ROUNDUP READY® ALFALFA—WHAT HAVE WE LEARNED TO DATE?

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ABSTRACT

There have been more than ten years of research experience and six years of grower experience with glyphosate-resistant (Roundup-Ready or RR) alfalfa to date. Here, we discuss the technical experiences with this technology, performance, and several of the positive and negative aspects. The information presented reflects grower views as well as research experience. The results of a survey of 113 growers who have grown RR alfalfa indicated that a large majority of them (91%) were either satisfied, very pleased, or that the technology far exceeded expectations. Eight growers responded that they were disappointed, and two extremely disappointed. A majority (72%) said that they would plant it again, 21% said maybe, and 7% said no. Better weed control, simplicity and flexibility of weed management were the key advantages cited by respondents, with control of problematic weeds a key point for many. Cost of seed was cited by 77% of all respondents as the major negative. Forty-one percent of respondents indicated a concern for Roundup-resistant weeds as a consequence of use of the technology, with only 25% indicating that it is not a concern. Twenty-seven percent of growers reported that RRA varieties yielded more than conventional varieties, 12% felt that they yielded less, and about 50% indicated that yields were equal to conventional varieties. UC field research data indicated few differences between RR alfalfa varieties and conventional varieties as a group, with greater differences within either conventional or RR variety groups. However, research showed yield differences due to stand establishment herbicide method favored the RR strategies in controlled trials due to crop injury of conventional herbicides. Flexibility in replant decisions was a key advantage of the RR alfalfa technology not foreseen in earlier research.

Key Words: Genetically engineered crops, glyphosate tolerance, weed control, *Medicago sativa,* yield, forage quality, profitability, Roundup resistance.

INTRODUCTION

Glyphosate tolerant or Roundup Ready (RR) Alfalfa was the fifth glyphosate-tolerant crop to be commercialized in the United States following canola, soybeans, cotton and corn (1996, 1997, 1997, and 1998, respectively). This technology consists of the insertion of a gene into alfalfa varieties which confers near complete resistance to injury from the herbicide glyphosate. The release of RR alfalfa has perhaps been more contentious and highly disputed than any of its predecessors. Important landmarks in the history of RR alfalfa in the United States are outlined in Table 1. Its introduction in the fall of 2005 was short lived and an injunction was issued by a circuit court judge in March of 2007 halting new plantings but allowing production on existing

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fields to continue. The key contentious issues were the possibility that RR alfalfa would contaminate non-GE alfalfa (especially organic), or whether its introduction would lead to rampant weed resistance.

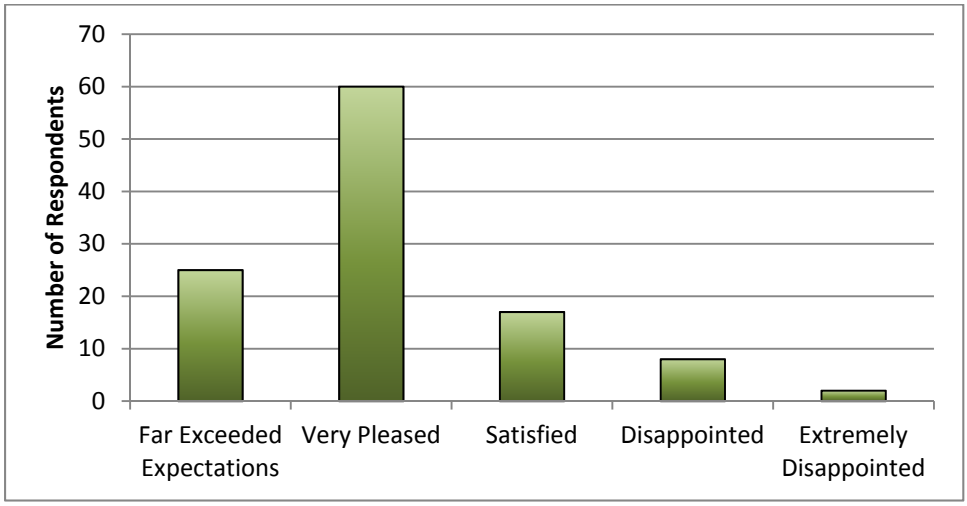
Roundup Ready alfalfa was deregulated for the second time in February of 2011 after a 4-year exhaustive Environmental Impact Study (EIS) by USDA-APHIS (regulatory agency responsible for genetically engineered crops), which found that this technology was safe for the environment. So, growers and the alfalfa industry as a whole now have a full production cycle (3-6 years) of experience with the initial plantings and a season or partial season's worth of experience with the new plantings that have occurred in 2011. Additional experience comes from field research conducted by public and private research scientists. With this experience, here we ask the question: *What have we learned to date about RR alfalfa?* The emphasis of this enquiry is on the technical and agricultural aspects of RR, not the legal or political aspects. For this article and the accompanying presentation, the authors draw from their own research experience, as well as the collective experience of alfalfa growers. For the latter purpose, we conducted a survey of alfalfa producers from around the country to get a better understanding of alfalfa hay-grower attitudes and perceptions regarding RR alfalfa (Putnam & Orloff, 2011, these proceedings). The full survey responses and background information are presented in the accompanying paper, which included growers who have not grown the crop. While there were over 380 responses to our survey, this paper includes data from the 113 respondents who have produced RR alfalfa.

