Dr. Toshio Yamaguchi (U.C. Davis)
Dr. Lianhai Fu (U.C. Davis)
Jordan Sottosanto (U.C. Davis)
Marina Large (U.C. Davis)
Prof. Larry Teuber (U.C. Davis)

Dr. Maris Apse (Arcadia BioSciences)
Dr. Jos van Boxtel (Arcadia BioSciences)

Prof. Juan M. Ruiz (Granada, Spain)
Prof. Shimon Gepstein (Technion Institute, Israel)
Dr. Amira Gepstein (Technion Institute, Israel)
Dr. Abdel Ismail (IRRI, Philipines)
Dr. Ju-Kon Kim (Myongji Univ, Korea)

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Arcadia BioSciences Inc.
California Specialty Crops Program,
Will.W. Lester Endowment, U.C.Davis

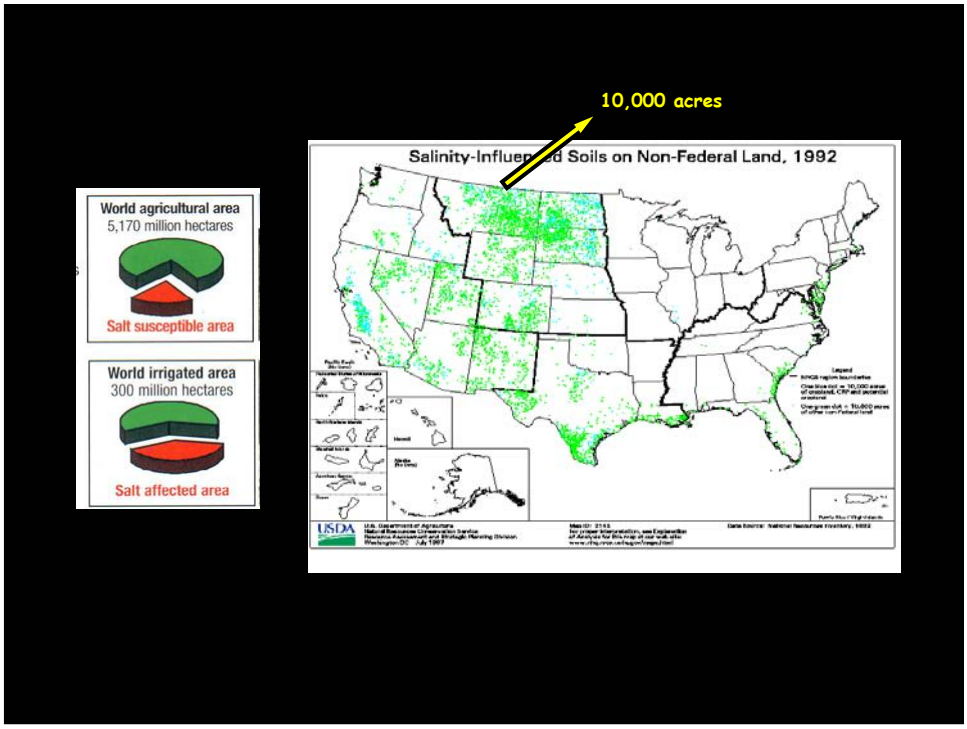
Extension and global distribution of salt-affected soils

