Fertilizer Value of Nitrogen in Irrigation Water for Coastal Vegetable Production

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Item 16

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Presentation

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California Agriculture

Research Article

Field trials show the fertilizer value of nitrogen in irrigation water

by Michael Cahn, Richard Smith, Laura Murphy *and* Tim Hartz

Increased regulatory activity designed to protect groundwater from degradation by nitrate-nitrogen (NO_3-N) is focusing attention on the efficiency of agricultural use of nitrogen (N). One area drawing scrutiny is the way in which growers consider the NO_3-N concentration of irrigation water when determining N fertilizer rates. Four drip-irrigated field studies were conducted in the Salinas Valley evaluating the impact of irrigation water NO_3-N concentration and irrigation efficiency on the N uptake efficiency of lettuce and broccoli crops. Irrigation with water NO_3-N concentrations from 2 to 45 milligrams per liter were compared with periodic fertigation of N fertilizer. The effect of irrigation efficiency was determined by comparing an efficient (110% to 120% of crop evapotranspiration, ET_C) and an inefficient (160% to 200% of ET_C) irrigation treatment. Across these trials, NO_3-N from irrigation water was at least as efficiently used as fertilizer N; the uptake efficiency of irrigation water NO_3-N averaged approximately 80%, and it was not affected by NO_3-N concentration or irrigation efficiency.

California agriculture faces increasing regulatory pressure to improve nitrogen (N) management to protect groundwater quality. Groundwater in agricultural regions, such as the Salinas Valley and the Tulare Lake Basin, has been adversely impacted by agricultural practices, with nitrate-N (NO_3-N) in many wells exceeding the federal drinking water standard of 10 mg/L (Harter et al. 2012). The threat to groundwater is particularly acute in the Salinas Valley, where the intensive production of vegetable crops has resulted in an estimated net loading (fertilizer N application – N removal with crop harvest) of > 100 lb/ac (> 112 kg/ha) of N annually (Rosenstock et al. 2014).

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Levels of NO_3-N in irrigation wells in the Salinas Valley commonly range from 10 to 40 mg/L. Given the typical volume of irrigation water applied to vegetable fields, NO_3-N in irrigation water could represent a substantial fraction of crop N requirements, provided that crops can efficiently use this N source. Indeed, the concept of "pump and fertilize" (substituting irrigation water NO_3-N for fertilizer N) has been suggested as a remediation technique to improve groundwater quality in agricultural regions (Harter et al. 2012).

Cooperative Extension publications from around the country (Bauder et al. 2011; DeLaune and Trostle 2012; Hopkins et al. 2007) agree that the fertilizer value of irrigation water NO_3-N can be significant, but they differ as to what fraction of water NO_3-N should be credited against the fertilizer N recommendation. There is a paucity of field data documenting the efficiency of crop utilization of irrigation water N. Francis and Schepers (1994) documented that corn could use irrigation water NO_3-N, but in their study N uptake efficiency from irrigation water was low, which they attributed to the timing of irrigation relative to crop N demand and the availability of N from other sources. Martin et al. (1982) suggested that uptake efficiency of irrigation water NO_3-N could actually be higher than from fertilizer N, but their conclusion was based on a computer simulation, not on field trials.

With this near total lack of relevant field data, California growers have legitimate concerns about the degree to

Inexpensive nitrate test strips allow on-farm estimation of irrigation water NO_3-N concentration. In Salinas Valley irrigation wells, levels of NO_3-N commonly range from 10 to 40 mg/L, which could supply a substantial portion of crop N requirements.

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Is nitrate in irrigation water bioavailable to crops?

- **Replicated trials simulating water with different nitrate concentrations (2013-2015)**
- **Commercial field trials using high nitrate well water (2016-2017)**
- **Discuss practical challenges of crediting N in water as fertilizer**

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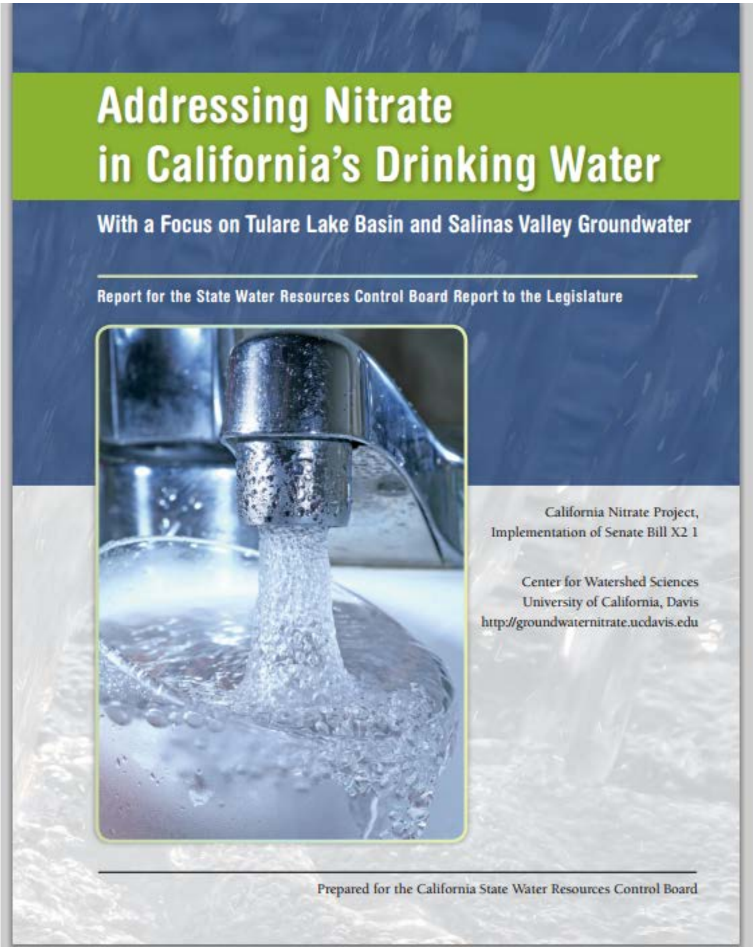
“Pump and fertilize” was proposed as a partial solution for remediating nitrate contamination of ground water

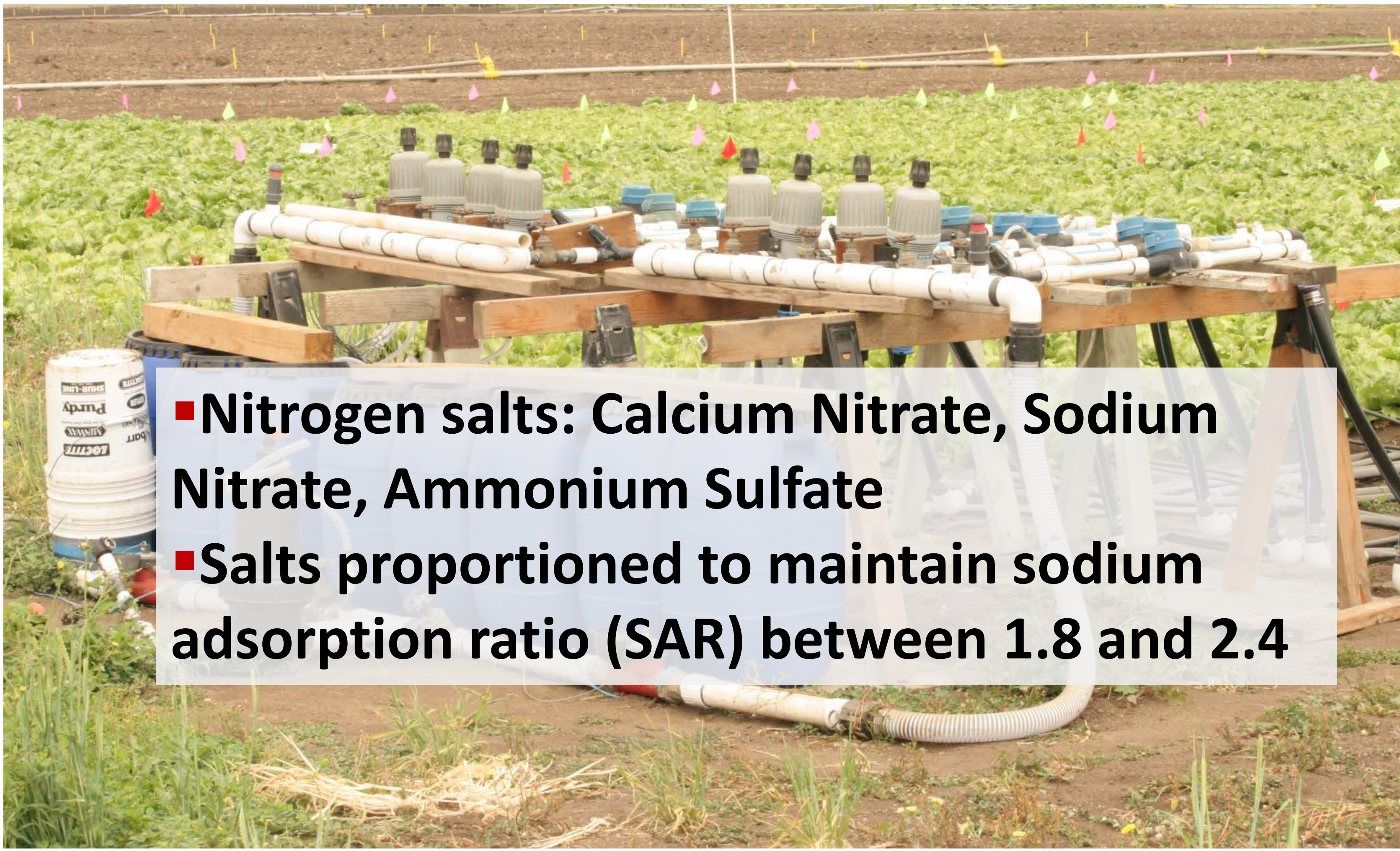


Harter and Lund 2012

How much fertilizer credit should be taken for nitrogen in irrigation water?

