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Evaluation of glyphosate against weeds and phytotoxicity, productivity and soil quality parameters in tea (*Camellia sinensis* O. kuntze)

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ABSTRACT

Glyphosate is an effective post emergence herbicide for weed control in tea. However, dose and timing of any new formulation need to be evaluated before being its recommendation to the growers. The weed flora of the experimental field was composed of *Ageratum conyzoides* (21.9%), *Ageratum houstonianum* (21.3%), *Chromolaena adenophorum* (13.0%), *Bidens pilosa* (9.6%), *Lantana camara* (6.2%), *Cynodon dactylon* (6.0%), *Fragaria vesca* (5.6%), *Imperata cylindrica* (5.2%), *Polygonum alatum* (5.1%) and *Erigeron canadensis* (5.1%). The new formulation glyphosate 71% SG was found to be comparable to the existing formulation glyphosate 41% SL against *Ageratum conyzoides*, *A. houstonianum*, *Chromolaena adenophora*, *Bidens pilosa*, *Fragaria vesca*, *Polygonum alatum*, *Erigeron canadensis*, *Imperata cylindrica* and *Cynodon dactylon* in reducing their population upto 120 days after application (DAA). Glyphosate 71% SG did not show any toxic symptoms on tea crop and tea leaf yield was similar as under standard formulation used in the present study. Glyphosate 71% SG (ammonium salt) sprayed at 6 kg/ha gave highest tea leaf yield (1940 kg/ha) which was statistically similar to the Glyphosate 71% SG (ammonium salt) applied at the rate of 3 kg/ha (1895 kg/ha). It was also comparable to the market sample. Uncontrolled growth of weeds even for a one season reduced tea leaf yield by 48.5%. The bulk density, water holding capacity, moisture content, soil pH, electrical conductivity, available NPK and organic C were not influenced significantly at harvest. The test herbicide glyphosate 71% SG and the market sample glyphosate 41% SL had increased the population of total bacteria, fungi and actinomycetes at harvest over their initial population. However, there was a slight decrease in the population of this microflora immediately after the application of herbicide not due to the herbicide but owing to seasonal variation as the differences between treatments were not significant.

Introduction

Tea (*Camellia sinensis* O. Kuntze), the cheapest beverage, has been habitually consumed by people since 3000 B.C. The tea industry in Kangra valley of Himachal Pradesh, India had a glorious history. In 2015, there were 5900 tea gardens in the area covering about 2312

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hectares of land with an annual production of 899 tonnes (Chauhan, 2015). Weeds are the major bottlenecks in managing tea gardens. Tea is infested with plurispecific weed flora composed of both annuals and perennials. They interrupt field practices and significantly reduce tea yield (Paul and Pierre 2012). Managing weeds in tea plantations has become a crucial issue due to high cost of labour and other inputs such as herbicides (Prematilake et al. 2004; Ilango et al. 2010; Mirghasemi et al. 2012), especially at a time the end product fetches a lower net sale price. Worldwide tea crop loss due to weeds has been estimated to be about 146 m kg annually which amounts to 14-15% of total production. The extent of yield loss due to weeds is dependent upon the intensity of weed growth, weed species present and their competing ability with the tea plants. Young tea plants are very sensitive to weed competition and may suffer from permanent setback if appropriate weed control measures are not taken (Kwaga and Fredrick 2015). Thus, all these situations make it necessary to rely on herbicides for an effective and timely weed control. In tea plantations, use of herbicides as a tool for controlling weeds is very much popular and have been widely used ever since their introduction-primarily due to their cost-effectiveness, efficiency in controlling diverse weed flora and less labour intensiveness. Thus, a low cost weed management strategy is of paramount importance for the sustainable productivity of tea plantations. Adoption of cultural and ecological methods is of great importance as they are environmental friendly and cost effective. There are some different issues associated with the presence of herbicides in the environment (Mehdizadeh, 2019), however, the use of herbicides has proven to be the most convenient and effective method and it could minimize soil erosion and eliminate loss of plant nutrients. Various herbicides have so far been recommended for weed control in tea fields. There are number of problematic weeds in tea fields at present (Kumar et al. 2014; Kumar and Ghosh 2015; Ilango et al. 2010) as they are resistant to normal dosage of recommended herbicides. As such, these weeds have to be managed using specific herbicide dosages or mixtures or by adopting other control measures. Glyphosate is an effective herbicide for weed control in tea (Bose et al. 2007; Ilango et al. 2010). However, dose and timing of any new formulation need to be validated before its ultimate recommendation to the growers. Therefore, the present investigation was undertaken to study the 'efficacy of glyphosate 71% SG against weeds in tea'.

