Journal of Crop and Weed, 18(3): 78-85 (2022)

ISSN- O : 2349 9400 ; P : 0974 6315

http://cwssbckv.org
www.cropandweed.com

Evaluation of glyphosate ammonium 79.2% SG for weed dry weight, crop phytotoxicity, yield, available NPK and economics of tea (*Camellia sinensis* L.)

S. TANHA, *P. CHOPRA, S. S. RANA, G. SINGH AND N. KAUR

Department of Agronomy, COA, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062

Received : 05.08.2022 ; Revised : 05.09.2022 ; Accepted : 12.09.2022

DOI : https://doi.org/10.22271/09746315.2022.v18.i3.1620

ABSTRACT

A field experiment to evaluate the phytotoxicity of glyphosate ammonium 79.2% SG in tea crop was conducted during the summer and monsoon seasons of 2018 at Palampur. Eight different weed control treatments were tested against weedy check and weed free in randomized block design with three replications. Glyphosate ammonium 79.2% SG at 4.356 kg ai ha^{-1} was slightly phytotoxic upto one month of its application. Glyphosate ammonium 79.2% SG at 2.178 kg ai ha^{-1} and tank mix application of glyphosate 1.0 L ha^{-1} along with 2,4-D (Na) 0.5 kg ha^{-1} had significantly higher made tea yield. The presence of weeds in weedy check resulted in a loss of 47.5% in made tea yield. Glyphosate at 1.0 L ha^{-1} along with 2,4-D (Na) at 0.5 kg ha^{-1} and glyphosate ammonium salt 79.2% at 4.356 kg ai ha^{-1} resulted in significantly greater available N. Significantly higher K in soil was recorded with glyphosate ammonium 79.2% at 4.356 & 2.178 kg ai ha^{-1}, glyphosate+2,4-D (Na) 1.0L+0.5 kg ha^{-1}, glyphosate ammonium 71.0% at 2.13 kg ai ha^{-1} and weed free check. Combined application of glyphosate at 1.0 L ha^{-1} with 2,4-D (Na) at 0.5 kg ha^{-1} and glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} had higher value of net returns of INR 2,71,487 ha^{-1} and INR 2,68,024 ha^{-1}, respectively. Both of these treatments also had highest value of net returns per rupee invested (2.27).

***Keywords*:** Available NPK, crop phytotoxicity, economics, glyphosate ammonium 79.2% SG, made tea

Tea [*Camellia sinensis* (L.) Kuntze] being seemingly ubiquitous is a tradition in India. A beverage that was imported from China almost 200 years ago has a crucial role in both our social and economic lives. It is a chief source of foreign exchange of India (Mitra and Neelanjana, 1991) and a relaxation drink for Indian. In most of the parts of India, it is considered as a semi-food (Gopalaswamy and Xavier, 1992) as majority of the people at bottom of the pyramid consumed it with the dry bread, biscuits and chapattis. Tea needs optimum agronomic care for a high and sustained productivity. Weeds are one of the main obstacles preventing tea plantations from performing at their full potential.

The tea is infested with a plurispecific weed flora. Worldwide, losses in tea due to weeds has been assessed to be about 146 million kg yearly which accounts to 14-15 per cent of total production. Weeds reduce the yield and quality of tea besides competing for nutrients and moisture (Opeke, 2005; Rana and Rana, 2016). In the early stages of crop growth, weeds remove 5–6 times more N, 5–12 times more P, and 2–5 times more K than the crop, resulting in a low tea yield. The process of weeding is crucial for effective management. However, because labour is so expensive, controlling weeds in tea plantations has become a critical issue. Because of the time, season, and cost involved, manual and mechanical methods are not a better alternative. Chemical control outperforms other strategies (Prematilake *et al*., 2004; Rajkhowa *et al*., 2005; Ilango *et al*., 2010; Mirghasemi *et al*., 2012; Kumar *et al*., 2014). Keeping this in view, a new formulation of ghyphosate i.e. Glyphosate ammonium 79.2% SG (it is particularly successful for application in farmland and non-crop areas on a variety of annual and perennial grassy and broadleaf weeds, and also on a variety of tree and woody brush species) is tested under the present study.

