

FUTURE OF ROUNDUP READY ALFALFA

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Introduction

The advent of glyphosate resistant crops has changed weed management practices in several cropping systems. Alfalfa, the “queen of forages” may also soon offer this attribute to producers. The development of glyphosate resistant alfalfa is well underway. Forage Genetics International and Monsanto anticipate marketing Roundup Ready alfalfa varieties in 2004. This is the first transgenic **perennial** agronomic crop with the gene for glyphosate resistance, and the dynamics of this trait in alfalfa are somewhat different than for annual crops like soybeans or corn.

For glyphosate resistant soybeans and corn, producers can more easily use reduced and no-tillage systems. Perennial weeds are readily controlled with a single application and the effects are usually evident for several years. The risks of crop injury and herbicide carryover are essentially eliminated with this technology. Thus the adoption of glyphosate resistant crops, particularly soybeans, has been unprecedented.

For annual crops, the time span of using glyphosate is one growing season; for perennial crops, single or multiple applications can be made for several years. Another significant difference between forage and grain production systems is that weed control in alfalfa seldom results in higher forage yields because weeds are harvested with the alfalfa. In fact, biomass yields may be lower in the seeding year when weeds are controlled than when they are not (Hall et al., 1995). The benefits of reducing weeds in forages are related to the impact of the weeds on forage quality, drying time, palatability, etc. This is true for conventional as well as transgenic alfalfa varieties.

While the current alternatives for weed management in the seeding phase of an alfalfa rotation usually provide adequate control, the use of glyphosate resistant alfalfa will provide advantages. Currently sethoxydim and clethodim are the only alternatives with no risk of injuring newly seeded alfalfa. The fact that glyphosate is safe to transgenic alfalfa varieties at all growth stages and under most environmental conditions and kills essentially all treated grass and broadleaf weeds means that the challenges of determining the best product or tank mixture for the weeds present and trying to find the best “window” of application for both crop safety and effective weed control are greatly simplified.

Once alfalfa is established, producers will be able to control annual and perennial weeds in alfalfa with glyphosate at nearly any point in the growing season. This will certainly be a new

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alternative because most current herbicide options to suppress perennial weeds in established alfalfa must be applied to nearly dormant alfalfa in the early spring, can not be applied the year after establishment, and are relatively expensive.

With the likelihood of Roundup Ready varieties reaching the market soon, several questions need to be addressed. These include the tolerance of alfalfa to glyphosate, the rate and frequency of glyphosate application, and the yield and quality of the harvested forage.

Methods

An experimental alfalfa variety with the CP4 gene for glyphosate resistance (the same one that is in Roundup Ready soybeans) was provided by Forage Genetics and evaluated in a field trial for herbicide tolerance and weed control. This variety and a conventional one ('LegenDairy') were planted at 18 lb/a on Apr. 19, 2000 in a conventionally prepared seedbed at the University of Wisconsin Agricultural Research Station near Arlington, WI. Plots were 3 by 16 ft and all herbicides were applied in 15 gal/a of water with their appropriate adjuvant. All glyphosate applications included AMS at 2.5 lb/a. Two rates of glyphosate were applied one, two or three times to direct seeded and companion seeded glyphosate resistant alfalfa. Both varieties also treated with standard postemergence herbicides (sethoxydim, clethodim or imazethapyr). Visual ratings of weed control or pressure and alfalfa vigor and forage harvests were taken regularly to measure herbicide performance and glyphosate tolerance. First cutting harvest data is presented as this one has the most biomass and usually the highest proportion of weeds. The trial was terminated after the first cutting in 2002.

Results

Weed control in the seeding year was as expected for glyphosate and the standard herbicides (Table 1). Glyphosate and Pursuit gave perfect control of both annual broadleaf and grass weeds. Quackgrass was present in the fall of 2000 in the companion seeded treatments that received glyphosate and in all treatments of the conventional variety. No quackgrass was observed in the direct seeded glyphosate resistant variety in 2000 nor at any time in this system when glyphosate was applied in the fall of each year.

