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Phytotoxic effects of glufosinate ammonium on cotton and soil micro-flora

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ABSTRACT

A field experiment was conducted at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India in *Kharif* season of 2016 and 2017 to evaluate the phytotoxicity of glufosinate ammonium 13.5% SL (15% w/v) on cotton and soil micro-flora and their consequent effects on crop growth, yield and economics. Findings depicted that there were no phytotoxic symptoms on cotton and there was better recovery of soil micro-flora population with the application of glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha, resulting in maximum growth, yield and economic profitability of cotton. However, prominent toxic effects of glufosinate ammonium 13.5% SL (15% w/v) on the crop and soil micro-flora were recorded at higher doses of 900 g/ha and 1800 g/ha, which significantly reduced cotton growth, yield and economic viability.

INTRODUCTION

Cotton (*Gossypium* sp.) is an important non-edible cash crop of India especially in north western, central and southern states. It plays a major role in Indian economy through amplifying textile industries. Globally, India is now at the first position in cotton cultivation with 12.24 mha area and 340.25 lakh bales of production (advance estimate for 2018-19 by Cotton Association of India 2019). This high value fibre crop due to its growing demand in textile sector, requires adequate attention for suitable cultivation practice in order to increase its productivity. It is disgrace to highlight that cotton growers in India are facing disparity between demand and supply of raw materials in textile sector due to lower productivity (506.07 kg/ha in 2017-18) as compared to global mean value (775 kg/ha) (Cotton Association of India 2019). Researchers are worried that India may lose its top position in cotton production to China in near future. While searching the reasons for such low yield of cotton, apart from climatic anomalies, infestations of pest and diseases have also received the spotlight. Recently, efforts are being made to improve productivity level through introduction of hybrid and Bt-cotton varieties by addressing the pest problems. However, weeds are still the major concern everywhere as they compete with crop for resources and make the crop vulnerable to insects and diseases by providing shelters for those harmful organisms and pathogens. If weeds are not checked on time, they may cause considerable or even full yield reduction of crop. Nandagavi and Halikatti (2016) highlighted that on an average, 40 to 85 % cotton yield can be reduced by weeds. Therefore, proper weed management practice is now the fundamental requisite for the cotton growers to address such drastic yield reduction. Quality is an important parameter for cotton which is also needed to be considered during advocating weed management practice.

Hand weeding/interculture by far is the best and common conventional practice to manage weeds and consequently to increase yield and quality of cotton crop. However, in the present scenario of labour shortage and frequent rise of wages coupled with its non-suitability for all agro-climatic conditions uniformly, this uneconomical weeding option is losing focus and alternative options are getting acceptance in its place. Chemical measures of weed control is now gaining popularity among farmers as it is quick, economical and effective way to destroy weeds and contribute higher crop yield (Prematilake *et al.* 2004, Mirghasemi *et al.* 2012). In cotton, among several herbicidal applications, a contact herbicide, glufosinate ammonium (synthetic version of phosphinothricin *i.e.* by-product of bialaphos from *Streptomyces viridochromogenes* and *S. hygroscopicus* as reported by Droge-Laser *et al.* in 1994) is now receiving high attention and getting widely used for successful management of wide range of weed flora

(Chompoo and Pornprom 2008) during critical crop-weed competition period. However, chemical formulations always leave footprint on crop and soil since they are toxic in nature. Residual toxicity depends on chemical structure, formulation, dose, time and way of application of herbicides. Phytotoxic effect of herbicide on crop *i.e.* visual symptoms of chlorosis, wilting, scorching, necrosis, epinasty, hyponasty, yellowing *etc*. and impairment of soil biological activity through toxic substances are the major obstacles in use of chemical measures of weed control as their consequent effect is associated with growth and yield of the crop. Considering the above facts, an experiment was executed to observe phytotoxic effects of glufosinate ammonium 13.5% SL (15% w/v) at different doses on cotton and soil micro-flora and their consequence on crop growth, yield and economics.

