Examining Alfalfa Varieties and Salt tolerance

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Wagner farm, WA state, photo

What does the Future Hold?

Area	Population		Irrigated Cropland	Water Supply		Water Demand
	1985	2025	x1,000 ha	1985	2025	Change %
Africa	**543**	**1440**	**118**	**4520**	**4100**	**73%**
Asia	**2930**	**4800**	**1690**	**13700**	**13300**	**60%**
Australiana	**22**	**33**	**26**	**714**	**692**	**30%**
Europe	**667**	**682**	**273**	**2770**	**2790**	**30%**
N. America	**395**	**601**	**317**	**5890**	**5870**	**23%**
S. America	**267**	**454**	**95**	**11700**	**10400**	**93%**
Globe	**4830**	**8010**	**2520**	**39300**	**37100**	**+50%**
Vorosmarty et al., Science, 2008						

Not enough water for everyone

-- especially in drought years or when environmental restrictions are greater

Thursday, January 16, 2014: bulldozed almond trees in an orchard at Sagoupse Enterprises, western Fresno County. This third generation farmer removed 160 older almond trees (~10% of the crop) to reduce his demand for irrigation during a time of drastic water shortage. — Fresno Bee Staff Photo

Read more here: http://www.fresnobee.com/2014/01/18/3721739/desperatemeasuresfor-valley-farmers.html#storylink=cpy

Applied Water – CA Crops (DWR)

Table 1. Rank of Crops in Water Use (DWR) 1998-2005.

Crops	AW AF (x1,000)	Percent of Ag. WU
Alfalfa	5,623	19.1%
Pasture	3,348	11.4%
Rice	3,005	10.2%
Almond/Pistachio	2,600	8.8%
Cotton	2,315	7.9%
Other Decid. Tree	2,264	7.7%
All Truck	2,119	7.2%
Corn (80% silage)	1,801	6.1%
Vine	1,726	5.9%
Subtropical Tree	1,371	4.7%
Grain (some forage)	980	3.3%
Other Field Crops (some forage)	943	3.2%
Tomato (Pr)	775	2.6%
sugarbeet	259	0.9%
Dry Bean	220	0.7%
Safflower	82	0.3%
Total Water Use	29,430	100%

Forages

Forages

Forages

Forages

Forages

A question of Value

Table 2. Farm Gate Value of Top California Commodities (CDFA)			
Crop	2009	2010	2011
	$Gross Farm Receipts (x $billion)		
Milk & Cream	4.537	5.928	7.681
Almonds (shelled)	2.294	2.903	3.866
Grapes	3.260	[illegible]	3.860
Cattle & Calves	1.676	[illegible]	2.825
Nursery	2.513	2.357	2.683
Berries, + Strawberries	1.725	1.814	1.948
Hay (all)	0.926	1.033	1.735
Lettuce	1.744	1.605	1.513
Walnuts	0.747	1.028	1.323
Tomatoes	1.540	1.246	1.265
Flowers and Foliage	0.937	1.015	1.012
Cotton Lint, All	0.286	0.592	0.894
Pistachio	0.593	1.159	0.879
Rice	0.937	0.930	0.774
Total California	**$37,479**	**41,123**	**47.423**

26% of CA
Gross receipts

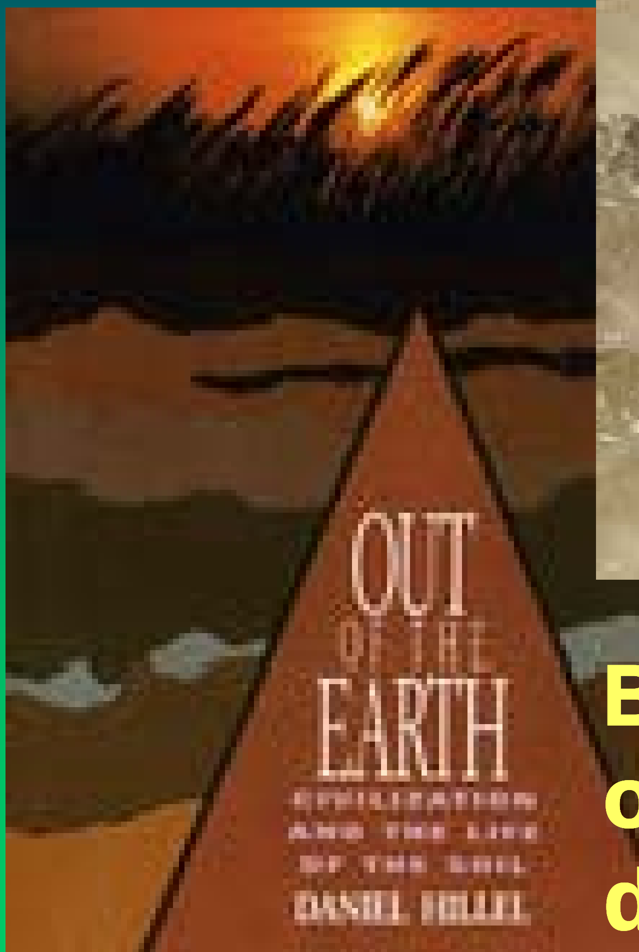
Salinity

Why is Salinity Important?

- Salinity poses a serious threat to agricultural production.
  - >800 million ha of land in the world is affected by salinity (Munns & Tester, 2008)
    - Accounts for 6% of total agricultural land area
  - Of the current 230 M ha of irrigated land, ~20% is salt affected.

- Most saline soils are found in arid and semi-arid regions

Irrigation and Salinity



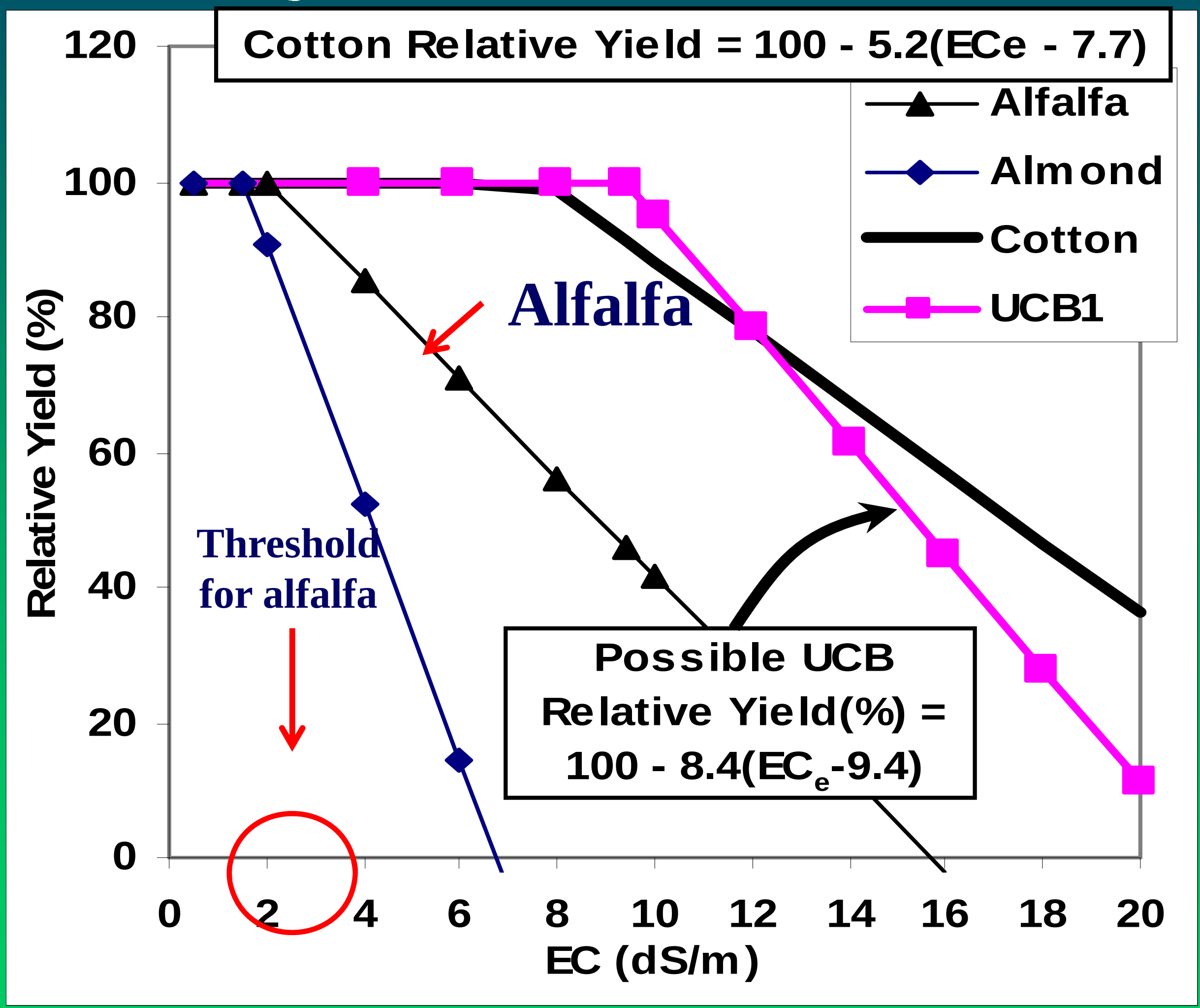
Babylon, Aral Sea, evidence of irrigation-induced salinity disasters

Salinity and Alfalfa

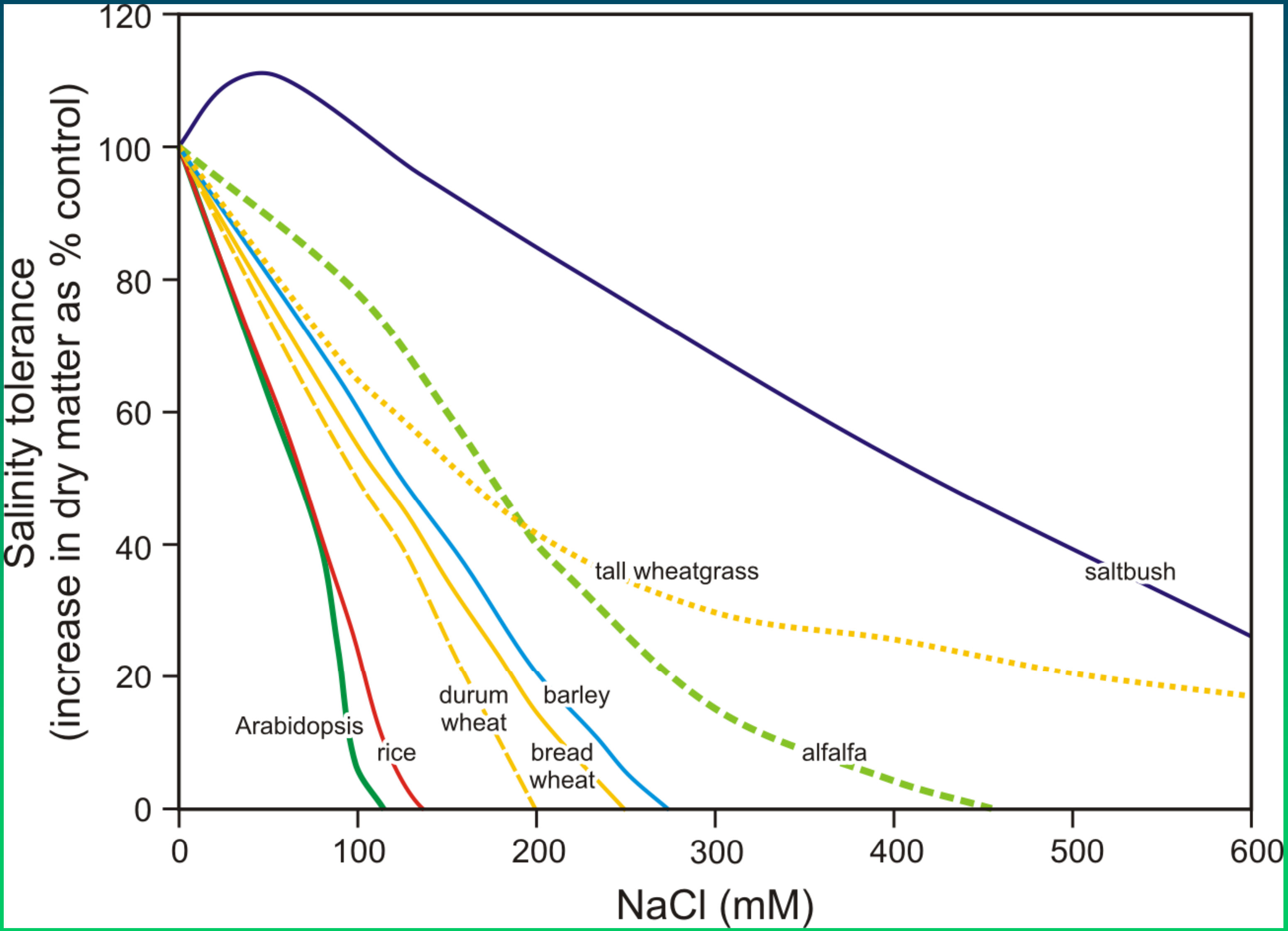
- Limited water supplies exacerbate salinity
- More precise methods increase salinity
- Alfalfa moved onto lower quality soils & water
- Deficit Irrigation likely (lack of drainage)
- Use of degraded water (dairy, municipal wastewater)
- Alfalfa is under higher $$ demand than many other salt-tolerant plants
- Alfalfa may be a good candidate for saline regions?

