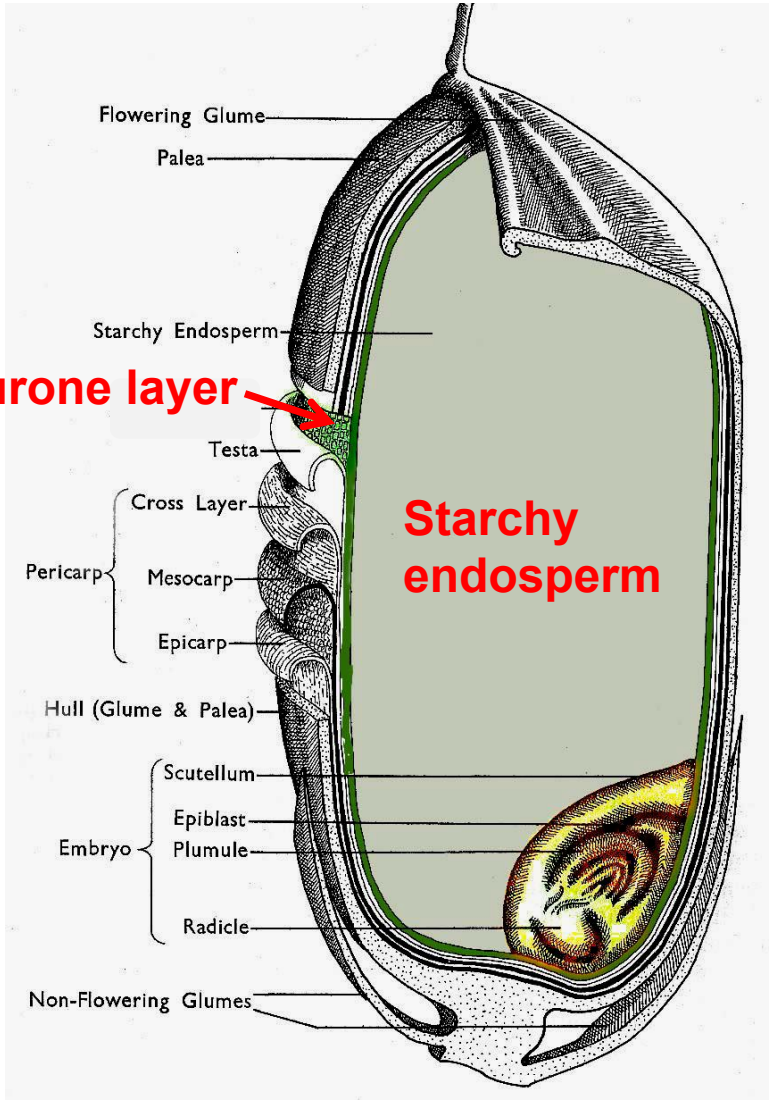
通过调控糊粉层发育提高水稻种子营养品质

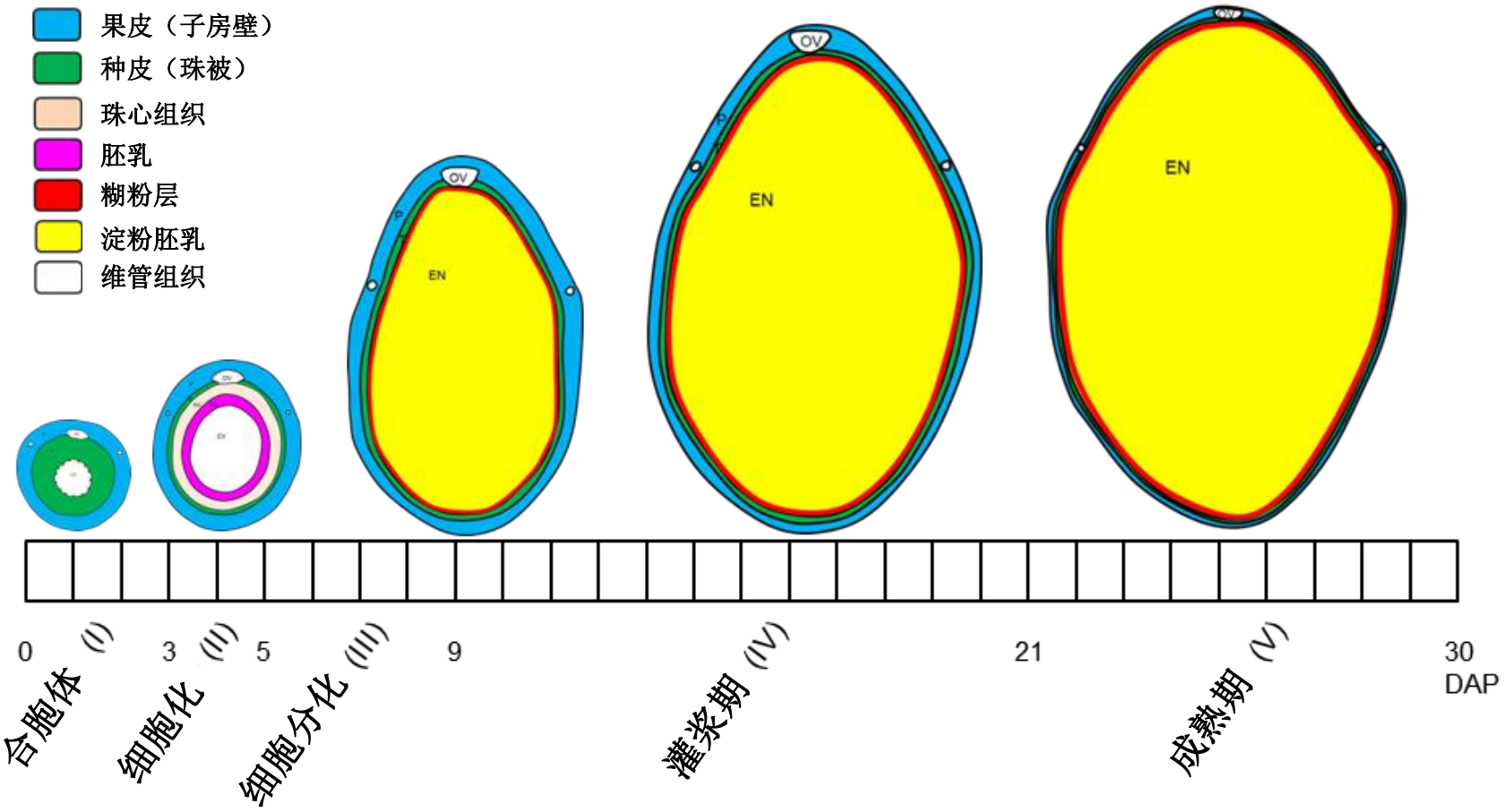
刘金鑫
jxliu@ibcas.ac.cn
中国科学院植物研究所
2019.8.8

水稻种子的结构

- Palea (内稃) and lemma（外稃）
- Pericarp (果皮)
- Testa (种皮)
- Embryo (胚)
- Endosperm (胚乳)
  - Starchy endosperm (淀粉胚乳)
  - Aleurone layer (糊粉层)

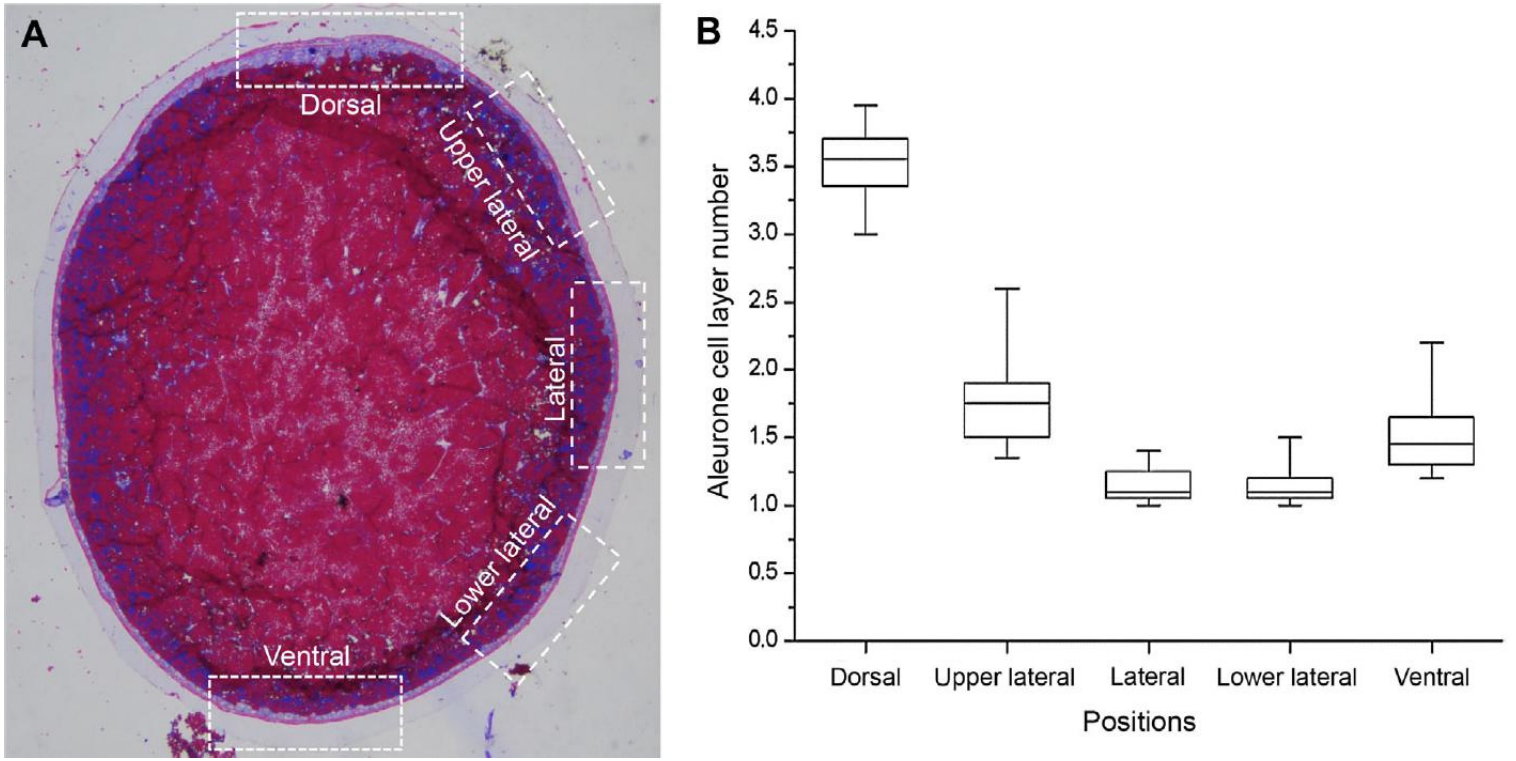


水稻胚乳发育时期



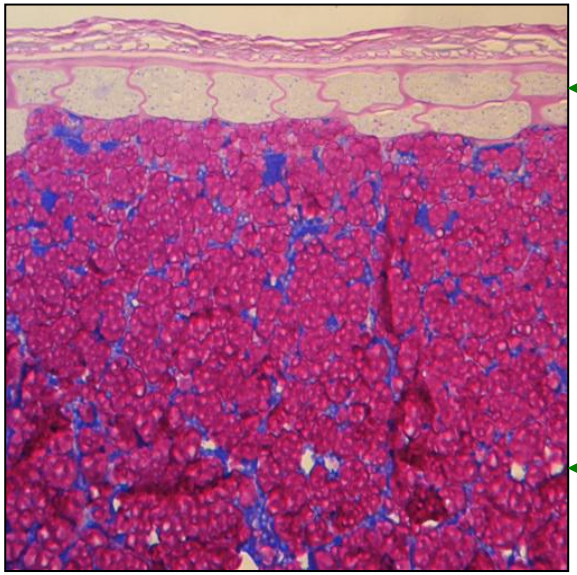
Modified from Wu et al., JIPB, 2016a, 2016b

水稻胚乳不同位置的糊粉层细胞



Wu et al, JIPB, 2016b

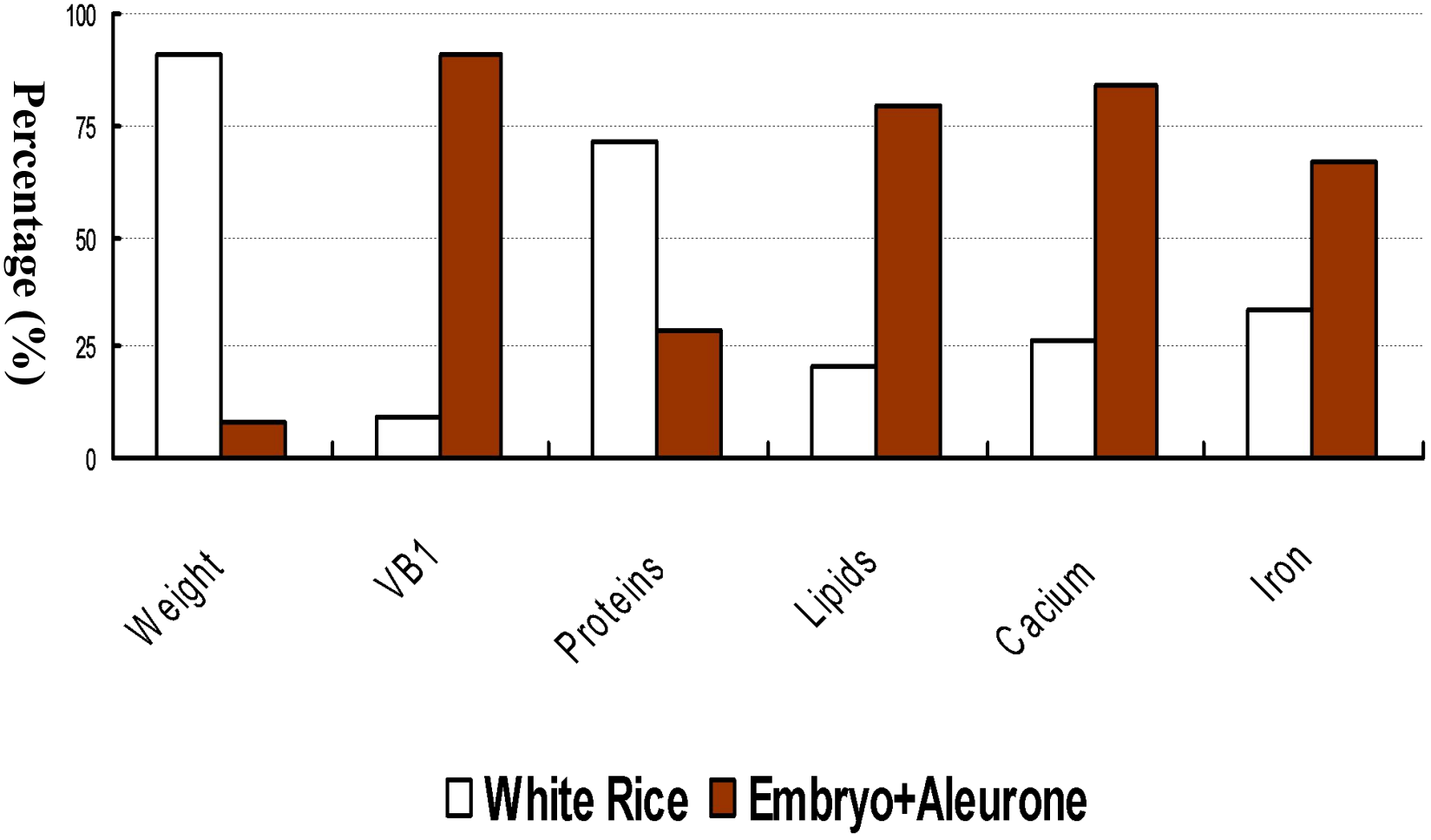
截然不同的细胞命运和营养累积



Aleurone （live cell）
Nutrition: proteins, lipids, vitamins, micronutrients

Starchy endosperm （PCD）
Nutrition: starch, proteins

水稻种子营养储存分布


Percentage (%)
100
75
50
25
0
Weight
VB1
Proteins
Lipids
Cacium
Iron
White Rice
Embryo+Aleurone