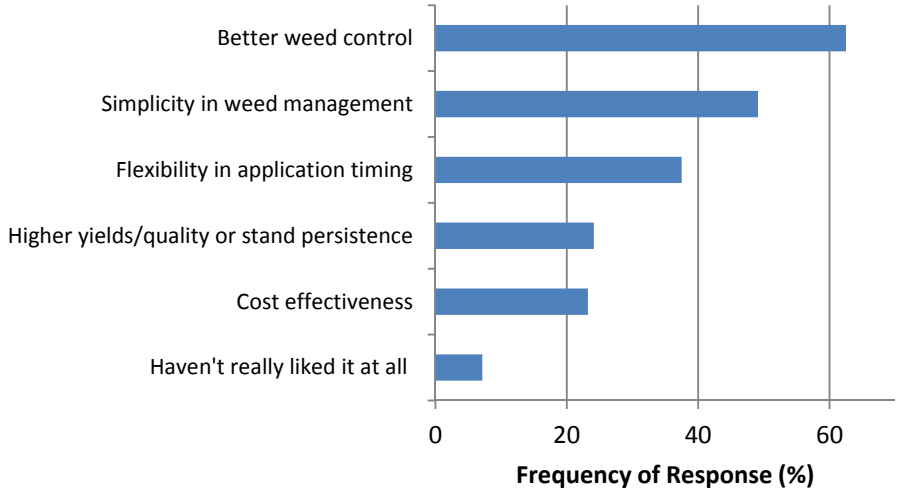
Table 1. Important landmarks in the history of Roundup-Ready alfalfa.

1997	First RR alfalfa plants developed (Montana State University)
2003	Environmental Assessment Petition for deregulation submitted
2005	USDA-APHIS makes finding of "No Significant Impact", RR alfalfa commercially available that fall, and sold by Forage Genetics Int'l and other seed companies
2005-2007	Greater than 300,000 acres planted in US
2006	Lawsuit filed by Center of Food Safety alleging important environmental effects of gene flow and resistant weeds not addressed by USDA-APHIS
Jan 2007	Legal Decision by 9th Circuit Judge stops further plantings, requires APHIS to complete Environmental Impact Statement (EIS)
Mar 2007	No further plantings allowed; current plantings could be harvested with restrictions
2007-2009	EIS under development by USDA-APHIS
Dec 2009	Draft EIS issued by APHIS for public comment. Tens of thousands received
June 2010	Alfalfa case reaches US Supreme Court. Court decides in favor of Monsanto that 9th Circuit should not have forced the ban, and that the decision should have been under the control of APHIS.
Dec 2010	Final EIS issued by APHIS. They find that RR alfalfa is safe for the environment.
Jan 2011	APHIS makes final determination of non-regulated status for RR alfalfa
Feb 2011	RR alfalfa returns to the market, growers may plant RR alfalfa
March 2011	New lawsuits filed by Center for Food safety, others. Pending litigation.

OVERALL LEVEL OF FARMER SATISFACTION

The majority (91%) of growers who have planted RR alfalfa who responded to the survey were satisfied, pleased, or felt that the technology exceeded their expectations (Figure 1). Seventy-six percent of the growers indicated they were very pleased or that it far exceeded their expectations. Eight growers were disappointed and two indicated they were extremely disappointed. Asked if they would plant it again, 72% said yes, and 21% said maybe, 7% said no. *Better weed control* was the most popular reason stated in response to what growers liked most about RR alfalfa, followed by *Simplicity in weed management* and *Flexibility in application timing*. It is not too surprising that the most popular response (77%) when growers were asked what was the major negative(s) associated with the RR technology was the *cost of RR alfalfa seed*. This response was approximately four times more common than any of the other responses, which all ranked similarly except for *difficulties in marketing RR alfalfa*, which was the least popular response. The respondents who were least satisfied with RR alfalfa indicated in their responses and comments that they were dissatisfied with the level of weed control and/or felt that RR alfalfa varieties did not perform as well as conventional varieties.





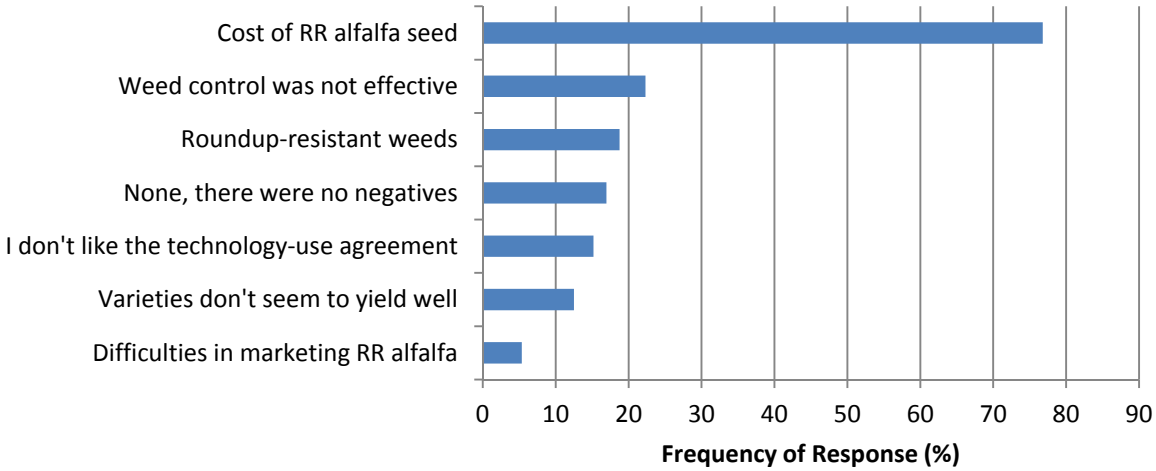


Figure 1. Level of grower satisfaction (top), positives (middle) and major negatives (bottom) associated with Roundup Ready Alfalfa. Results of a survey of 113 growers who have grown the crop.