MATERIALS AND METHODS

The research trial consisting of ten weed control treatments *viz.* T_1- Glyphosate ammonium salt 79.2% SG @ 1.089 kg ai ha^{-1}, T_2- Glyphosate ammonium salt 79.2% SG @ 2.178 kg ai ha^{-1} , T_3- Glyphosate ammonium salt 79.2% SG @ 4.356 kg ai ha^{-1}, T_4- Glyphosate ammonium salt 71% SG @ 2.13 kg ai ha^{-1}, T_5- Paraquat @ 0.5 L ha^{-1}, T_6- Glyphosate (41% SL) +2,4-D (Na) @ 1.0 L+0.5 kg ae ha^{-1}, T_7- Glyphosate (41%SL) @ 1.5 L ae ha^{-1}, T_8- Slashing and in-situ mulching of weeds before flowering, T_9- Weed free check and T_{10}-Weedy check was laid out in Randomized Block Design with three replications at tea plantation in CSK HP Krishi Vishvavidyalaya, Palampur during summer and monsoon seasons of 2018. The soil had a silty clay loam texture, was acidic in reaction, had low available nitrogen, and had medium phosphorus and

Email: pankuch@rediffmail.com

How to cite : Tanha, S., Chopra, P., Rana, S. S., Singh, G. and Kaur N. 2022. Evaluation of glyphosate ammonium 79.2% SG for weed dry weight, crop phytotoxicity, yield, available NPK and economics of tea (*Camellia sinensis* L.). *J. Crop and Weed*, 18 (3): 78-85.

potassium. With the use of a sickle, the tops of the tea bushes were pruned in the month of December 2017. Recommended dose of 90 kg N, 90 kg P_2O_5 and 40 kg K_2O per hectare was used, and it was applied as urea (46%), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. Full dose of the nitrogen, phosphorus and potassium were applied in the month of February. The herbicide application and intercultural operations were performed as per the treatments in respective plots. All the chemicals including glyphosate were applied manually through power sprayer fitted with flat fan nozzle following proper precautions while spraying of pesticides. Protective gears (*i.e.* face cover, safety mask, safety google, apron, pant, shoes, hand gloves etc.) were used while spraying of these chemicals in experimental plots. After application of herbicides, the plots were visited daily to notice any phytotoxicity symptoms and results were reported for period starting from 1-10, 10-20, 20-30 and 30-40 days following the use of a herbicide. On a scale from 0 (no chlorosis/necrosis or stunting—''No toxicity") to 10 (total plant death—''Complete toxicity"), the crop was evaluated for visual injury (chlorosis, necrosis, and/or stunting) caused by the use of herbicides. Weed's dry weight was noted at 30, 60, and 90 days after the experiment's start in the summer and at 30, 60, 90, and 120 days after the experiment's start in the monsoon season.

To work out weed control efficiency based on weed dry weight, procedure given by Mishra and Tosh (1979) was followed.

$$\text{Weed control efficiency } (\%) = \frac{DWC - DWT}{DWC} \times 100$$

Where,

DWC = Weed dry weight (g m^{-2}) in control plot and

DWT = Weed dry weight (g m^{-2}) in treated plot

For shoot growth studies, 4 bushes were selected in each plot. In each bush, 2 shoots with just unfolded first leaf were tagged immediately after the plucking. As such, a total of 8 shoots were tagged in each plot. These shoots were plucked on the day of corresponding next plucking round for observations. The results have been expressed month-wise. The observations recorded in intervals overlapping in two months were pooled in the month to which major part of interval belongs. After removing the surface moisture of the shoots with blotting paper, the fresh weight of the shoots was noted and average fresh weight was worked out and expressed as mg^{-1}shoot.

Manual plucking of green leaves from each plot was done. From each shoot of the bush in each plot, two leaves and a bud were plucked. The green leaf yield (g $bush^{-1}$) obtained per plot was transformed to kg ha^{-1}. The total green leaf yield was the sum total of all flushes i.e. early, main and back-end flush.50 g composite sample was drawn from the harvested crop. After recording its fresh weight, it was dried in hot air oven for 48 hours at 80 ^{0}C and the dry matter of the shoot was calculated as per following equation:Dry matter = Dry weight (g) x 100/ Fresh weight (g). The made tea output was determined by multiplying green leaf yield with the corresponding average dry matter content and expressed as KMTH (kilogram made tea per hectare).