MATERIALS AND METHODS

The field experiment was conducted during 2016 and 2017 consecutively at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India in randomised block design with 4 treatments (glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha, glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha, glufosinate ammonium 13.5% SL (15% w/v) 1800 g/ha, and Control (weedy check) keeping 5 replications. Sowing of *'KCH-14K59 BGII'* cotton variety was done on 18th and 21st June respectively during 2016 and 2017 at a spacing of 60 cm x 30 cm and harvested on 25th and 27th November in respective years. Individual plot size was 5 x 4 m. $N:P_2O_5:K_2O$ 120: 60:60 kg/ha (50% of N through urea and 100% of P_2O_5 and K_2O through S.S.P. and M.O.P. respectively at basal and 50% N in 3 equal splits at 50, 80 and 110 days after sowing (DAS) were used in this study as crop nutrition. Herbicide glufosinate ammonium 13.5% SL (15% w/v) as treatment wise doses was subjected to early post-emergent spray at 2 days after emergence (DAE) through knapsack sprayer fitted with flat fan/flood jet nozzle with spray volume of 500 L/ha. Other agronomic and plant protection practices were followed as per the recommendations. Phytotoxic data such as yellowing of leaf tips and margins, chlorosis, wilting, hyponasty, epinasty and scorching were recorded at 1, 3, 5, 7 and 10 days after application (DAA) of herbicide through visual assessment of crop response, and levels of toxicity of herbicide at different doses were rated in the phytotoxicity rating scale (PRS) of 0-10. Ratings '0' and '10' indicate 'no visible injury' and 'complete destruction of the crop' respectively. Soil samples of 0-15 cm depth were also collected from experimental plots at different DAS and toxicity on soil rhizospheric micro-flora was analysed by counting aerobic non-symbiotic nitrogen fixing (25, 50, 75 DAS) and phosphate solubilizing (25, 50, 90 DAS) bacteria on agar plates as number of viable cells per gram of soil using Jensen's agar medium and Pikovskaia's agar medium respectively, through serial dilution technique, pour plate method (Pramer and Schmidt 1965) followed by incubation at 30°C. The counts were taken at 5th day of incubation. Observations on plant growth and yield such as plant height, no. of sympodial branches/plant, dry matter weight/plant, number of bolls/plant, boll weight and seed cotton yield were recorded at harvest and economics was calculated thereafter. For statistical analysis in standard statistical software, analysis of variance (ANOVA) method (Goulden 1952 and Cochran and Cox 1959) was used and comparison of treatment means was done for 5% level of significance using critical differences (CD) as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Phytotoxicity on cotton

Two years' experimental results delineated that there was no visible symptoms of yellowing, chlorosis, wilting, hyponasty/epinasty and scorching on cotton at 1, 3, 5, 7 and 10 DAA to exhibit phytotoxic effect of glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha. (**Tables 1 and 2**). However, phytotoxic effect of glufosinate ammonium 13.5% SL (15% w/v) on the crop became prominent at higher doses, *viz.* 900 g/ha and 1800 g/ha during both the years. As compared to glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha, visible symptoms of phytotoxicity during both 2016 and 2017 were more prominent when glufosinate ammonium 13.5% SL (15% w/v) 1800 g/ha was applied as weed control measure in cotton field. Specifically, based on the phytotoxicity rating scale (PRS), application of glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha imposed 0-20% phytotoxic visible symptoms of yellowing, chlorosis and wilting; 0-30% of scorching during both the years and 0-10% and 0-30% of hyponasty/epinasty in 2016 and 2017, respectively. While application of glufosinate ammonium 13.5% SL (15% w/v) 1800 g/ha induced 1-60% and 1-50% yellowing; 1-50% and 1-60% chlorosis; 1-40% and 1-50% wilting; 1-40% and 1-60% hyponasty/epinasty and 11-60% and 1-60% scorching respectively during 2016 and 2017. Prominent phytotoxic effects of glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha and 1800 g/ha on cotton were

Table 1. Phytotoxicity of glufosinate ammonium 13.5% SL (15% w/v) on cotton plants in 2016

