Proceedings of the Integrated Crop Management Conference

Proceedings of the 28th Annual Integrated Crop Management Conference

Dec 1st, 12:00 AM

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When I ask most farmers about disease management in alfalfa, first thoughts are usually about foliar fungicides, followed by why a stand winterkilled, and sometimes why the new seeding failed. I believe that response is quite understandable relative to what they hear with marketing, and see when it's time to rotate an old stand or establish a new one. However, as with many crops, disease management in alfalfa clearly starts with variety selection. Second is to minimize stress using appropriate management practices. These practices include adequate soil pH and fertility, proper stand establishment practices, timely harvest management during both in-season and fall, wheel traffic management, insect control, and possibly the use of foliar fungicides. Let's start with varietal selection and finish with a five year summary of foliar fungicide trials.

Varietal selection decisions encompass a multitude of factors

Varietal characteristic ratings

Every year the National Alfalfa and Forage Alliance (NAFA) provides a publication listing most of the alfalfa varieties as to their ratings of winter survival, disease resistance, insect resistance and other traits (NAFA 2016). Figure 1 is a portion of the top of page four in this publication. The disease resistance information is on wilts and root rots. No leaf disease ratings are provided.

FD-|--Variety and market information---|-WS-|----------Disease----------|-----Insect-----|Nematode|----Other traits----|

FD	Variety	Contact for Marketing Information	Winter Survival	Bacterial Wilt	Verticillium Wilt	Fusarium Wilt	Anthracnose Race 1	Phytophthora Root Rot	Aphanomyces Race 1 Root Rot	Aphanomyces Race 2 Root Rot	Spotted Alfalfa Aphid	Pea Aphid	Blue Alfalfa Aphid	Potato Leafhopper	Stem Nematode	Southern Root Knot Nematode	Northern Root Knot Nematode	Multifoliolate Expression (H-High/M	Continuous Grazing Tolerance (	Standability Expression (R-Resistar	Salt Tolerance (G-Germination/F-Forage	R-RRA; H-75-95% Hybrid
FD 4-Dormant	Integra 8420	Wilbur-Ellis		HR	HR	HR	HR	HR	HR		HR	R			HR		HR	M				
	Integra 8444R	Wilbur-Ellis		R	HR	HR	HR	HR	R		HR				HR		R	M			G/F	R
	Lancer	Growmark/SS/TFC	2	HR	HR	HR	HR	HR	HR			HR		HR	R			L				
	Magnitude	Growmark/Allied	2	HR	HR	HR	HR	HR	HR		R	R			HR			H			G	
	Magnum 7	Dairyland	2	HR	HR	HR	HR	HR	HR	R		R			HR	R	HR					
	Magnum 7-Wet	Dairyland	2	HR	HR	HR	HR	HR	HR	R		R			HR	HR	HR					

Figure 1. The top of page four from the 2016 edition of Alfalfa Variety Ratings from the NAFA.

Winter survival and fall dormancy ratings

Figure 1 starts with the winter survival (WS) rating. This is the best means to identify varieties adapted to your region. The WS rating procedure is essentially a stress test subjecting varieties to an intensive cutting schedule and then evaluating winter survival. This procedure basically incorporates a plant's cold hardiness, fall dormancy, and resistance to root and crown diseases into one number on a one to six scale (Figure 2), where one is extremely winterhardy and six is non-winterhardy.

The fall dormancy (FD) rating found on the far left side of figure 1 (FD 4-Dormant) is based on a measure of fall plant growth in fall. This is on a scale of 1 to 11. The rating reflects rate of green-up after cutting and breaking of dormancy in spring, with 1 being the slowest. It used to also reflect a measure of cold hardiness with 1 being the most cold hardy and thus mostly likely to have greater winter survival. However, plant breeders have largely uncoupled the relationship of FD to winter survival (Figure 3), and the relationship to variety-adapted regions (Figure 4). Thus figure 4 is no longer used unless you are still growing varieties developed over 25-years ago. A lower FD rating still correlates to lower yield potential because of less growth in fall, slower green-up spring and slower green-up after cutting (Figure 5). Farmers can take advantage of faster green-up after cutting if they can cut and remove the forage before the initial regrowth occurs. If the initial regrowth occurs quickly (i.e. a FD 5 vs. an FD 3) but harvest delays result in wheel traffic damage of newly developing shoots, the advantage of faster green-up for the next cutting's yield is lost, and damaged plants could also be more predisposed to conditions favorable for disease development. Thus a FD 5 may be better suited for haylage harvest, but use a FD 4 or FD 3 for hay harvest since crop removal is slower.

