TOOLS OF THE TRADE: APPROACHES FOR WEED MANAGEMENT IN ESTABLISHED ALFALFA

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ABSTRACT

Controlling weeds in alfalfa is fundamental to producing high quality marketable hay. Integrated pest management strategies and principles allow producers to utilize information about the cropping system and weed biology, to target management strategies and limit weed reproduction. Cultural, mechanical, and chemical control practices should not be used individually, but in concert to manage the soil seed bank and weed populations throughout the life of an alfalfa stand. In established alfalfa, various pre and post-emergent herbicides are available to control different suites of weed species during the dormant season and in between cuttings. Whenever an herbicide is applied multiple times to a weed population, there is the threat of herbicide resistance developing. It is important to recognize the mode of action of herbicides utilized, and incorporate best management practices to prevent and delay herbicide resistance from developing. Employing a combination of integrated weed management strategies, can ensure the production of clean high quality forage.

Key Words: established alfalfa, weed control, herbicide resistance, seedbank, integrated pest management.

INTRODUCTION

Weed control is an ongoing challenge for any agricultural producer, from alfalfa growers to cattle ranchers. Whatever the system is, the principles of weed control tactics stay the same. The old gardeners saying "one year seeding, equals seven years weeding" should not be taken lightly by anyone who owns or has a long-term lease on their land. What plant species go to seed in the middle of your field or on the edge of your field, will have an impact on future weed pressure. Successfully managing weeds in any crop starts with answering and understanding the simple question: "Where do weeds come from?" While this may seem rudimentary, it is important to think about how management actions affect the reproduction and spread of weed propagules.

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Reducing the number of seeds in the soil seedbank should be the major focus of weed management within agronomic production. While some weed seeds like cheatgrass, may only last a handful of years in the soil, other seeds with hard coats like lambsquarters, can last for decades. Many weedy species can produce hundreds to tens of thousands of seeds per plant. Letting one generation of weeds successfully go to seed can reset the weed seedbank for years. Devoting resources to minimizing the amount of viable weed seeds that make it into the seedbank can pay dividends for future management efforts.

Weeds can be particularly problematic in forage production for a variety of reasons. First and foremost, weeds capture resources (sunlight, water, nutrients, and space) which could be utilized by the crop for growth. More weeds equal less crop growth, but not necessarily less overall tonnage to be harvested. However, alfalfa is considered the "queen of forages" for a reason: it's high protein content and digestibility make it a prime feed for livestock. Diluting alfalfa forage with weedy plant species can reduce the quality of the forage, reduce protein values, and reduce the marketability of the product produced.

In 1978, it was estimated weedy alfalfa would bring anywhere from $5-$20 less per ton on the California market. Adjusted for inflation, the value in 2018 dollars would range from $18-$75 per ton. Currently, weedy hay is being sold for $35-$100 less per ton on the California market. Table 1 shows a snapshot of premium and fair hay prices in October of 2018.

California Hay Prices Per Ton					
Date	Region	Premium	Fair	Difference	Comment
October 5th	Southeast California	$265	$170	$95	Weedy
October 12th	Intermountain Region	$195	$130	$65	
October 12th	Southeast California	$220	$120	$100	Grassy
October 19th	Intermountain Region	$180	$125	$55	
October 19th	North San Joaquin Valley	$230	$170	$60	
October 26th	Intermountain Region	$205	$152	$53	
October 26th	Sacramento Valley	$215	$180	$35	

Table 1.

While a small number of weeds may be tolerated, especially in organic hay, other weeds can be completely unacceptable in animal feed. Alfalfa production is driven by the demand for high quality forage from the dairy markets. Certain weeds such as cocklebur, swinecress, and Mexican tea when digested can negatively alter the flavor of the milk. While most weedy hay can be fed to dry cattle, hay contaminated with poisonous weeds, such as fiddleneck or groundsel, can make the hay unusable for any livestock feed. It can be very helpful to know what the history of weeds in a field is, before putting it into production. Fields that have a history of poisonous weeds in the seedbank may not be the best option to put into forage production without a rigorous weed control program implemented first.