食用保留糊粉层和胚的糙米均衡营养

水稻种子

脱壳

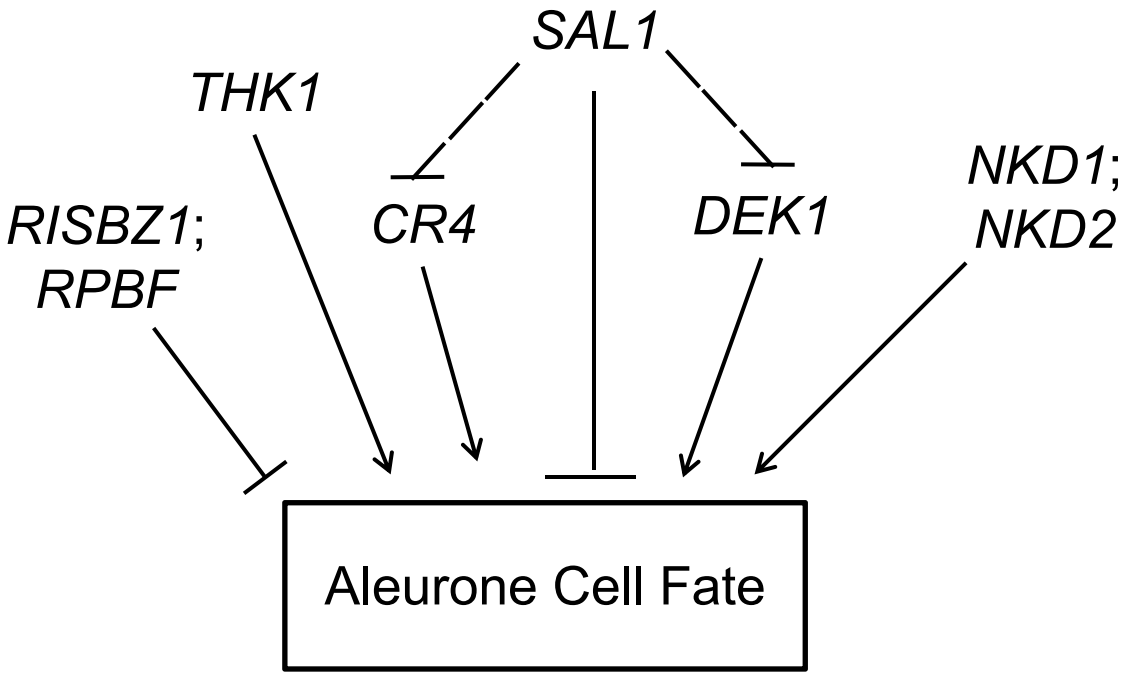
糙米

抛光

白米

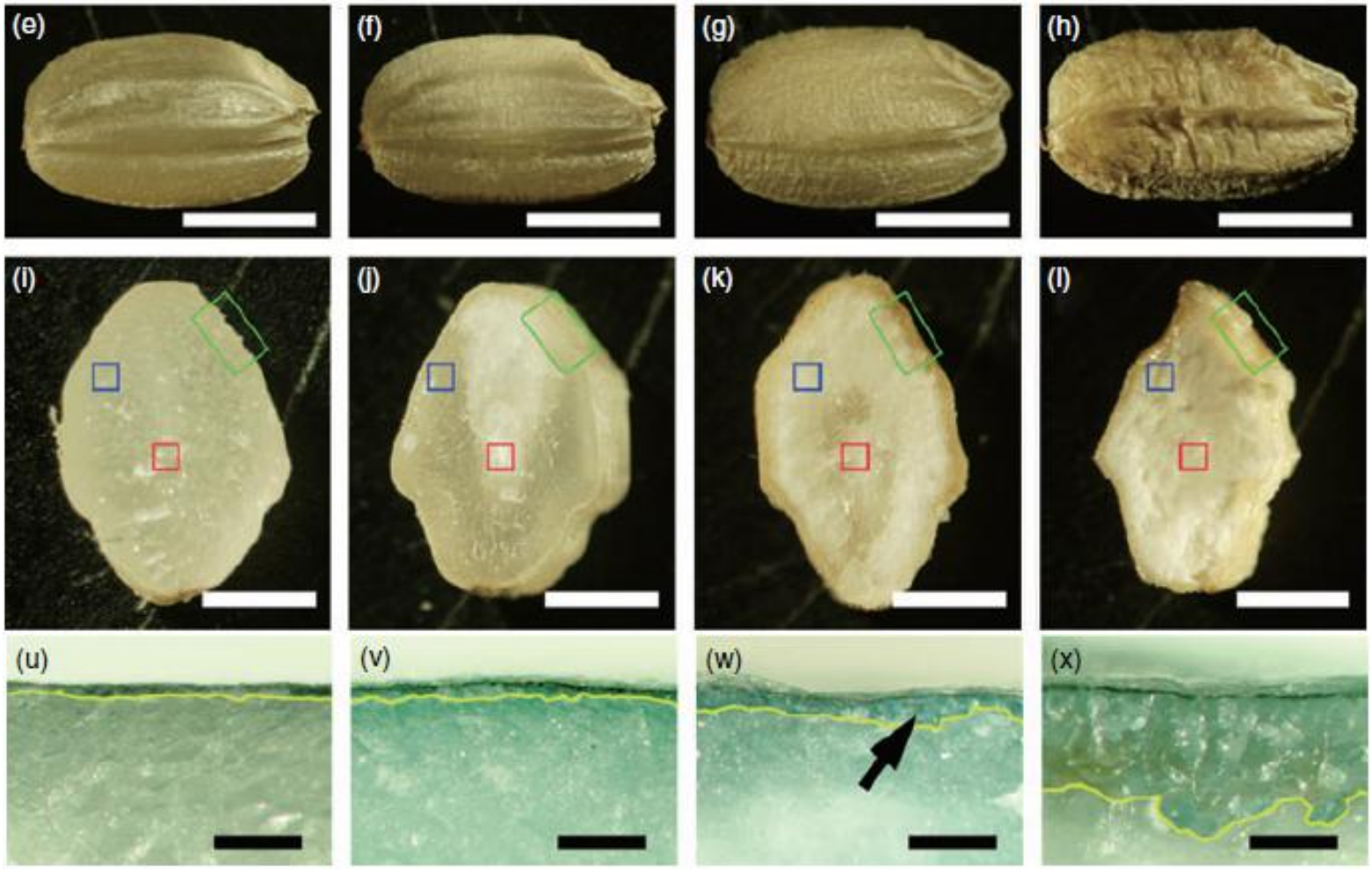
- 白米是水稻的淀粉胚乳，是其能量储存单元
- 糊粉层是水稻的主要营养元素如蛋白质、不饱和脂肪酸、维生素和微量元素等主要储存场所

胚乳糊粉层发育的基因调控网络



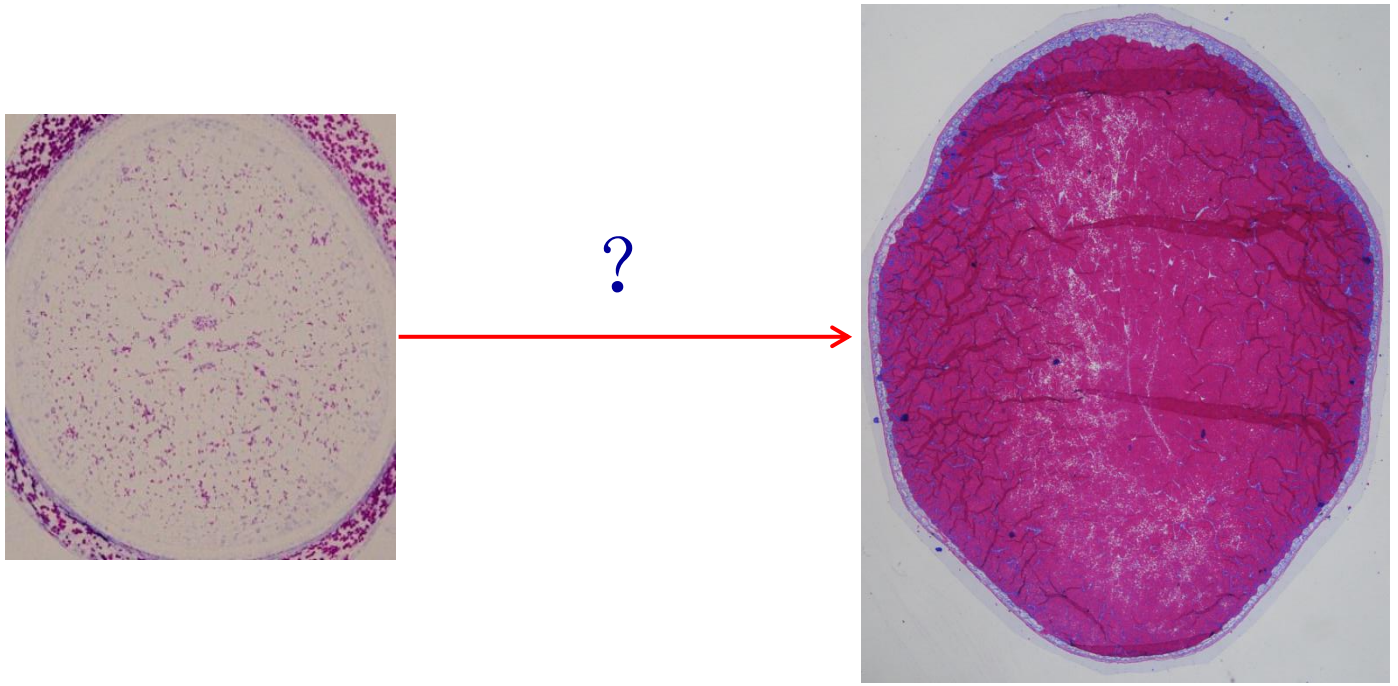
Becraft et al., science 2002
Lid et al., PNAS 2002
Shen et al., PNAS 2003
Yi et al., Plant Pysiol 2003
Kawakatsu et al., Plant J 2009
Hibara et al., Dev Biol 2009

抑制*RISBZ1*和*RPBF*表达导致水稻糊粉层加厚表型



Kawakatsu et al., Plant J 2009

解析水稻胚乳糊粉层细胞分化的分子机制



哪些关键基因参与调控其分化过程？

水稻糊粉层和淀粉胚乳细胞分化的分子机制？

如何通过改造胚乳结构改善水稻健康品质？

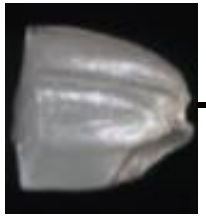
水稻半粒种子筛选方法

M3 grains from EMS-mutagensis

↓

Cut into two halves

Without embryo



With embryo

↓

Evans Blue staining

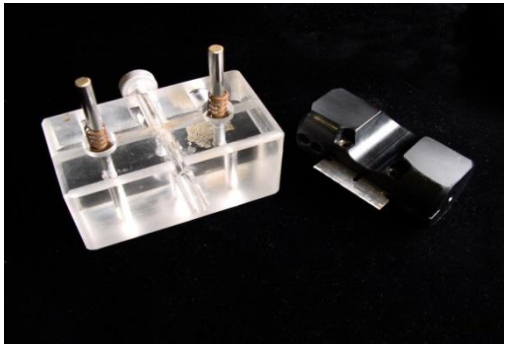
↓

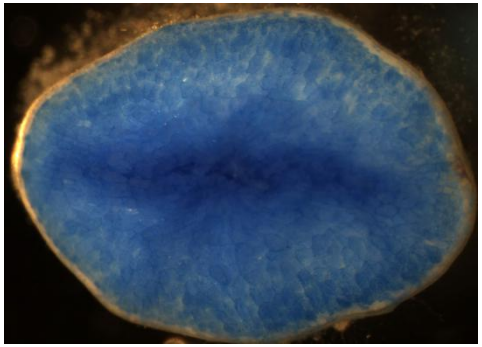
Putative *ta* mutants

With embryo → Germination

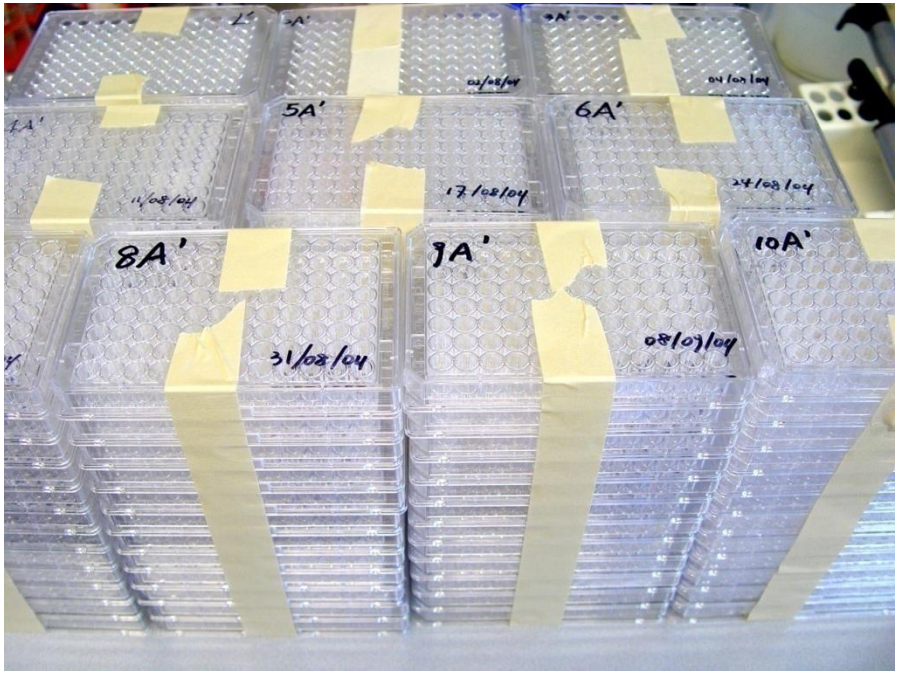
↓

M3 plants





水稻半粒种子筛选方法



germline collections ⟷ PCD assay plates

↓

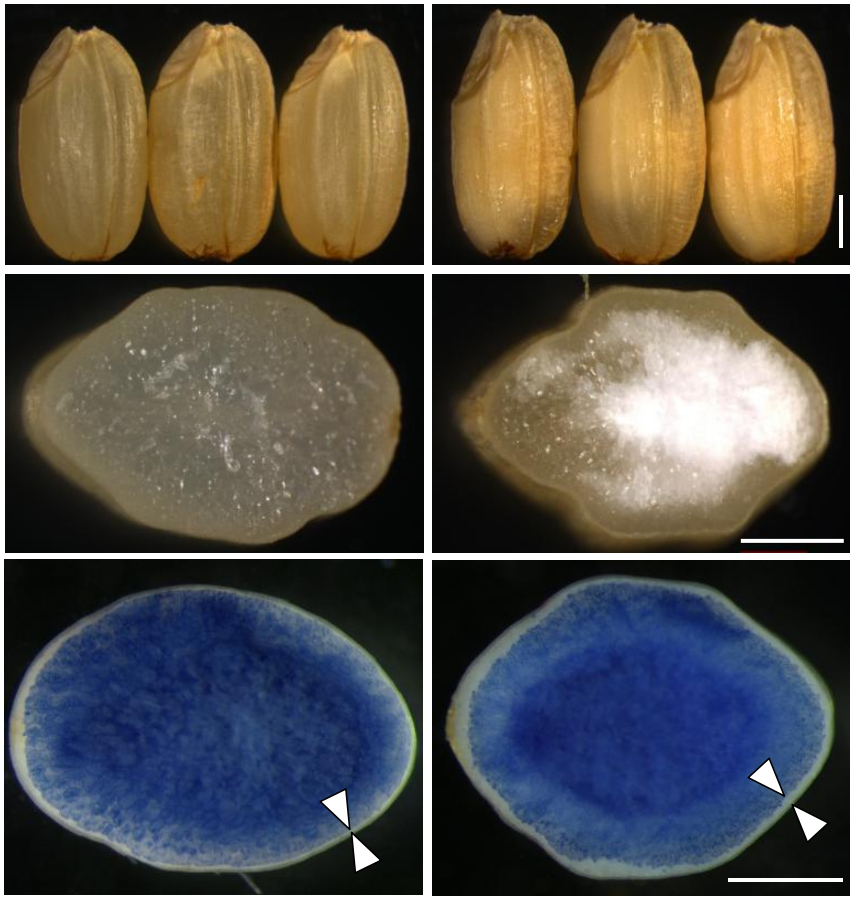
获得预选 *ta* 突变体 》 体外萌发

获得糊粉层加厚突变株系(*thick aleurone, ta*)

