

## PROGRESS IN ROUNDUP READY ALFALFA

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### ABSTRACT

Complete control of all weeds present in alfalfa is often difficult to achieve. Weed control can be costly and alfalfa injury occurs with some herbicides, especially in seedling alfalfa. Genetically modified alfalfa with resistance to glyphosate, perhaps the most effective broad spectrum contact herbicide available will probably be commercialized over the next 24 months, and will likely be of significant interest to alfalfa producers. Trials were established in four alfalfa production areas of California to compare the Roundup Ready weed control system with conventional weed management systems in both seedling alfalfa and established alfalfa. Different glyphosate rates and timings were evaluated in seedling alfalfa. The Roundup Ready system resulted in the best overall weed control of the treatments evaluated in seedling alfalfa and there was considerable flexibility in treatment timing. The Roundup Ready system of weed management shows significant promise for use in established alfalfa as well. This technology is not without some issues and concerns, including the potential for weed shifts and weed resistance with regular use of Roundup. Questions about the transfer of the Roundup-resistant gene to feral alfalfa and control of variety purity during seed production have been raised. The costs of the technology and market acceptance must be understood for growers to have full confidence in the technique. Despite these questions, once Roundup Ready alfalfa becomes available, it is likely to have a profound influence on weed control in alfalfa, providing a simple, broad-spectrum weed management tool that had not previously been available.

**Key Words:** Alfalfa, *Medicago sativa*, weed management, genetically modified crops, glyphosate, herbicide resistance

### INTRODUCTION

Complete weed control in alfalfa has been a continual challenge for alfalfa producers. Compared with many other crops, alfalfa competes well with weeds. However, despite alfalfa's competitive ability, weeds remain a problem. The high forage quality demands of the dairy industry in California are such that nearly perfect weed control is important. Similarly, for alfalfa hay to be suitable for sale to the horse industry, it must be almost entirely free of weeds. This has been difficult with conventional herbicides, as typically no single herbicide controls all the weeds present in many alfalfa fields. This is especially true for weed control in seedling alfalfa where herbicide tank mixes are often required and even when they are used weed escapes are not uncommon.

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## POTENTIAL BENEFITS

Glyphosate is undoubtedly the most effective non-selective foliar herbicide available. It controls a broader spectrum of weeds, both annuals and perennials, than any other herbicide. Now with the advent of transgenic crops it can be used to control weeds in crops resistant to glyphosate. The impact that herbicide tolerant crops have had on other commodities is remarkable. In 2002, 69 percent of the cotton acreage, 68 percent of the soybean acreage, 55 percent of the canola acreage, and 26 percent of the corn acreage in the United States were planted with varieties genetically altered for herbicide tolerance.

Commercial varieties of alfalfa genetically altered for resistance to glyphosate are on the horizon. Monsanto has entered into a cooperative agreement with the alfalfa breeding company Forage Genetics to produce Roundup Ready alfalfa. Roundup Ready alfalfa varieties may be available as soon as 2004 or 2005.

Conceptually Roundup Ready alfalfa as a weed control system has significant merit for alfalfa producers. Weed control costs could potentially be dramatically reduced while improving the level of weed control. Most alfalfa herbicides injure the crop to some degree. In theory, crop injury could be dramatically reduced or eliminated with Roundup Ready alfalfa. In addition, there are no effective weed control programs for some of the most difficult-to-control perennial weeds (dandelion and quackgrass) common in intermountain alfalfa stands. Control of difficult to control perennial weeds in the California's Central Valley (Bermudagrass, nutsedge, and Johnsongrass) could also be improved with glyphosate. Adequate control of these tough perennials could help extend stand life in some areas.

## UNANSWERED QUESTIONS

Even with these potential advantages, questions remain regarding the value of the Roundup Ready System in alfalfa production systems. Glyphosate has no soil residual activity. Many, if not most, of the herbicides used for winter and summer annual weed control have soil residual activity so that they persist long enough to provide complete weed control. Similarly Pursuit, and now Raptor, each have soil activity which helps control weeds that emerge following the herbicide application. *Could complete season-long weed control be achieved with a foliar herbicide like glyphosate given the prolonged emergence of the weeds that infest alfalfa?* Field trials were needed to compare the Roundup Ready weed management system with standard weed control strategies under the diverse environmental conditions and weed spectrum encountered in California. In addition, the Roundup Ready approach to weed control may require different application timing(s) than other conventional herbicide treatments.

