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Biotechnological approach: an option for integrated weed management in crop production

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ABSTRACT

Crops made resistant to herbicides by biotechnology are being widely adopted in various parts of the world. From the genesis of commercialization in 1996 to 2011, herbicide tolerance has consistently been the dominant trait. Those containing transgenes that impart resistance to post-emergence, non-selective herbicides such as glyphosate and glufosinate will have the major impact. These products allow the farmer to more effectively use reduced or no-tillage cultural practices, eliminate use of some of the more environmentally suspect herbicides and use fewer herbicides to manage nearly the entire spectrum of weed species. In some cases, non-selective herbicides used with herbicide resistant crops reduce plant pathogen problems because of the chemicals' toxicity to certain microbes. Herbicide tolerant crops can be produced by either insertion of a "foreign" gene (transgene) from another organism into a crop, or by regenerating herbicide tolerant mutants from existing crop germplasm.Biotech crops reached 160 million hectares, up 12 million hectares on 8% growth, from 2010 and 94 fold increase in hectarage from 1.7 million hectares in 1996 to 160 million hectares in 2011, makes biotech crops the fastest adopted crop technology in the history of modern agriculture. The inclusion of several transgenes in a single hybrid or variety commonly referred as stacked genes or stacked traits. For example, some corn and cotton hybrids have been genetically engineered to contain two transgenes, one for insect tolerance and another for herbicide tolerance (e.g., Bt/glyphosate, or Bt/glufosinate). Furthermore, some corn hybrids have three traits, two for herbicide tolerance and one for insect tolerance (e.g., Liberty, Clearfield, and Bt). Stacked traits occupied ~25% of the global 160 million hectares. From the genesis of commercialization in 1996 to 2011, herbicide tolerance has consistently been the dominant trait. In 2011, herbicide tolerance deployed in soybean, maize, canola, cotton, sugar beet and alfalfa, occupied 59% or 93.9 million hectares of the global biotech area of 160 million hectares. In 2011, the stacked double and triple traits occupied a larger area (42.2 million hectares, or 26% of global biotech crop area) than insect resistant varieties (23.9 million hectares) at 15%. The stacked genes were the fastest growing trait group between 2010 and 2011 at 31% growth, compared with 5% for herbicide tolerance and 10% for insect resistance. Over the past few years, several herbicide resistant crops (HRCs), both transgenic and non-transgenic, have become available in many countries for commercial cultivation. But in India, the technology of herbicide tolerant crops is in initial stage of field evaluation. Efforts have been made to evaluate and consolidate the agronomic management and advantages of herbicide tolerant transgenic crops.

***Keywords*:** Biotechnology, crop, production, management, weed

Agronomic benefits of herbicide tolerant crops

Spectrum of weeds control

Non-selective herbicides such as glyphosate and glufosinate aid in broadening the spectrum of weeds controlled, which is particularly important in no-till systems, and those "weedy" fields. The genetically modified herbicide tolerant maize and spring oil seed rape cultivars used were tolerant to glufosinate ammonium (Liberty, 200 g a.i. ha) , which gives post-emergence broad spectrum control of annual grasses and broad leaved weeds (Firbank, 2003). In general, glyphosate is the most widely used herbicide in the world and literature about its use and characteristics is extensive (Woodburn, 2000).

Experimental results revealed that application of glyphosate at 2700 g a.e ha^{-1} recorded lower weed density, dry weight and higher weed control efficiency when compared to other doses of glyphosate and hand weeding method in cotton. According to France *et al*. (1997), the systemic activity of glyphosate also helped with the control of perennial weeds and their perennial vegetative structures such as stolons and rhizomes. Keeling *et al*. (1998) also observed that, weed control is often excellent (95%) with the application glyphosate as post emergence in cotton. Post emergence application of glyphosate at 900, 1800 and 3600 g a.i. ha^{-1} registered lower weed density, dry weight and higher weed control efficiency in transgenic Hishell and 900 M Gold corn hybrids in the maize trial I and post emergence application of glyphosate at 900 and 1800 g a. e ha^{-1} registered lower weed density, dry weight and higher weed control efficiency in transgenic 30V92 and 30B11 corn hybrids in the maize trial II compared to their state and national checks. Grichar *et al.* (2004) who had found that single application of glyphosate as early or late post emergence effectively controlled the broad spectrum of weeds.

