Madras Agric. J., 99 (10-12): 778-781, December 2012
https://doi.org/10.29321/MAJ.10.100193

Evaluation of Weed Control Efficacy and Yield of Glyphosate Resistant Cotton Hybrids in Winter Irrigated Ecosystems of Tamil Nadu

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Cotton is one of the important crops that have been genetically altered to address challenges with weed and insect control. The research was conducted with glyphosate resistant cotton hybrids during winter irrigated season of 2009-10 and 2010-11 at the experimental site of Tamil Nadu Agricultural University, Coimbatore, with the objective, to find out the weed control efficacy and yield of transgenic cotton hybrid with the application of glyphosate. Glyphosate was applied as early POE application on 25 and 65 DAS at 900, 1350, 1800, 2700, 3600 and 5400g a.e. / ha in MRC 7347 BG-II RRF test hybrid. These treatments were compared with hand weeding on 15 and 30 DAS and unweeded control. In both sprays, Early POE application of glyphosate 2700, 3600 and 5400 g a.e. / ha registered lower weed density and higher weed control efficiency in transgenic cotton hybrid compared with other treatments. Seed cotton yield was significantly higher in post-emergence application of glyphosate at 2700 g a.e. / ha. Increased use of transgenic cotton with herbicide and pest resistance has resulted in more efficient insect and weed management practices.

Key words: Herbicide tolerant cotton, Weed control efficiency, Seed cotton yield

Cotton hybrids are cultivated under wider plant spacing and heavily fertilized, which in turn invite multiple weed species infestation. Due to increased scarcity for labourers, manual weeding is not economical and the available pre - emergence herbicide has lesser weed control efficiency in controlling major problematic weeds like *Cyperus rotundus* and *Cynodon dactylon*.

Critically viewing, the manual and mechanical methods of weed control, besides being less effective, costly, time consuming and to be repeated at frequent intervals. Mechanical weed control method was partially effective because most of the weeds growing in intra rows escaped weeding and incessant rains make the manual weeding impossible which resulted in an inefficient weed control situation and low seed cotton yield (Rajeswari and Charyulu, 1996).

The available post-emergence herbicides are mostly non-selective and even directed spray of some herbicides cause considerable crop damage. So, there is an ample scope for controlling weeds with the application of early post-emergence herbicide. This necessitates the development and testing of selective early post emergence herbicides for weed control in cotton. Under these circumstances, Roundup Ready Flex (RRF) Bollgard
II cotton hybrid which is resistant to both bollworms and glyphosate would be an added advantage to the cotton growers. This new technology is likely to reduce the cost of production and insecticide application by providing an effective alternative to chemical insecticides for control of *Helicoverpa armigera* (Huang *et al.,* 2002).

With these in view, evaluation of weed control efficiency and yield of glyphosate resistant cotton hybrids has been taken up during winter season (August sowing) of 2009 and 2010 .

Materials and Methods

The research was conducted with glyphosate resistant cotton hybrids during winter season of 2009-10 and 2010-11 at experimental site of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. Trial was conducted in soil with sandy clay loam type of soil and the soil is medium in organic carbon content and the available nutrient status is low in nitrogen, medium range of phosphorus and the potassium status is high.

The experiment was laid out in a randomized block design replicated thrice with the following treatments,

T_1 - Potassium salt of glyphosate 900 g a.e. / ha

T_2 - Potassium salt of glyphosate 1350 g a.e. / ha

T_3 - Potassium salt of glyphosate 1800 g a.e. / ha

T_4 - Potassium salt of glyphosate 2700 g a.e. / ha

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T_5 - Potassium salt of glyphosate 3600 g a.e. / ha

T_6 - Potassium salt of glyphosate 5400 g a.e. / ha

T_7 - HW on 15 and 30 DAS and Earthing up on 45

DAS T_8 - Unweeded check

Note : Potassium salt of glyphosate containing 500 g a.e / l

(T_1-T_6) - Application of glyphosate on twice at 25 DAS and 65 DAS

Test hybrid - MRC 7347 BG-II

RRF **Results and Discussion**

Predominant weed flora of the experimental field

Weed flora of the experimental field predominantly consisted of twelve species of broad-leaved weeds, five species of grasses and a sedge weed. Dominant among grassy weeds were *Dactyloctenium aegyptium* Beauv. and *Cynodon dactylon* (L.) Pers. *Trianthema portulacastrum* (L.), *Cleome gynandra* (L.), *Digera arvensis* (Forsk) and *Parthenium hysterophorus* (L.) were the dominant ones among the broad-leaved weeds. *Cyperus rotundus* (L.) was the only sedge present in the experimental fields.