Alfalfa, according to literature, is only moderately salt tolerant

- the Maas-Hoffman salinity tolerance rankings list alfalfa as moderately sensitive due to a low threshold value (2 dS/m EC_e)



Growth of important species with increasing salinity (Australian work)



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Munns & Tester, Ann Rev Plant Biol, 2008

Key Questions

- Is alfalfa capable of sustaining higher irrigation water and soil ECs than previously thought?
  - *Maas-Hoffman yield loss threshold of 2.0 dS/m ECe (soil salinity) too low?*
- Do lines differ in tolerance?
- Differences in tolerance between developmental stages?
- Do we understand the mechanisms of tolerance?
- How to confirm putative salinity tolerances in the field?

However, Salinity Effects on Alfalfa are complex

- Sodic effects on soil crusting, drainage
  - Stand Establishment -Standing water during germination – crusting
- Resistance to water intake (salinity)
- Toxicity of specific ions
- Effects on early growth, establishment
- Effects on established plants
- Stand Loss, stand longevity

Normal growth vs. growth under saline conditions

Osmotic Effect

Toxic Ion Effect

Growth in Patches due to Salinity

Water Management & Drainage

Blake Sanden, Slide

Our approach to salt tolerance testing

- Consider Salt composition characteristic of this production area (NaCl, Na_2SO_4, ~boron)
- Soil system (or soil:sand mix) using a soil characteristic of the production area
- High transpiration conditions
- Consider stages of growth
- Long term*: field (2 years); greenhouse (6 months+)
  - Salinity has a cumulative effect
  - Alfalfa is a perennial
- Compare greenhouse v. field

Source water* for saline irrigation in our experiments (diluting hypersaline agricultural drainage water)

ECw (dS/m)	SAR	pH	Cl^- (meq/l)	SO_4^{2-} (meq/l)	Na^+ (meq/l)	Ca^{2+} (meq/l)	Mg^{2+} (meq/l)	B (mg/l)	NO_3-N (mg/l)	CO_3+ HCO_3 meq/L
28.1	39.2	7.8	132	165	209	26.4	30.3	49	51.2	7.6

-- saline-sodic-- alkaline-- high in boron

***Saline drainage water from Panoche Water District– San* Joaquin River Improvement Project (SJRIP)**

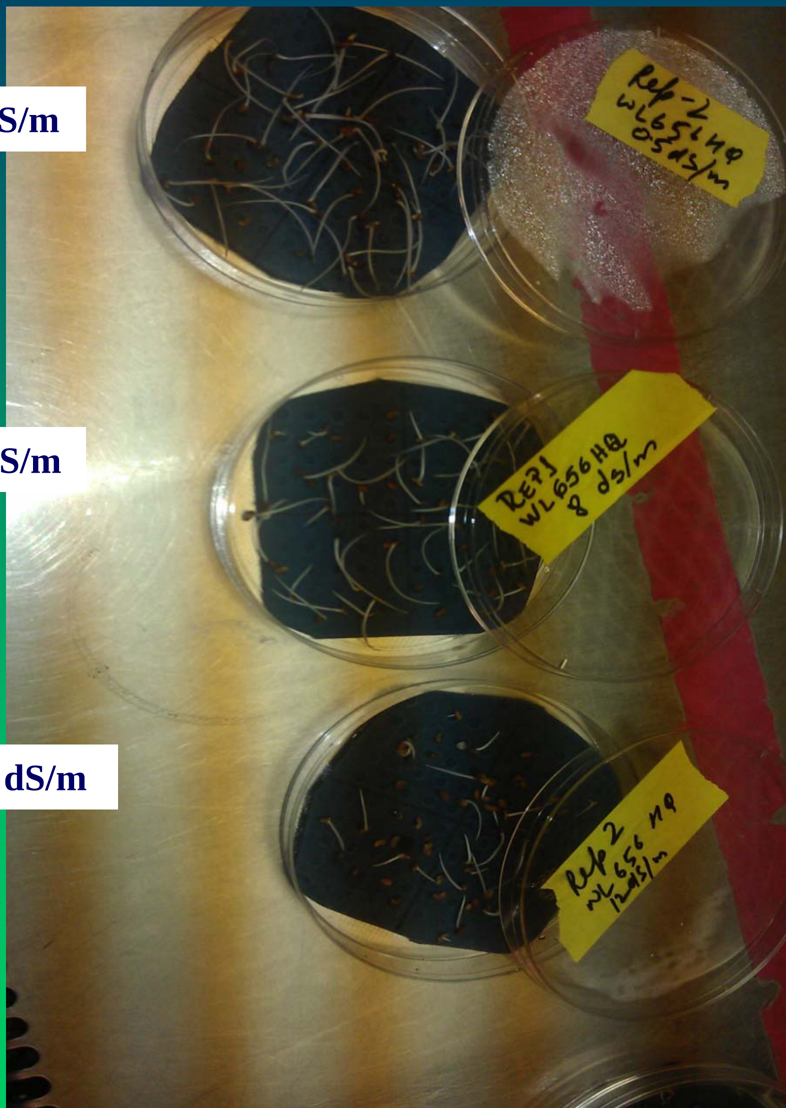
Materials & Methods

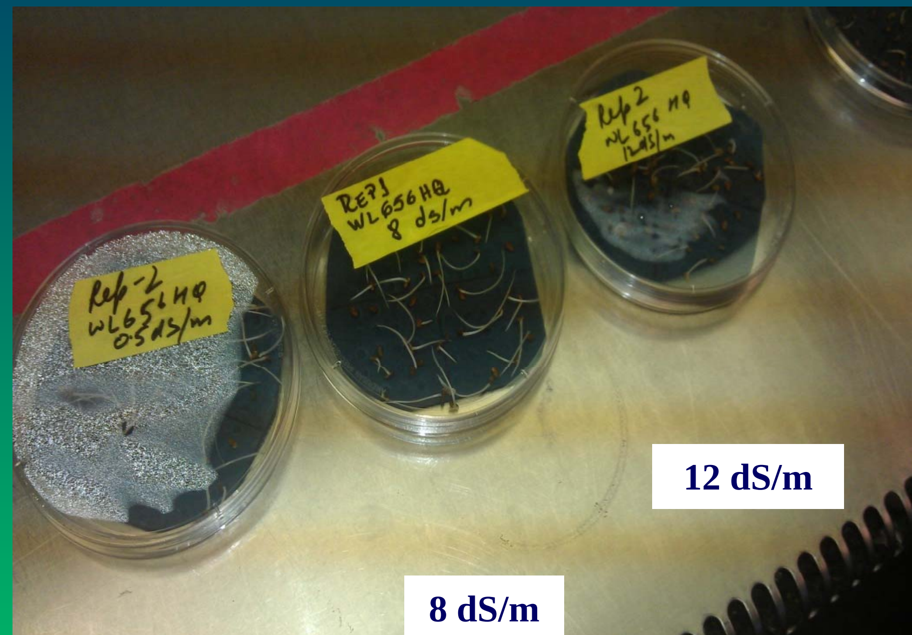
The study consisted of 3 phases:

- **Phase1: Seed Germination Response**
- **Phase 2: Evaluation of Seedling Emergence from soil**
- **Phase 3: Plant Response to Salinity: greeenhouse biomass, K/Na ratio and Cl- exclusion.**
- **Phase 4. Field Yield Evaluation of salinity tolerance**

PHASE 1
(Seed Germination)

Variety WL656HQ



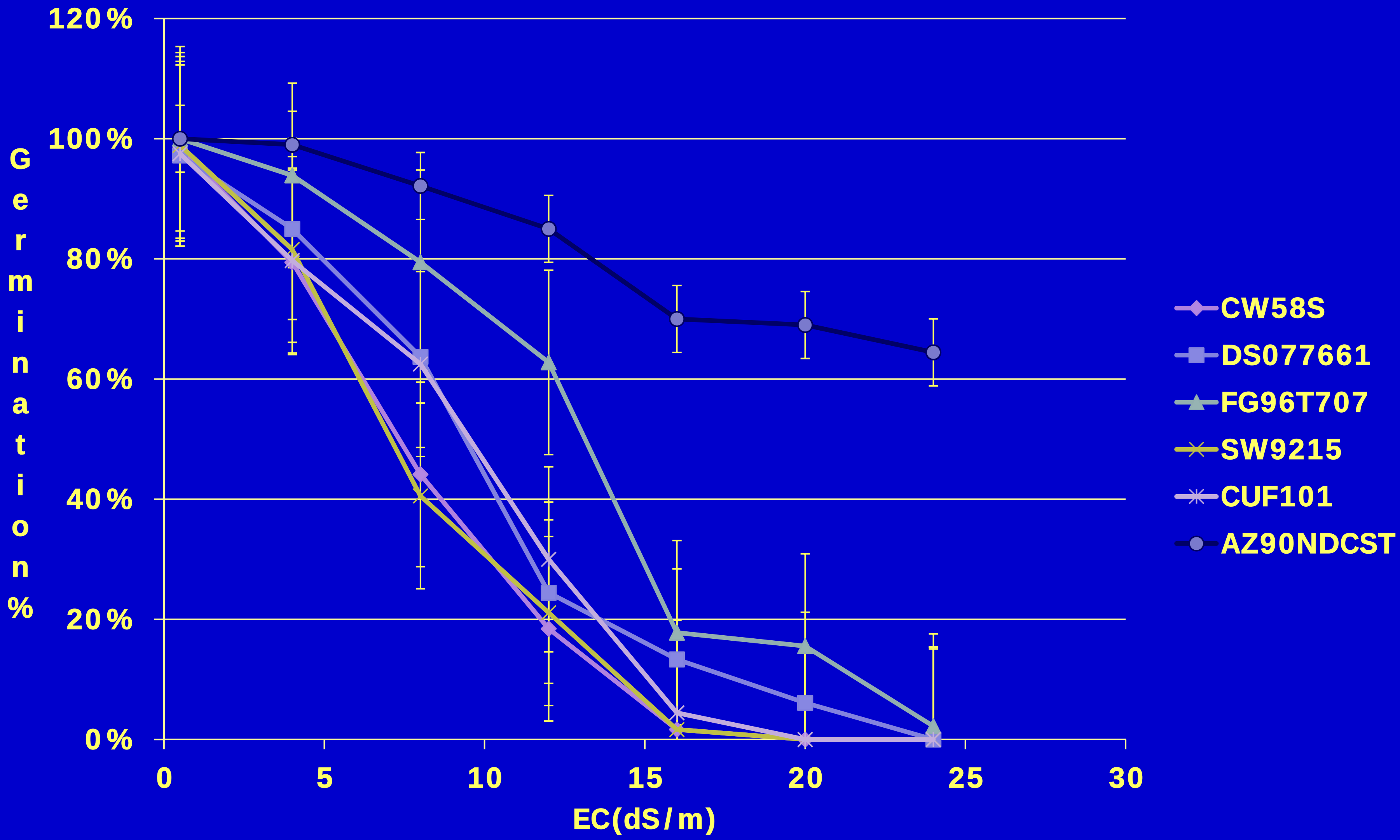


Effect of salinity treatments on the seed germination percentage of alfalfa cultivars

Salinity	Seed Germination%
0.5	97% [a]
4	88% [b]
8	60% [c]
12	41% [d]
16	13% [e]
20	7%[f]
24	4%[g]

**Means within same column and same letter are not significantly different at P<0.05.*

Final Germination Percentage (means ± S.E.)-- *Day 7*



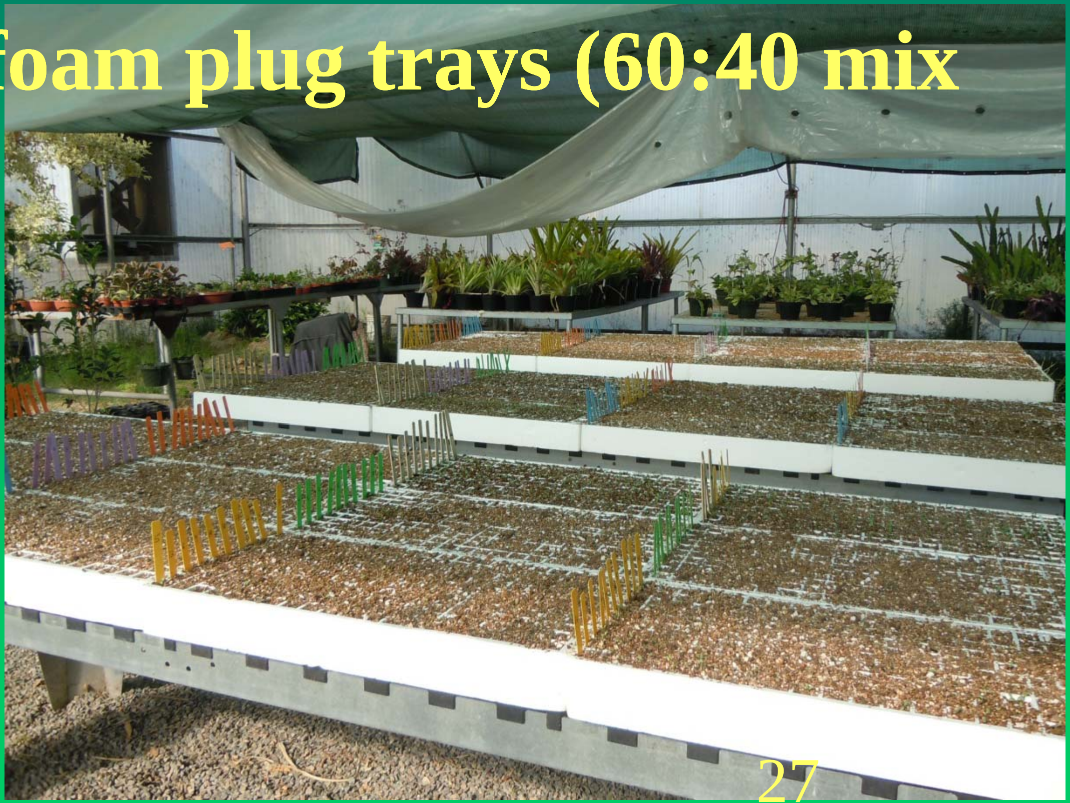
EC_{50} Values for Phase 1 (Day 7)