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Carry-over effect of herbicides

Glyphosate and glufosinate have almost no soil residual activity because they are tightly bound to the organic particles in the soil. Hence, there are few restrictions for planting or replanting intervals or injuries to the subsequent crops. This trait facilitates crop rotation by providing flexibility in selection of potential rotation crops. HTC will not cause any residual effect on succeeding crops

Succeeding crops like sunflower, soybean and pearl millet has been sown after cotton crop in the treatment blocks to assess the carry over effect of Potassium salt of Glyphosate (MON 76366). Observations were recorded on germination percentage, vigour, plant height and yield for all the treatments. Treatment differences found to be insignificant for all the parameters hence there was normal growth and development of succeeding crops. The results are in line with the findings of Nadanassababady *et al*. (2000) who had reported that bioassay of herbicide residues indicated that none of the herbicides evaluated for the chemical control of weeds in cotton persisted in the soil to the level of affecting the germination and growth of succeeding crops like finger millet and cucumber.

Post emergence application of glyphosate in transgenic maize hybrids did not affect the germination per cent, vigour and yield of succeeding green gram in both the transgenic maize trials. Franz *et al*. (1997) reported that, crops can be planted or seeded directly into treated areas of glyphosate because it has no pre-emergent activity even when applied at high rates.

Reduced crop injury

Various post-emergence type herbicides used for weed control in soybean, canola, or corn can cause crop injury and ultimately yield loss. Crop injury is more severe when the crop is under stress or unfavourable environmental conditions occur. In contrast, crop injury is reduced with the use of herbicide tolerant crops. The phytotoxicity symptoms were not observed in cotton with glyphosate at lower doses *viz.*, 900, 1350, 1800 and 2700 g a.i. ha^{-1}. Higher doses *viz.* 3600 and 5400 g a.i. ha^{-1} were noticed with phytotoxicity symptoms at early stages of herbicide application. Glyphosate cause almost no crop injury, compared to some traditional herbicides (e.g., lactofen, chlorimuron), especially when applied to cotton. The greatest beneût to growers is the broad-spectrum weed control with post emergence application of glyphosate to cotton without crop injury as earlier reported by Wilcut *et al*. (1996).

Regarding transgenic maize hybrids, there was no phytotoxic symptom observed in transgenic maize hybrids due to application of various doses of glyphosate at 900, 1800 and 3600 g a.i. ha^{-1} at throughout the crop growth in both the trials. Parkar (1999) revealed that no injury was recorded in maize crop due to application of POE glyphosate product at various levels of concentrations.

Use of environmentally safe herbicides

In general, glyphosate and glufosinate have lower toxicity to humans and animals compared to some other herbicides. Since they are absorbed by the organic particles in the soil and decompose rapidly, they pose little danger for leaching and contamination of ground water or toxicity to wildlife (Knezevic and Cassman, 2003). Glyphosate applied at lower doses like 900, 1350, 1800 and 2700 g a.i. ha^{-1} recorded with more number of bacteria, fungi and actinomycetes. In transgenic maize hybrids, POE application of glyphosate at lower doses like 900 and 1800 g a.i. ha^{-1} recorded with more number of bacteria, fungi and actinomycetes population compared to atrazine applied treatments.