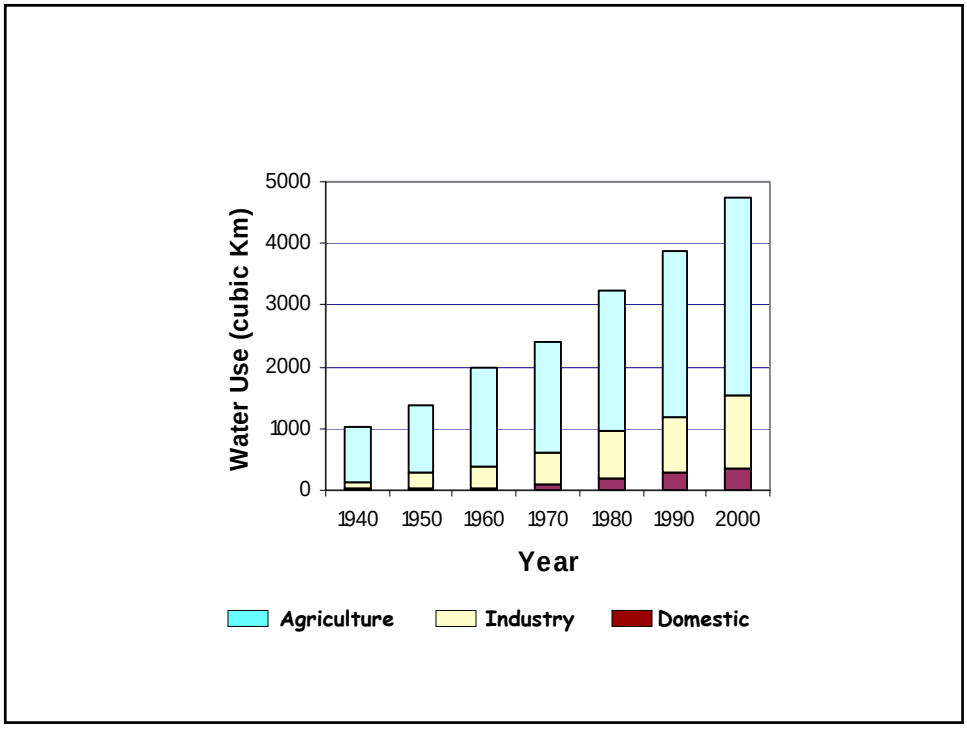
FIGURE 2 Global distribution of the salt-affected soils.

TABLE 1 Salt-Affected Soils on the Continents and Subcontinents

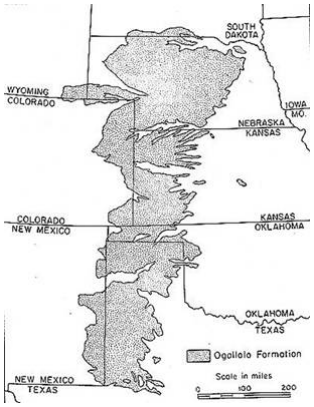
Continent	Area (millions ha)
North America	15.7
Mexico and Central America	2.0
South America	129.2
Africa	80.5
South Asia	87.6
North and Central Asia	211.7
South-East Asia	20.0
Australasia	357.3
Europe	50.8
Total	954.8

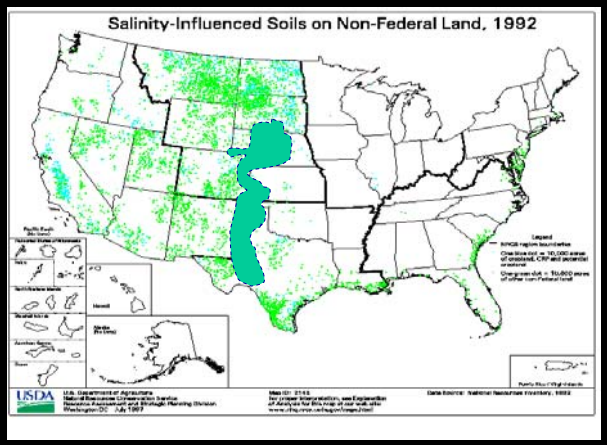
Pessarakli and Szabolcs, 1999


10,000 acres
World agricultural area
5,170 million hectares
Salt susceptible area
World irrigated area
300 million hectares
Salt affected area
Salinity-Influenced Soils on Non-Federal Land, 1992


Water Use (cubic Km)
5000
4000
3000
2000
1000
0
1940
1950
1960
1970
1980
1990
2000
Year
Agriculture
Industry
Domestic

Ogallala aquifer





A16 YT THE NEW YORK TIMES **NATIONAL** FRIDAY, OCTOBER 17, 2003

Pact on Colorado River Will Send Farmers' Water To the Growing Cities

Continued From Page A1

ity, referring to Colorado, Wyoming, Utah and New Mexico. "As all of these states develop, finding a point of water stability is essential."