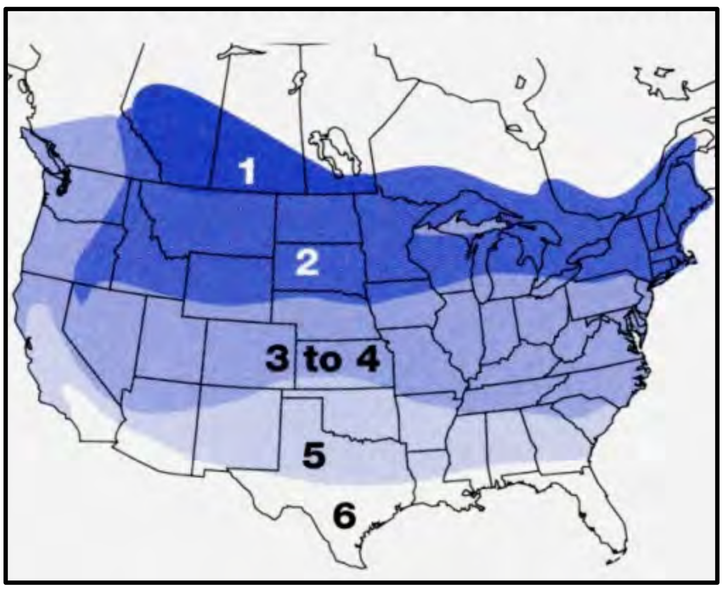

Figure 2. Current WS rating map

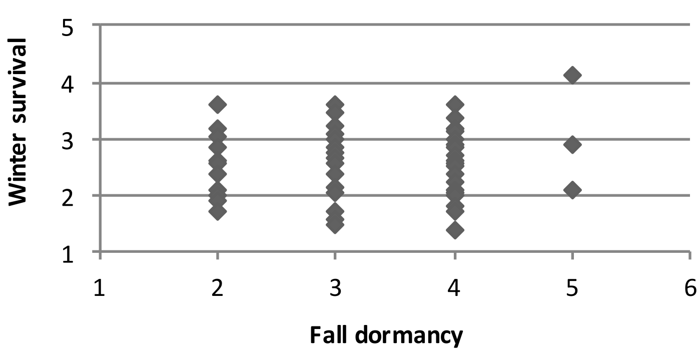

Figure 3. Relationship of FD to WS in recent University of Wisconsin and University of Minnesota trials.

Figure 4. 'Old' FD rating map

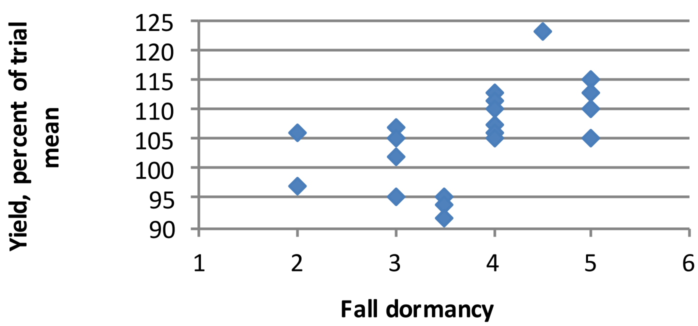

Figure 5. Yield vs FD in University of Wisconsin variety trials in 2015.

Following winter, an FD 5 will start growing in as little as two days with temperatures above 60°F, while an FD 2 would take about five days to start growing. This may be advantageous, and then again not. Once plants have started to grow, they lose some of their winterhardiness and expend stored carbohydrates. False starts over winter can reduce winter survival, expose plants to early frost and the need to re-initiate new shoots, which could actually slow initial growth in spring, also exposing plants to more favorable conditions for disease development and reduce first crop yield. Both WS and FD ratings are important factors to consider in selecting alfalfa varieties that fit your management goals with current alfalfa varieties.