Tolerance	**Variety #**	**Variety name**	**EC50 Value(dS/m)**
Tolerant	18	AZ90NDCST	31.4
“	17	AZGERM SALT II	28
Moderately tolerant	7	HYBRIFORCE800	13.32
“	2	SW8421S	13.06
“	9	FG96T707	12.8
“	6	AMERISTAND901SQ	11.8
“	13	CW8028	11.7
“	5	WL656HQ	10.6
“	1	SW9720	10.5
“	3	6906N	10.5
“	14	DS077661	[illegible]
“	4	CUF101	[illegible]
“	20	CUF101	[illegible]
“	10	CW9S	9.11
Sensitive	12	CW58S	8.77
“	15	SW9215	8.68
“	11	CW48S	8.65
“	8	DS067092	8.63
“	19	MESA SIRSA	8.07
“	16	AZ88NDC	6.76

PHASE 2
(Seedling Response)

Phase 2

- 20 Varieties.
- 6 salt levels (0.5, 4, 8, 12, 16 and 20 dS/m).
- Experimental design: split plot with 3 replications.
- Greenhouse-- styrofoam plug trays (60:40 mix of sand & soil)



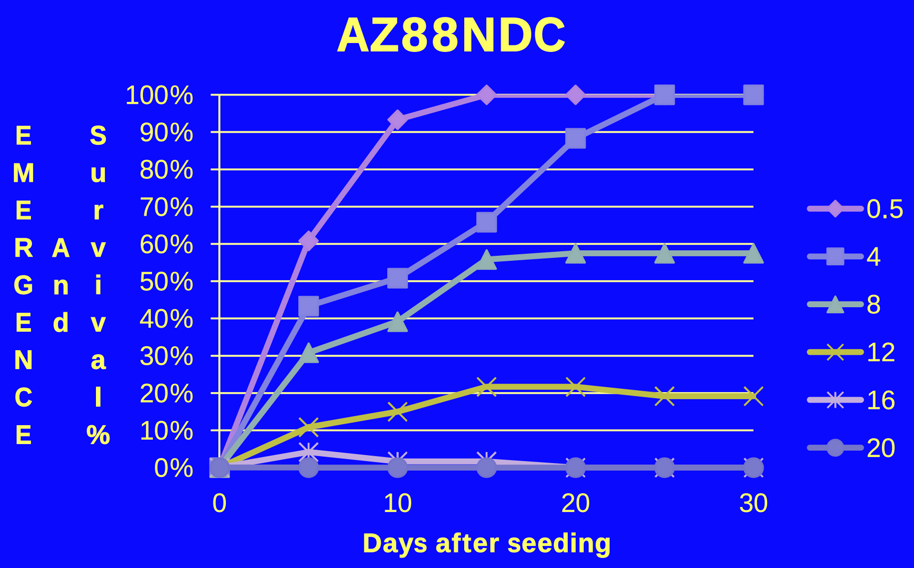
Effect of salinity treatments on the seedling biomass.

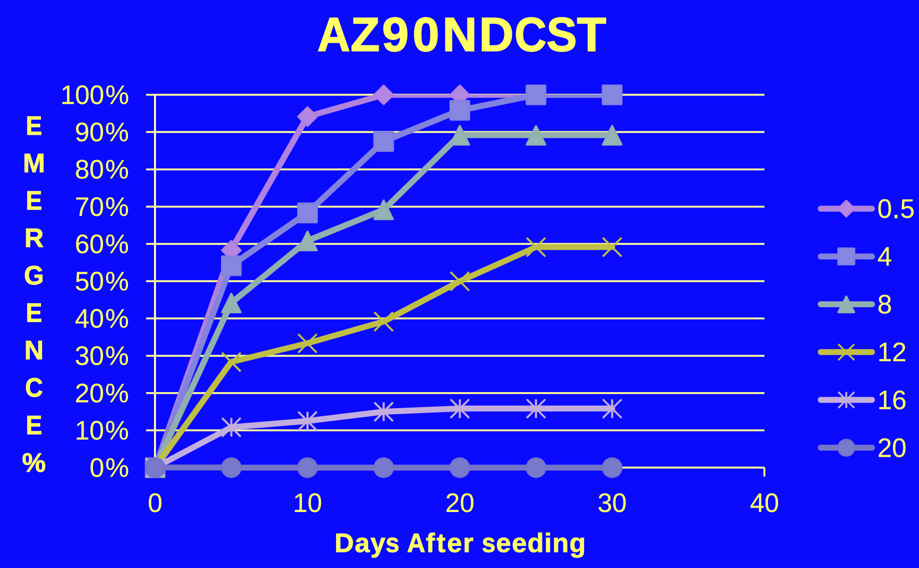
Salinity (dS/m)	*Biomass(g)**
0.5	0.2438[a]
4	0.2153[b]
8	0.1168[c]
12	0.0353[d]
16	0.0045[e]
20	0.0001[f]

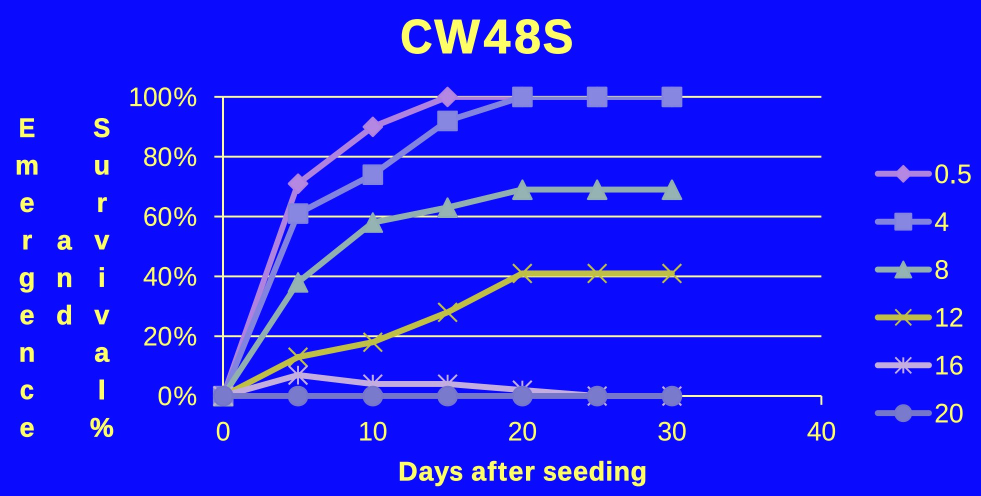
**Means within same column and same letter are not significantly different at P<0.05.*

Relative emergence and survival vs. time for AZ88NDC (sensitive), AZ 90 NDC (salt tolerant) and CW 48S (intermediate tolerance)

***expressed as a percentage of the control (0.5 dS/m treatment)**





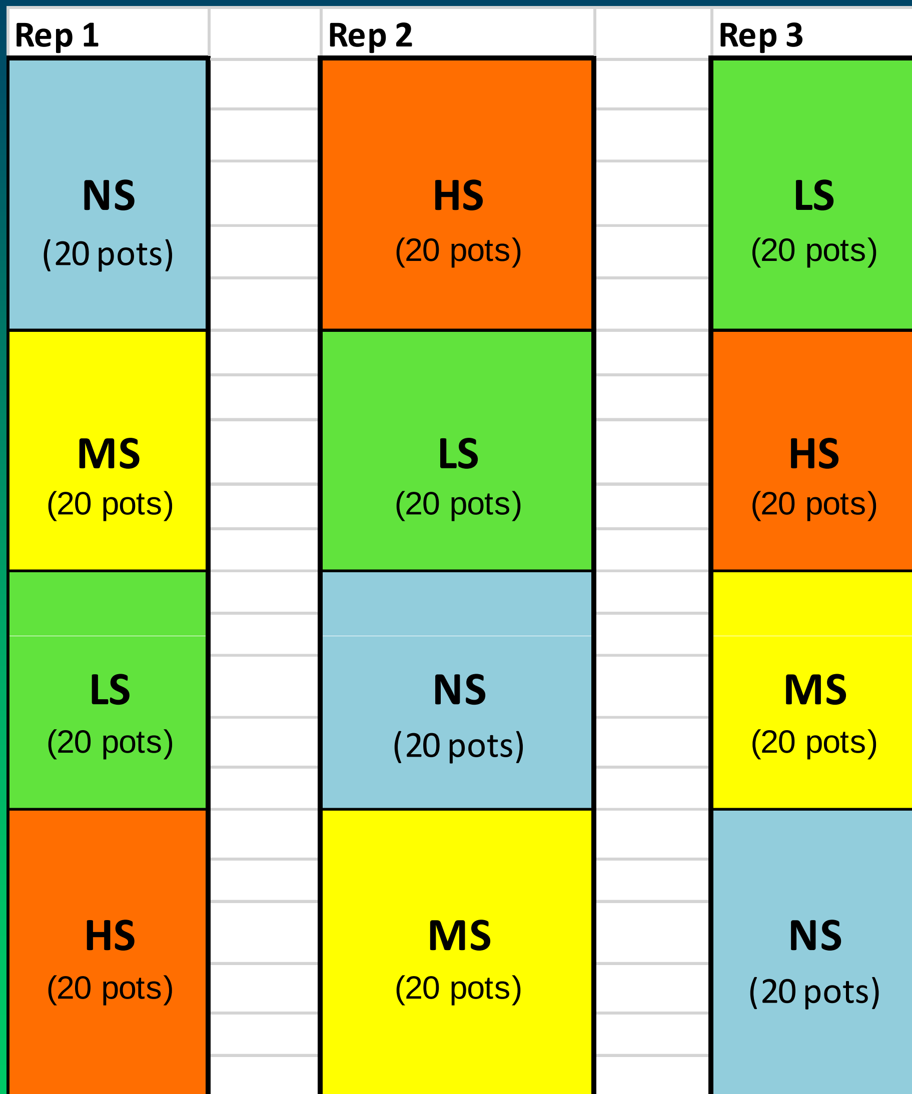


Relative Seedling DM yield (30 d)

Tolerance	Variety #	Variety name		EC (dS/m)				
			0.5	4	8	12	16	20
Tolerant	17	AZ90NDCST	100%	95%	49%	32%	9%	0%
"	18	AZGERM SALT II	100%	96%	64%	31%	14%	0%
"	7	HYBRIFORCE800	100%	97%	52%	17%	2%	0%
"	9	FG96T707	100%	91%	63%	19%	3%	0%
Moderately Tolerant	6	AMERISTAND901SQ	100%	91%	43%	7%	0%	0%
"	11	CW48S	100%	91%	51%	10%	0%	0%
"	12	CW58S	100%	94%	39%	8%	0%	0%
"	13	CW8028	100%	86%	38%	13%	0%	0%
"	10	CW9S	100%	90%	63%	16%	0%	0%
"	8	DS067092	100%	79%	46%	6%	0%	0%
"	14	DS077661	100%	97%	56%	16%	0%	0%
"	2	SW8421S	100%	91%	63%	19%	3%	0%
"	15	SW9215	100%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	1	SW9720	100%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	5	WL656HQ	100%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
"	3	6906N	100%	90%	47%	17%	0%	0%
Sensitive	16	AZ88NDC	100%	71%	27%	5%	0%	0%
"	19	MESA SIRSA	100%	66%	36%	6%	0%	0%
"	20	CUF101	100%	88%	38%	7%	0%	0%
"	4	CUF101	100%	88%	38%	7%	0%	0%

PHASE 3
(Greenhouse Yield Response)

Experimental Design



0.5 dS/m = Non-saline (NS)

5 dS/m = Low Saline (LS)

10 dS/m = Moderately Saline (MS)

15 dS/m = High saline (HS)