Under the agreement, farmers in the Imperial Valley, a fertile basin in Southern California that would be a wasteland without water from the Colorado, must eventually sell hundreds of thousands of acre-feet of water a year to San Diego County, a sprawling coastal metropolis of more than three million people with virtually no local water supplies.

The San Diego district will pay market prices for the water, or about $258 per acre-foot at the outset. The farmers typically pay only delivery fees for their water, which amount to $15 or $20 per acre foot.

An earlier version of the deal collapsed in December when many of Imperial Valley's farmers balked at the notion of selling their water, but as water experts predicted then, it was only a matter of time before agricultural interests relented to the unstoppable march of the urbanized West.

"About every 100 years, we have something like this we can agree upon," said Maureen Stapleton, general manager of the San Diego County Water Authority. "It is a day of historic celebration."

But noticeably absent from the festivities on Thursday, which included an afternoon reception at Hoover Dam and an evening banquet at the Mandalay Bay Resort and Casino in

Farmers give cities their water; the government gives farmers money.

middle on this," said Bruce R. Kuhn, a district board member who was the swing vote. "This is a first. This is like the pioneers coming West."

But Lloyd Allen, an Imperial farmer who is president of the irrigation district, showed up on Thursday in his cowboy hat and heaped praise on Ms. Norton and Gov. Gray Davis of California, who pushed the negotiations forward after December's impasse and helped break a deadlock by agreeing to state assistance for the Salton Sea, a salty body of water brimming with bird life in the Imperial Valley that relies on agricultural runoff to keep from drying up.

"I am going to go out there in the middle of that bridge and I am going to get on my hands and I am going to kiss that dam," Mr. Allen told the gathering. "And if I could hug it, I would hug it."

He continued, "This thing has made where I live a beautiful, beautiful valley. Now I find out it is going to make a lot more beauty over there on that coastal plain because you are going to get a lot of water from this."

California had promised to limit its use of Colorado River water in the

Associated Press

At the water pact signing yesterday at Hoover Dam were, from left, were Gov. Gray Davis of California; Bennett Raley, assistant Interior secretary for water and science; and Interior Secretary Gale A. Norton.

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Salt concentrations

	ppm	mg/L	mM	EC (dS/m)
Pacific Ocean	32,000	32,000	550	50
Colorado River	650/750	650/750	11/13	1/1.2
Chicken Soup	600	600	10.5	0.95

ECONOMICAL IMPACT:

- Decline in productivity and yields
- Increased input (seeds, fertilizer) to compensate for yield reduction
- Reduced efficient water use
- Increased labor requirements, high costs

ENVIRONMENTAL IMPACT:

- Reduction of green cover, leading to soil erosion (crust formation, wind and water erosion)
- Leaching of nutrients, loss of organic matter, run-off, leading to the contamination of water supplies
- Increase of carbon dioxide released to the atmosphere

What are our options?