Materials and Methods

The experiment was laid out in the well-established Tea garden at Palampur during *kharif*, 2015. In an established tea orchard the bushes were collar pruned with the help of sickle. The test herbicide Glyphosate 71% SG (ammonium salt) was sprayed on 1st June 2015. Knapsack sprayer with flood jet nozzle WFN 0.04 was used in a spray volume of 500 l/ha.

Table 1. Detail of treatments evaluated in the experiment.

Treatment	Dose /ha	
	a.i. (kg)	Formulation (kg/ha)
Glyphosate 71% SG (Ammonium Salt)	1.42	2.00
Glyphosate 71% SG (Ammonium Salt)	2.13	3.00
Glyphosate 71% SG (Ammonium Salt)	4.26	6.00
Glyphosate 41% SL (Market Sample)	2.13	5.20
Hand weeding	-	-
Control (Untreated)	-	-

The soil was clay loam to silty clay loam in texture classified as alfisols with typic hapludalf as its sub-order. The reaction of soils was acidic with pH 5.4 and CEC 9.1 to 13.2 mg/100 g soils. It was high in organic matter (1.25%), medium in available N (362 kg/ha) and phosphorus (23.2 kg/ha) and high in available K (325.7 kg/ha). Recommended dose of fertilizers i.e. 90 kg N, 90 kg P_2O_5, and 40 kg K_2O per hectare was applied in the form of urea (46%), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. Whole of the nitrogen, phosphorus and potassium was applied in mid of February 2015. The herbicides and intercultural practices were carried out as per the treatment in different plots. Post emergence application of glyphosate was done in the first week of June 2015. Hand weeding practice was performed at monthly interval. The crop was raised following all recommended package of practices for tea, except variable treatments.

In each plot, 50 × 50 cm quadrat was placed randomly at two spots. The species wise weed count was recorded on 30, 60, 90 and 120 days after application (DAA) of herbicides. Samples were collected for species wise weed count on 30, 60, 90 and 120 DAA by throwing 50 × 50 cm quadrat at random in each plot. These samples were oven dried at a temperature of 70 °C till constant weight. The green leaves from each plot were plucked manually four times in monsoon season (mid July to mid September 2015). Two leaves and a bud were plucked from each shoot of the bush from each plot. After the plucking leaves were cleaned, withered, rolled, fermented and dried. The rolled leaves were stored for fermentation and drying.

Data on toxicity of herbicide on tea crop was recorded on 0, 1, 3, 5, 7 and 10 days after herbicide application. The crop was assessed for visual injury (chlorosis, necrosis and/or stunting) due to application of the herbicide and evaluated on a scale of 0 (no chlorosis/necrosis or stunting) to 10 (complete plant death).

Soil samples from the experimental plots were collected from the space between the rows at a depth 0-15 cm on different interval viz. initial (pre-treatment) and at final harvest of the tea crop. The soil samples were analyzed for microbial load (Total Bacteria, Fungi, and Actinomycetes) by dilution plate method. The soil physical and chemical properties were assessed following standard procedures. The data were subjected to analysis of variance (ANOVA) for the randomized block design to test the significance of the overall differences among the treatments by the "F" test and conclusion was drawn at 5% probability level. Standard error of mean was calculated in each case. When the 'F' value from analysis of variance tables was found significant, the critical difference was computed to test the significance of the difference between the two treatments. The weed count and dry weight were analysed after subjecting the original data to square root transformation i.e. ($\sqrt{x + 0.5}$), and the treatments effects were compared using transformed means.