4 salinity levels x 20 varieties x 3 reps

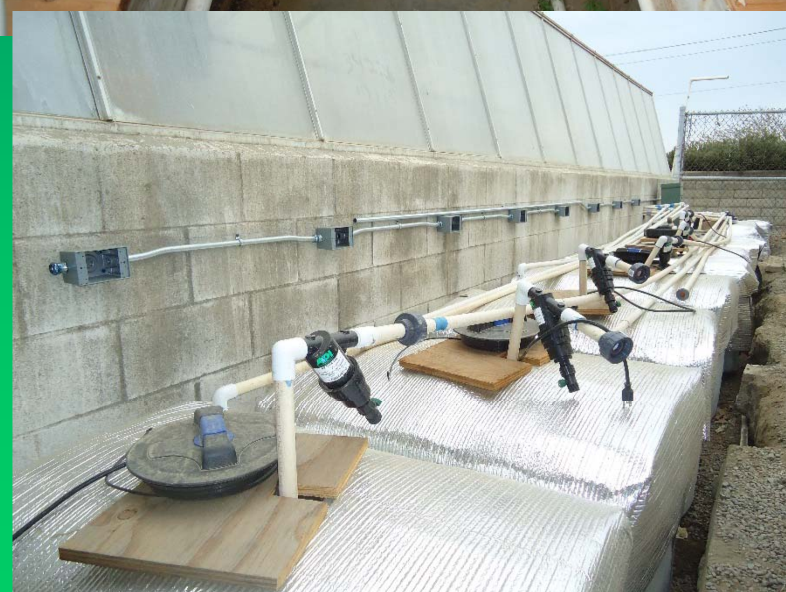
.= 240 pots

SPLIT PLOT DESIGN

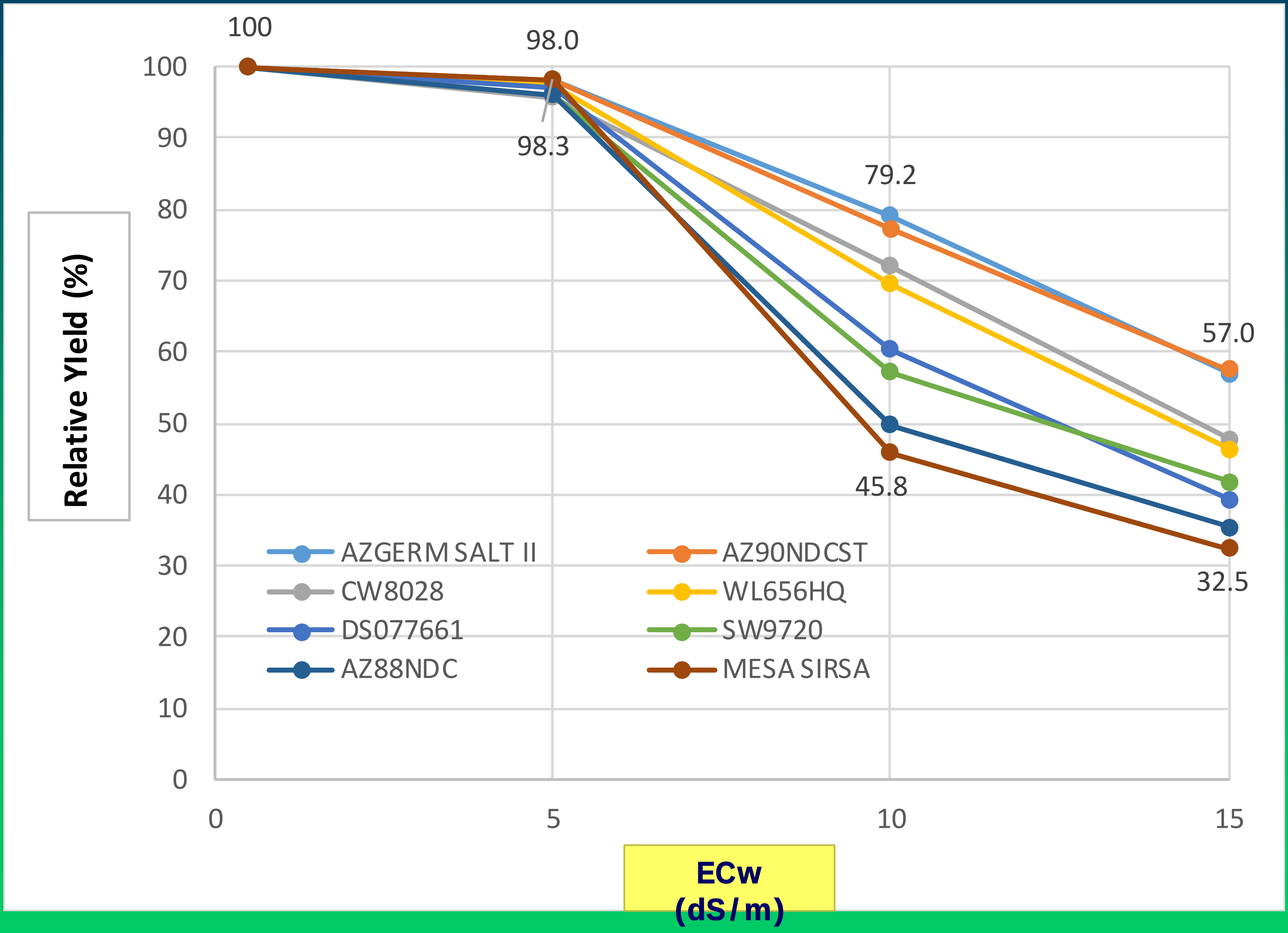
Main plot factor (salinity),

Sub-plot factor (variety)

Plants in the Greenhouse



<u>Shoots</u>-- Relative Yield (RY- %)*– *Cumulative for 7 Cuts*



Shoots-- Relative Yield (RY- %)*– *Cumulative for 7 Cuts*

Tolerance**	Var. #	Variety name	EC_w(dS/m)		
			5	10	15
T	18	AZGERM SALT II	98.0	79.2	57.0
"	17	AZ90NDCST	98.0	77.3	57.6
"	7	HYBRIFORCE800	95.5	76.2	56.3
"	9	FG96T707	97.9	74.7	53.6
"	8	DS067092	95.6	75.2	48.0
MT	2	SW8421S	97.6	70.3	52.6
"	13	CW8028	95.8	72.1	47.8
"	5	WL656HQ	97.5	69.6	46.4
"	3	6906N	97.2	68.3	46.4
"	12	CW58S	96.2	65.7	42.7
"	15	SW9215	96.9	64.5	43.2
MS	11	CW48S	96.2	62.2	40.8
"	14	DS077661	97.2	60.5	39.3
"	1	SW9720	96.2	57.2	41.9
"	6	AMERISTAND901SQ	97.0	57.9	40.8
"	20	CUF101(a)	94.7	54.9	44.3
"	4	CUF101(b)	94.6	54.7	43.9
S	10	CW9S	97.0	44.6	40.6
"	16	AZ88NDC	96.1	49.8	35.4
"	19	MESA SIRSA	98.3	45.8	32.5

**as % of non-saline (0.5 dS/m*

treatment

***Ranking based on RY at 10 dS/m*

T (Tolerant)= > 75% RY;
MT (mod. tolerant) = 65 - 74% RY
MS (mod. sensitive)= 55 - 64% RY;
S (sensitive) = < 50% RY

Note: order of listing based on sum of performance at 10 & 15 dS/m EC_w

Shoots- Relative Yield vs. Absolute Yield – *Cumulative for 7 Cuts*

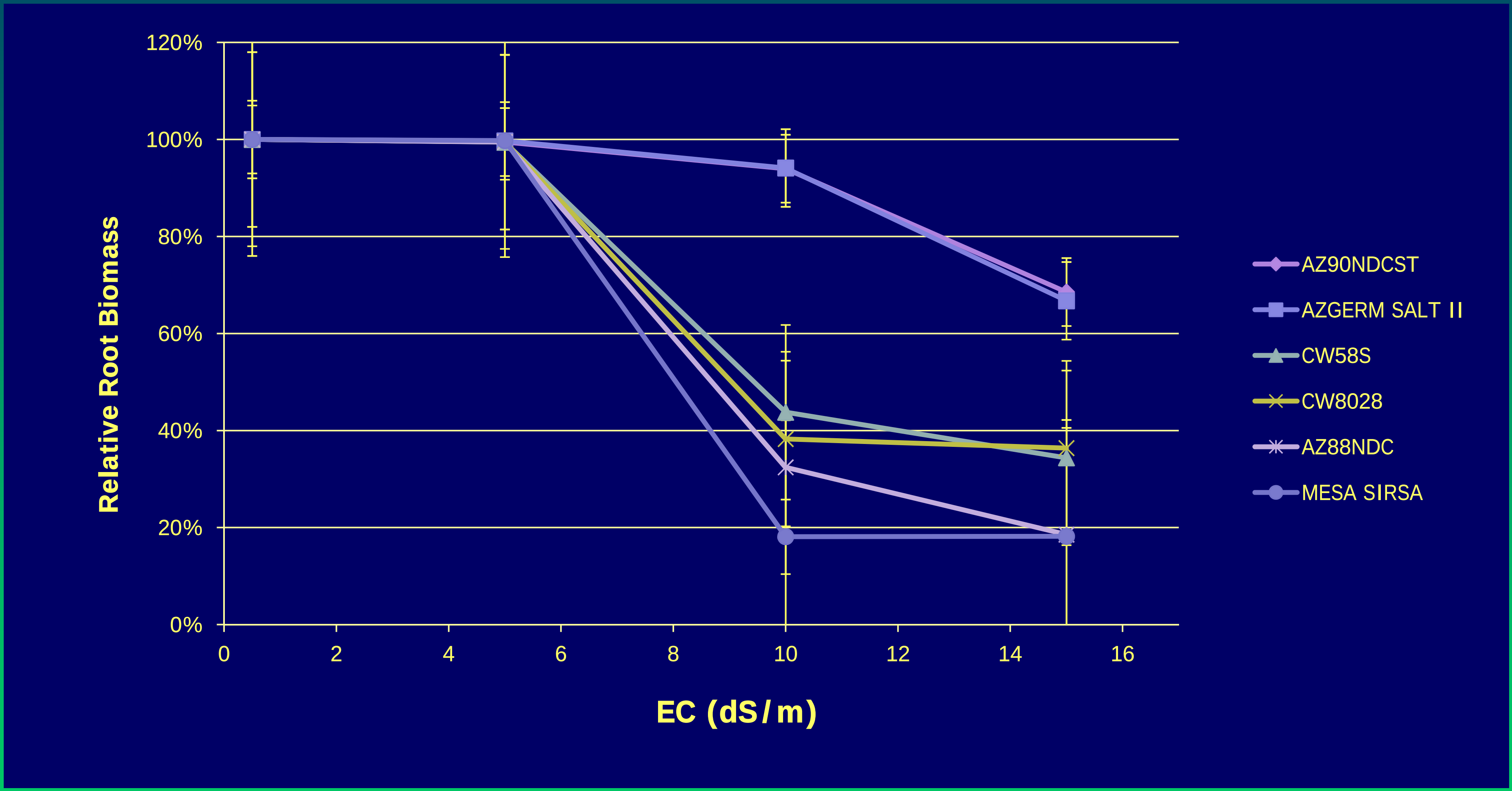
Relative Yield (%)

Tolerance**	Var. #	Variety name	EC_w(dS/m)		
			5	10	15
T	18	AZGERM SALT II	98.0	79.2	57.0
"	17	AZ90NDCST	98.0	77.3	57.6
"	7	HYBRIFORCE800	95.5	76.2	56.3
"	9	FG96T707	97.9	74.7	53.6
"	8	DS067092	95.6	75.2	48.0
MT	2	SW8421S	97.6	70.3	52.6
"	13	CW8028	95.8	72.1	47.8
"	5	WL656HQ	97.5	69.6	46.4
"	3	6906N	97.2	68.3	46.4
"	12	CW58S	96.2	65.7	42.7
"	15	SW9215	96.9	64.5	43.2
MS	11	CW48S	96.2	62.2	40.8
"	14	DS077661	97.2	60.5	39.3
"	1	SW9720	96.2	57.2	41.9
"	6	AMERISTAND901SQ	97.0	57.9	40.8
"	20	CUF101(a)	94.7	54.9	44.3
"	4	CUF101(b)	94.6	54.7	43.9
S	10	CW9S	97.0	44.6	40.6
"	16	AZ88NDC	96.1	49.8	35.4
"	19	MESA SIRSA	98.3	45.8	32.5

Absolute Yield (g/pot)

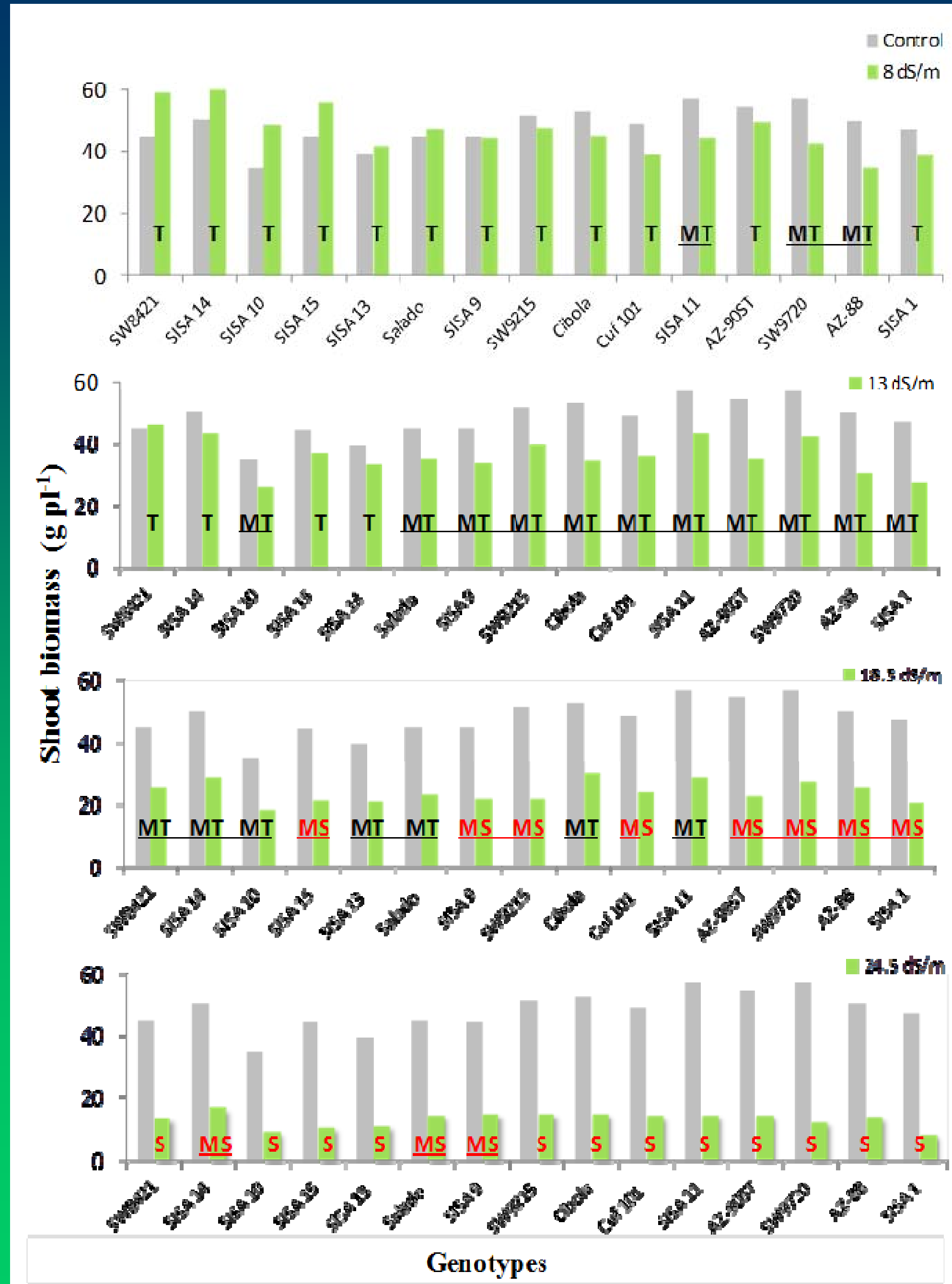
Tolerance	Var. #	Variety name	EC_w(dS/m)			
			0.5	5	10	15
T	18	AZGERM SALT II	36.5	35.8	28.9	20.8
"	17	AZ90NDCST	36.8	36.0	28.4	21.2
"	9	FG96T707	34.7	34.0	25.9	18.6
"	7	HYBRIFORCE800	31.2	29.8	23.8	17.6
"	2	SW8421S	30.0	29.3	21.1	15.8
MT	5	WL656HQ	29.2	28.5	20.4	13.6
"	1	SW9720	29.7	28.5	17.0	12.4
	11	CW48S	28.8	27.7	17.9	11.8
"	14	DS077661	29.2	28.4	17.7	11.5
"	12	CW58S	26.7	25.7	17.6	11.4
"	15	SW9215	26.7	25.8	17.2	11.5
"	6	AMERISTAND901SQ	29.2	28.3	16.9	11.9
MS	8	DS067092	22.9	21.9	17.2	11.0
"	3	6906N	23.4	22.8	16.0	10.9
S	13	CW8028	21.5	20.6	15.5	10.3
"	10	CW9S	26.7	25.9	11.9	10.8
"	20	CUF101(a)	21.8	20.7	12.0	9.7
"	4	CUF101(b)	21.9	20.7	12.0	9.6
"	16	AZ88NDC	26.0	25.5	11.9	8.4
"	19	MESA SIRSA	26.0	25.5	11.9	8.4

