Alternatives to the use of Roundup Herbicide

Hector Valenzuela
Professor and Vegetable Crops Extension Specialist
Department of Plant and Environmental Protection Sciences
College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa
hector@hawaii.edu

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1.0. Introduction

Roundup (active ingredient: Glyphosate) is among the most widely used herbicides in the world. The use of Roundup expanded over the past 15 years with the adoption of so-called Roundup-ready genetically modified (GM) crops. During the 2000s, in the U.S. the use of Roundup more than doubled, from 85-90 million pounds in 2001, to over 180 million pounds in 2007. Roundup is the most commonly used pesticide, and it is also widely used in homes, gardens, and urban settings. According to Monsanto, which produces Roundup, there are more approved uses for glyphosate (the active ingredient of Roundup), than for any other herbicide. Roundup, according to Monsanto, is used in 130 countries and on over 100 different crops.

Herbicide tolerance represents the main trait used on genetically modified crops. In 2006, the herbicide tolerance trait represented 81% of the total acreage planted globally to genetically modified crops, representing over 200 million acres (Bonny, 2008). Today, Roundup-ready varieties represent 90% of the soybeans and 80% of the corn acreage in the U.S (Killman, 2010). Roundup Ready soybean is the most widely planted genetically modified crop, accounting for 60% of the entire global acreage planted to genetically modified crops (Bonny, 2008).

Recent reports have documented potential negative environmental, socioeconomic, and human health impacts from exposure to Roundup (Antoniou et al., 2011; Riley et al., 2011). Public concerns about the potential societal risks from exposure to Roundup has lead to calls for the adoption of alternative management production practices (Antoniou et al., 2011; Riley et al., 2011). Some of the proposed alternative production practices, are outlined below.

2.0. Development of weed resistance to Roundup herbicide

Conventional and GM or biotech crop farmers also need alternatives to the use of Roundup, because important weed species throughout the world are increasingly showing resistance to the use of this herbicide (Avila-Garcia and Mallory-Smith, 2011; Beckie et al., 2011; de Carvalho et al., 2011; Horstmeier, 2001; Light et al., 2011; Norsworthy et al., 2010; Owens and Powles, 2010; Rauch et al., 2010; Riar et al., 2011; Sosnoskie et al., 2011; Travlos and Chachalis, 2010). As a result of weed resistance to Roundup, farmers have to use higher rates, and conduct more frequent applications (Schutte et al., 2010). Weed resistance to Roundup may develop in as short as 3-5 years when Roundup Ready crops are grown continuously without rotations (Barbassa, 2005; Horstmeier, 2001; Van Gessel, 2001). Not only does weed resistance to Roundup reduces the efficiency of production, and increases production costs, but farmland with populations of resistant weeds may result in greater leasing or rental rates to farmers (Anon., 2004).

3.0. Alternatives to the use of Roundup are available.

Alternative cultural management practices are available to control weeds without the use of Roundup (Blackshaw et al., 2007). Monsanto itself recognizes that alternative management practices exist, to the use of Roundup. In the home-page of its weed management web site Monsanto acknowledges that other than Roundup, “thankfully, there are ways farmers can successfully manage tough-to-control or resistant weeds” (Monsanto, 2011). In Argentina, according to Monsanto “several agronomic practices” exist as alternatives to Roundup (Bennett, 2006). In the U.S. according to Dale Ludwig, CEO of the Missouri Soybean Association, farmers have at their disposal "various strategies" as alternatives to the use of Roundup (Anon. 2005). Similarly, in July 2011 Weed Specialists from Iowa State University listed several alternative herbicides, and alternative management practices, that may be implemented by farmers in instances when Roundup is no longer providing effective weed control (Hartzler and Owen, 2011).

4.0. Alternative Herbicides to the use of Roundup

When weeds develop resistance to Roundup, Weed Specialists recommend alternative herbicide products to achieve effective weed control (Horstmeier, 2001; Barbassa, 2005). In fact, tank-mixes that include several herbicides, have become the norm for the past six (6) years in many crop production areas, as an alternative to the sole-reliance on Roundup (Scott, 2005; Wagoneer et al., 2011).