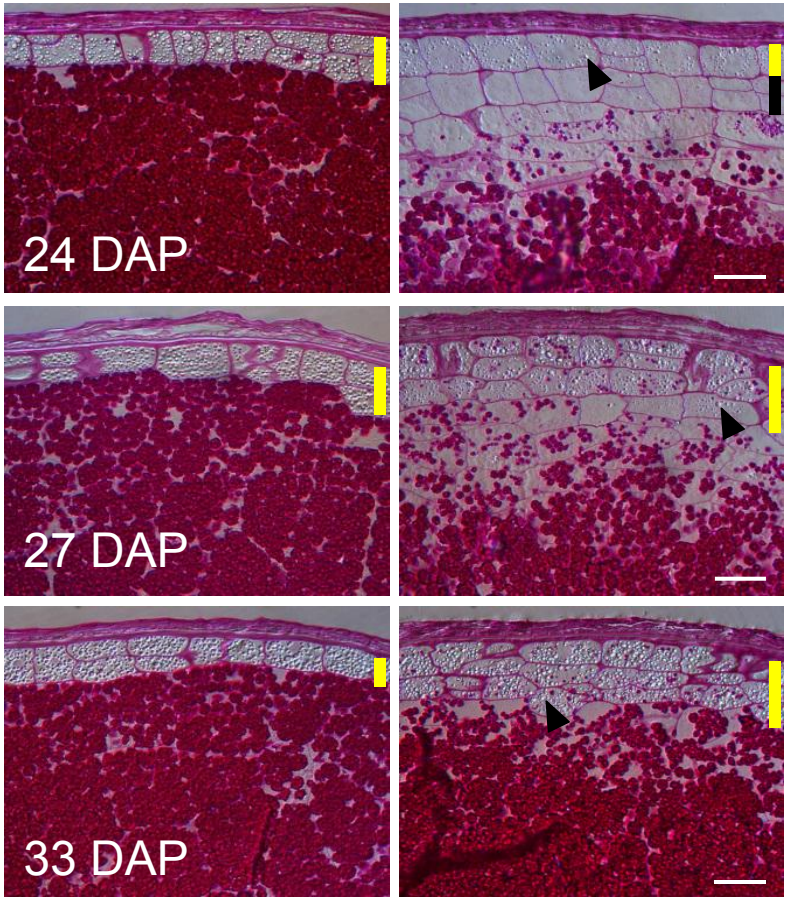
M2 lines screened	**8,925**
M3 seeds screened	**36,000**
Candidate *ta* obtained	**23**
Confirmed *ta* mutants	**2**

(Background material: Zhonghua 11, japonica type)