IDENTIFICATION, REPRODUCTION, AND DISTRIBUTION

Utilizing an integrated approach for weed management is crucial for long-term weed control. The first step when dealing with any unwanted plant is to identify it. Once you know what species you are dealing with, learning the biology of the weed can make control efforts more successful. Specifically understanding how and when the weed reproduces, by seed or by root, is the most important piece of information you can arm yourself with. What time of year do they flower? Will they sprout after cutting? How do the seeds move around? How long do the seeds last in the soil? All are questions which should be pondered by anyone trying to control weeds in their fields.

Weeds can generally be lumped into various categories: winter annuals, summer annuals, biennials and perennials. While all weeds in each category will not necessarily be controlled by the same tactics, each category of weeds can typically be targeted at the same time. Winter annual weeds start germinating in the fall and can have multiple flushes of germination throughout the winter. Summer annual weeds like warmth and germinate in the spring, with multiple flushes of germination throughout the summer. Biennial weeds take two years to produce seeds, often having low growing vegetative growth the first year, and producing flowers and seeds the second. Perennial weeds have the ability to form reproductive tissue underground, and have the ability to spread by roots or by seed. Preventing both seed set and perennial root formation is the fundamental goal in weed management.

Seeds are the life stage of plants, which are mobile and allow the species to spread. Wind, water, animals, and human activity can all move weed seeds around the landscape. While controlling the wind is not feasible, understanding how seeds move through the environment can guide management actions where seed movement and distribution can be controlled.

METHODS FOR WEED CONTROL

Cultural Control

Often overlooked, cultural control practices are crucial in an integrated weed management system. Cultural control can range from crop rotation to simply cleaning equipment between fields.

Crop rotation is a fundamental aspect of an integrated pest management system. Every cropping system creates a certain set of environmental conditions which select and favor the reproduction of various weeds species. Rotating cropping systems creates a different set of environmental conditions which will favor other weed species. Likewise, altering cropping systems allows a producer to implement and change various other mechanical and chemical control options throughout the season.

Weed seeds are often moved from field to field on tire treads, cultivation equipment, or cutting implements. Many weeds are widespread, and preventing movement may not seem economical. However, preventing the movement of poisonous, noxious, or herbicide-resistant species can pay

dividends in the long term. Cleaning soil off of equipment between fields not only is a cultural control method for weeds, but can also help limit the spread of nematodes and soil borne diseases.

Arguably, the most important cultural control aspect of good weed management is utilizing good agronomic practices. Alfalfa is a highly competitive plant, and a good stand will crowd out the vast majority of weeds. Keeping up with the fertility demands of the crop will help ensure that alfalfa has the best competitive advantage to crowd out weeds. Making sure the crop is adequately irrigated will also aid in weed management. Saturated soils will not only lead to root and crown diseases but may give some weeds the competitive advantage. On the other hand, not enough water will favor drought-tolerant species in the field.

Mechanical Control

Options for mechanical control methods are plentiful prior to planting but limited once in production. Swathing is an effective method utilized for weed control in alfalfa, particularly if earlier weed management practices were unsuccessful controlling winter annual weeds. As weeds mature, an early first cutting can remove the tops of winter annuals reducing seed production. This may not be an option in less dormant alfalfa producing areas. Swathing for weed control is a double-edge sword, as weed populations and seed set will be reduced but will often result in a weedy first cutting of hay. As first cutting hay is often high quality and more valuable, a weedy first cutting is not desirable. However, a weedy first cutting can be an acceptable outcome depending on where the hay is going to be utilized (i.e. fed to dry cattle).

While annual weed populations can be reduced through cutting, perennial weeds can be suppressed, but are not controlled through the cutting cycle. Most perennials will regrow from their roots, just like the alfalfa after it is cut. For alfalfa grown on beds, interbed cultivation is a possibility to control weeds growing in the furrows. In most alfalfa stands, dragging fields with a spring-toothed harrow during the dormant season can be effective to uproot small winter annual weeds before alfalfa plants break dormancy. Small annual broadleaf weeds are more effectively targeted with a spring tooth harrow, than annual grasses. While dragging fields can be beneficial, there is also the possibility of damaging the alfalfa crowns, which can increase the susceptibility of the crop to diseases.