<u>Roots + Crowns</u>- Relative Yield (%), end of experiment



USDA-Salinity Lab, Riverside (Monica Cornacchione & Don Suarez)

- Almost all lines tolerant at 8 dS/L
- Sorts out better at 15,18
- Shoot biomass at 13, 18.3 and 24.5 dSm^{-1} was 77 %, 50 %, and 27 %, respectively,
- Salinity had less effects on roots than shoots



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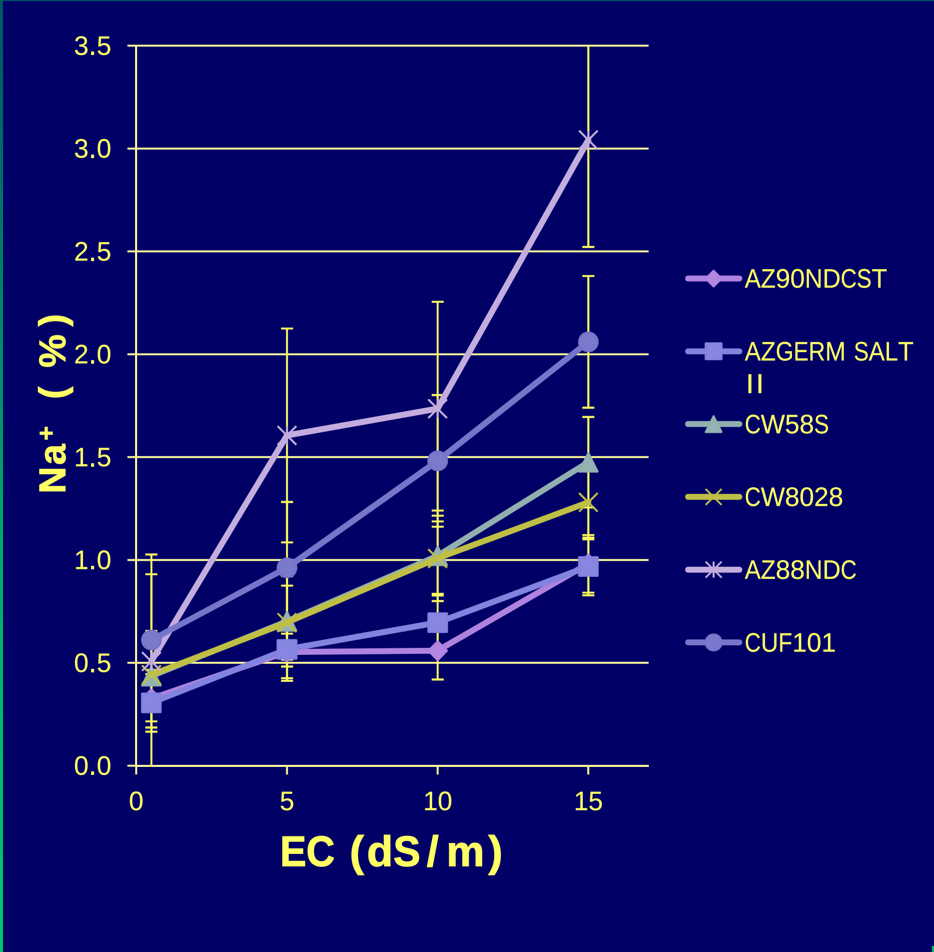
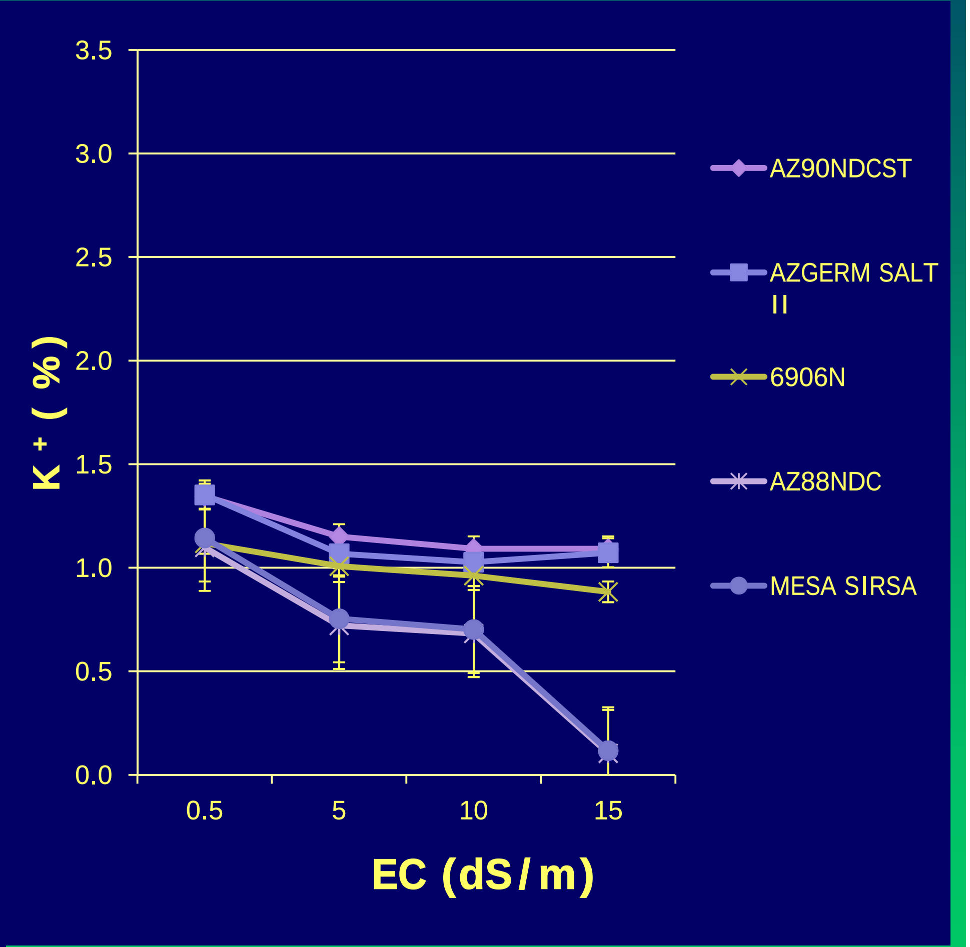
Ion Accumulation in Shoots/roots

Na (%) accumulated in alfalfa shoots--



K (%) accumulated in alfalfa shoots-



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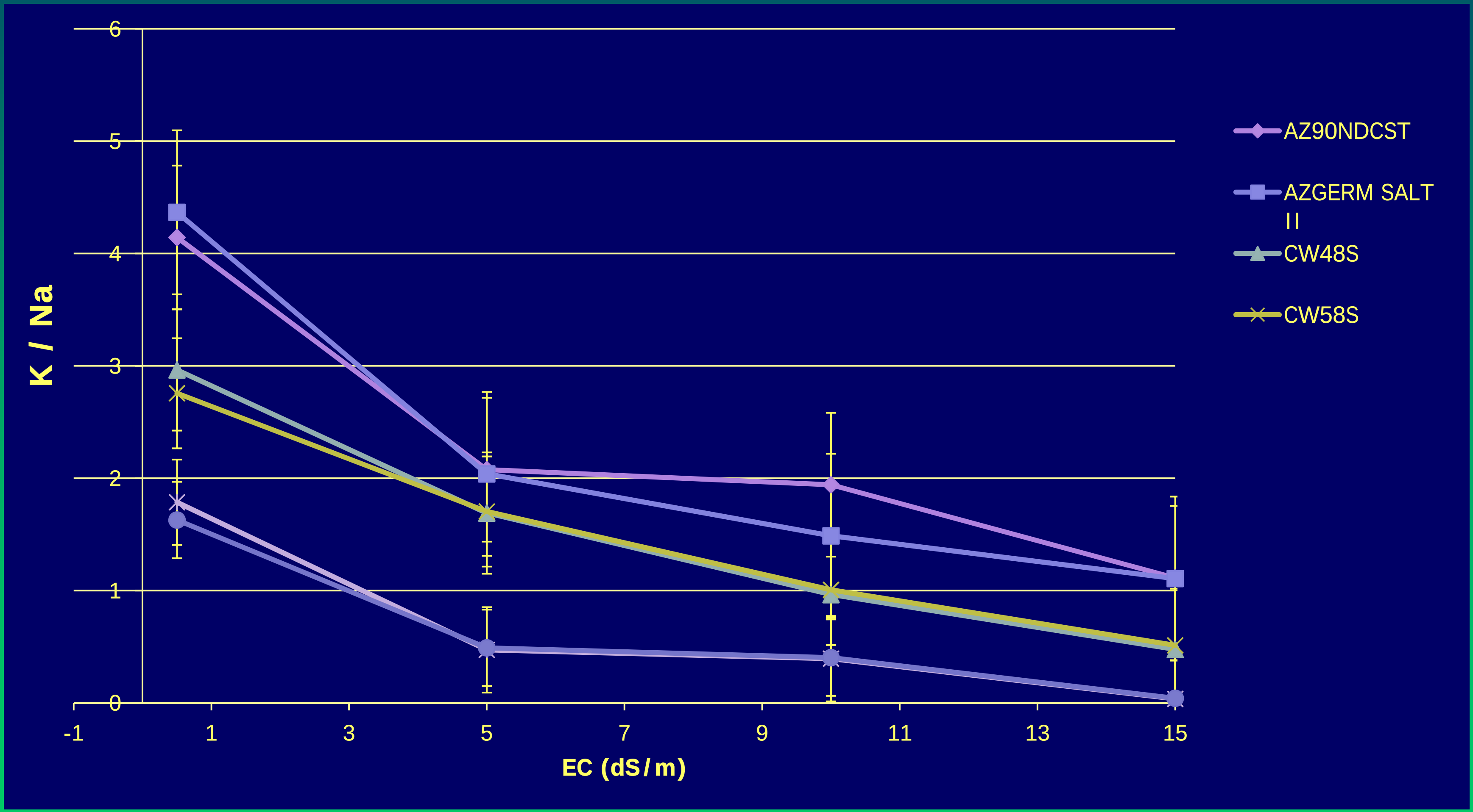
K/Na ratio in Alfalfa Shoots

