International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(5): 1569-1572

Received: 01-07-2017
Accepted: 02-08-2017

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Assessment of nutrient removal by weeds and grain yield of transgenic maize and its counterpart hybrids under herbicidal weed control programmes

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Abstract
Field studies were conducted during *kharif* 2009 and *rabi* 2009-10 at Tamil Nadu Agricultural University, Coimbatore to assess the nutrient removal by weeds and uptake by transgenic stacked maize hybrids and its counter parts under various weed control programmes. Treatments consisted of two transgenic hybrids named Hishell and 900 M Gold applied with glyphosate as early post emergence application (POE) at 900, 1800 and 3600 g a.e ha^{-1} compared with its counterpart hybrids applied with pre-emergence (PE) atrazine at 0.5 kg ha^{-1} followed by one hand weeding (HW) on 40 DAS. Among the treatments, maximum nutrient uptake by maize, higher grain yield and lower nutrient removal by weeds with glyphosate at 1800 g a.e ha^{-1} in transgenic 900 M Gold and glyphosate at 3600 g a.e ha^{-1} in transgenic Hishell were recorded during *kharif* and *rabi*, respectively.

Keywords: transgenic maize, nutrient removal, nutrient uptake, yield

Introduction
Maize is the third most important cereal food crop of India after rice and wheat and is cultivated in an area of 8.11 million ha with a production of 19.77 million tonnes, nearly 28 per cent of maize produced is used for food purpose, 11 per cent as livestock feed, 48 per cent as poultry feed, 12 per cent in wet milling industry for starch and oil production and 1per cent as seed (DMR, 2008) [1]. Removal of nutrients by weeds from soil solution affects the nutrient availability for the crop, thus affecting its accumulation of dry matter (Sreenivas and Satyanarayana, 1996) [2]. Tollenaar *et al.* (1997) [3] reported that, under limiting nitrogen conditions, maize yield was reduced due to weeds by 47 per cent but, under higher levels of N, the reduction was only 14 per cent. Balasubramanian and Veerabadran (1998) [4] reported that reduction in nutrient removal by weeds through suitable weed management practices enhanced the nutrient uptake, dry matter production and grain yield of crop. Similarly, weeds removed 35.3 kg of N, 4.9 kg of P and 29.2 kg of K ha^{-1} in maize (Saikia and Pandey, 1999) [5]. Sinha *et al.* (2000) [6] reported that nutrient depletion by weeds was minimum under hand weeding while it was maximum (23.18 kg N, 4.92 kg P and 27.83 kg K ha^{-1}) under unweeded control in maize in the calcareous soils of North Bihar. Rajcan and Swanton (2001) [7] stated that little informations were known about the P and K interaction effects on the influence of weed competition with maize but the occurrence of processes similar to those occurring with nitrogen is likely. The extent of nutrient loss varied from 30 to 40 per cent of the applied nutrients in maize with presence of weeds (Mundra *et al*., 2002) [8]. Reduction in the N uptake by weeds under maize based intercropping system. Nitrogen deficiency symptoms develop earlier in maize infested with weeds than in maize kept weed-free. This would imply in soil Ndepletion in maize grown with weeds, since maize yield reductions due to weeds are lower under high nitrogen rates than under lower rates (Silva *et al.*, 2004) [9]. Nutrient depletion by weeds was significantly higher (22.76 kg N, 4.83 kg P and 27.32 kg K ha^{-1}) in winter maize (Sinha *et al*., 2005) [10].
Transgenic stack hybrid maize (MON 89034 X NK603) was developed for preventing yield losses of maize crop due to pests and weeds and to improve productivity. The stacked maize crop having both insect protection and herbicide tolerant traits will provide protection to the crop from target pests and also provide tolerance to glyphosate herbicide.

MON 89034 is second generation Bt corn technology effective against lepidopteron insect pests with a unique and innovative dual mode of action. NK 603 is the glyphosate tolerant technology for the effective weed management system. The plants become tolerant to the herbicide while weed flora are suppressed after application of herbicide. Hence, field experiments were carried out to evaluate the nutrient removal by weeds and uptake, yield by transgenic stacked maize hybrids and its counterpart hybrids.