*ta1*胚乳呈现糊粉层加厚表型



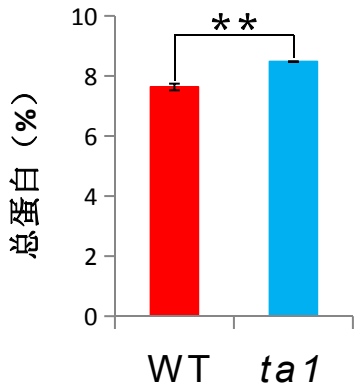
WT *ta1*

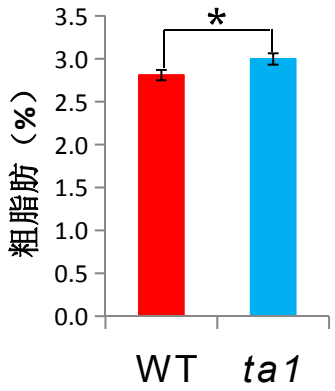


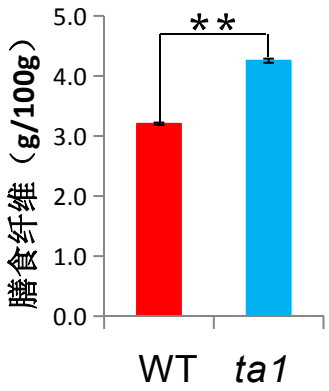
WT *ta1*

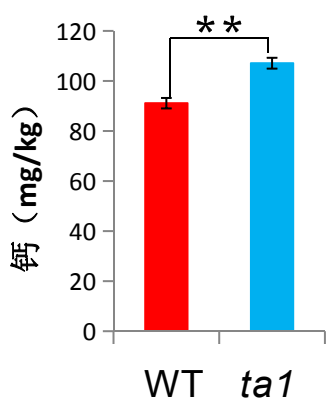
Unpublished data

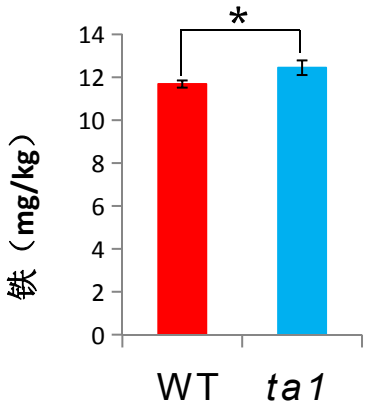
*ta1*成熟颖果营养物质含量增加

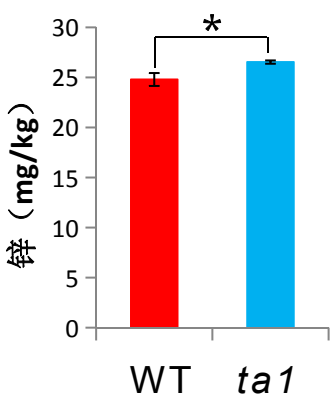


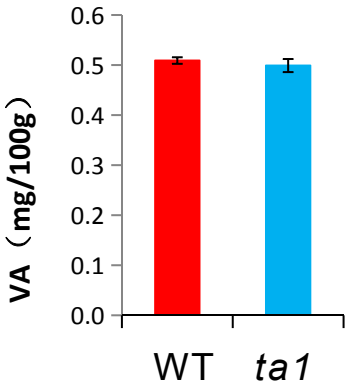


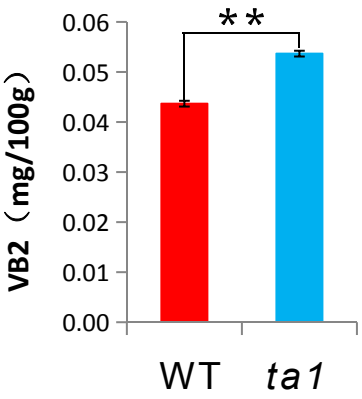


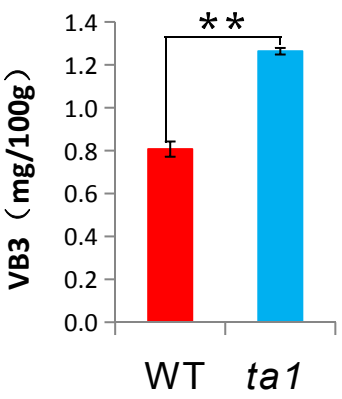






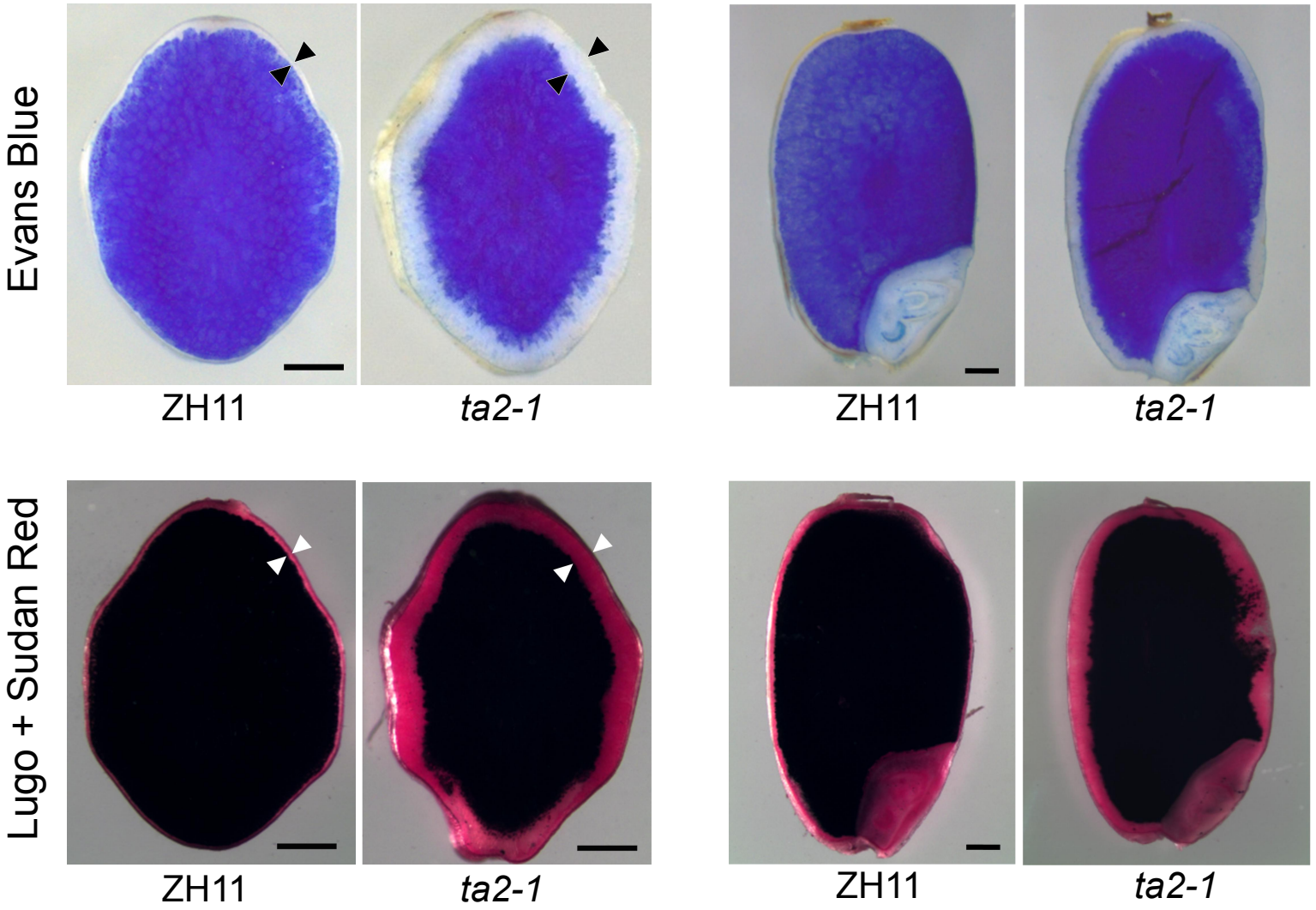






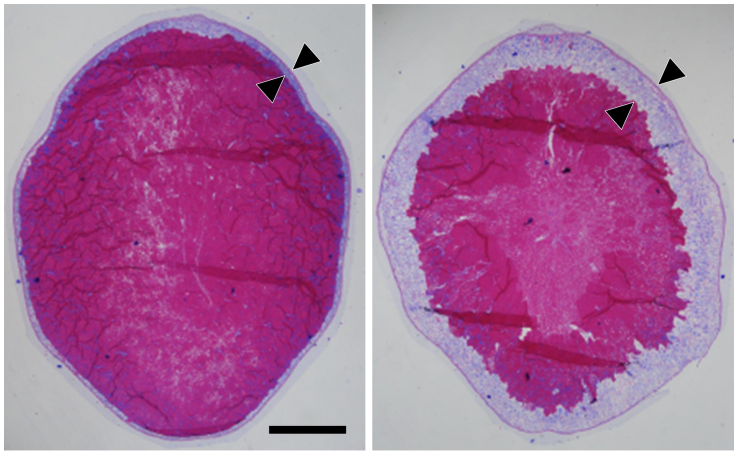
Unpublished data

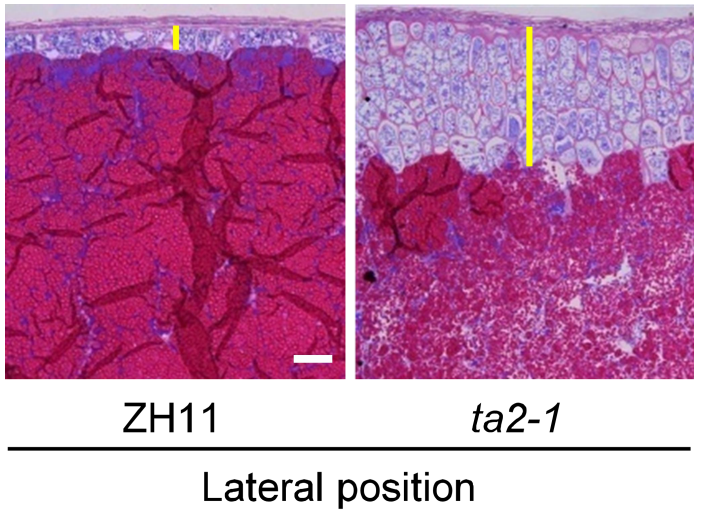
*ta2-1*突变体糊粉层明显加厚

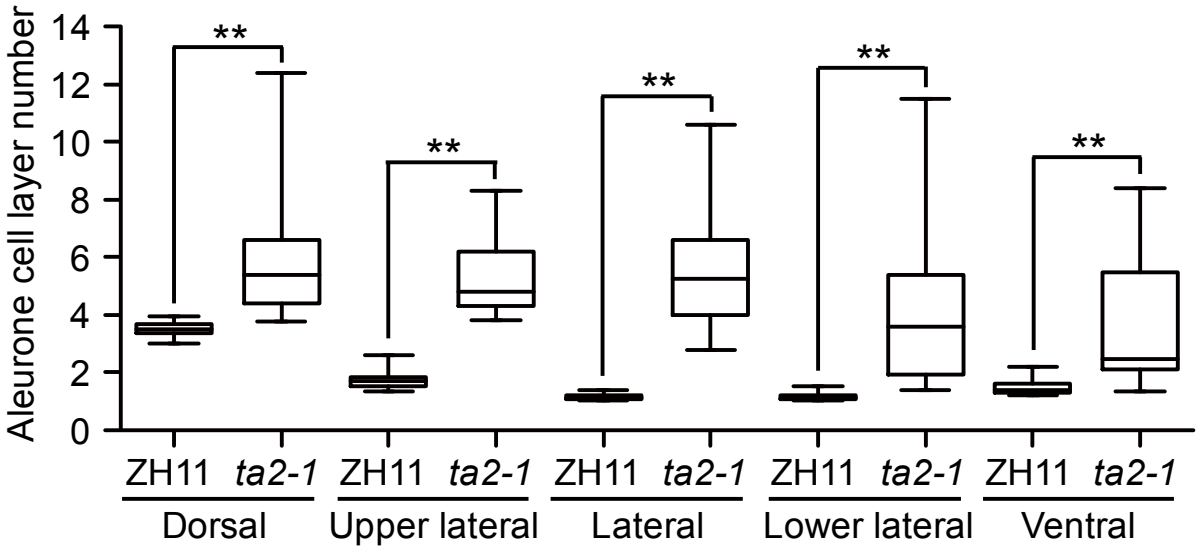