In 2001, quackgrass was essentially absent from the glyphosate treated plots. Treatments without glyphosate had quackgrass pressure equal to or greater than that of the check. In spring of 2002, quackgrass pressure averaged 13% in the glyphosate resistant variety that received only conventional treatments following seeding; in the conventional variety, quackgrass pressure averaged 17%.

Common dandelion appeared in the summer of 2001 and was present in all systems in the fall of that year (Table 1). Glyphosate applied in October 2001 reduced common dandelion pressure from an average of 8% in the fall to 0% in the glyphosate-treated plots in May 2002. Thus fall-applied glyphosate seems to offer excellent potential to maintain alfalfa free of common winter annual and perennial weeds and in-season applications would do the same with summer annual

species.

Oats in the temporary cover crop were treated with either glyphosate or clethodim (Select) on June 3, 2000. Oat heights taken on June 15 found the oats were 7 inches shorter when killed with glyphosate than with clethodim, indicating a faster kill of the oats with glyphosate than with the ACCase inhibitor (data not presented). This would be advantageous to the alfalfa as interference from the companion crop will be removed more quickly.

Yields for the first harvest are presented in Table 2. Yields were compared to the highest yielding treatment within each year and expressed as a percentage of that yield. The yield of direct seeded glyphosate resistant alfalfa treated three times with glyphosate averaged 89, 98 and 94% of the maximum yield in 2000, 2001 and 2002, respectively. The highest yielding treatment each year was always among the treatments of glyphosate applied to the Roundup Ready variety. In 2001, first cutting yields of all treatments were similar, but in 2002, yields of the glyphosate resistant variety treated with glyphosate averaged 94% of the maximum versus 75% for all other systems with the same variety. The conventional variety that only received herbicides in the seeding year averaged 71% of the maximum first cutting yield in 2002. The total yield for the three first cuttings shows that the glyphosate treatments in the direct seeded system averaged 9% more than the Pursuit treatment in this system and 27% more than the yield of the glyphosate resistant variety planted with oats. The glyphosate resistant variety is an experimental one that will not be commercialized. Nevertheless, it appears that the CP4 gene is in very good alfalfa germplasm.

Alfalfa vigor was excellent for all treatments and both varieties in 2001 but in 2002, the glyphosate resistant variety was more vigorous than the conventional variety with an average vigor rating over all treatments of 72 vs. 53%, respectively (Table 3). The maximum quantity of glyphosate applied in a single treatment was 3.375 lb ae/a (1.125 lb in each of three applications) which equates to more than one gallon of glyphosate products with 3 lb of acid equivalent per gallon. No injury was observed from this nor any other glyphosate treatment and alfalfa density after seeding and herbicide application was similar for all treatments (data not presented). Alfalfa heights after seeding were comparable for all treatments and alfalfa populations on June 22 were similar in all treatments (data not presented).

Discussion

Additional questions must be answered to have a clear picture of how Roundup Ready alfalfa will fit into current production systems. These include:

- Will glyphosate resistant varieties increase alfalfa stand life?
- How often and when might glyphosate be used in alfalfa? Will low rates applied annually be the best option or will normal rates be applied less frequently?
- Will more than one application a year ever be needed?
- Will a single fall application provide long-term perennial weed control in alfalfa?

My prediction is that glyphosate use will be as follows:

- Glyphosate will be applied after seeding alfalfa when weeds 3 to 4 inches tall.
- We should not see weeds of consequence the rest of seeding year nor in following year.
- From then on producers will use a “treat as needed” strategy.

- This may well result in glyphosate being applied in third year and every fall thereafter until stand thins and the field rotates to another crop.

The advent of Roundup Ready alfalfa could also result in an increase in no-till alfalfa seeding. These varieties may also increase the use of companion seeding as temporary cover crop. They will improve our ability to kill volunteer wheat in fields seeded with alfalfa following wheat harvest but they have little if any adoption in situations where producers want a forage/grass mixture.

Will the stand longevity increase with adoption of glyphosate resistant alfalfa varieties? We can now test the hypothesis that weed-free forage fields can be maintained for longer periods than if weeds are present. It remains to be seen whether this is true or whether other factors such as diseases or environmental stresses will override the fact that fields are weed free. Roundup Ready alfalfa will generate questions of how to kill these varieties but that will not be a problem.

