Genetic improvement of rice salt tolerance

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- Background
- Physiological basis of rice salt tolerance
- Genetic improvement of rice salt tolerance
- Exploration of salt-tolerant genes in halophytes

◆ Background

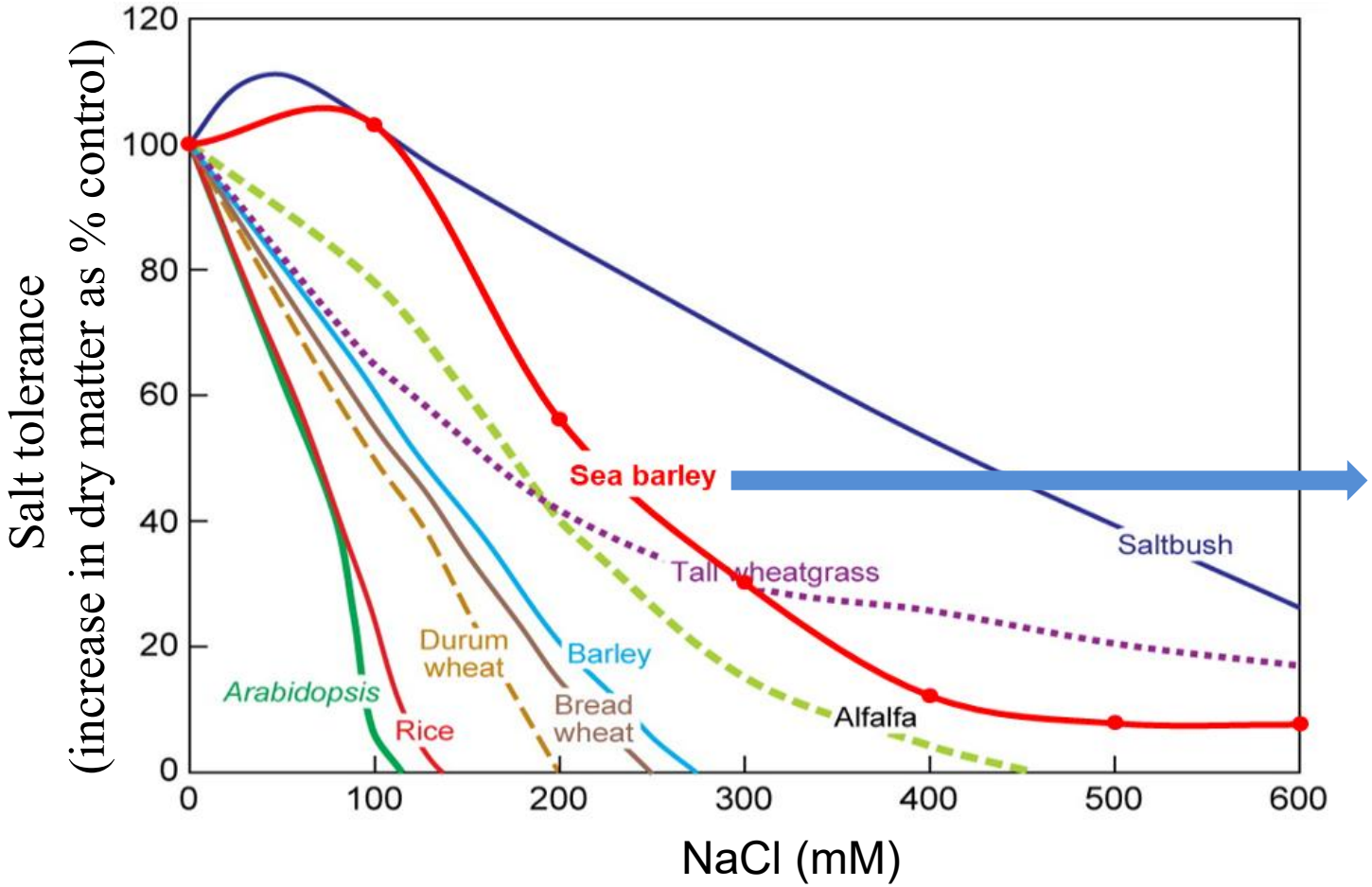
424 million hectares of topsoil (0-30 cm) and **833 million hectares** of subsoil (30-100 cm) are salt-affected:

- **85% of salt-affected topsoil are saline**, 10% are sodic and 5% are saline-sodic.
- **62% of salt-affected subsoil are saline**, 24% are sodic and 14% are saline-sodic.

China has 1/10 of the global salt-affected soils

China has 1/10 of the global salt-affected soils, of which **~200 million acres have agricultural development potential** (for cultivation and pasture, etc.).

The variation of salt tolerance in plants

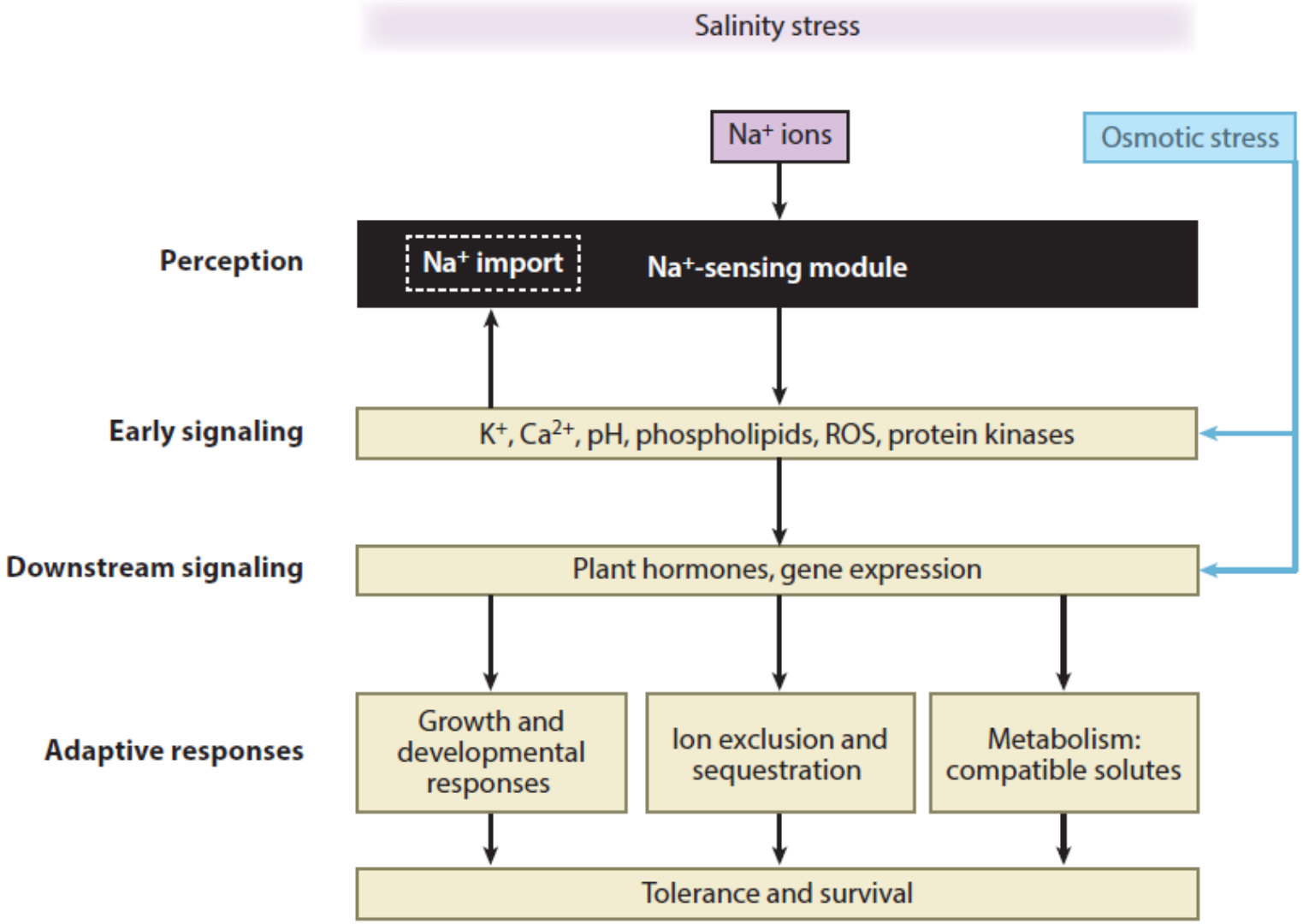


(Kuang et al, Plant Comm 2022)

(Adapted from *Munns & Tester, Annu Rev Plant Biol 2008*)