Materials and Methods

The research was conducted with glyphosate resistant maize hybrids during kharif 2009 and rabi 2009-2010 seasons at experimental site of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. The experiment was laid out in randomized complete block design (RBD) with sixteen treatments and replicated thrice. Treatments consisted of post emergence application of glyphosate at 900, 1800 and 3600 g a.e/haat 2 - 4 leaf stage of weeds (approximately 25 Days After Sowing of transgenic maize hybrids) in transgenic maize hybrids. In non-transgenic maize hybrids viz., Hishell, 900 M Gold, COHM 5 (local test hybrid) and Proagro (national test hybrid) with pre-emergence application of atrazine 0.5 kg/ha at 3 Days After Sowing (DAS) followed byone hand weeding (HW) at 40 DAS along with insect control was done by whorl application of carbofuran at 1.0 kg a.i/ha at 20 DAS.

Observations

Nutrient status: The oven dried crop and weed samples were powdered and analyzed for nutrient contents. Nitrogen, phosphorus and potassium uptake by crops and removal by weeds were expressed in kg ha^{-1}. The plant samples for N, P and K were analysed as per the standard procedures (Humphries, 1956; Jackson, 1973) [11, 12].

Grain yield: Grain yield in each net plot was weighed at 12 percent moisture level and expressed in kg ha^{-1}. The maize Stover in the net plot area was cut, sun dried and the weight was recorded in t ha^{-1}.

Statistical Analysis: The data were statistically analysed following the procedure (Gomez and Gomez, 2010) [13] for randomized block design. The data pertaining to weeds were transformed to square root scale. Whenever significant difference existed, critical difference was constructed at five per cent probability level. Such of those treatments where the difference are not significant are denoted as NS.

Results

Weed flora

Weed flora of the experimental fields consisted of predominantly ten species of broad leaved weeds, five species of grassy weeds and a sedge weed. The predominant broad leaved weeds were *Trianthema portulacastrum*, *Cleome gynandra*, *Boerhavia diffusa*, *Digera arvensis* and *Cyanotis axillaris*. Among the grassey weeds, *Cynodon dactylon* and *Dactyloctenium aegyptium* were dominant. *Cyperus rotundus* was the only sedge weed found in the experimental fields.

Nitrogen removal by weeds

Significant variation in N depletion by weeds was observed among different weed management practices in both the seasons. In *kharif* 2009, at 20 DAS, PE application of atrazine at 0.5 kg ha^{-1}*fb* HW in non-transgenic hybrid Proagro (T_{13}) and other non-transgenic maize hybrids were markedly reduced the N removal by weeds compared to other weed management practices. At 40 DAS, lesser N removal was recorded under transgenic 900 M Gold applied with POE glyphosate at 3600 g a.e ha^{-1} (T_6) and was comparable with other POE application of glyphosate at different levels in transgenic Hishell and in 900 M Gold with 900 and 1800 g a.e ha^{-1}. This was followed by PE application of atrazine at 0.5 kg ha^{-1}*fb* HW in non-transgenic maize hybrids. Whereas, at 60 DAS, POE application of glyphosate at 3600 and 1800 g a.e ha^{-1}in both the transgenic hybrids recorded lesser N removal. This was closely followed by POE application of lower dose of glyphosate in same hybrids (T_1 and T_4). Unweeded checks recoded with higher nitrogen removal by weeds at all stages (Table 1).

In *rabi*2009-10, at 20 DAS, PE of atrazine at 0.5 kg ha^{-1}*fb* HW in non-transgenic 900 M Gold (T_{10}) recorded significantly lesser nitrogen removal. This was comparable other non-transgenic hybrids with same treatment. Nitrogen removal by weeds at 40 DAS was lesser in both the transgenic hybrids applied with POE glyphosate at 3600 g a.e ha^{-1} (T_3 and T_6) and was comparable with POE application of glyphosate at 1800 g a.e ha^{-1} under same hybrids. this was closely followed lower dose of glyphosate application in both transgenic maize hybrids (T_1 and T_4). Whereas, at 60 DAS, POE application of glyphosate at 3600 and 1800 g a.e ha^{-1} under both the transgenic hybrids recorded lesser nitrogen removal by weeds. This was followed by lower dose of glyphosate under both transgenic maize hybrids (T_1 and T_4) and PE application of atrazine at 0.5 kg ha^{-1}fb HW in non-transgenic Hishell (T_7) and Proagro (T_{13}). Unweeded check plots recorded with higher nitrogen removal by weeds at all stages of observation (Table 1).

