Environmental Assessment of Roundup Ready Sugar beet: A Case Study of Four Idaho Sugar Beet Fields, 2006

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Introduction and Background

The Beet Sugar Development Foundation (BSDF) which represents the beet sugar processing companies and the sugar beet seed companies doing business in North America, requested a study to assess the environmental impact of Roundup Ready (RR) sugar beet to conventional sugar beet, in Idaho. This report is a case study of four center pivot fields, in the Magic Valley of Idaho, each planted one-half with Roundup Ready sugar beet and the other half with conventional sugar beet. The BSDF provided funding and identified the scope of the report.

A review of the literature finds many differing opinions as to the benefits and risks of planting transgenic-derived crops. There are concerns that herbicide resistant (transgenic) sugar beets may cause harm to human health and/or the environment. however, studies show that sugar from transgenic sugar beets is indistinguishable from that produced from conventional beets (Klein et al., 1998). Studies conducted in the U.S. and Europe report several environmental improvements from growing RR sugar beet over conventional sugar beet. With the introduction of transgenic crops there has been a measurable reduction in pesticide use (Carpenter et al, 2002; Gianessi et al, 2005). Two studies demonstrated that by using RR sugar beet, there was a decrease in aphid infestations, due to the later applications of glyphosate vs. the early herbicide applications that are necessary for conventional sugar beet. In the RR fields, weeds are left longer before the herbicide applications and the weeds provide food for phytophagous insects (Dewar et al., 2000). Transgenic crops have been attributed with a reduction in cultivation, resulting in less soil erosion, less fossil fuel consumption, and improved soil and water quality. According to the Conservation Technology Information Center (CTIC) there is a correlation of the introduction of transgenic crops and reduced tillage. The affects of tillage, fuel consumption and subsequent reduction in fuel emissions have been shown to impact the environmental assessment between conventional and transgenic crops (Bennett et al. 2004).

However, there are just as many reports opposing transgenic crops declaring negative impacts to the soil fauna and the ecosystem. There is also concern among weed scientists, agronomists, and growers that glyphosate resistant weeds will develop from overuse of glyphosate. In addition to resistance occurring in weeds, some are concerned about weed species shifts and weedy traits developing in the crops.

Weeds are considered by many growers to be their primary pest problem in sugar beets. One of the reasons for this is because of the lack of effective herbicides to control the broad weed spectrum in sugar beet producing areas. Broadleaf weeds such as kochia, common lambsquarters, hairy nightshade, and redroot pigweed are commonly found in many Idaho sugar beet fields. Grass weed problem species in sugar beets include wild oat, green foxtail, barnyardgrass, and wild proso millet. Several other annual and perennial broadleaf and grass weed species can be found in many fields.

Historically, sugar beet growers have had to rely on hand labor for sugar beet production. Prior to the development of monogerm sugar beet seed, hand labor was plentiful for weed control because migrant labor crews were assured of long-term employment. After monogerm seed was developed and as sugar beet emergence has improved over the years, the need for growers to plant dense populations of sugar beets has diminished, thus eliminating the need to hire thinning crews. Consequently, nearly all growers "plant to stand" or plant sugar beets at a seeding rate that will provide them with an adequate crop stand that does not need to be thinned. This change in production practice along with tighter controls of immigrant labor has reduced the availability of hand labor crews.

Of the postemergence herbicides currently registered for use in sugar beets, application timing is probably the most critical aspect of obtaining satisfactory weed control. Environmental conditions often interfere with timely herbicide applications resulting in poor weed control. Additionally, with the development of Roundup Ready corn, cotton, and soybeans, many basic chemical manufacturers have either stopped or cut back on their herbicide discovery programs resulting in no new sugar beet herbicides for about the past 10 years. With the currently available sugar beet herbicides and unavailability of hand labor crews, growers continue to rely heavily on mechanical control as part of their overall weed management program in sugar beets.