Chemical Control

When most producers think of weed control, chemical options are often the first to come to mind. While chemical control can be very effective, it is only part of an integrated system and should not be the only weed control option utilized.

When choosing to control weeds though chemical applications in alfalfa, it is ever important to know what weed species are present in the field. Depending on what weeds are present will narrow down what herbicides could be effective and when applications need to be made. Generally, herbicides are more effective for both annual and biennial weeds when they are small or before they have germinated. Perennial species which have just germinated can be targeted

like an annual species in their first few weeks of growth. Perennial species which have developed reproductive root tissue are difficult to control after a stand has been established.

Successful herbicide applications in established alfalfa is all about timing, as most chemical applications are made during the dormant season or between cuttings. Application of the same chemistries to actively growing alfalfa will often result in significant crop injury and yield reductions.

Dormant season products are commonly applied from late fall until early spring (weather allowing) to control winter annual weeds. Common herbicides include photosystem two inhibitors Hexazinone (Velpar), Metribuzin (Tricor DF) and Diuron (Karmex). These three products all have long residual activity which can help limit the amount of weed seeding germination throughout the season. However, long residual activities can limit crop rotational options for one or more years. Dormant season applications made early before germination of many winter annual species do not require a tank mix partner. Later applications are often tank mixed with Gramoxone (paraquat) to burn down emerged weeds. In the past four years, two other burn down options for broadleaf weeds have been registered for alfalfa in California: the PPO inhibitors Shark (carfentrazone) and Sharpen (saflufenacil). After alfalfa has broken dormancy, application of any of the products mentioned above will cause crop injury and a significant reduction in yield.

Summer annual weeds are often also targeted with pre-emergence herbicides from different modes of action. The lipid synthesis inhibitor EPTC (eptam), the PPO inhibitor Chateau (flumioxazin), and the microtubule inhibitors Treflan (trifluralin) and Prowl H20 (pendimethalin) all provide residual weed control of seedlings before germination. To be effective these products can be applied between cuttings and need to be incorporated into the soil with irrigation or rainfall before seedling germination. Burn down products can also be useful to control summer annuals between cuttings. Applications of Shark or Gramoxone can be utilized between cuttings to control emerged weeds. Depending on the suite of weed species present, Raptor (imazamox) can be another option to control emerged weeds between cuttings. These mid-season applications of products with post-emergence activity should be used with caution as crop injury often occurs after treatment.

While there are limited options for post-emergence broadleaf weed control during the growing season, there are good options to control grasses. ACCase inhibitors Select Max (clethodim) and Poast (sethoxydim) can be applied to control emerged annual grasses and higher rates can be used on perennial grasses. Perennial grasses often require multiple treatments, but typically can be controlled. When Select and Poast are sprayed between cuttings, it is important to irrigate before application as these herbicides are more effective on actively growing plants. ACCase inhibitors can also be more effective during warmer weather, because the grasses will be actively growing. However, many winter and summer annual grasses will be controlled by the herbicides with pre-emergence activity discussed above.

Germinating perennial weeds can be targeted using the same methods as annuals, but after establishment, perennial weeds need to be treated differently. With the ability to form

reproductive tissue underground, certain species can spread and take over without ever needing to set seed. Like alfalfa, which is a perennial, they will often regrow after cutting. Some perennial species are more susceptible to herbicides than others. Research has shown curlydock can be controlled with fall applications of 2,4-DB as can dandelion. Other perennial species, such as field bindweed, Canada thistle and buckhorn plantain, are typically only partially controlled by herbicides currently on the market for alfalfa production.

Generally, it is best to control established perennial weeds before planting alfalfa, unless a Roundup Ready variety is selected. Roundup Ready alfalfa has been back on the market since 2011 after a four-year hiatus following an injunction from the court regarding its impacts. Like other Roundup Ready crops, the broad-spectrum herbicide Roundup (glyphosate) can be sprayed over the top of actively growing alfalfa to control weeds. There are lots of benefits of being able to use Roundup, as it has excellent activity on many tough-to-control annual and perennial species. The technology can also broaden application timing, because it does not have to be applied between cuttings or during dormancy. Because of these factors Roundup Ready alfalfa can be utilized to clean up fields with historically high weed pressure.

