GENETIC ADVANCES IN ALFALFA AND GRASSES: ARE WE MAKING PROGRESS?

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BACKGROUND

Of all traits of importance, yield typically gets top billing. Yield alone is not enough, of course – stands need to persist as long as desired and nutritive value needs to be adequate. But, given those qualifications, yield is the most important overall trait. I'll begin by considering evidence for yield improvement in alfalfa. There is very little. Here are several ways to look at yield; in all cases, yield improvements appear to be limited or stagnant. Gains that have been made have resulted from either improved disease or pest resistances or improved management practices. Some of the data presented here are derived from a paper that I published recently (Brummer and Casler, 2014).

Painting with a broad brush, one can consider yield gains based on USDA ag statistics. Looking at alfalfa yields for the USA as a whole shows essentially no yield improvement in on-farm yields for the past 25 years. Breaking the country down by state yields somewhat similar results, with the one exception of California, which has not seen a yield stagnation until (perhaps) the past 10 years or so. We'll see if that changes as water becomes more limiting.

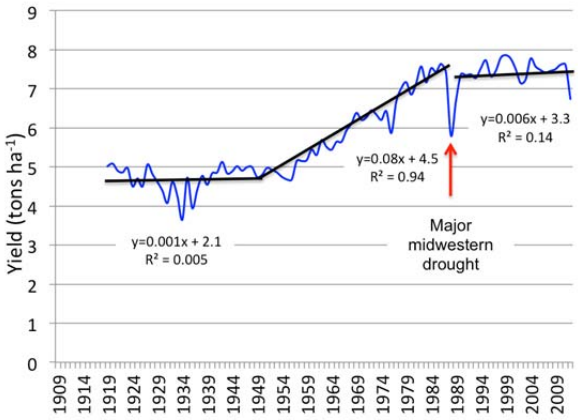

Figure 1. US average on-farm alfalfa yield trend for the past 100 years.

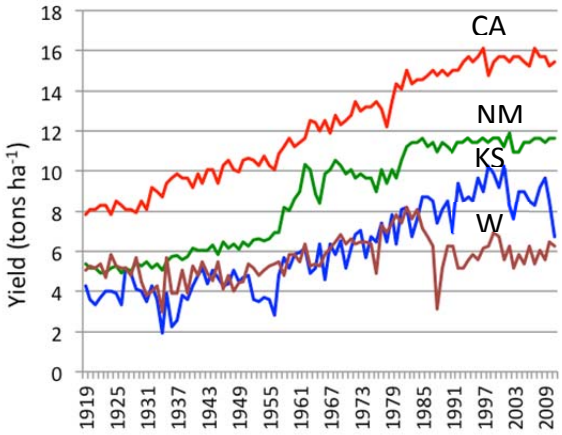

Figure 2. On-farm alfalfa yields for four states over the past 100 years.

But broad-stroke, on-farm statistics cover up a magnitude of issues – the good producers are lumped with the poor, the actual yields may be suspect due to the lack of good yield monitors such as those on grain combines, and there's no accounting for stand life (and associated yield declines the typically attend older stands. An alternative means of considering yields is to look at university yield trial results. These trials tend to be highly maintained, very uniform, and

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Table 1. Yields of five top cultivars compared with Vernal in three alfalfa trials conducted at Tulelake, CA.

Year Seeded	Yield in First Full Production Year		Top Five as Percentage of Vernal
	Top Five	Vernal	
1999	8.8	7.5	117%
2004	9.0	8.0	113%
2010	8.4	7.6	110%

Table 2. Yield trends in Tulelake, CA alfalfa trials.

Harvest Year	Trial Mean Yield	Vernal	Mean as a percentage of Vernal
1999 Trial			
2000	8.3	7.5	111
2001	7.6	7.3	103
2002	9.2	8.9	103
2003	6.8	7.0	98
Average	7.2	7.0	103
2004 Trial			
2005	8.6	8.0	107
2006	8.9	8.4	105
2007	7.5	7.3	102
2008	7.4	6.9	107
2009	7.7	7.9	98
Average	7.5	7.2	104
2010 Trial			
2011	8.0	7.6	105
2012	8.4	7.8	108
2013	8.5	8.2	104
Average	8.3	7.9	105

conducted in a similar manner year to year. Thus, the biggest changes are cultivar entries and the weather. I looked at the yield trends in trials conducted in the upper Midwestern USA and adjacent areas of Canada. I plotted the yield of the top five entries in each trial between 1987 and 2012. Overall, there was no relationship across years (R^2 =0.005); high yields occurred equally in older trials as newer ones.

But what about California? Is it different? Here's another way to look at yield results. Consider the Tulelake trials – are trials planted over the past 15 years showing an improvement in yields of top entries compared to Vernal, the standard dormant cultivar check, which was released from Wisconsin in 1953? The results from three trials, seeded in 1999, 2004, and 2011 at Tulelake, CA do not show any improvement in the top cultivars versus the old cultivar, Vernal (Table 1). If anything, the advantage vs. Vernal is declining over time. I am showing the yields from the first production year in order to gauge the genetic potential for yield, prior to stand decline due to diseases. One might argue that yields of new cultivars improve relative to older ones over time, as a stand ages. The results from the Tulelake trials does not bear this out, as the relative superiority of the trial mean to Vernal remains basically stable (Table 2). The mean is rarely more than 10% higher than Vernal and sometimes it is even lower!