This technology should not impact the development of herbicide resistant biotypes of summer annual weeds common to grain crop systems because the repeated harvests in hay field should prevent any escaping weed from producing seed. However, we can “never say never” to Mother nature. Some weeds do produce seed in established alfalfa. Weeds that merit watching for potential shift to resistant biotypes in alfalfa fields are those that produce seed, even in well managed fields. These include common dandelion, shepherd’s purse, downy brome grass, crabgrasses, broadleaf plantain and chickweeds. We consider the risk of weeding developing resistance to glyphosate as low. With good stewardship, careful crop monitoring, and integrated management practices, resistance can at least be greatly delayed and hopefully prevented.

Summary

Glyphosate resistant alfalfa has excellent glyphosate tolerance and will allow complete and flexible weed management applications for nearly all weeds that appear after alfalfa establishment in any phase of the stand life. This technology may foster the adoption of no-till seeding methods to establish alfalfa and may enhance the use of temporary cover crops. Questions to be answered are whether this technology will increase the stand life alfalfa in the rotation; how often and when might glyphosate be used; the optimum rate to apply; and how the yield, feed value, pest resistance, and winter hardiness of varieties with the glyphosate resistance gene compare to commercial varieties.

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Table 1. Annual control in the seeding year and quackgrass and dandelion pressure in the glyphosate resistant alfalfa variety trial in 2000, 2001 and 2002.

Treatment ¹	Application		Alfalfa Variety/System ²	Weed ctr (%)		Weed pressure (%)				
	Rate	Date		Bdlf Grass		quackgrass			dandelion	
	(lb ai/a)		7/19/2000		10/00	6/01	5/02	10/01	5/02	
Direct seeded glyphosate resistant alfalfa										
1. Glyphosate three times	0.75	6/15/00	RR/DS	100	100	0	1	0	9	0
	0.75	10/4/00								
	0.75	10/3/01								
2. Glyphosate three times	1.125	6/15/00	RR/DS	100	100	0	0	0	12	0
	1.125	10/4/00								
	1.125	10/3/01								
3. Pursuit	.047	6/3/00	RR/DS	100	100	6	23	19	8	5
4. Check	--	--	RR/DS	0	0	3	16	12	5	6
Companion seeded glyphosate resistant alfalfa										
5. Check (oatlage)	--	--	RR/CS	83	30	3	13	0	8	0
Glyphosate once	0.75	10/3/01								
6. Glyphosate three times	0.75	6/3/00	RR/CS	99	82	4	4	0	6	0
	0.75	10/4/00								
	1.125	10/3/01								
7. Glyphosate twice	0.75	6/3/00	RR/CS	100	86	4	20	0	5	0
	0.75	10/3/01								
8. Select	.125	6/3/00	RR/CS	0	100	3	19	8	10	10
Direct seeded conventional alfalfa										
9. Pursuit	.047	6/3/00	CNV/DS	97	100	3	21	18	9	7
10. Poast Plus	.140	6/15/00	CNV/DS	0	100	6	22	20	13	7
11. Pursuit + Poast Plus	.047 .140	6/15/00 6/15/00	CNV/DS	100	100	6	24	14	12	4
LSD (10%) =	--	--	--	9	14	2	11	10	4	3

¹ AMS applied at 2.5 lb/a with all glyphosate treatments; crop oil concentrate (1%) and UAN (2 pt/a) applied with all Pursuit treatments; crop oil concentrate (1%) applied with all Poast Plus and Select treatments.

² RR = Roundup Ready; DS = direct seeded; CS = companion seeded; CNV = conventional variety.

³ These data are for annual weeds; common species were common lambsquarters, pigweeds, giant foxtail, ladythumb smartweed, barnyardgrass, large crabgrass.

Table 2. Forage composition and first cutting alfalfa yields in the glyphosate resistant alfalfa variety trial in 2000, 2001 and 2002.

