

## **WEED RESISTANCE MANAGEMENT AND CHALLENGES WITH ROUNDUP RESISTANT ALFALFA**

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### **Summary**

Weeds are a challenge to profitable alfalfa production. The Roundup Ready alfalfa production system, has potential to simplify weed management, and improve control of both annual and perennial weeds. Roundup has proven to be a reliable herbicide treatment in other transgenic crops and has improved weed management in the short term. However, weed species shifts and the selection for Roundup-resistant weeds have resulted from the increased use of this technology. Alfalfa is especially vulnerable for several reasons: tillage is not practical, alfalfa is produced in large fields with a great diversity of weeds, and there is significant potential for long-term repeated use of a single herbicide because it is a perennial crop. Alfalfa growers can learn from the experience gained with other Roundup Ready crops to minimize weed shifts and the evolution of resistant weeds. Weed control systems that integrate tillage between plantings, crop rotations, rotations with herbicides of different modes of action (preferably soil residual herbicides), and tank mixtures are important. The long-term effectiveness and sustainability of the Roundup Ready system in alfalfa depends upon how well growers adopt the concept of herbicide rotation into their production systems. Use a preemptive approach—one should not wait until weed shifts and resistance occur before utilizing herbicide rotation strategies.

### **DEVELOPMENT OF ROUNDUP READY ALFALFA**

Alfalfa, is an important crop throughout the Western US. Because nearly all weeds reduce the palatability and nutritional value of alfalfa, livestock industries—especially the dairy and horse industry—expect nearly weed-free hay. This can be difficult to achieve using conventional alfalfa herbicides. Typically, no single herbicide controls all weeds present in a field and some weeds, especially perennial weeds, are not adequately controlled with any of the current conventional herbicides. In addition to being difficult to achieve, complete weed control in alfalfa is costly. Growers continually seek ways to enhance the level of weed control while minimizing costs.

Glyphosate (Roundup)-resistant or Roundup Ready alfalfa (RR alfalfa), developed in late 1997 and made commercially available in the fall of 2005, makes broadcast applications of Roundup to alfalfa possible. The biotechnology-derived plants have an altered enzyme that allows them to tolerate a Roundup application while susceptible weeds are killed. This technology allows growers to deal with some of the most difficult-to-control weed species. Beginning in 2001, trials conducted by UC Farm Advisors throughout California demonstrated the effectiveness of this technology. Roundup was especially effective for seeding alfalfa, as less alfalfa injury resulted and superior weed control was realized compared to standard herbicides. One of the

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greatest advantages of this technology is that it suppresses perennial weeds such as dandelion, nutsedge, Bermudagrass, and quackgrass that have not been adequately controlled with conventional practices. Initial experience in commercial fields has confirmed these research findings and has further demonstrated the benefits of this technology—increased ease of use and superior weed control.

### **WEED SHIFTS AND RESISTANCE WITH RR ALFALFA**

The greatest concern with this new weed-management system is the potential for weed shifts and weed resistance. A weed shift occurs when weeds easily controlled by Roundup, such as chickweed decline, and difficult-to-control weeds such as burning nettle increase. Weed resistance is different from a weed shift. An example of weed resistance is ryegrass which is normally controlled by Roundup. If ryegrass develops resistance for Roundup then it can no longer be controlled with this herbicide. It is important to understand the distinction between a *weed shift* and *weed resistance* because the significance, as well as the management approaches for dealing with each, is different.

The possibility of weed shifts and weed resistance is particularly a concern with RR alfalfa, the first perennial crop with this transgenic trait, due to a long alfalfa stand life and the potential for repeated use of a single herbicide over several years. For some growers alfalfa is the primary crop, and they want to minimize the amount of time the field is planted to low-profit rotation crops. Therefore, in areas like the Intermountain area of northern California there may be continuous alfalfa in a field for 12 or more years with only one year of a small grain rotation crop between alfalfa plantings. Stand life is shorter in warmer production areas like the Central Valley of California (3-4 year stand life is typical), and there are more rotation crops. However, cotton and corn are commonly rotated with alfalfa, and if transgenic RR varieties are produced, this again could result in a prolonged time period where a single herbicide is used repeatedly.