For instance, when Horseweed first showed resistance to Roundup in 2001, Specialists suggested alternatives such as crop rotations, alternative herbicides, and tillage (Horstmeier, 2001). Since then, several herbicides have been suggested as alternatives for Horseweed control (Davis et al. 2010; Kruger, 2010; Owen et al., 2011; Scott, 2005; Wagoneer et al., 2011). David Heering, the Roundup technical manager for Monsanto, also recommends the use of alternative herbicides for effective weed control (Barbassa, 2005). In comparisons of GM-cotton and non-GM/conventional systems the cost of the Roundup based herbicide program ran to about $83 per acre, while the cost for the conventional (non-Roundup) herbicide program ranged between $62 to $91 per acre (Hollis, 2009).

A range of alternative herbicides is available for weed control in cotton (Hollis, 2009), soybeans (Steward et al., 2010a), corn (Loux et al., 2011; Moran et al., 2011), alfalfa (Dillehay and Curran, 2010), GM beets (Wilson et al., 2011), and in roadsides (Gannon and Yelverton, 2011). Alternatives to the use of Roundup suggested by University of California Weed Specialists included soil cultivation with farm equipment, hand weeding, and the use of alternative herbicides that kill weed seeds prior to germination (Barbassa, 2005).

Again, Monsanto also recommends the use of alternative herbicides. For instance, Monsanto recommends the use of residual herbicides that provide “early season control.” The Monsanto weed management website explains that the use of residual herbicides “has shown increased yields because of reduced weed pressure” (Monsanto, 2011).

In summary, as described above, research has shown that alternative herbicides exist to manage some of the most troublesome weeds, that have already developed resistance to Roundup (Whitaker et al., 2010).

5.0. Field or Cultural Management Practices as alternatives to the use of Roundup

Research has shown that by following an Integrated Pest or Weed Management program, ‘cultural’ practices can be adopted to effectively manage weeds on the farm (Blackshaw et al., 2007).

Field or cultural management practices recommended by Monsanto itself to manage weeds as

alternatives to the use Roundup includes crop rotations of "2 or more crops" and rotating to "a different crop each year" (Monsanto, 2011). Other strategies recommended by Monsanto include shifting "planting dates and fertility programs which help reduce certain difficult-to-control weeds from becoming established." Monsanto also recommends adapting the tillage operation as well as using other herbicides with "additional modes of action which help prevent some weeds from becoming dominant in the system."

The timing of weed control operations is important to minimize weed pressure late in the season. Monsanto thus recommends to "Control weeds in corn before they reach 4 inches tall and in soybeans before they reach 8 inches tall."

Monsanto also highlights soil cultivation as an important alternative weed management strategy. The Monsanto website indicates that "Tillage serves as another way to control weeds and break certain weed patterns" and explains that "Tillage reduces complete reliance on herbicides. " Furthermore, according to Monsanto "Periodic tillage can substitute for glyphosate-based burndown programs" (Monsanto, 2011).

Below are examples of a range of alternative management practices cited in the weed science literature, to achieve effective weed control.

Prevention. A foremost goal of an integrated weed management program is to prevent aggressive weed species from becoming a problem in the first place. A number of strategies may be followed to prevent the introduction of weeds from outside the farm such as from machinery, farm workers, soil movement, work animals, manures and organic amendments, or the irrigation water (Christoffoleti et al., 2007). Once weeds have been introduced into the farm, preventive practices can also be taken to prevent weeds from going to seed, to reduce the population of seed-banks in the soil, and to destroy the vegetative propagules of perennial weeds (Christoffoleti et al., 2007).

Biofumigant cover crops for weed control, as described by Bangarwa et al. (2011b). In some instances biofumigant amendments may not be sufficient as a stand-alone strategy for weed suppression, but may be used as a component of an Integrated Weed Control program (Bangarwa et al., 2011c).

Biofumigant organic amendments, such as seed meal from mustard/Brassica and Sinapis cover crops, for selective weed control (Earlwine et al., 2010; Handiseni et al., 2011).