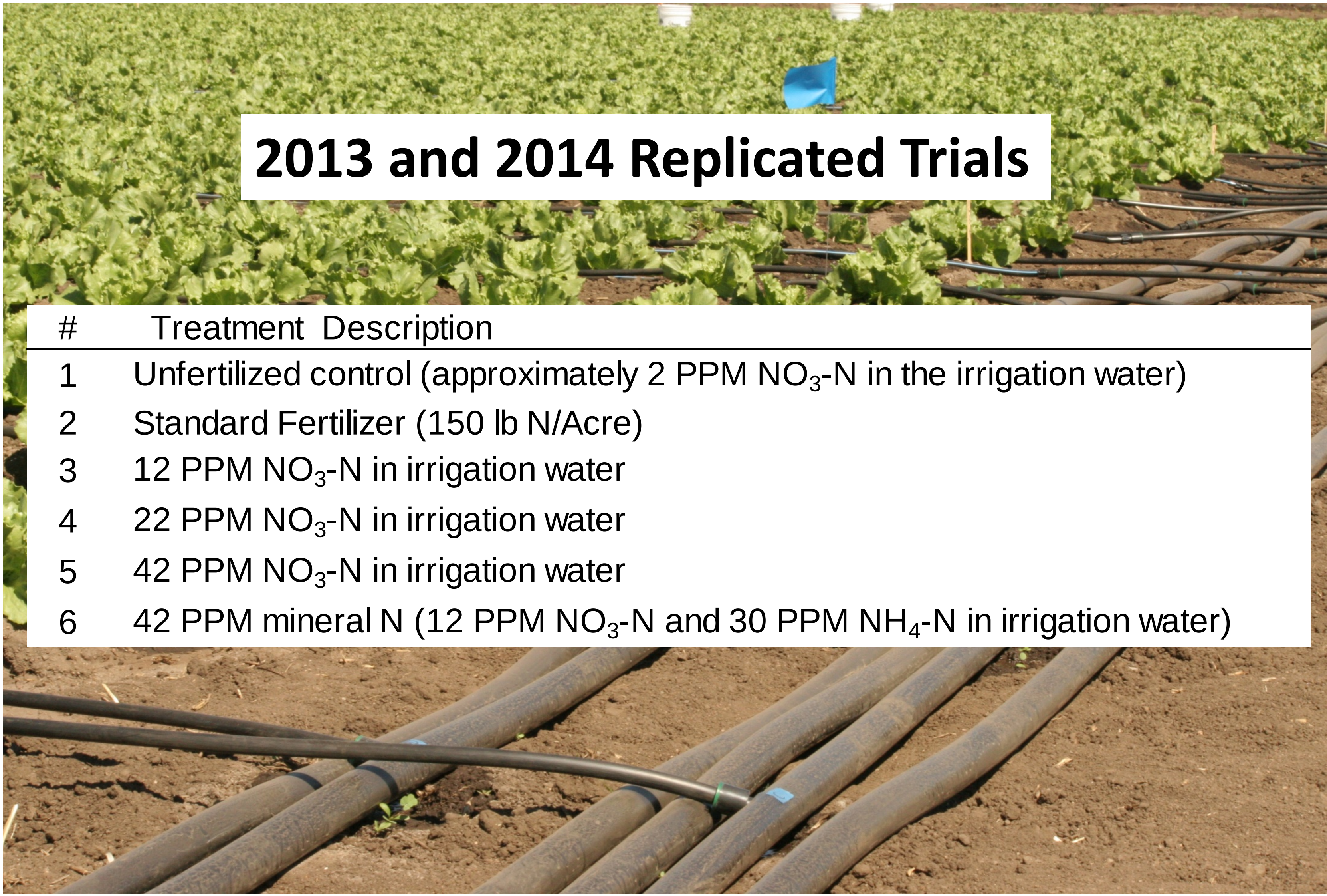
- Is N in water fully equivalent to fertilizer N?
- Does a low concentration of nitrate in water have fertilizer value?
- Does over-applying water for leaching salts affect N recovery?
- Does the form of N in water (nitrate vs ammonium) affect crop recovery?

Irrigation Manifold for Simulating Water with Varying Concentrations of N



- Nitrogen salts: Calcium Nitrate, Sodium Nitrate, Ammonium Sulfate
- Salts proportioned to maintain sodium adsorption ratio (SAR) between 1.8 and 2.4

Water N treatments were applied by drip



2013 and 2014 Replicated Trials

#	Treatment Description
1	Unfertilized control (approximately 2 PPM NO_3-N in the irrigation water)
2	Standard Fertilizer (150 lb N/Acre)
3	12 PPM NO_3-N in irrigation water
4	22 PPM NO_3-N in irrigation water
5	42 PPM NO_3-N in irrigation water
6	42 PPM mineral N (12 PPM NO_3-N and 30 PPM NH_4-N in irrigation water)

Two irrigation rates were evaluated

Irrigation Treatment	Crop ET	Applied Water Sprinkler	Applied Water Drip	Applied Water Total
		---------	inches	---------
Standard Water Rate	110%	3.7	7.0	10.6
High Water Rate	160%	3.7	10.1	13.8

Irrigation rates were based on estimated crop evapotranspiration (ETc) using CIMIS weather station 214

How is nitrate in irrigation water converted to applied N?

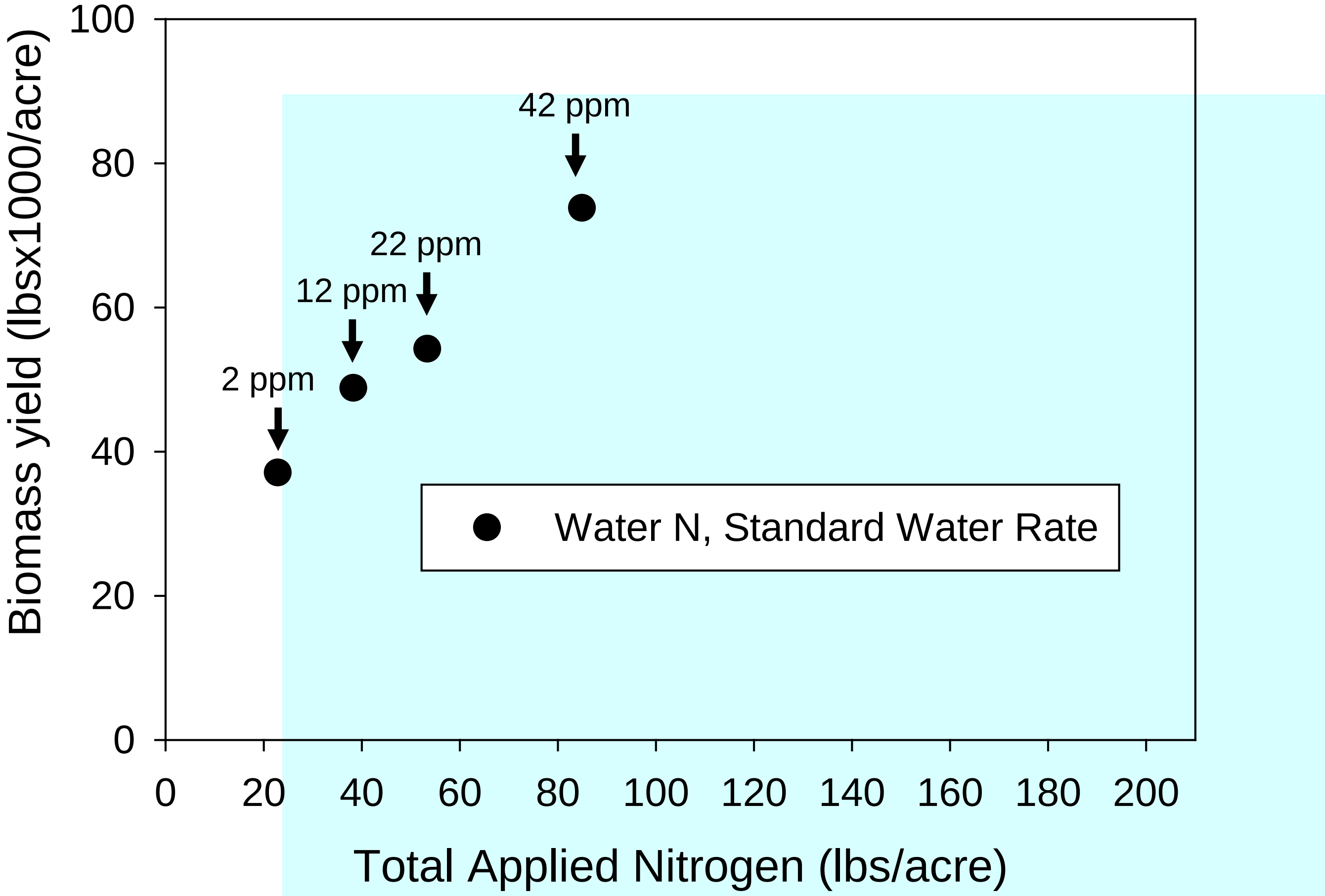
Pounds of nitrogen/acre=

applied water (inches) x NO_3-N conc. (ppm) x 0.23

Irrigation Treatment	Applied Water	Fertilizer N value NO_3-N concentration 12 ppm	22 ppm	42 ppm
	inches	------ lbs N/acre ----		
Standard Water Rate	7.0	19	35	68
High Water Rate	10.1	28	51	98

Nitrogen in water affected both plant size and N content of tissue

Biomass Yield of Iceberg Lettuce (spring planting, 2013)



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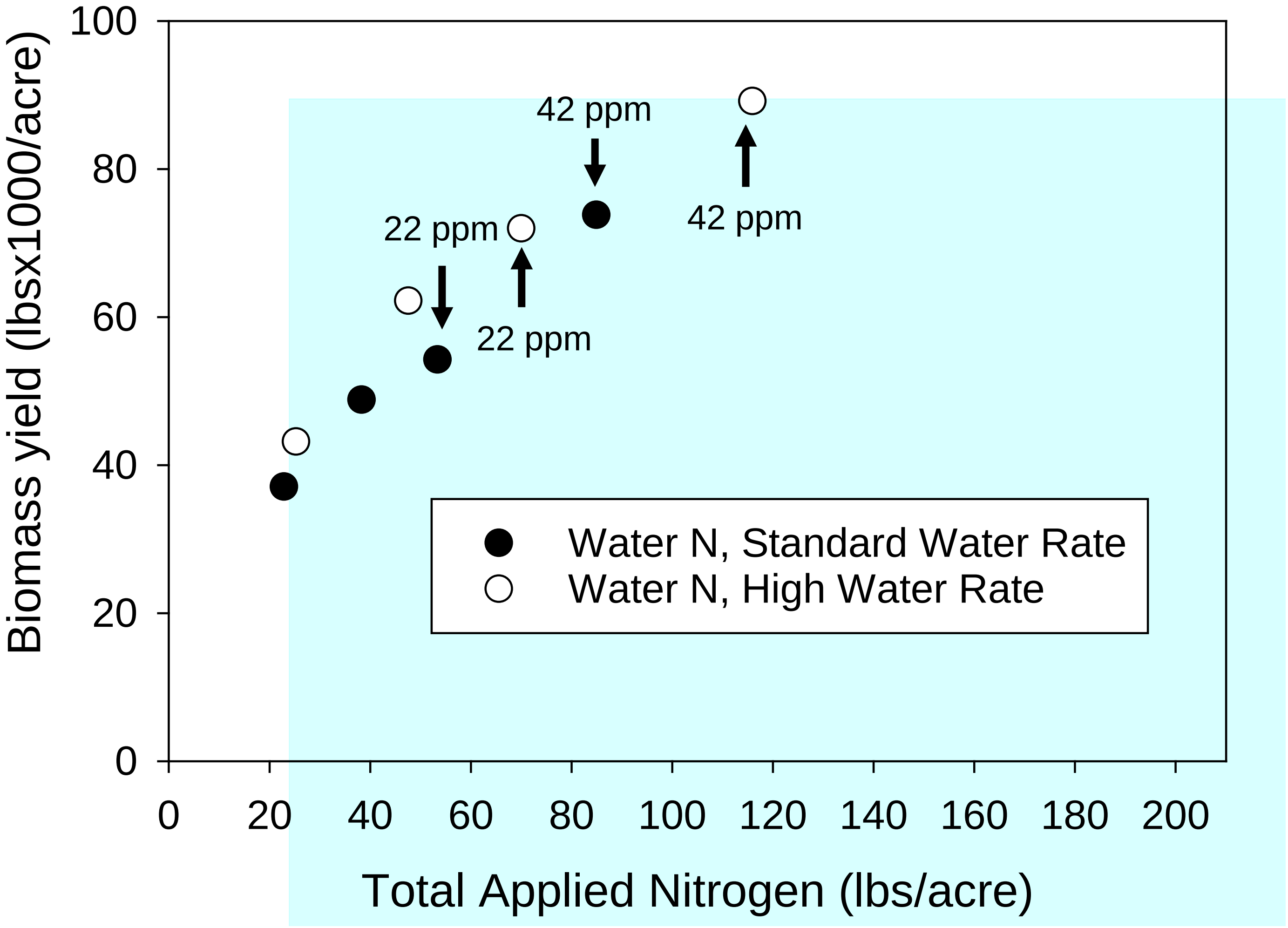