Phosphorus removal by weeds

Weed control methods caused significant variation in P uptake by weeds in maize. During *kharif* 2009, significantly lesser amount of phosphorus was removed by weeds with application of PE atrazine at 0.5 kg ha^{-1}*fb* HW in Proagro (T_{13}) and other non-transgenic maize hybrids with same treatment (T_7, T_{10} and T_{15}). At 40 DAS and 60 DAS, POE application of glyphosate at 3600 g a.e ha^{-1} in transgenic 900 M Gold maize hybrid reduced the P uptake by weeds and was comparable POE application of glyphosate at different rates in transgenic Hishell and 900 M Gold maize hybrids. This was followed by PE application of atrazine at 0.5 kg ha^{-1}fb HW in non-transgenic maize hybrids. However, similar trend of P removal by weeds were recorded during *rabi* 2009-10 as that of *kharif* 2009 at all stages of observations (Table 2).

Potassium removal by weeds

PE atrazine at 0.5 kg ha^{-1}*fb* HW in CoHM 5 (T_{15}) maize hybrid significantly reduced the potassium removal by weeds. The same treatment applied in other non-transgenic hybrids also registered significantly lesser and comparable amount of K removal by weeds. Whereas, at 40 DAS and 60 DAS, POE application of glyphosate at 3600 g a.e ha^{-1} recorded lesser K uptake by weeds under transgenic 900 M Gold. This was comparable with different rated of glyphosate applied as POE in transgenic Hishell and 900 M Gold. The next best treatment was PE application of atrazine at 0.5 kg ha^{-1}*fb* HW in all non-transgenic hybrids. The similar trend was also observed under both transgenic and non-transgenic hybrids with various weed control treatments during *rabi*, 2009-10 (Table 3).

Table 1: Nitrogen (kg ha^{-1}) removal by weeds as influenced by different weed management practices in maize

Treatments	Kharif, 2009			Rabi, 2009-10		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1 - T. Hishell POE glyphosate @ 900 g ha^{-1}	10.07	1.63	3.38	9.16	4.75	4.97
T_2 - T. Hishell POE glyphosate @ 1800 g ha^{-1}	11.42	0.69	2.00	10.05	2.21	1.49
T_3 - T. Hishell POE glyphosate @ 3600 g ha^{-1}	8.92	0.37	0.75	10.51	0.98	0.65
T_4 - T. 900 M Gold POE glyphosate @ 900 g ha^{-1}	10.56	2.03	4.00	7.98	5.29	4.40
T_5 - T. 900 M Gold POE glyphosate @ 1800 g ha^{-1}	9.74	0.84	2.29	11.06	2.05	1.59
T_6 - T. 900 M Gold POE glyphosate @ 3600 g ha^{-1}	10.09	0.19	0.66	8.96	0.78	0.30
T_7- Hishell PE atrazine @ 0.5 kg ha^{-1} + HW+ IC	4.75	16.06	6.94	3.52	11.63	5.52
T_8 - Hishell No WC and IC	10.25	25.85	29.60	11.01	18.86	26.76
T_9 - 900 M Gold PE atrazine @ 0.5 kg ha^{-1}+ HW+ IC	4.99	14.02	6.88	3.39	12.15	8.15
T_{10} - 900 M Gold No WC and IC	10.67	23.90	27.10	10.99	22.59	23.98
T_{11} - Proagro PE atrazine 0.5 @ kg ha^{-1} + HW+ IC	3.98	11.71	6.89	3.98	11.96	6.59
T_{12} - Proagro 4640 No WC and IC	13.98	22.99	28.12	10.58	20.95	25.54
T_{13} - CoHM 5 PE atrazine @ 0.5 kg ha^{-1} + HW+ IC	4.36	12.27	6.70	4.53	12.19	7.61
T_{14} - CoHM 5 No weeding & IC	13.59	21.83	26.06	9.88	18.58	23.08
SEd	1.4	1.3	1.21	0.98	1.12	1.17
CD (P=0.05)	2.82	2.64	2.43	1.96	2.27	2.36

