

Herbicide tolerant crops:

problems and prospects

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Biotechnological interventions resulted in crops made resistant to herbicides are being widely adopted in various parts of the world. From the genesis of commercialization during 1996 to 2017, herbicide tolerance has consistently been the dominant group. Crops 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 crop production. 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.

Key words: Crops, Herbicide, Problems, Prospects, Tolerant crops, weeds

Biotech crops reached 189.80 million ha during 2017 from 1.7 million ha in 1996, in 24 countries, an increase of 4.7 million ha compared to 2016, makes biotech crops the fastest adopted crop technology in the history of modern agriculture. Inclusion of several transgenes in a single hybrid or variety commonly referred as stacked genes or stacked traits. For instance, some maize and cotton hybrids were genetically engineered to contain two transgenes, one for insect tolerance and another for herbicide tolerance (e.g., Bt/glyphosate, or Bt/glufosinate). Further more, some maize 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 189.80 million ha. From the genesis of commercialization in 1996 to 2017, herbicide tolerance has consistently been the dominant trait. In 2017, herbicide tolerance deployed in soybean, maize, canola, cotton,

sugar- beet and alfalfa, occupied 59% or 112.0 million ha of the global biotech area of 189.80 million ha. In 2017, the stacked double and triple traits occupied a larger area (49.35 million ha, or 26% of global biotech crop area) than insect resistant varieties (28.47 million ha) at 15%. Over the past few years, several herbicide resistant crops, 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 were made to evaluate and consolidate the agronomic management and advantages of herbicide tolerant transgenic crops.

Problems of herbicide tolerant crops

Herbicide tolerant crop cultivation may lead to the development and occurrence of 'super weeds'. Lack of different mode of actions, phyto-toxicity, limited weed spectrum of

alternatives, poor activity on herbicide resistant weed species and increased cost; are other related problems. Besides lack of herbicide residual activity, timing may be too late to protect yield potential, more applications, increased cost of application, unavailability of weed population maps; poor understanding of weed seed bank dynamics; increased variability of control. Further, increased time required high level of management skill needed, additional tactics needed and potential for crop injury.

Economic risk of alternative crop rotation and lack of adapted rotation crops, and thus minimal impact on the weed community and inconsistent impact on herbicide resistant weed populations. Herbicide tolerant crops require alternative strategies (tillage or herbicide), potential for yield loss, need for increased rotation diversity with increased seed cost, increased intra-specific competition and reduced potential yields.

Table 1. Effect of glyphosate on weed control and yield in transgenic cotton

Weed management Techniques		TNAU, Coimbatore		PAU, Ludhiana	
		Weed control (%)	Seed cotton yield (kg/ha)	Weed control (%)	Seed cotton yield (kg/ha)
Glyphosate	900 g/ha	92.3	2,539	95.9	1,126
Glyphosate	1,350 g/ha	93.7	2,708	96.5	1,435
Glyphosate	1,800 g/ha	96.6	2,915	97.2	1,346
Glyphosate	2,700 g/ha	97.3	3,144	-	-
Hand Weeding	15 and 30 DAS	85.2	2,504	84.3	1,032

DAS, Days after sowing

Prospects of herbicide tolerant crops

Broad-spectrum weed 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. Genetically modified herbicide tolerant maize and spring oil seed rape cultivars used were tolerant to glufosinate ammonium (Liberty, 200 g/ha), which gave post-emergence broad spectrum control of annual grasses and broad leaved weeds. In general, glyphosate is the most widely used herbicide in the world and literature about its use and characteristics is extensive.

Results of field trials conducted at Tamil Nadu Agricultural University (TNAU), Coimbatore, revealed that application of glyphosate at 2,700 g/ha recorded lower weed density, dry weight and higher weed control efficiency when compared with other doses of glyphosate and hand-weeding in cotton. Similarly from the field experiments on bio-efficacy of glyphosate in Roundup Ready Bt cotton hybrid conducted during summer at Punjab Agricultural University (PAU), Ludhiana, it is

inferred that potassium (K) salt of glyphosate at 900 and 1,800 g/ha applied twice as post-emergence gave effective control of weeds and produced significantly higher seed cotton yield than hand weeding (Table 1). Systemic activity of glyphosate also helped with the control of perennial weeds and their perennial vegetative structures such as stolons and rhizomes. Weed control is often excellent (95 %) with the application glyphosate as post-emergence in cotton.

Post-emergence application of glyphosate at 900 and 1,800 g/ha registered lower weed density, dry weight and higher weed control efficiency in transgenic Hishell and 900 M Gold maize hybrids (Table 2.) and post-emergence application of glyphosate at 900 and 1,800 g a.e/ha registered lower weed density, dry weight and higher weed control efficiency in transgenic 30V92 and 30B11 maize hybrids than their state and national checks at TNAU, Coimbatore.

Similarly, the field trials carried out at PAU, Ludhiana also revealed that glyphosate at 900 and 1,800 g/ha applied at 25 days after sowing recorded effective control of sedges,



Herbicide tolerant cotton

grasses and broad leaf weeds and significantly reduced weed population and dry matter as compared to university recommended practice and was safe to both the transgenic hybrids (Table 2). Single application of glyphosate as early or late post-emergence effectively controlled the broad spectrum of weeds in maize.

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. Herbicide tolerant crops facilitate crop rotation by providing flexibility in selection of potential rotational crops and will not cause any residual effect on succeeding crops which were proved through the field trials.

Succeeding crops in sequence like sunflower, soybean and pearl millet were sown after cotton to assess the carry over effect of potassium (K) salt of glyphosate and normal growth and development of succeeding crops were noticed. Earlier findings revealed 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. 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.