Results and Discussion

Ageratum conyzoides (21.9%) and *Ageratum houstonianum* (21.3%) were the dominant weed species in experimental area. These were followed by *Chromolaena adenophorum* (13.0%), *Bidens pilosa* (9.6%), *Lantana camara* (6.2%), *Cynodon dactylon* (6.0%), *Fragaria vesca* (5.6%), *Imperata cylindrica* (5.2%), *Polygonum alatum* (5.1%) and *Erigeron canadensis* (5.1%).

Data on population of weeds have been recorded at 30, 60, 90, and 120 days after application (DAA). The species-wise count of broad-leaf weeds *viz., Ageratum conyzoides, A. houstanianun, Lantana camara, Fragaria vesca,* and *Chromolaena adenophorum, Bidens pilosa, Polygonum alatum, Erigeron canadensis* are presented in Table 2. Data for narrow leaf weeds *viz., Imperata cylindrica, and Cynodon dactylon* are presented in Table 3. Perusal of data revealed that weed control treatments brought about significant variation in the count of broadleaf and grasses at all the stages of observation in tea. The test product Glyphosate 71% SG (ammonium salt) was most effective at 6 kg/ha followed by 3 kg/ha and was comparable to the market sample of Glyphosate 41% SL at 5.2 kg/ha. The highest weed population was recorded in the control. Effective control of *Ageratum* sp, *Chromolaena adenophorum*, *Bidens pilosa*, *Fragaria vesca*, *Cynodon dactylon*, *Erigeron canadensis* and other weeds with glyphosate in tea has been reported (Kumar et al. 2014; Bose et al. 2007; Kumar et al. 2017).

Table 2. Effect of treatments on broad-leaf weeds count (No. /m²) at 30, 60, 90 and 120 days after application (DAA) in tea.

