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ROUNDUP READY™ SOYBEANS: AN OVERVIEW OF THE TECHNOLOGY

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Roundup Ready™ Soybeans will be the first product of biotechnology that will be widely available in soybeans. These soybeans are the culmination of over 10 years of research and development by Monsanto Company and selected soybean seed company partners and will offer soybeans growers selective post emergent weed control from Roundup® the world's most widely used herbicide.

History of Development

The search for a plant tolerant to glyphosate, the active ingredient in Roundup, has been going on for many years. Roundup kills plants by inhibiting the EPSP enzyme, an enzyme found only in plants and some microorganisms. Inhibition of this enzyme blocks aromatic amino acid synthesis, which will result in the death of the plant. Many attempts were made to select plants that were tolerant to Roundup via normal plant mutation methods and other selection processes. When these attempts proved unsuccessful, the efforts turned to identifying an organism that would tolerate or metabolize glyphosate.

The Roundup Ready gene, identified in a soil micro-organism, produces an EPSP enzyme that is not inhibited by glyphosate. This EPSP enzyme allows the micro organism to synthesize amino acids in the presence of glyphosate. The gene was isolated and inserted into soybeans via particle gun transformation. The present line was selected from numerous lines that contained the gene because it contained excellent agronomic, reproductive and herbicide tolerance characteristics. The original plant was selected in 1991 and since that time hundreds of studies have been conducted to satisfy regulatory and food safety requirements, verify that the plants tolerate commercial applications of Roundup, verify the yield of the original selection and its progeny in different genetic backgrounds and to identify the correct weed control recommendations for labeling of Roundup treatments in soybeans containing the Roundup Ready gene.

Characteristics of Roundup Ready Soybeans

The original soybean selection containing the Roundup Ready gene was tested extensively to determine if it had desirable agronomic characteristics, including seedling vigor and growth habits. Concurrent with these tests, numerous studies were conducted to determine if the plant reproduced normally, both when treated with Roundup and unsprayed. Yields were then

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verified to determine if the plants yielded similarly when treated or unsprayed. All of these studies indicated that the plants had excellent agronomic characteristics and that the yield was not affected by treatments of Roundup herbicide, even up to rates of 64 oz/A (1.5 LB AE/A).

The next step was to start crossing the Roundup Ready plants with commercial lines and verify yields in different maturity groups. These crosses resulted in varieties that were tolerant to Roundup and yielded very well, when treated with Roundup or other commercial herbicides. These studies demonstrated that the gene expressed equally well in all maturity groups and genetic backgrounds studied. Roundup could be applied from emergence through flowering with no impact on yield. This level of tolerance is unsurpassed with post emergent herbicides.

Another important series of studies were conducted to determine if the gene caused any negative impact on soybean yields. A series of studies called iso-population studies were conducted to determine the impact of the gene on yields. Iso-population studies are studies where the Roundup Ready gene is crossed into a population and selections are made of plants that contain the gene and plants that do not contain the gene. These populations are essentially equal except one group contains the Roundup Ready gene, and the other group does not contain the gene.

These crosses and selections were made in various maturity groups and yields were compared in studies across the soybeans growing areas. The plots were treated with the same commercial herbicides and yields compared. In all cases the yields were equal, proving that the presence of the Roundup Ready gene has no impact on soybean yield.

In addition many analytical and feeding studies were conducted to determine if the soybeans containing the Roundup Ready gene were different in any way from regular soybeans. As expected these studies verify that the only difference is the presence of the modified enzyme. This presence translates to one additional protein in the soybean. This protein results in no differences in feeding characteristics, oil content or protein percentage. A soybean containing the Roundup Ready gene is the same as any other soybean from a processing or feeding point of view.

**Regulatory Status**

Roundup Ready soybeans have been approved by the United States Department of Agriculture (USDA), the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA). These three agencies have reviewed environmental information, food safety studies and the information necessary to approve the use of Roundup herbicide in the soybeans containing the gene.

The USDA is concerned primarily with the introduction of a new species into the environment. Since the soybean contains a gene not present in other plants, Roundup Ready soybeans needed to be studied to determine if the plant posed any danger to the environment. Since soybeans do not outcross with other plants in the United States, and the soybean did not possess any unusual characteristics, the USDA approved the Roundup Ready soybean in May 1994, granting it unregulated status.
The FDA does not grant formal approvals, but data was submitted and consultations were held to determine if they would pose any objections to Roundup Ready soybeans entering the food chain. The FDA notified Monsanto in November of 1994 that soybeans containing the Roundup Ready gene could be sold.