Management and Rehabilitation of salt-affected soils

Deep ploughing + levelling

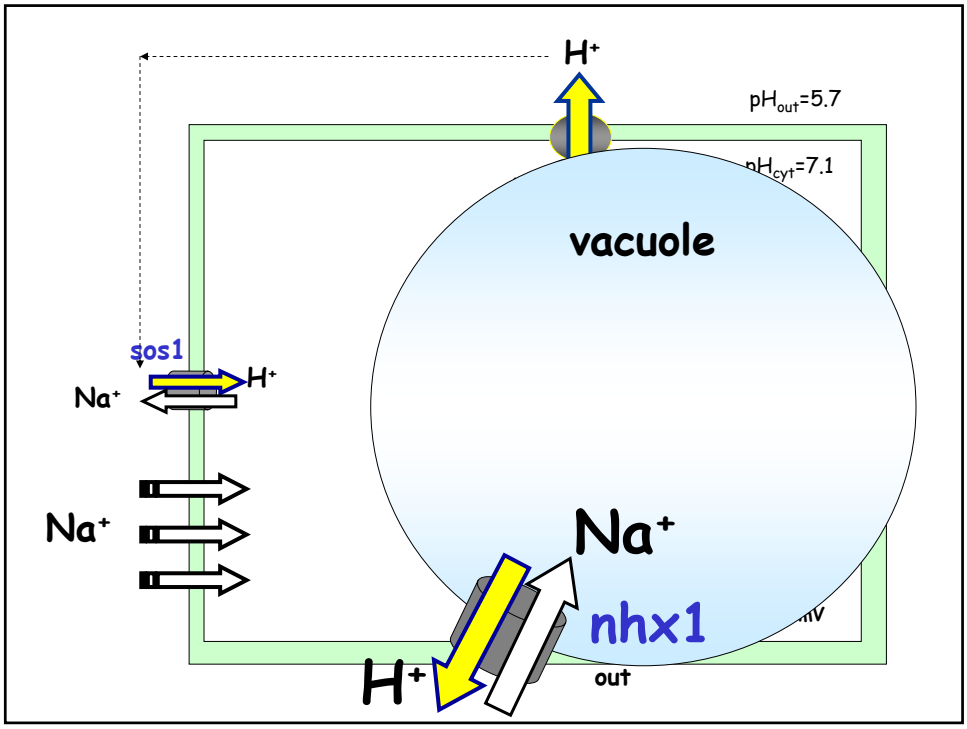
Leaching

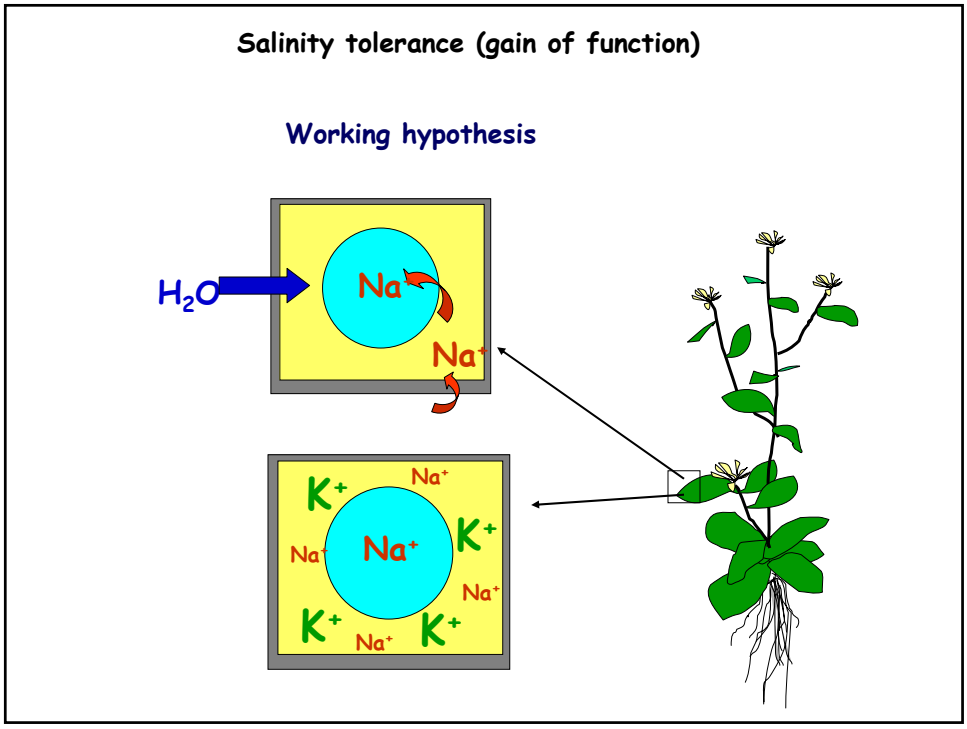
Drainage

Spreading of gypsum

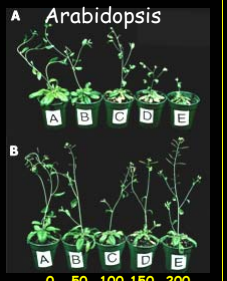
Mulching

Organic manure

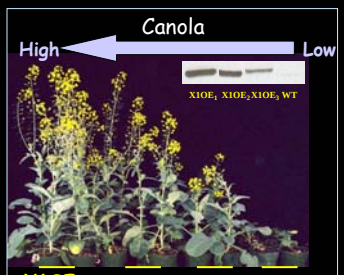

H+
pHout=5.7
pHcyt=7.1
vacuole
sos1
H+
Na+
Na+
Na+
nhx1
H+
out


Salinity tolerance (gain of function)