Liu et al., PNAS, 2018

*ta2-1*糊粉层细胞层数显著增加

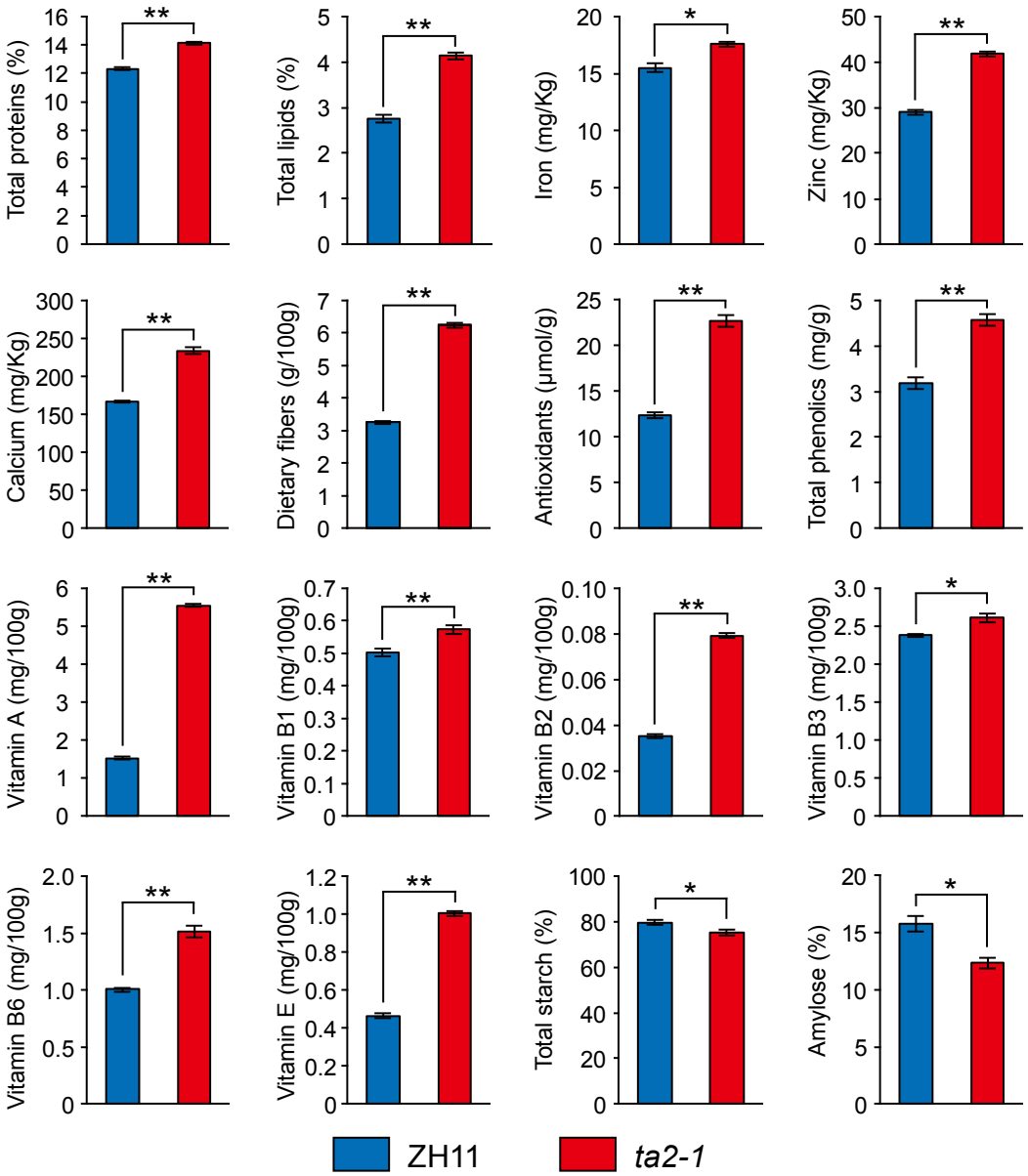




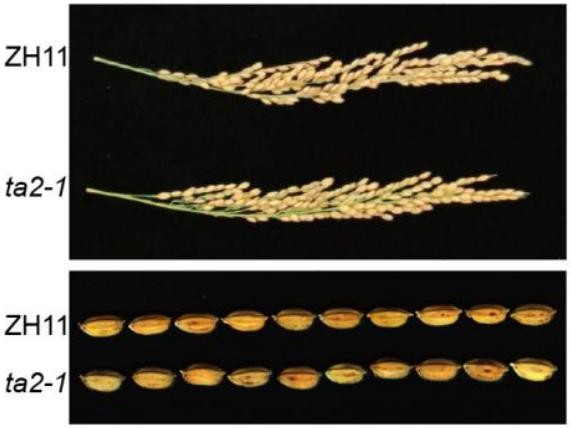


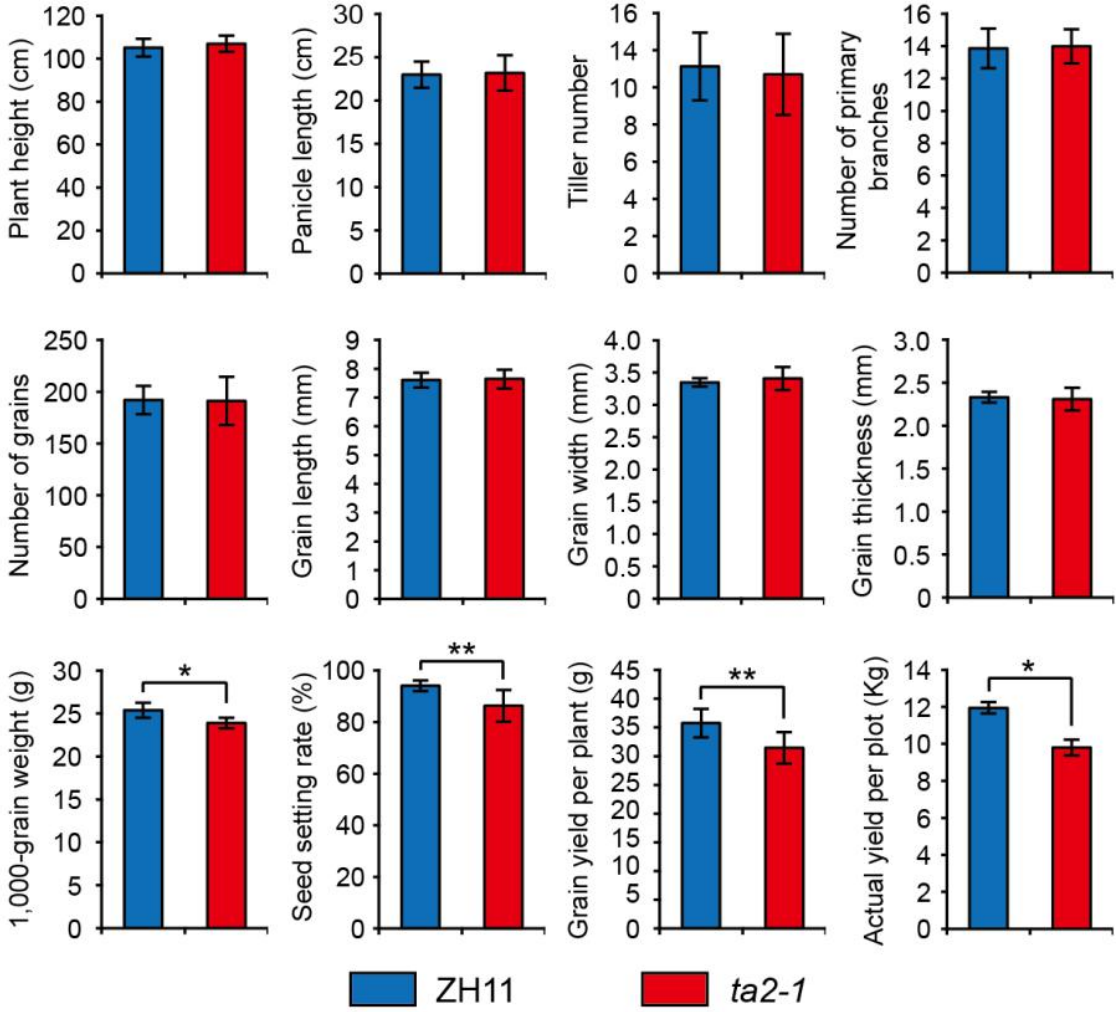
Liu et al., PNAS, 2018

*ta2-1*糙米中营养成分含量明显提升

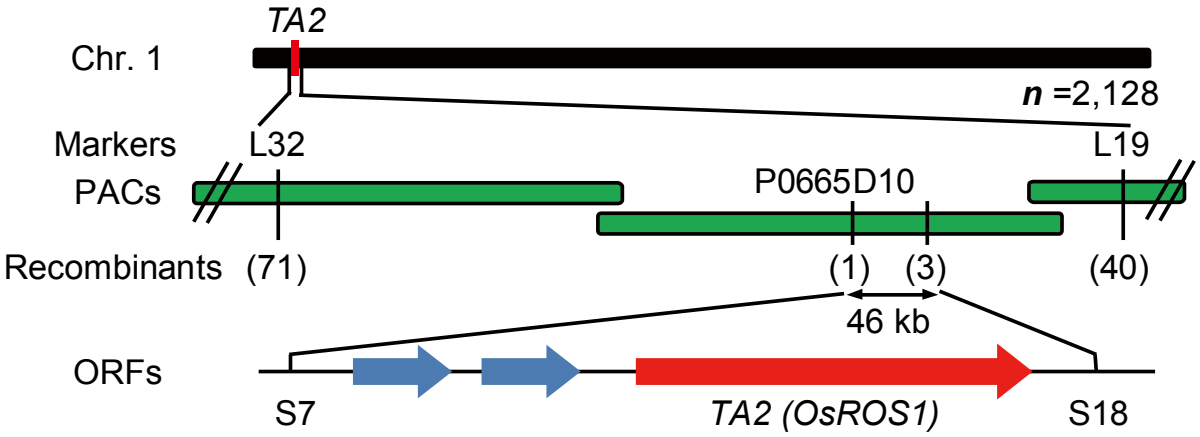


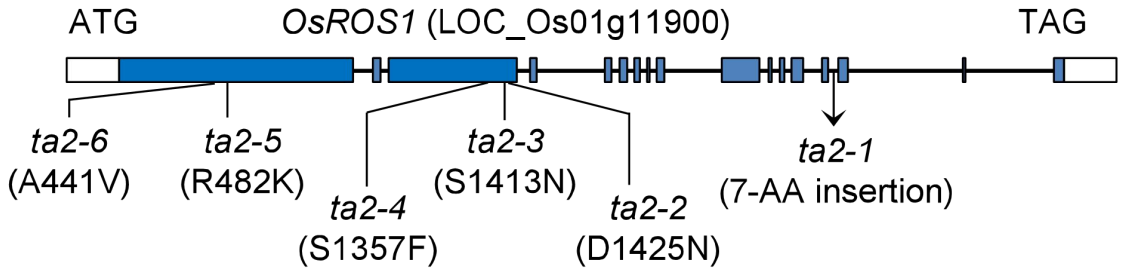
*ta2-1*的主要农艺形状

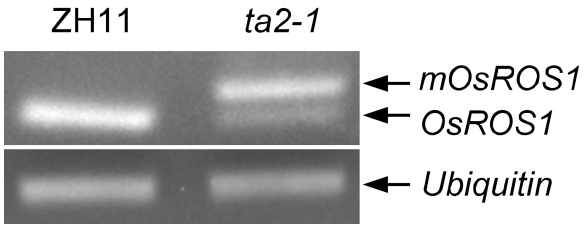




TA2 编码DNA去甲基化酶OsROS1

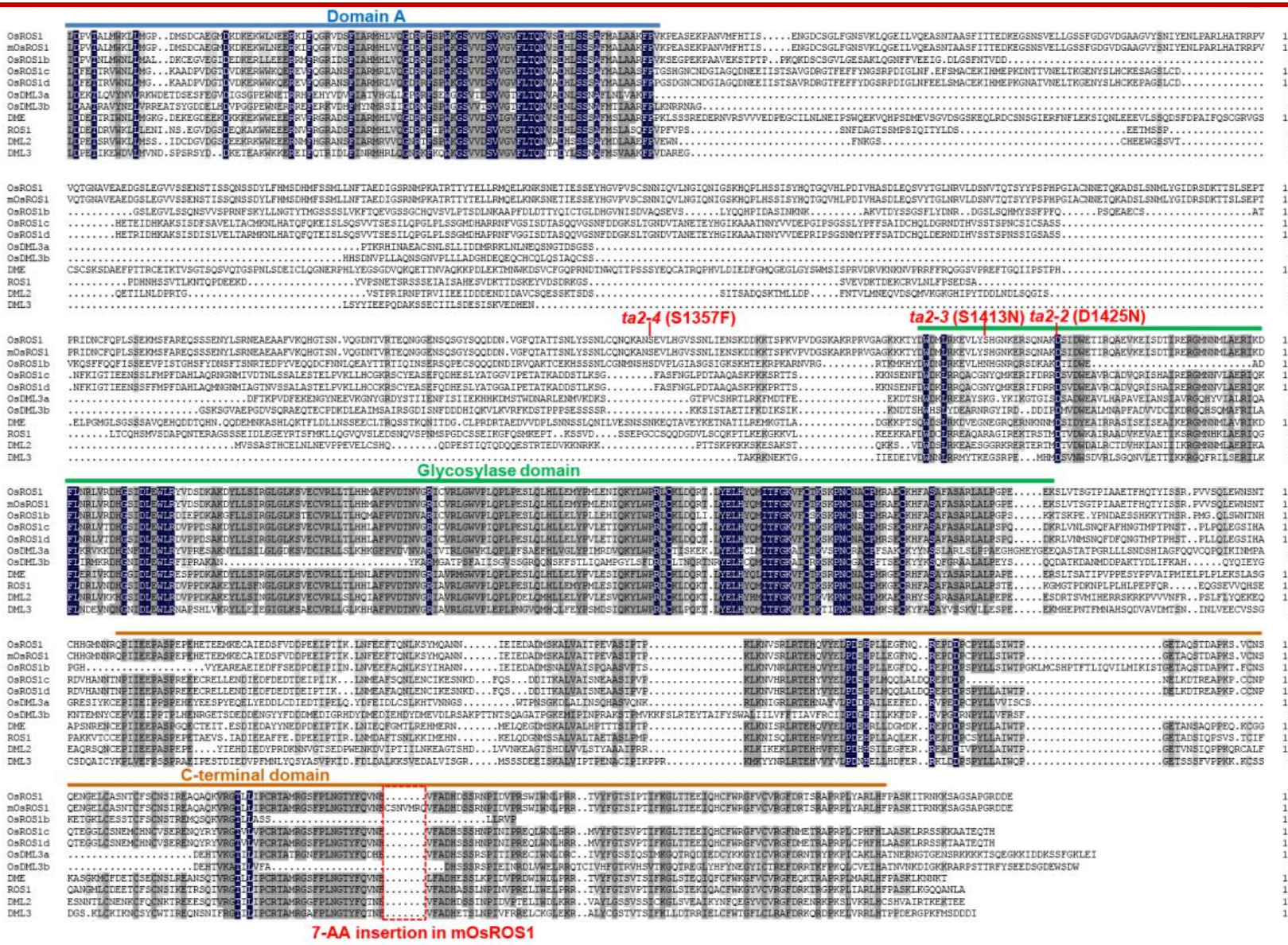




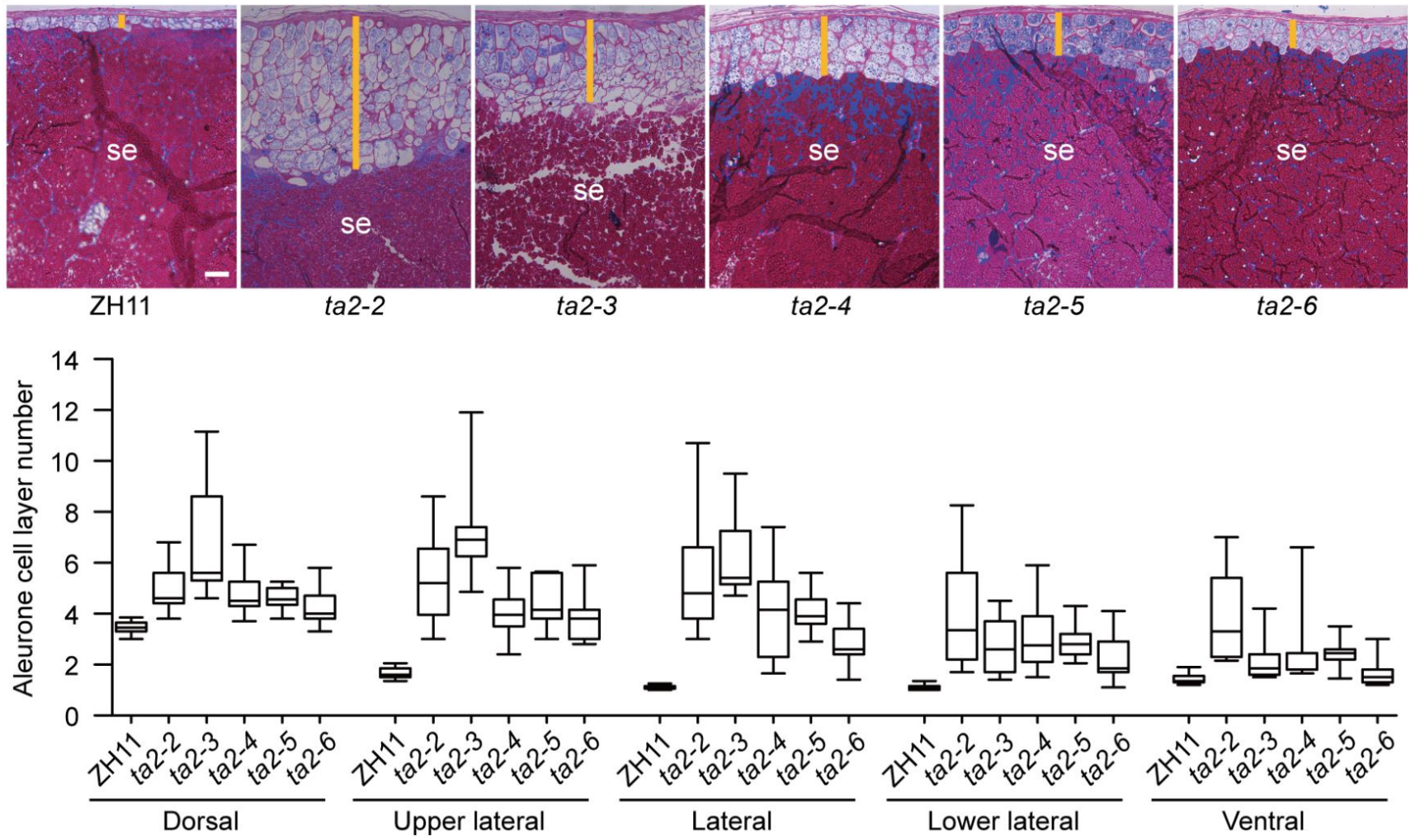


	N	E	–	–	–	–	–	–	–	V	F
OsROS1	AAT	GAG	- - -	- - -	---	---	---	---	---	GTA	TTT
mOsROS1	AAT	GAG	TGT	TCA	AAT	GTT	ATG	CGG	CAG	GTA	TTT
	N	E	C	S	N	V	M	R	Q	V	F