Available nitrogen in soil was estimated by using the Alkaline Permanganate method (Subbiah and Asija 1956). Available phosphorus was estimated by using the Olsen's method (Olsen *et al*., 1954). Available potassium was estimated by using Neutral Ammonium Acetate Extraction method (Black, 1965). Microbial biomass carbon in soil was determined by fumigation extraction method (Vance *et al*., 1987). Gross returns were obtained by multiplying the quantity of produce (made tea) per hectare with the prevailing market price of produce. Net returns were obtained by subtracting the cost of cultivation from gross returns. Net return per rupee invested was calculated by dividing net returns with cost of cultivation.

RESULTS AND DISCUSSION

Bidens pilosa L., *Paspalum disticum* L., *Chromolaena adenophorum* (L.) King & Robinson, *Achyranthus aspera* L. and *Artemisia* sp. L., were the dominant weeds constituting 17.6, 15.3, 11.9, 11.2 and 11.2%, respectively, of the total weed population at maximum weed population stage (90 DASE) during summer season, while, the corresponding proportion of these weeds during maximum population stage (30 DASE) during monsoon season was 22.2, 15.2, 12.3, 10.5 and 16.4%, respectively. There was no major changes in the composition of weed flora, as for controlling weeds during summer and monsoon seasons the treatments were applied during mid April and mid July, respectively with almost regular receipt of rains. However, the proportion of *Lantana camara* L. and *Ageratum conyzoides* L. was more during summer and monsoon, respectively as compared to another season. Apart from these weeds, the other different weeds emerged during respective seasons have very little proportion.

Weed dry weight

During summer season, there was decreasing trend in dry matter of weeds from initial to 30 DASE because of treatments effect. Thereafter, there was sharp increase in the dry matter of weeds from 30 DASE to 90 DASE, because this period coincided with the grand growth stage of weeds. The dry matter of the weeds increased

Table 1: Treatment's impact on the total dry weight of the weeds (g/m^2) in tea

Treatment	Summer season				Monsoon season			
	Initial	30 DASE	60 DASE	90 DASE	30 DASE	60 DASE	90 DASE	120 DASE
T_1	18.50 (343.40)	8.43 (70.13)	9.80 (95.33)	11.38 (130.81)	7.50 (55.37)	8.76 (76.00)	9.28 (85.99)	9.92 (98.78)
T_2	18.77 (351.67)	5.61 (30.67)	6.94 (47.33)	8.24 (67.19)	4.81 (22.44)	6.38 (40.01)	7.43 (54.20)	7.96 (63.54)
T_3	17.97 (325.00)	4.68 (21.29)	5.79 (32.57)	7.71 (58.58)	3.80 (13.81)	5.68 (31.86)	6.14 (36.81)	6.75 (45.07)
T_4	18.01 (348.73)	6.60 (42.72)	7.86 (61.29)	10.02 (101.40)	7.08 (49.44)	7.19 (51.07)	8.25 (67.33)	8.76 (75.72)
T_5	20.90 (437.67)	10.50 (110.53)	11.32 (127.47)	14.97 (225.21)	9.03 (80.65)	9.80 (95.33)	10.43 (109.87)	11.01 (123.07)
T_6	23.30 (251.67)	4.96 (24.53)	5.48 (29.3)	6.45 (41.60)	3.73 (13.30)	4.35 a (18.66)	5.90 b (34.54)	6.47 (41.13)
T_7	18.10 (329.40)	6.11 (37.48)	7.01 (48.15)	9.11 (41.60)	5.69 (31.62)	7.47 (54.87)	7.88 (61.30)	9.21 (84.40)
T_8	20.43 (420.73)	8.59 (73.39)	9.29 (86.07)	12.31 (150.65)	5.30 (27.43)	7.22 (51.51)	9.50 (89.47)	11.81 (138.76)
T_9	19.62 (390.52)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_{10}	18.47 (341.33)	18.74 (350.84)	20.03 (400.57)	21.21 (449.67)	21.39 (457.44)	18.22 (331.00)	18.98 (359.75)	19.91 (396.48)
SEm(±)	**1.55**	**0.34**	**0.68**	**0.45**	**0.39**	**0.38**	**0.48**	**0.60**
LSD (0.05)	**NS**	**1.36**	**1.05**	**2.04**	**1.18**	**1.14**	**1.43**	**1.83**

