2017 USAFRI Research Project Objectives

Developing High Yielding and High Quality Alfalfa Varieties and Cropping Systems for High Salinity Conditions
University of California - Putnam

Project Award: $41,165

Justification:

- Salinity of soils and aquifers significantly threatens the sustainability of irrigated (and non-irrigated) agriculture in many parts of the world. Salinization associated with irrigation has been estimated to impact as much as 20 percent of the world's irrigated farmland (Munns, 2011). In alfalfa-growing regions, high salinity waters and soils can be found in southern Canada, northern Plains states (ND, SD), the Pacific Northwest states of WA, OR, and ID, the southern plains states of TX, OK, NM, AZ, the high desert regions of the Intermountain West (UT, NV, CO) and in the desert Southwest (AZ, NM, CA). Salinity is particularly a problem in irrigated regions. Salinity threatens the long-term sustainability of agriculture in the San Joaquin valley, with millions of acres of good soils rendered unproductive due to drought and salinity (Schoups et al., 2005).

Where does alfalfa fit into this scenario? About 50% of US alfalfa is produced in the western region (Table 1), 95% under irrigation, and in many areas with saline water sources. Cropping systems and varieties adapted to a more saline future are needed. Alfalfa is one of the more profitable agronomic crops, and is the key crop for western dairies – which now account for about 48-50% of US milk produced. A wide range of water sources are impacted by salinity (e.g. Colorado River, irrigation drainage areas, processing wastes, municipal and livestock wastewater) and could be used with appropriate management. Future cropping systems for saline areas are not likely to include the higher-value vegetable crops, or orchards/vineyard crops, which are generally highly salt sensitive. Forages and grains will continue to be moved onto more marginal land and irrigated with lower-quality water as high-value vegetable, fruit, and nut crops utilize the better soils and water sources. Additionally, salinity tolerance may be highly related to drought tolerance, an important objective for the future.

Table 1. Alfalfa Hay & Alfalfa Forage (hay+silage+greenchop) production, hay equivalent basis (13%DM). (2012 USDA-NASS Agricultural Ag. Census).

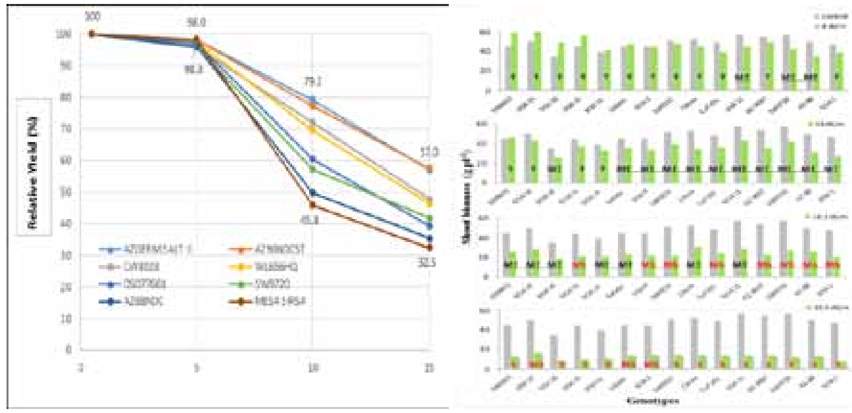
Region	Alfalfa Hay	Alfalfa Forage (Hay+Silage+Green)	Alfalfa Forage (% of US)
	tons per year	tons per year	%
MidWest	20,132,158	23,215,460	42.5%
Northeast	2,224,016	3,501,677	6.4%
South	435,991	501,753	0.9%
West	26,677,006	27,348,810	50.1%
Total US	**49,469,171**	**54,567,699**	**100%**

Alfalfa Response to salinity. Tanji and Kielan in their 2002 FAO document classified alfalfa as moderately sensitive (MS) to salinity, similar to corn. This is based upon sand tank studies (e.g. Maas and Hoffman, 1977 and Ayers and Westcott, 1985) developed using saline/nutrient solutions continuously applied in nearly hydroponic systems. These studies identified 2 dS/m ECe as the threshold value start of alfalfa yield reductions, with a 7 percent decrease in yield with each additional 1 dS/m increase in ECe. Later, Sanden and Sheesly (2007) suggested that for every 2 unit increase in soil ECe above 2 dS/m, it can be expected that there would be a 10 percent decrease in evapotranspiration, based on projected osmotic stress.