Working hypothesis
H2O
Na+
Na+
K+
Na+
Na+
K+
Na+
K+
Na+
K+

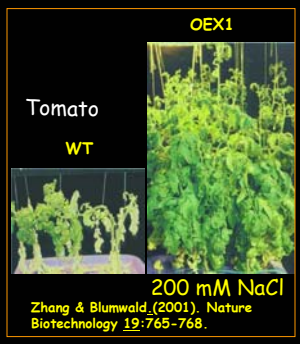
Overexpression of *AtNHX1* increases salt tolerance



(Apse, et al., 1999). Science 285,1256-1258



X1OE$_1$ X1OE$_2$ X1OE$_3$ WT
200 mM NaCl
Zhang, et al. (2001) PNAS 98:12832-12836.



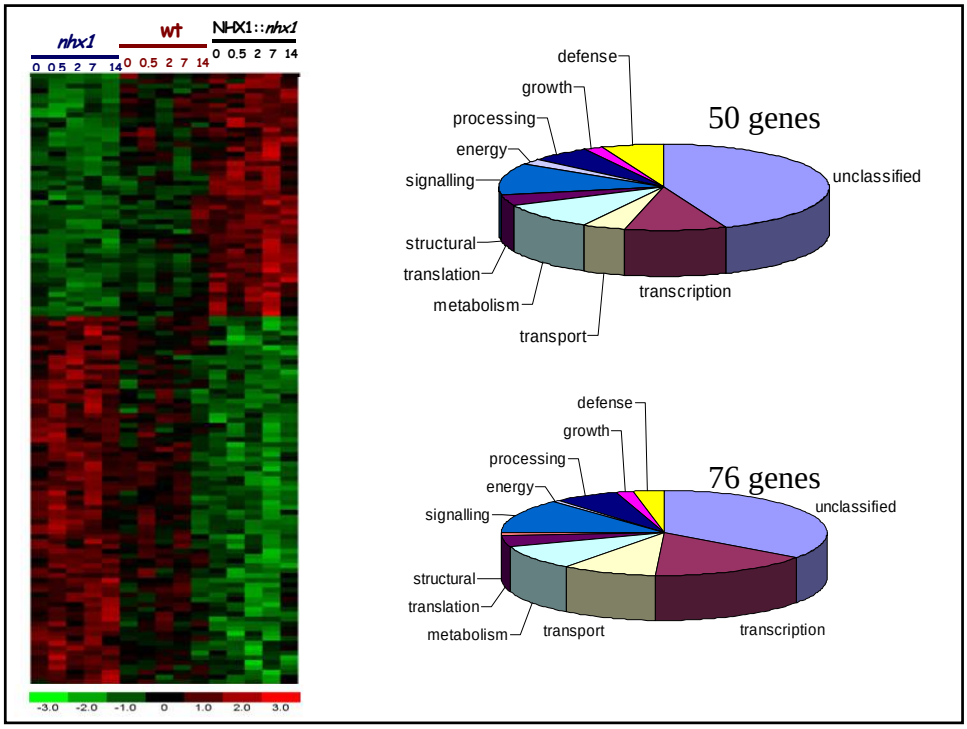
Zhang & Blumwald (2001). Nature Biotechnology 19:765-768.