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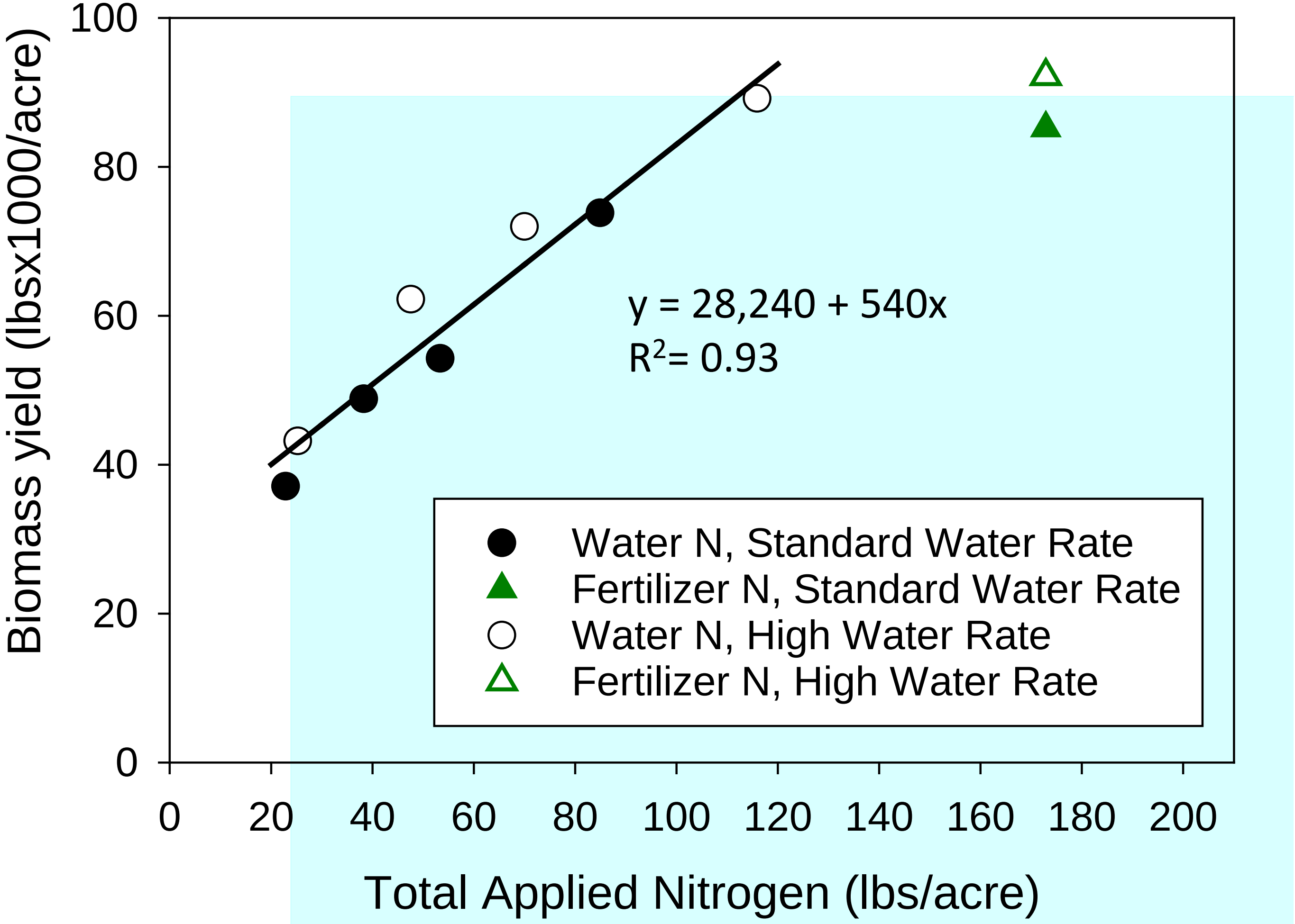
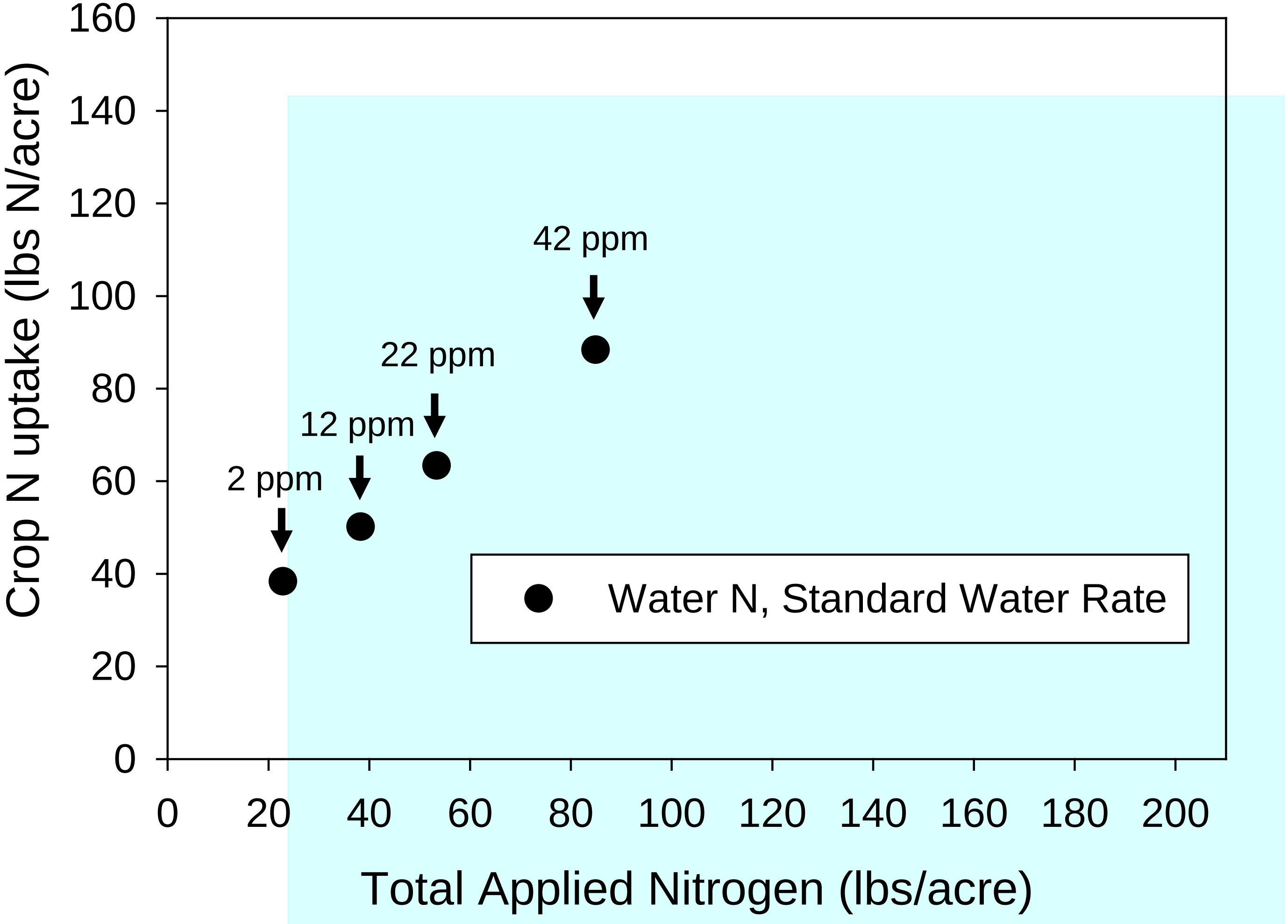


Nitrogen Uptake of Iceberg Lettuce



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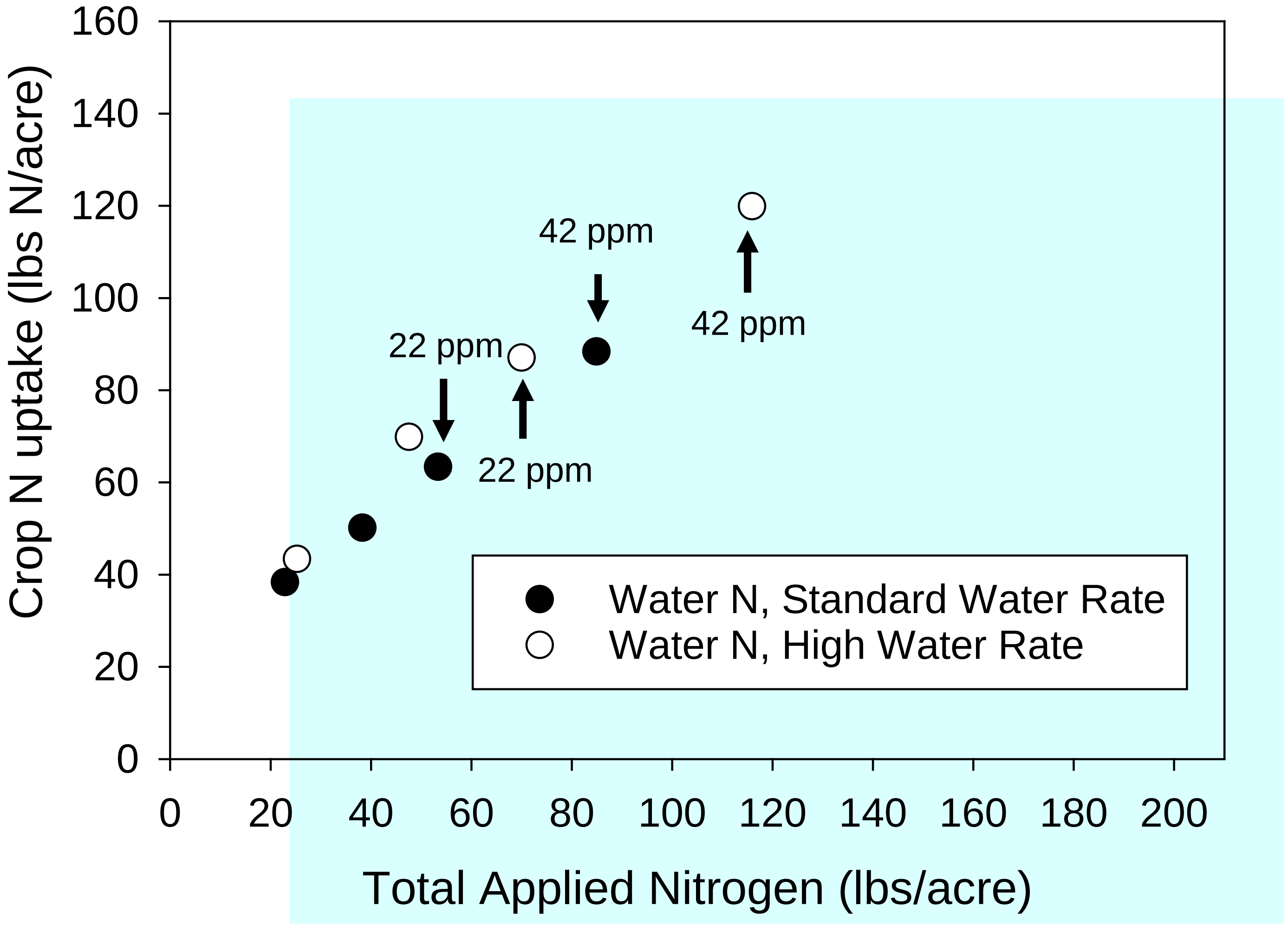