WEED CONTROL

Regardless of how people feel about genetically engineered (GE) crops or more specifically RR alfalfa, most people who are familiar with the herbicide Roundup recognize it to be one of the most, or the most, effective broad spectrum herbicides available. This is reflected in the survey results where *"Better weed control"* was the most popular response to the survey question pertaining to what growers liked most about RR alfalfa. Roundup controls a broader spectrum of weeds than any other herbicide registered for use in alfalfa. Researchers have evaluated the effectiveness of Roundup in Roundup Ready alfalfa as a weed management system (Van Dynze et al., 2004). Roundup has been found to be especially effective for weed control in seedling alfalfa controlling a broad spectrum of both broadleaf and grassy weeds with no perceptible crop injury. This has been borne out in grower fields as well. Roundup has provided excellent control of most weeds except for those known to be tolerant to Roundup such as burning nettle and glyphosate-resistant ryegrass. There are some common weeds that are less sensitive to Roundup including panicle willowherb, filaree, henbit, malva, wild buckwheat, knotweeds, purslane and clovers. In general, these weeds have been effectively controlled in RR alfalfa systems by treating when the weeds are small. Sometimes they are not completely killed, but they are so stunted by the herbicide and alfalfa competition that they are not visible.

Flexibility of RR System. Flexibility in application timing was the second most popular survey response to the question regarding what RR alfalfa growers liked most about the technology. Compared with other herbicides, there is an extremely wide application window to control emerged weeds with Roundup. This is due to the level of tolerance to Roundup that RR alfalfa has at different growth stages and because of Roundup's effectiveness at killing relatively large weeds. Very early applications of Roundup to seedling alfalfa (one to two trifoliate alfalfa leaf stage) are typically not effective because Roundup lacks soil residual activity and weeds may emerge after application. However, on the other end of the application window it is possible to control fairly mature weeds with Roundup. Growers may become complacent with their weed

management practices, particularly application timing, due to the effectiveness of Roundup on relatively large weeds. However, timely applications, especially to seedling alfalfa, are important to minimize the effect of weed competition on alfalfa vigor and stand. For fall-seeded seedling alfalfa, a single application in fall may be inadequate for complete weed control due to the absence of soil residual activity with Roundup. It may be necessary to apply a second application in spring for total weed control, but the flexibility exists with the RR system for this to be possible.

Controlling Problematic Weeds. The Roundup Ready system has been especially beneficial for controlling many problematic weeds, namely dodder and several perennial weeds (Canevari et al., 2006). Dodder, because it is a rootless parasitic weed, is particularly challenging. Dinitroanaline herbicides such as pendimethalin (Prowl) and trifluralin (Treflan) provide partial pre-emergence control but there are always weeds that escape treatment, especially late in the season. The Roundup Ready system has proven very effective for dodder control. Because alfalfa is a perennial itself and is not mechanically cultivated, there are numerous perennial weeds that are troublesome including nutsedge, Johnsongrass, Bermudagrass, quackgrass, dandelion, and plantain. Conventional herbicides are relatively ineffective for controlling most of these weeds. The combination of a competitive crop like alfalfa, the frequent cutting in an alfalfa production system and in-season use of the herbicide Roundup on RR alfalfa has been very effective at controlling yellow nutsedge. In fact, studies have shown that two Roundup applications (1.5 lbs/A glyphosate) once nutsedge has emerged (the first application in the spring and a second approximately 2 months later) provided up to 90% control during the season. This system has been more effective for controlling nutsedge than any other alfalfa herbicide. Quackgrass is common problem in the colder intermountain areas of the Northwest. This weed is practically eliminated in a Roundup Ready alfalfa production system. Previously, effective control of these troublesome weeds was exceedingly difficult.

Are Herbicides Even Needed in Alfalfa? Several survey respondents questioned whether there was a need for herbicides in alfalfa in general, and specifically the need for Roundup. Most of these comments came from growers in the Midwest or East. Some had mixed stands of alfalfa and grass (which would preclude the use of most herbicides) and some commented on alfalfa's innate ability to compete with weeds. Many of these growers fed their alfalfa on farm rather than marketing it off the farm – thus there is not the intense financial penalty for weeds in alfalfa on some of these farms. Growers' perceptions on the need for herbicides in alfalfa may be a reflection of regional differences in alfalfa production systems across the US. In the West, an overwhelming majority of alfalfa is sold off the farm to dairy and horse customers (see companion survey, Putnam & Orloff, 2011, these proceedings). These markets have a low threshold for weed tolerance. "Dairy-quality" alfalfa is cut frequently at an immature alfalfa growth stage (typically early to mid-bud) reducing the ability of alfalfa to compete with weeds. For these reasons, herbicides are often needed in the West, and this was reflected in the survey results—where for most western states the growers using herbicides on their alfalfa is the norm—representing 95 percent or more of the acreage.

HERBICIDE RESISTANT WEEDS

When it comes to weed control issues, the primary concern with the RR technology is the evolution of weeds with resistance to Roundup. The use of the term *evolution* instead of *development* of resistance is intentional. A common misconception is that the Roundup resistant trait is passed directly into the weeds from the alfalfa. This is not the case. Weeds with varying levels of resistance to Roundup (as well as other herbicides) likely already exist in weed populations but at an extremely low frequency. It is not until continued selection pressure (such as repeated use of only Roundup) is applied that these weeds become dominant, conferring resistance to a weed population. An herbicide such as Roundup controls the susceptible biotypes, preventing them from reproducing and leaving only those individuals carrying the genes for resistance. As repeated use of any herbicide controls the susceptible individuals, the resistant weeds continue to multiply and ultimately can become predominant.