The development of glyphosate resistant sugar beets, or Roundup Ready sugar beets, offer beet growers an opportunity to effectively control weeds in this crop with potentially fewer inputs. Sugar beets are an excellent crop to introduce the glyphosate resistant gene into for several reasons. Glyphosate offers an excellent effective alternative to some of the standard sugar beet herbicides. It can be tank mixed with nearly all of the currently registered products to broaden the weed control spectrum, reduce herbicide resistance selection pressure, and reduce the potential for weed species shifts. More importantly, since sugar beets cannot be grown continuously, like corn and soybean, the selection pressure for glyphosate resistant weeds is reduced. However, with the introduction of Roundup Ready corn and alfalfa in the sugar beet production areas of Idaho and eastern Oregon, growers will need to be very aware of how much and how often they use glyphosate for weed control in these Roundup Ready crops.

Currently, seven weed species have been identified in 15 states across the United States to be resistant to glyphosate. Those weeds include Palmer amaranth (*Amaranthus palmeri*), common waterhemp (*Amaranthus rudis*), common ragweed (*Ambrosia artemisiifolia*), giant ragweed (*Ambrosia trifida*), horseweed (*Conyza canadensis*), Italian ryegrass (*Lolium multiforum*), and rigid ryegrass (*Lolium rigidum*). No glyphosate resistant weeds have been identified in Idaho, but glyphosate resistant Italian ryegrass has been identified in Oregon.

The BSDF wanted to address some of the concerns raised about the environmental safety of biotechnology-derived crops. A report published by the Council of Agricultural Science and Technology (CAST) in 2002 identified nine potential environmental impacts from the adoption of biotechnology-derived soybean, corn and cotton crops. This case study will evaluate some of these potential impacts based upon observations and agronomic practices utilized by the four sugar beet growers in Idaho. The following list from the CAST report was utilized as a checklist of potential impacts to evaluate for the Idaho case study. Not all nine impacts are covered in this report.

1. Changes in pesticide use patterns. Does the use of pesticides change and do these changes alter practices that affect water quality or soil health?

2. Soil management and conservation tillage. Does the use of biotechnology crops lead to the increase of conservation tillage and no-till? Will this cause a positive environmental impact on soil erosion, moisture retention, soil nutrient content, water quality, fossil fuel use and emissions?

3. Crop weediness. Will the biotechnology-derived crops develop weediness traits?

4. Gene flow and outcrossing. Do biotechnology crops hybridize with local plants or crops and impact the genetic diversity in the area?

5. Pest resistance. Will the pests become resistant to the herbicide used? How is the development of resistance being managed?

6. Pest population shifts. Do the biotechnology-derived crops cause changes in weed or secondary insect pest populations that impact the agricultural system?

7. Non-target and beneficial organisms. Do the biotechnology-derived crops have an impact on natural enemies of pests or on other organisms in the soil and crop?

8. Land use efficiency/productivity. Does the adoption of biotechnology derived crops impact the need for cultivating forested or marginal land?

9. Human exposure. Do the traits of herbicide tolerance pose any new or different safety concerns?

This case evaluates pesticide usage based upon several factors relating to pesticide toxicity and the ability of the pesticides to leach or runoff into water. Tillage practices and fuel consumption are also compared. Economic impacts and crop yields were not considered for these four fields.

The literature contains examples measuring the environmental impacts of various cropping systems based upon pesticide toxicity and quantity of pesticide used. In

August, 2006 Cerdeira and Duke published a paper that reviews the current status and environmental impact of glyphosate-resistant crops. This paper contains a very thorough discussion and provides a comprehensive literature review. A literature review is included, at the end of this report, covering the relevant topics and issues discussed.