Treatment	Yellowing DAA					Chlorosis DAA					Wilting DAA					Hyponasty/Epinasty DAA					Scorching DAA				
	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10
Glufosinate ammonium 13.5% SL (15% w/v)450 g/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha	0	1	2	2	2	0	1	2	2	2	0	1	1	2	2	0	1	1	1	1	0	2	3	3	3
Glufosinate ammonium 13.5% SL (15% w/v) 1800 g/ha	1	3	5	5	6	1	2	5	5	5	1	2	4	4	4	1	2	4	4	4	2	5	6	6	6
Control (weedy check)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. Phytotoxicity of glufosinate ammonium 13.5% SL (15% w/v) on cotton plants in 2017

Treatment	Yellowing DAA					Chlorosis DAA					Wilting DAA					Hyponasty/Epinasty DAA					Scorching DAA				
	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10
Glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha	0	2	2	2	2	0	1	1	2	2	0	1	1	2	2	0	1	1	2	3	0	2	2	3	3
Glufosinate ammonium 13.5% SL (15% w/v) 1800 g/ha	1	3	4	5	5	1	3	4	5	6	1	2	5	5	5	1	3	5	5	6	1	4	5	6	6
Control (weedy check)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3. Toxicity of glufosinate ammonium 13.5% SL (15% w/v) on soil micro-flora in 2016

Treatment	Non-symbiotic Nitrogen fixing bacteria (CFU x 10^4/g of soil)			Phosphate- solubilizing bacteria (CFU x 10^4/g of soil)		
	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	90 DAS
Glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha	25.16	66.73	86.64	9.67	31.48	49.82
Glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha	26.12	54.87	77.87	8.34	27.54	43.87
Glufosinate ammonium 13.5% SL (15% w/v) 1800 g/ha	21.44	46.76	61.78	6.89	20.61	35.16
Control (weedy check)	33.11	38.11	52.76	12.19	16.27	28.62

gradually noticed from 1 DAA to 3, 5, 7, 10 DAA and afterwards. Control (weedy check) plot did not show any visible crop injury as it was kept apart from herbicidal application.

Phytotoxicity of glufosinate ammonium 13.5% SL (15% w/v) at higher doses (900 g/ha and 1800 g/ha) on cotton through spray drift and root uptake from soil were prominent due to the non-selective, contact nature of the herbicide with some extent of systemic action. Glufosinate ammonium 13.5% SL (15% w/v) blocks glutamine synthetase, an enzyme that converts glutamate and ammonia into glutamine and plays important role in nitrogen metabolism in plant. Applications of glufosinate ammonium 13.5% SL (15% w/v) specially at higher doses thus increase NH_4^+ concentration in plant (Mersey *et al.* 1990) resulting in cell membrane leakage, wilting, scorching, chlorosis, hyponasty/epinasty, yellowing of leaves etc. Inhibition of glutamine synthetase also undergoes disturbance in electron transport system and production of free radicals resulting in lipid peroxidation and cell death (Hess 2000). Further, ammonium toxicity in plant cells functions as uncoupler of photophosphorylation which in turn inhibits CO_2 assimilation (Kocher 1983). You and Barker (2002) also observed phytotoxicity of glufosinate ammonium at higher doses in tomato plants.

Toxicity on soil micro-flora

Toxicities of glufosinate ammonium 13.5% SL (15% w/v) on soil rhizospheric micro-flora, *viz*. aerobic non-symbiotic nitrogen fixing and phosphate-solubilizing bacteria were observed during both the years at various doses of application (**Table 3 and 4**). Initially, as compared to control (weedy check) where no herbicide was applied (non-symbiotic nitrogen fixing bacteria at 25 DAS: 33.11 CFU x 10^4/g of soil in 2016 and 32.21 CFU x 10^4/g of soil in 2017; phosphate-solubilizing bacteria at 25 DAS: 12.19 CFU x 10^4/g of soil in 2016 and 10.97 CFU x 10^4/g of soil in 2017), there were noticeable reductions of soil micro-flora population with the application of the herbicide 450 g/ha (non-symbiotic nitrogen fixing bacteria at 25 DAS: 25.16 CFU x 10^4/g of soil in 2016 and 23.96 CFU x 10^4/g of soil in 2017; phosphate-solubilizing bacteria at 25 DAS: 9.67 CFU x 10^4/g of soil in 2016 and 8.45 CFU x 10^4/g of soil in 2017), 900 g/ha, (non-symbiotic nitrogen fixing bacteria at