Rice is the most salt-sensitive among staple food crops

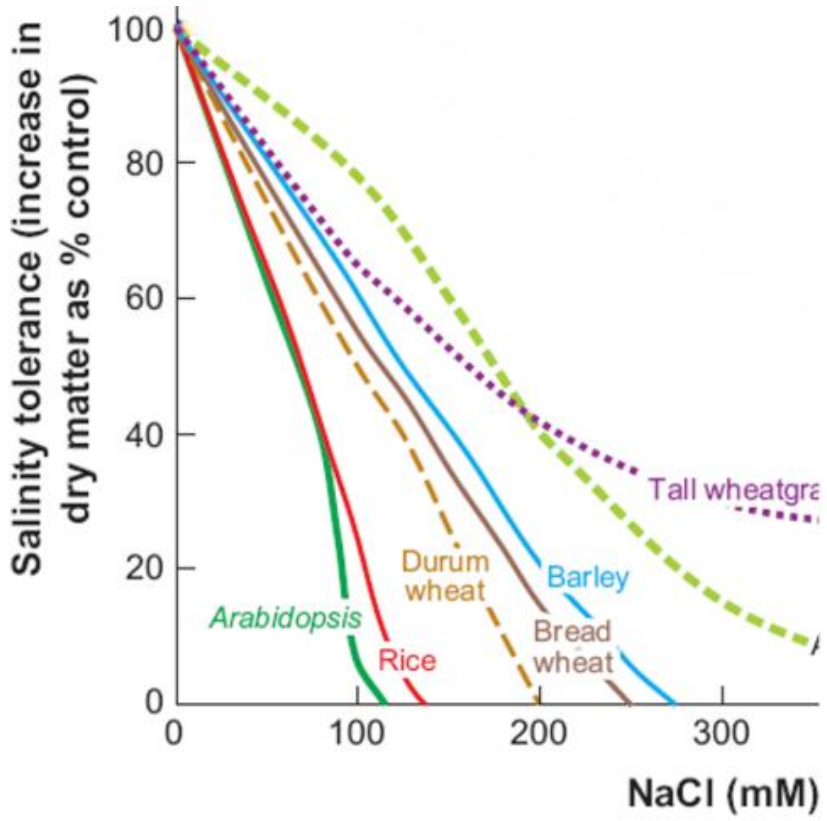
Responses of plants to salt stress

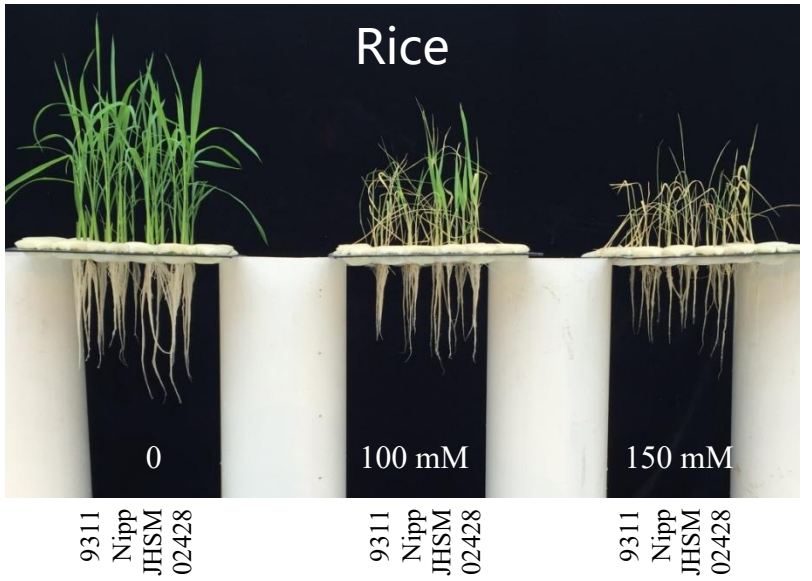


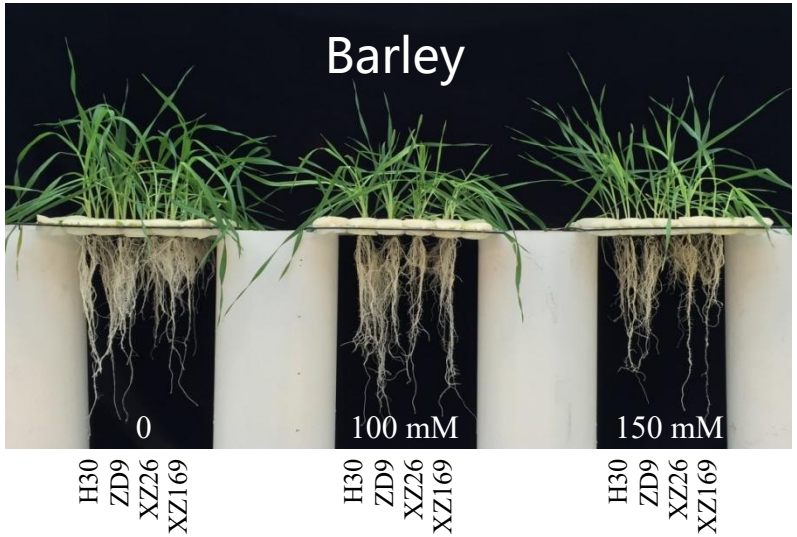
(Zelm et al, Annu Rev Plant Biol 2020)

◆ Physiological basis of rice salt tolerance

1. Comparison of salt tolerance in cereal crops



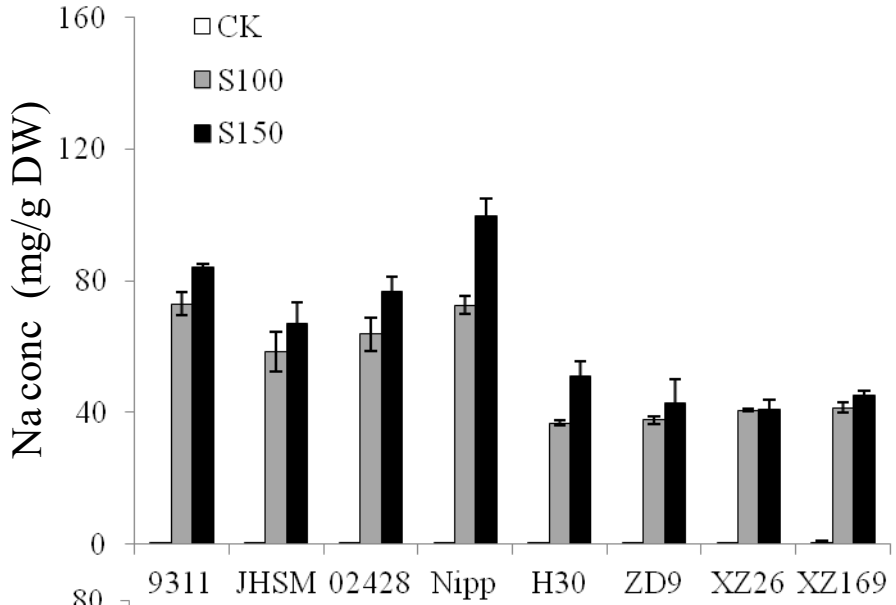


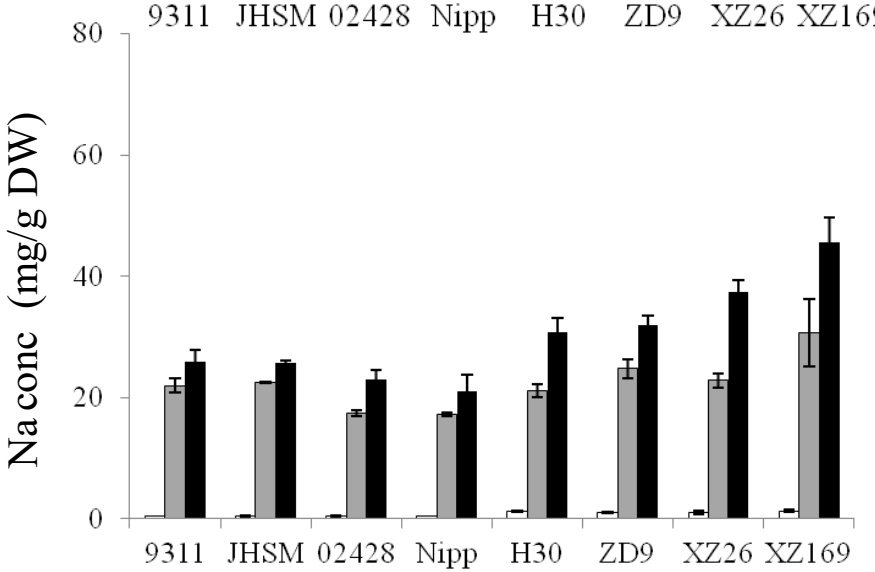


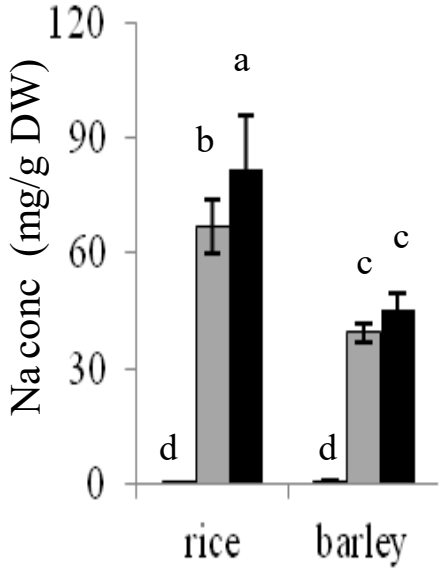
2. Physiological difference: shoot Na^+ concentration

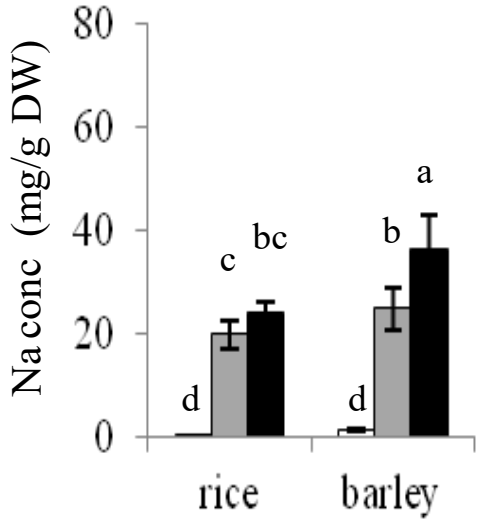
Shoot

Root



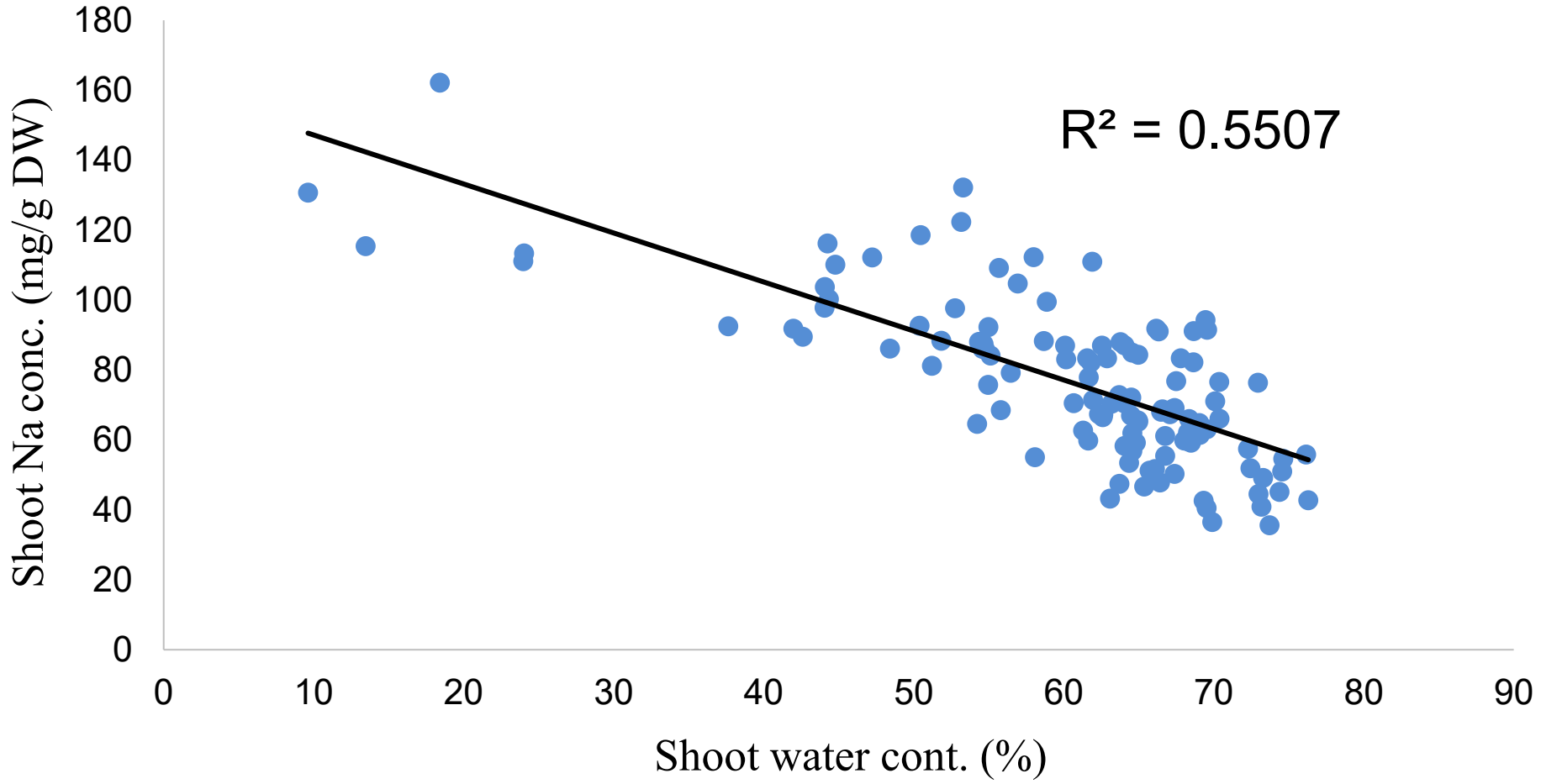






(Fu et al, PPB 2018)

3. The relationship between shoot Na^+ concentration and salt tolerance in rice



135 accessions of rice germplasm (Treated by 100 mM NaCl for 2 weeks)

How to reduce the shoot Na^+ content ?