** Parenthesized values are means of original values; Data transformed to square root transformation ("x+1)*
**DASE: Days after starting of experiment*

T_1- Glyphosate ammonium salt 79.2% SG @ 1.089 kg ai ha^{-1}, T_2- Glyphosate ammonium salt 79.2% SG @ 2.178 kg ai ha^{-1} , T_3- Glyphosate ammonium salt 79.2% SG @ 4.356 kg ai ha^{-1}, T_4- Glyphosate ammonium salt 71% SG @ 2.13 kg ai ha^{-1}, T_5- Paraquat @ 0.5 L ha^{-1}, T_6- Glyphosate (41%SL) +2,4-D (Na) @ 1.0L+0.5 kg ae ha^{-1}, T_7- Glyphosate (41%SL) @ 1.5 L ae ha^{-1}, T_8- Slashing & in-situ mulching of weeds before flowering, T_9- Weed free check and T_{10}-Weedy check

Table 2: Treatment's impact on weed control efficiency (%) in tea

Treatment	Summer season			Monsoon season			
	30 DASE	60 DASE	90 DASE	30 DASE	60 DASE	90 DASE	120 DASE
T_1	79.80	76.26	69.96	87.77	76.93	76.19	75.41
T_2	91.32	88.09	85.10	95.01	87.79	84.74	83.43
T_3	93.76	91.85	86.84	96.96	90.38	89.80	88.53
T_4	87.79	84.51	77.83	89.05	84.58	81.27	80.77
T_5	68.83	68.04	49.06	82.29	71.25	69.27	69.61
T_6	93.05	92.58	90.51	97.01	94.24	90.41	89.70
T_7	89.55	87.89	81.52	93.10	83.46	82.67	78.24
T_8	79.24	78.68	66.12	93.89	84.45	75.08	64.72
T_9	100.00	100.00	100.00	100.00	100.00	100.00	100.00
T_{10}	-	-	-	-	-	-	-
SEm(±)	**1.33**	**3.89**	**1.66**	**0.90**	**1.46**	**2.13**	**2.72**
LSD(0.05)	**4.92**	**3.97**	**11.52**	**2.69**	**4.34**	**6.34**	**8.07**

**DASE: days after starting of experiment*

Table 3: Treatment's impact on phytotoxicity in tea

Treatment	Crop phytotoxicity			
	0 and 1 DAHA	3 and 5 DAHA	7 DAHA	10 DAHA
T_1	0	0	0	0
T_2	0	0	0	0
T_3	1.0	1.0	1.0	1.0
T_4	0	0	0	0
T_5	0	0	0	0
T_6	0	0	0	0
T_7	0	0	0	0
T_8	-	-	-	-
T_9	-	-	-	-
T_{10}	-	-	-	-

** DAHA: days after herbicide application*

Table 4: Treatment's impact on fresh weight of plucked shoot (mg) of tea

Treatment	Summer months			Monsoon months		
	May	June	July	August	September	October
T_1	191.55	116.47	158.68	134.19	101.43	62.01
T_2	204.54	153.00	179.03	153.15	112.14	73.24
T_3	198.67	134.82	171.00	147.77	106.96	70.61
T_4	196.57	125.20	167.22	137.69	105.02	62.97
T_5	189.85	114.20	161.67	128.09	89.42	58.61
T_6	210.00	152.07	184.74	160.67	116.67	70.96
T_7	198.31	145.07	175.39	150.13	109.26	67.67
T_8	194.83	121.09	164.35	130.44	96.93	60.97
T_9	212.33	162.66	185.00	171.72	119.14	74.88
T_{10}	180.99	106.33	146.67	118.00	80.00	50.50
SEm(±)	**13.12**	**9.52**	**7.15**	**8.10**	**5.98**	**3.94**
LSD(0.05)	**NS**	**28.21**	**21.17**	**23.99**	**17.70**	**11.66**

Table 5: Treatment's impact on made tea yield, available NPK and microbial biomass carbon in soil