25 DAS: 26.12 CFU x 10^4/g of soil in 2016 and 24.98 CFU x 10^4/g of soil in 2017; phosphate-solubilizing bacteria at 25 DAS: 8.34 CFU x 10^4/g of soil in 2016 and 7.11 CFU x 10^4/g of soil in 2017) and 1800 g/ha (non-symbiotic nitrogen fixing bacteria at 25 DAS: 21.44 CFU x 10^4/g of soil in 2016 and 20.32 CFU x 10^4/g of soil in 2017; phosphate-solubilizing bacteria at 25 DAS: 6.89 CFU x 10^4/g of soil in 2016 and 5.79 CFU x 10^4/g of soil in 2017). However, from 25 DAS onwards, toxic effects of glufosinate ammonium 13.5% SL (15% w/v) gradually faded away and recoveries of bacterial population were observed. It might be due to the fact that after initial catastrophe, soil microbes bounced back not only through degradation of herbicidal compound into its half-life (Bera and Ghosh 2013) but also obtaining carbon based substrates from the degraded herbicide for their developments, physiological processes and multiplications. As compared with other doses (*i.e.* 900 g/ha and 1800 g/ha) of glufosinate ammonium 13.5% SL (15% w/v), better and faster recoveries were noticed from the plot where it was applied 450 g/ha (non-symbiotic nitrogen fixing bacteria: 66.73 CFU x 10^4/g of soil in 2016 and 65.31 CFU x 10^4/g of soil in 2017 at 50 DAS and 86.64 CFU x 10^4/g of soil in 2016 and 85.24 CFU x 10^4/g of soil in 2017 at 75 DAS; phosphate-solubilizing bacteria: 31.48 CFU x 10^4/g of soil in 2016 and 30.28 CFU x 10^4/g of soil in 2017 at 50 DAS and 49.82 CFU x 10^4/g of soil in 2016 and 48.72 CFU x 10^4/g of soil in 2017 at 90 DAS). It indicated that toxicity of herbicide on soil did not last long at lower dose (*i.e.* 450 g/ha) and soil micro flora population again started to increase in short period of time. Persistence of herbicidal toxicity on soil and slow recoveries of bacterial population were however noted at higher doses of glufosinate ammonium 13.5% SL (15% w/v), specially with more pronounced effect at 1800 g/ha. High glufosinate ammonium 13.5% SL (15% w/v) toxicity immediately after application on soil and its residual toxicity persistence with the increment of dose were also reported by Ghosh *et al.* (2017) in tea.

Growth, yield attributes and yield of cotton

During both the years of experiment, phytotoxic effects of glufosinate ammonium 13.5% SL (15% w/v) at various doses on cotton and soil micro-flora in turn exhibited significant impacts on plant growth, yield attributes and yield (**Table 5**). Marked reductions of plant height, sympodial branches/plant, dry matter weight/plant, no. of bolls/plant, boll weight, and seed cotton yield were noticed with the increment of doses of glufosinate ammonium 13.5% SL (15% w/v) during 2016 and 2017 due to intensive build-up of phytotoxicity on crop and soil micro-flora.

Maximum growth in terms of plant height (84.7 cm in 2016 and 82.4 cm in 2017), sympodial branches/plant (16.3 in 2016 and 15.5 in 2017), dry matter weight/plant (146.5 g in 2016 and 141.3 g in 2017) was obtained with the application of glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha, followed by application of glufosinate

Table 4. Toxicity of glufosinate ammonium 13.5% SL (15% w/v) on soil micro-flora in 2017

Treatment	Non-symbiotic nitrogen fixing bacteria (CFU x 10^4/g of soil)			Phosphate- solubilizing bacteria (CFU x 10^4/g of soil)		
	25 DAS	50 DAS	75 DAS	25 DAS	50 DAS	90 DAS
Glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha	23.96	65.31	85.24	8.45	30.28	48.72
Glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha	24.98	53.67	76.57	7.11	26.24	42.75
Glufosinate ammonium 13.5% SL (15% w/v) 1800 g/ha	20.32	45.46	60.45	5.79	19.27	33.92
Control (weedy check)	32.21	36.91	51.56	10.97	15.07	27.38