◆ Genetic improvement of rice salt tolerance

Candidate genes for reducing shoot Na^+ content

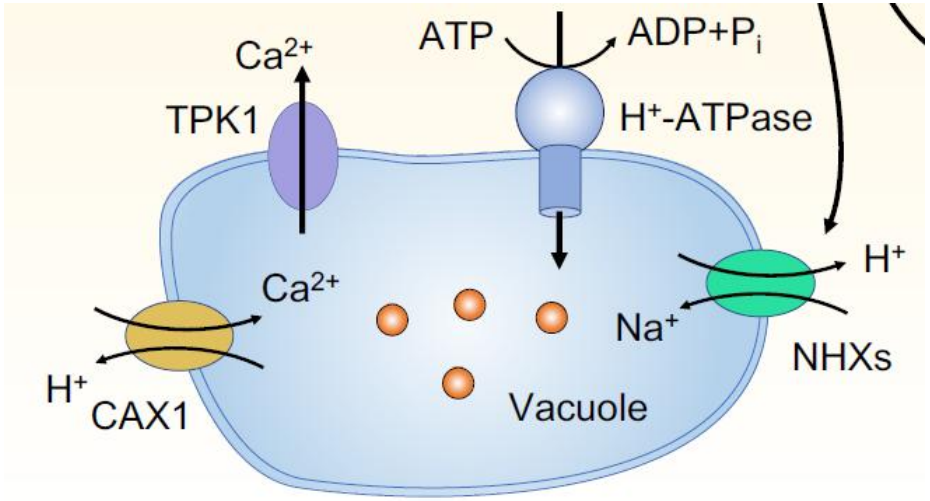
***HvNax3*—a locus controlling shoot sodium exclusion derived from wild barley (*Hordeum vulgare* ssp. *spontaneum*)**

Yuri Shavrukov · Narendra K. Gupta · Junji Miyazaki · Manahil N. Baho · Kenneth J. Chalmers · Mark Tester · Peter Langridge · Nicholas C. Collins

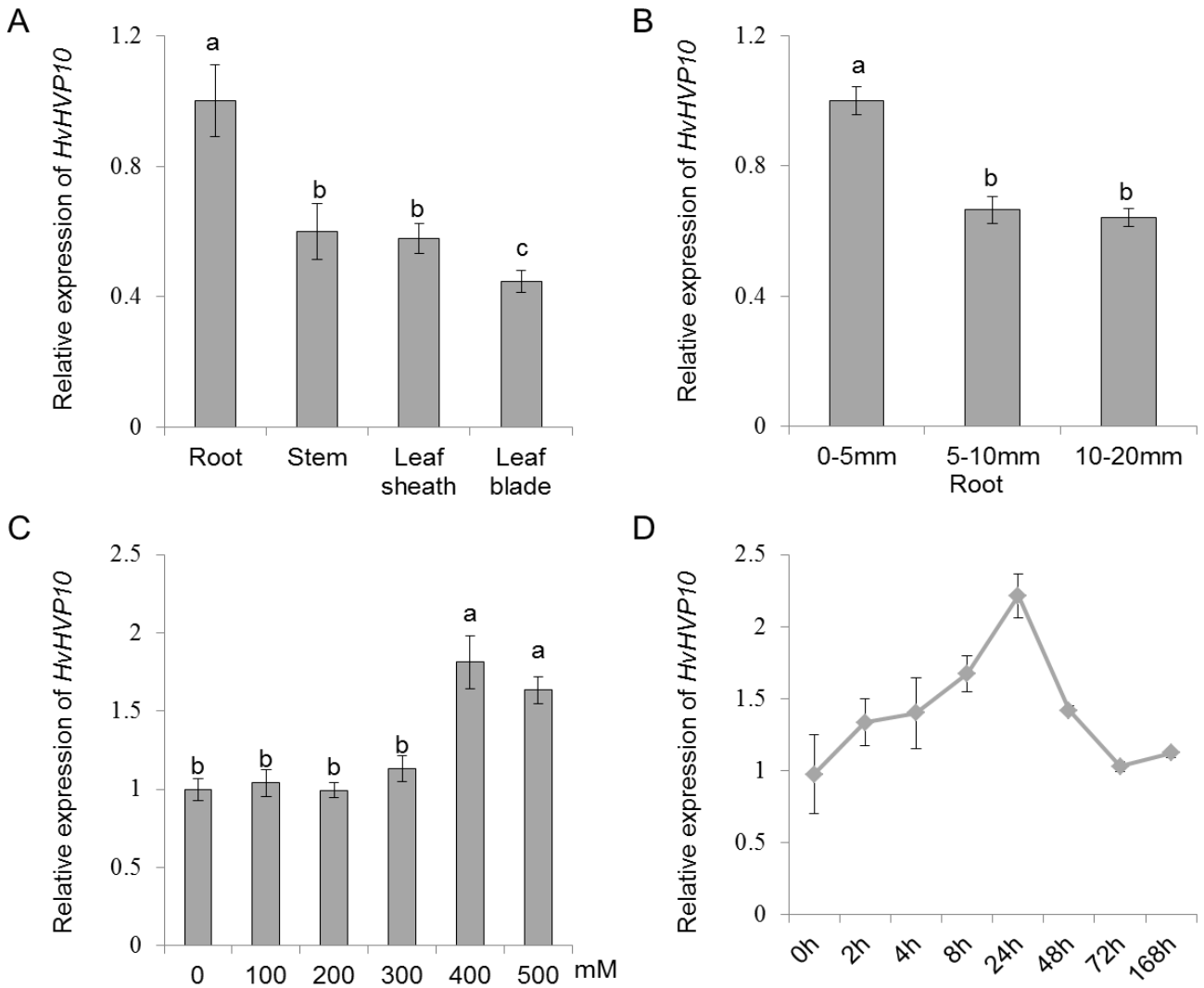
***HVP10* encoding V-PPase is a prime candidate for the barley *HvNax3* sodium exclusion gene: evidence from fine mapping and expression analysis**

Yuri Shavrukov · Jessica Bovill · Irfan Afzal · Julie E. Hayes · Stuart J. Roy · Mark Tester · Nicholas C. Collins

