
ROLE OF ROUNDUP READY 2 YIELD TRAIT TECHNOLOGY IN SUSTAINABLE AGRICULTURE

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Abstract: effective weed control has always been a critical challenge for crop producers because excessive weed growth forces the crops to compete for space, water, nutrients and sunlight often leading to significant losses in crop yield. herbicides used in conventional agricultural systems are selective and are not much effective to remove all types of weeds. besides, the intense use of herbicides in conventional agriculture may lead to groundwater contaminations which may further causes the illness or death of several wildlife species including man. if farmers use herbicide resistant crops, like roundup ready (genetically modified) it can remove all weeds in a single application. this means less spraying, less labor on the field, and lower operating costs.

Round up ready technology (transgenic plant by monsanto) plant had with innate herbicide resistance for multiple weeds. roundup ready (rr) crops are the gm crops with contain inbuilt both herbicide and gm seed as package. these plants have had their dna altered to allow them to withstand the herbicide glyphosate (the active ingredient in monsanto's herbicide roundup) which was legalized by usda [1] animal and plant health inspection service (aphis) [2] and commercialized in 1996. they are also known as "glyphosate tolerant" soybeans. from 1996 to till today, the herbicide- tolerant crops (ht) constantly occupied the largest planting area of biotech crops. in 2013 alone, herbicide tolerant crops occupied 99.4 million hectares or 57% of the 175.2 million hectares of biotech crops planted globally. evidences are available that farmers adopted this recent roundup ready technology they experienced many benefits like reduced soil erosion, reduced labor and fuel costs and conserving valuable soil moisture in drier climates. farmers can also to use herbicide-tolerant plants for environmental protection as they release fewer or less harmful or no herbicides into the environment. moreover, farmer doesn't have to come in direct contact with the herbicide as it happens in traditional spraying.

but in contrast, scientists from different groups and universities raised the concerns that this technology will affect the sustainability as weed populations may shift to other species or become more tolerant to glyphosate. they also expressed worries about possible unexpected adverse health effects, environmental damage and commercial misuse that yet are not supported by any firm evidence. it is a relatively new technology that may bring huge benefits, but that also has the potential for misuse.

in this research review we are going to highlight about the history, development, advantages and controversies related to this recent technology. definitely this paper will provide update knowledge of roundup ready technology which will be helpful for researchers and policy makers.

keywords: herbicide tolerance, roundup ready technology, controversies, regulation.

Introduction: Excessive weeds not only compete with crops for water, nutrients, sunlight, and space but also provide shelter for many insects and disease pests. Weeds affect the crop yield by causing clogging the irrigation and drainage systems. They also deposit weed seeds into crop harvests. If left uncontrolled, weeds can reduce crop yields significantly. To combat this problem farmers use tillage, hand weeding, herbicides, or may be a combination of all techniques. Unfortunately, tillage leaves valuable topsoil exposed to wind and water erosion. Besides, the intense use of herbicides may lead to groundwater contaminations which may further cause the illness or death of several wildlife species including man. Over spray of herbicides may kill both the target and non target crops.

For thousands of years, humans have bred plants to improve the morphology, flavor, and durability or to

resist insects or diseases through cross-pollination from one plant to another. The process of selecting the desired traits, transferring them, testing the new variety and arriving at a final commercial product is a lengthy process and can take years [3]. All plants have an **inherent quality** to tolerate some specific herbicides. The growth and development of these are not significantly affected by herbicides used to control various weeds growing around them [4]. Herbicide tolerance in plants is **not new**. Since many years, scientists and farmers have known that herbicide tolerance can be transferred from one plant to another through crossbreeding both in agriculture crops and in wild plants even before the techniques of modern biotechnology [5], [6]. Herbicide tolerant (HT) crops are the GM crops with contain both herbicide and GM seed as package. These crops have been made to be tolerant to either Monsanto's weed