However, more recent data with improved varieties has suggested that alfalfa may be much more tolerant of high levels of salinity than suggested by these studies. Sharon Benes and colleagues at Fresno State have conducted a series of greenhouse studies over the past 7 years on alfalfa salinity tolerance to better understand overall salinity tolerance, influence of growth stage, and the differences between varieties (Figure 1). Similarly, recent sand-tank research conducted at the USDA-ARS Salinity

Lab in Riverside, CA found alfalfa to be tolerant to EC levels much greater than EC of 2.0 (Figure 1). In field experiments conducted with alfalfa cultivars conducted in western Fresno County, CA, Putnam et al (2016) tested the forage yield responses of a broad range of alfalfa cultivars to irrigation waters applied at 5.5 dS/m ECw salinity levels (resulting in ECe of the soil at about 9.0 dS/m at the end of the trial) and found normal field trial yields (12 tons/acre) after 3 years. In a subsequent field yield trial where we challenged crops to much greater salinity (9 to 10 dS/m ECw, resulting in soil ECe of 16.0 dS/m for 0-3 ft depth), we only saw only a 12% yield decline over 2 years (2015-16), compared to the 50-60 percent yield losses predicted by FAO projections (Putnam, 2017). To summarize these greenhouse, sand tank and field studies to date, we can conclude that:

Figure 1. Greenhouse yield studies (Left, Benes et al. unpublished), and Sand Tank Studies (Right - Cornacchione and Suarez, 2015) show both a high level of tolerance to salinity in alfalfa and significant differences between varieties.



- Alfalfa is considerably more saline-tolerant than levels suggested in earlier studies,
- It is possible to produce an economic crop with high saline (ECw 7-10 dS/m) water.
- Soil interactions (lack of water infiltration, crusting, lack of water) may be more important under high salinity and sodic conditions than salinity itself.
- Considerable genetic variation for salinity tolerance can be observed, suggesting that genetic advancement is highly promising.
- It is unclear to what extent salinity tolerance of varieties observed under greenhouse or controlled conditions can be translated to field conditions.

Although confirming overall salinity tolerance in alfalfa, most researchers, including ourselves, have had trouble translating salinity tolerance of varieties to field conditions due to excess variability. We believe this is due to the methods of irrigation and secondary soil influences (water infiltration, crusting, inadequate infiltration and/or soil moisture), which may be more important than salinity itself in causing reductions in yield and excessive variation in the field. In this trial, we will take a series of steps to improve uniformity with integrated drip/flood systems, and aerial photography to adjust for variation. This project 1) formulates better field testing methodologies to test salinity tolerance in the field, 2) will publish field results for yield and quality variety response to salinity, 3) supports public and private breeding efforts to develop saline-resistant lines, and 4) furthers an understanding of the mechanisms for salinity tolerance in alfalfa lines and 5) develops agronomic recommendations to manage salinity in the field.

Objectives:

- The goal of this project is to develop cropping solutions and improved varieties for alfalfa grown profitability under high salinity conditions to meet the needs of a water-challenged future.

Specific objectives are to 1) Characterize yield and quality differences among multiple alfalfa varieties in tolerance to high salinity irrigation under field conditions; 2) Evaluate the economic viability of alfalfa crop production under high-salinity systems (EC 8-12 dS/m waters) and develop recommendations for producing alfalfa under saline conditions, and 3) Develop new germplasm and varieties with high forage production under saline stress.

This research will enable us to begin to develop a better understanding of the genetic, physiological, and agronomic mechanisms of salinity tolerance in alfalfa, and set the stage for future hypothesis-driven research.