Methods

Field Description

Four Idaho center pivot fields, in the Magic Valley of Idaho, were planted to sugar beet in the spring of 2006; one-half RR sugar beet and one-half conventional sugar beet. Fields were planted between April 25 and May 2, 2006. Each half of the center pivot was planted within one day of the other half, except for Field I, where the RR half was planted six days before the conventional half. The RR hybrid was Beta 3H411 RR, the conventional hybrid was Beta 00046, neither variety has resistance to curly top virus. Each center pivot field was selected for low curly top pressure to try to eliminate any differences that might occur with the presence of curly top virus.

Table 1. Field location, acreage, and soil type

Field	Idaho County	Soil Type	Acres—RR	Acres--Conventional
I (Carlquist)	Jerome	Portneuf silt loam	56	51
II (Gott)	Jerome	Sluka silt loam	61	63
III (D. Grant)	Minidoka	Sluka silt loam	67	36
IV (Grant/Hagen)	Jerome	Portneuf silt loam	65	65

Tillage practices

Field I:

Each half of Field I was plowed and disked once in the fall. One extra trip was made in the conventional half to pick rock. In the spring the conventional side received two cultivations while the RR side received just one. But the RR side had one field operation to crust bust. Each side of the field had one aeration treatment.

Field II:

Each half of Field II was plowed once, disked twice, and rollerharrowed in the spring before planting. Both the conventional and RR sides had three cultivations during the growing season.

Field III:

Each half of Field III was plowed in the fall and rollerharrowed once in the spring. The conventional half was cultivated three times and the RR half was only once. The conventional side also used a pickett weeder one time, and a dammer diker. The dammer diker was used for water conservation and to retain water in the field

Field IV:

Each half of Field IV was plowed and disked once in the fall. In the spring each half was rollerharrowed one time, followed later by a crust bust, later on. The conventional side of the field had two cultivations, and the RR side had only one. Each half of the field had dammer dike.

Fertilizer and Pesticide applications

Fertilizer applications:

Field I: There was no fall fertilizer applied. In the spring both conventional and RR plantings had 60 pounds of nitrogen applied before harrowing. The RR portion had an additional 40 pounds of nitrogen applied July 3, by air.

Field II: There was no fall fertilizer applied. In the spring both conventional and RR plantings had 120 pounds of nitrogen applied.

Field III: Fall fertilizer was applied the same for both conventional and RR plantings; 22 pounds of nitrogen, 102 pounds of phosphorus and 153 pounds of sulfur. Both sides had 120 pounds of nitrogen applied in the spring, and the RR portion of the field had an addition 40 pounds of nitrogen applied July 5.

Field IV: There was no fall fertilizer applied. In the spring, before bedding, 130 pounds of nitrogen and 20 pounds of sulfur was applied to both conventional and RR portions of the field, along with an "at bedding" application of 15 gallons of 10-34 and 1 gallon of humic acid. On July 14-15, 30 pounds of nitrogen was applied with water through the center pivot, covering both the convention and RR ready portions of the field.

Each field applied an insecticide for the control of sugar beet root maggot, either aldicarb (Temik) or carbofuran (Furadan) was used. Both sides of each field used seed treated with clothianidin insecticide (Poncho) to protect seedlings from various insects. Fields I and IV also used diazinon (Diazinon AG500) for control of leafminer and aphid, thiophanate-methyl (Topsin M70) and sulfur were tank-mixed to control powdery mildew. Fields II and IV applied esfenvalerate (Asana) for control of adult root maggot.

Roundup Ready Beet:

Each RR half of the four fields had glyphosate (Roundup) applied as follows:

Field I: Roundup applied at 32 oz/acre on June 2.

Field II: Roundup applied at 32 oz/acre on May 26 and 27 oz/acre on June 16. Outlook (dimethenamid-P) was tank mixed with Roundup and applied on one strip in the field (approximately 24 rows) on May 26 at 18 oz/acre.

Field III: Roundup applied at 32 oz/acre on May 30 and 22 oz/acre on June 26. On June 10, 40 acres received 22oz/acre to correct an application mistake made on May 30.