Table 5. Growth, yield attributes and yield of cotton in 2016 and 2017

Treatment	Plant height (cm)		Sympodial branches/plant		Dry matter weight/plant (g)		No. of bolls/plant		Boll weight (g)		Seed cotton yield (t/ha)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha	84.7	82.4	16.3	15.5	146.5	141.3	28.02	25.70	4.14	3.25	1.97	1.89
Glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha	78.4	74.1	14.1	13.4	132.4	125.3	24.80	21.40	3.87	2.71	1.72	1.67
Glufosinate ammonium 13.5% SL (15% w/v) 1800 g/ha	71.8	68.3	12.3	11.8	121.7	115.9	19.60	16.30	3.43	2.34	1.51	1.43
Control (weedy check)	67.9	65.6	9.9	9.4	113.9	110.4	14.42	11.70	2.87	1.99	1.17	1.08
LSD (P=0.05)	3.15	2.92	0.78	0.50	4.55	4.23	1.62	1.06	0.16	0.11	0.13	0.13

ammonium 13.5% SL (15% w/v) 900 g/ha (plant height: 78.4 cm in 2016 and 74.1 cm in 2017; sympodial branches/plant: 14.1 in 2016 and 13.4 in 2017; dry matter weight/plant: 132.4 g in 2016 and 125.3 g in 2017) and lowest among herbicidal doses at 1800 g/ha (plant height: 71.8 cm in 2016 and 68.3 cm in 2017; sympodial branches/plant: 12.3 in 2016 and 11.8 in 2017; dry matter weight/plant: 121.7 g in 2016 and 115.9 g in 2017). Control (weedy check) resulted in lowest growth in all the mentioned attributes due to the rapid infestation of weeds competing with the crop for resources.

Yield attributes and yield of cotton also followed the identical trend of growth attributes under application of various doses of glufosinate ammonium 13.5% SL (15% w/v) during both the years of study. Highest no. of bolls/plant (28.02 in 2016 and 25.70 in 2017) and boll weight (4.14 g in 2016 and 3.25 g in 2017) were recorded where glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha was applied, followed by glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha (no. of bolls/plant: 24.80 in 2016 and 21.40 in 2017; boll weight: 3.87 g in 2016 and 2.71 g in 2017) and 1800 g/ha (no. of bolls/plant: 19.60 in 2016 and 16.30 in 2017; boll weight: 3.43 g in 2016 and 2.34 g in 2017). Consequently, seed cotton yield was also highest (1.97 t/ha in 2016 and 1.89 t/ha in 2017) with the application of glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha followed by glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha (1.72 t/ha in 2016 and 1.67 t/ha in 2017) and 1800 g/ha (1.51 t/ha in 2016 and 1.43 t/ha in 2017). Lowest no. of bolls/plant, boll weight and seed cotton yield were observed from control (weedy check). Lowest growth and yield of cotton due to weed infestation as in case of control (weedy check) was also reported by Anjum *et al.* (2007).

Increment of herbicidal dose imposed prominent phytotoxic effects on the crop and thus interfered with its internal metabolic processes and photosynthesis. Decrease of chlorophyll content through leaf yellowing, chlorosis, scorching etc. by non-selective herbicide spray drift and uptake from soil in turn decreased crop growth and thereby its yield through hampering photosynthetic process of dry matter production and partitioning. Interference of herbicidal phytotoxicity with chlorophyll content was also observed in different crops (Rao and Dubey 1983, Nandihalli and Bhowmik 1992, Singh *et al*. 1996, Kushwaha and Bhowmik 1999). De Snoo *et al.* (2001) also reported the phytotoxicity of glufosinate ammonium through spray drift and its consequent effects on growth and development of non-target vegetation. Further, impairment of plant nitrogen and phosphate nutrition through suppression of non-symbiotic nitrogen fixing and phosphate-solubilizing bacteria by toxic effects of glufosinate ammonium 13.5% SL (15% w/v) specially at higher doses (900 g/ha and 1800 g/ha) restricted cotton growth and yield as they play pivotal roles respectively, in nitrogen cycling (Zechmeister-Boltenstern 1996) and solubilisation and availability of inorganic phosphorus to the crop (Chen *et al.* 2006).