During winter 2009-10, before herbicide spray, broad leaved weeds dominated the weed flora recording 89.2 per cent and it was followed by grasses (6.37 per cent) and sedge (4.43 per cent) (Table 1). With regard to the dominance of weed species during winter 2010 -11, before first spraying of glyphosate, broad leaved weeds dominated recording 93.20 per cent, and this was followed by sedge (5.67 per cent) and then grasses (1.13 per cent).

With respect to individual weed species during both the years, density of *Trianthema portulacastrum* recorded about 80 per cent before first spraying of glyphosate. Higher weed flora composition registered during both the years might be due to adequate rainfall during cropping period favoured a conducive field environment for weed growth.

Table 1. Absolute density (AD) and relative density of predominant weed species in herbicide tolerant transgenic cotton before first herbicide spray (25 DAS)

Weeds	Winter, 2009-10		Winter, 2010-11	
	AD (No./m^2)	RD (%)	AD (No./m^2)	RD (%)
Grasses				
Dactyloctenium aegyptium	5.72	4.75	1.33	1.13
Other grasses	1.95	1.62	0.00	0.00
Total grasses	7.67	6.37	1.33	1.13
Sedges				
Cyperus rotundus	5.33	4.43	6.67	5.67
BLW				
Trianthema portulacastrum	80.00	66.48	87.00	73.94
Parthenium hysterophorus	0.67	0.56	2.00	1.70
Cleome gynandra	4.67	3.88	4.00	3.40
Digera arvensis	14.0	11.64	10.67	9.07
Other BLW	7.99	6.640	6.00	5.10
Total BLW	107.33	89.20	109.67	93.20
Total weed density	120.33	100.00	117.67	100.00

Data not statistically analysed

Dactyloctenium aegyptium, Cynodon dactylon, *Cyperus rotundus, Trianthema portulacastrum*, *Parthenium hysterophorus* and *Digera arvensis* were the dominant weed flora in the experimental field which caused a lot of management problems during both the seasons. The results are in line with the findings of Gnanavel and Babu (2008) who have reported that *Cyperus rotundus* L., *Cynodon dactylon* and *Trianthema portulacastrum* were the most common weeds which compete with cotton and could assimilate biomass faster than cotton.

Weed control efficacy

The total weed density was significantly altered by different weed control treatments during both the years. Before first spraying of herbicide, lower density of total weeds were recorded in hand weeding. Whereas, at 10 and 25 days after herbicide spraying, glyphosate at 2700, 3600 and 5400 g a.e. ha^{-1} registered significantly lower total weed density, which were also comparable with hand weeding twice. Lower doses of glyphosate at 900, 1350 and 1800 g a.e. ha^{-1} did not prove effective in controlling total weeds (Table 2).

At 25 days after first herbicide spraying, application of glyphosate at 5400, 3600 and 2700 g a.e. ha^{-1} recorded lower weed dry weight (Table 4) due to better control of weeds at critical stage (50 DAS) of crop growth during winter 2009-10 and 2010-11, in herbicide tolerant transgenic cotton.

Considerable reduction in the density of grasses, sedge and broad leaved weeds were observed under glyphosate at 5400, 3600 and 2700 g a.e. / ha . Wilcut *et al*. (1996) who has also reported that, glyphosate controlled a broad spectrum of annual and perennial grasses, sedge, and broadleaf weeds and might be a viable alternative to other commonly used herbicides. Glyphosate applied at lower doses not effective in controlling sedge weed, *Cyperus rotundus* and some broad leaved weeds like *Parthenium hysterophorus* and *Commelina benghalensis*. Koger and Reddy (2005) also found that glyphosate provided marginal or no control of weeds such as Bermuda grass (*Cynodon dactylon* (L.) Pers.), hemp dogbane (*Apocynum cannabinum* L.), hemp *Sesbania*, *Ipomoea* species, horse nettle (*Solanum carolinense* L.) and tropical spiderwort (*Commelina benghalensis* L.).