Treatment ¹	Application		Alfalfa Variety/System ²	1 st cut compos.			1 st cut alfalfa yields			
	Rate (lb ai/a)	Date		---% alfalfa---			-----ton dm alf/acre-----			
				00	01	02	00	01	02	total
Direct seeded glyphosate resistant alfalfa										
1. Glyphosate three times	0.75	6/15/00	RR/DS	96	100	100	3160	4105	2310	9575
	0.75	10/4/00								
	0.75	10/3/01								
2. Glyphosate three times	1.125	6/15/00	RR/DS	100	100	100	4035	4330	2025	10390
	1.125	10/4/00								
	1.125	10/3/01								
3. Pursuit	.047	6/3/00	RR/DS	90	88	75	3535	3615	1935	9085
4. Check	--	--	RR/DS	32	93	82	1800	3760	1785	7345
Companion seeded glyphosate resistant alfalfa										
5. Check (oatlage)	--	--	RR/CS	33	93	100	960	3405	1240	5605
Glyphosate once	0.75	10/3/01								
6. Glyphosate three times	0.75	6/3/00	RR/CS	91	99	100	2730	3930	1800	8460
	0.75	10/4/00								
	1.125	10/3/01								
7. Glyphosate twice	0.75	6/3/00	RR/CS	na ³	92	100	na	3740	1740	na
	0.75	10/3/01								
8. Select	.125	6/3/00	RR/CS	53	94	82	1970	3925	1915	7810
Direct seeded conventional alfalfa										
9. Pursuit	.047	6/3/00	CNV/DS	80	91	75	2910	3975	1635	8520
10. Poast Plus	.140	6/15/00	CNV/DS	na	91	74	na	3700	1590	na
11. Pursuit + Poast Plus	.047 .140	6/15/00 6/15/00	CNV/DS	na	88	81	na	3635	1650	na
LSD (10%) =	--	--	--	10	5	11	--	--	640	--

¹ AMS applied at 2.5 lb/a with all glyphosate treatments; crop oil concentrate (1%) and UAN (2 pt/a) applied with all Pursuit treatments; crop oil concentrate (1%) applied with all Poast Plus and Select treatments.

² RR = Roundup Ready; DS = direct seeded; CS = companion seeded; CNV = conventional variety.

³ NA means yields were not taken of this treatment in 2000.

Table 3. Alfalfa vigor in the glyphosate resistant alfalfa variety trial in 2000, 2001 and 2002.

Treatment ¹	Application		Alfalfa Variety/System ²	Alfalfa vigor ratings	
	Rate (lb ai/a)	Date		Apr. 01	May 02
-----%-----					
Direct seeded glyphosate resistant alfalfa					
1. Glyphosate three times	0.75	6/15/00	RR/DS	100	70
	0.75	10/4/00			
	0.75	10/3/01			
2. Glyphosate three times	1.125	6/15/00	RR/DS	100	80
	1.125	10/4/00			
	1.125	10/3/01			
3. Pursuit	.047	6/3/00	RR/DS	100	68
4. Check	--	--	RR/DS	91	70
Companion seeded glyphosate resistant alfalfa					
5. Check (oatlage)	--	--	RR/CS	88	63
Glyphosate once	0.75	10/3/01			
6. Glyphosate three times	0.75	6/3/00	RR/CS	98	73
	0.75	10/4/00			
	1.125	10/3/01			
7. Glyphosate twice	0.75	6/3/00	RR/CS	100	77
	0.75	10/3/01			
8. Select	.125	6/3/00	RR/CS	98	67
Direct seeded conventional alfalfa					
9. Pursuit	.047	6/3/00	CNV/DS	97	50
10. Poast Plus	.140	6/15/00	CNV/DS	91	52
11. Pursuit + Poast Plus	.047 .140	6/15/00 6/15/00	CNV/DS	94	58
LSD (10%) =	--	--	--	6	17

¹ AMS applied at 2.5 lb/a with all glyphosate treatments; crop oil concentrate (1%) and UAN (2 pt/a) applied with all Pursuit treatments; crop oil concentrate (1%) applied with all Poast Plus and Select treatments.

² RR = Roundup Ready; DS = direct seeded; CS = companion seeded; CNV = conventional variety.

³ Vigor ratings from 0 to 10; 0 = dead alfalfa; 10 = healthy, vigorous alfalfa

⁴ Weed yields based on visual estimates of percentage composition before harvest.