T2 lines recovering from exposure to 100 mM NaCl for 35 days! (van Boxtel et al, 2005).

Rice [AgNHX1] (Ohta et al., 2002)
Maize [AtNHX1] (Yin et al., 2004)
Tobacco [GhNHX1] (Wu et al., 2004)
Cotton [AtNNHX1] (Zhang et al., 2004)
Wheat [AtNHX1] (Xue et al., 2004)

Only ONE gene?

DNA arrays from plants exposed to 100 mM NaCl (sublethal!!) for 0.5, 2, 7 and 14 days.
The plants were grown in pots,
All the plants were at the same developmental stage,
The only difference was the time of exposure to NaCl.



Challenges and Opportunities

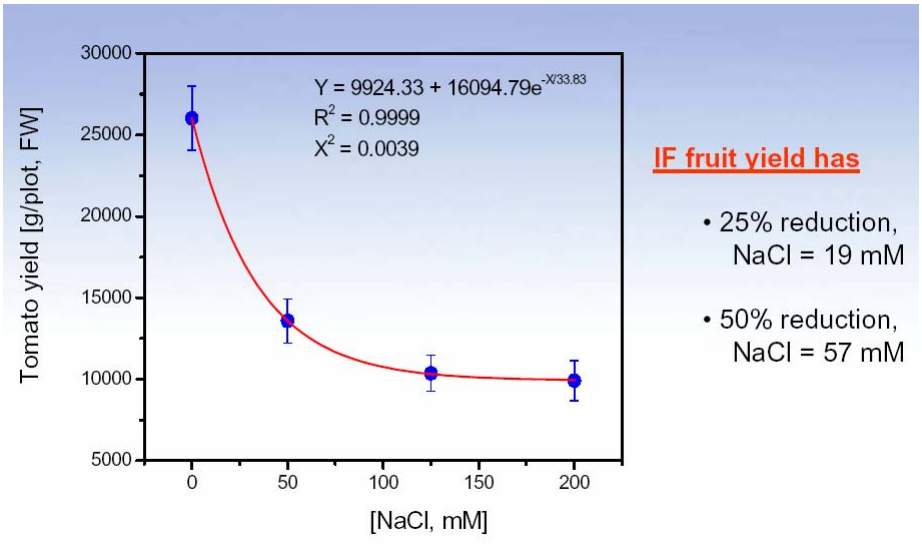
(1) From the lab to the field!

(a) Variability of salt levels in the field

- (i) naturally salty soils
- (ii) irrigation with salty water
  - type of irrigation!

(b) Interactions with other factors

- (i) soil fertility
- (ii) temperature
- (iii) soil pH (alkaline soils with pH>8.3)
- (iv) soil composition
  - Na_2SO_4
  - $MgSO_4$
  - Selenium
  - Boron



ZhongJin Lu et al, 2004

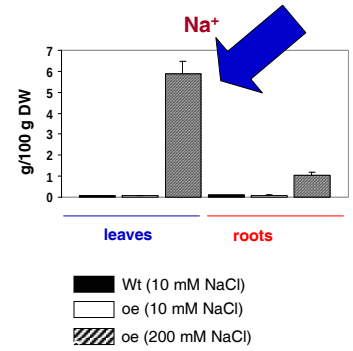
Challenges and Opportunities

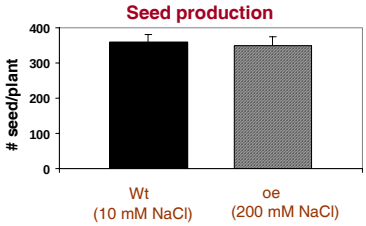
(2) Promoters most commonly used are primarily constitutively expressed (CaM35S, ubiquitin, actin, etc.). Stress-induced and/or tissue specific promoters display better phenotype.