Treatment	Dose (kg/ha)	*Days after application*					*Days after application*				
		30	60	90	120	Mean	30	60	90	120	Mean
		Ageratum conyzoides					***Ageratum houstonianum***				
Glyphosate 71% SG	2.0	0.77 (0.1)	1.04 (0.6)	1.73 (2.5)	1.82 (2.8)	1.34 (1.5)	0.77 (0.1)	0.78 (0.1)	1.00 (0.5)	1.14 (0.8)	0.92 (0.4)
Glyphosate 71% SG	3.0	0.71 (0.0)	0.71 (0.0)	1.35 (1.3)	1.31 (1.2)	1.20 (0.6)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.84 (0.2)	0.74 (0.1)
Glyphosate 71% SG	6.0	0.71 (0.0)	0.71 (0.0)	0.76 (0.1)	0.81 (0.2)	0.75 (0.1)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.73 (0.0)	0.71 (0.0)
Glyphosate 41% SL	5.20	0.78 (0.1)	0.81 (0.2)	1.45 (1.6)	1.26 (1.1)	1.07 (0.7)	0.78 (0.1)	0.75 (0.1)	1.23 (1.0)	1.26 (1.1)	1.01 (0.6)
Hand weeding	-	1.64 (2.2)	1.73 (2.5)	1.96 (3.4)	1.90 (3.1)	1.81 (2.8)	1.45 (1.6)	1.73 (2.5)	1.98 (3.4)	2.14 (4.1)	1.83 (2.9)
Weedy check	-	3.55 (12.1)	3.86 (14.4)	4.35 (18.4)	3.38 (10.9)	3.78 (14.0)	3.51 (11.8)	3.82 (14.1)	3.73 (13.4)	3.46 (11.5)	3.63 (12.7)
LSD (P=0.05)		0.30	0.28	0.21	0.13	0.29	0.28	0.15	0.17	0.20	0.21
		Lantana camera					***Chromolaena adenophorum***				
Glyphosate 71% SG	2.0	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.84 (0.20)	0.74 (0.05)	0.71 (0.00)	0.71 (0.00)	1.30 (1.20)	0.84 (0.20)	0.89 (0.35)
Glyphosate 71% SG	3.0	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.74 (0.05)	0.72 (0.01)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	1.00 (0.50)	0.78 (0.13)
Glyphosate 71% SG	6.0	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.89 (0.30)	0.75 (0.08)
Glyphosate 41% SL	5.20	0.78 (0.10)	0.75 (0.10)	1.23 (1.00)	0.77 (0.10)	1.18 (0.89)	0.78 (0.10)	0.75 (0.10)	1.00 (0.50)	1.05 (0.60)	0.88 (0.30)
Hand weeding	-	1.27 (1.10)	1.00 (0.50)	1.23 (1.00)	1.30 (1.20)	1.20 (0.95)	1.67 (2.30)	1.58 (2.00)	1.87 (3.00)	2.03 (3.60)	1.79 (2.73)
Weedy check	-	1.98 (3.42)	2.58 (6.16)	3.26 (10.10)	2.39 (5.22)	2.55 (6.23)	2.75 (7.20)	3.10 (9.10)	3.69 (13.10)	3.26 (10.10)	3.20 (9.88)
LSD (P=0.05)		0.15	0.10	0.11	0.14	0.18	0.27	0.34	0.10	0.23	0.24
		Fragaria vesca					***Bidens pilosa***				
Glyphosate 71% SG	2.0	0.71 (0.00)	0.71 (0.00)	1.23 (1.00)	0.84 (0.20)	0.87 (0.30)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Glyphosate 71% SG	3.0	0.71 (0.00)	0.71 (0.00)	1.00 (0.50)	1.00 (0.50)	0.86 (0.25)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Glyphosate 71% SG	6.0	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.89 (0.30)	0.75 (0.08)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Glyphosate 41% SL	5.20	0.78 (0.10)	0.75 (0.10)	1.00 (0.50)	1.05 (0.60)	0.76 (0.30)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.84 (0.20)	0.74 (0.05)
Hand weeding	-	1.27 (1.10)	1.00 (0.50)	0.95 (0.40)	1.30 (1.20)	1.30 (1.13)	1.23 (1.00)	1.48 (1.70)	1.79 (2.70)	2.03 (3.60)	1.63 (2.25)
Weedy check	-	2.22 (4.42)	2.58 (6.15)	2.76 (7.14)	2.40 (5.24)	2.49 (5.74)	2.75 (7.20)	3.10 (9.10)	3.26 (10.10)	3.11 (9.20)	3.06 (8.9)
LSD (P=0.05)		0.10	0.24	0.19	0.22	0.20	0.08	0.10	0.13	0.12	0.15
		Polygonum alatum					***Erigeron Canadensis***				
Glyphosate 71% SG	2.0	0.71 (0.00)	0.71 (0.00)	0.10 (0.50)	0.10 (0.50)	0.86 (0.25)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.10 (0.50)	0.78 (0.13)
Glyphosate 71% SG	3.0	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.78 (0.10)	0.73 (0.03)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Glyphosate 71% SG	6.0	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Glyphosate 41% SL	5.20	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.84 (0.20)	0.74 (0.05)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.84 (0.20)	0.74 (0.05)
Hand weeding	-	1.23 (1.00)	1.41 (1.50)	1.23 (1.00)	1.58 (2.00)	1.36 (1.38)	1.23 (1.00)	1.41 (1.50)	1.34 (1.30)	1.58 (2.00)	1.39 (1.45)
Weedy check	-	1.82 (2.80)	2.51 (5.80)	3.12 (9.20)	2.39 (5.20)	2.46 (5.75)	1.82 (2.82)	2.51 (5.82)	3.12 (9.22)	2.39 (5.20)	2.46 (5.77)
LSD (P=0.05)		0.28	0.30	0.20	0.30	0.23	0.27	0.21	0.29	0.26	0.26

DAA: Days after Application; Data analyzed after Square Root Transformation; Values given in parenthesis are the original means.

Table 3. Effect of treatments on narrow leaf weeds count (No. /m^2) at 30, 60, 90 and 120 days after application (DAA) in tea.