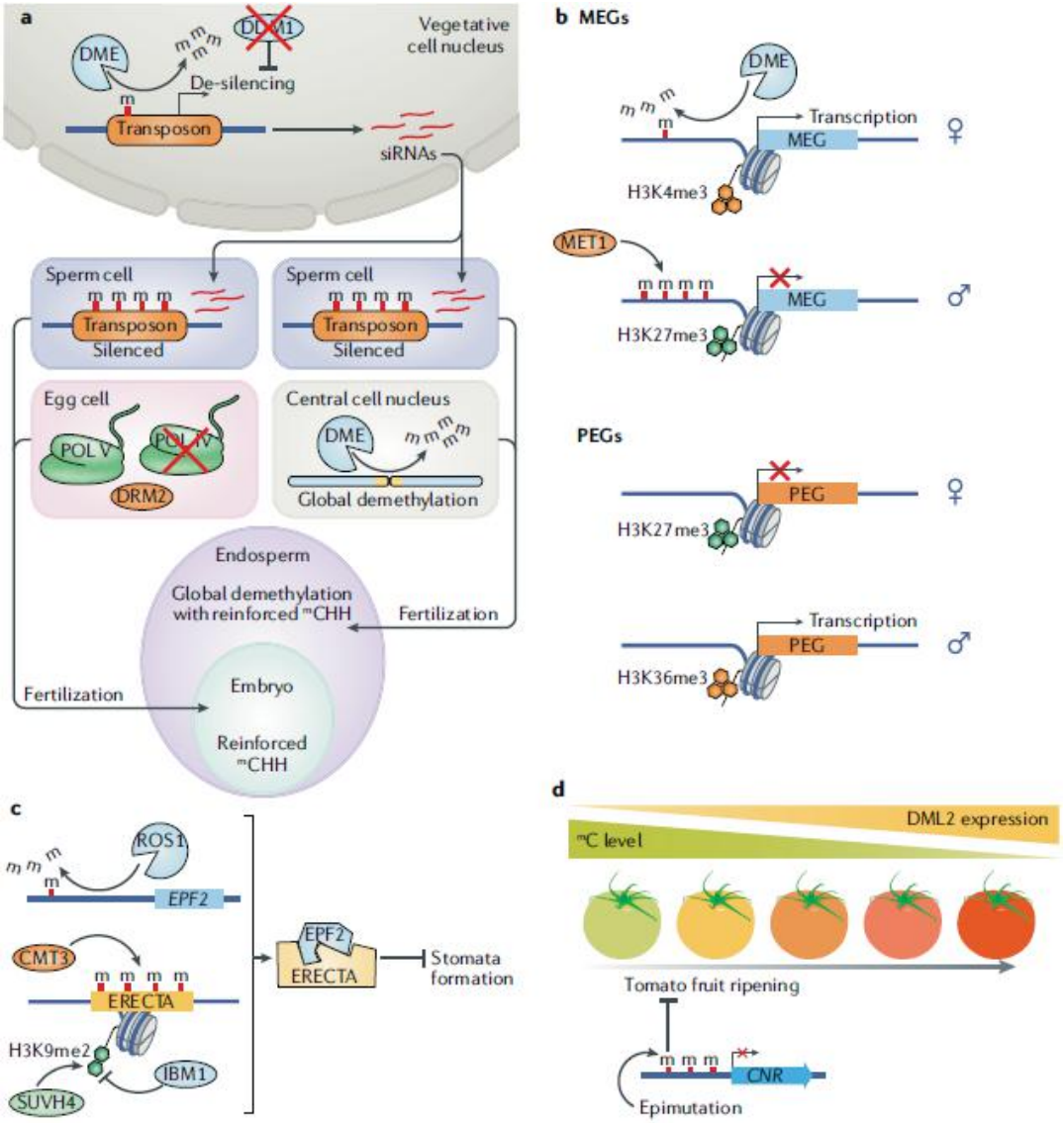
mOsROS1在C-terminal domain插入7个氨基酸



*ta2*不同等位突变呈现糊粉层加厚表型

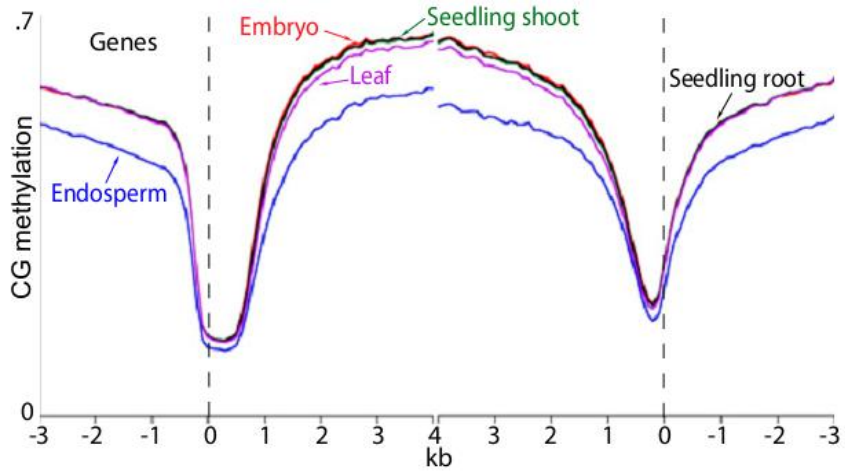


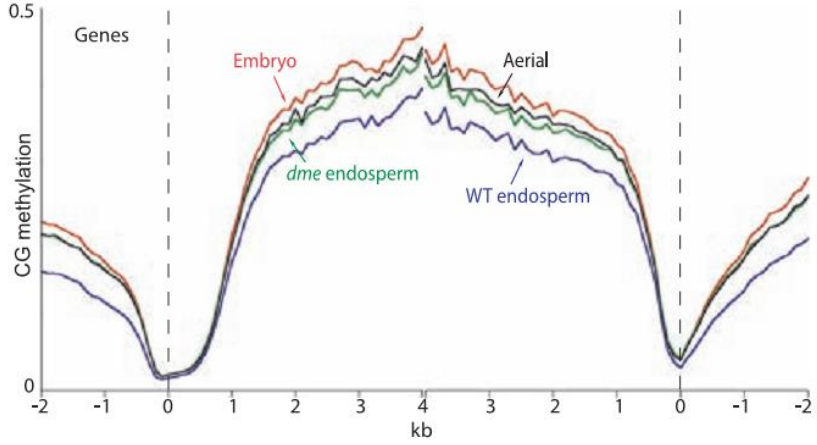
DNA去甲基化过程在植物生长发育中具有重要作用

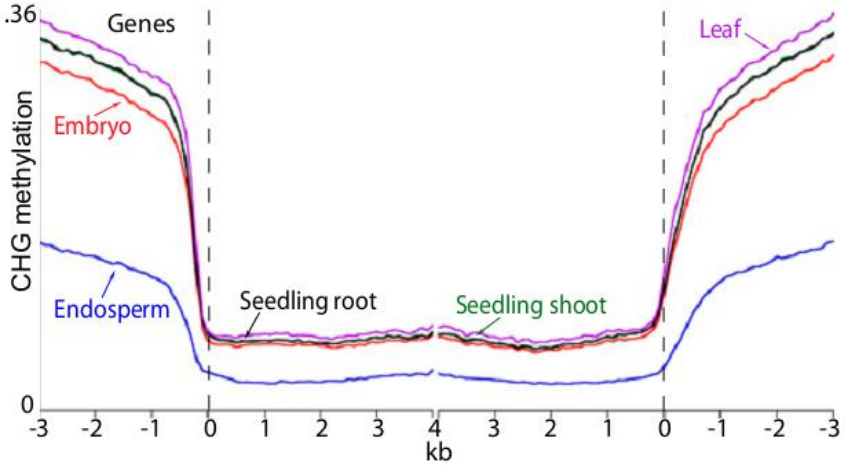


Zhang et al, Nat Rev Mol Cell Bio, 2018

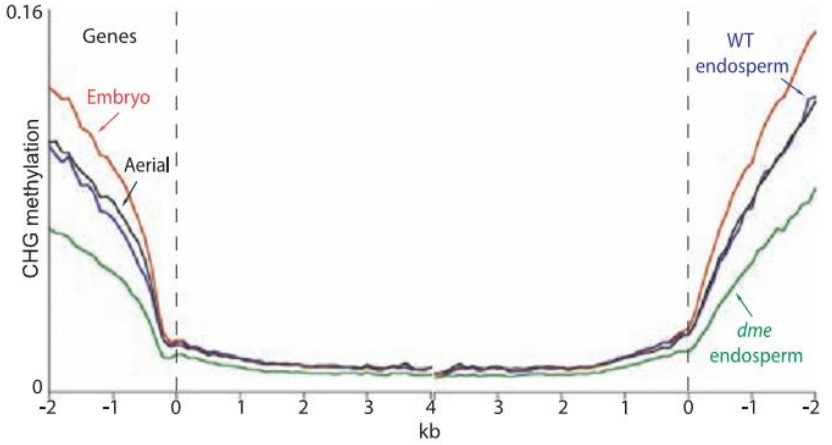
胚乳基因组DNA呈现较低的DNA甲基化水平







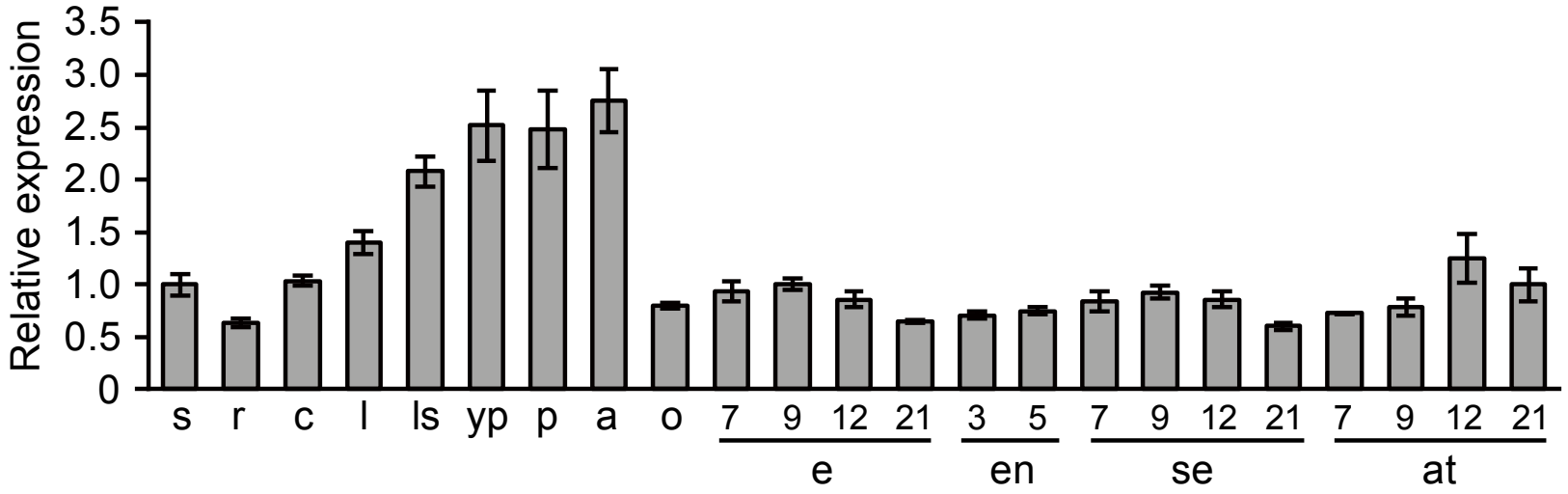
C

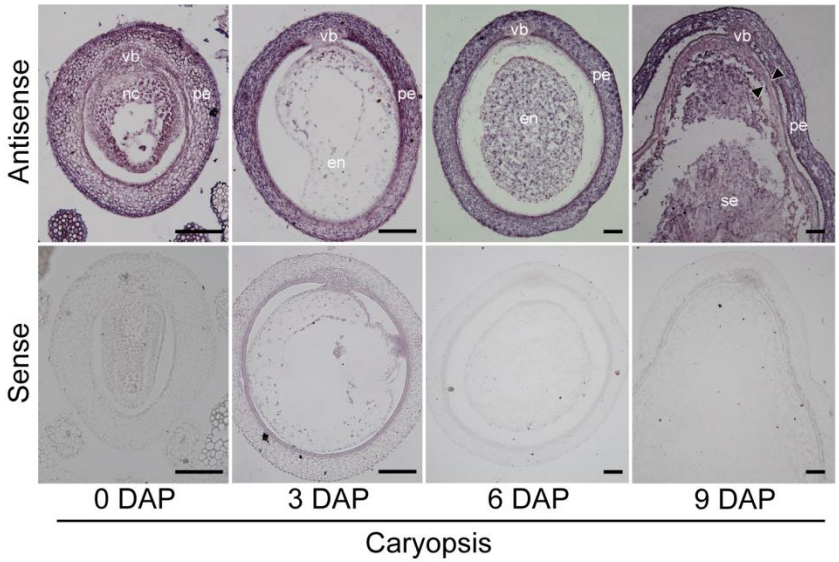


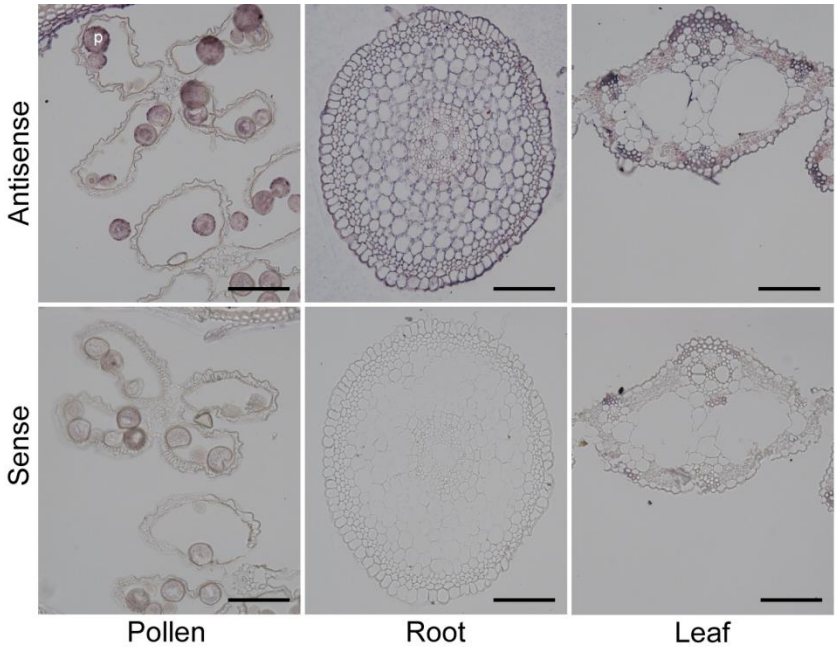
Hiseh et al, Science, 2009

Zemach et al, PNAS, 2010

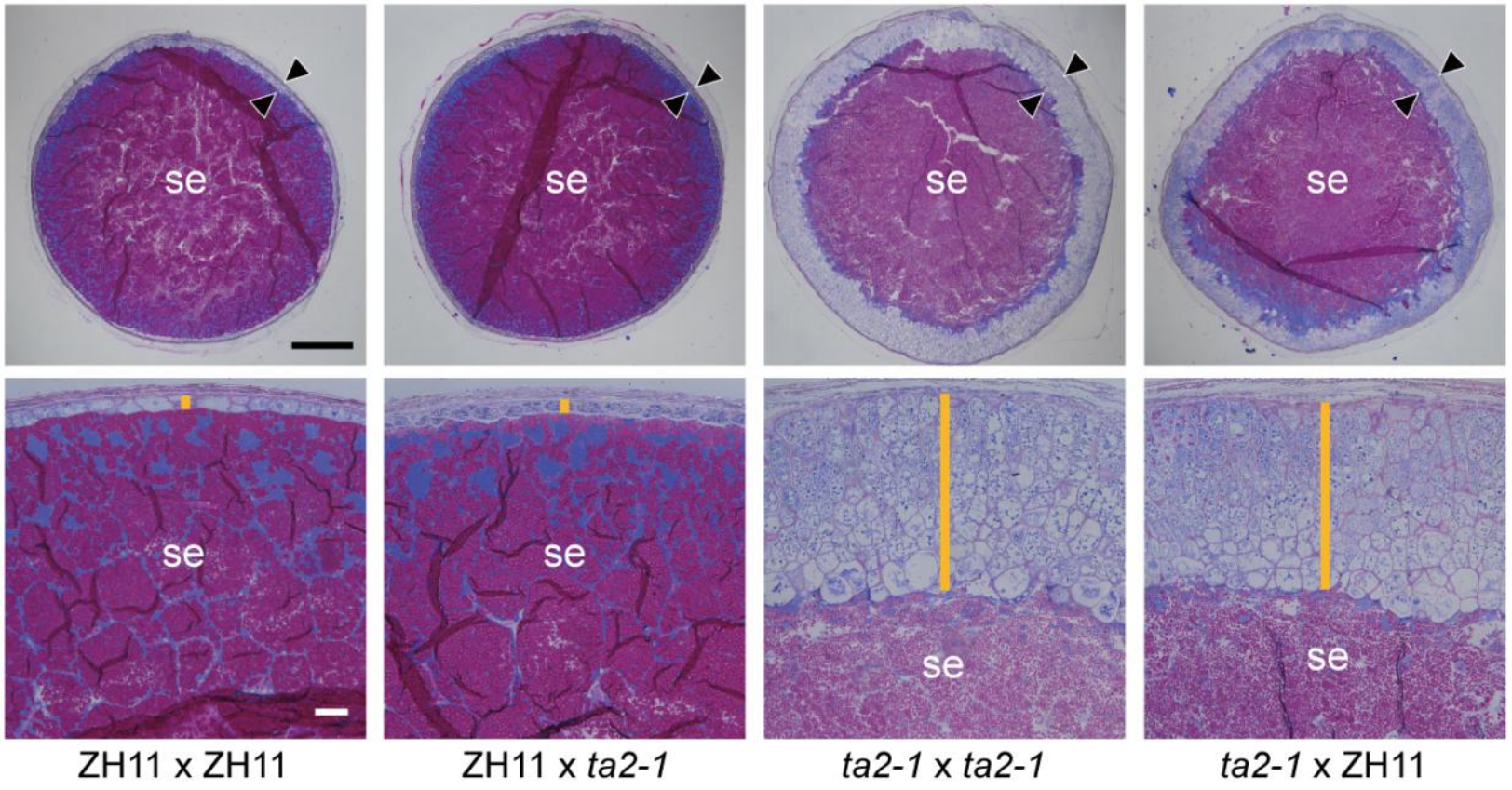
*OsROS1*在营养组织、胚和胚乳中均有表达