Another way to look at changes in yield is the regression of yields on year of cultivar release. I show four graphs of 2013 yield data, from trials at Davis (sown in 2011), Tulelake (2010), Modesto (2011) and Imperial (2012) (Figure 3). These trials include cultivars from the past 15-18 years. None shows any evidence of yield improvement in newer cultivars since the mid/late 1990s, or mid 1970s in Imperial! From these data, we may conclude that there has been little if any progress in yield itself for the past 20 years, and perhaps longer.

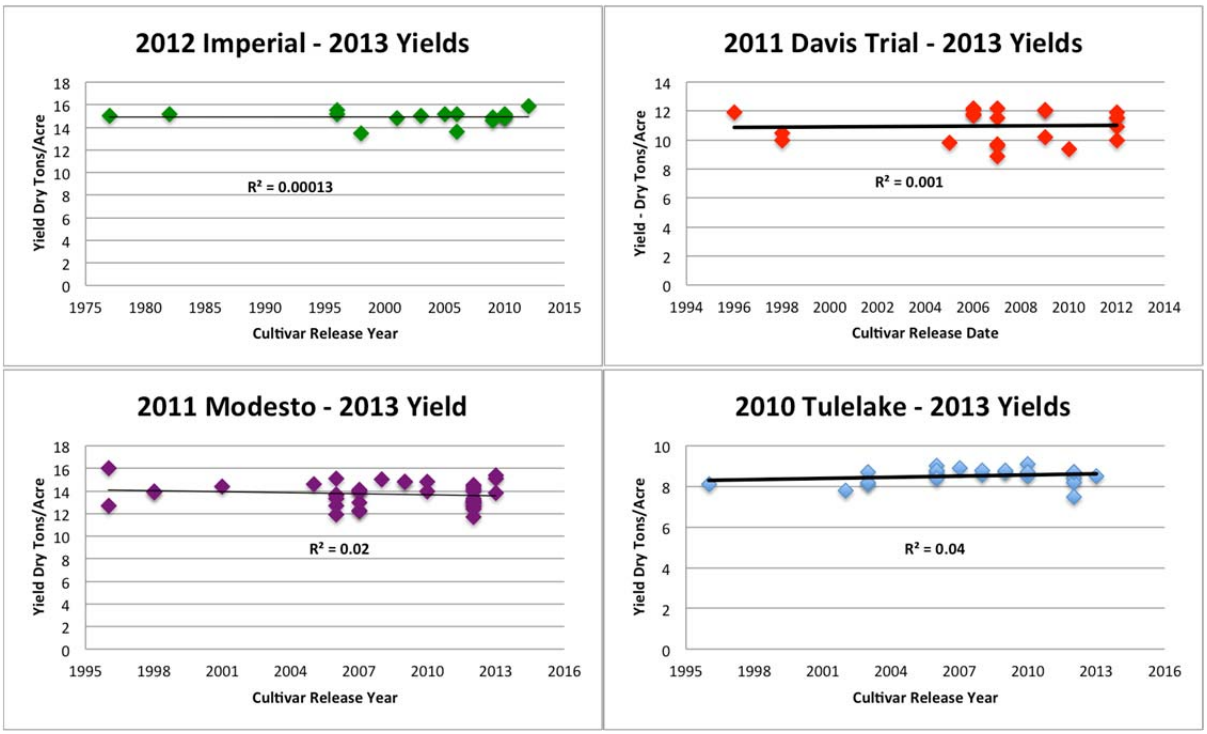

Figure 3. 2013 total yearly yield of individual cultivars plotted against the year of cultivar release for four locations in California.

INTERPRETATION

The data I present above clearly suggests that yield is not increasing – at least, the genetic potential of newer cultivars is similar to older cultivars to produce biomass (although perhaps better than very old cultivars). This analysis does not tell the entire story on genetic progress, however. First, in fields with significant disease or insect pests, resistant cultivars will perform better. Resistances are effectively defensive traits; they don't add yield, but if a disease or pest is present, they prevent (substantial) yield losses. The full extent of field-level production problems is often not faced in university trials.

Second, additional traits have been and are being introduced into alfalfa that offer other benefits than yield. Two transgenes have been introduced into alfalfa. Roundup tolerant cultivars may make weed control easier or more effective, and this may or may not be reflected in yield results. Similarly, the recently deregulated low lignin alfalfa cultivars may provide improvements to nutritive value or possibly to yield (by enabling delayed harvesting). Other options have been introduced by various breeding programs, including additional disease and pest resistances, delayed maturity, lodging resistance, and others. Each of these has a place, and may provide optimal performance, even if the overall yield level is not superior to an older cultivar. The benefits need to be weighted against the cost.

The future may be bright for yield improvement, despite the less than stellar record so far. First, most cultivars now have very high levels of resistance to the major suite of disease and insect pests (although new problems – such as blue alfalfa aphid – keep cropping up). That breeders

have been effective with these resistances means that more attention can be paid to selecting for yield. New genetic technologies offer the potential to expedite yield selection using genetic markers. Some of our own data suggests that we can effectively double yield increases using "genomic selection." These technologies need further research, but are quite promising to bring yield improvements to alfalfa cultivars in the near future.

REFERENCE

Brummer, E.C. and M.D. Casler. 2014. Cool-season forages. In S. Smith, B. Diers, J. Specht, and B. Carver (eds.). Genetic gain in major U.S. field crops. CSSA Spec. Publ. 33. ASA, CSSA, and SSSA. Madison, WI. doi:0.2135/cssaspecpub33.c3.