Treatment	Dose kg/ha	*Imperata cylindrica*					*Cynodon dactylon*				
		30	60	90	120	Mean	30	60	90	120	Mean
Glyphosate 71% SG	2.0	0.71	0.71	0.71	0.71	0.71	0.71	0.85	1.23	1.55	1.08
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.23)	(1.00)	(1.90)	(0.78)
Glyphosate 71% SG	3.0	0.71	0.71	0.71	0.71	0.71	0.71	0.71	1.05	1.23	0.92
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.60)	(1.00)	(0.40)
Glyphosate 71% SG	6.0	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.89	0.75
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.30)	(0.08)
Glyphosate 41% SL	5.20	0.71	0.71	0.71	0.71	0.71	0.71	0.71	1.34	1.58	1.08
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(1.30)	(2.00)	(0.83)
Hand weeding	-	1.23	1.00	1.18	1.23	1.16	1.23	1.41	1.34	1.58	1.39
		(1.00)	(0.50)	(0.90)	(1.00)	(0.85)	(1.00)	(1.50)	(1.30)	(2.00)	(1.45)
Weedy check	-	1.98	2.12	2.88	1.92	2.23	2.15	2.55	2.88	2.12	2.42
		(3.40)	(4.00)	(7.80)	(3.20)	4.60)	(4.10)	(6.00)	(7.80)	(4.00)	5.48)
LSD (P=0.05)		0.26	0.17	0.06	0.30	0.10	0.12	0.18	0.20	0.22	0.20

DAA: Days after Application; Data analyzed after Square Root Transformation; Values given in parenthesis are the original means.

The data on total weed count and weed dry weight before and on 15 and 30 Days After Application (DAA) as well as Weed Control Efficiency are presented in Table 4. Total weed count and dry matter accumulation were significantly reduced with the application of Glyphosate 71% SG (ammonium salt). Minimum count of weeds and their dry weight (g/m^2) were recorded when Glyphosate 71% SG (ammonium salt) was applied at 6 kg/ha which was comparable to Glyphosate at 3 kg/ha and the market sample.

The highest Weed Control Efficiency was recorded (100%) when the test chemical was used at 6 or 3 kg/ha. These treatments were better than hand weeding which had 93.98% weed control efficiency at 15 days after application. The efficacy of the applied herbicide at high rate persisted up to 30 days giving 100% control of weeds. Effective control of weeds in tea with glyphosate has been reported (Kumar et al. 2014; Kumar and Ghosh 2015; Ilango et al. 2010).

Data presented in Table 4 revealed that Glyphosate 71% SG (ammonium salt) sprayed at 6 kg/ha gave highest Tea leaf yield (1940 kg/ha) which was statistically similar to the Glyphosate 71% SG (ammonium salt) applied at the rate of 3 kg/ha (1895 kg/ha). It was also comparable to the market sample. Lowest Tea leaf yield was recorded in the untreated control treatment. Glyphosate 71% SG when applied at standard (3 kg/ha) and 2X (6 kg/ha) dose did not show any phytotoxic symptoms on the Tea crop at all as revealed from Table 5. Mirghasemi et al. (2012), Kumar et al. (2014), Kumar and Ghosh (2015) and Kumar et al. (2017) also observed no adverse effect of glyphosate on tea crop, quality and green leaf yield.

Table 4. Effect of treatments on total Weed Population (no./m²), Dry Weight (g/m²), Weed Control Efficiency (%) and leaf yield in Tea.