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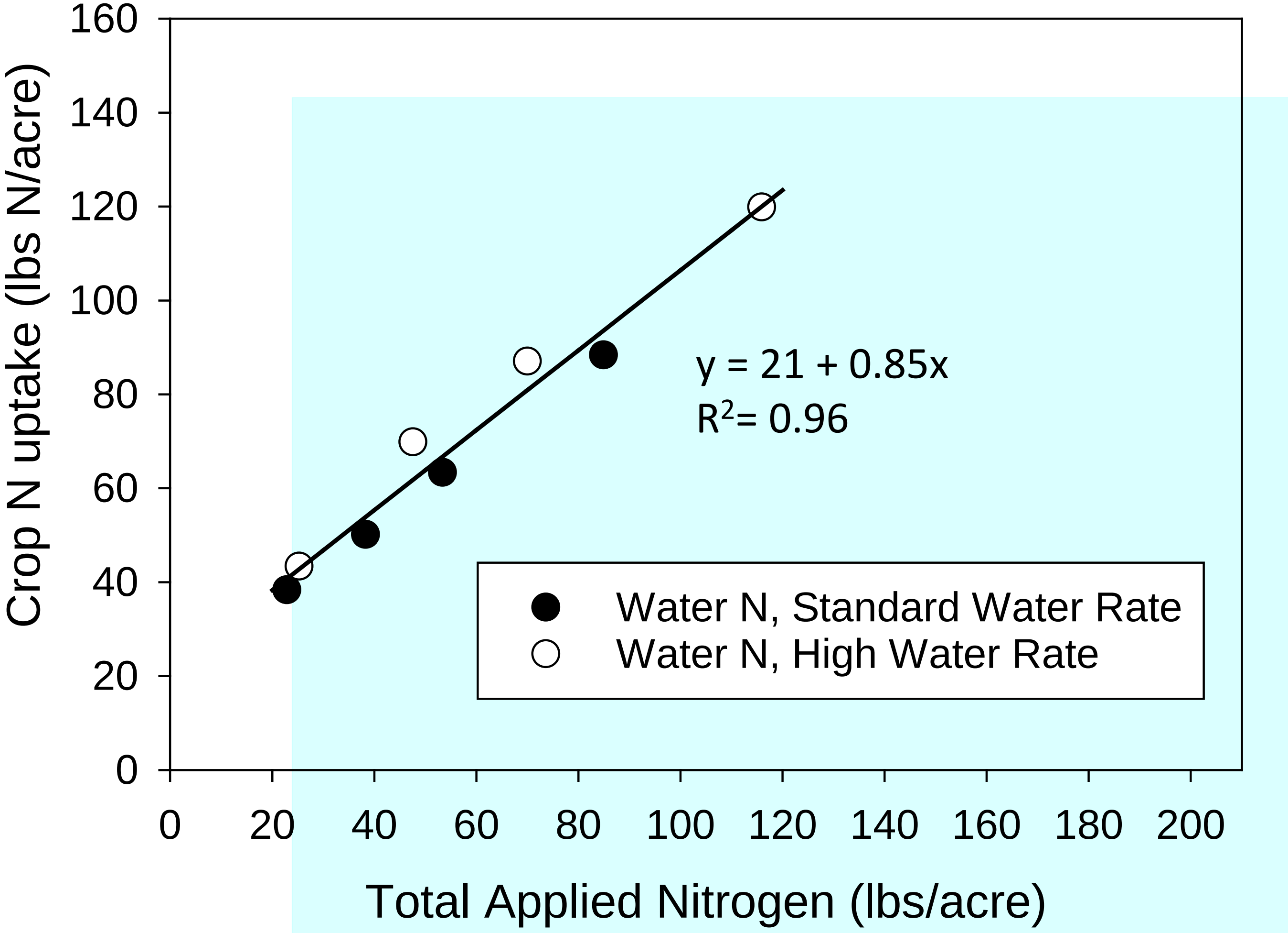

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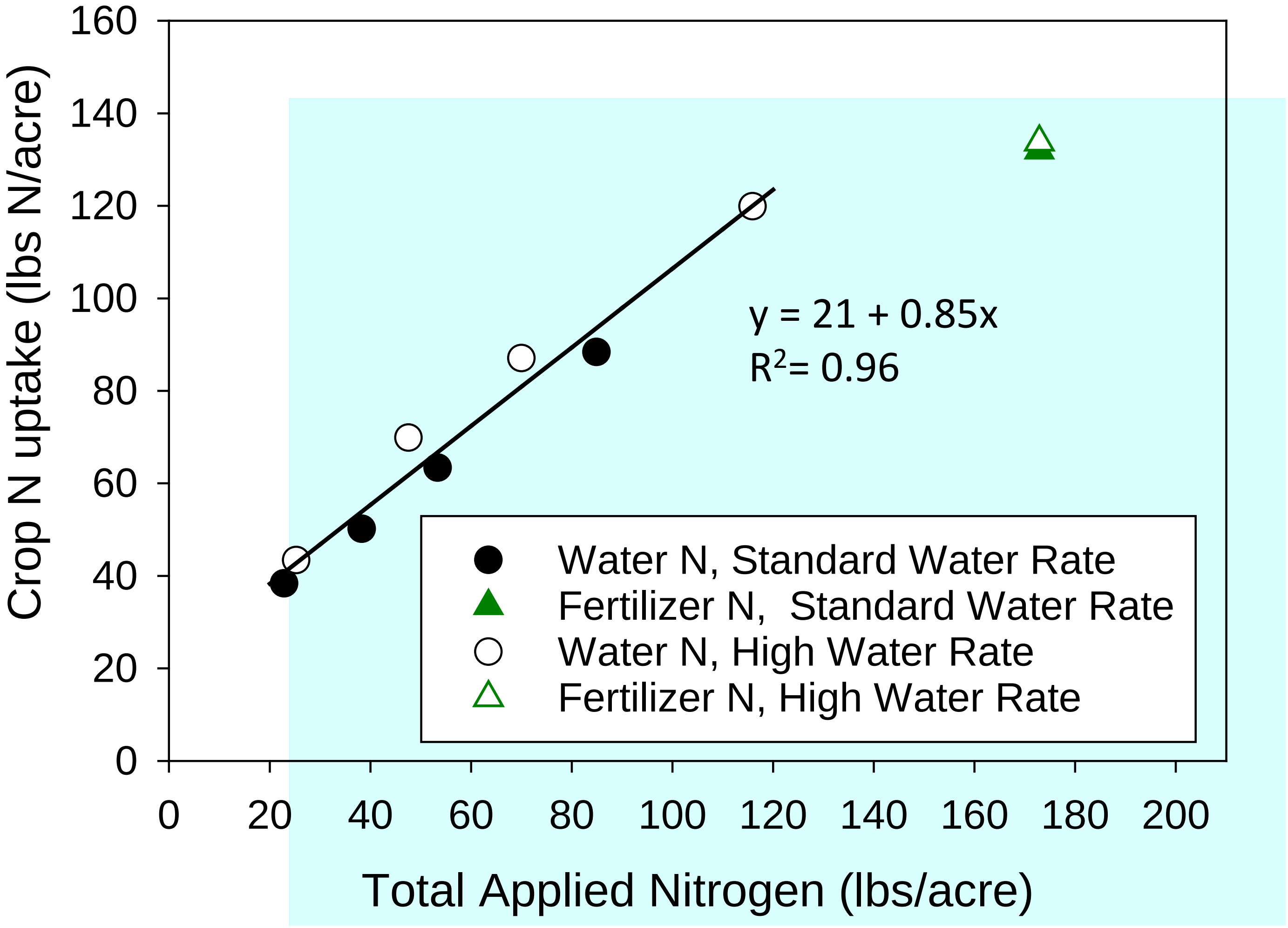