Table 2: Phosphorus removal (kg ha^{-1}) by weeds as influenced by different weed management practices in maize

Treatments	Kharif, 2009			Rabi, 2009-10		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1 - T. Hishell POE glyphosate @ 900 g ha^{-1}	2.84	0.16	0.36	2.34	0.40	0.51
T_2 - T. Hishell POE glyphosate @ 1800 g ha^{-1}	2.28	0.06	0.23	2.36	0.24	0.18
T_3 - T. Hishell POE glyphosate @ 3600 g ha^{-1}	2.08	0.04	0.11	2.38	0.09	0.07
T_4 - T. 900 M Gold POE glyphosate @ 900 g ha^{-1}	2.02	0.17	0.40	1.73	0.63	0.57
T_5 - T. 900 M Gold POE glyphosate @ 1800 g ha^{-1}	3.01	0.10	0.33	2.27	0.17	0.18
T_6 - T. 900 M Gold POE glyphosate @ 3600 g ha^{-1}	1.74	0.02	0.09	2.90	0.10	0.03
T_7- Hishell PE atrazine @ 0.5 kg ha^{-1} + HW+ IC	0.74	1.72	0.84	0.75	2.19	0.97
T_8 - Hishell No WC and IC	2.14	3.38	3.15	2.95	3.77	3.37
T_9 - 900 M Gold PE atrazine @ 0.5 kg ha^{-1}+ HW+ IC	0.87	2.14	0.90	0.64	1.90	1.08
T_{10} - 900 M Gold No WC and IC	2.09	3.58	3.77	1.97	2.95	2.83
T_{11} - Proagro PE atrazine 0.5 @ kg ha^{-1} + HW+ IC	0.70	1.83	0.93	0.91	2.11	1.26
T_{12} - Proagro 4640 No WC and IC	1.94	2.69	3.04	2.74	3.33	2.89
T_{13} - CoHM 5 PE atrazine @ 0.5 kg ha^{-1} + HW+ IC	0.75	2.16	0.89	0.65	1.97	1.05
T_{14} - CoHM 5 No weeding & IC	3.30	3.34	3.31	2.10	2.69	2.81
SEd	0.31	0.18	0.34	0.24	0.15	0.36
CD (P=0.05)	0.62	0.36	0.68	0.48	0.56	0.72

Table 3: Potassium removal (kg ha^{-1}) by weeds as influenced by different weed management practices in maize and Grain yield (t ha^{-1})

Treatments	Kharif, 2009			Rabi, 2009-10		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1 - T. Hishell POE glyphosate @ 900 g ha^{-1}	10.98	0.82	1.61	9.95	2.62	2.78
T_2 - T. Hishell POE glyphosate @ 1800 g ha^{-1}	13.40	0.36	1.06	10.49	1.16	0.76
T_3 - T. Hishell POE glyphosate @ 3600 g ha^{-1}	9.77	0.23	0.55	11.88	0.55	0.42
T_4 - T. 900 M Gold POE glyphosate @ 900 g ha^{-1}	12.00	1.10	2.39	8.32	2.77	2.31
T_5 - T. 900 M Gold POE glyphosate @ 1800 g ha^{-1}	10.16	0.44	1.25	12.99	1.08	0.88
T_6 - T. 900 M Gold POE glyphosate @ 3600 g ha^{-1}	10.49	0.11	0.50	8.96	0.49	0.24
T_7- Hishell PE atrazine @ 0.5 kg ha^{-1} + HW+ IC	4.85	8.72	3.18	2.72	8.77	3.80
T_8 - Hishell No WC and IC	12.03	25.75	27.60	14.51	23.38	24.77
T_9 - 900 M Gold PE atrazine @ 0.5 kg ha^{-1}+ HW+ IC	5.30	8.25	3.54	2.62	8.56	4.47
T_{10} - 900 M Gold No WC and IC	12.89	28.49	27.78	12.91	22.50	24.75
T_{11} - Proagro PE atrazine 0.5 @ kg ha^{-1} + HW+ IC	4.90	9.16	4.32	3.31	8.42	5.08
T_{12} - Proagro 4640 No WC and IC	14.51	21.04	23.43	14.90	26.11	27.58
T_{13} - CoHM 5 PE atrazine @ 0.5 kg ha^{-1} + HW+ IC	3.27	8.80	4.19	2.82	8.58	4.57
T_{14} - CoHM 5 No weeding & IC	13.22	24.95	21.89	13.92	28.67	29.91
SEd	1.11	0.99	1.00	0.99	0.95	1.05
CD (P=0.05)	2.21	1.98	2.00	1.98	1.90	2.09