Treatment	Made tea yield (kg ha^{-1})	Available nutrient (kg ha^{-1})			Microbial biomass carbon (µg g^{-1})
		N	P	K	
T_1	735	231.73	17.66	180.01	99.63
T_2	839	241.20	17.48	186.85	103.22
T_3	785	254.07	18.19	190.63	102.35
T_4	758	241.40	17.09	183.73	99.22
T_5	703	222.13	16.92	177.44	91.26
T_6	850	260.17	16.30	184.92	95.57
T_7	797	244.23	17.64	179.71	105.30
T_8	721	234.57	16.58	174.33	97.31
T_9	898	269.03	17.12	181.06	97.65
T_{10}	609	223.40	16.19	160.23	100.90
SEm(±)	**32**	**8.29**	**0.31**	**3.23**	**5.67**
LSD (0.05)	**93**	**24.55**	**NS**	**9.57**	**NS**
Initial		273.70	16.50	196.42	

Table 6: Treatment's impact on gross returns (INR ha^{-1}), net returns (INR ha^{-1}) and net returns per rupee invested in tea

Treatment	Gross returns (INR ha^{-1})	Net returns (INR ha^{-1})	Net returns per rupee invested
T_1	338100	224728	1.98
T_2	386093	268024	2.27
T_3	361100	243694	2.08
T_4	348833	236452	2.10
T_5	323533	213002	1.93
T_6	391000	271487	2.27
T_7	366620	249368	2.13
T_8	331507	212366	1.78
T_9	413233	249527	1.52
T_{10}	280140	177884	1.74

consistently upto 90 DASE in weed free check. Tank mix combination of glyphosate at1.0 L ha^{-1} together with 2,4-D (Na) at 0.5 kg ha^{-1} (T_6) being at par with glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3) resulted in substantially decreased dry matter build up by total weeds at all stages of observation. Glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) and glyphosate 1.5 L ha^{-1} (T_7) were at par to these treatments at 30 and 90 DASE. At 30 DASE, glyphosate ammonium 71% at 2.13 kg ai ha^{-1} (T_4) was also equally effective to these treatments. Among different herbicides, paraquat 0.5 L ha^{-1} (T_5) was discovered to be least efficient at all phases of observation in lowering the dry matter of all weeds.

Compared to summer, the dry matter accumulation by weeds in treated plots during monsoon was less at 30 DASE , which started to increase upto 120 DASE (Not reader oriented sentence, please re phrase). However in general, in weedy check, decreasing trend in the total weed dry matter was noticed from 30 to 120 DASE. In this season also, tank mix combination of glyphosate 1.0 L ha^{-1} together with 2,4-D (Na) 0.5 kg ha^{-1} (T_6) and glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3), which were significantly superior during summer season have also performed in similar way at all stages of observation. However, at 30 DASE, glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) was similarly effective to these treatments in decreasing the dry matter accumulation by total weeds and was next better at other stages of observation. At 30 DASE, glyphosate ammonium 71% at 2.13 kg ai ha^{-1} (T_4) and glyphosate 1.5 L ha^{-1} (T_7) also was statistically similar to glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2). Apart from weedy check, higher total weed dry matter accumulation was recorded in plots treated with paraquat 0.5 L ha^{-1} (T_5). The tank mix combination of glyphosate along with 2,4-D was found to be most effective to reduce count and dry weight of weeds. Kabir *et al*. (1991) & Kumar and Ghosh (2015) reported better weed control of with glyphosate application in tea crop.

Weed control efficiency (WCE)

During summer, among remaining weed control treatments, significantly higher weed control efficiencies were achieved with tank mix application of glyphosate 1.0 L ha^{-1} together with 2,4-D (Na) 0.5 kg ha^{-1} (T_6) and glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3) at all stages of observation (Table 2). The corresponding weed control efficiency obtained by these two treatments varied from 93.1 to 90.5% and 91.8 to 86.8% at different observational stages. However, glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) and glyphosate 1.5 L ha^{-1} (T_7) were also at par to these treatments for efficiency of weed control at 30 and 90 DASE and next better at 60 DASE. Glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) had achieved weed control efficiency in the range of 91.3 to 85.1% and glyphosate 1.5 L ha^{-1}(T_7) had 89.6 to 81.5% during all stages of observation. Efficiency for weed control was lowest with paraquat 0.5 L ha^{-1} (T_5) followed by slashing & in-situ mulching of weeds (T_8) and glyphosate ammonium 79.2% at 1.089 kg ai ha^{-1} (T_1) during all stages of observation.