killer Roundup (glyphosate) or Bayer's weed killer Liberty (glufosinate ammonium). These are broad spectrum herbicides which kill all the weeds except crops as a result of the genetic modification. Recently, the first crops tolerant to Dow's 2, 4-D, a more toxic weed killer, have been approved for commercial growing in South Africa [7]. But Monsanto's Roundup Ready soybeans are the leading product. Other herbicide-tolerant crops include maize, sugar beet, and oil seed rape (canola) [8]. From 1996 to till today, the herbicide-tolerant crops constantly occupied the largest planting area of biotech crops. In 2013 alone, herbicide tolerant crops occupied 99.4 million hectares or 57% of the 175.2 million hectares of biotech crops planted globally. According to CAST (Council for Agricultural Science and Technology) no-till soybean acreage has increased by 35% since the introduction of HT soybean. A similar trend is observed in Argentina where soybean fields are 98% planted with HT varieties [9]. Also for the first 17 years of commercialization (1996-2012), benefits from herbicide tolerant crops are valued at US\$ 47.7 billion, 41% of global biotech crop value of US\$ 116.9 billion, and for 2012 alone at US\$ 6.6 billion or 35% of global value of US\$ 18.7 billion. However scientists from different groups and universities expressed future worries which are yet to be proved. Therefore, in this research paper we have highlighted the economic advantages, future possible impacts on both human health and environment and on other agricultural crops. We also highlighted the best possible solutions for concerns expressed by various scientists. We hope that this research paper will be useful for public, policy makers and scientific community.

Methodology: This research review paper is based on the secondary data from Monsanto, American Medical Association (AMA) [10], and American Association for the Advancement of Science (AAAS) [11], EPA [12] and fact sheets from FAO. [13]. Information was also obtained from Ministry of health and nutrition web sites and articles addressing genetically modified food. Selected references to the articles reviewed can be found in the head of References of the working document. Additionally, many press releases have been reviewed on a regular basis. Meetings with local university scientists, doctors and experts from, Biotechnology department, Vikram University, Ujjain have also been a useful source of information that provided opportunities for exchanging views. Information was also obtained from blogs, research centers and other online media sources.

Results and Discussion: Roundup Ready soybean, the first biotechnology derived herbicide resistant

crop, was introduced by Monsanto in 1996. Later this technology was adopted in soybean, cotton, corn, canola and sugar beets. Due to its broad-spectrum weed control qualities, crop safety and flexibility now it is spreaded all over the world. American farmers had mistakenly taken a big risk by planting Glyphosate Tolerant soybeans. At that time when farmers sown the first RR soybeans in the U.S. both EU and Japan refused to import of this GM (RR) soybeans. Later, the EU announced its decision to grant the GE beans permission on April 3, 1996.

After widespread adoption of RR soybeans, glyphosate resistant weeds like horseweed (*Conyza canadensis*), Giant Ragweed (*Ambrosia trifida*), Common Waterhemp (*Amaranthus tuberculatus* (syn. *rudis*)), Johnsongrass (*Sorghum halepense*) etc. began to emerge [14]. Then after, Monsanto launched the Second Generation Technology which is an updated version of its Roundup Ready trait in soybeans. The new version, MON 89788, was legalized in the U.S. and Canada in 2007. These soybeans are branded as "Roundup Ready 2 Yield[®]" and marketed as the second generation of the popular Roundup Ready[®] technology. Later in 2009, Monsanto brought all of its products together under one brand called Genuity and acknowledged as "Genuity Roundup Ready 2 Yield. [15]. In 2011, the U.S. legalized another Improved Fatty Acid Profile Soybean," MON 87705 from Monsanto under Roundup Ready [16].