Alfalfa root rots: Phtophthora and Aphanomyces

These soil borne pathogens are common and long-lived in Iowa soils, with a higher prevalence in wetter, heavier, more poorly drained soils. Aphanomyces (*A. euteiches*) and phytophthora (*P. medicagins*) root rot may kill seedlings, reduce yield, decrease stand density, and shorten stand life. A disease survey in Iowa found the presence of *A. euteiches* is as common as *P. medicagins* (Munkvold and Carlton, 1995). Figure 6 shows identification of the presence of both diseases in the solid black counties, just aphanomyces in the "A" counties, and just phytophthora in the "P" counties. *A. euteiches* race 2 resistance is a greater concern, a more virulent race than race 1. Race 2 resistant varieties are also resistant to race 1. Iowa State University routinely recommends selecting both *A. euteiches* and *P. medicaginis* resistant alfalfa varieties for planting in Iowa.

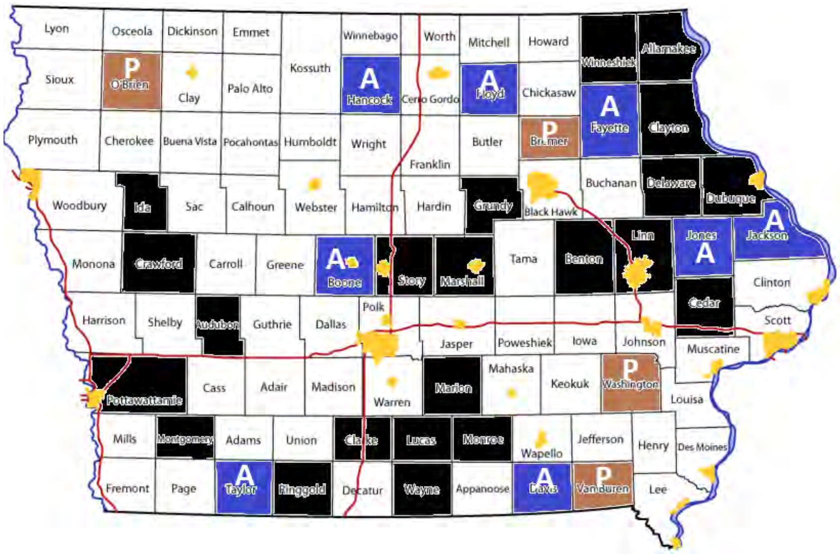

Figure 6. Iowa counties detected with either *A. euteiches* (A), or *P. medicaginis* (P) or both (solid black) in alfalfa fields in 1994.

Yield trials

Multiple-year yield trials from University and private companies are excellent sources of information to complement varietal characteristic ratings mentioned above. Unfortunately fewer Universities conduct alfalfa trials these days. Those with current variety trials include:

- University of Wisconsin: http://fyi.uwex.edu/forage/category/trial-results/
- University of Minnesota: http://www.maes.umn.edu/publications/field-crop-trials/alfalfa
- Michigan State University: http://forage.msu.edu/publications/
- Ohio State University: http://www.oardc.ohio-state.edu/forage2015/
- Penn State University: http://extension.psu.edu/plants/crops/forages/species/forage-variety
- Cornell University: http://plbrgen.cals.cornell.edu/research-extension/forage-project/ny-forage-yield-results

Comparing multiple years of yield data is critical. Varieties that yield in the top 10% of local trials for the three to four years of the trial imply an adapted variety with excellent stress tolerance, rapid regrowth and winter survival. However, still pay attention to variety disease resistance and soil characteristics. Many yield trials are only conducted on well-drained soils and may not challenge a disease susceptible variety in less than optimal soil conditions. Most university recommendations are to have high resistance (HR) across all wilts and root rots provided in Figure 1. However, many varieties still lack HR to Aphanomyces race 2, as assessment of the significance of this disease is somewhat recent.