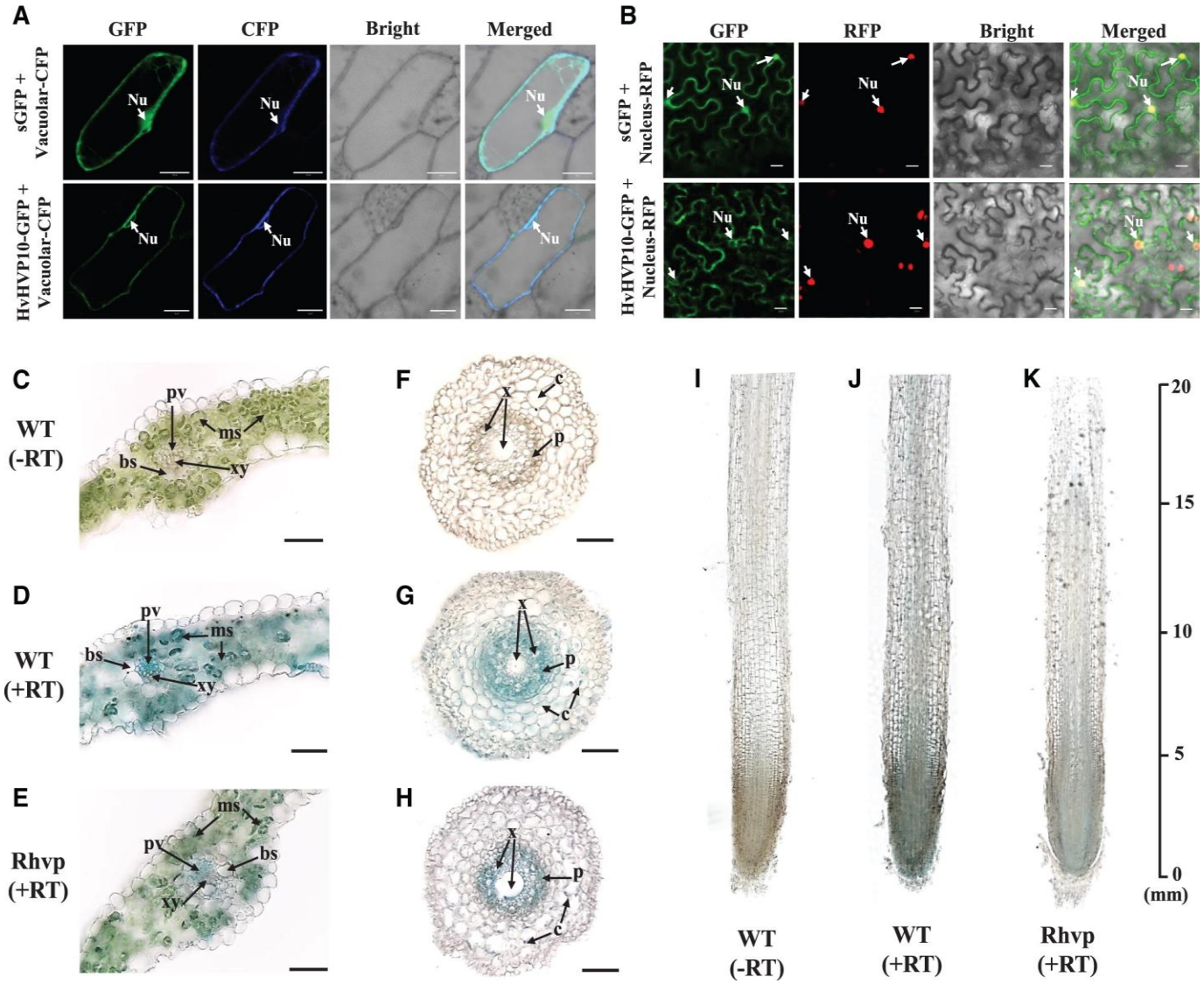
Vacuolar compartmentalization of Na^+



1. *HvHVP10* is mainly expressed in roots and induced by salt

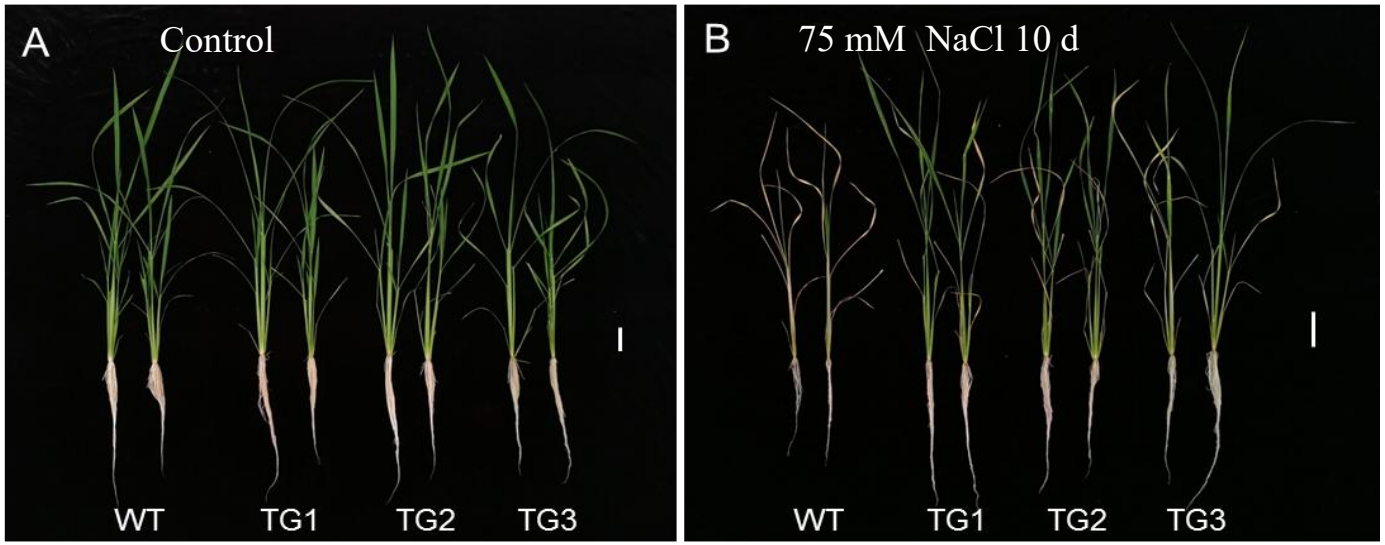


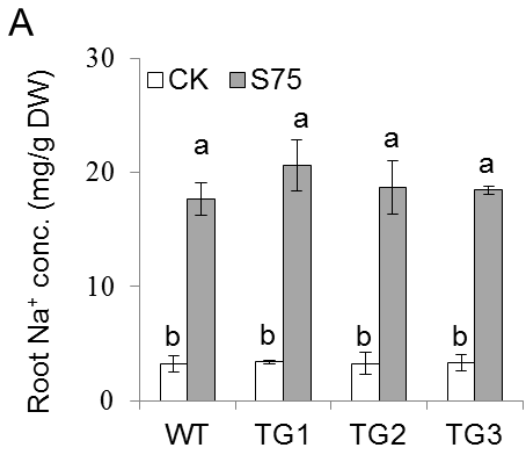
2. HvHVP10 is a tonoplast-localized protein

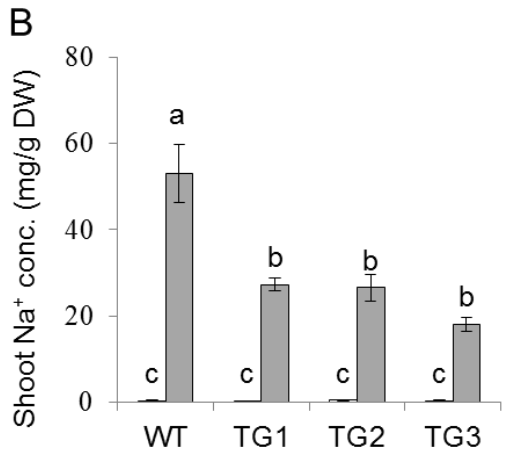


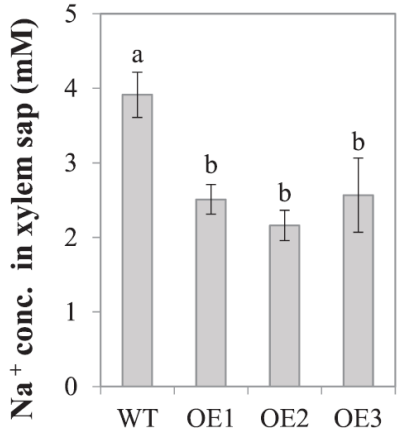
3. Significant improvement of salt tolerance of the transgenic rice