The evolution of Roundup resistance is distinct from 'Weed Shifts" (Orloff et al., 2009). Weed shifts are a far more important immediate issue for farmers than the genetic evolution of resistant weed populations. Weed shifts simply favor weeds (for example malva and buring nettle) that are not killed by Roundup – and those become larger problems for growers in a RR alfalfa system if herbicides are not rotated. We have observed these weed shifts in the first several years of research on this trait (Van Dynze et al., 2004). However, as a practical matter, weed shifts, though distinct biologically from evolution of weed resistance, have many of the same solutions and management considerations as weed resistance, and thus are often discussed as a single phenomenon.

The survey indicated that many growers are concerned about the possibility of Roundup-resistant weeds. Of the growers who have produced RR alfalfa, 41percent indicated that *yes*, they are concerned about Roundup-resistant weeds and 34 percent indicated *not sure, maybe*. Whereas, only 25 percent indicated they were not concerned.

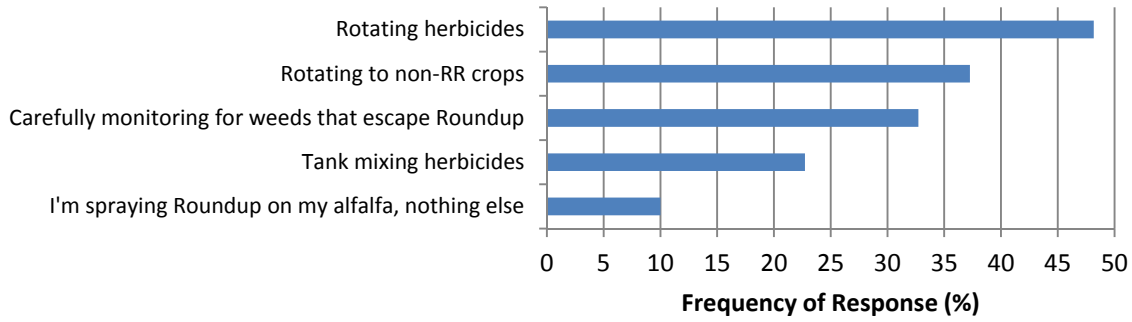


Figure 2. Relative frequency of grower responses to the question *Are you using or plan to use any of these practices to prevent resistance?*

Practices to Reduce the Likelihood of Roundup-Resistant Weeds. The possibility of Roundup-resistant weeds in Roundup Ready alfalfa production systems is a legitimate concern. The authors are unaware of any Roundup-resistant weeds originating from RR alfalfa fields to date. However, weed resistance has been a significant issue in other RR crops, and alfalfa

producers should be proactive and learn from experiences gained in these crops as a preemptive measure to avoid, or at least minimize problems with both weeds shifts and weed resistance. Transgenic herbicide-resistant crops do have potential to foster weed resistance since a grower is more likely to use a single herbicide repeatedly in herbicide resistant crops like RR alfalfa. The key is for growers to reduce the selection pressure by rotating crops, rotating herbicides and utilizing tank mixes as needed. Relying solely on Roundup to control weeds for the entire stand life would be a mistake in the long term.

Roundup is not a soil active herbicide and growers in the survey who mentioned inadequate weed control with the RR alfalfa system were primarily having problems controlling late-emerging weeds due to the lack of soil residual activity. Therefore, it is logical to periodically use a winter dormant soil residual herbicide like hexazinone (Velpar), diuron (Karmex), metribuzin (Sencor) or flumioxazin (Chateau) periodically during the life of an alfalfa stand. Summer grasses such as yellow or green foxtail and barnyardgrass can be a problem throughout much of the summer. Therefore, applying a soil residual herbicide like Prowl or Treflan later in the stand life when the alfalfa density declines and grasses invade can be a wise practice. The actual herbicide-resistance prevention program a grower employs should be tailored to their specific production area and the weeds encountered.

Whether to rotate herbicides or use a tank mix depends on the weed spectrum encountered in a field. Both approaches are effective for resistance management. If the weed spectrum is completely controlled with an alternative herbicide, that herbicide can be used alone. However, if Roundup is needed to completely control the weed spectrum encountered then a tank mix is preferred. To prevent Roundup resistance it is important not to lower the use rate, as low rates of Roundup tend to accelerate resistance problems. Rotating herbicides was the most popular strategy that growers indicated they used or planned to use for resistance management (Figure 2).

A fundamental problem influencing the effectiveness of resistance management strategies is that individual growers may be good stewards and use sound management practices to mitigate weed resistance problems, however, they are affected by the actions of their neighbors. If neighboring producers chose not to use the practices mentioned above and herbicide resistance occurs, all growers who use glyphosate for weed control end up paying the price. Weeds, especially weeds whose seed is dispersed by wind, move easily from one field to another. Therefore, it is incumbent on all producers of RR crops to employ a diversity of weed management practices and not rely solely on a single herbicide to minimize the selection pressure that leads to a proliferation of Roundup-resistant weeds. (See Orloff *et al*., 2009 for a complete review of methods to avoid weed resistance and weed shifts in RR alfalfa systems.)

CROP INJURY WITH CONVENTIONAL HERBICIDES

Most conventional herbicides injure alfalfa to some degree but quantifying the level of injury has been difficult because of the difficulty in discerning the impacts of weed competition and herbicide injury. It is difficult to assess what weed-free alfalfa would yield without using an herbicide. If no herbicide is applied, in some environments the weed pressure is so great that the weeds impact alfalfa growth. The advent of RR alfalfa has improved our ability to assess the degree of phytotoxicity that occurs with conventional herbicides. Trials were established in the

intermountain area of Northern California and by Robert Wilson in Nebraska to evaluate the weed control and crop injury with conventional herbicides that can be used alone or in tank mixes with Roundup in seedling alfalfa for a more integrated weed management strategy. Herbicide treatments the first year were untreated, Roundup, Raptor, and the combination of Roundup and Raptor. The untreated plots had the highest yield due to the contribution of the weeds to the total forage (in the intermountain plots the weeds accounted of 58% of the forage). The yield of Raptor-treated plots was 0.28 tons per acre less than Roundup-treated plots over one cutting at IREC and 0.5 tons per acre less over two cuttings at the Nebraska site. This degree of crop injury is in close agreement with another study conducted at IREC on alfalfa varieties and weed control systems (Table 2). These studies were with spring-seeded alfalfa. Alfalfa injury associated with conventional herbicides may be less with fall-seeded alfalfa.