Glyphosate applied at two stages like 25 and 65 DAS in glyphosate tolerant transgenic cotton. Earlier reports by Tingle *et al*. (2003) suggested the most significant weed interference occurred during the first eight weeks after cotton emergence and a linear decrease in cotton yield could be expected with increasing weed densities. In this view, first glyphosate spray controlled early season weeds and the second glyphosate spray controlled weeds

Table 2. Effect of glyphosate application on total weed density in herbicide tolerant transgenic cotton

Treatment	Total weed density (No. m-2)					
	Winter, 2009-10			Winter, 2010-11		
	First spray (25 DAS)			First spray (25 DAS)		
	Before spray	10 DAHS	25 DAHS	Before spray	10DAHS	25 DAHS
T_1 - Gly. 900 g a.e. ha-1	11.04	5.59	3.31	10.62	5.46	3.99
	(120.3)	(29.3)	(9.00)	(111.7)	(28.0)	(14.0)
T_2 - Gly. 1350 g a.e. ha1	10.91	5.44	2.94	10.62	4.67	3.74
	(117.3)	(28.0)	(6.67)	(112.0)	(20.0)	(12.0)
T_3 - Gly. 1800 g a.e. ha-1	10.95	5.73	2.43	10.64	3.99	2.94
	(118.0)	(31.3)	(4.00)	(112.0)	(14.0)	(6.67)
T_4 - Gly. 2700 g a.e. ha-1	10.98	4.22	2.00	10.97	4.21	2.23
	(118.7)	(16.0)	(2.00)	(119.0)	(16.0)	(3.00)
T_5 - Gly. 3600 g a.e. ha-1	11.25	4.61	1.80	10.97	4.23	1.80
	(124.7)	(19.3)	(1.33)	(119.0)	(16.0)	(1.33)
T_6 – Gly. 5400 g a.e. ha-1	11.42	4.29	1.41	10.86	3.56	1.41
	(128.7)	(17.3)	(0.00)	(116.7)	(10.7)	(0.00)
T7- HW on 15 & 30 DAS	5.73	4.94	5.46	5.12	6.25	6.53
	(30.7)	(27.3)	(28.00)	(26.03)	(37.3)	(40.7)
T8 - Unweeded check	10.82	11.82	10.60	10.90	10.98	11.01
	(120.3)	(136.0)	(110.7)	(117.7)	(118.7)	(119.3)
SEd	0.51	0.46	0.32	0.36	0.28	0.30
CD (P=0.05)	1.10	0.96	0.68	0.76	0.60	0.62

Figures in the parenthesis are original values DAHS – Days after herbicide spray

up to harvest. The greatest benefit 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).

During winter 2009-10, at 10 days after first spraying of herbicide, higher weed control efficiency of 97.48 per cent was recorded in glyphosate at 5400 g a.e. ha-1 (Table 3). Lower weed control efficiency (86.94 per cent) was noted with glyphosate at 900 g a.e. ha-1. At 25 days after first spraying, higher weed control efficiency (98.41 per cent) was observed with glyphosate at 3600 g a.e. ha-1 followed by glyphosate at 2700 and 5400 g a.e. ha-1 which resulted with more than 98 per cent of WCE. During second spraying of glyphosate also, higher weed control efficiencies of 98.96 and 99.70 per cent were recorded with glyphosate at 5400 g a.e. ha-1 at 10 and 25 days after second spraying, respectively. Hand weeding twice recorded lower weed control efficiency of 73.96 and 71.24 at 10 and 25 days after herbicide spraying, respectively. Glyphosate at 2700 and 3600 g a.e. ha-1 were the next superior

Table 3. Effect of different weed management methods on weed control efficiency (per cent) in herbicide tolerant transgenic cotton

Treatment	Weed control efficiency (%)							
	Winter, 2009-10				Winter, 2010-11			
	1st spray (25 DAS)		2nd spray (65 DAS)		1st spray (25 DAS)		2nd spray (65 DAS)	
	10 DAHS	25 DAHS	10 DAHS	25 DAHS	10DAHS	25DAHS	10DAHS	25DAHS
T_1 - Gly. 900 g a.e. ha-1	86.94	93.36	91.11	92.79	88.68	91.27	88.28	92.33
T_2 - Gly. 1350 g a.e. ha1	91.51	95.02	94.38	95.95	89.06	92.44	91.16	95.96
T - Gly. 1800 g a.e. ha-1	92.35	97.97	97.08	98.16	92.25	95.12	95.49	98.00
T - Gly. 3600 g a.e. ha-1	95.54	98.41	98.44	98.75	94.80	97.34	97.75	98.83
I6 - Gly. 5400 g a.e. ha-1	97.48	100.0	98.96	99.70	95.83	97.81	98.59	99.54
T - HW on 15 & 30 DAS	94.98	95.48	73.96	71.24	80.21	74.91	55.48	56.67
T87 - Unweeded check	-	-	-	-	-	-	-	-

Data not statistically analysed ; DAHS – Days after herbicide spray

treatments in recording higher weed control efficiencies of 98.55 and 98.75 percent at 25 days after second spraying of herbicide.