ZH11和*ta2-1*正反交F1胚乳中糊粉层的表型

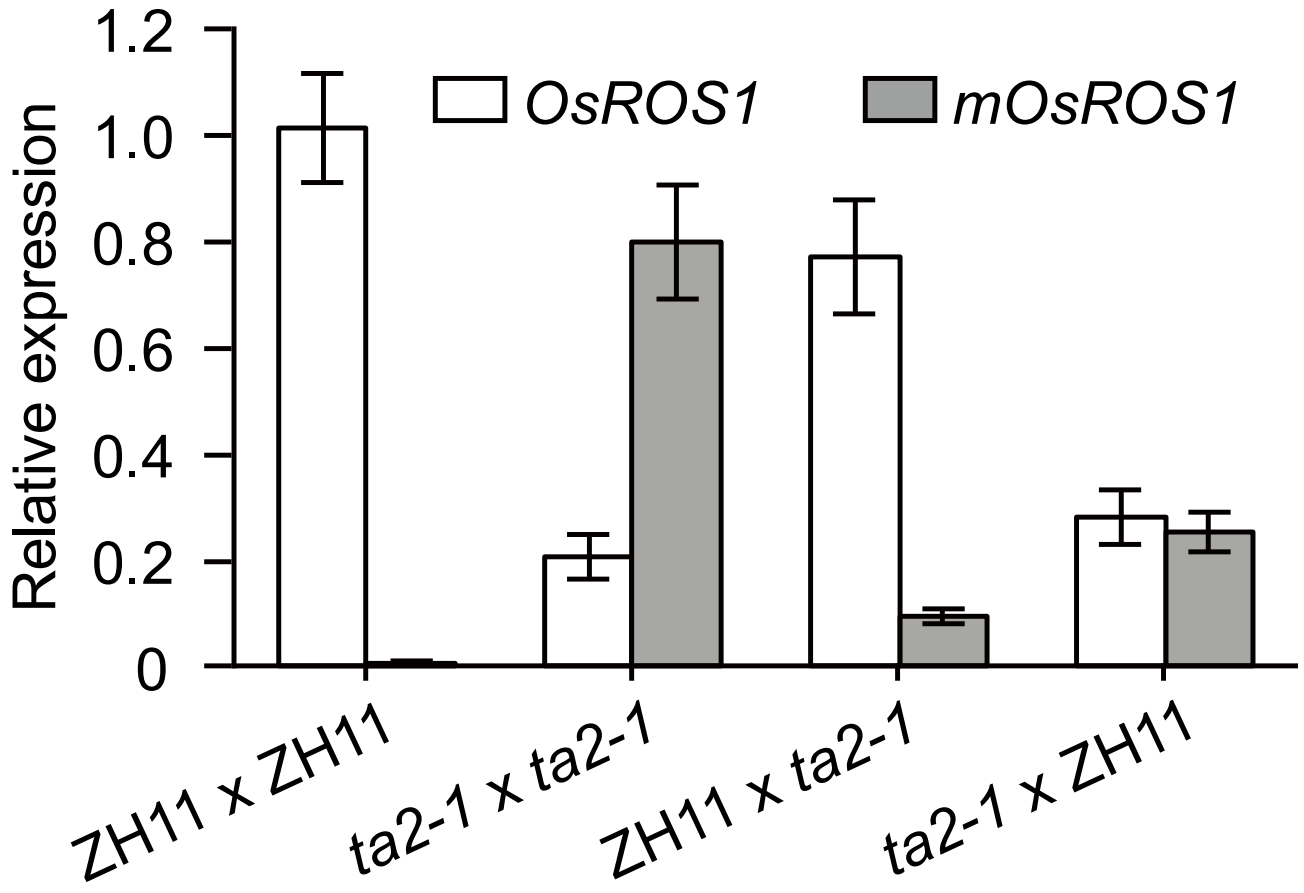


*ta2-1*糊粉层加厚表型呈现配子体母本效应

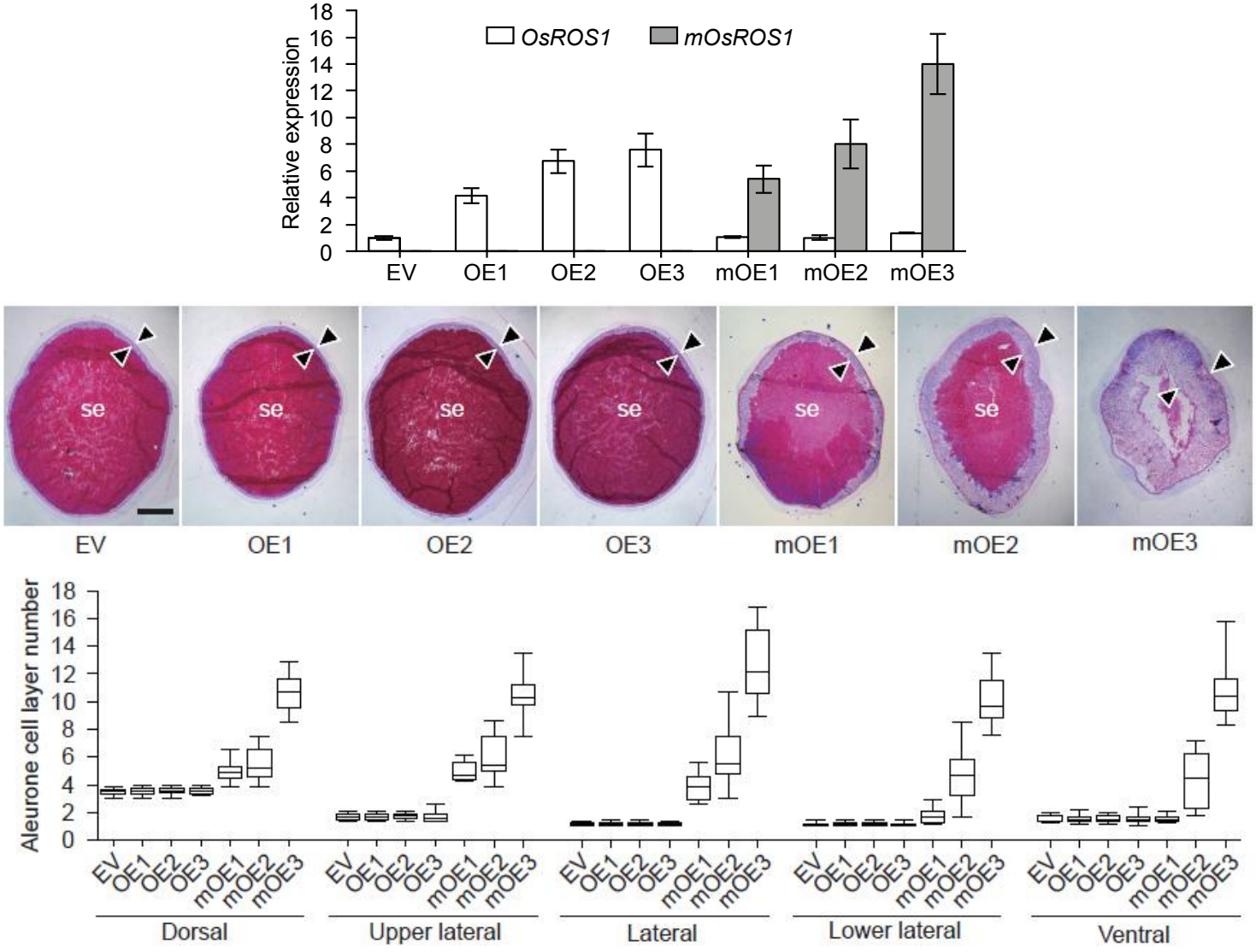
Cross combination	Endosperm phenotypes		Grains with *ta* phenotype (%)	*P* for 1:1
	Wild-type	*ta*		
TA2/ta2-1 x *TA2/ta2-1*	321	313	49.4	0.7506 (N.S.)
ZH11 x *ta2-1*	197	0	0	N.A.
ZH11 x *TA2/ta2-1*	171	0	0	N.A.
ta2-1 x ZH11	0	589	100	N.A.
ta2-1 x *TA2/ta2-1*	0	422	100	N.A.
TA2/ta2-1 x ZH11	199	193	49.2	0.7618 (N.S.)
TA2/ta2-1 x *ta2-1*	212	214	50.2	0.9228 (N.S.)

N.S., not significant; N.A., not applicable.

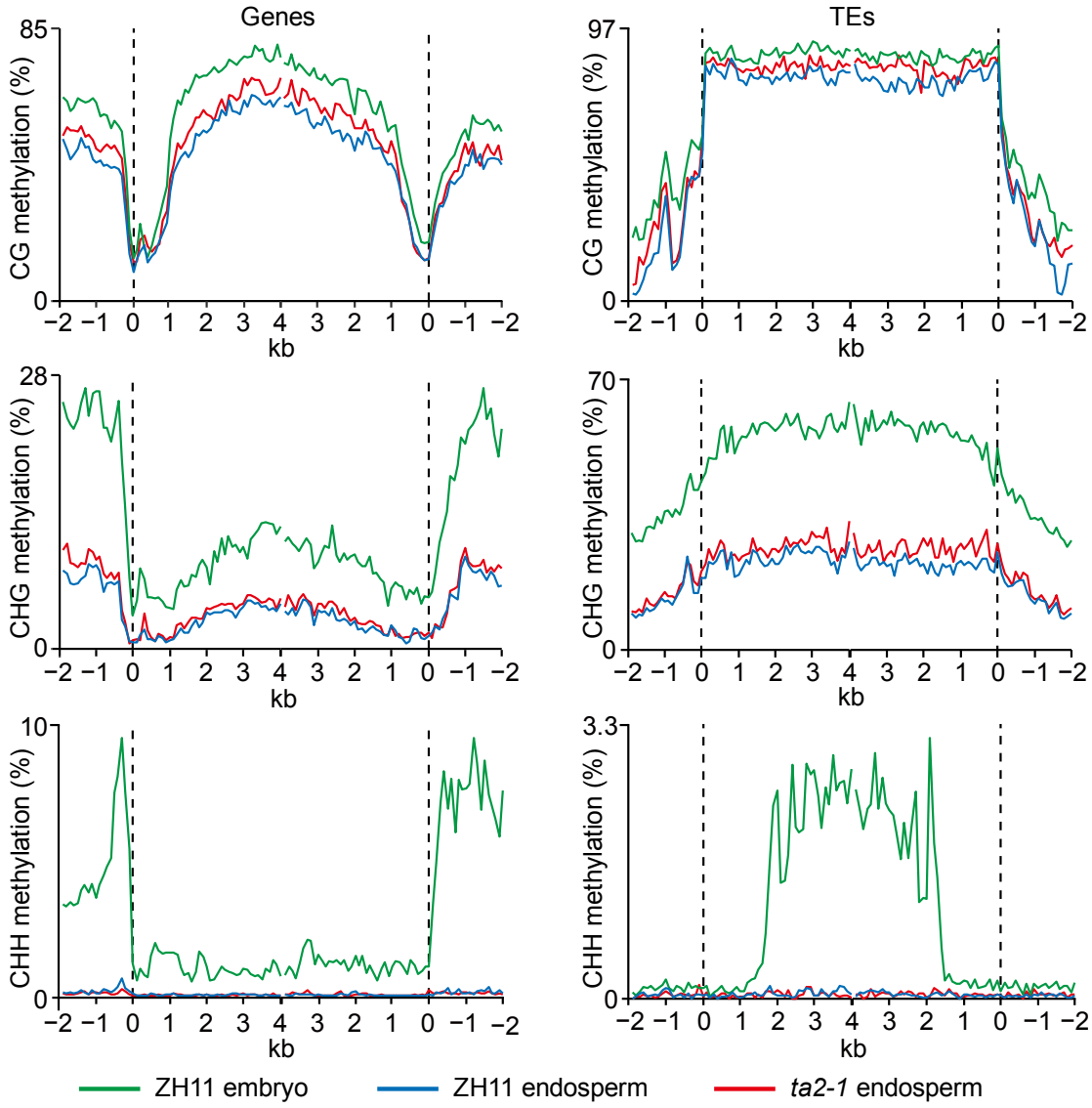
*OsROS1*和*mOsROS1*在ZH11和*ta2-1*正反交F1胚乳中的表达水平