During monsoon season, combination of glyphosate 1.0 L ha^{-1} together with 2,4-D (Na) 0.5 kg ha^{-1} (T_6) being at par with glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3) had significantly higher weed control efficiencies in the range of 97.0 to 89.7% and 97.0 to 88.5%, respectively, from 30 to 120 DASE. However, glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) was also at par to these treatments at all stages of observation except 90 DASE, where it was next better treatment in this regard. At 60 and 120 DASE, glyphosate ammonium 71% at 2.13 kg ai ha^{-1} (T_4) behaving statistically similar to glyphosate ammonium 79.2% at 4.356 and 2.178 kg ai ha^{-1} (T_2) was the next

better treatment which had significantly higher weed control efficiency. While, at 60 DASE, glyphosate at 1.5 L ha^{-1} (T_7) and slashing and in-situ mulching of weeds behaving statistically similar to these treatments and at 30 DASE with only glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) had significantly higher weed control efficiencies. However, at 90 DASE, glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) being at par with its higher dose also had higher efficiency for weed control. The higher weed control efficiencies achieved by different herbicides was because dry weight of weeds over weedy check had significantly decreased. During different observational stages, the lowest weed control efficiencies were achieved with paraquat at 0.5 L ha^{-1} (T_5). Higher weed control efficiency with the use of glyphosate's ammonium salt 71% at 2.13 kg ai ha^{-1} and hand weeding was also reported by Kumar *et al*. (2017).

Crop phytotoxicity

Herbicide's application effect on the health of crop was visually recorded at different stages i.e. 0-10, 10-20, 20-30 and 30-40 days after herbicide application in summer and monsoon seasons. During both seasons, no adverse effect in terms of chlorosis, necrosis or stunted growth was seen on tea after all the herbicides had been applied. However, glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3) showed symptoms of slight curling of old leaves which remained upto 20 days after its application and rated 1 on 1-10 phytotoxicity rating (Table 3). These curling symptoms started to disappear after 20 days of its application and plants completely recovered after one month of herbicide spray. This clearly indicated that all other herbicides except glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3) can be safely applied in tea. Similar outcomes were reported by Kumar *et al*. (2017) and Cheramgoi *et al*. (2015) with the application of ammonium salt of glyphosate 71% and glyphosate, respectively.

Shoot growth studies

Fresh weight of plucked shoot

Weed control treatments had substantial influence on fresh weight of shoots plucked in different months during both the seasons (Table 4). During summer season, significantly higher fresh weight of plucked shoots was obtained with tank mix application of glyphosate at 1.0 L ha^{-1} together with 2,4-D (Na) at 0.5 kg ha^{-1} (T_6) and glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) which behaved statistically similar to each other in all observational months. However, glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3) and glyphosate at 1.5 L ha^{-1} (T_7) were also at par to these treatments during June and July months and was next better treatment during May month. In July month, glyphosate ammonium 71% at 2.13 kg ai ha^{-1} (T_4) and slashing and in-situ mulching of weeds before flowering (T_8) were also found statistically alike to these treatments and had significantly higher fresh weight of tea shoot.

Same trend was followed during monsoon season, where combination of glyphosate at 1.0 L ha^{-1} and 2,4-D (Na) at 0.5 kg ha^{-1} (T_6) being at par with glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) had significantly higher fresh weight of tea shoot. In this regard, except during August, glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3) was equally effective. Likewise, glyphosate ammonium 71% at 2.13 kg ai ha^{-1} (T_4), which was at par to these treatments also proved its superiority for fresh weight of tea shoot during September. However, during August month, both formulations i.e. glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3) and glyphosate ammonium 71% at 2.13 kg ai ha^{-1} (T_4) were found to be the other better treatments. These herbicides effectively controlled weeds, resulting in better availability of nutrients and other resources to tea bushes and helped in better growth of shoots.

Beside weedy check, among various weed-control methods, lowest fresh weight of tea shoot was recorded with paraquat at4 0.5 L ha^{-1} (T_5) during all months.