## CALIFORNIA FIELD TRIALS

### **Seedling Alfalfa – Establishment Year**

Uniform weed control trials were conducted in the intermountain area, Sacramento Valley, and San Joaquin Valley of California. Testing the Roundup Ready concept over varied environments allows for a better comparison of the benefits and shortcomings of the system. Roundup Ready alfalfa (fall dormancy appropriate to the production area) was seeded in the fall at each site. An

additional spring-seeded trial was conducted at the intermountain site. Different glyphosate rates and application timings were evaluated. The glyphosate rates tested were 1 and 2 pounds active ingredient per acre (0.75 and 1.5 lbs. ae/A). There were three different herbicide application timings based on the alfalfa growth stage: A) unifoliolate to first trifoliolate, B) 3–4 trifoliolate leaves, and C) 6–9 trifoliolate leaf stage. The conventional standards tested were imazamox (Raptor) and tank mix of imazethapyr (Pursuit) and bromoxynil (Buctril) or clethodim (Prism). A tank mix of glyphosate and Pursuit was also evaluated. Sequential treatments (when deemed necessary) were evaluated to ascertain the need for multiple treatments to control weeds that emerged after the initial application. The treatments were nearly identical at all sites. A complete list of all the treatments and their description is presented below. The timings refer to the application timings above (*Timing D* is the second treatment for a sequential application). Treatments were applied with a CO<sub>2</sub> pressurized backpack sprayer, except at the Kearney Agricultural Center, where a tractor-pulled plot sprayer was used.

#### **Description of Treatments:**

1. Roundup (0.75 lb. a.e./ac) Timing A - Very early application of Roundup at unifoliolate to 1st trifoliolate.
2. Roundup (0.75 lb. a.e./ac) Timing B - Early application of Roundup at the standard 3-4 trifoliolate stage.
3. Roundup (0.75 lb. a.e./ac) Timing C - Late application of Roundup applied at 6 - 9 trifoliolate stage, which would be generally too late for most conventional herbicides and effective weed control, but late applications are a common occurrence due to herbicide timing restrictions on alfalfa or environmental limitations which prevent timely treatments.
4. Roundup (1.5 lb. a.e./ac) Timing B - Early application of Roundup at the 3-4 trifoliolate stage with higher rate to address problem weeds.
5. Roundup (1.5 lb. a.e./ac) Timing C - Late application of Roundup at 6-9 trifoliolate stage. Weeds are expected to be bigger and harder to kill. Higher rate to address increased weed size.
6. Conventional, Timing B (Pursuit, Prism, 2,4-DB, Poast, Buctril) - One application of Pursuit or other herbicides applied alone or in a tank mix combination at the 3-4 trifoliolate stage to control the weed spectrum. Other herbicides could include Buctril, Prism, Poast or 2,4-DB.
7. Conventional, Timing B (Raptor alone) - Raptor alone applied at 3-4 trifoliolate stage. No further weed control measures.
8. Conventional, Timing C (Pursuit, Prism, 2,4-DB, Poast, Buctril) - One application of Pursuit and/or other herbicides applied alone or in tank mix combinations applied at the later stage of 6-9 trifoliolate alfalfa.
9. Mix Strategy, Timing B (Roundup + Pursuit) - A tank mix of Roundup (0.75 lb. a.e./ac) and Pursuit applied at the 3-4 leaf stage of alfalfa  
Sequential Treatments (D is timing of the second flush of weeds and is not tied to a stage of the alfalfa).
10. Roundup followed by Roundup, Timing A & D (0.75 lb. a.e./ac followed by 0.75 lb. a.e./ac) Roundup applied very early at unifoliolate to 1st trifoliolate followed by second application to control second flush if necessary.
11. Roundup followed by Roundup, Timing B & D (0.75 lb. a.e./ac followed by 0.75 lb. a.e./ac) Roundup applied early at 3-4 trifoliolate followed by second application to control second flush if necessary.
12. Conventional followed by Conventional (Conventional Timing A & D) Treatment begins at the very early trifoliolate stage. A second application (e.g. Prism or Pursuit, or Pursuit + Pursuit low rate) made for later weeds.
13. Roundup followed by Conventional (Timing B & D) Roundup application (0.75 lb. a.e./ac) early. Follow up with conventional herbicide to control second flush if necessary.
14. Untreated Control - This treatment will demonstrate the penalty for not controlling weeds during the seedling phase.