Field IV: Roundup applied at 22 oz/acre on May 22 and 24 and 32 oz/acre on June 13-17. Outlook (dimethenamid-P) was applied to one strip in the field (approximately 24 rows) on May 26 at 18 oz/acre.

Conventional Beet:

Conventional sugar beet traditionally have a variety of herbicides and herbicide combinations to control the weed spectrum present. Each conventional half of the four fields had the following herbicide applications banded on 22 inch row spacings:

Field I: Two 8 inch band applications: On May 17 post-emergent herbicide applications were made with Progress (desmedipham, phenmedipham, ethofumesate, procymidone) at 12 oz/acre and Upbeet (triflusulfuron-methyl) at 0.33oz/acre, and on May 24 Progress (desmedipham, phenmedipham, ethofumesate, procymidone) at 12 oz/acre and Stinger (clopyralid) at 2 oz/acre were applied.

Field II: Three 11 inch band applications: On May 3 a pre-emergent treatment of Nortron (ethofumesate) was applied at 19 oz/acre, post-emergent treatments of Progress (desmedipham, phemedipham, ethofumesate, procymidone) at 10 oz/acre and Upbeet (triflusulfuron-methyl) at 0.25 oz/acre were applied on May 20, and on May 25 Progress (desmedipham, phemedipham, ethofumesate, procymidone) at 14 oz/acre plus Upbeet (triflusulfuron-methyl) at 0.25 oz/acre and Stinger (clopyralid) at 1.75 oz/acre were applied.

Field III: Four 10 inch band applications: On May 1 a pre-emergent treatment of Nortron (ethofumesate) was applied at 20 oz/acre with Roundup (glyphosate) at 0.5 pint/acre, and post-emergent treatments of Progress at 8 oz/acre plus methylated seed oil (MSO) at 8 oz/acre and Stinger (clopyralid) at 0.25 oz/acre were applied on May 11. Additional post-emergent treatments occurred on May 20 with Progress (desmedipham, phemedipham, ethofumesate, procymidone) at 10 oz/acre plus MSO at 8 oz/acre and Stinger (clopyralid) at 0.25 oz/acre and on June 2 with Progress (desmedipham, phemedipham, ethofumesate, procymidone) at 8 oz/acre plus MSO 8oz/acre and Stinger (clopyralid) at 0.25 oz/acre.

Field IV: Three 9 inch band applications: On April 28 a pre-emergent treatment of Nortron (ethofumesate) was made at 18 oz/acre. Post-emergent treatments were applied on May 18 with Betamix (desmedipham, phenmedipham) 11oz/acre plus Upbeet (triflusulfuron-methyl) at 0.31 oz/acre and on May 26 Betamix (desmedipham, phenmedipham) was applied at 15 oz/acre with Upbeet (triflusulfuron-methyl) at 0.31 oz/acre.

Models Used to Predict Environmental Impact of Pesticides

The study compared the environmental impact of pesticide use based on the Environmental Impact Quotient developed by Kovach et al. 1992 and the Windows Pesticide Screening Tool developed and utilized by the USDA—Natural Resources Conservation Service. Both models only look at the use of pesticides and their ecotoxicity.

Windows—Pesticide Screening Tool (Win-PST):

The USDA—Natural Resources Conservation Service (USDA—NRCS) has developed the Win-PST model incorporating databases for pesticide properties and soil type. USDA—NRCS utilizes the Win-PST model to predict the impact of pesticides selected during the conservation planning process. The current farm bill provides cost-share dollars to producers for various on-farm conservation practices, including pest management and the selection of pesticides with low toxicity and those least likely to leach into groundwater or runoff to surface water. Win-PST predicts the environmental impact to surface and ground water based upon pesticide properties and soil type. The pesticides applied to the four fields and the soil types of the fields were entered into the Win-PST database, utilizing the latest version of Win-PST available through USDA—NRCS. The latest version, released in 2006 contains the newest data for pesticide properties. Assumptions made for the Win-PST runs were: a higher risk of rainfall or irrigation event close to the application; and all herbicides were broadcast, surface applied, except for Nortron (ethofumesate) which was assumed to be soil incorporated.