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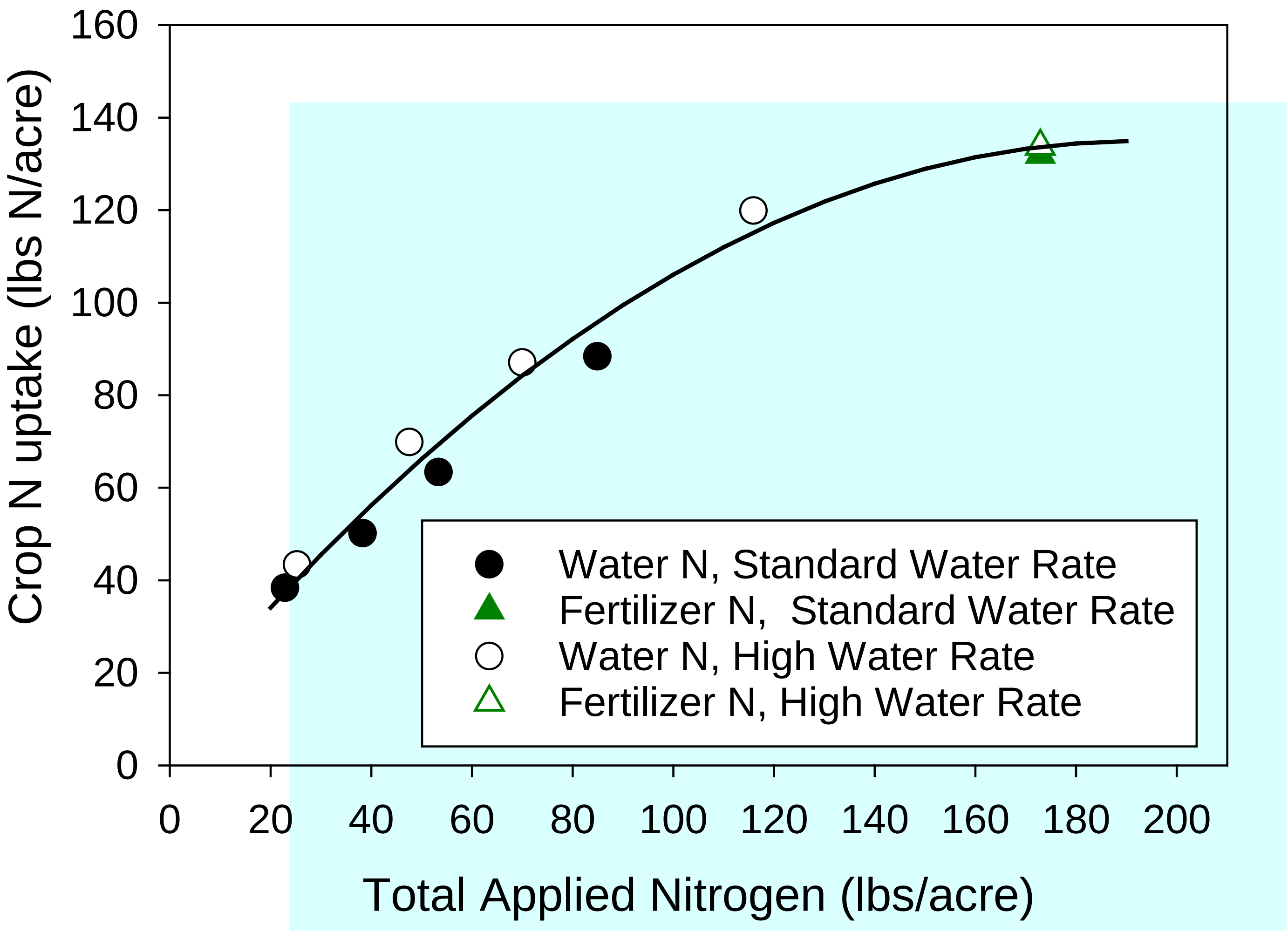
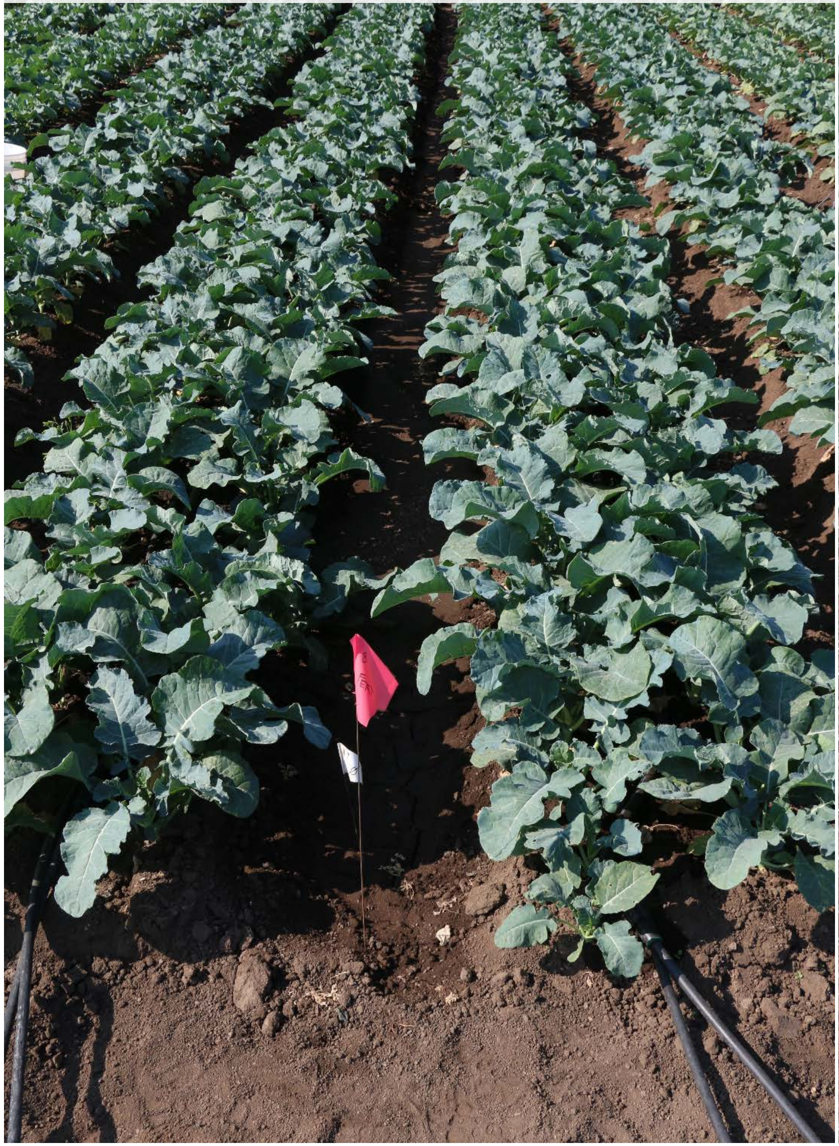
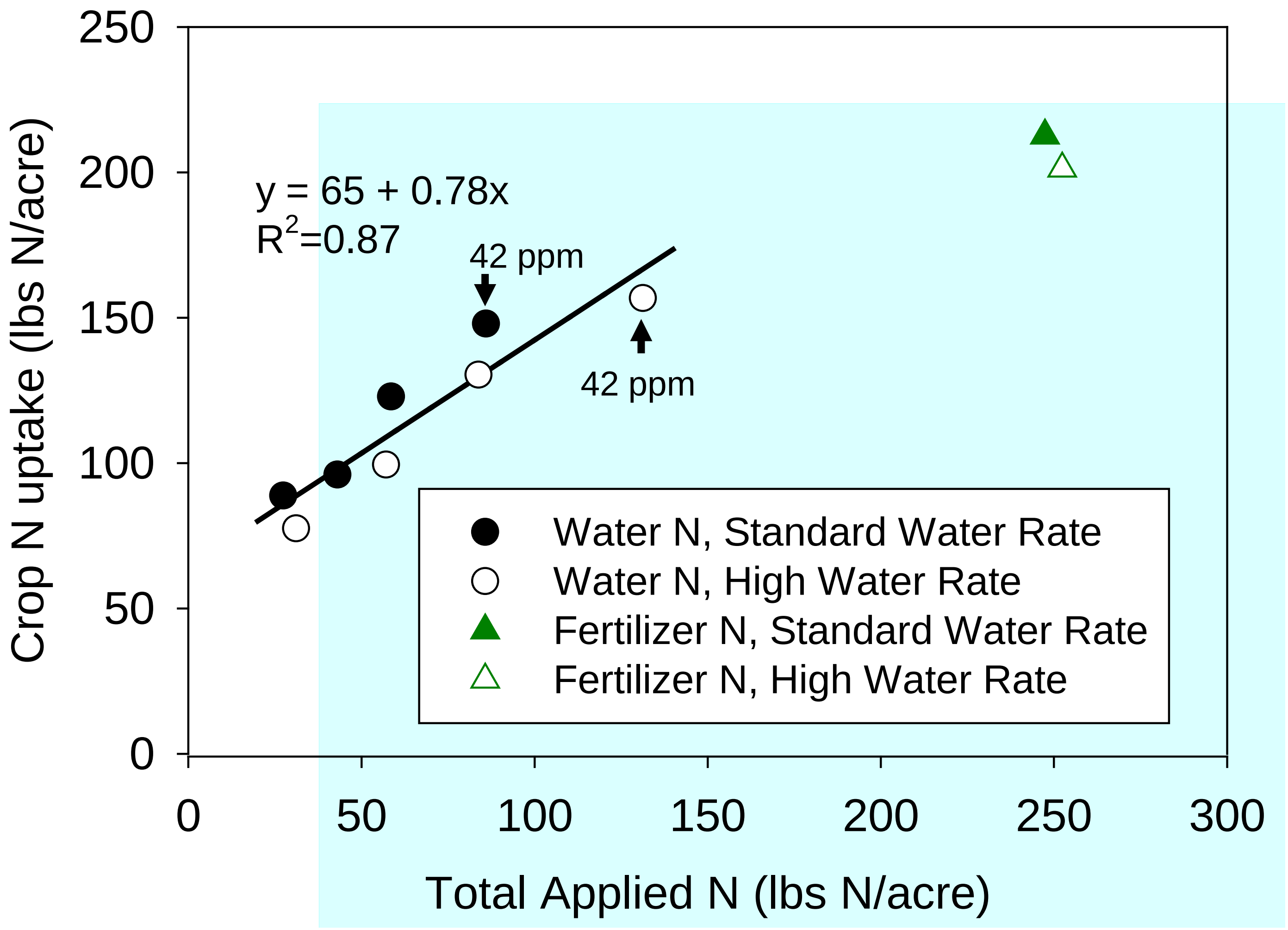


Broccoli: Deep rooted + high N demand (> 250 lbs N/acre)