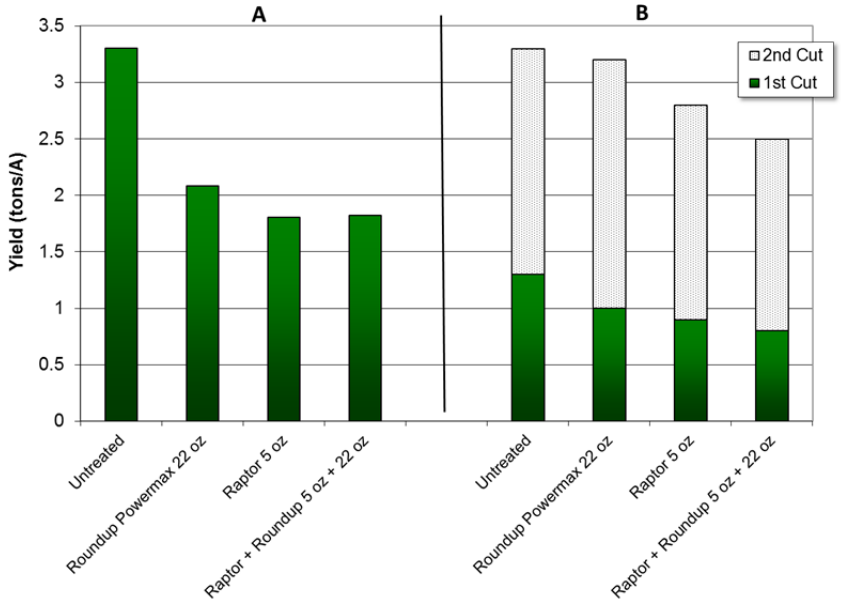


Figure 3. The effect of seedling alfalfa herbicide treatments on first year forage yield at the UC Intermountain Research and Extension Center (A) and the University of Nebraska Panhandle Research and Extension Center (B), 2011. *Note: Untreated plots yields were alfalfa and weeds (alfalfa yield in the untreated plots at IREC was 1.40 tons/A, total yield was 58% weeds).*

MITIGATING STAND ESTABLISHMENT FAILURES

One of the most significant benefits of the RR alfalfa system, which was largely unforeseen by the authors, has been the increased ability to replant areas of the field (overseed) where stand establishment was unsuccessful. Unfortunately, it is not that uncommon for growers to experience an inadequate stand in a portion of the field due to seeding too deep, frost, wind erosion, seedling disease, or numerous other causes. These areas are typically very challenging for producers. They often have high weed infestation levels due to the lack of alfalfa competition, but using the typical conventional herbicides to control the weeds is problematic. The soil residual activity of imazamox (Raptor) and imazethapyr (Pursuit) would affect subsequent alfalfa emergence and growth in an overseeding or replanting operation. And, if a grower waited for the replanted section of the field to reach the two-three trifoliate leaf maturity

stage required for an application, the weeds in the remainder of the field would be so large that complete control would probably be unattainable. However, with the RR system, growers can treat the whole field including the area to be replanted, replant, and then treat that area again if necessary. The key points being that Roundup has no soil residual properties and that the alfalfa can be treated at any growth stage without injury. Growers have found this to be a valuable tool during stand establishment.

YIELD OF RR AND CONVENTIONAL VARIETIES

Alfalfa producers wonder about the yield potential of RR alfalfa compared with conventional varieties. Roundup Ready alfalfa is still relatively new, and information about varietal performance is limited. According to the survey, most of the growers (50 percent) believed that RR alfalfa varieties yielded about the same as conventional varieties. Twenty-seven percent felt that RR varieties yielded higher than conventional and 12 percent believed that RR varieties yielded less than conventional; while 11 percent indicated they didn't know.

A trial was initiated in the intermountain area (Tulelake, CA) in 2005 to compare the yield of 12 conventional varieties (plus the standard check variety Vernal) with 12 RR varieties. It would have been desirable to compare the same varieties with and without the Roundup-resistance trait. However, this is not feasible due to the way RR varieties are developed. Producing a RR variety is not as simple as inserting the resistance gene into a given variety. Each transgene insertion event must be deregulated by USDA APHIS. Only two events were deregulated, J101 and J163. All RRA varieties on the market have J101 alone or in combination with J163 (depending on the breeding process). The trait must then be bred into commercial alfalfa varieties using conventional plant breeding techniques. Therefore, we selected 12 commonly grown conventional varieties and evaluated them compared with 12 experimental RR varieties (6 of which have since been commercialized). Conventional varieties were treated with a conventional herbicide program typical for the area (Raptor in the seedling year, Velpar plus Gramoxone in years 2 – 4, and Sencor plus Gramoxone in the final 5th year). The RR varieties were treated with Roundup or treated with the same conventional herbicides in separate blocks. By doing this, it was possible to distinguish between the variety effects and any crop injury that may result from the application of conventional herbicides.