Environmental Impact Quotient (EIQ):
The EIQ was developed by Kovach et al. in 1992 to predict the impact of different pesticide treatments. The pesticides used in this case study were evaluated with the latest version of the EIQ, last updated in 2004.
The EIQ is derived by calculating the individual impact on farm worker, consumer and ecology; non-target organisms, fish, birds, honeybees and other beneficial insects, leaching potential, surface loss potential and soil and plant surface half-life. The individual values are calculated based upon the pesticide toxicity and the effect on each environmental factor, then added together for the total environmental impact.

Fuel Consumption and Emissions
To assess the impact of tillage practices and fuel consumption of each system, University of Idaho fuel consumption data, based on standard engineering equations, was utilized. Assumptions for emissions are made based upon fuel usage in the four fields participating in this case study.

Weed Studies
Weed emergence was monitored in each of the fields until row closure. To do this, two rows in the conventional beets and two rows in the Roundup Ready beets were selected and permanently marked with flags. Flags were set nine feet apart and the weeds were counted in a 4-inch wide band the length of each nine feet of row, to provide weed densities in 3 square feet. Once the fields had been sprayed with any of the postemergence herbicides, only live weeds were included in the weed counts. A weed was considered living only if the plant was green and the newest leaves and apical meristem appeared healthy.

Results

This report only contains information on the four fields in this case study. The main focus of the report is the comparison of pesticide applications and tillage practices between the two systems.

Typically conventional sugar beet require a suite of herbicides and herbicide mixtures to provide adequate weed control. Besides the herbicides used growers in this case study relied on cultivation and hand weeding to control weeds on the conventional sugar beet system. This study has demonstrated that the RR sugar beet required fewer herbicide applications, less additional mechanical weeding, and no hand weeding.

Win-PST results
The predicted offsite transport for Roundup was very low—low risk for leaching into the ground water; and potential for runoff to surface water is low—high. This range in values is due to the probability of Roundup moving into surface water with the soil particles it has strongly adsorbed to. If soil movement to surface water does not occur, the environmental risk for Roundup, in surface water, would be low.
The herbicides used for the conventional sugar beet range from low—high risk for leaching into ground water and low—high for runoff into surface water. Progress and

Stinger are predicted to have a higher potential risk for leaching and Progress, Stinger, Betamix, Outlook and Nortron all are predicted to have a higher risk for runoff. Complete results from the Win-PST runs are in the Appendix. Overall, none of the herbicides used on either conventional or Roundup were determined to be hazardous, in this scenario.

EIQ values

Table 2. Environmental Impact Quotient (EIQ) for each herbicide

Herbicide	Total EIQ value (farm worker+consumer+ecological/3)
Roundup (glyphosate)	15.3
Stinger (clopyralid)	18.1
Nortron (ethofumesate)	30.0
Upbeet (triflusulfuron-methyl)	No value
Desmedipham	21.7
Phenmedipham	30.2
Procymidone	No value
Outlook (dimethenamid-P)	14.0

Results from the EIQ and the field level environmental impact show that Roundup has the lowest total EIQ compared to all of the other herbicides used in this case study.

Fuel usage/Emissions

University of Idaho estimates that it takes 0.7 gallon of fuel per acre for each cultivation and 0.55 gallon of fuel per acre for each pesticide application, pulling a sprayer.