(3) There have been a number of successes in the production of abiotic-stress tolerant plants using tobacco or *Arabidopsis*. We have to introduce these tolerance genes in crop plants.

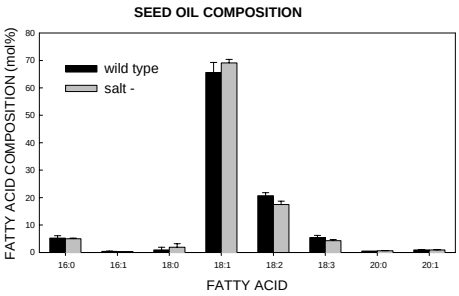
(4) We should produce transgenes in specific genetic backgrounds already characterized by breeding practices.

Canola (*Brassica napus*)

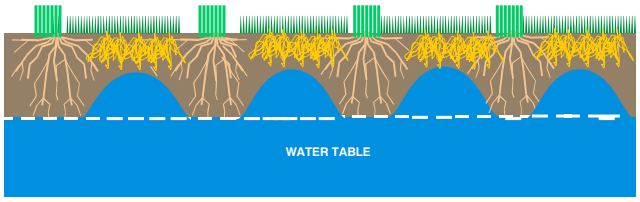




Wt (10 mM NaCl)
oe (10 mM NaCl)
oe (200 mM NaCl)



Strategy for soil reclamation (alfalfa)



Assuming:
1) an average (conservative) alfalfa yield of ≈ 20 ton/ha/year,
2) and a NaCl accumulation in the plant foliage of 8% of the dry mass,

the total amount of salt collected by the plants should be ≈ 1.6 ton/ha/year

The plants (containing NaCl) could be used for feed, eliminating the need for the use of salt blocks.

Challenges and Opportunities

(2) Promoters most commonly used are primarily constitutively expressed (CaM35S, ubiquitin, actin, etc.). Stress-induced and/or tissue specific promoters display better phenotype.