Made tea production (MTP)

Data on how treatments affected the production of made tea has been given in Table 5. Lower yield was recorded from weedy check treatment followed by paraquat at 0.5 L ha^{-1} (T_5), slashing and in-situ mulching of weeds before flowering (T_8) and glyphosate ammonium 79.2% at 1.089 kg ai ha^{-1} (T_1). Application of glyphosate 1.0 L ha^{-1} combined with 2,4-D (Na) at 0.5 kg ha^{-1} (T_6) and glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) had 39.57 and 37.76 per cent, respectively, higher made tea yield over weedy check. The higher yields obtained with the combined application of glyphosate along with 2,4-D (Na) (T_6) demonstrates how effective this combination is at controlling weeds in tea. This herbicide combination was effective in controlling all types of weeds due to synergistic effect between these two herbicides. The presence of weeds in weedy check has resulted in a loss of 47.45% in made tea yield. Kabir *et al*. (1991) and Bose *et al*. (2007) also reported higher tea yield with the use of glyphosate alone and glyphosate's ammonium salt 71% at 3.0 kg ai ha^{-1}. Paul and Pierre (2012) in weedy check reported lower green leaf yield of tea in comparison to weed control treatments.

Available NPK and microbial biomass carbon

Application of glyphosate at 1.0 L ha^{-1} together with 2,4-D (Na) at 0.5 kg ha^{-1} (T_6) and glyphosate ammonium

salt 79.2% at 4.356 kg ai ha^{-1} (T_3) had significantly higher available nitrogen which was comparable to weed free check (T_{10}) (Table 5). Significantly lower available nitrogen was recorded in paraquat at 0.5 L ha^{-1} (T_5) and weedy check (T_{10}). Substantially more potassium in soil was recorded with glyphosate ammonium 79.2% at 4.356 (T_3) & 2.178 kg ai ha^{-1} (T_2), glyphosate+2,4-D (Na) at 1.0L+0.5 kg ha^{-1} (T_6), glyphosate ammonium 71.0% at 2.13 kg ai ha^{-1} (T_4) and weed free check (T_9). Lower available potassium in soil was recorded in slashing and in-situ mulching of weeds (T_8) followed by paraquat at 0.5 L ha^{-1} (T_5). Although effects were not significant for available phosphorus but numerically higher available phosphorus was recorded with glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3) followed by glyphosate ammonium 71% at 2.13 kg ai ha^{-1} (T_4) and glyphosate at1.5 L ha^{-1} (T_7). With respect to microbial biomass carbon, all treatments having glyphosate had more microbial biomass carbon than weed free check. Soil microbial biomass has been shown to increase after glyphosate application (Nguyen *et al*., 2016), presumably because the microbes use the glyphosate carbon (C), nitrogen (N), and phosphorus (P) during degradation (Mijangos *et al*., 2009) or due to the availability of more decomposing plant (weeds) and microbial material as substrates. Kumar *et al*. (2017) furthermore reported no negative effects of pesticides including ammonium salt of glyphosate and glyphosate on soil microbial population after one month of their application.

Economics of treatments

Gross returns, net returns and net returns on per rupee invested under different weed control treatments are presented in Table 6. Highest cost of cultivation incurred under weed free treatment which was followed by slashing and in-situ mulching of weeds before flowering and glyphosate at 1.0 L ha^{-1} combined with 2,4-D (Na) at 0.5 kg ha^{-1} (T_6). The higher cost of cultivation of treatments in which hand weeding (T_{10}) and slashing (T_8) was adopted was due to higher cost of manual labour. Among herbicides, higher cost of cultivation for glyphosate at 1.0 L ha^{-1} combined with 2,4-D (Na) at 0.5 kg ha^{-1} (T_6) was due to higher cost of chemicals and processing cost of the finished product (tea). Gross returns of any treatment are directly proportional to the made tea production. Highest gross returns were obtained in weed free treatment. Among remaining treatments, glyphosate+2,4-D (Na) at 1.0 L+ 0.5 kg ha^{-1} (T_6) followed by glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) and glyphosate 1.5 L ha^{-1} (T_7) had higher gross returns of INR 3,91,000, 3,86,093and 3,66,620 ha^{-1}, respectively.