Economics

Production economics of cotton under different weed management options (**Table 6**) revealed that it was greatly influenced by phytotoxic effects of glufosinate ammonium 13.5% SL (15% w/v) at various doses on the crop and soil micro-flora. Maximum net returns (` 39,029/ha) and B:C (2.02) were obtained under application of glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha, which was followed by application of glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha (net returns: ` 28,429/ha and B:C of 1.72) and glufosinate ammonium 13.5% SL (15% w/v) 1800 g/ha (net returns: ` 17,029/ha and B:C of 1.41). Greater phytotoxicity of glufosinate ammonium 13.5% SL (15% w/v) at higher doses (*i.e.* 900 g/ha and 1800 g/ha) on cotton and soil beneficial micro-flora reduced the crop yields on one hand and incurred high mean cost of cultivations (` 39,371/ha and ` 41,771/ha, respectively) on the other through the use of high quantity of costly herbicide. Compared to others, glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha application was most profitable as less quantity of herbicide was applied (*i.e.* less cost of cultivation: ` 38,171/ha) and higher seed cotton yield was obtained due to no or negligible phytotoxic effects of

Table 6. Economics of cotton under different weed management options (mean of two years)

Treatment	Cost of cultivation ($x10^3$ `/ha)	Gross returns ($x10^3$ `/ha)	Net returns* ($x10^3$ `/ha)	B:C
Glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha	38.17	77.20	39.03	2.02
Glufosinate ammonium 13.5% SL (15% w/v) 900 g/ha	39.37	67.80	28.43	1.72
Glufosinate ammonium 13.5% SL (15% w/v) 1800 g/ha	41.77	58.80	17.03	1.41
Control (weedy check)	35.86	45.00	9.14	1.25

*Price of seed cotton in 2016 and 2017: ` 40,000/t.

the herbicide on crop and soil micro-flora. Control (weedy check) was economically atrophied (mean net return: ` 9,139/ha and B:C of 1.25) as no measure was taken to manage resource grabbing weeds and consequently crop could not express its natural yield. Higher dose of glufosinate ammonium 13.5% SL (15% w/v) *i.e.* 1800 g/ha was comparatively superior over weedy check in terms of yield and net return because of its high efficiency of suppressing dominant weed flora in the cotton field. However, considering the facts of significant phytotoxicity build up on cotton and soil biological health as well as higher cost of cultivation due to use of costly herbicide, farmers are advised not to go for application of such a high dose of herbicide when the same herbicide at low dose *i.e.* 450 g/ha has succeed to provide farmers best yield and highest economic viability (B:C).

Glufosinate ammonium 13.5% SL (15% w/v) 450 g/ha had shown no phytotoxicity symptom on cotton and negligible toxicity on soil micro-flora and thus it can be recommended as relatively a safe chemical for weed management in cotton in new alluvial zone of West Bengal, India for realising better growth, yield and economic profitability. But glufosinate ammonium 13.5% SL (15% w/v) at higher doses had toxic effects on cotton and soil micro-flora which consequently had affected crop growth, yield and economics.

REFERENCES

Anjum FH, Tanveer A, Tahir M, Nadeem MA and Ali A. 2007. Growth and yield response of *gossypium hirsutum* to plant spacing and *Trianthema portulacastrum* density. *International Journal of Agriculture and Biology* 1560–8530/2007/09–4–559–563.

Bera S and Ghosh RK. 2013. Soil Physico-chemical properties and microflora as influenced by bispyribac sodium 10% SC in transplanted *Kharif* Rice. *Rice Science* **20**(4): 298–302.

Chen YP, Rekha PD, Arun AB, Shen FT and Lai WA. 2006. Phosphate solubilizing bacteria from subtropical soil and their tricalcium phosphate solubilizing abilities. *Applied Soil Ecology* **34**(1): 33–41.

Chompoo J and Pornprom T. 2008. RT-PCR based detection of resistance conferred by an insensitive GS in glufosinate-resistant maize cell lines. *Pesticide Biochemistry and Physiology* **90**: 189–195.