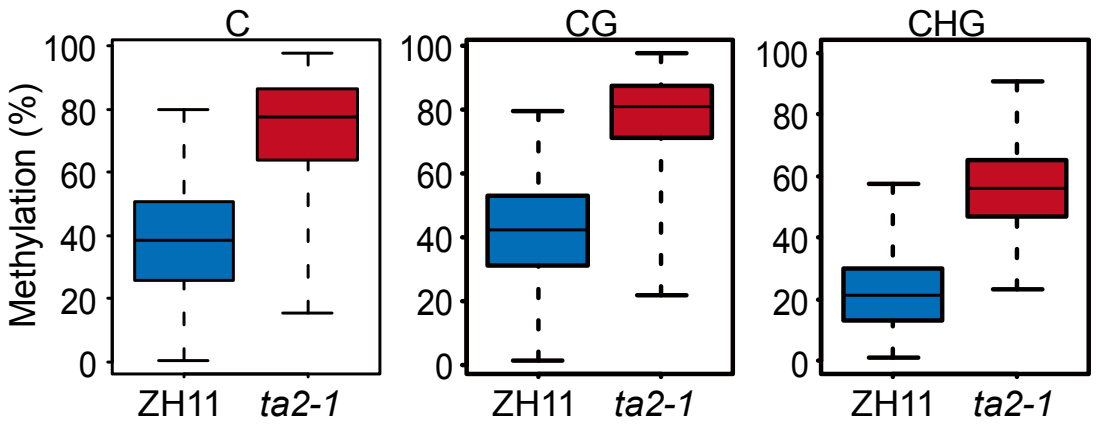
在ZH11中过表达*mOsROS1*产生糊粉层加厚表型

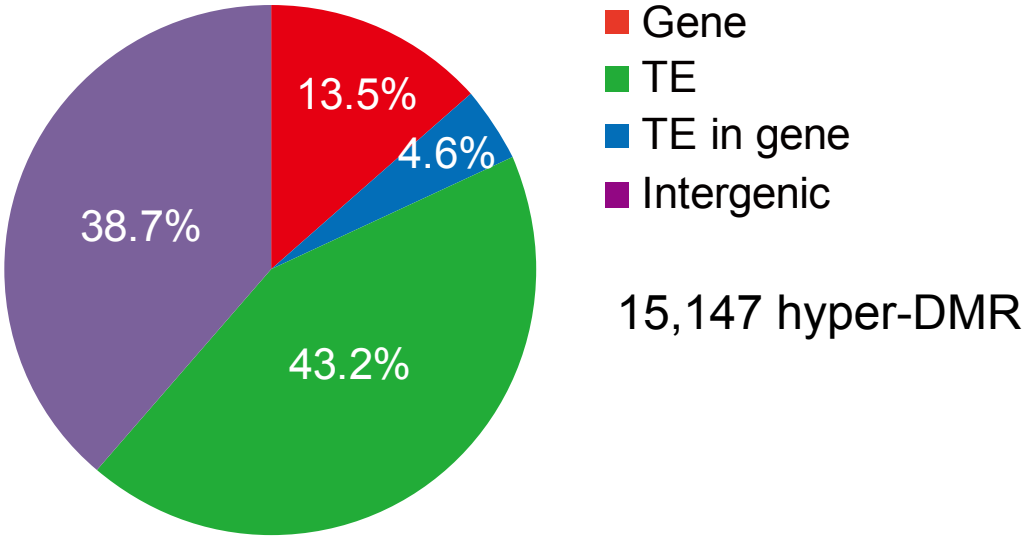


ZH11和*ta2-1*胚乳基因组中基因区域和TE区域DNA甲基化水平分布

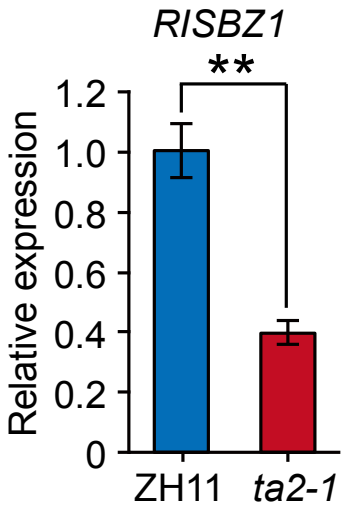


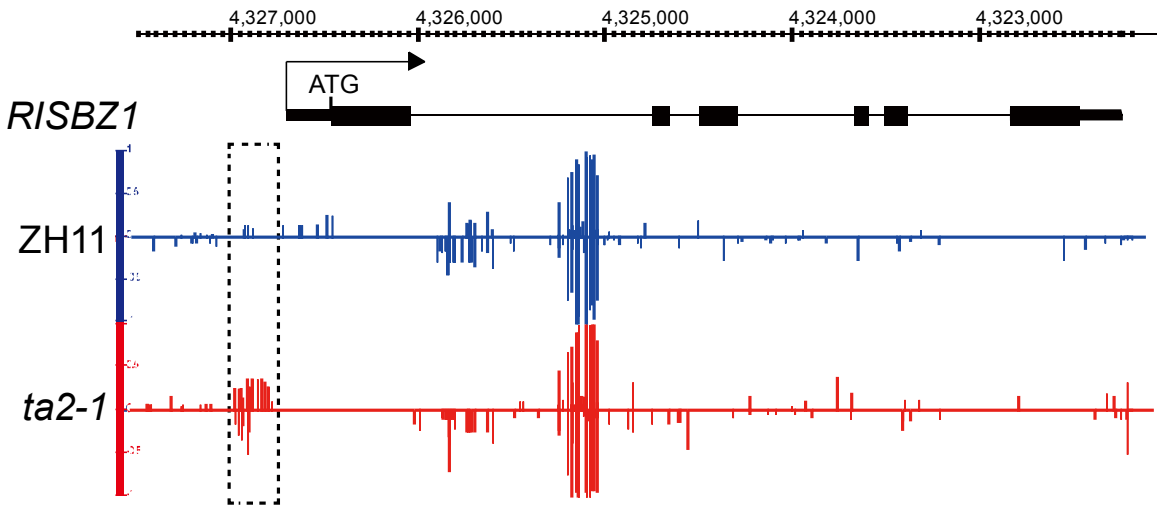
*ta2-1*胚乳基因组hyper-DMR分析

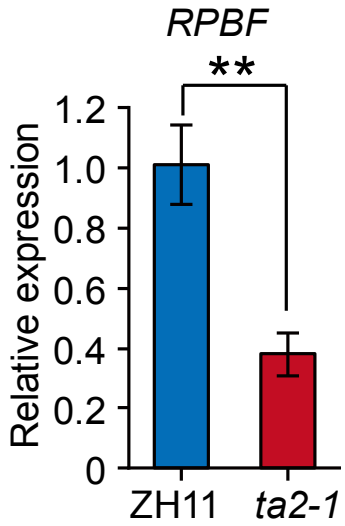


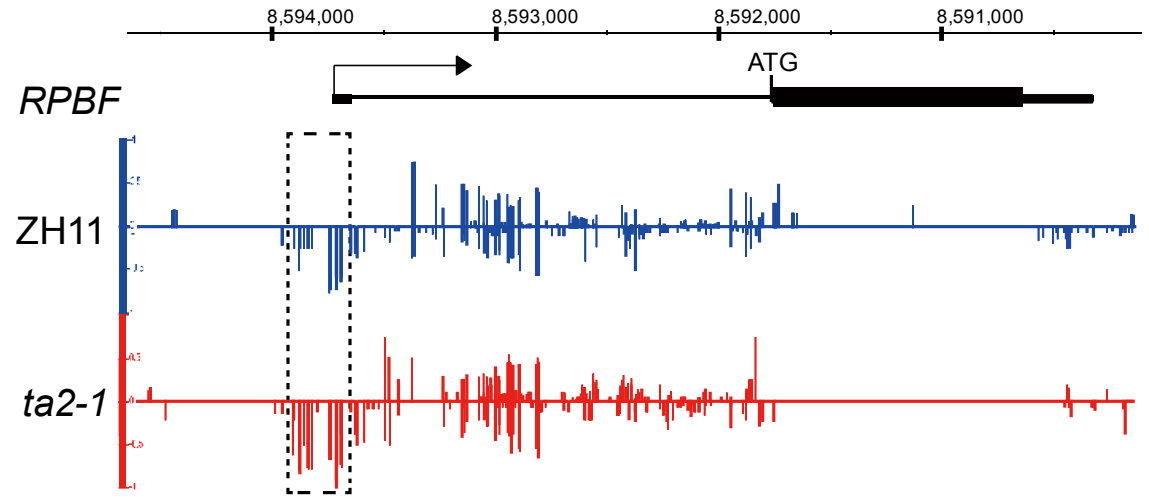


在*ta2-1*胚乳中*RISBZ1*和*RPBF*启动子区域甲基化水平升高导致表达水平显著降低

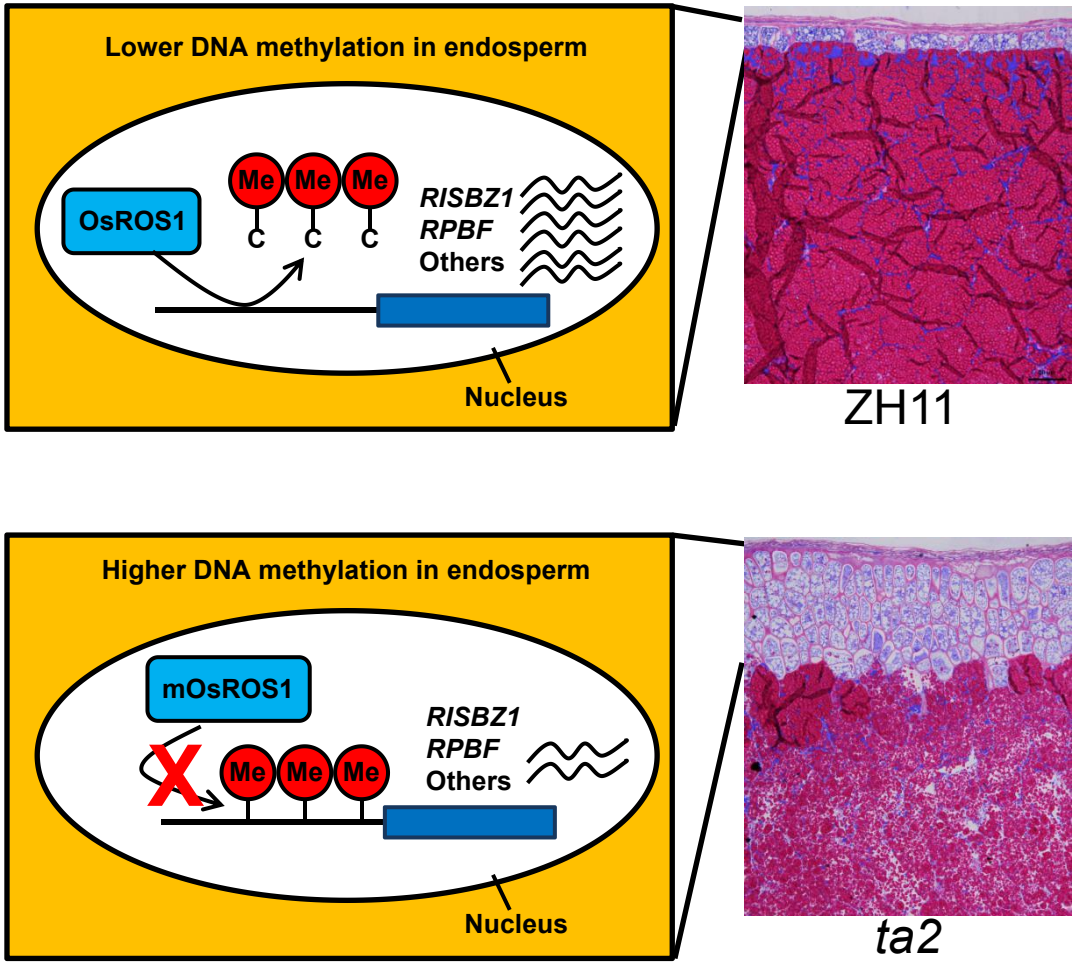




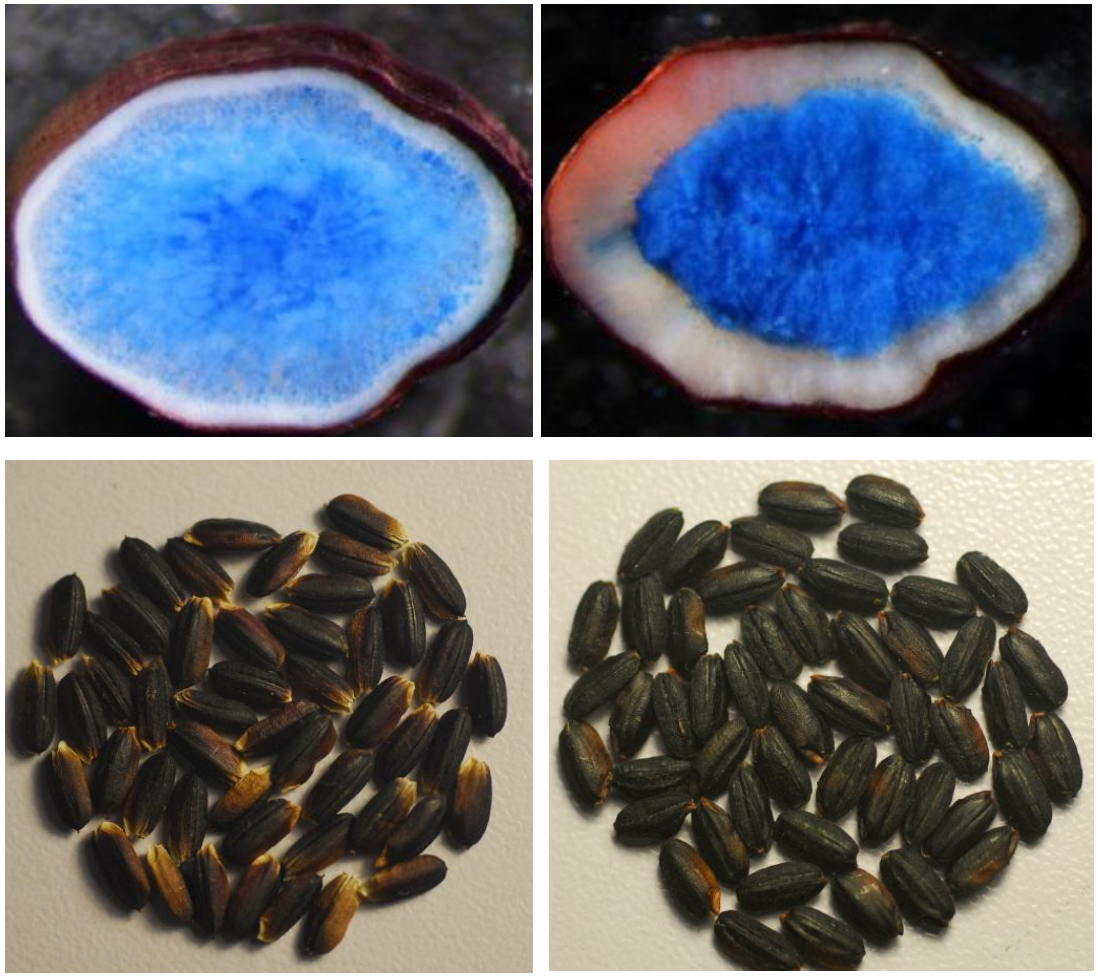




OsROS1调控胚乳糊粉层分化的分子机制

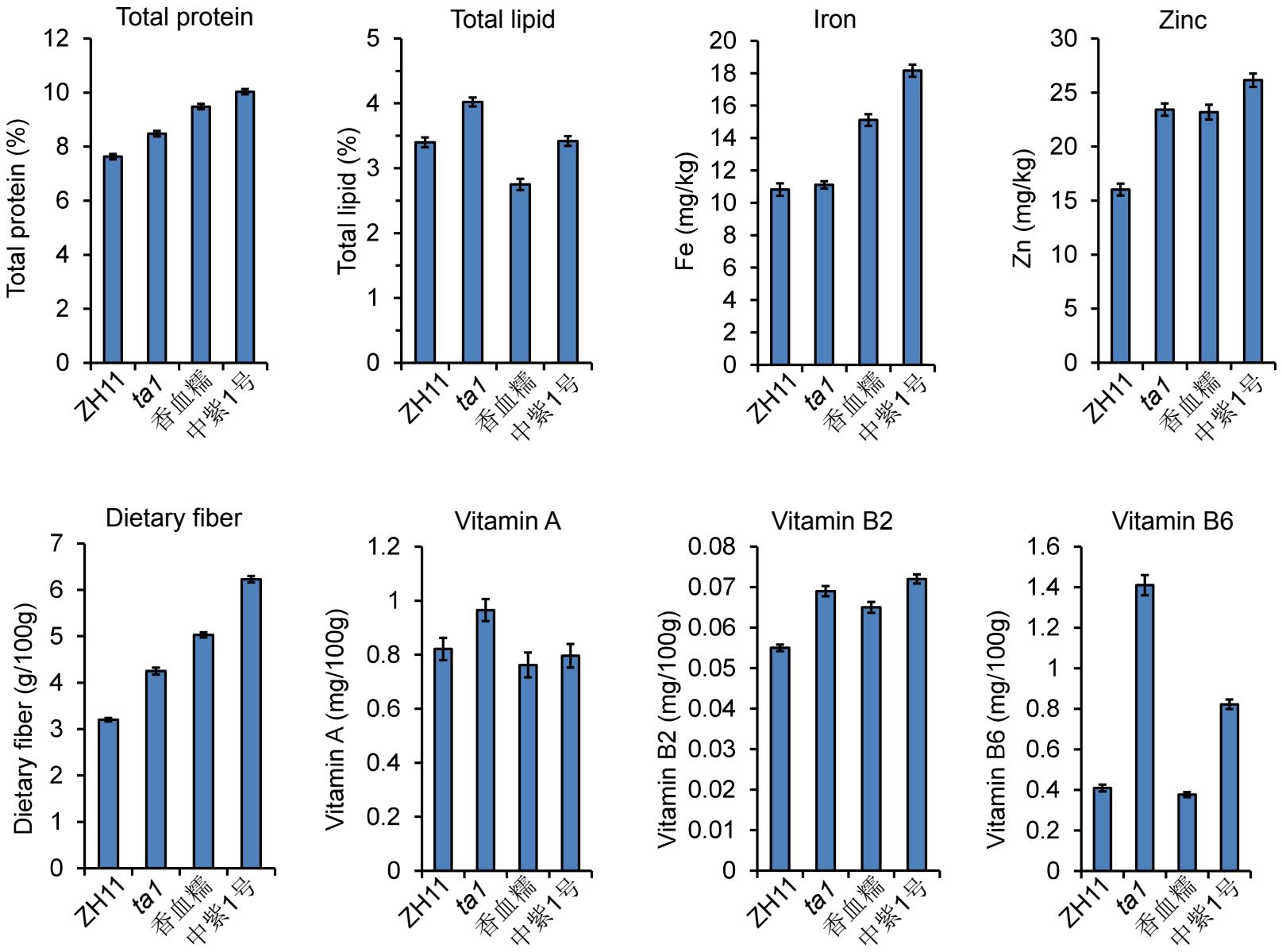


将糊粉层加厚性状导入到紫米品种



中紫1号　　中紫2号

*ta1*突变导致紫米种子糊粉层加厚、营养含量提高

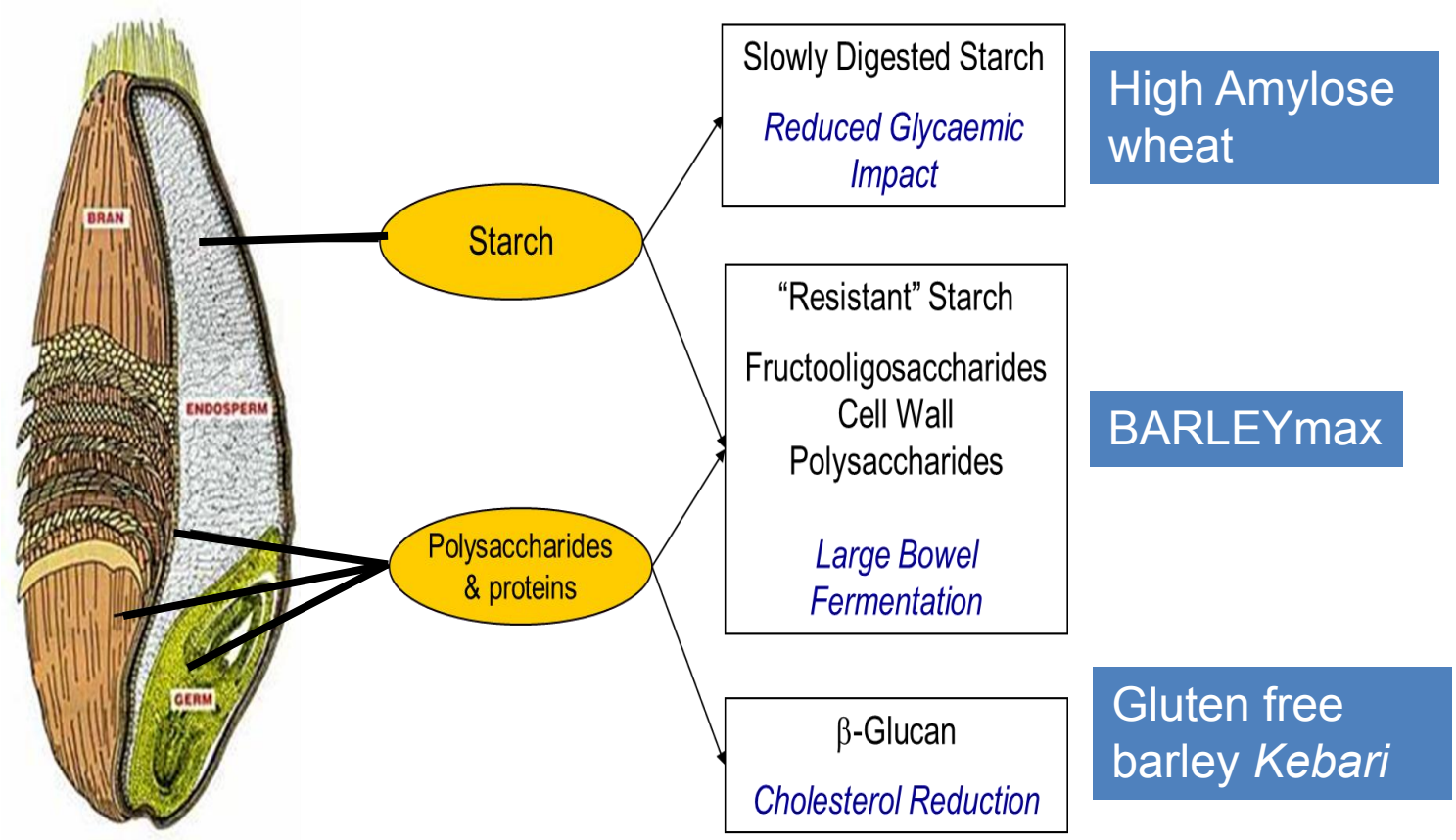


Unpublished data

高营养水稻品种中紫1号已申请品种保护权

开发糊粉层增厚的高营养功能型禾谷类作物

Diet-related Diseases: Cardiovascular disease, Type II diabetes, Obesity and Weight Control, Gut Health, Colon Cancer……..



与澳大利亚联邦科学与工业研究组织合作

致　谢

刘春明　研究员

张士永　研究员

吴小坝

李东起

朱孟超

Ronald Yu

Philip Larkin

This work was supported by the Ministry of Science and Technology of China, the CAS-Innovation Project “Molecular Modules for Breeding Design”, and the CAS-CSIRO Bilateral Collaboration Project.