Table 3. Fuel usage for cultivation and herbicide sprays--Conventional

Field	Conventional Cultivations (Gal/acre)	Conventional Herbicide applications (gal/acre)	Conventional Fuel usage for all acres TOTAL GALLONS
I—51 acres	1.4	1.1	127.5
II—63 acres	2.1	1.7	239.4
III—36 acres	2.1	2.2	154.8
IV—65 acres	1.4	1.7	201.5

Table 4. Fuel usage for cultivation and herbicide sprays—Roundup Ready

Field	RR cultivations (gal/acre)	RR herbicide Applications (gal/acre)	RR Fuel usage for all acres TOTAL GALLONS
I—56 acres	0.7	0.6	72.8
II—61 acres	2.1	1.1	195.2
III—67 acres	0.7	1.1	123.6
IV—65 acres	0.7	1.1	117.0

According to Kern and Johnson (1993), for every four gallons of reduced fuel usage, the resulting reduction is 38.6 pounds Carbon per acre (released as CO2). Using these values, the fields planted to RR sugar beet produced 2,036.15 less pounds of CO2 emitted into the atmosphere.

Weed Results

Table. Weed counts per 3 square feet (18 feet of row by 0.33 ft wide)[1].

Grower	Date	Clns		Colq		Hans		Kocz		Rrpw		Vopo		Shpu		Grft		Bygr		Wioa	
		RR	Con	RR	Con	RR	Con	RR	Con	RR	Con	RR	Con	RR	Con	RR	Con	RR	Con	RR	Con
Carlquist	5/17	0	0	0	0	29	20	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	5/30	0	0	0	0	30	25	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	6/12	0	0	0	0	8	16	0	1	0	0	0	1	0	0	0	0	0	0	0	0
	6/24	0	0	0	0	3	15	0	1	0	0	0	1	0	0	0	0	0	0	0	0
	7/13	0	0	0	0	5	16	0	1	0	0	1	1	0	0	0	0	0	0	0	0
Hagen/Grant	5/17	0	1	3	3	0	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	6/12			1	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6/24	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7/13	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. Grant	5/13	0	0	66	32	41	72	0	0	4	1	0	0	0	0	0	0	0	0	0	0
	5/30	0	0	73	11	36	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
	6/12	0	0	2	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6/24	0	0	10	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7/12	0	0	9	9	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Gott	5/25	4	0	17	0	49	6	0	0	6	0	0	0	2	0	16	0	1	0	0	3
	6/12	1	0	4	0	9	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0
	6/24	1	0	1	0	5	0	0	0	0	0	0	0	0	0	2	0	0	0		

[1]Glyphosate applied at Field I (Carlquist) on June 2; at Field II (Hagen/Grant) on May 26 and June 16; at Field III (Grant) on May 30, June 10 and 26; and Field IV (Gott) on May 22 and June 13.

Discussion

The Idaho case study demonstrated that RR sugar beet can be planted and managed with less overall impact to the environment.
The growers made fewer trips, for both herbicide applications and cultivation, across the RR sugar beet side of the fields compared to the conventional side. Previous studies documented in the literature have shown that reduced tillage helped to reduce soil erosion from water and wind, fossil fuel use, air pollution from dust, loss of soil moisture, and soil compaction. Reduced tillage improves soil structure which leads to reduced risk of runoff and pollution of surface waters with sediment, nutrients, and pesticides (Cerdira and Duke, 2006). There are no documented studies that make a direct correlation between the planting of herbicide tolerant crops and less soil compaction. However, the RR sugar beet fields, in the Idaho case study, had fewer trips made with heavy farm equipment, suggesting there may be less soil compaction.