There are aspects of the alfalfa production system that both favor and discourage the development of weed shifts and resistant weeds. First, rotation opportunities in a perennial crop like alfalfa are less compared with annual cropping systems. Resistance and weed shifts are believed to evolve more rapidly in crops like alfalfa that are solid seeded, relatively low value, and grown on large acreages. Mechanical cultivation and hand weeding are not practical in a solid-seeded lower-value crop like alfalfa. On the other hand, alfalfa is an aggressive competitor with most weeds, and many weed species do not tolerate frequent cutting.

Weed shifts or resistant weeds are unavoidable and will eventually occur with any herbicide after repeated use. Fortunately, resistance to Roundup is not as common as resistance to many other herbicides. Two weed species have documented resistance to Roundup in California—rigid ryegrass and marestail. Roundup-resistant ryegrass was first found in California orchards where there was a long history of continual Roundup use. Roundup resistant marestail originated in the southern San Joaquin Valley of California in orchards, vineyards, and ditch banks where tillage was no longer used and Roundup was used continuously for several years, oftentimes with multiple applications per season.

Roundup is the most effective broad-spectrum post-emergence herbicide available, and it would be a shame to lose its effectiveness as a result of mismanagement. Weed shifts and/or weed resistance have occurred with the other transgenic RR crops released before RR alfalfa. This has typically occurred after approximately 6 years of continual use. Alfalfa growers can learn lessons gained from experience with these other crops as a preemptive measure to avoid, or at least minimize problems with weed shifts and weed resistance. The obvious questions are, “What management practices can be utilized to avoid weed shifts and weed resistance, and how do we effectively utilize this new technology?”

### **RECOMMENDED WEED MANAGEMENT PROGRAM FOR RR ALFALFA**

Roundup Ready alfalfa is still a relatively new technology, so we have limited field experience to date. The following are some suggestions to consider based upon proven resistance management strategies, our understanding of alfalfa production practices, and our initial experience with RR alfalfa. Ultimately, growers and pest control advisors hold the key to avoiding weed shifts and resistance by reducing selection pressure.

Controlling weeds when alfalfa is in the seedling stage is the most challenging as alfalfa is most vulnerable to weed competition when it is in this stage. Additionally, complete weed control in seedling alfalfa is often difficult to achieve and frequently requires tank mixes of different herbicides to control the broad spectrum of weeds found in an individual field. Crop injury and yield loss are also usually far greater in seedling than in established alfalfa. Numerous field trials throughout the country have proven the effectiveness of Roundup in herbicide-resistant transgenic alfalfa. Therefore, it is only logical to use Roundup for weed control in transgenic seedling alfalfa for the cost savings, improved weed control, reduced crop injury, and to eliminate the alfalfa seedlings that do not carry the Roundup resistance gene. Ordinarily, the 1.0 pound active ingredient rate (22 oz of Roundup UltraMax) is sufficient. However, a higher rate may be needed if the field contains tolerant weeds such as malva or filaree. A tank mix may be advised if especially tolerant weeds such as burning nettle are present. For example, a tank mix with Raptor or Pursuit may be advised if burning nettle is present, or a tank mix with Prism may be necessary if the field contains ryegrass.

Alfalfa stand life varies considerably throughout the West depending on the production area, grower practice, and the existence of profitable rotation crops. However, a stand life of 3 to 4 years is common in the Central Valley of California. For the principles outlined above, it is unwise to rely solely on Roundup applications for weed control throughout the life of a transgenic alfalfa field. This practice would encourage weed shifts and resistance, and over time weed control would diminish in most cases. Once a resistant weed population has gained a foothold, it is practically impossible to eliminate and the usefulness of an herbicide is greatly diminished.

Most alfalfa producers treat alfalfa during the dormant season for winter annual weeds that infest the first cutting. It is strongly recommended that growers not rely solely on Roundup for their winter weed control program for the duration of the stand. They should rotate to another herbicide or tank mix at least once in the middle of the life of a stand, and perhaps twice if the stand life is over 5 years.