Treatments	Dose (kg/ ha)	Weed population (No./m²)			Weed dry weight (g/m²)			Weed Control Efficiency (%)		Leaf yield (kg/ha)
		Before Spray	15 DAA	30 DAA	Before Spray	15 DAA	30DAA	15DAA	30DAA	
Glyphosate 71% SG	2.0	7.11 (50.0)	0.95 (0.4)	1.00 (0.5)	4.96 (24.1)	0.71 (0.0)	0.72 (0.0)	99.9	99.9	1701
Glyphosate 71% SG	3.0	7.18 (51.1)	0.71 (0.0)	0.71 (0.0)	5.06 (25.1)	0.71 (0.0)	0.71 (0.0)	100.0	100.0	1895
Glyphosate 71% SG	6.0	7.11 (50.0)	0.71 (0.0)	0.71 (0.0)	5.04 (24.9)	0.71 (0.0)	0.71 (0.0)	100.0	100.0	1940
Glyphosate 41% SL	5.20	7.15 (50.6)	0.71 (0.0)	0.71 (0.0)	4.96 (24.1)	0.71 (0.0)	0.71 (0.0)	100.0	100.0	1840
Hand weeding	-	6.98 (48.2)	2.14 (4.1)	2.47 (5.6)	5.01 (24.6)	1.44 (1.6)	1.85 (2.9)	93.9	89.6	1770
Weedy check	-	7.11 (50.1)	7.26 (52.1)	7.69 (58.6)	5.06 (25.1)	5.16 (26.1)	5.35 (28.1)	-	-	1000
LSD (P=0.05)		NS	0.02	0.04	NS	0.07	0.22			58.0

DAA: Days after Application; Data analyzed after Square Root Transformation; Values given in parenthesis are the original means.

Table 5. Phytotoxicity effect of Glyphosate 71% SG (Ammonium Salt) on Tea bushes.

Treatment	Dose (kg/ha)	Epi & Hyponasty DAA					Necrosis DAA					Wilting DAA					Vein clearing DAA				
		7	15	30	45	60	7	15	30	45	60	7	15	30	45	60	7	15	30	45	60
Glyphosate 71% SG	3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glyphosate 71% SG	6.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weedy check	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The mean mechanical properties - per cent sand, silt and clay; physical properties - the bulk density (BD), water holding capacity (WHC) and moisture content (MC) and chemical properties – pH, electrical conductivity (EC), organic carbon, total nitrogen, available phosphorus (P_2O_5) and potash (K_2O) of the initial soil of the experimental field are presented in Tables 6 and 7. The bulk density (BD), water holding capacity (WHC) and moisture content (MC) of soil did not vary before

application of treatments and after plucking tea leaves due to application of Glyphosate 71% SG (ammonium salt) (Table 6). No variations were found among the different textural classes of soil, the sand, silt and clay due to the application of Glyphosate 71% SG (ammonium salt) before application of treatments and at harvest. The soil pH and electrical conductivity (EC) at harvest was not influenced with the test herbicide Glyphosate 71%SG (ammonium salt). The data presented on Table 7 clearly showed that the organic carbon and available NPK were also not differed significantly due to treatments.

Table 6. Physical and Mechanical properties of the experimental soil before treatment and at harvest

Treatment	Dose (kg/ha)	BD (g cc^{-1})	Moisture Content (%)	WHC (%)	Sand (%)	Silt (%)	Clay (%)
Before treatment							
Glyphosate 71% SG	2.0	1.31	16.98	50.86	33.86	43.11	22.93
Glyphosate 71% SG	3.0	1.32	15.78	51.54	31.74	43.32	24.34
Glyphosate 71% SG	6.0	1.31	15.94	51.11	37.02	43.30	19.66
Glyphosate 41% SL	5.20	1.31	15.89	50.43	33.86	43.28	22.46
Hand weeding	-	1.32	16.04	50.87	31.74	43.32	24.34
Weedy check	-	1.31	15.36	50.94	30.16	44.22	25.51
LSD (P=0.05)							
At harvest							
Glyphosate 71% SG	2.0	1.30	16.90	50.00	33.44	41.80	23.93
Glyphosate 71% SG	3.0	1.30	15.09	50.34	31.65	43.62	24.34
Glyphosate 71% SG	6.0	1.31	15.14	50.11	34.01	45.09	20.11
Glyphosate 41% SL	5.20	1.31	15.19	49.87	32.89	42.30	24.76
Hand weeding	-	1.31	15.92	50.23	32.74	42.32	24.24
Weedy check	-	1.31	15.26	49.80	31.16	43.52	25.21
LSD (P=0.05)							

Table 7. Chemical properties of the experimental soil before treatment and after harvest.