Establishment

To minimize disease problems with alfalfa establishment, consider the following:

- Use fungicide treated seed when planting. Varieties resistant to some diseases such as phytophthora root rot do not express the resistance in the early seedling stage, so the fungicide seed treatment mefenoxam (Apron XL) is commonly used to provide protection during the early growth phase. Mefenoxam also provides protection against *Pythium* spp., common in Iowa soils persisting in soil and on residue. High soil moisture and cool temperatures favor infection of alfalfa seedlings to *Pythium* spp., often referred to as "damping-off". However, mefenoxam does not provide early protection against aphanomyces. Recently the fungicide Stamina, which protects seedlings against aphanomyces was labeled for use as an alfalfa seed treatment and is being used along with mefenoxam (Samac et al. 2014). For organic production, the main alternative at this time is to delay planting until soils are warmer, or seed alfalfa in late summer. A future option has current research studying a natural mineral aluminosilicate seed coating (zeolite). This product is showing strong activity against seedling alfalfa pathogens (Samac et al. 2014).

- Do not plant too early in spring. Alfalfa can germinate at temperatures in the 40s ˚F, thus planting in April is common. However, without a fungicide seed treatment, planting should be delayed until soil temperatures are in the 50s ˚F and increasing. Those using an oat nurse crop may be tempted to plant earlier, as oats can germinate at soil temperatures in the mid- to upper 30s ˚F. Oats for grain production should be planted as early as possible and at a full seeding rate, but oats as a nurse crop in alfalfa establishment should be planted at about half of a full seeding rate and at a soil temperature best suited for alfalfa.
- Always achieve the Big 3 with planting operations: 1) Proper seeding depth, 2) Seed-to-soil contact, and 3) Uniform seed distribution. Seed alfalfa at ¼ to ½ inch deep in loam soils, and ½ to 1-inch deep in sandy soils. Always achieve good seed-to-soil contact, whether with press wheels or a cultipacker. Rapid germination and emergence minimizes chances of having seedling disease issues.

Disease management and soil fertility, harvest practices, scouting and foliar fungicides

Soil fertility

Nutrient deficiency is a non-infectious disease that can also stress plants and increase their vulnerability to infectious root, crown and leaf diseases. Good alfalfa management requires proper soil pH, and adequate amounts of phosphorous (P), potassium (K) and sulfur (S) fertilizer. Recommendations are provided in ISU Extension publication PM1688-*A General Guide for Crop Nutrient and Limestone Recommendations in Iowa* (Mallarino et al. 2013), and CROP3072-*Sulfur Management for Iowa Crop Production* (Sawyer et al.2015).

Over the last decade ISU Extension education programs have practically beat-to-death the need for S fertilizer in alfalfa production. However, I am still seeing fields that are sulfur deficient (Figures 7 and 8). The S soil test is not reliable for determining S fertilizer recommendations, but plant analysis testing works well. For recommendations, please refer to *Sulfur Management for Iowa Crop Production* (Sawyer et al. 2015).

Figure 7. A rolling Fayette silt loam hillside near Calmar on June 4, 2014 with lighter colored sulfur deficient alfalfa on the knolls.

Figure 8. A random collection of 10 alfalfa stems each from the lighter and darker colored areas of the field in Figure 6.

ISU does not provide recommendations for boron in PM1688 *A General Guide for Crop Nutrient and Limestone Recommendations in Iowa* (Mallarino et al. 2013). Boron (B) soil fertility trials have not achieved a consistent yield response to B fertilization of alfalfa, thus a reliable correlation of B soil test level to yield response from fertilization is not possible. The two most recently completed B trials in 2104 and 2011 are available at the following links.

- http://farms.ag.iastate.edu/sites/default/files/FoliarMicronutrients.pdf
- http://farms.ag.iastate.edu/sites/default/files/EffectSulfurBoron.pdf

Apparently, adequate soil B levels existed in the three to four percent organic matter loam soils in which these trials were conducted. Alfalfa production on lighter, sandy soils may still require B fertilizer.