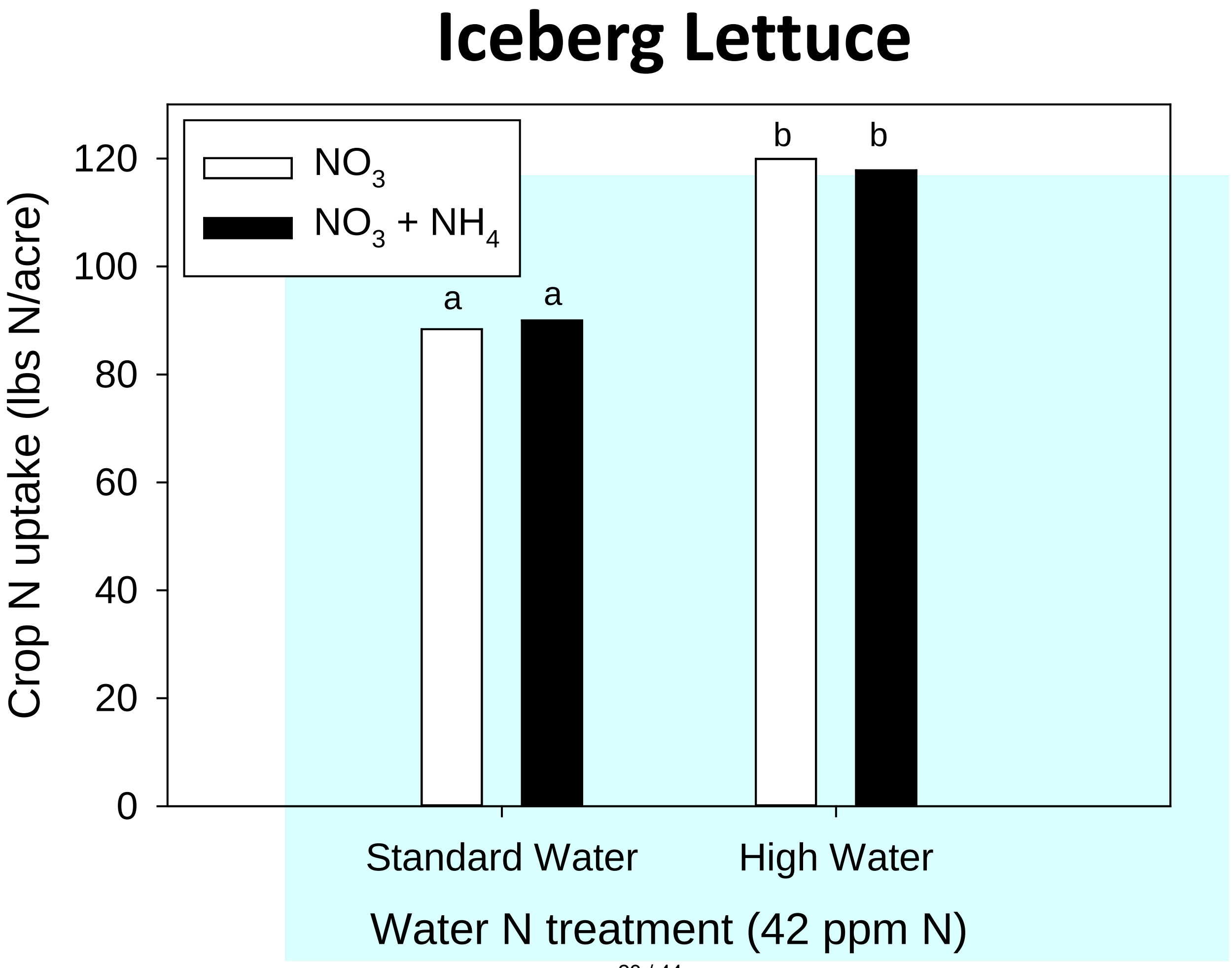


Nitrogen Uptake of Broccoli

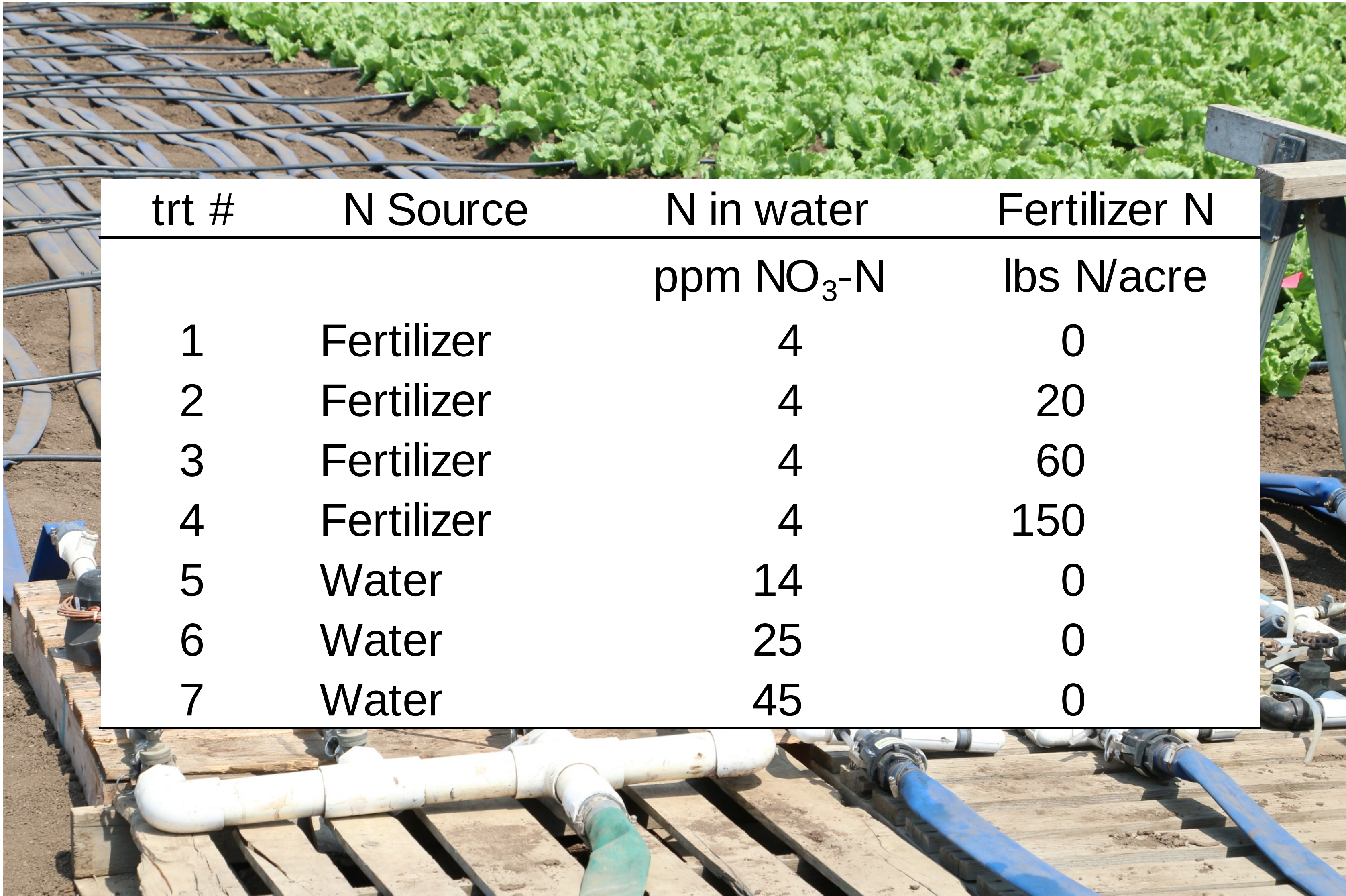


Ammonium *vs* Nitrate sources of N in Irrigation Water

Crop uptake of N was similar for NH_4 and NO_3-N sources in irrigation water

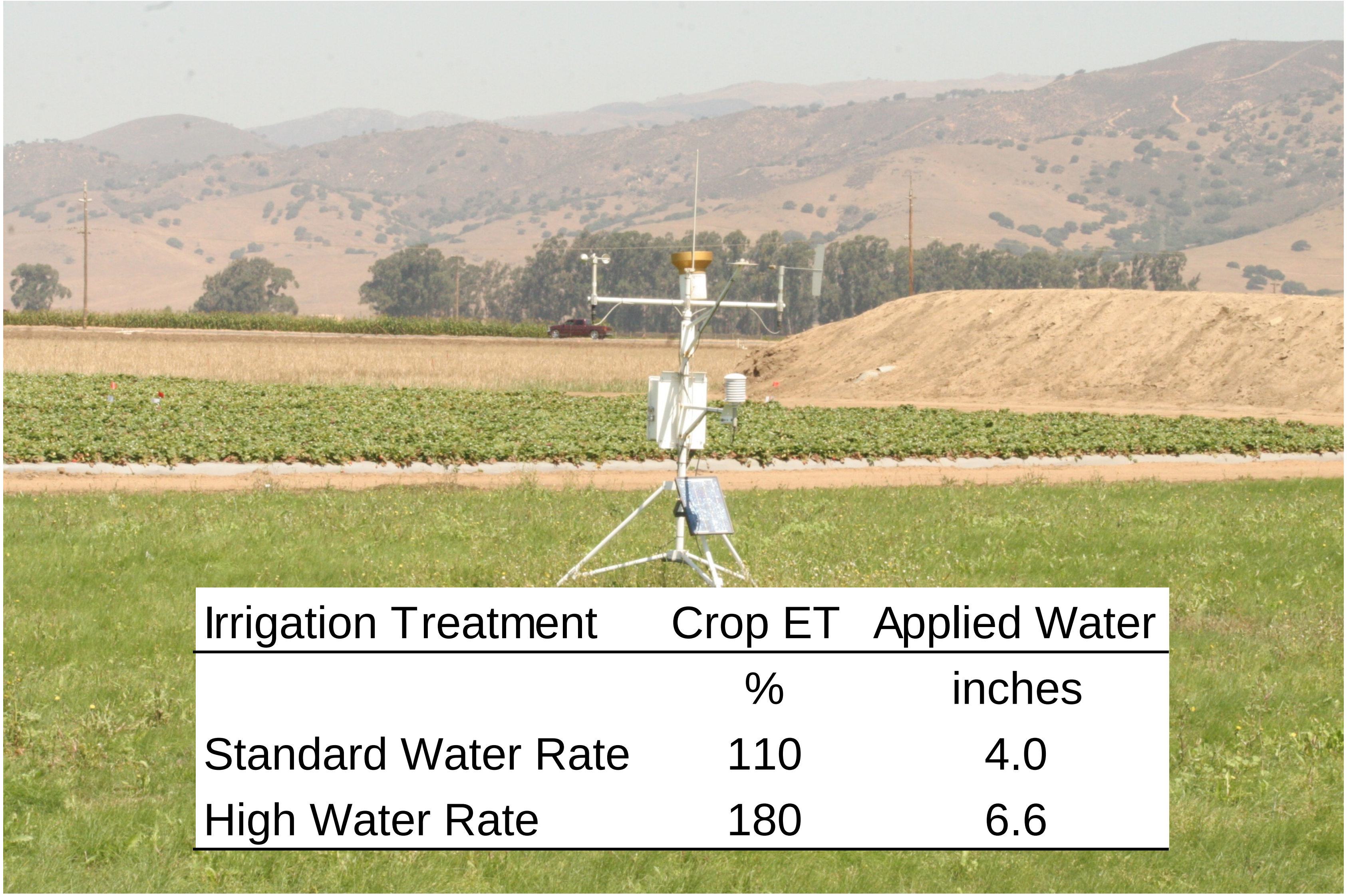


2015 Trials compared water and fertilizer sources of N



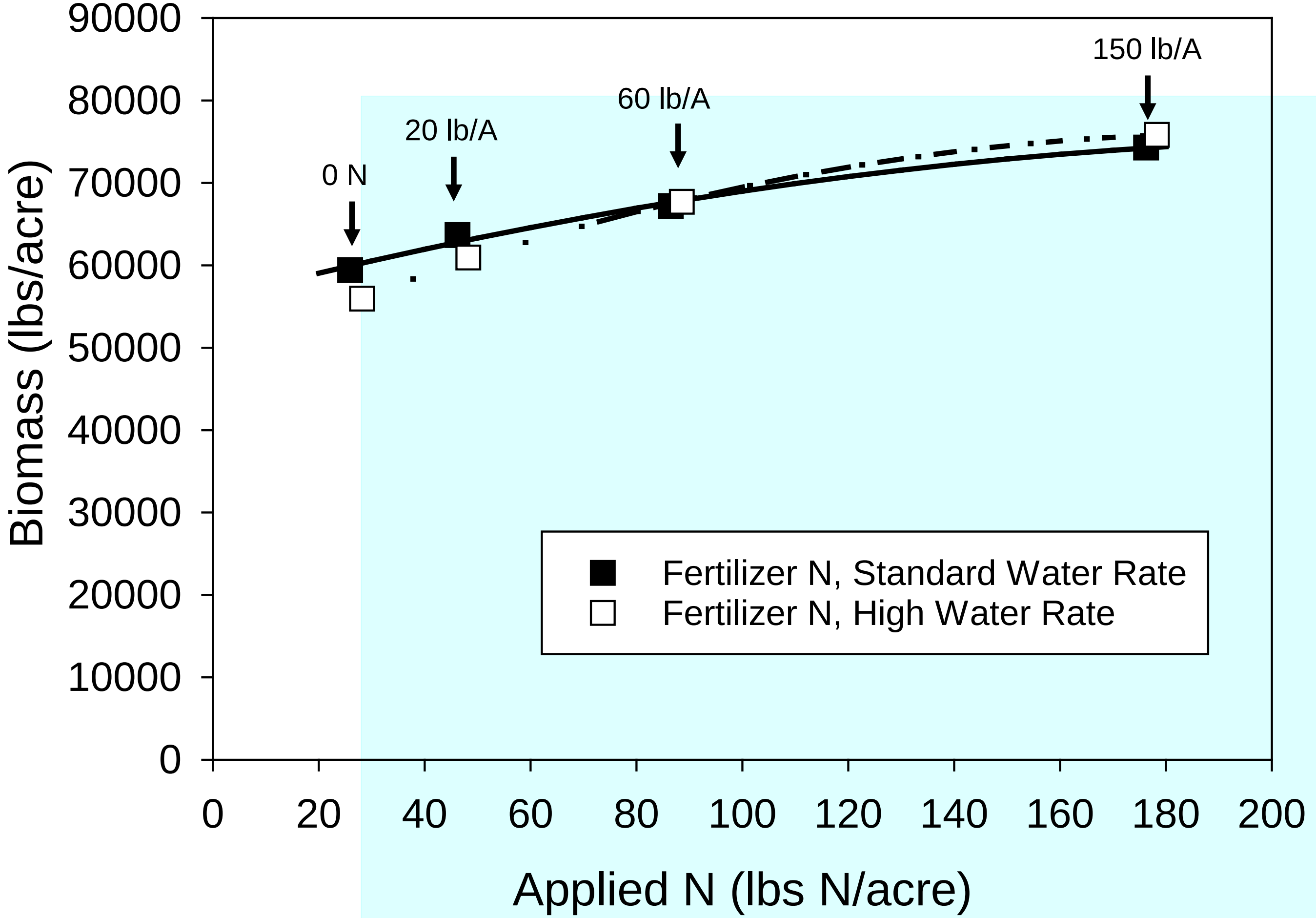
trt #	N Source	N in water	Fertilizer N
		ppm NO_3-N	lbs N/acre
1	Fertilizer	4	0
2	Fertilizer	4	20
3	Fertilizer	4	60
4	Fertilizer	4	150
5	Water	14	0
6	Water	25	0
7	Water	45	0