Treatment	Dose (kg/ha)	pH	Organic carbon (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Before treatment						
Glyphosate 71% SG	2.0	5.70	0.785	332	20.71	230.59
Glyphosate 71% SG	3.0	5.73	0.789	336	20.78	240.29
Glyphosate 71% SG	6.0	5.70	0.788	323	21.86	238.58
Glyphosate 41% SL	5.20	5.80	0.789	343	22.17	239.56
Hand weeding	-	5.79	0.785	330	20.63	240.27
Weedy check	-	5.79	0.789	333	20.12	249.19
LSD (P=0.05)						
At harvest						
Glyphosate 71% SG	2.0	5.81	0.583	330	20.11	240.00
Glyphosate 71% SG	3.0	5.80	0.585	343	19.08	245.12
Glyphosate 71% SG	6.0	5.88	0.588	356	21.97	240.68
Glyphosate 41% SL	5.20	5.83	0.585	350	21.56	250.56
Hand weeding	-	5.84	0.589	347	21.05	246.90
Weedy check	-	5.84	0.587	335	21.92	253.11
LSD (P=0.05)						

The test herbicide and as well as market sample did not show any significant influence on the population of total bacteria in *Rhizosphere* soil at initial stage though after the application of herbicides small variations were found between the treated and un-treated plots. Thereafter at harvest, the population built up considerably in herbicidal treated plots (Table 8). There was slight effect on the population of fungi in *Rhizosphere region* initially after application of glyphosate but later at harvest, the data showed increase in population over the initial population of the fungi. Like the bacteria and fungi, slight influence of glyphosate treatments on Actinomycetes population was observed over the hand weeding and control plots. Thereafter, the population increased to a considerable level. Matthew et al. (2012) also concluded that glyphosate stimulates microbial respiration particularly on soils with a history of glyphosate application. It has no significant effect on functional diversity or microbial biomass K and does not reduce the exchangeable K (putatively available to plants) or affect non-exchangeable K. The respiration response in soils with a long-term glyphosate response would suggest that there was a shift in the microbial community that could readily degrade glyphosate. However, in all the three cases (total bacteria, fungi and Actinomycetes) the herbicide treatments did not vary significantly among themselves in all the doses of the test Glyphosate as well as the standard glyphosate application at all the stages of observation. Kumar et al. (2017) also reported similar results.

Table 8. Influence of herbicides on total bacteria (CFU x 106 g^{-1} of soil), fungi (CFU x 104 g^{-1} of soil) and actinomycetes (CFU x 104 g^{-1} soil).

Treatment	Dose (kg/ha)	Population				
		Initial	3 DAA	10 DAA	30 DAA	at harvest
Total bacteria (CFU x 10^6 g^{-1} of soil)						
Glyphosate 71% SG	2.0	40.67	21.22	29.78	38.78	101.78
Glyphosate 71% SG	3.0	39.22	27.00	31.11	32.22	102.00
Glyphosate 71% SG	6.0	40.33	26.33	29.56	32.33	100.44
Glyphosate 41% SL	5.20	45.89	20.78	38.33	42.89	101.44
Hand weeding	-	38.11	29.89	33.22	34.44	85.33
Weedy check	-	41.56	29.89	34.78	43.89	71.22
LSD (P=0.05)		NS	NS	NS	NS	NS
Fungi (CFU x 10^4 g^{-1} of soil)						
Glyphosate 71% SG	2.0	20.33	13.11	14.11	16.00	29.41
Glyphosate 71% SG	3.0	20.44	10.33	11.78	14.00	28.00
Glyphosate 71% SG	6.0	21.67	10.67	11.89	14.44	32.00
Glyphosate 41% SL	5.2	22.67	9.00	11.78	17.00	28.00
Hand weeding	-	20.44	11.78	13.11	14.44	23.25
Weedy check	-	21.67	10.78	11.22	14.78	22.90
LSD (P=0.05)		NS	NS	NS	NS	NS
Actinomycetes (CFU x 10^4 g^{-1} soil)						
Glyphosate 71% SG	2.0	59.00	37.44	40.33	46.00	70.12
Glyphosate 71% SG	3.0	59.44	29.11	33.44	40.00	74.23
Glyphosate 71% SG	6.0	64.11	29.78	33.56	41.11	75.00
Glyphosate 41% SL	5.20	65.67	25.00	33.22	49.00	73.20
Hand weeding	-	56.11	30.56	35.89	45.89	68.00
Weedy check	-	63.78	30.67	35.00	43.56	64.67
LSD (P=0.05)		NS	NS	NS	NS	NS