Biological control with arthropods and beneficial microbial organisms in crop fields, or in landscapes/turf or sods (Blossey, 2007; Boyette and Hoagland, 2010; Shabana et al., 2010; Weaver et al., 2007).

Cover Crops can be used as part of the rotation program to manage weed pressure, and

increase cash crop competitiveness (Brainard et al., 2011; Mischler et al., 2010; Norsworthy et al., 2011; O'Reilly et al., 2011; Teasdale et al., 2007). Cover crops may help to increase the activity of weed seed predators (Ward et al., 2011). Mechanization, such as the use of roller-crimpers to terminate cover crops, and to create a thick mulch for use in no-till organic systems, facilitates the use of cover crops for weed suppression (Davis, 2010; Smith et al., 2011).

Cultivar or variety selection, based on growth habit, to increase competitiveness against weeds (Hutchinson et al., 2011; Spies et al., 2011; Toure et al., 2011), and for the selection of varieties that are better adapted in organic production systems (Mason et al., 2007).

Cultivation of fields, including precision guided mechanical cultivation systems (Fennimore et al., 2010). Cultivation plus hand-weeding in some instances may be as effective for weed suppression as the use of standard herbicide applications (Place et al., 2010).

Flaming with propane burners, as used in organic systems (Ulloa et al., 2010ab).

Increasing crop diversity, via crop rotations, or polycultures, to suppress specific weeds and increase competitiveness of the cash crop (Anderson, 2011).

Integrated Pest Management. The orchestrated and synergistic use of several control methods, such as those described here, rather than relying on a single component pesticide-based system (Chikowo et al., 2009; Place et al., 2010; Young et al., 2010).

Intercropping, polyculture, or diversified cropping systems to manage weed populations (Fernandez-Aparicio et al., 2010; Picasso et al., 2008; Saucke and Ackerman, 2006). Polycultures may include species with enhanced competitive abilities such as aromatic herbs (Dhima et al., 2010).

Livestock-crop systems. The adoption of integrated crop-livestock systems may help to reduce the reliance on herbicide-based systems for weed control (Tracy and Davis, 2009).

Living mulches, provide a protective living-barrier to suppress weed growth in high-value horticultural systems (Gibson et al., 2011).

Mulches, either plastic (Daugovish and Mochizuki, 2010) or biodegradable (Anzalone et al., 2010) provide a barrier to suppress weed growth.

Organic Weed Control strategies are increasingly being documented in the literature, as in the case of bean and sweet corn (Johnson et al., 2010).

Organic Amendments, may be used to manage weed populations, and to increase the competitiveness of the cash crop (Amisi and Doohan, 2010). **Organic residues** of allelopathic

plants may also suppress weeds (Marles et al., 2010).

Organic herbicides such as vinegar and citric acid, used as part of an Integrated Weed Management program (Evans et al., 2011).

Organic mulches modify the microclimate, provide shade, and a physical barrier to weed growth (Mischler et al., 2010; Smith et al., 2011).

Plant spacing and row arrangement. Increasing planting density or using narrow-rows may help to reduce weed competition (Amstrong and Sprague, 2010; Reddy and Boykin, 2010; Ryan et al., 2011; Stephenson and Brecke, 2010). The planting row-orientation may also be modified to improve weed suppression (Borger et al., 2010).

Polycultures. See under 'Intercropping'.

Rotations. Enhancing crop diversity in the farm with rotations, is one of the most effective ways to break the life cycle of important weed species (Amuri et al., 2010; Horstmeier, 2001; Simard et al., 2011). Also see reference under 'Increasing crop diversity.'

Timing of weeding operations, based on crop-growth stages, as observed with rice in Africa (Toure et al., 2011), with rice in Thailand (Sanusan et al., 2010) or with the timing of flaming treatments (Ulloa et al., 2010). Optimal weed control is obtained when weeding within the critical-weed free period that is specific for each crop species (Dillehay et al., 2011; Swanton et al., 2010).

Variety Selection, see under 'Cultivar Selection.'

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