Hydroponic experiment



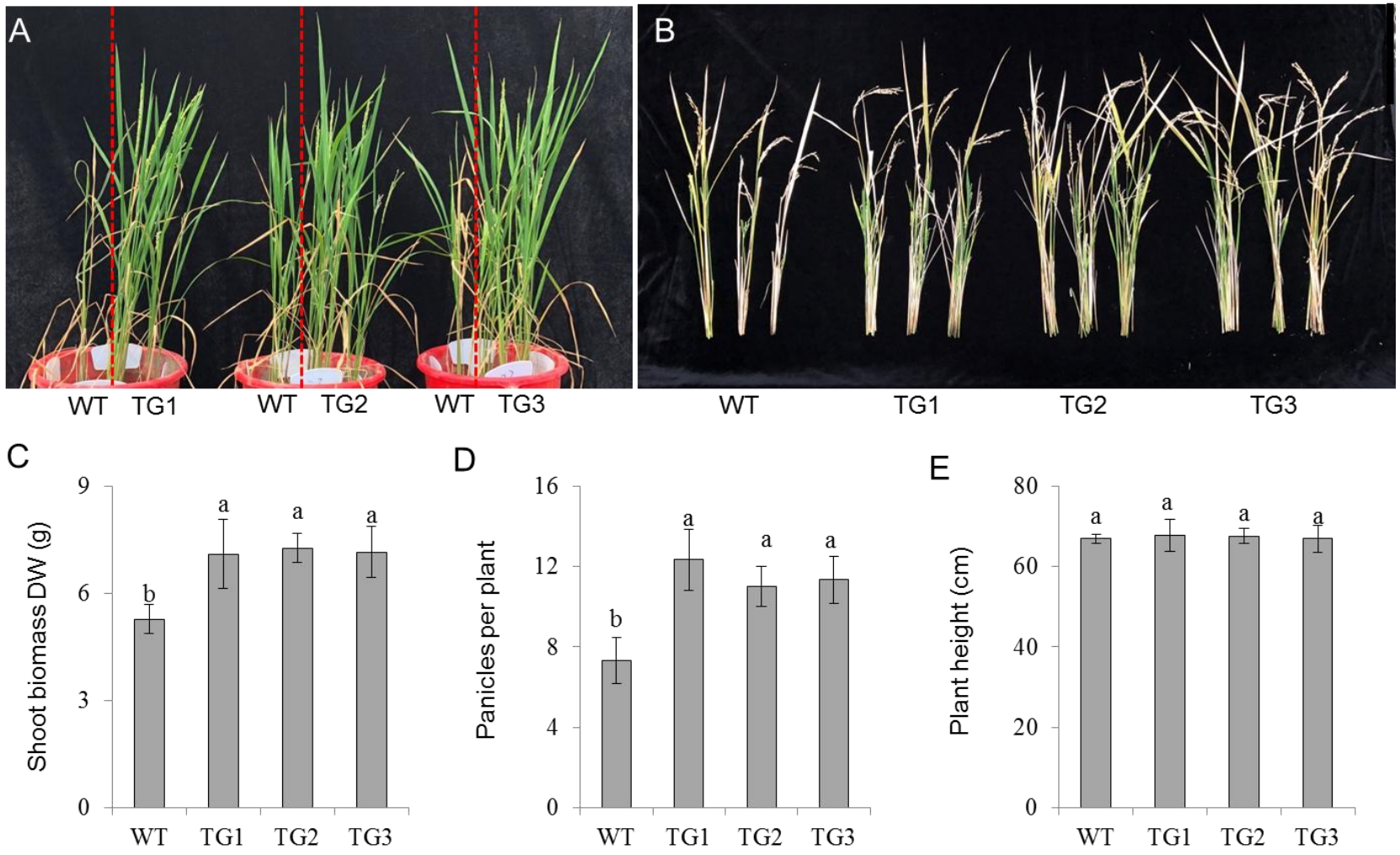






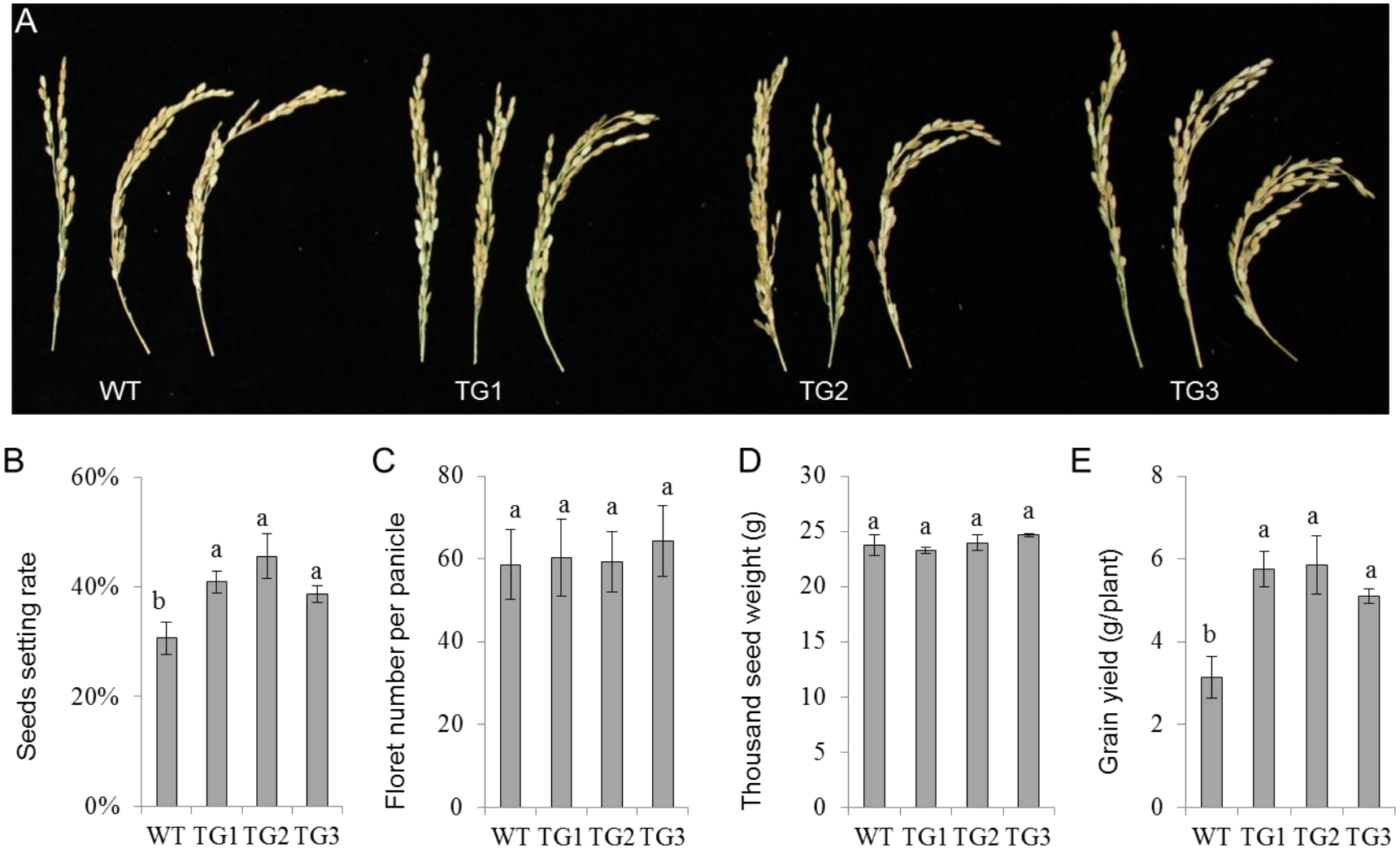
4. Significant increase of the biomass of the transgenic rice

Soil-based experiment



All lines grown in 3‰ saline soils (slightly salinized).

5. Increased seed setting rate of the transgenic rice

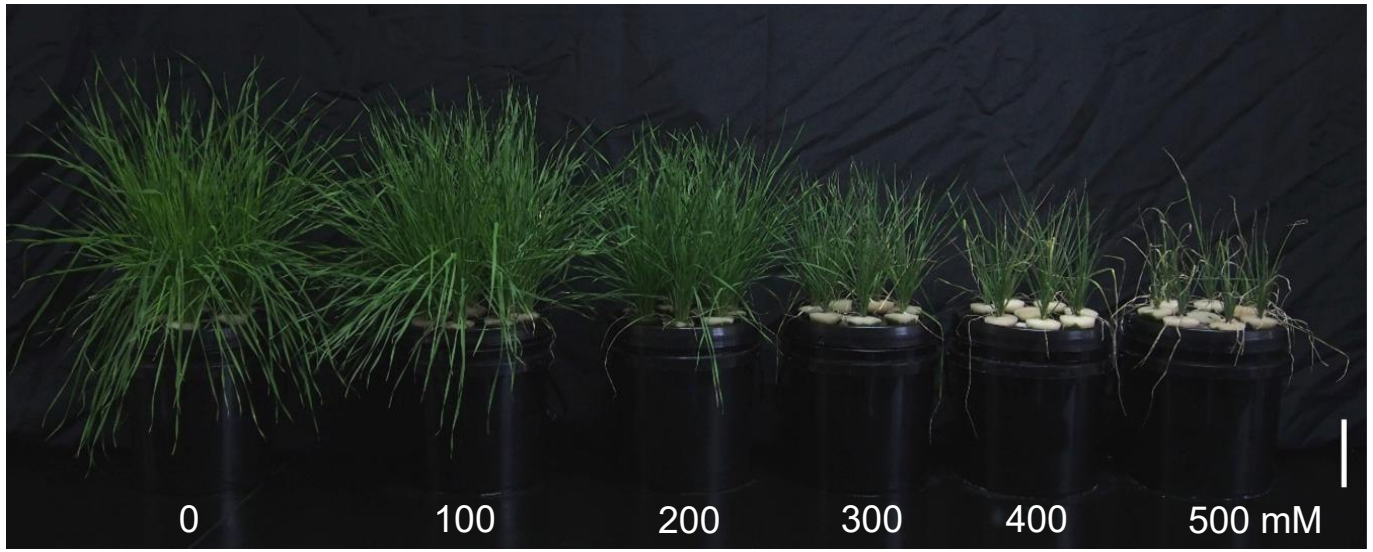


(Fu et al, Plant Physiol 2022)

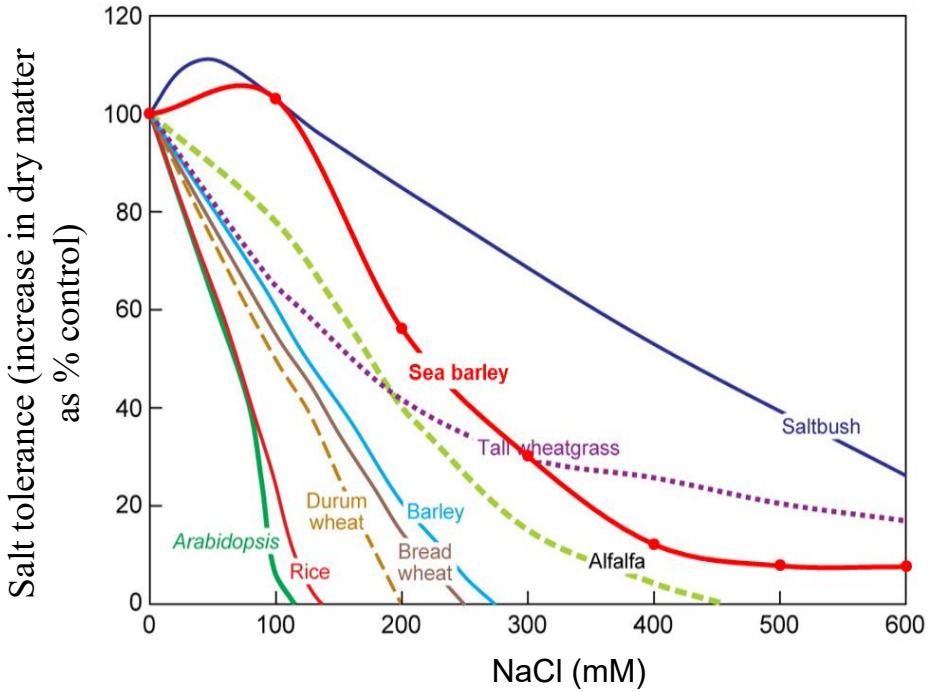
◆ Exploration of salt-tolerant genes in halophytes

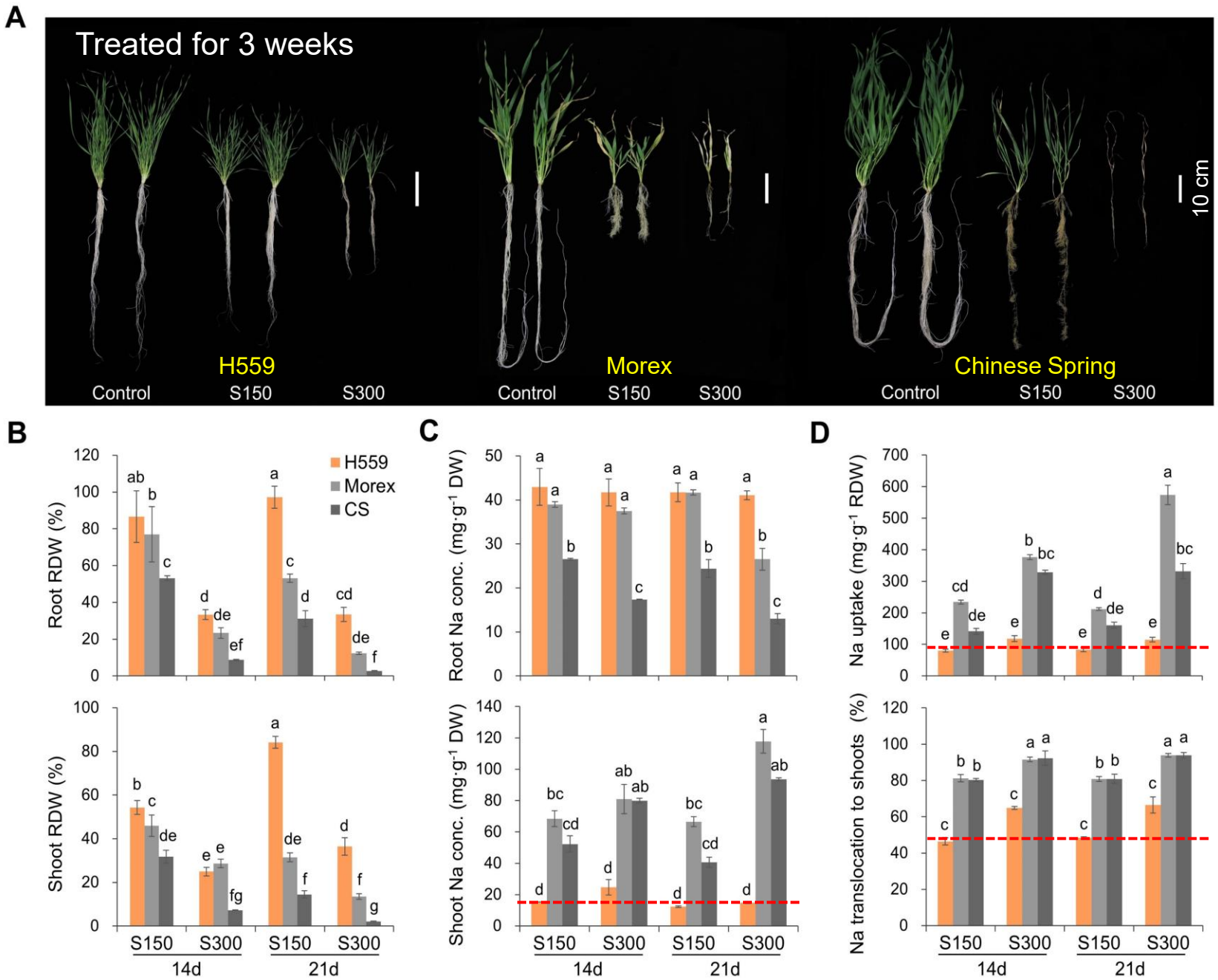
1. Halophytes in the Poaceae family: *Hordeum marinum*

(Sea barley)