Harvest practices

The causal organisms of fungal leaf diseases provide sources of inoculum as the disease develop on fallen infected leaves. Under favorable environmental conditions, spores can be discharged into air currents and onto alfalfa foliage. The greatest concern is for infection to occur on young regrowth soon after harvest. If favorable weather for disease development exists for an extended period of time, the infestations may become serious. Best harvest practices to follow to reduce foliar disease infestations include:

- Scout for severity of leaf disease. If significant leaf disease is evident early in the regrowth, and the weather forecast suggests above average rainfall, consider applying a foliar fungicide. We will discuss the economics of this in the last section of this document. If leaf disease severity is not significant until later in the regrowth cycle, and leaf drop of diseased leaves is likely, move up the harvest to avoid leaf loss and subsequent reduction in forage quality. Delaying harvest at this point allows for additional leaf drop and more inoculum on the soil surface available to re-infect the plant during early regrowth. If harvested early, odds improve for the early regrowth to be largely disease free.
- Mower-condition a wide swath to maximize drying rate. Alfalfa often reaches 65% moisture in five to eight hours with this practice. Less time from cutting to harvest equals less leaf loss, less traffic damage, quicker green-up after harvest, and overall less stress on the stand.
- Rake or ted at greater than 40% whole plant moisture. If these rather aggressive operations are used at less than 40% moisture, leaf loss can be quite significant.
- Haylage versus hay production. One benefit of haylage over hay production is less leaf loss, thus less chance of infected leaves to provide inoculum for infection of the regrowth. Another advantage is

cutting-to-harvest operations are accomplished over a shorter timeline, thus green-up and canopy cover is achieved sooner.

- Control wheel traffic during and after harvest. Approximate yield reductions for the next crop caused by wheel traffic during cutting and harvest operations is about a 13% reduction 2 days after cutting, and a 28% reduction 5 days after cutting. Controlled wheel traffic may also reduce damage to alfalfa crowns and possible subsequent spread of crown rot.
- Fall harvest management is largely stress management for a stand, and is always a challenge since no one can predict when the first killing frost (approximately 25oF) occurs. The best guideline for fall harvest management is based on alfalfa growing degree days (GDD). As long as alfalfa plants accumulate at least 500 GDD from the time of fall harvest until the killing frost, they will have stored enough root carbohydrate to survive a typical winter. (Undersander and Bland, 2000). For northern and southern Iowa, that basically means in most years to harvest by September 10 and 20, respectively. If you chose to harvest in late fall "after the killing frost", you can actually harvest ahead of the killing frost as long as time from date of harvest to the actual killing frost is less than 200 GDD. Granted, who knows when the killing frost will occur. However, you can watch the 10-day forecasts, and once a killing frost enters into the forecast "i.e. 9 days from today", harvest ASAP weather permitting. If harvesting in late fall, remember to leave a six-inch stubble height.

The same harvest management practices recommended for maximizing alfalfa production, also minimizing leaf drop and plant damage. Maximizing the rate of regrowth provides quicker canopy cover following harvest which reduces risk of rain drop impact on previously infected leaf litter discharging inoculum into the canopy. Less infected leaf litter on the soil surface means less risk of new infections of the young regrowth.

Scouting

Crop scouting notes from previous seasons help identify the most prominent reoccurring diseases. For visual identification of alfalfa diseases, the NAFA publishes the *Alfalfa Analyst* (Undersander et al.). Table 1 lists the most common alfalfa leaf diseases in Iowa, the environments most favorable for their occurrence, and when they are most likely to occur during the season. The first three leaf diseases in Table 1 are by far the most common that I find in northeast Iowa, followed by much lower occurrences of stemphylium leaf spot in summer and downy mildew in spring. While the NAFA publication *Alfalfa Variety Ratings* does not provide disease resistance ratings for leaf diseases, individual seed companies may have information on some of their varieties.

Table 1. The following is a list of common leaf diseases in alfalfa, environments most favorable for their occurrence, and likelihood of when they might occur during the season (1 = most likely; 2 = somewhat likely; 3 = less likely).