Conclusion

Based on these results, the test product-Glyphosate 71% SG (Ammonium salt) at 3.00 kg/ha can be recommended for effective control of both grasses and broad leaf weeds in Tea and was comparable to the market sample. It was safe to use at higher doses. There was no adverse effect of the herbicide at higher dose even on soil physical, chemical and biological properties.

Conflicts of Interest

No conflicts of interest have been declared.

References

Bose A, Ravikumar A, Roy S.B. 2007. Integrated weed management to control *Pteridium* spp. and *Polygonum chinensis* in young tea plantations of India. In: Proceedings of 21st Asian Pacific Weed Science Society Conference held at Colombo, Sri Lanka w.e.f. 2-6 October pp 565-567.

Chauhan P.T. 2015. Kangra tea to get Europeon GI tag soon. *News Service Shimla*, May 19.

Ilango R.V.J, Saravanan M, Parthibaraj R, Kumar P.M. 2010. Evaluation of Excel Mera-71 for weed control in tea fields. *Newsletter* - UPASI Tea Research Foundation. 20(1): 1.

Kgawa Y.M, Fredrick C.N. 2015. Survey of Weeds on Tea (*Camellia sinensis* L. Kuntze) Plantations on the Mambilla Plateau in Nigeria. Global Advanced Research Journal of Agricultural Science. 4: 900-904.

Kumar A, Ghosh R.K. 2015. Bioefficacy of glyphosate for management of Weeds in Tea. 25th Asian-Pacific Weed Science Society Conference on "Weed Science for Sustainable Agriculture, Environment and Biodiversity",Hyderabad, India during 13-16 October, 2015: p 377.

Kumar A, Ghosh A, Mondal D, Ghosh R, Bandopadhyay P. 2017. Bio-efficacy of ammonium salt of Glyphosate 71% SG for weed dynamics in tea (*Camellia sinensis* L.) and its effect on soil microflora. Int J Current Microbiol Appl Sci. 6: 2160-2170.

Kumar S, Rana S.S, Angiras N.N, Ramesh. 2014. Weed management in tea with herbicides mixture. Ind J Weed Sci. 46: 353-357.

Matthew L, Nicola L, Jyotisina S, Cliff R, Richard P.D. 2012. The effect of glyphosate on soil microbial activity, microbial community structure and soil potassium. Int J Soil Biol. 55: 335-342.

Mehdizadeh M. 2019. Sensitivity of oilseed rape (*Brassica napus* L.) to soil residues of imazethapyr herbicide. International Journal of Agriculture, Environment and Food Sciences. 3: 46-49.

Mirghasemi S.T, Daneshain J, Baghestani M.A. 2012. Investigating of increasing glyphosate herbicide efficiency with nitrogen in control of tea weeds. International Journal of Agriculture and Crop Sciences. 4: 1817-1820.

*Paul B.V.D, Pierre B.J. 2012. Evaluation of the efficacy of herbicides in tea (C*ammelia sinensis*) production in Rawada. Int J Appl Agric Res. 7: 197-202.*

Prematilake K.G, Froud-Williams R.J, Ekanayake P.B. 2004. Weed infestation and tea growth under various weed management methods in a young tea (*Camellia sinensis* [L.] Kuntze) plantation. Weed Biol Manag. 4: 239-248.

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