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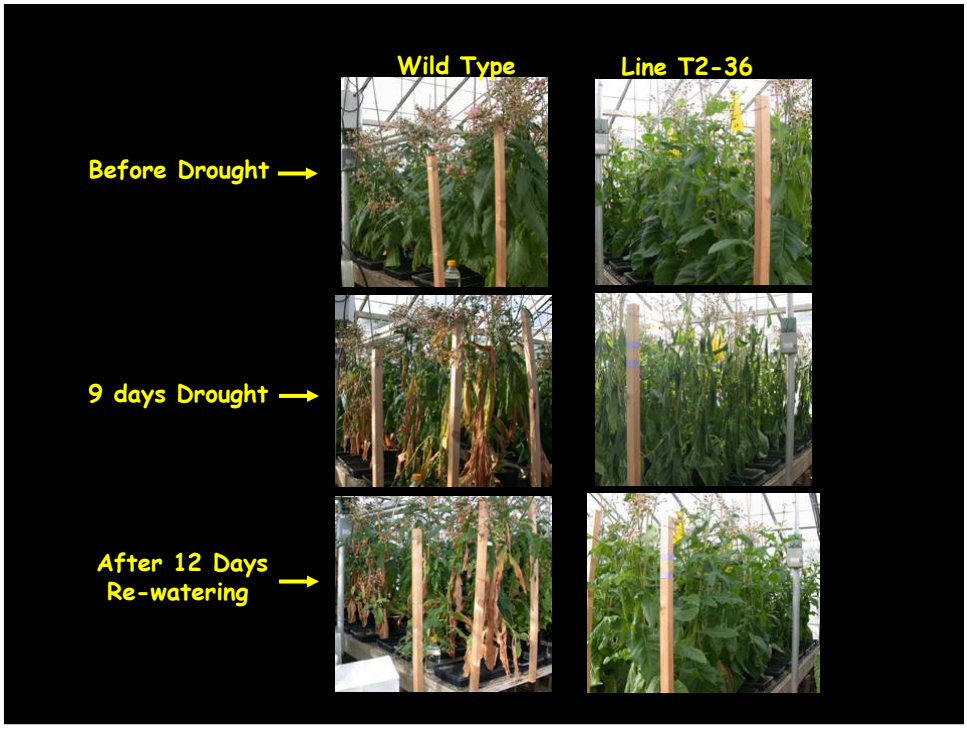
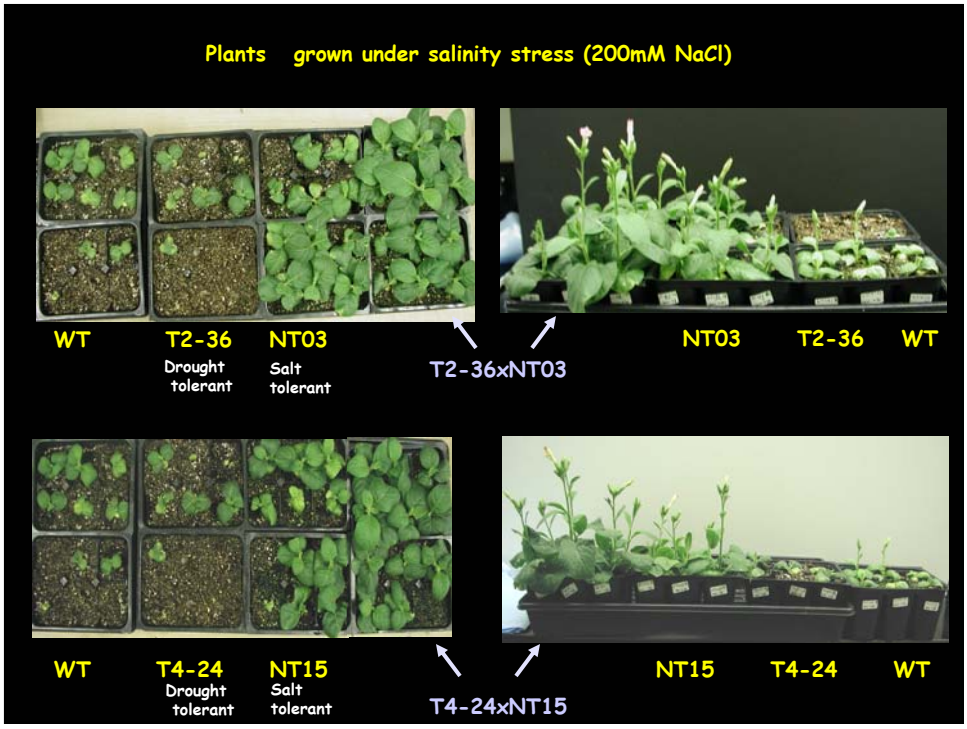
(5) We need to develop rational concepts for combining genes.


Wild Type
Line T2-36
Before Drought
9 days Drought
After 12 Days
Re-watering


Plants grown under salinity stress (200mM NaCl)
WT
T2-36
Drought tolerant
NT03
Salt tolerant
T2-36xNT03
NT03
T2-36
WT
WT
T4-24
Drought tolerant
NT15
Salt tolerant
T4-24xNT15
NT15
T4-24
WT

Challenges and Opportunities

(1) Promoters most commonly used are primarily constitutively expressed (CaM35S, ubiquitin, actin, etc.). Stress-induced and/or tissue specific promoters display better phenotype.

(2) There have been a number of successes in the production of abiotic-stress tolerant plants using tobacco or *Arabidopsis*. We have to introduce these tolerance genes in crop plants.

(3) We should produce transgenes in specific genetic backgrounds already characterized by breeding practices.

(4) We need to develop rational concepts for combining genes.

(5) It is the **phenotype** that counts!!