Roundup Ready Soybean, produced by Monsanto (OECD UI: MON-04032-6) is the second generation variety of glyphosate resistant soybeans. Glyphosate kills plants by interfering with the synthesis of the essential amino acids phenylalanine, tyrosine and tryptophan. The animals cannot synthesis these amino acids and only plants and micro-organisms can make them and animals obtain them by eating plants.^[3] Plants and microorganisms make these amino acids with an enzyme that only plants and lower organisms have, called 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) which is absent in animals [17]. Roundup Ready Soybeans express a translation of EPSPS from the CP4 strain of the bacteria, *Agrobacterium tumefaciens* expression of which is regulated by an enhanced 35S promoter (E35S) from cauliflower mosaic virus (CaMV), a chloroplast transit peptide (CTP₄) coding sequence from *Petunia hybrida*, and a nopaline synthase (nos 3') transcriptional termination element from *Agrobacterium tumefaciens*.^[6] The plasmid with EPSPS and the other genetic elements mentioned above was inserted into soybean germplasm with a gene gun by scientists at Monsanto and Asgrow [18], [19].

Advantages: The credit of benefits not entirely goes

to Monsanto who manufactured Roundup Ready soybeans but also goes to farmers. There is extensive scientific consent that food on the market derived from GM crops poses no greater risk to human health than conventional food [20]. [21]. GM crops also provide a number of ecological benefits [21].

- It kills all the weeds a field without harming the soybeans planted in that particular field. This is a vast benefit because the farmer can use one application (Roundup) which kills all weeds. In traditional agriculture the farmer has to spray different and more expensive sprays to fight his weed problem. This superior and inexpensive property of Roundup Ready helps the farmer to maximize his crop yield and therefore turn a better profit.
- The genetically changed Roundup Ready soybeans also in a way are better for the environment because the farmer needs only one spray rather than a whole collection of dangerous herbicides that could leak into the water system. As long as Roundup is sprayed carefully and at the correct time (not before or during a heavy rain) it is practically harmless to the environment. Moreover, as herbicide is innate in the seed the farmer will not come in contact repeatedly with dangerous chemical herbicides.
- Also Roundup Ready Soybeans would benefit the consumers because it is a very inexpensive way to produce soybeans. Consequently, the price of soybeans one would think would naturally begin to drop. The consumers would also not have to worry about any unknown chemicals that may have been sprayed on normal soybeans. Because Roundup Ready soybeans need only Roundup to control weeds. Hence they are altogether a very safe and beneficial way to feed the world with quality soybeans.

Controversies: Critics have objected the GM crops on several grounds which mainly include ecological, economic, human health and food safety.

Impact on Herbicide Use: The adoption of RR soybeans increased the amount of glyphosate use. Accordingly weeds also adopted glyphosate resistance and even shifting to other healthy plants was occurred. As a result more susceptible weeds were eliminated but less susceptible varieties breed among themselves and evolved into super weeds.^[2] At the same time more and more of the soybean crop was planted in Roundup Ready seeds each year and the use of glyphosate rate per crop in a year also increased from 0.69 pounds per acre in 1996 to 1.36 pounds in 2006, or 9.8% per year [22]. The first glyphosate resistant weed in soybeans discovered

in the U.S. was horseweed (also known as marehail), discovered in Delaware in 2000 [23]. Since then, it has spread to 20 other states of US and even in Brazil and Canada. The most problematic weed, Palmer amaranth plant which can produce nearly half million seeds. They are resistant to both glyphosate and ALS inhibitors in soybean [24]. As more and more acres are impacted by glyphosate resistant weeds, farmers have begun using other, often more toxic herbicides to deal with them. Because glyphosate resistant Palmer amaranth is often already resistant to other herbicides (such as ALS inhibitors), often the last option left are PPO Inhibiting Herbicides [24]. The same was also identified in cotton and soybeans in Georgia in 2005 which later spread to many other states [23].

But, all herbicides are not equal in toxicity. Glyphosate is as less toxic than many other herbicides and expressing its use in pounds by skeptics is unscientific. Moreover, similar situation was happened when DDT was used to control the weeds in the past. Hence it is advisable to change the cropping patterns frequently to avoid this situation.