Table 2. Weed control and grain yield in transgenic maize hybrids

Weed management techniques	TNAU, Coimbatore		PAU, Ludhiana	
	Weed control (%)	Grain yield (tonne/ha)	Weed control (%)	Grain yield (tonne/ha)
Hishell POE glyphosate @ 1,800 g/ha	96.69	10.34	95.2	8.50
900 M Gold POE glyphosate @ 1,800 g/ha	95.41	10.46	90.8	8.14
Hishell PE atrazine @ kg/ha + HW + IC	91.54	9.23	68.6	7.71
900 M Gold PE atrazine @ 0.5 kg/ha + HW+ IC	88.38	8.77	74.4	7.16
Proagro PE atrazine @ 0.5 kg/ha + HW+ IC	84.84	7.43	69.9	5.98
CoHM 5 PE atrazine @ 0.5 kg/ha + HW+ IC	82.92	7.08	71.7	7.73



Herbicide tolerant maize



Herbicide tolerant maize

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. Phytotoxicity symptoms were not noticed in cotton with glyphosate at lower doses viz., 900, 1,350, 1,800 and 2,700 g/ha. Glyphosate cause almost no crop injury, compared to some traditional herbicides like lactofen and chlorimuron, especially when applied to cotton. The greatest benefit to growers is the broad-spectrum weed control with post-emergence application of glyphosate to cotton without crop injury. Regarding transgenic maize hybrids, there was no phytotoxic symptom observed in transgenic maize hybrids due to application of various doses of glyphosate throughout the crop growth in both the trials. No injury was recorded in maize crop due to application of POE glyphosate product at various levels of concentrations.

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 groundwater or toxicity to wildlife. Glyphosate applied at lower doses like 900, 1,350, 1,800 and 2,700 g/ha

recorded with more number of bacteria, fungi and actinomycetes. In transgenic maize hybrids, Post-emergence application of glyphosate at lowers doses like 900 and 1,800 g/ha recorded with more number of bacteria, fungi and actinomycetes population compared to atrazine applied treatments. This is due to glyphosate applied directly on the weeds that added organic materials to the soil, during decomposition of organic material microbial population might have been increased. Reports showed that glyphosate was available to soil and rhizosphere microbial communities as a substrate for direct metabolism leading to increased microbial biomass and activity. Results of earlier trials revealed that glyphosate had only small and transient effects on the soil microbial community, even when applied at greater than field rates.

Management of herbicide resistant weeds

Since the discovery and report of triazine resistance almost 40 years ago, weeds resistance to herbicides were well documented. For instance, there are 40 dicot and 15 monocot weed species known to have biotypes resistant to triazine herbicides. Also, at least 44 weed species are reported to have biotypes resistant to one or more of 15 other herbicides or herbicide families. 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 maize and soybean have similar or identical mechanisms of action such as the inhibition of

enzymes. Therefore, herbicide (e.g., glyphosate and glufosinate) tolerant crops particularly cotton can provide a new mode of action when used in an integrated weed management programme as an aid in resistance management.

Weed management flexibility

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. Total weed density was significantly lowered with non-selective post-emergence application of glyphosate in transgenic cotton and maize hybrids when compared to hand weeding plots in transgenic cotton and national and state checks in transgenic maize without any injury to crops.

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 stages, which resulted in lower yield. A broad spectrum of weeds with wider adaptability to extremities

of climatic, edaphic and biotic stresses is 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. However, complete weed control could not be achieved by using any single method alone. Herbicidal weed control seems to be a competitive and promising way to control weeds at initial stages of crop growth. Higher yield of herbicide tolerant transgenic cotton recorded with glyphosate at 2,700 g/ha over hand weeding twice during winter season (Table 1) due to efficient control of weeds during the cropping period as observed at TNAU, Coimbatore, and PAU, Ludhiana field trials. Round up Ready Flex cotton could provide producers with acceptable weed control without compromising cotton yield. Glyphosate at 2,700 g/ha 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 glyphosate at 900, 1,800 and 3,600 g/ha in Hishell and 900 M Gold transgenic hybrids (Table 2), even though higher and comparable weed control and yield were obtained with

glyphosate at 900 and 3,600 g/ha, higher net return and benefit cost ratio was recorded in glyphosate at 1,800 g /ha in transgenic 900 M Gold in all the four seasons in trial I. Post-emergence application of glyphosate at 900 and 1,800 g/ha registered higher grain yield in transgenic 30V92 and 30B11 corn hybrids in the maize trial II compared to their state and national check. Average yield obtained in transgenic hybrids was 10 tonne/ha and conventional transgenic maize hybrids was 8 tonne/ha at TNAU, Coimbatore. Research reports of PAU, Ludhiana revealed that morphological and phenotypic characters of both the transgenic hybrids were similar to their non-transgenic counterparts. Transgenic hybrids with glyphosate applications recorded higher maize grain yield, net return and B:C ratio than university recommendation practices in transgenic or non-transgenic maize hybrids. Earlier research findings brought out that yields of herbicide resistant maize hybrids were maximum with glyphosate at 0.84 kg/ha when applied at fifth leaf stage.

SUMMARY

Herbicide tolerant crops in general provided broad-spectrum of weed

control, reduced crop injury and phyto-toxicity, less herbicide carry-over on the succeeding crops, herbicides like glyphosate and glufosinate are environmentally safe with less persistence and residues, new means for weed resistance management, crop and weed management are flexible and simple, better performance in yield and higher profitability in income of herbicide tolerant crops. 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.

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