The Life Cycle Assessment (LCA) was utilized by Bennett et al., 2004 for a European sugar beet study designed to compare RR sugar beet to conventional sugar beet in order to assess the environmental impacts. The LCA was originally developed to assess the environmental and human health impacts associated with a product or process. The LCA evaluates the environmental burdens associated with a product, process, or activity by identifying energy and materials used and wastes released into the environment throughout the life cycle (Bennett et al., 2004). The procedures and models used by Bennett et al. are described in detail in their paper and used a large number of data sources. They estimated the effect of emissions and energy use on the environment by characterizing emissions in terms of a common unit, such as CO2 equivalent (global warming), CFC equivalent (ozone depletion), SO2 equivalent (acidification) , PO4 equivalent (nutrification of soil and water), NOx equivalent (summer smog), and PM10 (particulate matter). Other common units were used relative to the pesticide toxicity and impact on the environment. However, the conventional pesticides evaluated by Bennett et al. differed in ecotoxicity from the conventional herbicides used in this case study, therefore, we did not use the data developed by Bennett for RR sugar beet. There were similarities in the types, amounts and number of application trips between the Idaho case study and the Bennett study. Bennett et al. found that extracted energy use was 50% less for the RR sugar beet than for conventional sugar beet. They also found that the RR sugar beet production accounted for 50% less of ozone depletion and 19% lower values for contributions to global warming than the conventional crop.

With herbicide resistant soybeans, corn, canola and cotton, herbicide use was much less with the RR crops than conventional. Sankula (2006) reported that all herbicide resistant crops accounted for 87% of overall pesticide use reduction in 2005. However, in the Idaho study, more herbicide product was applied on the RR half of the field than conventional side in some cases. Some conventional herbicides are banded, resulting in actual less overall formulated product per acre than the Roundup applications. But the number of applications, and herbicide combinations were greater on the conventional half of the fields, in all cases. In a report by Gianessi (2002), Roundup (glyphosate) treatments produced weed control equivalent to three applications of Nortron (ethofumesate) combined with two applications of desmedipham and phemedipham and triflusulfuron in Idaho.

None of the herbicides used in this case study are considered highly toxic to humans or the environment. The toxicity table in the Appendix compares all of the herbicides. However, the conventional herbicides for the most part are slightly more toxic than Roundup (glyphosate) and may have greater leaching and runoff potential. Roundup (glyphosate) is strongly adsorbed to soil particles and does not leach into ground water in most soils. Various studies have shown that glyphosate (Roundup) appears in surface water less than several alternative herbicides (Carpenter et al., 2002). Nortron (ethofumesate) and Upbeet (triflusulfuron-methyl) are more toxic to fish. Ground water and surface water, in the region of this case study, was not sampled for presence of pesticides. The Win-PST results are predictive for these pesticide properties and their expected impact to water quality. Glyphosate (Roundup) is classified by the U.S. Environmental Protection Agency (EPA) as a reduced risk pesticide. It is also one of the few herbicides actually registered for aquatic weed control, due to its low aquatic toxicity. There is greater potential for human exposure to pesticides in the conventional sugar beet fields, due to the field workers hand weeding. Field workers brushing against plants that may have been treated with pesticides are at greater risk for pesticide exposure, through dermal exposure and ingestion. Actual worker exposure data was not collected for the case study. Assumptions for exposure are based upon professional experience.

Conversely, there is controversy regarding the environmental risks and the sustainability of planting herbicide tolerant crops. Dr. Charles Benbrook, Benbrook Consulting Services, Inc. has provided and published several reports on the world wide web, containing information regarding the environmental risks of transgenic crops. One such report by Miguel Altieri cites concerns about transnational companies that prompted the first wave of agrochemically-based agriculture are now the main proponents of biotechnology. The concern is that these companies may be solely profit driven and are releasing transgenic crops too fast without proper consideration for long-term impacts on people or the ecosystem. The trends, so far, is that these companies are creating a broad international market for a single product, thus increasing the genetic uniformity. Alteri predicts that herbicide resistant crops will likely lead to increased herbicide use and production costs, due to increasing herbicide resistance. Weed resistance, to glyphosate, is a concern in all cases of herbicide tolerant crops. There also is concern that herbicide resistant traits from the crops, could cross over to related weed species, resulting in glyphosate resistant weeds, or that certain crops will develop weedy traits. Sugar beets are arguably one of the most ideally suited crops to incorporate glyphosate resistance. This is primarily because sugar beets cannot be grown year after year in the same field without disease problems and because there are no highly effective herbicides registered for use in sugar beets. However, because of the development of other glyphosate resistant crops such as corn, soybean, canola, and alfalfa, which are grown in many of the sugar beet production areas in the US, glyphosate weed resistance potential is higher than if only Roundup Ready sugar beets were grown in these areas. As noted in the Executive Summary titled Global Status of Commercialize Biotech/GM Crops: 2006 (James, 2006), adherence to good farming practices with biotech crops, such as rotations and resistance management, will remain critical as it has been during the first decade (of GM crops).