However, Roundup Ready alfalfa does have some downsides. While the herbicide is relatively cheap compared to other treatments, the upfront cost of the seed is more expensive. While most weedy species are controlled, there can be shifts in weedy populations to tolerant species, such as purslane, burning nettle, and cheeseweed. In higher elevation climates that experience frequent frost during the spring, there has been documentation of yield loss in the first cutting following applications of the herbicide. As with all herbicides, there is the possibility of selecting for resistant weed species, especially considering California has six documented weed species resistant to Roundup. For example, hairy fleabane, a primary weed species in orchards and vineyards with widespread glyphosate resistance, is rapidly becoming a major weed species in Central Valley alfalfa. When utilizing a Roundup Ready alfalfa system, integrating and utilizing other herbicide options can reduce the likelihood of weed shifts and resistance from occurring.

Threats of Herbicide Resistance

Whenever herbicides are utilized repeatedly on the same population of weeds, there is the possibility of herbicide resistant weeds being selected for, and resistant populations developing. According to the International Survey of Herbicide Resistance there have been 14 separate instances of herbicide resistance occurring within alfalfa production globally, five in the United States and one in California. In general, there have been 30 confirmed cases of herbicide resistance weed species within California.

When one herbicide stops working, historically the solution has been to rely on another chemistry. Yet, weed species have been shown to develop resistance to multiple modes of action. In California there is a population of Italian ryegrass which is resistant to four modes of action: ACCase inhibitors (Select, Post), ALS inhibitors (Raptor), PS1 inhibitors (Gramoxone) and EPSP synthase inhibitors (Roundup).

When weeds develop resistance to herbicides, those tools are removed from the grower's toolbox as effective management methods. As there are limited numbers of new chemicals for weed

control hitting the market, it is ever important to conserve the tools we do have. Prevention of herbicide resistance is the first step.

Herbicide resistance develops because the same product is used repeatedly. Preventing or delaying herbicide resistance can be achieved by altering the selection pressure put on the weed population. This is another reason why utilizing an integrated approach to weed management, including mechanical and cultural control methods is so important. Altering and combining (tankmixing) herbicides can be an effective tool if the herbicides have a different mode of action. Rotation of chemistries and crops, while integrating mechanical control methods, are all essential to help prevent and delay resistance.

There are 11 modes of action commonly used in established alfalfa production, if you include Roundup. (See Table 2.) Generally, the products can be split into those with pre-emergent activity and post-emergent activity (with a few chemistries that have activity on both). Eleven modes of action give growers an opportunity to switch the mode of action or combine modes of action to help achieve weed control while delaying herbicide resistance.

Once herbicide resistant plants have developed resistance to multiple modes of action, like Italian ryegrass, control options become very limited. It is best to limit the development and spread of resistant populations before multiple resistance develops.

When dealing with an older field heavily infested with weeds, weed management efforts can only go so far. While killing the initial flushes of weeds can be possible through integrated strategies, to quote Carl Bell from 1986, “Removing weeds from a weak alfalfa stand will only result in another weed invading the field.” Or, to quote Mick Canevari from 2016, “The best weed control is a healthy stand of alfalfa.” Old thin stands of alfalfa are breeding grounds for developing large weed seedbanks. When alfalfa stands start to lose productivity, crop rotation is the best option to ensure minimization of seedbank buildup and less weed issues in the future. Preventing seed set and seed movement is fundamental to long-term weed management.