Haney *et al.* (2000) who had reported that glyphosate was available to soil and rhizosphere microbial communities as a substrate for direct metabolism leading to increased microbial biomass and activity. Higher doses of glyphosate with 3600 and 5400 g a.i. ha^{-1} led to slight reduction in microbial population as observed at initial stages and recovered within 45 days. The results corroborate with the observations of Weaver *et al*. (2007) who had reported that glyphosate had only small and transient effects on the soil microbial community, even when applied at greater than field rates.

Mode of action for resistance management

Since the discovery and report of triazine resistance almost 40 years ago, weed resistance to herbicides has been well documented. For example, there are 40 dicot and 15 monocot species known to have biotypes resistant to triazine herbicides. Also, at least 44 weed species have been reported to have biotypes resistant to one or more of 15 other herbicides or herbicide families (Heap, 2001). The list of herbicide-resistant weeds will continue to grow, especially with repeated use of herbicides with the same mode of action. Many of the selective herbicides in corn and soybean have similar or identical mechanisms of action such as the inhibition of enzyme acetolactate synthase (ALS) or the inhibition of acetyl-co-enzyme-A-carboxylase (ACCase). Therefore, herbicide tolerant crops particularly cotton (e.g., glyphosate and glufosinate) can provide a new mode of action when used in an IWM program as an aid in resistance management.

Crop management flexibility

The herbicide tolerant technology is simple to use. It requires neither special skills nor training. The technology does not have major restrictions and is flexible, which is probably one of the reasons for such wide adoption by producers. In particular, crops that are tolerant to broad-spectrum herbicides such as glyphosate extend the period of herbicide application for effective weed control, which is helpful in dealing with rainy and windy days during the optimal periods for weed control measures. In contrast, poor weather during the critical period for weed control can greatly limit the effectiveness of more selective herbicides (Peterson *et al*., 2002). According to AICRPWC (2011), total weed density was significantly lowered with post-emergence application of glyphosate in transgenic cotton and corn hybrids when compared to hand weeding plots in transgenic cotton and national and state checks in transgenic maize. Keeling *et al*. (1998) also observed that, weed control is often excellent (95 %) with the application glyphosate as post emergence in cotton.

Increased yield and income

Cotton crop being slow in its initial growth and is grown with wider spacing, is always encountered with severe weed competition during early stage, which results in low yield. A broad spectrum of weeds are infesting the cotton fields. High persistence nature of weeds is attributed to their ability of high seed production and seed viability. Hand weeding or hoeing twice is the most commonly adopted method of weed control in cotton. Higher yield of herbicide tolerant transgenic cotton recorded with glyphosate at 2700 g a.e ha^{-1} over hand weeding twice during both the seasons during winter 2009-10 and winter 2010-11. It could be attributed to efficient control of weeds during the cropping period. The findings are in accordance with observation of Main *et al*. (2007) who had earlier reported that Roundup Ready Flex cotton could provide producers with acceptable weed control without compromising cotton yield. Glyphosate at 2700 g a.e ha^{-1} recorded with higher gross and net returns and B:C ratio in herbicide tolerant transgenic cotton.

Higher grain yield was recorded with POE application of Round up at 900, 1800 and 3600 g a.i. ha^{-1} in Hishell and 900 M Gold transgenic hybrids, even though higher and comparable weed control and yield were obtained with glyphosate at 900 and 3600 g a.i. ha^{-1}, higher net return and benefit cost ratio was recorded in glyphosate at 1800 g a.i. ha^{-1} in transgenic 900 M Gold in all the four seasons in trial I. Post emergence application of glyphosate at 900 and 1800 g a.i. ha^{-1} registered higher grain yield in transgenic 30V92 and 30B11 corn hybrids in the maize trial II compared to their state and national checks. Average yield obtained in transgenic hybrid was 10 t ha^{-1} and conventional transgenic maize hybrid was 8 t ha^{-1}. The findings are in accordance with observation of Tharp *et al.* (1999) who had earlier reported that maize yields of herbicide resistant hybrids were maximum with glyphosate at 0.84 kg a.i. ha^{-1} of glyphosate when applied at fifth leaf stage of maize.