	Favorable environment			**If present, symptoms most evident during:**			
Common leaf diseases in alfalfa	**Wet**	**Cool**	**Warm**	**May**	**June**	**July - early Aug**	**Late Aug - Sept**
Spring black stem	x	x		1	2	3	2
Common leaf spot	x	x		1	1	2	1
Lepto leaf spot	x	x		1	1	1	1
Downy mildew	x	x		1	2	3	1
Stemphylium leaf spot	x		x	3	2	1	2
Summer black stem	x		x	3	2	1	3
Bacterial leaf spot	x		x	2	1	1	2

Foliar fungicides – a summary of five years of trials

Is the use of foliar fungicides in alfalfa production profitable? The typical answer to this question is "it depends!" Over the past five years Iowa State University (ISU) has conducted 15 site-years of foliar fungicide research trials with alfalfa at the ISU Northeast Research and Demonstration Farm near Nashua. These trials provided 191 fungicide treatments by harvest comparisons.

Comparisons in these trials included one or two alfalfa varieties, foliar applications ahead of first, second, third or fourth crops, foliar application timing on three to four-inch or six to eight-inch canopy heights, fungicide products Headline SC, Quadris, Fontelis, Aproach, and copper hydroxide. Data from copper hydroxide treatments were not included in this article due to its poor performance relative to the other products. Approach does not yet have an approved label for use in alfalfa.

Weather during 2012 through 2016 included some extreme conditions from a droughty summer in 2012 to record rainfall in the spring of 2013 (Table 2). The high rainfall in June 2016 did not appear to significantly affect disease ratings relative to other seasons with normal rainfall, in that most of the rain came within a week of second crop harvest. If these high rainfall events occurred three weeks before harvest, the disease severity and response to a foliar fungicide would likely have been much different. The possible impact from high rainfall events in late summer of 2016 was not evaluated since fourth crop comparisons were not part of the trial.

On average, first crop provided a higher percent yield response to a foliar fungicide application than for later crops. Three main factors contribute to this. 1) Spring environments are usually more favorable for alfalfa diseases. 2) Yield potential for first crop is higher than for later crops. 3) The growth period for first crop is considerably longer for that of later crops. Also important is hay price. For example, a 10 percent yield increase from a fungicide application does not add as much value to $80 per ton hay as it would to $200 per ton hay. So, yield per cutting plus yield response to fungicide plus hay price are all critical in contributing to profitability.

Table 2. Average monthly rainfall and growing degree days (base 41˚F) for 2012 through 2016 from the ISU Northeast Research Farm, Nashua, Iowa.

	2012		2013		2014	
Month	**Rain**	**GDD**	**Rain**	**GDD**	**Rain**	**GDD**
April	3.71	189	6.40	346	7.21	203
May	4.97	557	9.92	718	2.87	568
June	1.71	819	8.22	907	10.35	852
July	1.77	952	2.65	1,133	1.41	823
Aug.	3.19	908	3.29	893	3.82	921
Sept.	1.67	713	1.14	603	2.78	577
Total	17.02	4,138	31.62	4,600	28.44	3,944

	2015		2016		Long-term normal	
Month	**Rain**	**GDD**	**Rain**	**GDD**	**Rain**	**GDD**
April	4.33	326	2.07	312	3.62	285
May	3.50	597	2.85	587	4.45	546
June	5.78	829	10.39	921	5.03	828
July	4.00	906	5.48	949	4.72	971
Aug.	4.63	828	6.85	923	4.25	894
Sept.	2.61	804	13.35	732	3.04	637
Total	24.85	4,290	40.99	4,424	25.11	4,161

Limited rainfall occurred in the summer of 2012. For trials conducted within this timeframe, disease incidence was low and the average yield response to fungicide treatments was only about five percent. This resulted in a net loss to fungicide treatments even with hay priced at $200 per ton (Table 3). This is a logical cause and effect and strongly supports that foliar fungicide applications under dry climatic conditions are not profitable. However, fungicide treatments during the extremely wet spring of 2013 resulted in some of the most profitable net returns for both first and second crop.

Some trials compared timing of fungicide applications at a three to four-inch canopy versus a six to eight-inch canopy. Since foliar fungicides only protect what they are applied to, an application to the six to eight-inch canopy should offer more protection. While there were small numerical differences in disease reduction and yield response with these treatments favoring the later application, they were not statistically significant. Waiting for an eight-inch canopy height for second, third or fourth crop in a four-cut system could also be problematic in that these products have a 14 day preharvest interval. I suggest a compromise by targeting about a five-inch canopy height for these applications. However, I still prefer the six to eight-inch canopy height timing for treating first crop.