Common Herbicides Used in Established Alfalfa Production				
Active Ingredient	Trade Name	Mode of Action Group Number	Mode of Action	Pre or Post Activity
Clethodim	Select	MOA: 1	ACCase Inhibitors	Post
Sethoxydim	Poast	MOA: 1	ACCase Inhibitors	Post
Halosulfuron	Sandea	MOA: 2	ALS Inhibitors	Post
Imazethapyr	Pursuit	MOA: 2	ALS Inhibitors	Both
Imazamox	Raptor	MOA: 2	ALS Inhibitors	Both
Pendimethalin	Prowl H20	MOA: 3	Microtubule Inhibitors	Pre
Trifluralin	Treflan	MOA: 3	Microtubule Inhibitors	Pre
2,4-DB	Butyrac	MOA: 4	Synthetic Auxins	Post
Hexazinone	Velpar	MOA: 5	Photosystem 2 Inhibitors	Both
Metribuzin	Tricor DF	MOA: 5	Photosystem 2 Inhibitors	Pre
Diuron	Karmex	MOA: 7	Photosystem 2 Inhibitors (different binding site)	Pre
EPTC	Eptam	MOA: 8	Lipid Synthesis Inhibitors	Pre
Glyphosate	Roundup	MOA: 9	EPSP synthase Inhibitors	Post
Norflurazon	Soilcam	MOA: 12	Pyridazinone Inhibitor (pigment synthesis)	Pre
Carfentrazone	Shark	MOA: 14	PPO Inhibitors	Post
Flumioxazin	Chateau	MOA: 14	PPO Inhibitors	Pre
Saflufenacil	Sharpen	MOA: 14	PPO Inhibitors	Post
Paraquat	Gramoxone	MOA: 22	Photosystem 1 Electron Diverter	Post

Table 2.

REFERENCES

Bell, C. 1986. The Relationship of Alfalfa Stand to Weeds. Proceedings of the 16th California Alfalfa Symposium.

Canevari, W. M. 1996. Getting Control of Tough Weeds in Alfalfa. Proceedings of the 26th California Alfalfa Symposium.

Canevari, W. M. 2001. Timing Is Everything - what makes you money in weed control? Proceedings of the 31st California Alfalfa Symposium.

Canevari, W. M. 2012. Key Strategies for Weed Management. Proceedings of the 42nd California Alfalfa Symposium.

REFERENCES

Canevari, W. M., J. Schmierer. 2008. Summer Annual Grass Control - what are the strategies? Proceedings of the 38th California Alfalfa Symposium.

Canevari, W. M., S. B. Orloff, and R.N. Vargas. 2007. Chapter Eight: Weed Management in Alfalfa. *Irrigated Alfalfa Management for Mediterranean and Desert Zones*. University of California Division of Agriculture and Natural Resources, Publication 8294. https://wric.ucdavis.edu/PDFs/WeedManagementInAlfalfa.pdf

Canevari, W. M., S. B. Orloff, W. T. Lanini, R.G Wilson, and R.N. Vargas. 2017. *Susceptibility of Weeds to Herbicide Control in Established Alfalfa*. UC IPM Pest Management Guidelines: Alfalfa. University of California Division of Agriculture and Natural Resources, Publication 3430. http://ipm.ucanr.edu/PMG/r1700411.html

Cudney, D.W. 1978. Economics of Weed Control in Alfalfa. Proceedings of the 8th California Alfalfa Symposium.

Fischer, B.B. 1993. Strategies for Weed Control in Alfalfa Hay Production. Proceedings of the 23rd California Alfalfa Symposium.

Heap, I. 2018. *The International Survey of Herbicide Resistant Weeds*. Online. Internet. Friday, October 19, 2018. Available www.weedscience.org

Orloff, S.B. and B. Tickes. 2014. Weed Management in Alfalfa: where we have been and where we're going. Proceedings of the 44th California Alfalfa Symposium.

Orloff, S. B., W. M.Canevari and W. T. Lanini. 2006. Avoiding Weed Resistance and Weed Shifts in Roundup-Ready Alfalfa. Proceedings of the 36th California Alfalfa Symposium.

Puschner, B. 2017. Poisonous Weeds and Toxic Factors in Hay Crops: why you should worry. Proceedings of the 47th California Alfalfa Symposium.

Schmierer, J.L, and S.B. Orloff. 1995. Chapter Six: Weeds. *Intermountain Alfalfa Management Guide*. University of California Division of Agriculture and Natural Resources, Publication 3366.

Tickes, B. 2008. Alfalfa Weed Control in the Low Deserts: 40 years of discovery and innovation. Proceedings of the 38th California Alfalfa Symposium.

USDA. 2018. California Hay Report. Colorado Department of Ag Market and News. https://www.ams.usda.gov/mnreports/ml_gr311.txt

Wilson, R.E. 1998. Controlling Difficult Weeds in Established Alfalfa. Proceedings of the 28th California Alfalfa Symposium.