The EPA is concerned with approving the use of Roundup in Roundup Ready Soybeans, and the soybeans do not require approval by this agency. In May of 1995 EPA approved the use of Roundup in Roundup Ready soybeans. The federal label allows use of 64 oz per acre of Roundup per season. This can be applied anytime following emergence, through flowering of the soybeans. In addition, normal pre-plant and pre-harvest treatments can also be applied.

**Drift Management**

The use of Roundup in the crop will result in applications being made during the summer when sensitive crops may be present in adjacent fields. Growers and custom applicators will need to understand and follow correct application and equipment guidelines to avoid drift onto sensitive crops.

Roundup is has very low volatility, so danger from drift is from movement of spray particles onto sensitive crops. Sprayers should be equipped with nozzles that apply the correct particle size to allow for good coverage of the plant, but minimize chance for drift. In addition care should be taken when wind is blowing toward the sensitive crop. Spray booms should be operated as close to the crop as possible and spray pressure should adjusted to the correct recommendation for the nozzle. In general low pressure nozzles, operated at recommended pressures results in fewer fine particles and less drift.

*Each sprayer should be checked and calibrated to ensure that it is properly equipped and adjusted.*

**Weed Control Systems**

Roundup Ready soybeans treated with Roundup will provide soybean growers with a herbicide option that possesses the broadest weed spectrum and the widest application window of any post emergent herbicide program. Roundup is labeled for use on Roundup Ready soybeans from emergence through flowering. Weeds can be treated at any size during this window, with use rate varying dependent the size and species of the weeds present. The specific recommendations will vary dependent upon the soybean cultural practice and weed size and species.

**No-till Systems**

One of the largest risks associated with growing no-till soybeans has been the uncertainty associated with weed control. The total reliance on chemical methods, both for pre-plant and in crop weed control has caused some growers to be approach this technique with a great deal of caution. Growers who have already adopted no-till are finding that they are being faced with controlling weeds that they have not found to be problems in conventionally tilled fields. In
particular, they are seeing more perennial species. Roundup will provide the new no-till grower with a wide application window and a very wide spectrum of control that is not presently available.

The key to a successful no-till program is to start with a clean field. Prior to planting, the field needs to be treated with Roundup or Roundup plus 2,4-D to control existing vegetation. Numerous studies conducted by Monsanto and others have demonstrated that this technique is most successful to obtaining a good stand of soybeans and good in crop weed control. After the vegetation is controlled in prior to planting, plant and follow the recommendations made for conventional systems.

### Weed Control Recommendation in Narrow Row/Drilled soybeans

**USE RATES:**

- Apply 24 oz/A for weeds 0-6" tall
- Apply 32 oz/A for weeds 6-12" tall
- Apply 48 oz/A for weeds 12-18" tall

**NOTES:**

A single in-crop application of Roundup provides season-long control of labeled weeds. For best results, apply four or more weeks after planting or when weeds are 4-8" tall.

### Weed Control Recommendation in Wide Row soybeans.

**USE RATES:**

- Apply 24 oz/A for weeds 0-6" tall
- Apply 32 oz/A for weeds 6-12" tall
- Apply 48 oz/A for weeds 12-18" tall
- Sequential application:
  - Apply 16 oz/A for weeds 0-3" tall
  - Apply 24 oz/A for weeds 3-6" tall

**NOTES:**

A single in-crop application of Roundup provides season long control of initial stand of labeled weeds. For best results, apply four or more weeks after planting or when weeds are 4 to 8" tall.

In new flushes of weeds occur, they can be controlled by a sequential application of Roundup, applied three weeks after initial in-crop application.
Special Recommendations

A Roundup in-crop application rate of 32-64 oz/A will provide suppression and/or control of nutsedge and perennial weeds like hemp dogbane, milkweed, field bindweed, Canada thistle, horseradish, quackgrass and other perennial weeds.

Black nightshade/groundcherry/morninglory: Up to 3" tall, apply 24 oz/A; 3-6" tall apply 32 oz/A; and 6-12" tall apply 48 oz/A.

Weeds such as blacknightshade, woolly cupgrass, shattercane, wild proso millet and giant ragweed tend to emerge throughout the season, so a sequential application will be required if a new weed flush occurs.

Summary

Soybeans containing the Roundup Ready gene will be available in 1996. Growers who plant Roundup Ready soybeans will be able to use Roundup selectively in a crop for the first time. This will provide them with greater flexibility in controlling weeds than they have had with any other herbicide program. Roundup can be applied from emergence through flowering of the soybeans, which is the widest application window of any broad spectrum post emergent herbicide. It also will control a broad spectrum of weeds and provide options for controlling perennial species during the growing season. The flexibility provided by Roundup Ready soybeans and Roundup will provide soybeans growers agronomic and herbicide options that have not existed in the past and should prove to be another excellent tool to increase productivity.