Impact on Crop Yields: According to Monsanto Roundup Ready crops will increase crop yields. But, it was found that the original Roundup Ready soybeans (MON 04032) have not increased crop yields, whether on a per-acre or national basis [24]. Some other studies have reported both increases and decreases in yield of Roundup Ready crops compared to non Roundup Ready crops soybeans. Laboratory studies also suggest that Roundup Ready crops have not increased and may even have decreased the yield. Yes, there is a possibility to get such type of results. It may be due to typical pesticide systems and combinations of multiple herbicides used prior to the introduction of Roundup Ready soybeans. Glyphosate has been effective against many species of weeds and therefore more convenient because farmers can often avoid using several different herbicides and spraying schedules, but it does not necessarily provide better weed control than several other herbicides combined. (12) Roundup Ready 2 (RR2Y) in this case does not increase yields, but simply removes the previous yield reduction associated with first generation soybean. Though this RR biotechnology is a method to reduce labor and costs, but some skeptics express worry about their safety and deep doubt about such companies like Monsanto and DuPont and demanded to ban this product. They argue that genetically modified crops haven't been sufficiently tested on animals to know whether their consumption could have a long-term impact on human health. According to them [25] pharmaceuticals are tested for use on humans, and genetically modified crops also should be tested. But the logical option for consumer

concerns about RR crops is to label the products that contain genetically modified ingredients and let the consumer make a wise choice. But for many scientists it is another potential regulatory burden. The labeling foods that contain genetically modified ingredients have been standard practice in Europe, Japan, Australia and New Zealand and even Russia. This bill in fact it doesn't ask for a ban of GM foods but it really asks for the right to know. It also doesn't say that you can't grow it or sell it. It just lets the consumers know so they can make an informed choice.

In another argument, scientists and doctors argue that 20 years of eating genetically modified crops with no clear widespread ill effects is evidence of their safety. Even American Medical Association (AMA) [10] recently issued a statement finding that although there is a small risk of adverse reaction, GM foods have been consumed for close to 20 years, and during that time, no evident consequences on human health have been reported and/or validated in the peer-reviewed literature. However, the AMA recommends that products containing GMOs go through compulsory testing prior to commercial use.

Health and Environmental Concerns: The arguments against RR genetic engineering crops twist between concerns about human health and environmental health and whether GMOs are as effective as claimed. Critics argue that because there isn't enough data or little research on the effects of genetically modified crops on animals before implementation of this product. Some scientists believe that transgenic crops are toxic to specific insect pests which may kill other beneficial insects. This might lead to a reduction in the species diversity and even may cause the extinction of vulnerable species. Some scientists argue that RR genetic engineering has the potential to relieve human hunger and increase crop yield more rapidly and efficiently. The environmental concern is that, in due course weeds will become resistant to these herbicides or insects will become more resistant to the pesticide *Bacillus thuringiensis*, or Bt, as in cotton or soy. This problem can be solved by using Roundup in combination with other herbicides as we do the same with tuberculosis and AIDS in which multiple vaccines are used. Here also exactly the same logic and the same principle is to be followed [16].

Recently some genetically modified, Roundup Ready wheat was found growing in field of conventional

hybrid wheat in US. So, Critics has got the opportunity to raise the issue of so called genetic pollution. As RR seeds are sterile the possibility of genetic pollution is minimum or zero. But the investigation is going on by the USDA, how this genetically engineered wheat arrived in the field [26].

The regulation: There are differences in the regulation of GM crops between countries especially between the USA and Europe. Regulation varies in a given country depending on the intentional use of GM products. For example, a crop not projected for food use is generally not reviewed by authorities [27], [28]. These controversies raised by critics have led to litigation, international trade disputes, and protests, and to restrictive legislation in most countries. Though this GM biotechnology is a way to reduce labor and costs some skeptics express worry about their safety and deep doubt about such companies like Monsanto and DuPont that profit from the technology. Skeptics say genetically modified crops haven't been sufficiently tested on animals to know whether their consumption could have a long-term impact on human health. According to them [29], pharmaceuticals are tested for use on humans, and genetically modified crops also should be tested prior to approval.

Conclusions: Even after years of public resistance, mandatory labeling and strict anti-GMO regulations, even the European Union has give up some ground on the subject. The main conclusion to be drawn from this research paper is that the efforts of more than 130 research projects, covering a period of more than 25 years of research, and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not as such more risky than usual plant breeding technologies.

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