Averaged over all 12 RR varieties, the first-year alfalfa yields were 0.5 tons/acre greater when the alfalfa was treated with Roundup than when treated with Raptor. In the subsequent 4 years when alfalfa was treated with winter-dormant herbicides, there was not a consistent difference in yield when RR varieties were treated with Roundup versus conventional herbicides. There was no differences in two years, the conventional treatment actually yielded higher in year four (reason unknown) and Roundup-treated plots yielded higher in year five when Sencor and paraquat were applied as the conventional treatment. This suggests that in the intermountain area when herbicides are applied over the dormant period before there is significant regrowth, crop injury is negligible or nonexistent. However, this would not be the case if herbicide application is delayed until after alfalfa breaks dormancy and resumes growth in spring.

Over the 5-year stand life, the cumulative alfalfa yield was 1.1 tons/acre greater when the RR alfalfa was treated with Roundup vs. traditional herbicides, averaged across varieties. All

varieties yielded more than Vernal, the check cultivar. Comparing management systems over 5 years, the Roundup system (Roundup applied to the 12 RR varieties) yielded similarly to the conventional system (conventional herbicides applied to the 12 conventional varieties). There were large differences between individual varieties within both the conventional and RR varieties. There was a yield advantage to the RR system across varieties, due to crop injury in the conventional system.

Table 2. Influence of Herbicide and Variety strategy on total alfalfa yields, Tulelake, CA, 2005-2009. Each strategy is the average of 12 varieties, within each herbicide treatment. This enables comparison of whole systems (conventional vs. RR Ready), as well as the influence of herbicide alone (Conventional vs. Roundup herbicides on the same RR lines).

Combined Variety/Herbicide Strategy

Variety	Herbicide Treatment	2005	2006	2007	2008	2009	5-Year Average	
		tons/A						
Roundup Ready	Roundup	4.55	9.96	8.28	7.23	8.15	7.63	A
Conventional	Conventional	4.59	9.87	8.2	7.15	8.00	7.56	A
Roundup Ready	Conventional	4.04	9.47	8.18	7.60	7.77	7.41	B
	LSD	0.29	NS	NS	0.19	0.16	0.14	
	CV	16.10	12.53	4.99	6.56	5.01	4.74	

In addition to this test at a single location, RR varieties have been evaluated in a range of California environments in standard variety trials as part of an ongoing alfalfa variety evaluation program at the University of California. The performance of both RR and conventional alfalfa varieties (all treated with conventional herbicides) has been evaluated for over 8 years (Figure 4). All of these sites except for Tulelake were semi-dormant to non-dormant varieties, with 6-9 cuts/year. Although in some cases there was a numerical trend for lower yields in the RR versus Conventional varieties in the non-dormant varieties in these trials, this was not consistent, and was not apparent in the dormant group of varieties (FD 3-4). In general, the differences between varieties within a group (RR or conventional) were much more important than the differences between the RR and conventional lines.

Oftentimes RR alfalfa varieties are grouped together and collectively categorized as being higher or lower yielding than conventional varieties. Some growers tend to consider all RR alfalfa varieties as performing a certain way. The truth is that not much of the genetics are actually altered and growers should be careful to evaluate each variety individually for its agronomic characteristics regardless of whether if it is RR or conventional. Yields, disease and insect resistance, persistence and fall dormancy remain important traits to consider, in addition to the insertion of the Roundup-resistance technology.

It is not surprising that the RR alfalfa gene does not confer unique agronomic capabilities to alfalfa other than resistance to glyphosate, which is the general conclusion of our studies. If each of the chemical units that make up DNA were represented by an alphabetic letter, it would take 170,000 pages to encompass all of the information in the cell of an alfalfa plant (Lemaux, 2004).

If one introduces a single gene, it represents about one-half to one page in the analogy (a gene is half a page; a bit more is added to encompass the on and off switches). That information would represent 0.0006% of the genetic information which would be new. That page of information can insert anywhere in the genome which is why different RR varieties can be different even if they contain the same gene. It should be noted that the first RR alfalfa varieties to be commercialized have been largely in the Fall Dormancy 3-4 class, with fewer in the semi- and non-dormant classes (FD 5-10), and that further plant breeding will introduce second- and third-generation varieties in subsequent years.