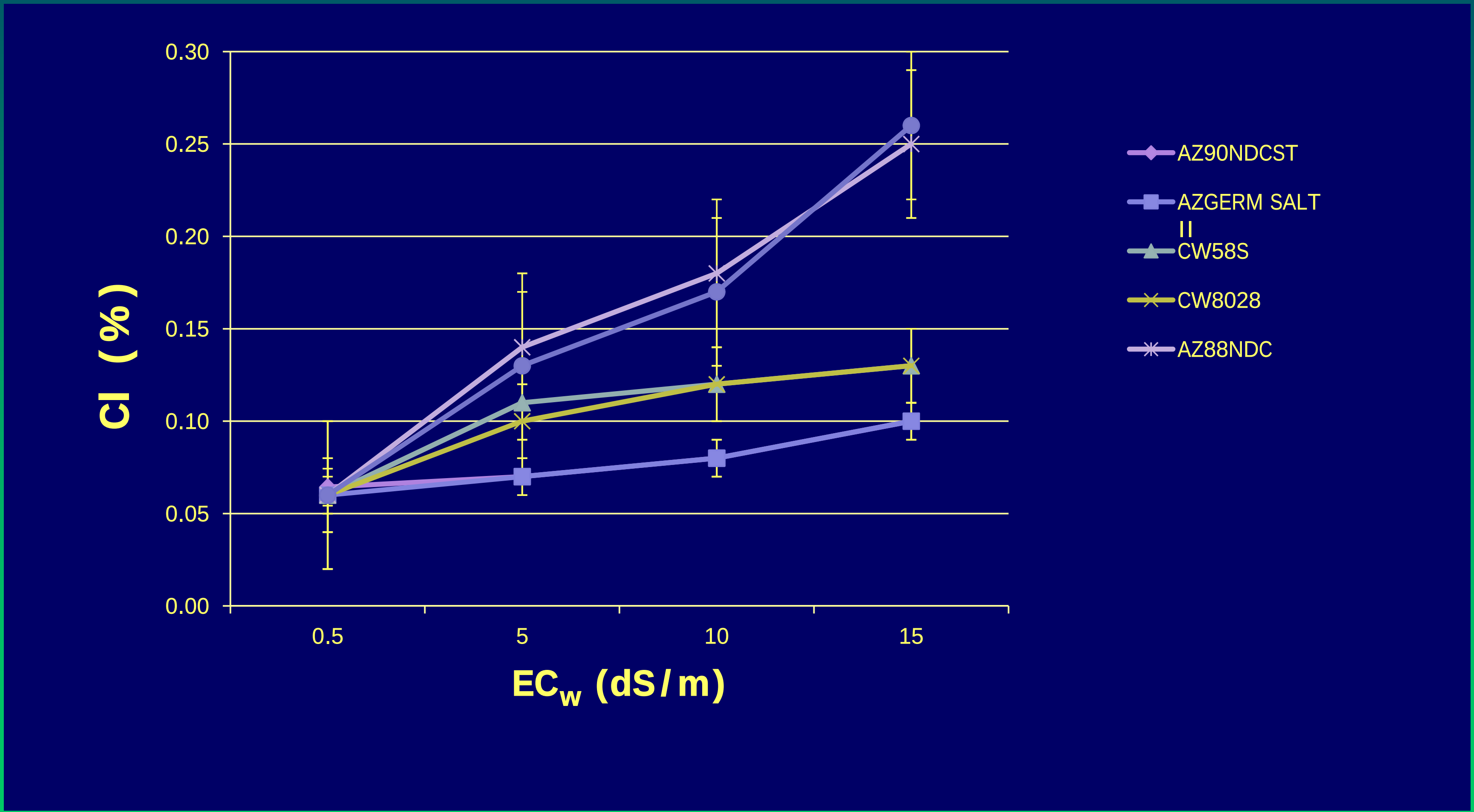


Shoot Na+ and K+ (% dry matter) and K/Na ratio– *Cut 7 (final)*

#	Variety Name	ST ranking*	Na+ (%) 0.5	Na+ (%) 5	Na+ (%) 10	Na+ (%) 15	K+ (%) 0.5	K+ (%) 5	K+ (%) 10	K+ (%) 15	K/Na 0.5	K/Na 5	K/Na 10	K/Na 15
17	AZ90NDCST	T	0.33	0.55	0.56	0.98	1.35	1.15	1.09	1.09	4.14	2.07	1.94	1.11
18	AZGERM SALT II	"	0.30	0.57	0.70	0.97	1.35	1.07	1.03	1.07	4.37	2.04	1.49	1.11
9	FG96T707	"	0.31	0.63	0.89	1.15	1.17	1.15	1.02	0.95	3.78	1.84	1.14	0.83
7	HYBRIFORCE800	"	0.38	0.63	0.90	1.42	1.20	1.10	1.02	0.85	3.14	1.70	1.21	0.59
2	SW8421S	MT	0.32	0.63	0.96	0.76	1.11	1.05	0.93	0.95	3.45	1.67	1.05	0.83
5	WL656HQ	"	0.40	0.63	0.94	1.47	1.15	1.09	1.02	0.76	2.90	1.73	1.11	0.52
8	DS067092	"	0.44	0.70	1.00	1.47	1.17	1.08	0.94	0.82	2.68	1.54	0.95	0.52
1	SW9720	"	0.37	0.70	0.96	1.03	1.11	1.09	1.01	0.83	2.96	1.56	1.06	0.81
15	SW9215	"	0.47	0.70	0.98	1.47	1.12	1.15	1.06	0.75	2.69	1.63	1.09	0.52
3	6906N	"	0.47	0.80	1.08	1.22	1.11	1.00	0.96	0.88	2.46	1.26	0.89	0.72
6	AMERISTAND901SQ	"	0.47	0.80	1.08	1.22	1.17	1.09	1.06	0.81	2.98	1.57	1.11	0.64
11	CW48S	"	0.40	0.64	1.09	1.46	1.22	1.09	1.05	0.69	2.96	1.69	0.96	0.48
12	CW58S	"	0.44	0.70	1.02	1.48	1.20	1.11	1.02	0.75	2.76	1.70	1.01	0.51
13	CW8028	"	0.44	0.70	1.01	1.28	1.15	1.09	0.95	0.83	2.57	1.57	1.08	0.64
14	DS077661	"	0.42	0.64	0.98	1.40	1.21	1.10	1.02	0.76	2.86	1.71	1.04	0.55
10	CW9S	"	0.42	0.64	0.95	1.42	1.21	1.10	0.95	0.68	2.86	1.71	1.01	0.49
20	CUF101	S	0.61	0.96	1.48	2.06	1.07	0.89	0.70	0.05	1.76	0.93	0.47	0.28
4	CUF101	"	0.61	0.96	1.48	2.06	1.07	0.89	0.70	0.05	1.76	0.89	0.46	0.28
16	AZ88NDC	"	0.51	1.61	1.74	3.04	1.09	0.72	0.68	0.10	2.14	0.47	0.39	0.04
19	MESA SIRSA	"	0.55	1.54	1.74	2.84	1.14	0.75	0.70	0.11	1.97	0.49	0.40	0.04

**T= Tolerant, MT= Moderately Tolerant and S= Sensitive*

Cl (%) accumulated in alfalfa shoots

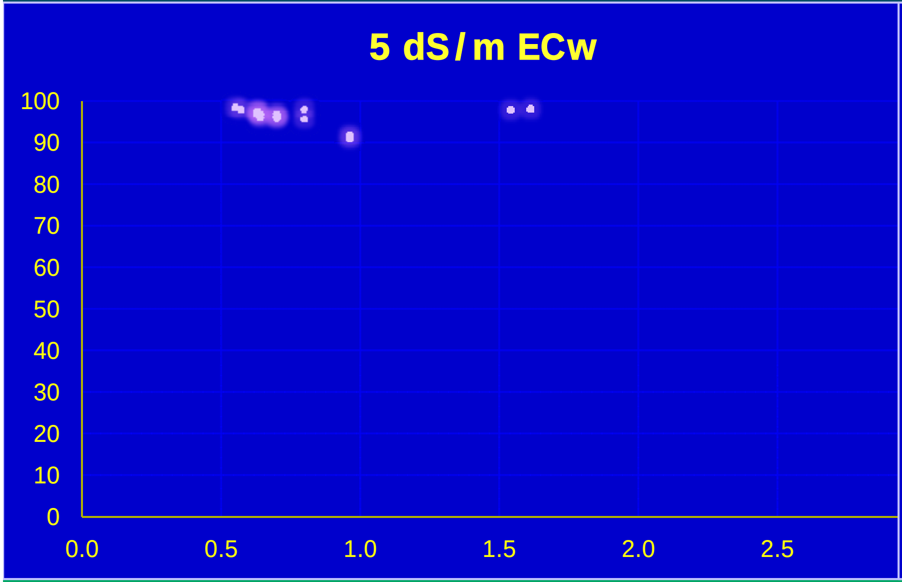


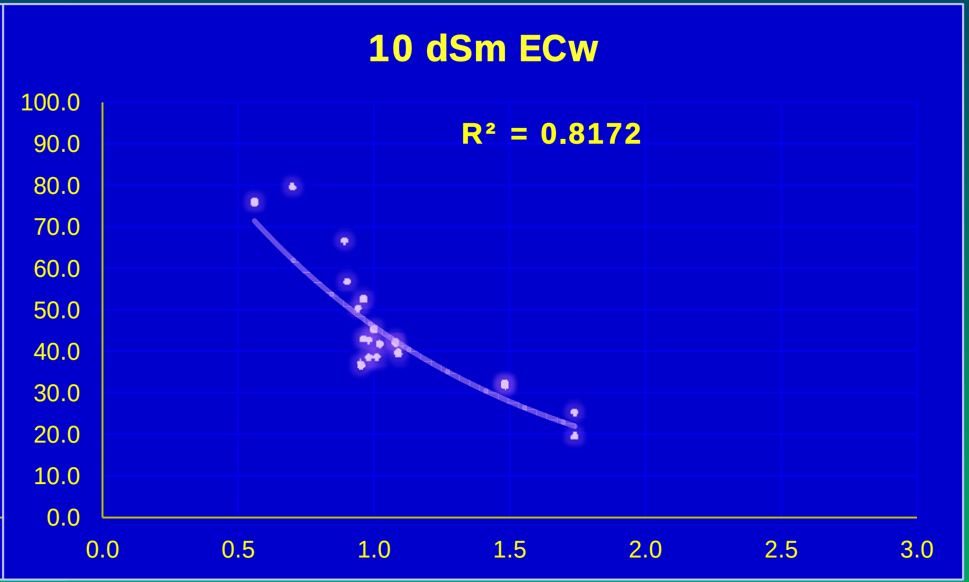
Cl^- (%) accumulated in alfalfa shoots– *Cut 7 (final)*

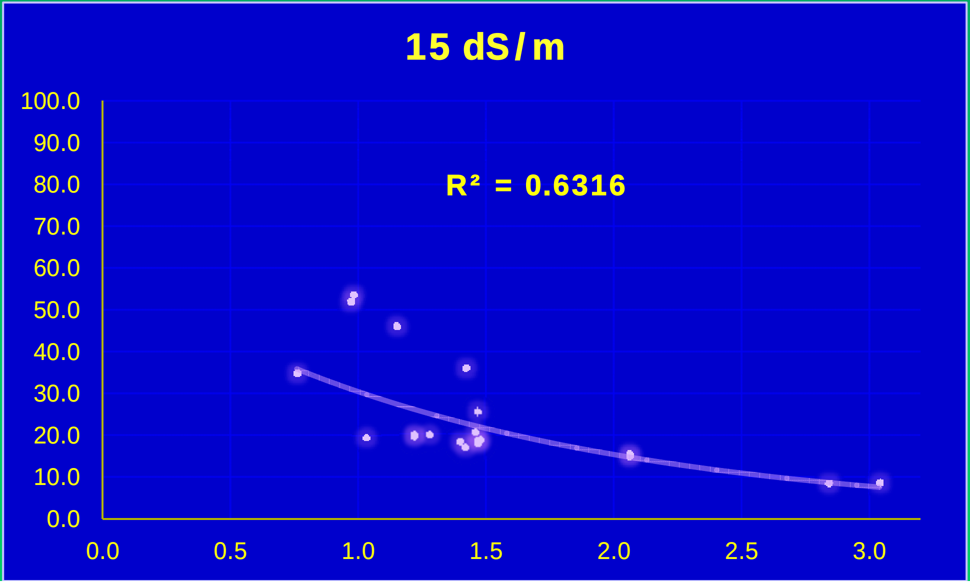
Var#	Variety Name	ST ranking*	Cl^- %			
			0.5	5	10	15
17	AZ90NDCST	T	0.64	0.75	0.87	1.04
18	AZGERM SALT II	"	0.66	0.75	0.86	1.01
9	FG96T707	"	0.58	0.85	1.06	1.16
7	HYBRIFORCE800	MT	0.64	1.07	1.13	1.25
2	SW8421S		0.63	1.01	1.23	1.43
5	WL656HQ	"	0.63	1.06	1.18	1.33
13	CW8028	"	0.68	1.07	1.27	1.37
12	CW58S	"	0.66	1.11	1.28	1.37
10	CW9S	"	0.67	1.16	1.24	1.34
8	DS067092	"	0.68	1.14	1.22	1.43
6	AMERISTAND901SQ	"	0.66	1.12	1.44	1.58
1	SW9720	"	0.65	0.95	1.12	1.24
15	SW9215	"	0.62	1.13	1.29	1.43
11	CW48S	"	0.57	1.16	1.54	1.69
3	6906N	"	0.66	1.00	1.43	1.30
14	DS077661	"	0.65	1.02	1.27	1.38
20	CUF101	S	0.65	1.23	1.42	1.76
4	CUF101	"	0.68	1.24	1.18	1.76
16	AZ88NDC	"	0.67	1.41	1.83	2.54
19	MESA SIRSA	"	0.63	1.33	1.75	2.65

**T= Tolerant, MT= Moderately Tolerant and S= Sensitive*

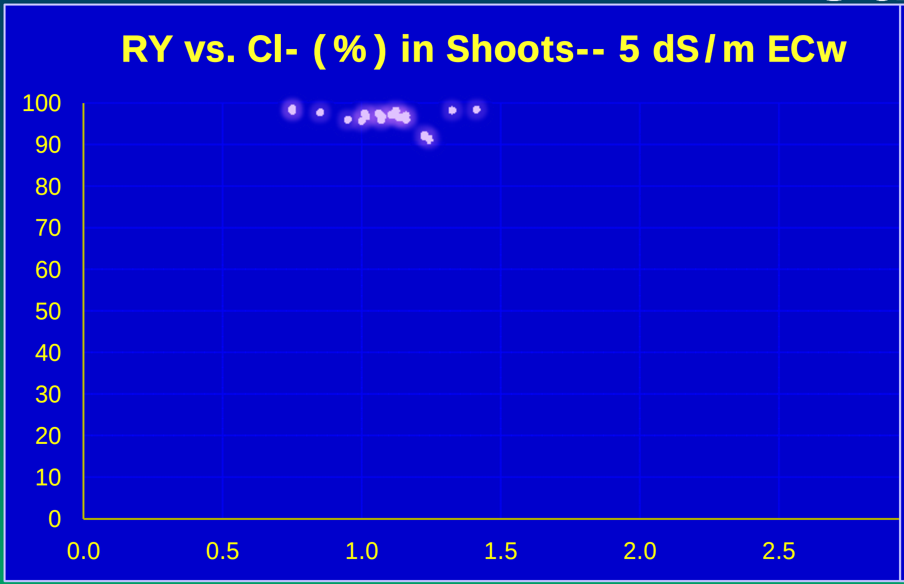
Relative Yield (%) vs. Na^+(%)–
Shoots, Cut 7