Table 3. Yield, percent yield response to fungicide, and net return to three difference hay prices for individual alfalfa crop harvests during 2012 through 2016.

Year	Crop	Average DM yield of untreated control	Average % yield increase with fungicide treatment	Assumed hay prices below ($/ton) result in average net returns to fungicide treatment ($/a)[1]		
				$80/ton	$140/ton	$200/ton
2012	1st	1.83	12.13	-4.68	+10.56	+25.80
	2nd	1.84	2.81	-19.46	-15.30	-11.14
	3rd	1.13	7.27	-18.09	-12.90	-7.71
	4th	1.21	5.32	-19.67	-15.67	-11.67
	Total	6.0 ton/a DM (7.1 ton/a 15% moisture hay; 15.0 ton/a 60% moisture haylage)				
2013	1st	2.23	13.28	2.52	+23.16	+43.80
	2nd	1.62	10.64	-7.86	+5.00	+17.86
	3rd	1.50	9.47	-12.54	-3.20	+6.14
	4th	1.34	9.50	-13.80	-5.40	+3.00
	Total	6.7 ton/a DM (7.9 ton/a 15% moisture hay; 16.8 ton/a 60% moisture haylage)				
2014	1st	2.29	6.58	-12.10	-2.43	+7.25
	2nd	2.06	7.14	-12.30	-2.78	+6.75
	3rd	1.57	7.54	-14.70	-6.98	+0.75
	4th	1.48	No treatments			
	Total	7.4 ton/a DM (8.7 ton/a 15% moisture hay; 18.5 ton/a 60% moisture haylage)				
2015	1st	2.30	10.08	-3.53	+12.57	+28.67
	2nd	2.29	8.80	-7.40	+5.80	+19.00
	3rd	1.96	9.30	-8.87	+3.23	+15.33
	4th	1.41	No treatments			
	Total	8.0 ton/a DM (9.4 ton/a 15% moisture hay; 20.0 ton/a 60% moisture haylage)				
2016	1st	2.32	6.83	-10.80	-0.15	+10.50
	2nd	1.98	7.15	-12.80	-3.65	+5.50
	3rd	1.68	7.40	-14.20	-6.10	+2.00
	4th	0.84	No treatments			
	Total	6.8 ton/a DM (8.0 ton/a 15% moisture hay; 17.0 ton/a 60% moisture haylage)				

[1] The net return calculations include the average cost of fungicide plus application.

It is reasonable to assume that if foliar fungicide applications reduce disease infestations, leaf retention may be improved and result in higher forage quality at harvest. In order to measure forage quality differences, subsamples of harvested forage from some of these trials were sent to forage testing labs. Even though we had some visual evidence of better leaf retention, there was little to no effect of fungicide detected on the forage quality analyses and calculated RFV and milk per ton. Thus the main reason to use foliar fungicides is to achieve increased yield and not necessarily count on increased forage quality.

Some trials included two alfalfa varieties. Variety 'A' average 14 percent lower leaf disease incidence than variety 'B', and yielded better than variety 'B' in absence of a fungicide treatment, yet both yielded similar when treated with a fungicide. It is understandable that alfalfa varieties may have different tolerances to leaf diseases. However, there are no industry standards in place to provide leaf disease resistance ratings for alfalfa varieties or recommendations for the use of a foliar fungicide.

Just as with fungicide applications for corn and soybeans, we need to select our opportunities where the probability of economic return is the greatest. To apply fungicides to alfalfa without much thought to harvest schedule or environmental conditions does not follow proper stewardship of pesticide use nor would it result in maximizing profits.

Conclusion

A comprehensive alfalfa disease management program starts in variety selection and yield trials. Other best management practices (BMPs) that minimize stress, strongly complement the program. Proper soil fertility and stand establishment, timely harvest management in season and in fall, controlled wheel traffic, insect pest management, selective use of foliar fungicides, and some luck to avoid significant weather events, are all interdependent in a successful disease management program. It is no accident that the same BMPs recommended for maximizing alfalfa production also minimize plant disease issues.

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