Fortunately, there are several herbicides to choose from that have a different target site of action than Roundup. The soil-residual herbicides applied during the dormant season to established alfalfa [such as hexazinone (Velpar), diuron (Karmex) and metribuzin (Sencor)] would be appropriate herbicides for a rotation or tank-mix partner. The rotation herbicide or tank-mix partner of choice depends on the weeds present in the field and their relative susceptibility to the herbicides. Paraquat (Gramoxone) is another candidate for rotation or tank mixing, but Gramoxone, like Roundup, is applied late in the dormant season. By rotating Gramoxone with Roundup, growers could potentially be selecting for early-emerging weeds that may be too large to control at the typical timing for Roundup or Gramoxone. Or, they could be selecting for late emerging weeds that germinate after the application.

Weed control in the last year of an alfalfa stand is often challenging because the stand is typically less dense and competitive, and there are also fewer herbicide options to choose from due to the plant-back restrictions associated with many of the soil-residual herbicides. Therefore, Roundup is a good choice for controlling weeds in the final year of an herbicide-resistant alfalfa field. This underscores the importance of having rotated herbicides before the final year so that Roundup will remain effective and control the majority of the weeds in a last-year alfalfa stand.

Summer annual grasses, such as yellow and green foxtail, barnyardgrass, cupgrass and jungle rice, and sometimes pigweed, can be problematic in established alfalfa. These weeds emerge over an extended time period whenever soil temperatures and moisture are adequate, typically from late winter or early spring—as early as February in the Central Valley—throughout the summer. They may emerge between alfalfa cuttings, so several applications may be necessary for a foliar herbicide like Roundup to provide season-long control. Multiple applications of a single herbicide during a season is cited as promoting weed resistance. Therefore, growers should not rely solely on Roundup for summer grass control for multiple seasons. It still remains to be seen how many applications of Roundup will be required for season-long summer grass control. In long growing-season areas, as many as two to three applications per season may be needed. Rather than making multiple applications of Roundup, a better approach may be to apply the pre-emergence herbicide trifluralin (Treflan), and follow-up with Roundup as needed for escapes. This approach helps avoid weed shifts and resistance, and may be more economical compared with multiple applications of Roundup.

Herbicides rotation and use of tank mixtures should be done for both dormant applications to control winter annual weeds and for spring/summer applications intended to control summer annual weeds. For example, rotating to Velpar for winter annual weed control for a year does nothing to prevent weed species shifts or the development of resistance in the summer annual weed spectrum. Herbicides for summer annual weed control should be rotated as well.

There is no definitive rule on how often herbicides should be rotated. The suggestion to rotate or tank mix at least once in the middle years of the life of a stand (or more often for long-lived alfalfa stands) is only a suggestion. The key point, which cannot be overemphasized, is the importance of diligent monitoring for weed escapes. Producers should stay alert to the development of weed species shifts and resistant weeds. If the relative frequency of occurrence

**Figure 1.** A weed species shift occurs when both susceptible

of a weed species increases dramatically, chances are that it is tolerant to Roundup and immediately rotating herbicides or tank mixing is advised. If a few weeds survive among a weed species that is normally controlled easily with Roundup, it could be an indication of possible weed resistance, assuming misapplication and other factors can be eliminated as possible causes. In these situations, it is imperative to prevent reproduction of a potential resistant biotype. Treat weed escapes with an alternative herbicide or use another effective control measure.

**CONCLUSIONS**

The Roundup Ready production system has potential to simplify weed management, while also improving the spectrum of weed control. However, growers should learn from the experience gained in other crops and stay alert to the development of weed shifts and resistant weeds. The key is for growers to reduce selection pressure—not to rely on repeated applications of Roundup year-after-year, application-after-application. Rotate crops, rotate herbicides and utilize tank mixes as needed, depending on the weed species and weed escapes present. A grower should not wait for there to be a problem before he employs these practices; a preemptive approach is strongly encouraged.