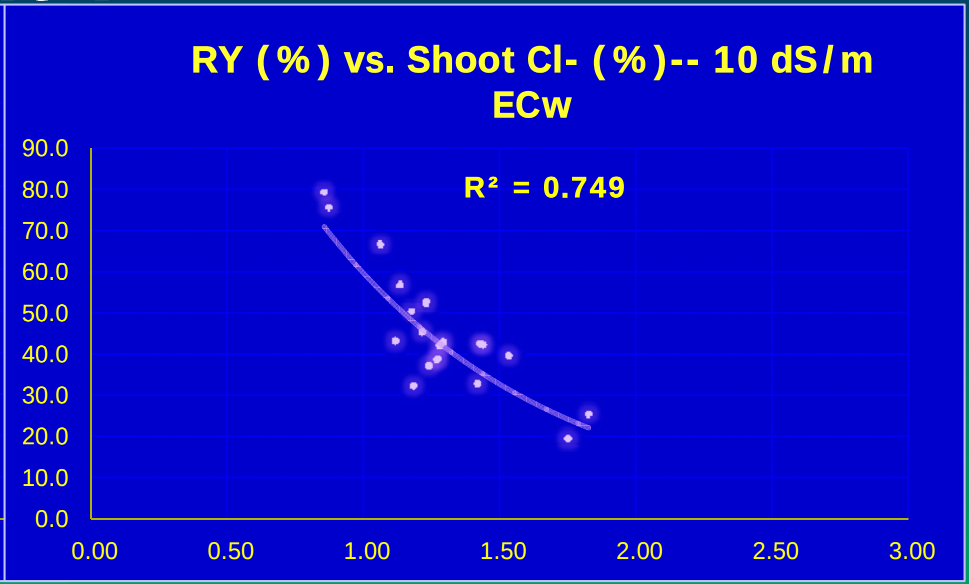


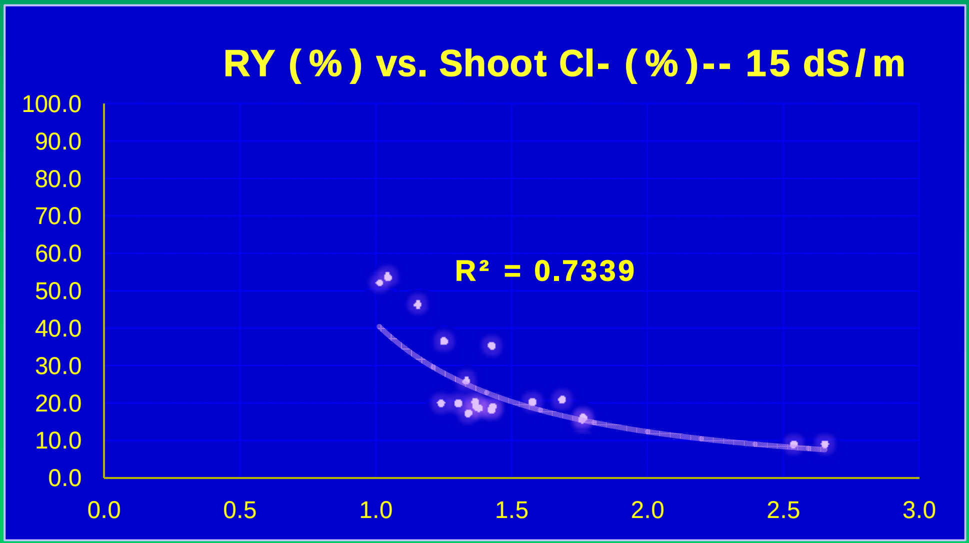




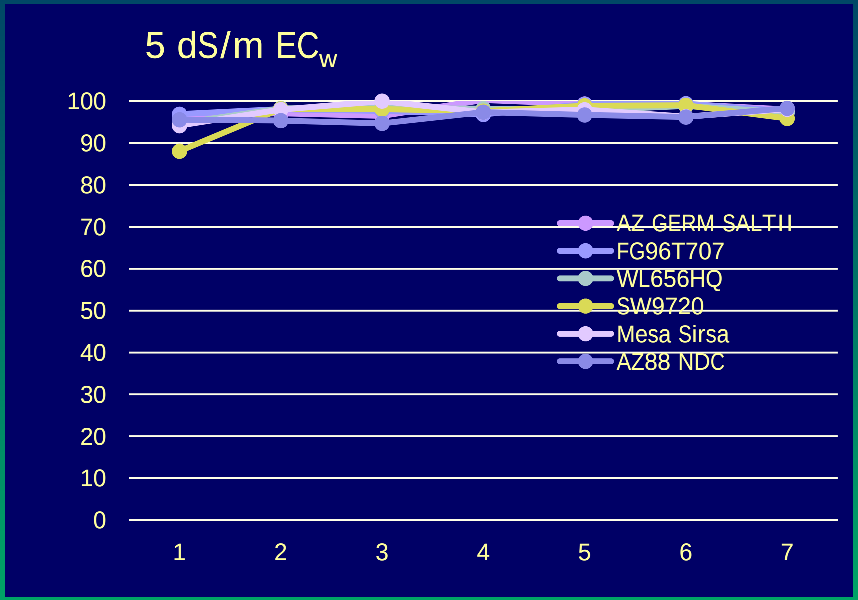
Relative Yield (%) vs. Cl^- (%)– *Shoots, Cut 7*

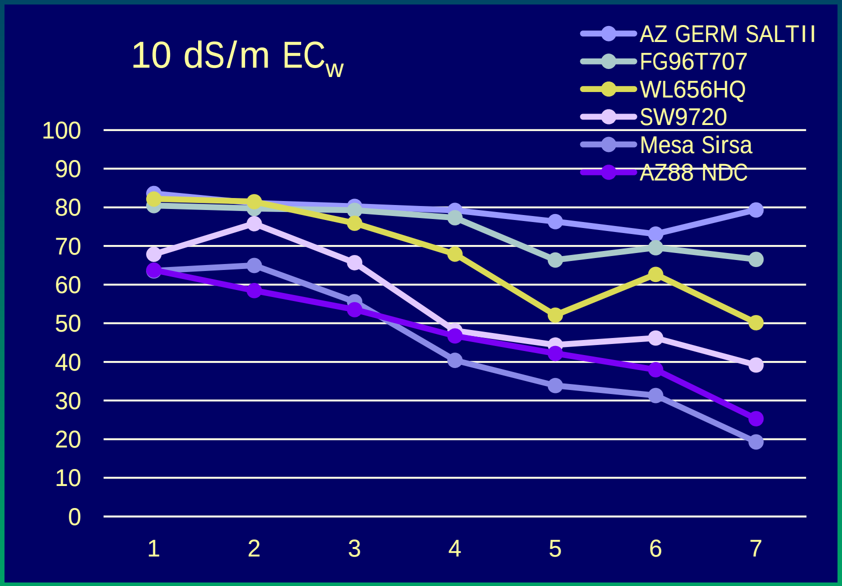


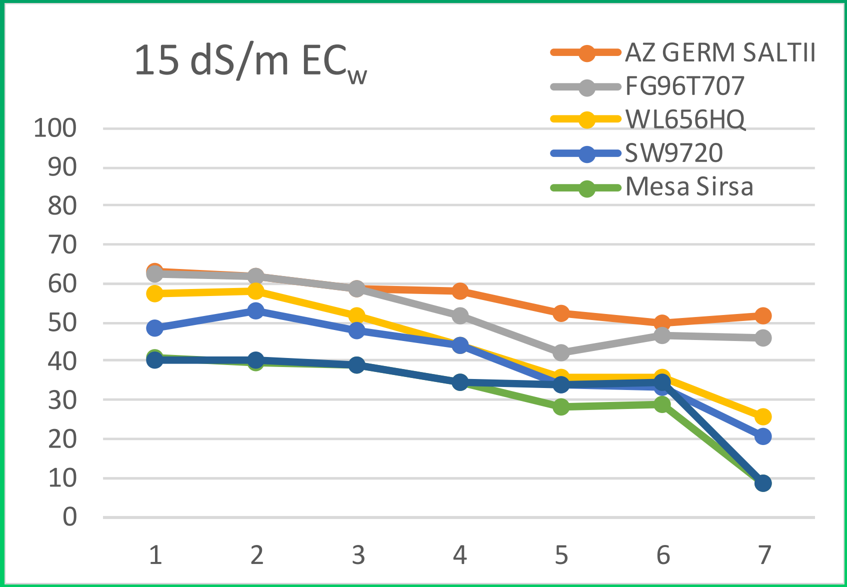




Relative Yield (%) of Shoots vs. Time (cut)

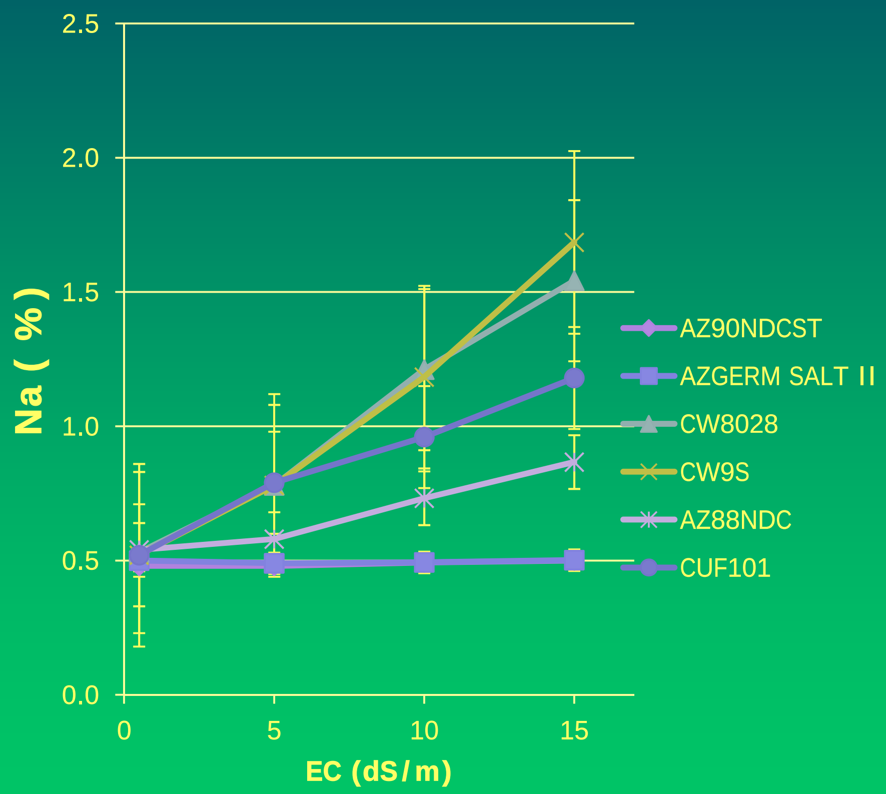




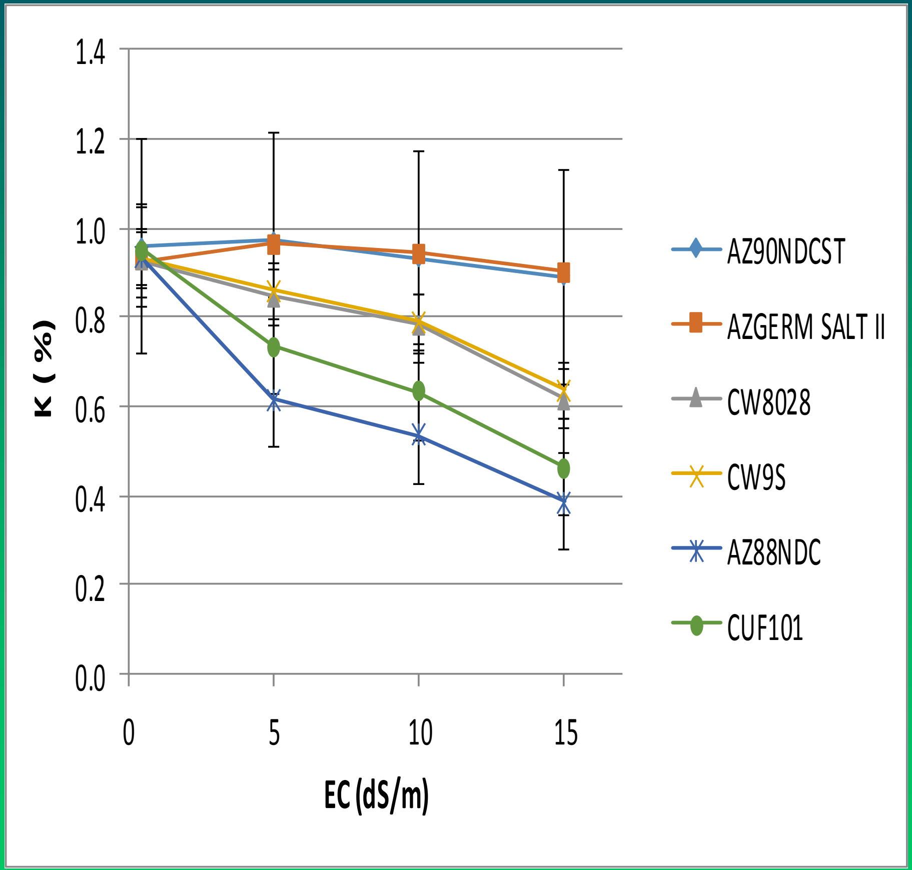


Ion Accumulation in Roots + Crowns

Na (%) accumulated in alfalfa roots + crowns



K (%) accumulated in alfalfa roots + crowns



Na (%), K(%) and K/Na accumulated in Roots + Crowns-End of Expt.