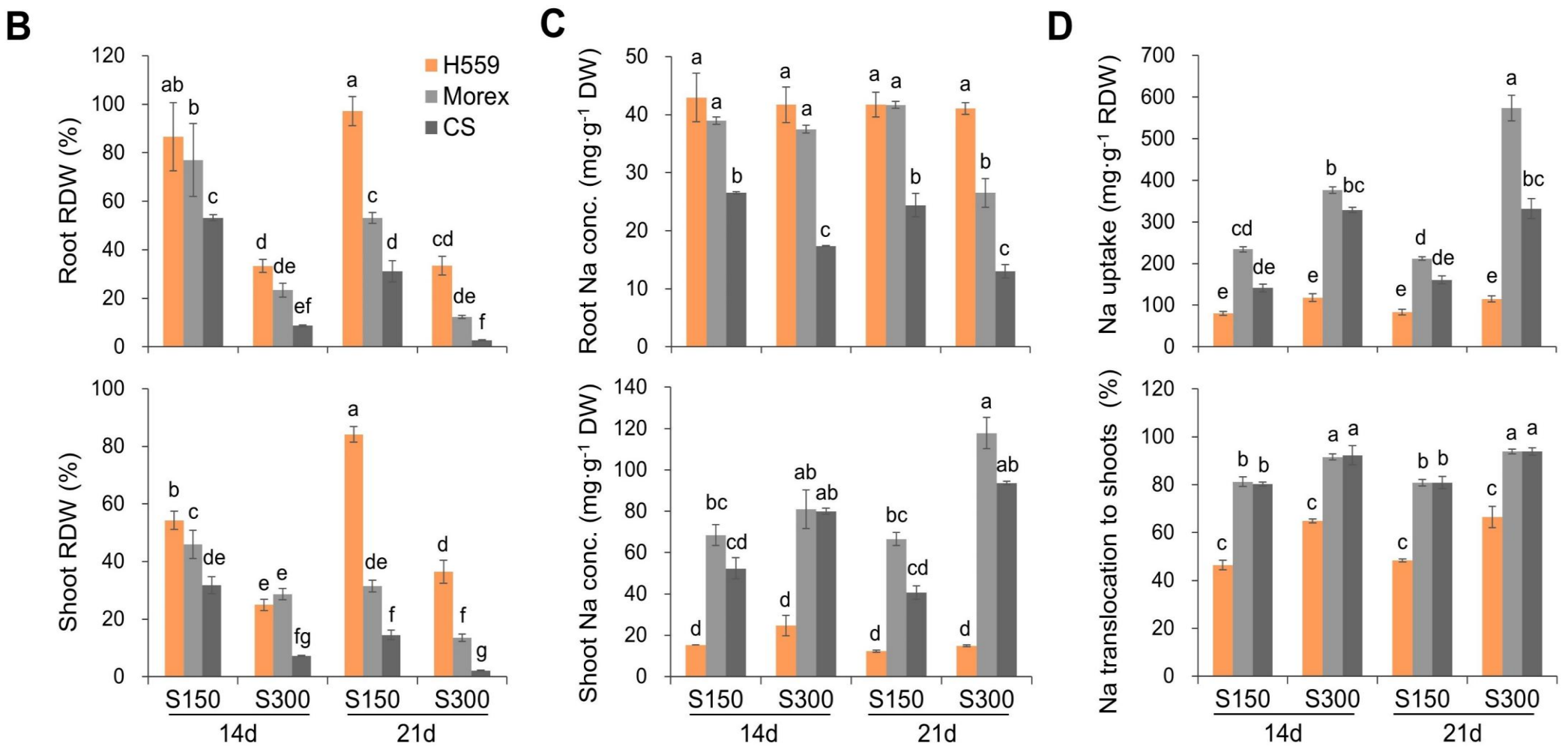


Hordeum marinum accession H559

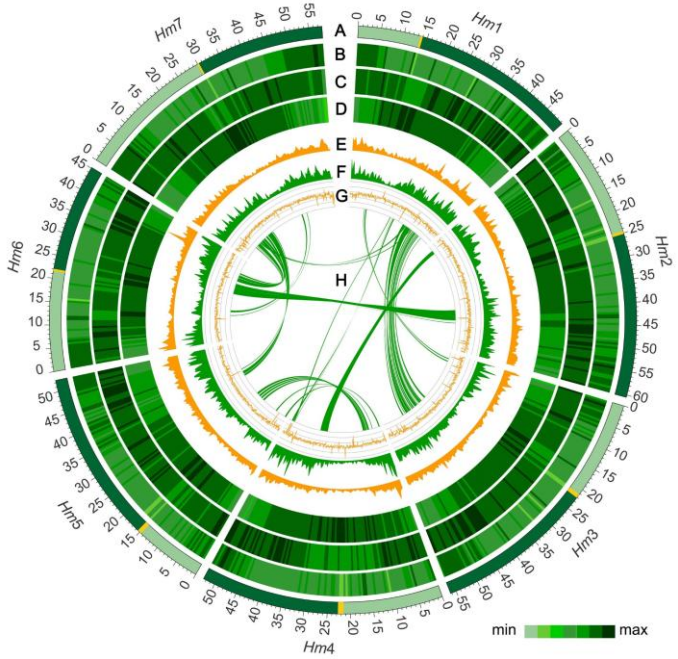



A
Treated for 3 weeks
H559
Morex
Chinese Spring
Control
S150
S300
10 cm
B
Root RDW (%)
Shoot RDW (%)
H559
Morex
CS
C
Root Na conc. (mg·g-1 DW)
Shoot Na conc. (mg·g-1 DW)
D
Na uptake (mg·g-1 RDW)
Na translocation to shoots (%)
14d
21d

2. Sea barley: low Na^+ accumulation and translocation



3. A high-quality reference genome of sea barley

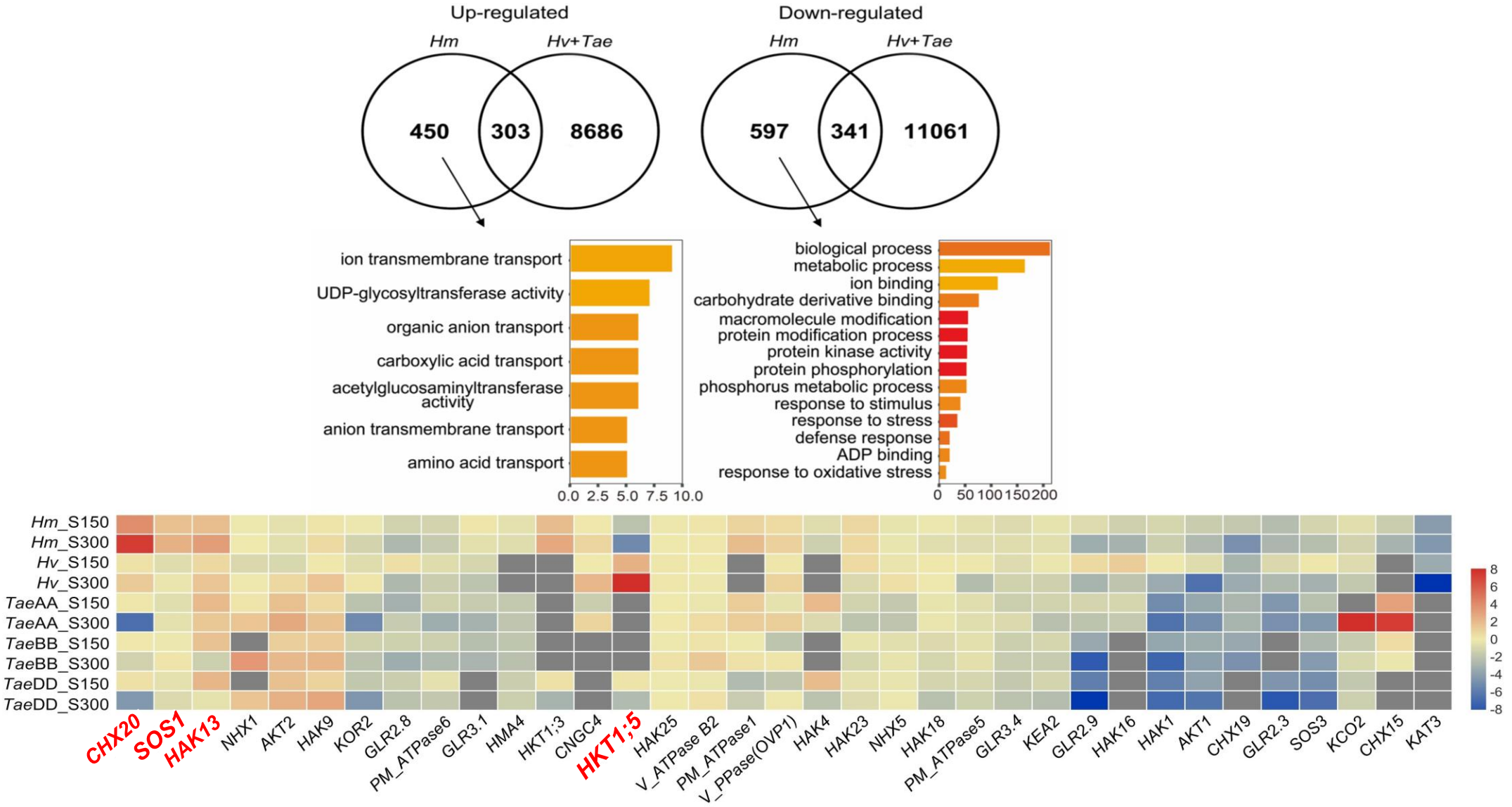


Platform	Total Data (G)	Coverage (×)
Illumina	789.1	~207.7
PacBio	325.3	~85.6
10x Genomics	388.4	~102.2
Hi-C	434.9	~114.4

