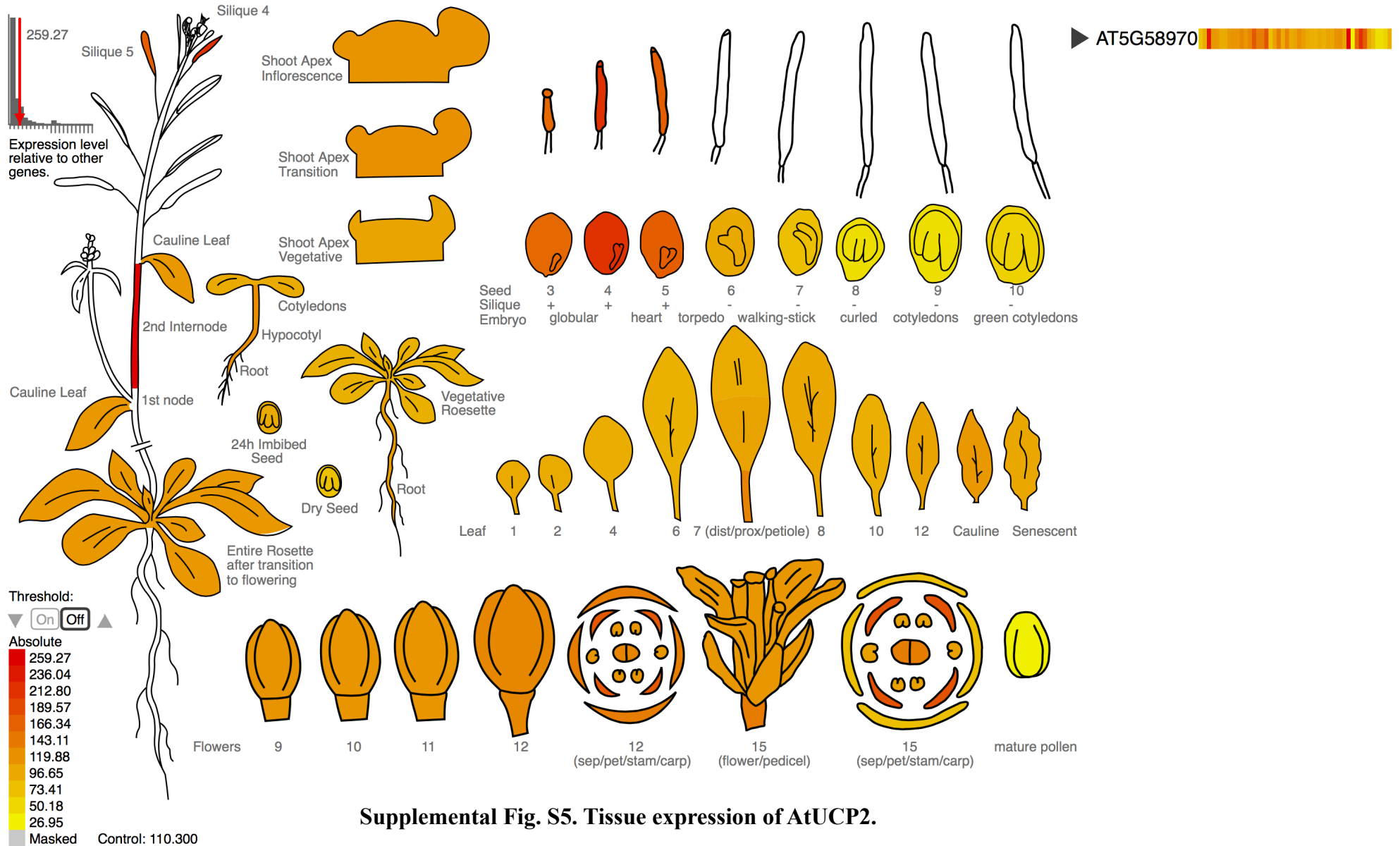
AT5G58970(probe set 247746\_at)

ATUCP2\_UCP2\_\_uncoupling protein 2

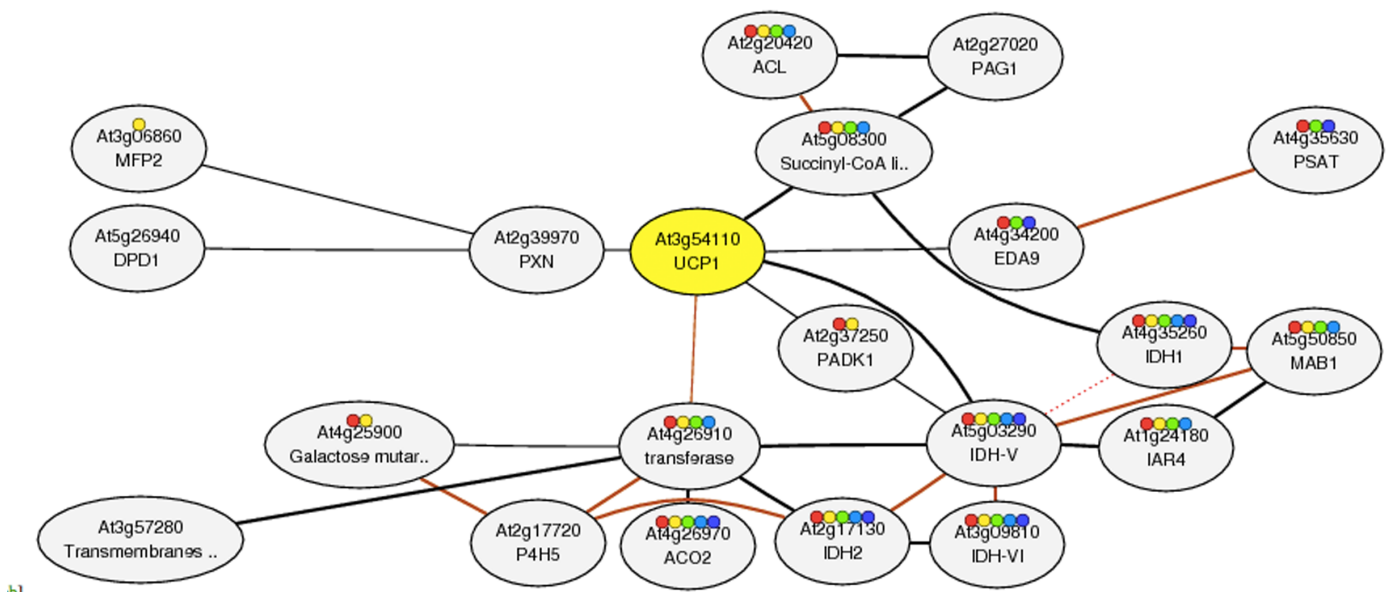


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Supplemental Fig. S5. Tissue expression of AtUCP2.



h1

**Supplemental Fig. S6. Gene co-expression networks of AtUCP1.** The microarray data from the ATTED database show the genes co-expressed with At3g54110 (AtUCP1). Among these genes are several citric acid cycle enzymes such as aconitase (At4g26910), isocitrate dehydrogenase (At4g35260, At2g17130, At5g03290 and At3g09810),  $\alpha$ -ketoglutarate dehydrogenase (At4g26910) and succinyl-CoA ligase (At2g20420 and At5g08300) as well as the peroxisomal transporter for  $\text{NAD}^+$  (At2g39970).