Var #	Variety Name	ST ranking*	Na^+ (%)				K^+ (%)				K/Na			
			0.5	5	10	15	0.5	5	10	15	0.5	5	10	15
17	AZ90NDCST	T	0.48	0.48	0.49	0.5	0.96	0.97	0.93	0.9	2.00	2.02	1.90	1.78
18	AZGERM SALT II	"	0.5	0.49	0.49	0.5	0.93	0.96	0.94	0.9	1.86	1.96	1.92	1.80
9	FG96T707	"	0.54	0.58	0.73	0.87	0.94	0.9	0.81	0.7	1.74	1.55	1.11	0.84
7	HYBRIFORCE800	"	0.52	0.6	0.64	0.93	0.96	0.89	0.82	0.7	1.85	1.48	1.28	0.77
15	SW8421S	MT	0.5	0.86	1.27	1.4	0.94	0.88	0.78	0.6	1.88	1.02	0.61	0.46
5	WL656HQ	"	0.46	0.88	1.17	1.77	0.93	0.85	0.77	0.6	2.02	0.97	0.66	0.35
8	DS067092	"	0.51	0.84	1.18	1.74	0.94	0.82	0.76	0.6	1.84	0.98	0.64	0.36
1	SW9720	"	0.51	0.88	1.17	1.26	0.95	0.88	0.81	0.6	1.86	1.00	0.69	0.48
2	SW9215	"	0.52	0.9	1.23	1.76	0.97	0.87	0.77	0.6	1.87	0.97	0.63	0.35
3	6906N	"	0.49	1.02	1.33	1.47	0.96	0.79	0.76	0.6	1.96	0.77	0.57	0.43
13	CW8028	"	0.53	0.78	1.22	1.54	0.93	0.85	0.78	0.6	1.75	1.09	0.64	0.40
12	CW58S	"	0.52	0.8	1.24	1.78	0.93	0.79	0.77	0.6	1.79	0.99	0.62	0.36
6	AMERISTAND901SQ	"	0.46	0.88	1.18	1.56	0.92	0.87	0.79	0.6	2.00	0.99	0.67	0.41
11	CW48S	"	0.48	0.79	1.28	1.78	0.95	0.89	0.78	0.7	1.98	1.13	0.61	0.37
14	DS077661	"	0.52	0.78	1.22	1.69	0.96	0.86	0.76	0.6	1.85	1.10	0.62	0.37
10	CW9S	"	0.52	0.78	1.18	1.69	0.93	0.86	0.79	0.6	1.79	1.10	0.67	0.38
20	CUF101	S	0.52	0.79	0.96	1.18	0.95	0.73	0.63	0.5	1.83	0.92	0.66	0.39
4	CUF101	"	0.52	0.79	0.96	1.18	0.95	0.73	0.63	0.5	1.83	0.92	0.66	0.39
16	AZ88NDC	"	0.54	0.58	0.73	0.87	0.93	0.62	0.53	0.4	1.72	1.07	0.73	0.45
19	MESA SIRSA	"	0.52	0.6	0.64	0.93	0.96	0.61	0.53	0.4	1.85	1.02	0.83	0.41

**T= Tolerant, MT= Moderately Tolerant and S= Sensitive*

Phase 3- *Mineral Ions*

For most varieties, Na^+ and Cl^- concentrations in shoots (and roots + crowns) steadily increased (and K^+ decreased) as EC_w increased

- **Suggests toxic ion exclusion and K+ discrimination (over Na+) are key tolerance mechanisms in these alfalfa varieties.** ***More so than compartmentalization of toxic ions in vacuoles.***
- **This pattern seen in root tissue as well as shoot tissue**
- **Although ion accumulation was important for resistant lines, RY was not always related, suggesting that tolerance to the osmotic stress is also key.**

2010-12 YIELDS. WSREC ALFALFA SALINITY TRIAL. TRIAL PLANTED 10/27/09

	FD	2010 Yield	2011 Yield	2012 Yield	Average		% of CU…
			Dry t/a				
Released Varieties							
WL 656HQ	9	9.7 (12)	13.9 (1)	16.3 (3)	13.3 (2)	A B	1
Hybriforce 800	8	10.7 (2)	13.3 (5)	15.2 (7)	13.1 (4)	A B C	1
Ameristand 901STQ	9	9.6 (17)	13.4 (4)	15.5 (5)	12.8 (6)	A B C D E	1
Magna 995	9	9.7 (13)	12.8 (9)	15.5 (6)	12.7 (7)	A B C D E F	1
CUF101	9	10.1 (7)	12.4 (11)	14.9 (10)	12.4 (10)	A B C D E F G H	1
Medina	8.5	10.9 (1)	11.7 (19)	14.5 (14)	12.3 (11)	B C D E F G H	
CW 95	9	10.0 (8)	12.0 (15)	14.4 (15)	12.2 (12)	C D E F G H I	
CW 485	8	10.3 (5)	11.9 (16)	13.9 (16)	12.0 (13)	D E F G H I	
UC 452		10.0 (9)	12.5 (10)	13.5 (19)	12.0 (14)	E F G H I	96.5
Highline	9	10.1 (6)	12.3 (12)	13.4 (21)	11.9 (15)	E F G H I	95.7
Integra 8900	9	9.1 (23)	11.8 (18)	14.8 (12)	11.9 (16)	E F G H I	
AmeriStand 803	8	9.2 (22)	11.6 (21)	14.8 (11)	11.9 (17)	E F G H I	
SW9803	9	8.8 (24)	12.1 (13)	14.6 (13)	11.8 (18)	F G H I	95.0
CW 585	8	9.8 (11)	12.1 (14)	13.5 (20)	11.8 (19)	F G H I	94.8
BAR 9242	8.5	9.2 (21)	11.7 (20)	13.8 (18)	11.6 (22)	H I	92.9
GrandSlam	8	9.6 (16)	10.9 (24)	13.2 (23)	11.3 (23)	I	90.4
CW 8028	8	9.9 (10)	11.9 (17)	11.8 (24)	11.2 (24)	I	89.9
Experimental Varieties							
FG 96T706	9	9.4 (20)	13.5 (3)	17.1 (1)	13.3 (1)	A	107.2
FG 94T02	9	10.4 (3)	13.7 (2)	15.7 (4)	13.3 (3)	A B	106.6
FG 96T707	9	9.7 (15)	12.8 (8)	16.5 (2)	13.0 (5)	A B C D	104.6
DS593	9	9.7 (14)	12.9 (7)	15.1 (8)	12.6 (8)	A B C D E F G	100.9
SW9812	9	9.4 (19)	13.1 (6)	15.1 (9)	12.5 (9)	A B C D E F G H	100.7
DS077661	8	10.4 (4)	11.5 (22)	13.3 (22)	11.7 (20)	F G H I	94.2
DS067092	8	9.5 (18)	11.4 (23)	13.8 (17)	11.6 (21)	G H I	93.1
MEAN		9.80	12.38	14.59	12.26		
CV		10.2	11.9	10.5	8.2		
LSD (0.1)		0.99	1.46	1.51	0.99		

Trial seeded at 25 lb/acre viable seed at WSREC, Five Points, CA.

Entries followed by the same letter are not significantly different at the 10% probability level according to Fisher's (

FD = Fall Dormancy reported by seed companies.

Phase 4. Field Yield Trials

EC at 4 years:

T=21.9°C	EC (dS/m)
1	8.64
7	9.56
13	8.71
19	9.62
25	8.10
31	8.84
Avg.	8.91

3 years field data – normal yields

Imperial Valley – a ton of salts per irrigation

Overall Conclusions

- Production at ECw of 5.0 dS/m insufficient pressure to reduce performance in greenhouse or field studies, but large yield losses between 5 and 15 dS/m EC_w
- Maas-Hoffman Yield Loss threshold of 2.0 dS/m ECe appears to be too low for alfalfa with current varieties
- Appears to be considerable variation in genetic response to salinity at different stages – opportunity for genetic advancement
- Shoot Na & K/Na and Cl concentrations may be useful predictors, but do not tell entire story
- Need to Understand ‘relative yield’ vs. ‘robust field performance’ - given the complexities of salinity

Key Putative Mechanisms

- Resistance to osmotic stress in general (roots able to function with lower soil water concentrations due to salinity)
- Sequestering of ions cellularly or transport
- Tolerance of specific ion toxicity in leaves

Future Work

- Standardize Phase 2 and 3 protocols to allow seed companies to test under conditions using
  - mixed salt solutions
  - soil (or soil: sand mix), rather than greenhouse potting mix

- Evaluate the more salt tolerant varieties in the field.
  - higher transpiration in the field (potential for greater uptake of Na^+ and Cl^-
  - field conditions are difficult to control and standardize as compared to the laboratory or greenhouse but are more realistic

- Examine effects of salinity on N_2 fixation and the N fertilizer requirement of alfalfa

Many thanks to Contributors

- Dr. John Bushoven, Dept. Plant Science, *CA State University, Fresno*

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- Inderjot Chahal
- Sangeeta Bansal
- Grace Cun

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- Giuliano Galdi
- Lucas Vasques

Industry
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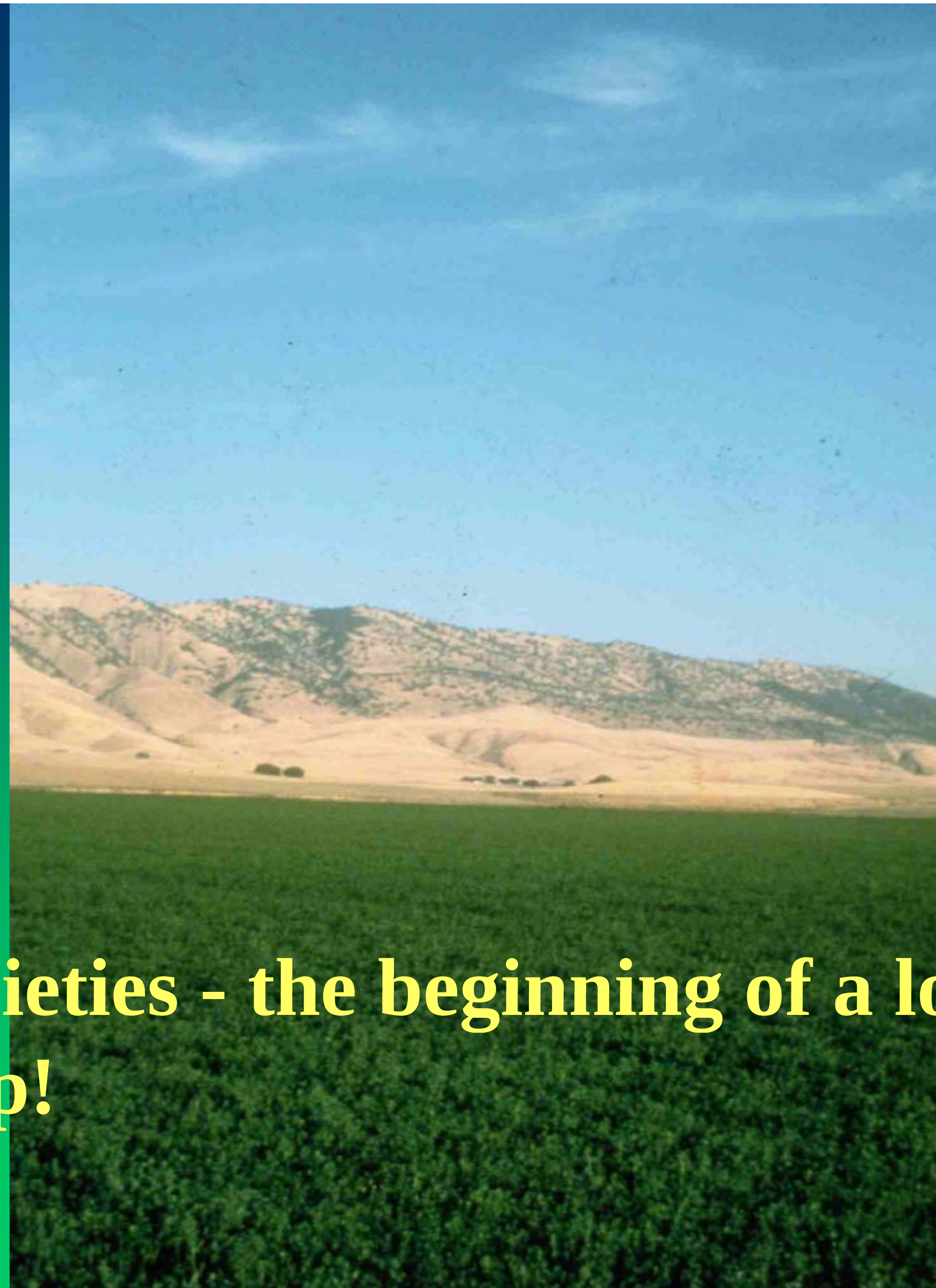
- Dan Karsten (S&W Seed)
- Dan Gardner (Dairyland / Alforex). *Now at S&W seeds*
- Don Miller and John Reich (Cal West / Alforex)
- John Lyons (Novozymes)



Alfalfa Varieties - the beginning of a long relationship!

2014 NAAIC Meeting