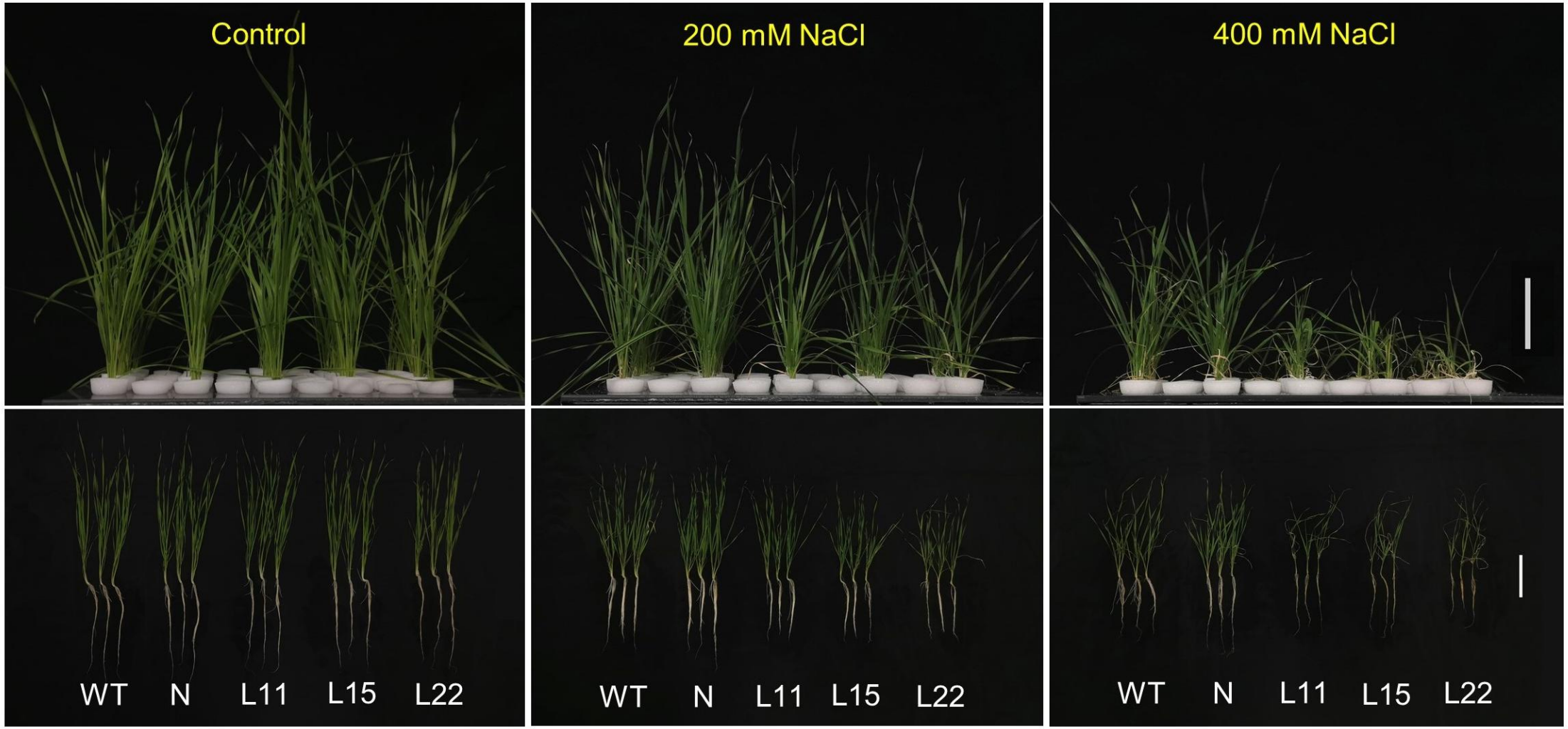
Assembly statistics	Values
Estimate of genome size (Mb)	3,996
Total length of scaffolds (Mb)	**3,816**
Total number of scaffolds	**1,197**
Scaffold N50 (Mb)	**524.47**
Scaffold N90 (Mb)	450.13
Total number of contigs	2,090
Contig N50 (Mb)	**6.83**
Contig N90 (Mb)	1.81
Gap counts	893
Gap length (Mb)	0.09
Anchored (Mb)	**3,694 (96.8%)**
GC content (%)	44.5
Percentage of repeat sequences	82.2%
Complete BUSCOs (%)	97.9
LTR Assembly Index (LAI)	12.7

(Kuang et al, Plant Comm 2022)

4. Identification of salt-tolerant genes in sea barley

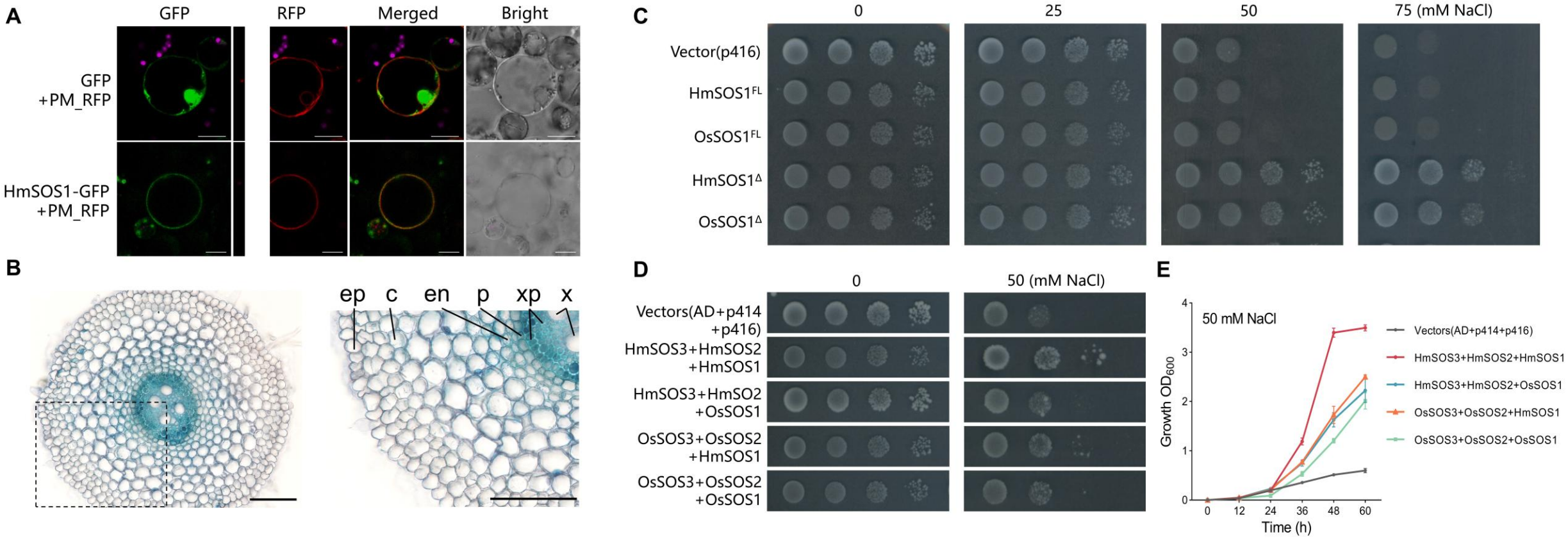


Identification of salt-tolerant genes in sea barley (*HmSOS1*)



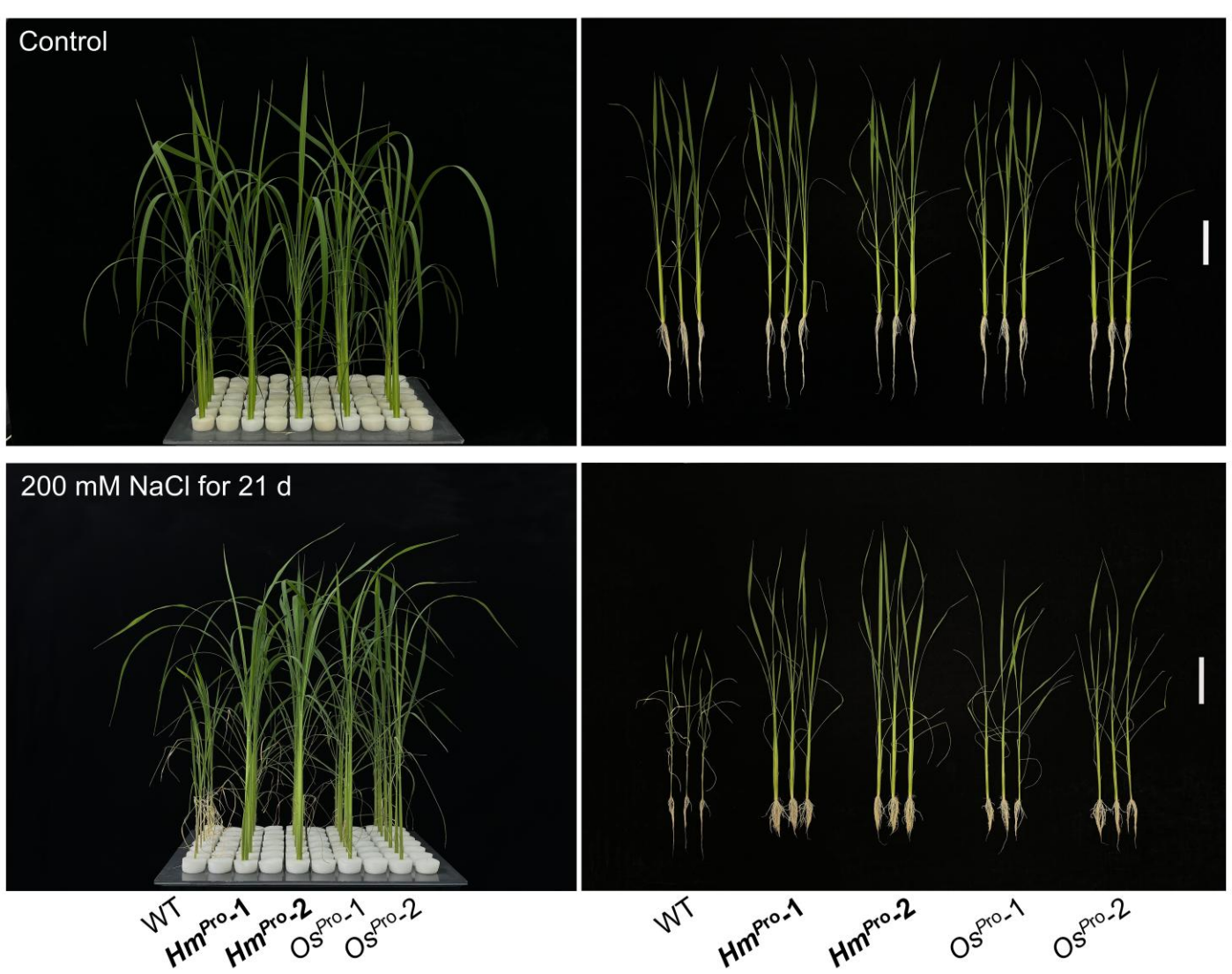
(Kuang et al, Plant Comm 2022)