Cochran WG and Cox GM. 1959. *Experimental Designs. Asia* Publishing House, Bombay.

Cotton Association of India. 2019. Indian cotton scenario-2018-2019. In: Cotton statistics & news, Weekly publication of Cotton Association of India, No. 41. 8th January, 2019. Retrieved from https:// www.caionline.in on 29th July, 2019.

De Snoo GR, Jong FM, Der Pol RJ and Van Der Linden MG. 2001. Effects of glufosinate ammonium on off crop vegetation—interim results. *Meded Rijksuniv Gent Fak Landbouwkd Toegep Biol Wet*, **66**(2b):731–741.

Droge-laser W, Siemeling U, Puhler A and Broer I. 1994. The metabolites of the herbicide-phosphinothricin (glufosinate) (identification, stability, and mobility in transgenic, herbicide-resistant, and untransformed plants). *Plant Physiology* **105**: 159–166.

Ghosh A, Mondal D, Kumar A, Ghosh RK and Bandopadhyay P. 2017. Influence of glufosinate ammonium on some soil properties and rhizospheric micro-organisms of tea crop (*Camellia sinensis* L.) in eastern Himalayan region of India. *International Journal of Plant & Soil Science* **18**(6): 1–7.

Gomez KA and Gomez AA. 1984. *Statistical Procedures for Agricultural Research.* John Wiley & Sons, New York.

Goulden CH. 1952. *Methods of Statistical Analysis.* John Wiley and sons Inc., New York.

Hess FD. 2000. Light-dependent herbicides: an overview. *Weed Science* **48**: 160–170.

Kocher H. 1983. In: Aspects of applied biology: 4, Influence of environmental factors on herbicide performance and crop and yield biology. *Association of Applied Biologists*, Oxford, Pp.227–234.

Kushwaha S and Bhowmik PC. 1999. Inhibition of pigment biosynthesis in cucumber cotyledons by isoxaflotole. *Photosynthetica* **37**(4): 553–558.

Mersey BG, Hall JC, Anderson DM and Swanton CJ. 1990. Factors affecting the herbicidal activity of glufosinate-ammonium absorption, translocation and metabolism in barley and green foxtail. *Pesticide Biochemistry and Physiology* **37**: 90–98.

Mirghasemi ST, Daneshian J and Baghestani MA. 2012. Investigating of increasing glyphosate herbicide efficiency with nitrogen in control of tea weeds. *International Journal of Agriculture and Crop Sciences* **4**(24): 1817–1820.

Nandagavi RA and Halikatti SI. 2016. Bio-efficacy of herbicides in Bt cotton. *Journal of Farm Sciences* **29**(2): 182–186.

Nandihalli UB and Bhowmik PC. 1992. Inhibition of chlorophyll and carotenoid biosynthesis by the herbicide ICIA-0051. *Photosynthetica* **26**(3): 355–362.

Pramer D and Schmidt EL. 1965. *Experimental Soil Microbiology.* Minneapolis: Burgess Publ. Co.

Prematilake KG, Froud-Williams RJ and Ekanayake PB. 2004. Weed infestation and tea growth under various weed management methods in a young tea (*Camellia sinensis* [L.] Kuntze) plantation. *Weed Biology and Management* **4**(4): 239–248.

Rao AN and Dubey PS. 1983. Growth, pigment concentration and yield of sorghum cv *vidisha* as influenced by triazine herbicides. *Indian Journal of Weed Science* **15**(1): 23–28.

Singh T, Sharma BD, Mangat R and Panwar RS. 1996. Effect of chemical weed control on nutrient uptake by tori (*Brassica compestris* var. *tori*) and associated weeds. *Annals of Biology* **12**(2): 274–277.

You W and Barker V. 2002. Herbicidal actions of root-applied glufosinate ammonium on tomato plants. *Journal of the American Society for Horticultural Science* **127**(2): 200–204.

Zechmeister-Boltenstern S. 1996. Non-symbiotic nitrogen fixation. Pp. 122–134. In: *Methods in Soil Biology*, Springer, Berlin, Heidelberg.