As mentioned previously, the literature has documented seven weed species that are resistant to glyphosate in the United States. There are reports of some other glyphosate resistant species in the US, but have not been documented by the International Survey of Herbicide Resistant Weeds web site (Heap, I. The International Survey of Herbicide Resistant Weeds.)

Based on the experiences of corn, soybean, and cotton growers in the midwest and southern states, glyphosate resistance in certain weed found in these crops is a certainty. Several reasons have been attributed to the selection of glyphosate resistance including application of below-label glyphosate rates, applications when weeds were larger than optimal for control, and an over-reliance of glyphosate as the sole herbicide for weed control. Other reasons likely contributed to the selection pressure as well. Nevertheless, it should be assumed that sugar beet growers can make the same mistakes as corn, soybean, and cotton growers.

Idaho and eastern Oregon sugar beet growers have the unique opportunity to implement resistant management strategies now while Roundup Ready crop acres are relatively low. For approximately 30 years many dryland wheat growers relied upon the effectiveness of glyphosate for control of volunteer grain and other weeds without the selection of glyphosate resistant weeds. Weed Scientists believe this is primarily due to the fact that glyphosate was rarely applied more than once a year in a wheat or barley field to control weeds between crops thereby not creating the selection pressure for glyphosate resistant biotypes. Sugar beet growers can probably best serve themselves by reducing the number of glyphosate applications to their sugar beet crop and use herbicides with other modes of action for controlling weeds in their other crops including corn and alfalfa. Another alternative is for sugar beet growers to use herbicides with other modes of action in combination with glyphosate applications in sugar beets.

If the sugar beet growers totally embrace Roundup Ready Sugar Beets and the beet seed companies discontinue developing non-transgenic or non herbicide resistant beets, it is likely that chemical manufacturers will discontinue producing some of the primary sugar beet herbicides since they are not used widely in other crops. Those herbicides include ethofumesate, desmedimpham, phenmedipham (Betanal, Betanex, Betamix, and Progress), cycloate (Ro-Neet), pyrazon (Pyramin), and triflusulfuron (UpBeet).

It has also been reported that glyphosate is toxic to some non-target species in the soil, such as spiders, mites, carabid and coccinellid beetles and to earthworms. The Monsanto Company Backgrounder published a report in 1999, reporting on some follow-up field studies to these claims. Monsanto believed that the initial laboratory tests were highly artificial tests where the Roundup was applied at the maximum use rate onto artificial substrates. Monsanto found no dose-related effects, in the field, on beneficial soil insects. They did see reduced populations of herbivorous insects and ground invertebrates, which was attributed to loss of vegetation and habitat, not direct toxicity from the pesticide. There have also been reports of significantly higher incidence of Fusarium in Roundup Ready soybeans and in fields of wheat and dry beans where Roundup was used. There is speculation that a direct correlation occurs from the use of Roundup and increases in Fusarium, causing a subsequent ecological impact, below ground.

The Idaho case study comparing these four fields of conventional and Roundup Ready sugar beet only compared herbicide use, tillage and trips in the field. For a more complete environmental impact assessment of RR sugar beet in Idaho, the authors recommend a more long-term study where actual field measurements are collected and compared.

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Appendices

The appendices contain the following:

a) Raw data collected by Amalgamated Sugar Company, for each field
b) Win-PST data runs for each pesticide used in the case study
c) Comparison table of the toxicity for each pesticide

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