Discussion

Weeds usually grow faster than crop plants and thus absorb the available nutrients quickly resulting in inadequate supply of the nutrients to the crop. In transgenic maize hybrids, glyphosate at 3600 and 1800 g a.e ha^{-1} recorded lesser nitrogen, phosphorus and potassium removal. This might be due to lesser weed density and dry weight. The dry weight was another factor determining the nutrient removal by weeds. The findings are in line with the observation made by Gonzalez and Salas (1995) [14] who found that with 100 g m^{-1} dry weight, the uptake of nitrogen, phosphorus and potassium within the corn plant decreased by 14.6, 2.7 and 9.5 kg ha^{-1}, respectively. Similarly, season long weed control offered by

glyphosate, nutrient removal by weeds was reduced upto harvest of crop.

Whereas, in non-transgenic hybrids, the nutrient removal by weeds was checked from crop germination itself. PE application of atrazine effectively controlled the majority of geminated and germinating weeds. The final estimate of nutrient depletion by weeds at 60 DAS was reduced in the supplemental hand weeding at 40 DAS. Such positive effect was due to lower population and dry weight of weeds resulting from positive control. Absence of weed control in the critical stages of crop has resulted in more weed growth and nutrient removal by weeds, thus reduced the availability of nutrients to the crops that leads to lower growth and yield which was observed under unweeded controls. Kumar *et al.*, (2005) [15] concluded that pre-emergence application of atrazine recorded least weed weight, nutrient removal by weeds and highest grain yield and nutrient uptake by crop. Similarly, the weeds emerging with the crop competing with them for nutrients especially nitrogen, grow faster and utilize it in larger amounts than the crop, resulting in poor crop yield (Singh *et al.*, 2009) [16].

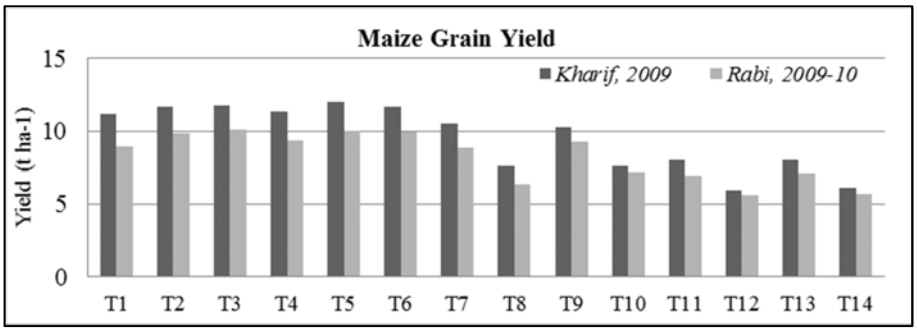

Fig 1: Effect of different weed management methods on Maize yield

The highest grain yield of maize was obtained with POE application of glyphosate at 1800 g a.e ha^{-1} in transgenic 900 M Gold (12.01 t ha^{-1}) and glyphosate at 3600 g a.e ha^{-1} in transgenic Hishell (10.12 t ha^{-1}) during *kharif* and *rabi* seasons, respectively (Fig. 1). This could be attributed to efficient control of weeds during the cropping period. The findings are in accordance with observation of Tharp *et al.* (1999) [17] who had earlier reported that maize yields of herbicide resistant hybrids were maximum with glyphosate at 0.84 kg ae ha^{-1} of glyphosate when applied at fifth leaf stage of maize.

Acknowledgement

The authors thank Monsanto India Pvt. Ltd., Mumbai for financial assistance rendered for carrying out the research work.

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