Weed control efficiency at 10 and 25 days after first spraying of glyphosate was higher with 95.83 and 97.81 per cent in glyphosate at 5400 g a.e. ha-1 during winter 2010-11 (Table 3). During both the stages of observation, hand weeding twice accounted lower weed control efficiency of 80.21 and 74.91 per cent. Like first spray, in second spraying also higher weed control efficiency (98.59 and 99.54 per cent) was recorded with glyphosate at 5400 g a.e. ha-1 and lower weed control efficiency (55.48 and 56.67 per cent) was obtained with hand weeding twice at 10 and 25 days after second spraying of herbicide.

Cotton productivity is mainly decided by the weed control efficiency of weed management methods as earlier observed by Grichar *et al*. (2004) who have noted that, trends in cotton yield recorded through weed control, which was further proved through glyphosate application system provided 96

Table 4. Effect of weed control methods total weed dry weight at 25 days after first herbicide spray and seed cotton yield in transgenic cotton

Treatment	Winter, 2009-10		Winter, 2010-11	
	Total weed dry weight ($g.m^{-2}$)	Seed cotton yield (kg / ha)	Total weed dry weight ($g.m^{-2}$)	Seed cotton yield (kg / ha)
T_1 - Gly. 900 g a.e. ha^{-1}	2.57 (4.58)	2607	2.80 (5.28)	2470
T_2 - Gly. 1350 g a.e. ha^{1}	2.33 (3.43)	2841	2.65 (5.08)	2575
T_3 - Gly. 1800 g a.e. ha^{-1}	1.84 (1.26)	2984	2.29 (2.92)	2846
T_4 - Gly. 2700 g a.e. ha^{-1}	1.77 (1.03)	3195	2.11 (2.21)	3092
T_5 - Gly. 3600 g a.e. ha^{-1}	1.76 (1.00)	3114	1.92 (1.58)	3023
T_6 - Gly. 5400 g a.e. ha^{-1}	1.41 (0.00)	2849	1.85 (0.22)	2753
T_7- HW on 15 & 30 DAS	2.26 (3.12)	2504	4.34 (17.0)	2323
T_8 - Unweeded check	8.42 (69.0)	839	8.36 (67.9)	713
SEd	0.25	157.8	0.21	144.2
CD (P=0.05)	0.45	322.6	0.44	286.3

Figures in the parenthesis are original values

per cent control of weeds, producing greater than 950 kg ha^{-1} of seed lint cotton.

Seed cotton yield

During both the years of study, among the treatments, glyphosate at 2700 g a.e. ha^{-1} recorded the higher seed cotton yield of 3195 and 3092 kg ha^{-1} during winter 2009-10 and 2010-11, respectively. This was followed by glyphosate at 3600 g a.e. ha^{-1} (3114 and 3023 kg ha^{-1}) and glyphosate at 1800 g a.e. ha^{-1} (2984 and 2846 kg ha^{-1}) registering higher seed cotton yields during first and second year of study, respectively. However these above said treatments did not differ significantly with glyphosate at 2700 g a.e. ha^{-1} in recording higher seed cotton yield.

Treatments such as glyphosate at 900, 1350 and 5400 g a.e. ha^{-1} recording comparatively lesser seed cotton yields than other doses, but were comparable to hand weeding twice. Whereas, unweeded control recorded lower seed cotton yield of 839 and 713 kg ha^{-1} with first and second years, respectively. Increased use of transgenic cotton with herbicide and pest resistance has resulted in more efficient insect and weed management practices.

Higher yield of herbicide tolerant transgenic cotton recorded with glyphosate at 2700 g a.e. ha^{-1} over hand weeding twice (21.6 per cent) and (24.9 per cent) and unweeded control (73.7 per cent) and (76.9 per cent) during winter 2009-10 and winter 2010-11, respectively. 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. As reported by Scroggs *et al*. (2007), seed cotton yield was maximized with the glyphosate POST program that included three applications of glyphosate and also stressed the importance of early-season weed control as well as controlling weeds late in the season. From the results of the field experiments, it could be concluded that post emergence spraying of potassium salt of glyphosate at 2700 g a.e. ha^{-1} twice on 25 and 65 DAS for complete control of broad spectrum weeds with higher seed cotton yield in herbicide tolerant transgenic cotton during winter season.

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Received: May 14, 2012; Revised: July 4, 2012; Accepted: September 15, 2012