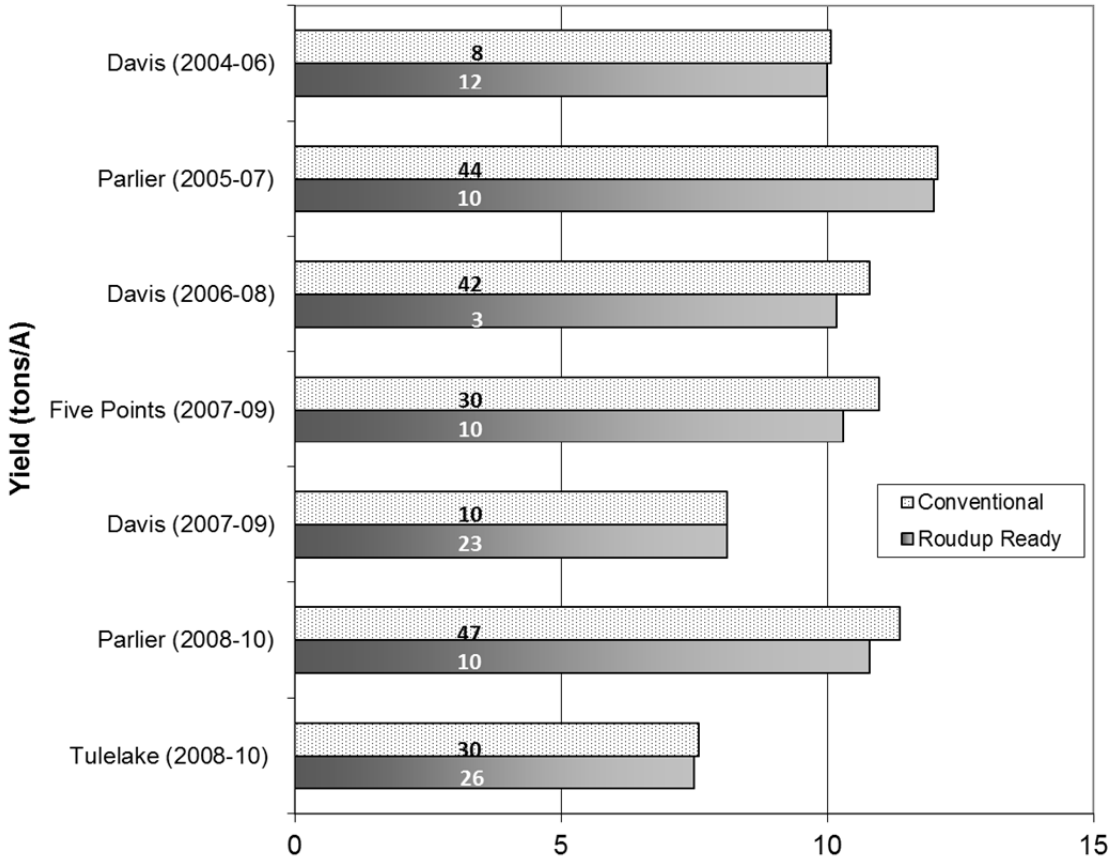


Figure 4. Comparison of yield performance of RR and conventional varieties in standard UC alfalfa variety trials in a range of California production areas (number in parentheses indicates number of varieties averaged).

FORAGE QUALITY AND STAND PERSISTENCE EFFECTS

Most of the RR alfalfa growers (approximately 50 percent) who responded to the survey believed that the forage quality of RR and conventional varieties was about the same. However, 41 percent of the growers felt that RR varieties were higher in quality than conventional varieties compared with less than 3% percent of growers who felt RR varieties were lower quality. When considering the forage quality of RR varieties and conventional varieties, there are two distinct considerations. First, are RR varieties genetically superior (or inferior) in forage quality compared with conventional varieties? Or, are any differences in forage quality between RR and

conventional alfalfa fields due to difference in weed control since most weeds are lower in forage quality compared to alfalfa?

There is little current information available from universities about the forage quality of different alfalfa varieties including RR varieties due to the high cost of such an undertaking. However, this year we were able to evaluate the forage quality of first-cutting samples taken from an alfalfa variety trial in Tulelake. There were 10 RR varieties and 22 conventional varieties in the study. There was a statistically significant difference between varieties as a whole in acid detergent fiber (ADF) and total digestible nutrients (TDN), which is simply calculated from ADF. Differences in crude protein (CP) and neutral detergent fiber (NDF) were not as significant (P = 0.062 and 0.091 for CP and NDF, respectively). Although there were differences between individual varieties, the mean for the 22 conventional varieties and 10 RR varieties was practically identical (Figure 5). These data are just from a single cutting in a single year but do suggest that in the absence of weeds there is not a major difference in forage quality between RR and conventional varieties considered as a group. Once again, similar to yield results, differences within groups (e.g. RR or conventional) were much greater than the differences between groups. This further illustrates the importance of comparing individual varieties rather than RR versus conventional varieties as a collective group.

A plurality (49%) of growers felt that RR alfalfa gives longer persistence compared with 36% who felt that persistence was about the same as conventional varieties and less than 4% who felt it might be inferior to conventional varieties. We know of no evidence that RR varieties per-se have innate superior persistence. However, it is widely known that effective weed management systems of any type (whether conventional or RR technology) are likely to confer superior stand persistence in alfalfa – often the effects of excessive weed competition during seedling growth lasts many years throughout the life of the stand. Crop injury of conventional herbicides is also an important factor in determining young seedling development, especially roots, and such effects can last beyond the first year of growth – conferring superior stand persistence to any weed management technique that reduces crop injury. Thus, these anecdotal reports of better persistence, though not widely tested, may have validity due to seedling and stand establishment effects, not the gene itself.

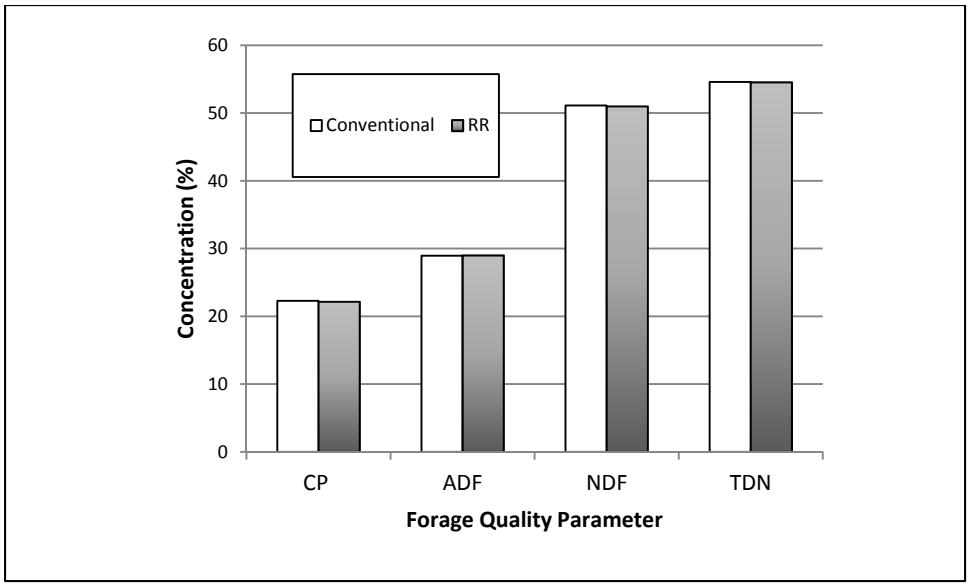


Figure 5. Comparison of the forage quality of 10 RR and 22 Conventional alfalfa varieties in a standard alfalfa variety trial. Tulelake, 2011.