## **RESULTS**

There was very little to no injury to the alfalfa with the Roundup treatments. At some sites there were very slight injury symptoms but they were insignificant and short-lived. Alfalfa at the

Kearney Agricultural Center site showed an initial reduction in plant height when treated with Roundup at the 6-9 trifoliolate stage compared with other timings, but the injury was no longer evident by the time of first cutting. The Raptor and the Pursuit plus Buctril tank mix treatments resulted in more injury. However, the injury was generally less than 20 percent at most locations. Alfalfa crop mortality occurred in all Roundup treatments. The Roundup Ready alfalfa planted for the trials was a blend of experimental varieties and contained a small percentage of plants without Roundup resistance.

Better than 95 percent control of nearly all weeds was achieved with Roundup at all sites. These weeds included prickly lettuce, wild radish, shepherd's purse, volunteer wheat, volunteer oats, common groundsel, annual bluegrass, swinecress, chickweed, purslane, nightshade, and kochia. Roundup was less effective on henbit. While the 2.0 pounds active ingredient per acre rate (1.5 lbs. a.e./A) of Roundup resulted in more rapid weed kill, it was generally not needed. A 0.5 pound active ingredient per acre rate was sufficient to control the summer annual weeds in the spring-seeded trial in the intermountain area.

The importance of the timing of Roundup application varied depending on weed species, location, and time of the year. At the intermountain site an application made at the unifoliolate to first trifoliolate timing resulted in subsequent invasion of prickly lettuce and henbit, but shepherd's purse was completely controlled, as there was no subsequent emergence of this weed after the initial application. A second application (3/28/02) was needed to control all the weeds that could infest first cutting. Similarly, a second application of Roundup was needed at one of the San Joaquin Valley sites (West Side Research and Extension Center) when the first Roundup application occurred when the alfalfa was at the cotyledon to unifoliolate stage.

All of the Roundup timings resulted in excellent weed control in other trials. This was the case in the spring trial in the intermountain area and the trial on the east side of the San Joaquin Valley (Kearney Research and Extension Center). The situation was similar in the San Joaquin County trial, where all Roundup timings performed well. However, a second flush of annual bluegrass and canarygrass germinated in all treatments by early December. None of the herbicide treatments controlled this second flush of weeds.

Raptor and the Pursuit combinations controlled most weeds, but not as complete control as with Roundup. Weeds not adequately controlled with Pursuit alone were purslane, prickly lettuce, henbit, kochia and the grasses. Raptor was more effective than Pursuit for the control of the grasses and was generally slightly more effective on some of the broadleaf weeds.

### **Established Alfalfa**

A second set of uniform weed control trials were conducted in the intermountain area, Sacramento and San Joaquin Valleys of California. These studies are being conducted as a split plot design with treatments replicated three to four times. Roundup Ready alfalfa was established with the use of either glyphosate only and conventional herbicides only. Conventional herbicides consisted of Raptor or Pursuit and depending upon location and weed species present, Prism was applied in combination with one or the other. If needed, in season applications were made during the first growing season. Beginning with the second growing season, and continuing for the next two to three years, Roundup treatments will be compared with conventional treatments,

separately and in combination. In each of the blocks (Roundup only and conventional herbicides only) treatments included:

1. Roundup (1.5 lb a.e./A) one application for winter annual weeds and additional in season applications as needed.
2. Roundup (0.75 lb a.e./A) one application for winter annual weeds and additional in season applications as needed.
3. Roundup – variable Roundup rates (each at least 0.75 lb a.e./A) to address special weed problems with a maximum yearly rate of 6 lb a.e./A.
4. Velpar (.05 lb ai/A) during dormant period with or without paraquat (Gramoxone Max) (0.375 lb ai/A) followed by either trifluralin (Treflan Granules) (2 lb ai/A) or Prism (0.176 lb ai/A) during the growing season depending upon location.
5. Velpar (0.5 lb ai/A) during dormant season with or without Gramoxone followed by Roundup as needed during the growing season.
6. Untreated Control.