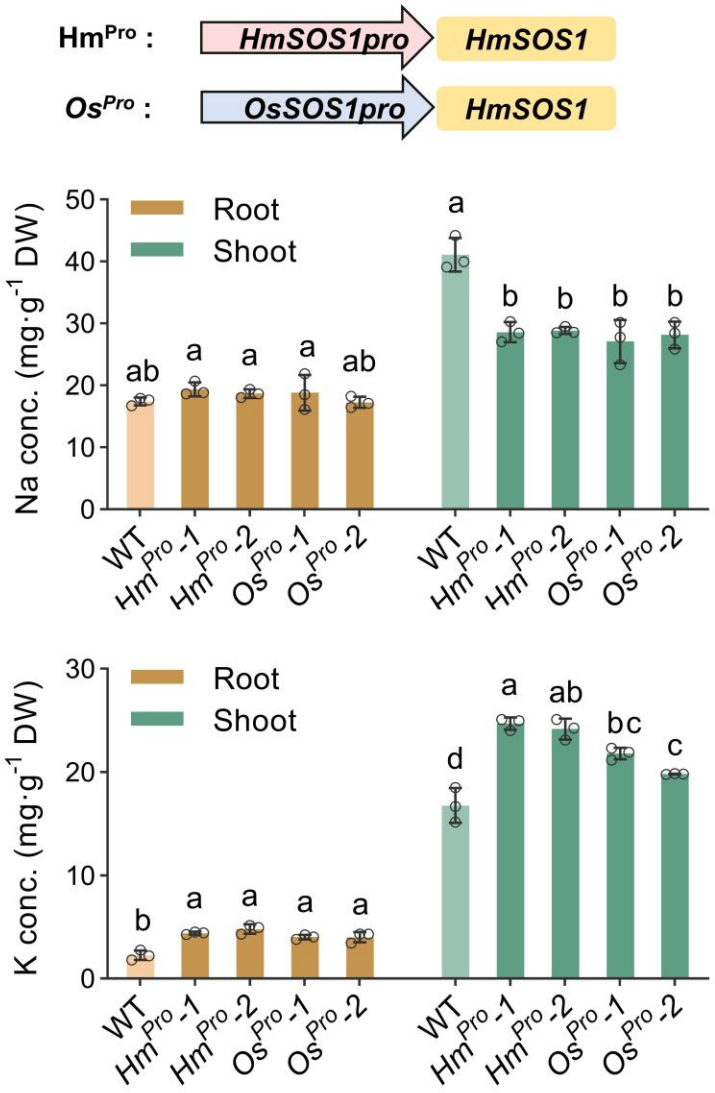
HmSOS1: a root PM transporter for sodium efflux



(Kuang et al, Unpublished)

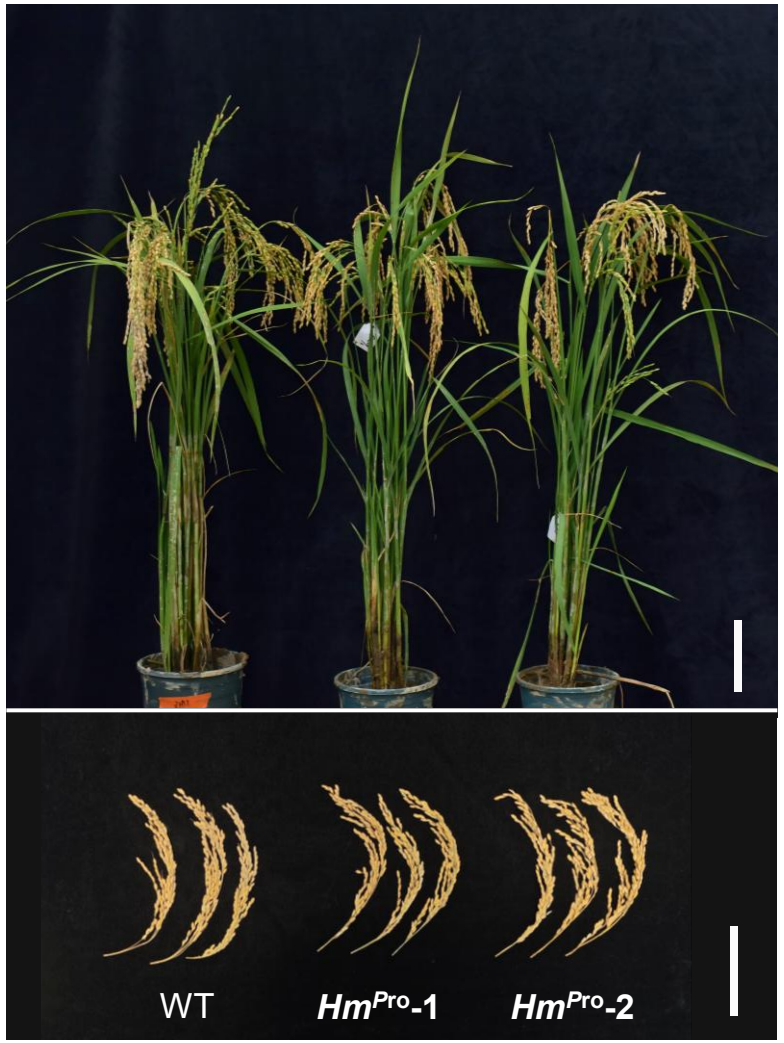
5. Significant improvement of salt tolerance of the transgenic rice

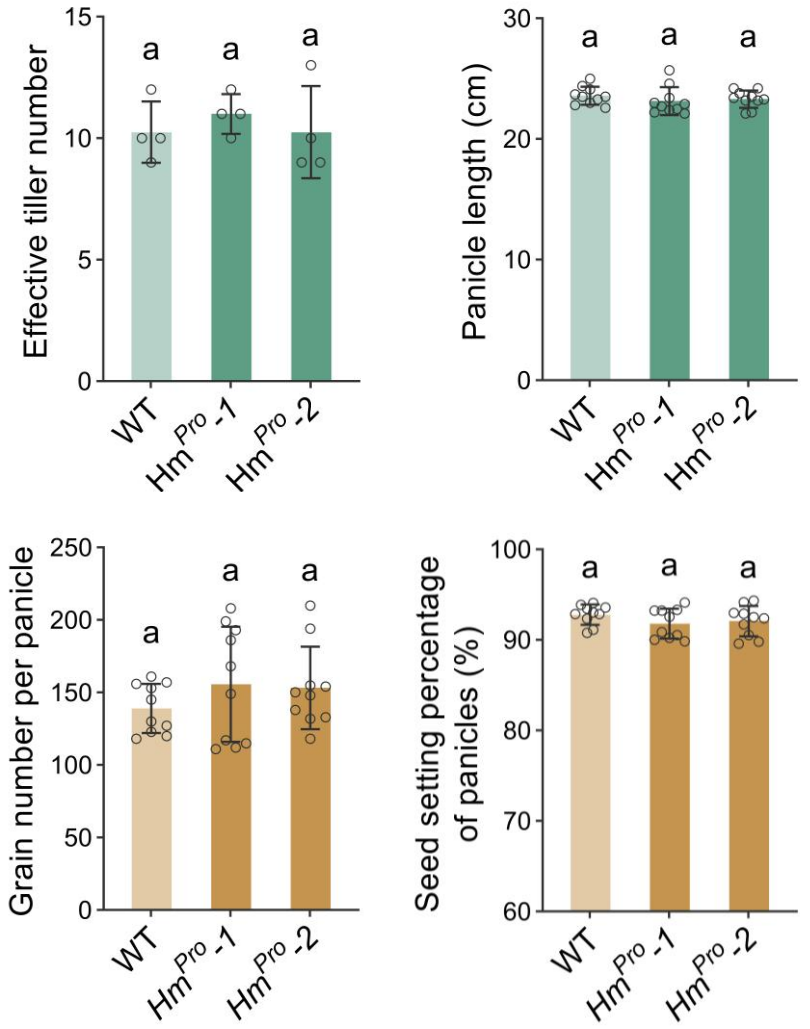




(Kuang et al, Unpublished)

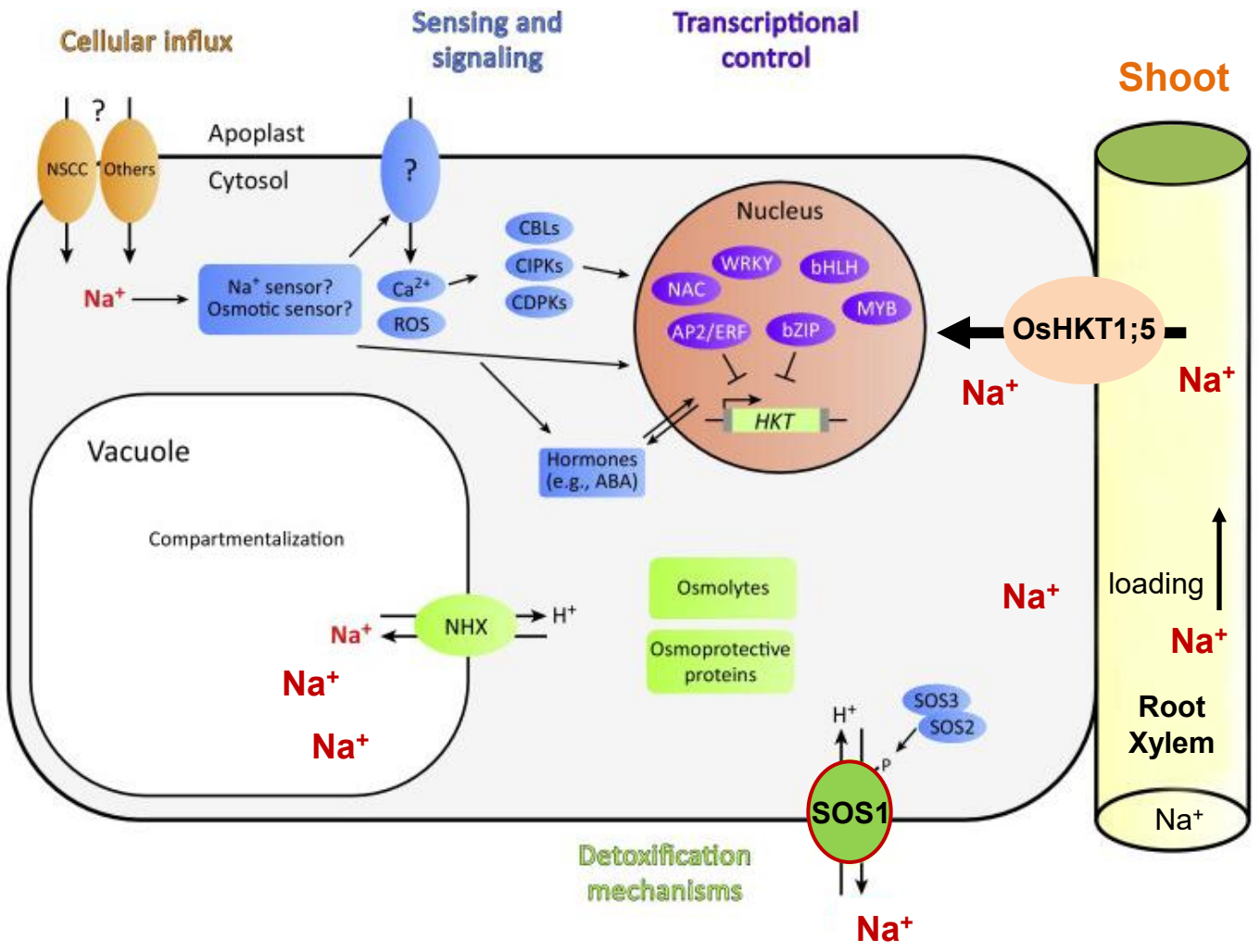
No effect on the agronomic traits under normal condition





(Kuang et al, Unpublished)

Summary: Strategies for reducing shoot Na^+ content in rice




Thank you!