Two irrigation rates were evaluated



Irrigation Treatment	Crop ET	Applied Water
	%	inches
Standard Water Rate	110	4.0
High Water Rate	180	6.6

Lettuce Biomass Yield



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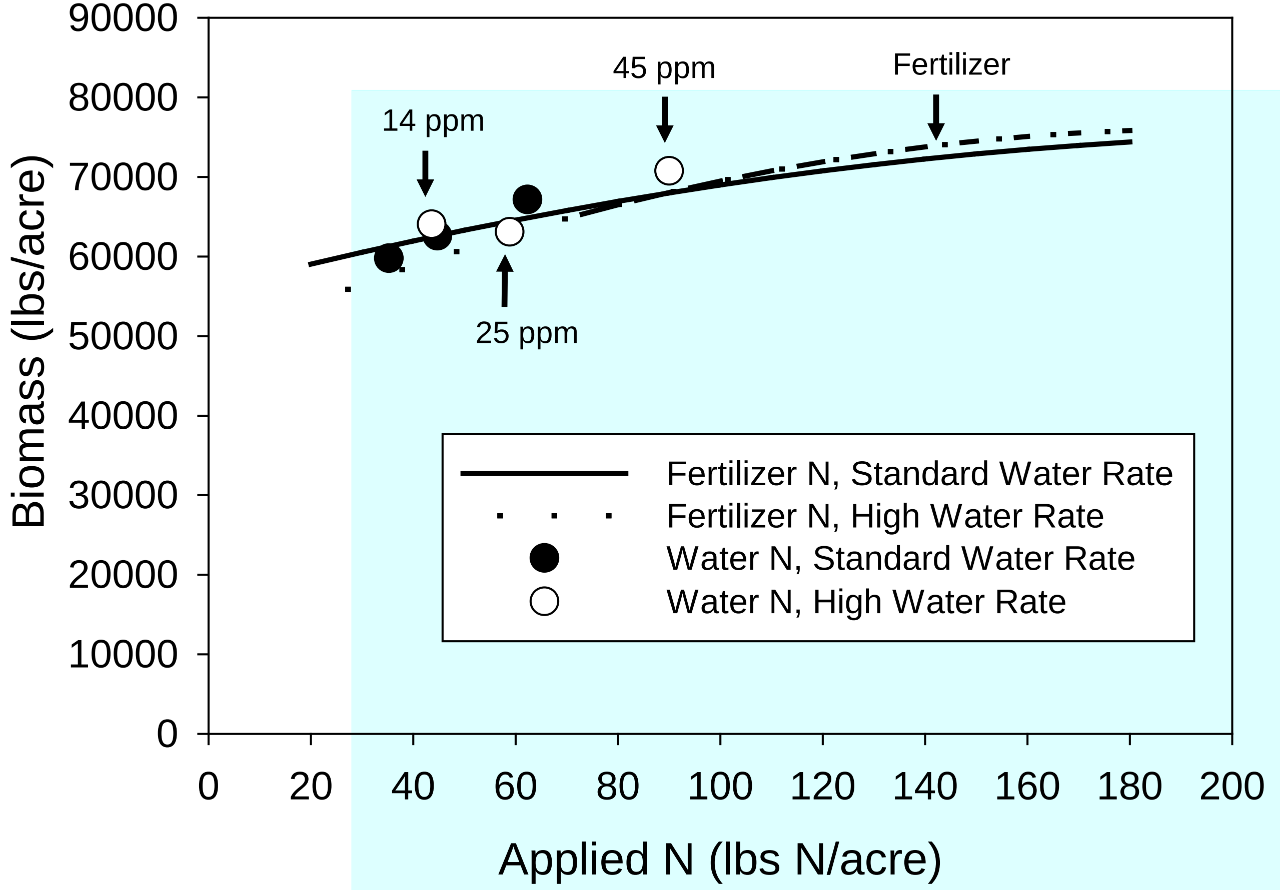
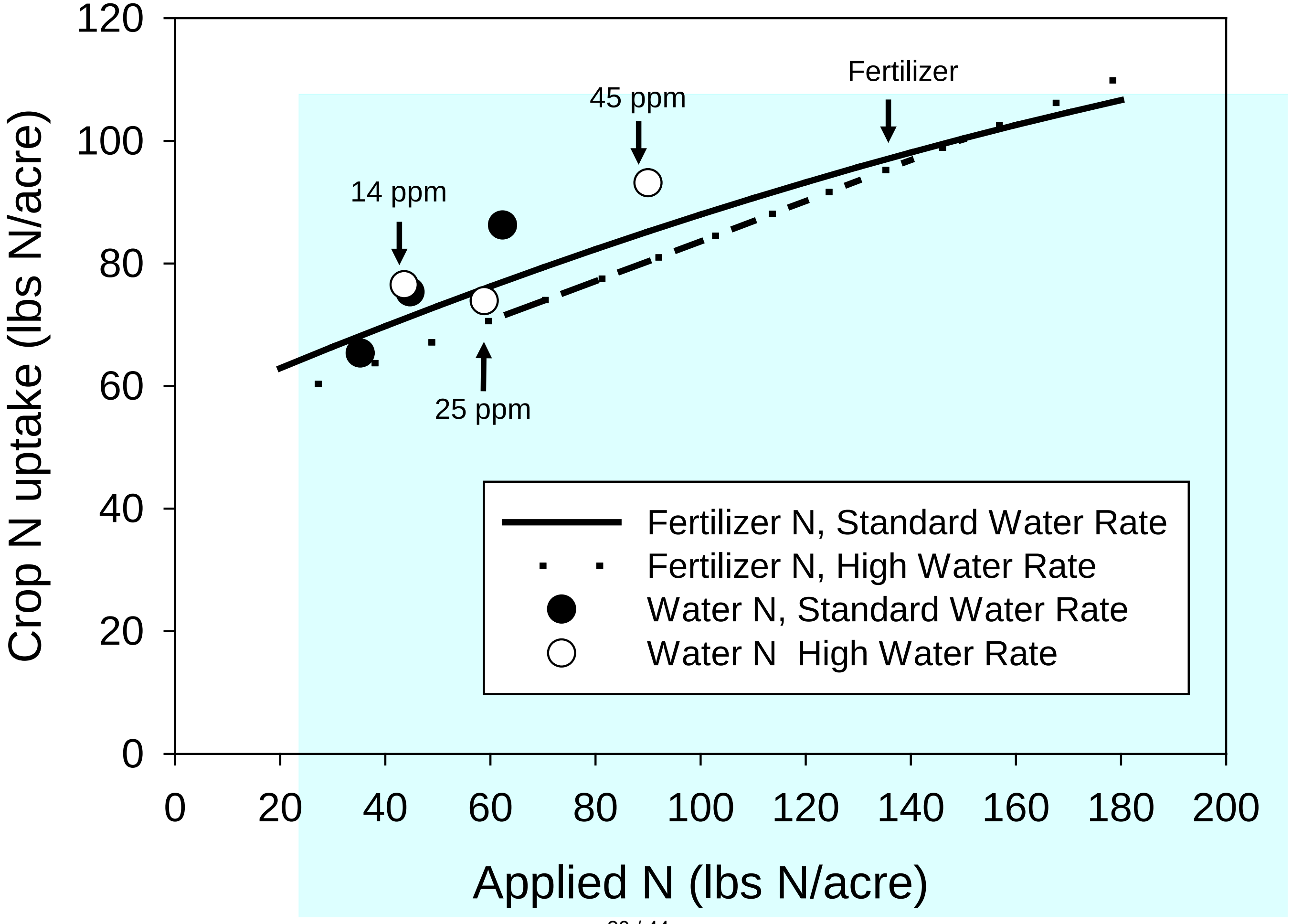
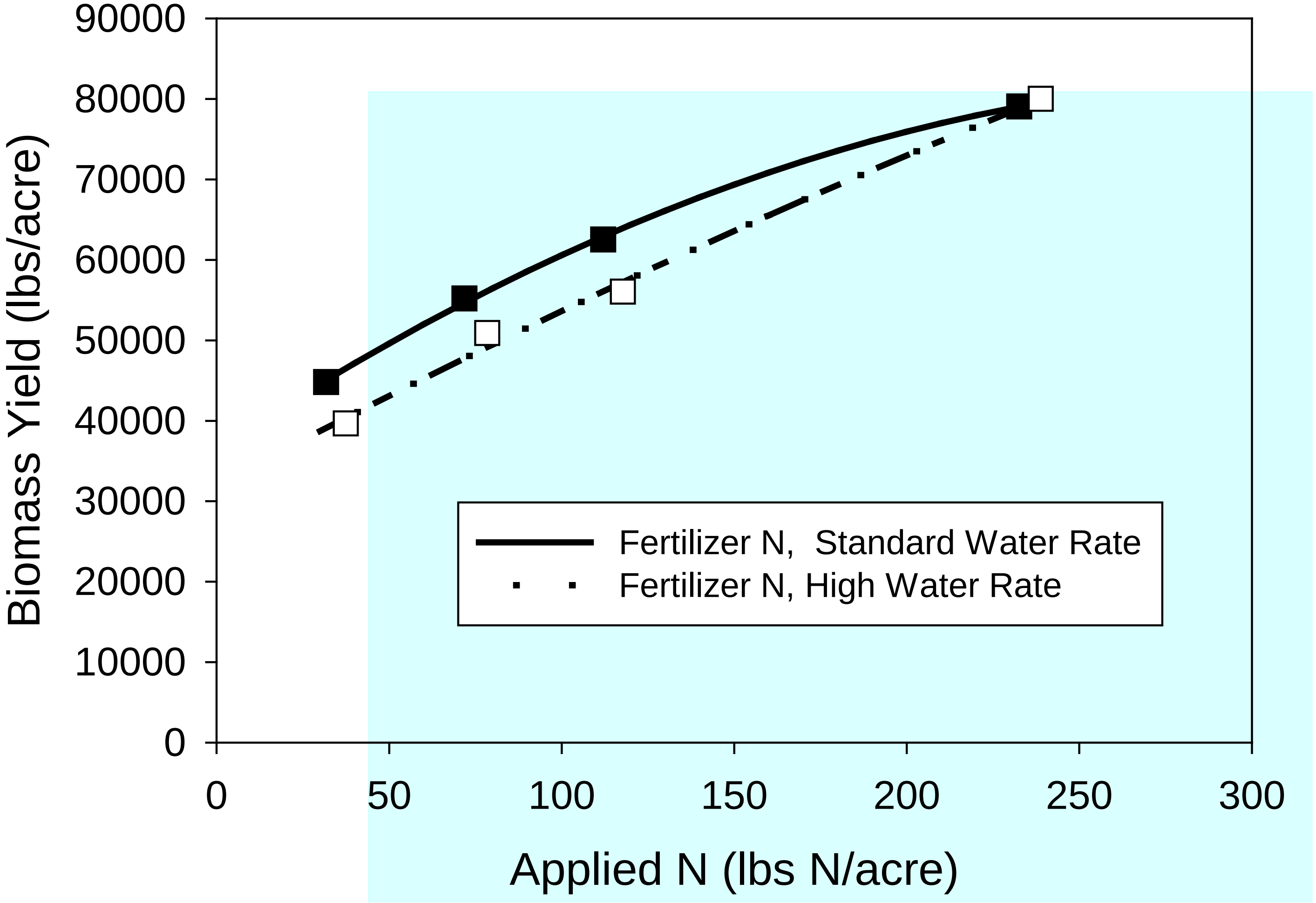