## Results

Initial applications were made at all sites, but additional in season applications were not needed at any of the sites. Evaluations at first cutting indicated excellent control of all weeds present with no differences between the Roundup and conventional herbicide systems. Alfalfa injury was greater with the Velpar + Gramoxone treatments, as would be expected. In the blocks established with conventional herbicides only, the Roundup treatments exhibited greater alfalfa injury than in the blocks established with Roundup. The greater injury was due to the fact that the Roundup applied to the conventionally established blocks, being the first Roundup applied, caused injury to the five percent (plus or minus) of the alfalfa plants in the population without the Roundup Ready gene. Even though those plants did not have the Roundup Ready gene, they were not killed, as was the case when they were in the seedling stage. First cutting yields indicated little to no difference between the Roundup only and conventional herbicide only system. One site indicated a higher percentage of alfalfa in the control treatment in the block that was established with Roundup when compared to the block established with Pursuit + Prism. Roundup at establishment also had a lower percentage of weeds. Evaluations of weeds, at all sites, during the growing season indicate no need for additional applications in any treatment. Applications will be repeated for the next two years and evaluated for weed control, potential for weed species shifts and the value of herbicide rotations. Evaluations will also be made for stand persistence and comparisons of costs will be made based on results of these studies.

The Roundup Ready system of weed management shows significant promise for use in seedling and established alfalfa. It resulted in the best overall weed control of the treatments evaluated and there was considerable flexibility in treatment timing. One of the major causes for weed control failures with conventional herbicides is late application—the weeds become too large for complete control. It appears that this will not be nearly as critical with glyphosate as it is with standard herbicides. Extremely early applications, at the unifoliate to first trifoliate growth stage are ill advised because at some sites and under some conditions subsequent weed invasion can occur because open areas in the young stand facilitate weed encroachment. Crop injury from glyphosate appears to be less than with most conventional herbicides.

During the first establishment year the Roundup system provided just as effective weed control as the conventional herbicide system with little to no difference in first cutting yields. Additional

repeat applications for the next two years will be evaluated for potential weed species shifts with each system.

### **CONCERNS AND OTHER ISSUES**

While this new technology has many advantages, Roundup Ready alfalfa will not be a panacea. Even though glyphosate is an extremely effective broad spectrum herbicide, there are still weeds such as malva and filaree that it does not adequately control. Continued use of glyphosate can over time result in a weed shift. While glyphosate is not as prone to weed resistance as are other herbicides, it still is feasible. Glyphosate-resistant ryegrass has already been found in the Sacramento Valley. Uninterrupted use of Roundup in a perennial crop like alfalfa, especially if followed by other Roundup Ready crops, increases the likelihood of resistance. The key is to avoid continual reliance on a single herbicide for weed control—integrate several weed management strategies including cultural and chemical weed control and alternate herbicides with different modes of action.

There are other issues related to Roundup Ready alfalfa that warrant consideration. Glyphosate obviously will not control Roundup Ready alfalfa. Hence, volunteer alfalfa may become more of a dilemma in rotation crops such as tomatoes, peppers, beans, etc., as glyphosate is often used to kill alfalfa prior to plowing or disking out an alfalfa stand in some areas. Similarly, volunteer alfalfa will be especially problematic when it appears in other Roundup Ready crops such as cotton and corn. Feral alfalfa growing along roadsides and non-crop areas may cross with Roundup Ready alfalfa. This is a concern, as many government agencies rely on glyphosate for control. Public acceptance of genetically altered crops is an issue with alfalfa as it is with any transgenic crop. Adoption of Roundup Ready alfalfa by California producers will depend largely on the amount of the technology fee and the performance (both yield and quality) of Roundup Ready alfalfa varieties compared with conventional alfalfa varieties.

### **CONCLUSION**

These results clearly demonstrate that there is a fit for Roundup Ready alfalfa in California alfalfa production systems. The commercial availability of Roundup Ready alfalfa awaits regulatory approval and may depend on agreements with alfalfa importing countries such as Japan. The introduction of Roundup Ready alfalfa varieties into California would be a significant advancement and would likely become a landmark in alfalfa weed control practices.

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