Herbicide tolerant crops are strongly impacting weed management choices. In many crops their use will decrease the cost of effective weed management in the short to medium term. However, they offer the farmer a powerful new tool that, if used wisely, can be incorporated into an integrated pest management strategy that can be used for many years to more economically and effectively manage weeds. In maize and cotton transgenic crops, post emergence weed management with glyphosate proved to be the better management option for the control of weeds.

REFERENCES

Clive James, 2011. ISAAA Report on Global Status of Biotech/GM Crops. http://www.isaaa.org

Duke S.O. 1999. Weed management: implications of herbicide resistant crops. In: *Proc. Workshop on Ecological Effects of Pest Resistance Genes in Managed Ecosystems* January 31 - February 3, 1999 Bethesda, Maryland.

Firbank, L.G. 2003. An introduction to the Farm-Scale Evaluations of genetically modified herbicide-tolerant crops. *J. Appl. Eco l.* **40**, 2 – 16.

Franz, J.E., M.K., Mao and J.A. Sikorski. 1997. *Glyphosate: A Unique Global Hebricide. Monograph* 189. Washington, D.C. American Chemical Society.

Grichar, W.J, B.A. Besler, K.D. Brewer and B.W. Minton. 2004. Using soil-applied herbicides in combination with glyphosate in a glyphosate-resistant cotton herbicide program. *Crop Prot*.**, 23**: 1007–10.

Haney, R.L., S.A. Senseman, F.M. Hons and D.A. Zuberer. 2000. Effect of glyphosate on soil microbial activity and biomass. *Weed Sci.,* **48**: 89-93.

Heap, I. 2001. International survey of herbicide resistant weeds. Online. *HRAC, NAHRAC and WSSA.*

Keeling, J.W., P.A. Dotray, T.S. Osborne and B.S. Asher. 1998. Annual and perennial weed management strategies in Roundup Ready cotton with Roundup Ultra. *Proc. Southern Weed Science Society,* Champaign, IL, Vol. **51**, P.49.

Knezevic, S.Z. and K.G. Cassman. 2003. Use of herbicide-tolerant crops as a component of an integrated weed management program. Online. *Crop Management doi:10.*1094/CM-2003-0317-01-MG.

Main, C.L., A.J. Michael and E.C. Murdock. 2007. Weed response and tolerance of enhanced glyphosate-resistant cotton to glyphosate. *J. Cotton Sci***., 11**:104–9.

Nadanassababady, T. O.S. Kandasamy and G. Ramesh. 2000. Integration of pre and non-selective post-emergence herbicides and cultural method for weed control in cotton and its effect on succeeding crops. *Trop. Agric. Res***., 12**: 217-25.

Peterson, J.M, K.G., Cassman and R. Cantrell. 2002. Changes in cultural practices of farmers in southeast Nebraska as a result of their adoption of transgenic crops. *J. Ext.* **40**:1.

Tharp, B.E., O. Schabenberger and J.J. Kells. 1999. Response of annual weed species to glufosinate and glyphosate. *Weed Technol***., 13**:542-47.

Weaver, M.A, L.J. Krutz, R.M. Zablotowicz and K.N. Reddy. 2007. Effects of glyphosate on soil microbial communities and its mineralization in a Mississippi soil. *Pest Manag Sci.* **63**: 388-93.

Wilcut, J.W., H.D. Coble, A.C. York, and D.W. Monks. 1996. The niche for herbicide-resistant crops in U.S. agriculture. In. *Herbicide-Resistant Crops: Agricultural, Environmental, Economic, Regulatory, and Technical Aspects.* (S.O. Duke Ed.) CRC Press, Boca Raton, FL. pp. 213-230.

Woodburn, A.T. 2000. Glyphosate: Production, pricing and use worldwide. *Pest Manag***.** *Sci.* **56**: 309-319.