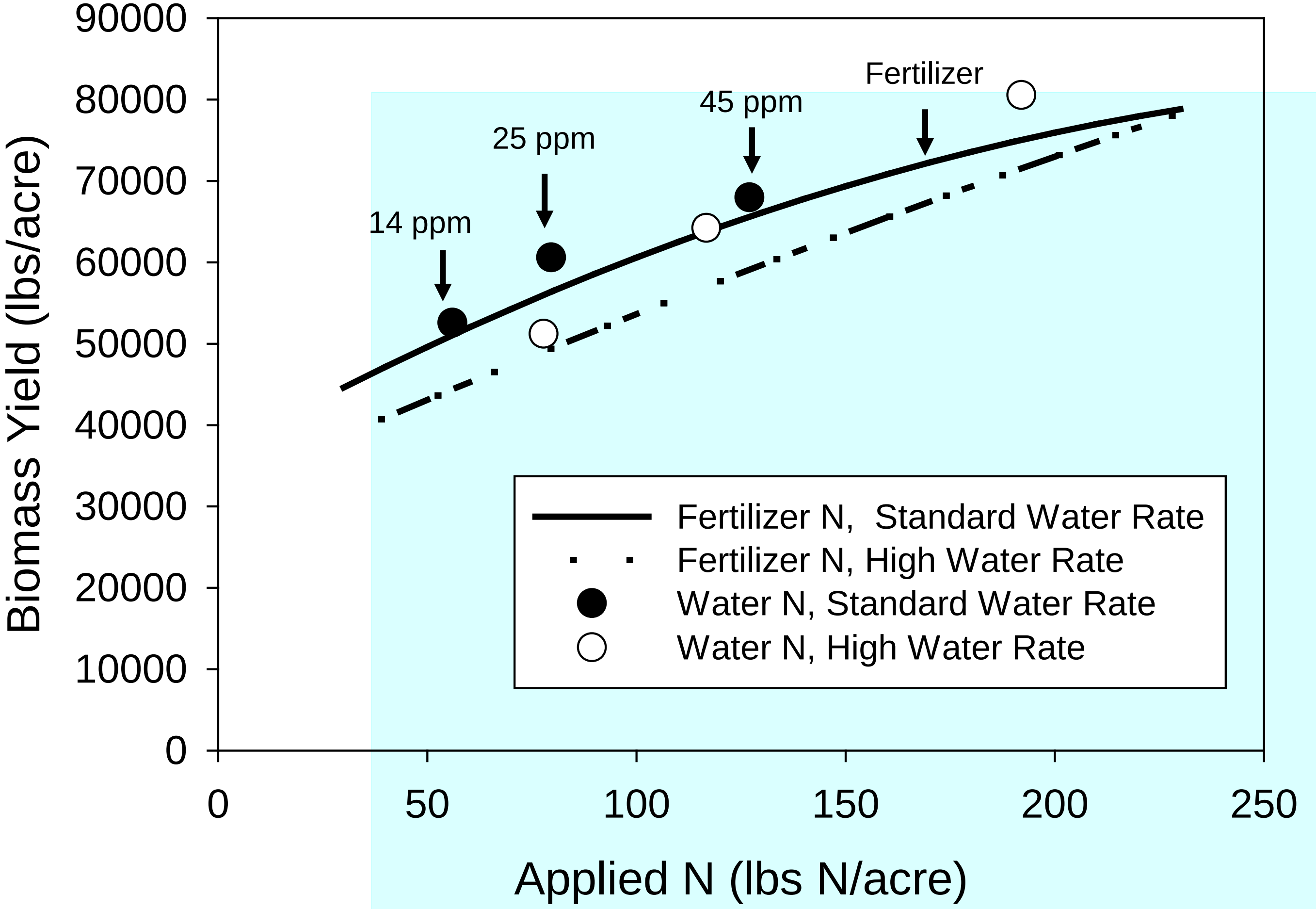
Lettuce N Uptake



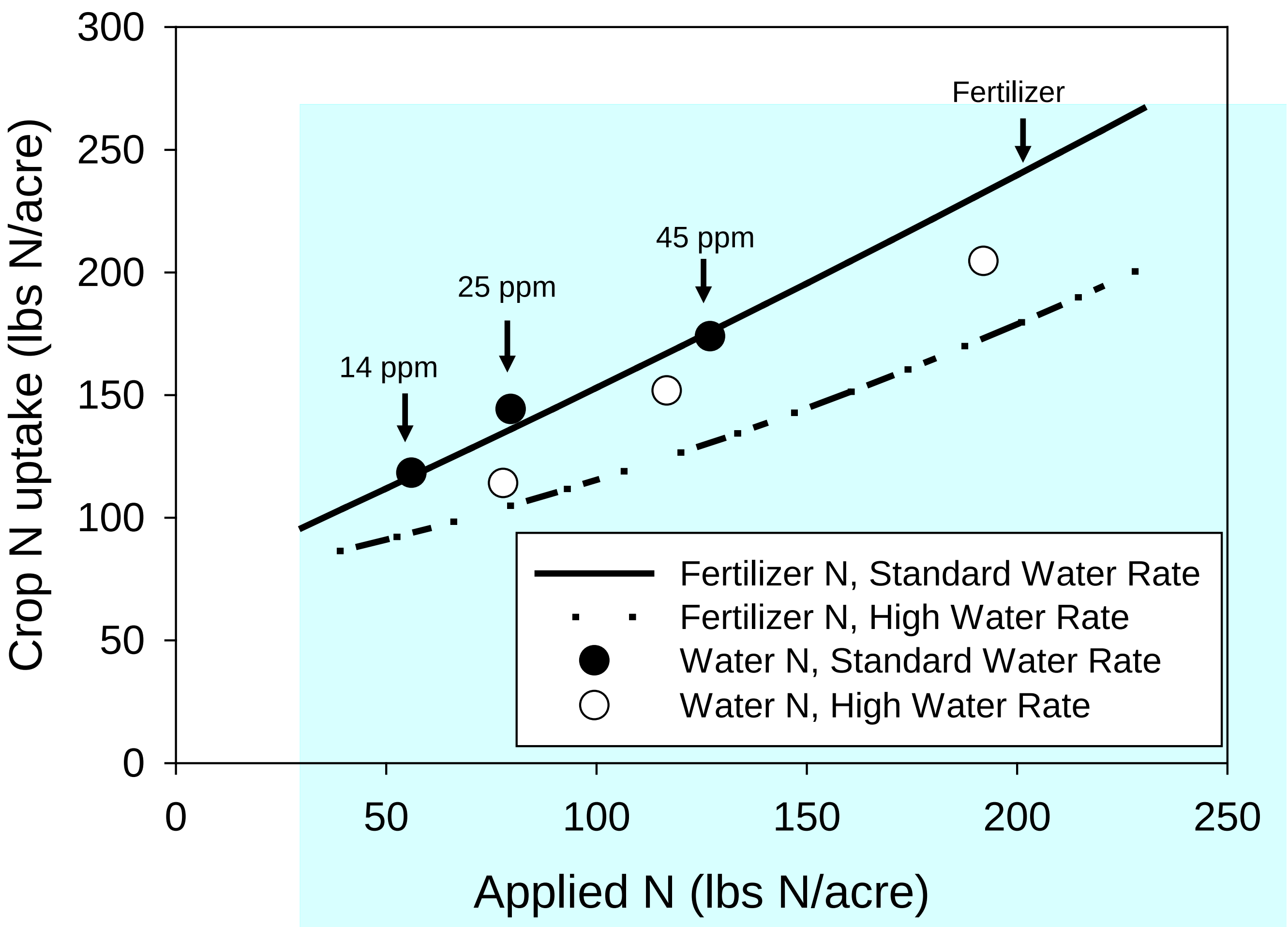
Broccoli Biomass Yield



Broccoli Biomass Yield



Broccoli N Uptake



Conclusions from Replicated Trials

- ✓ N in irrigation water has the same nutrient value for lettuce and broccoli as fertilizer sources of N
- ✓ Low concentrations of nitrate-N (12 ppm) in irrigation water are taken up by lettuce and broccoli
- ✓ Fertilizer value of NH_4 and NO_3 sources of N are equivalent
- ✓ Volume of water applied to the crop can affect the recovery rate of N from the irrigation water but the recovery appears to be equivalent or slightly better than from fertilizer
- ✓ We did not test if high N water applied before thinning has fertilizer value for a vegetable crop

Should growers credit N in water applied during pre-irrigation and germination?

- **Applied water >> Crop Evapotranspiration**
- **Crop N uptake is minimal between germination and the first fertilization**

Crediting for N in water and residual soil N

Soil Nitrate

Current N status of Soil

+

N in water

Future N contribution

Some practical challenges to crediting for N in water

- ✓ Multiple wells often used to irrigate a crop
- ✓ Nitrate concentration in some wells changes during the season
- ✓ Need to estimate how much water will be applied when fertilizing
- ✓ Need to also adjust for nitrate in the soil
- ✓ Many plantings to manage simultaneously in most mid to large scale vegetable operations

Commercial Trials in 2016 and 2017

- **Conducted at sites with high nitrate well water**
- **Varying levels of salinity in water**
- **Varying levels of residual N in soil**

Manifold for Irrigation Treatments

Treatments

1. Grower Standard
2. Best Management Practice (BMP)
3. Intermediate

Soil and Water N concentrations

Trial #	Soil NO_3-N*	Water NO_3-N	Applied water #	Applied N in Water	Water Salinity
	ppm		inches	lbs N /acre	dS/m
	------------------------ 2016 ------------------------				
Trial 1	8	32	5.0	36	0.8
Trial 2	29	84	5.3	101	1.2
	------------------------ 2017 ------------------------				
Trial 3	7	26	4.4	26	1.1
Trial 4	35	80	5.0	89	1.4
Trial 5	20	42	6.8	65	1.8

* 1 ft depth at thinning

water applied by drip after thinning

Estimating N concentration when irrigating from multiple wells:

Determine average nitrate concentration in irrigation water

Commercial Large Plot Trials (nonreplicated)

		Applied Fertilizer N		
Trial #	Crop	Standard	BMP	Intermediate
		------------ lbs/acre ------------		
		------------ 2016 ------------		
Trial 1	Iceberg	154	140	--
Trial 2	Iceberg	62	32	0
		------------ 2017 ------------		
Trial 3	Romaine	120	128	160
Trial 4	Iceberg	63	7	32
Trial 5	Iceberg	155	118	122
Average		111	85	78

Commercial Yield Evaluation

Marketable Yield Large Plot Trials

	Marketable Yield relative to Standard		
	Standard	BMP	Intermediate
	lbs/acre	------------ %	-----------
	-------------- 2016 ----------------		
Trial 1	53573	2	--
Trial 2	42387	-1	--
	------------- 2017 ----------------		
Trial 3	36832	10	4
Trial 4	41526	8	17
Trial 5	22511	21	16
Average	33623	8	12

Summary

- ✓ Nitrate in irrigation water is bioavailable to vegetables, even when at low concentrations (12 ppm N)
- ✓ Crops will be most efficient in utilizing N in water if irrigation amounts follow the evapotranspiration demand of the crop.
- ✓ Factoring in irrigation water N into fertilizer decisions can be challenging in commercial vegetable operations.
- ✓ Simplest approach to account for N in water is to begin crediting after the crop is established.


Questions?