COST EFFECTIVENESS

It is extremely difficult to quantify the cost effectiveness of the RR alfalfa system because the assumptions that would go into the analysis are so site specific. The cost effectiveness of the RR alfalfa production system was the least popular response when growers indicated what they liked most about RR alfalfa. When asked about cost effectiveness, what immediately comes to mind is whether the savings in herbicide costs covers the increased cost of RR alfalfa seed. The cost of the RR alfalfa genetics is similar to the cost of most proprietary varieties that growers purchase today. When comparing the cost of RR and conventional alfalfa seed, the primary difference is the $150.00 per 50 pound bag charge for the RR trait that growers pay apart from the cost of the genetics. At a seeding rate of 20 pounds per acre this equates to a $60 per acre increase for RR alfalfa at planting time. The herbicide cost for an application of Roundup is significantly less than $10 per acre (excluding application costs). The cost of conventional herbicides to control weeds in seedling alfalfa is often $30 - $45. The herbicide cost for a dormant alfalfa weed control program in established alfalfa is typically $25 to $40 and can increase another $25 to $35 or more for an application of Treflan or Prowl for summer annual grasses.

The herbicide savings with the RR system obviously depends on the number of glyphosate applications required. However, it is readily apparent that the herbicide savings can quickly offset the increased seed cost. Unfortunately, this also means that there is considerable incentive for growers to rely solely on Roundup as the herbicide of choice to recoup the upfront cost of RR alfalfa seed. For the reasons stated earlier, growers should factor into their cost comparisons the need to alternate herbicides or use herbicide tank mixes for resistance management. This will reduce the immediate cost effectiveness of the RR system but is important for the long-term sustainability of this system. Other economic factors including almost complete elimination of crop injury, any effect stand life or a higher hay price for “cleaner” hay should be factored into the evaluation. Ultimately, the RR system must be cost effective for growers to continue using it.

Reducing Seeding Rates to Control Costs. Growers in some areas of the western US often apply 25, 30, or even 40 lbs of seed per acre to establish an alfalfa stand. This is likely due to the historically low price of alfalfa seed. However, it has become increasingly apparent that this represents a much larger cost factor when considering RR alfalfa compared with conventional seed. Recent multi-state research by Sulc et al. (2010), indicates that seeding rates can be effectively reduced to as low as 12-15 lbs/acre for RR alfalfa, with large cost savings to the grower. Farmers often increase seeding rates as an 'insurance policy' or to make up for sub-optimum soil preparation, timing, or other stand establishment issues. It is apparent that with more expensive genetics such as RR alfalfa, growers have increased incentive to adopt improved methods of soil preparation, timing, distribution and depth control that are more precise so that seeding rates can be reduced and cost of stand establishment of RR alfalfa is more economical.

ENVIRONMENTAL BENEFITS

Some herbicides commonly used for winter weed control in alfalfa (such as Velpar and Karmex) have been detected in drinking water in a minority of observations in the Central Valley of California. However, these concerns were significant enough to cause the CA Department of Pesticide Regulation (DPR) to propose withdrawing Velpar registration in 2010. Subsequently, they decided against this move. However, in those regions (primarily the northern part of the San Joaquin Valley), growers have looked for herbicides to control problematic winter weeds such as groundsel (a poisonous weed), which causes severe health problems in animals, without threatening ground or surface water. Given the fact that rainfall occurs during winter, it's often difficult to prevent movement of soluble herbicides with rainwater or subsequent irrigation applications. RR alfalfa has proved to be an important tool for those situations. In the most highly regulated state in the US, the CA DPR's concern about the water contamination potential of glyphosate is a tiny fraction of that of other herbicides, due to its lack of residual presence and near zero runoff potential. This environmental benefit of RR alfalfa, anticipated by Van Dynze et al., 2004, has been confirmed by subsequent grower experience during 2005-2011, and a number of growers in these sensitive regions have opted for the technology.

CONCLUSION

A large majority of growers who have produced RR alfalfa are generally pleased with the system with *better weed control* and *simplicity of weed management* being the most commonly cited advantages. Roundup controls a broader spectrum of weeds than other alfalfa herbicides and is especially effective on some problematic weeds such as dodder, nutsedge and many perennial weeds. To maintain the long-term effectiveness of the RR alfalfa system and to avoid herbicide resistance, it is important that growers utilize a variety of weed control strategies rather than relying solely on Roundup applications in the RR alfalfa system. The performance of RR varieties in terms of yield potential and forage quality appear to be similar to conventional varieites. As with any variety, RR or conventional, it is important to evaluate the performance of individual varieties rather than assuming all RR varieties are the same.

The RR alfalfa system greatly simplifies weed management in alfalfa. Depending on your philosophy toward GE crops, your market, and the weed pressure encountered, the RR system

has been shown to have significant benefits for many producers. It has proved to offer some important environmental benefits for those areas where traditional herbicides are problematic. Environmental factors (rain, temperature, timing) are also more important for conventional herbicides than for Roundup (less flexibility with conventional). Effective control of most weeds in alfalfa is often feasible with conventional herbicides; they just require a higher level of weed science expertise—ability to properly identify weeds, use more precise application timing, and have the knowledge to select the proper herbicide, rate, or herbicide tank mixes to control the weeds encountered in a field. The advantages and cost effectiveness of RR alfalfa are not so great as to preclude a grower who chooses to produce conventional alfalfa from competing effectively with RR alfalfa growers. Which approach makes the most sense for a grower comes down to a personal decision, specific weed pressure and species, economic analysis, and the sensitivity of markets.

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