Weed management through the use of herbicides produced larger net returns than treatments in which hand weeding was done or no weeding was done. This resulted from the weeding operation's increased cost of physical labour. Amongst weed control treatments, highest net returns of INR 2,71,487 ha^{-1} were acquired through application of glyphosate 1.0 L ha^{-1} combined with 2,4-D (Na) 0.5 kg ha^{-1} (T_6) followed by glyphosate ammonium 79.2% at 2.178 (T_2) having net returns of INR 2,68,024 ha^{-1}. These two treatments resulted in an increase of INR 93,603 and 90,140/ha, respectively in net returns as compared to weedy check. The more net returns in these respective treatments were due to significantly more yield and less cost of cultivation. Glyphosate at 1.5 L ha^{-1} (T_7) and glyphosate ammonium 79.2% at 4.356 (T_3) having net returns of INR 2,49,368 and 243,694 ha^{-1}, respectively were the other better treatments. Apart from weedy check, slashing and in-situ mulching of weeds before flowering (T_8) and paraquat at 0.5 L ha^{-1} (T_5) had recorded lower net returns as compared to other weed control treatments. Prematilake *et al*. (2004) also reported similar results with ammonium salt of glyphosate.

Herbicide use resulted in higher net returns per rupee invested values, while weed free treatment as well as weedy check had lower values. Amongst different weed control treatments, application of glyphosate at 1.0 L ha^{-1} combined with 2,4-D (Na) at 0.5 kg ha^{-1} (T_6) and glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} (T_2) had highest value of net returns per rupee invested (2.27). Glyphosate at 1.5 L ha^{-1} (T_7), glyphosate ammonium 71% at 2.13 kg ai ha^{-1} (T_4) and glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} (T_3) followed these treatments and had net returns per rupee invested values of 2.13, 2.10 and 2.08, respectively. Lowest value of net returns per rupee invested (1.52) was obtained in weedy free check followed by weedy check. Net return per rupee invested under weedy check was higher than the weed free check. This resulted from the higher cost of manual weeding because the latter could not increase the yield in the same proportion as it increased the cost of cultivation. The results so obtained clearly indicated the superiority of managing weeds through use of herbicides.

CONCLUSION

Glyphosate ammonium 79.2% SG at 4.356 kg ai ha^{-1} being at par with glyphosate at 1.00 L + 2,4-D (Na) at 0.5 kg ha^{-1} successfully controlled weeds in tea. Glyphosate ammonium 79.2% SG at 2.178 kg ai ha^{-1} was the next best herbicide in this regard. Glyphosate ammonium 79.2% SG at 4.356 kg ai ha^{-1} was slight phytotoxic to the crop and phytotoxicity on the crop was observed upto one month of its application.

REFERENCES

Black, C.A. 1965. Methods of soil analysis. Part-I, American Society of Agronomy, Madison, Wisconsin, USA.

Bose, A., Ravikumar and 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 during 2-6 October pp 565-567.

Cheramgoi, E., Nyabundi, K., Maritim, J. and Tanui, S. 2015. Evaluation of Roundup Weather Max for the control of weeds in tea. *Tea Technical Issue* **36**(2): 91-97.

Gopalaswamy, T.P. and Xavier. 1992. Marketing of tea: Strategies for Indian tea industry, WP-XXVI. Indian Institute of Management, Bangalore.

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

Kabir, S.E., Chaudhuri, T.C. and Hajra, N.G. 1991. Evaluation of herbicides for weed control in Darjeeling tea. *J. Indian Agric.,* **35**(3): 179-185.

Kumar, A. and Ghosh, R.K. 2015. Bioefficacy of glyphosate for management of weeds in tea. In: 25th Asian-Pacific Weed Science Society Conference on *"Weed Science for Sustainable Agriculture, Environment and Biodiversity",* held at Hyderabad, India during13-16 October, 2015 p. 377.

Kumar, A., Ghosh, A., Mondal, D., Ghosh, R. and 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. Curr. Microbiol. Appl. Sci.,* **6**(8): 2160-2170.

Kumar, S., Rana, S.S., Angiras, N.N. and Ramesh. 2014. Weed management in tea with herbicides mixture. *Indian J. Weed Sci.,* **46**: 353–357.

Mijangos, I., Becerril, J.M., Albizu, I., Epelde, L. and Garbisu, C. 2009. Effects of glyphosate on rhizosphere soil microbial communities under two different plant compositions by cultivation-dependent and -independent methodologies. *Soil Biol. Biochem.,* **41**(3): 505-513.

Mirghasemi, S.T., Daneshain, J. and Baghestani, M.A. 2012. Investigating of increasing glyphosate herbicide efficiency with nitrogen in control of tea weeds. *Int. J. Agric. Crop Sci.,* **4**(24): 1817-1820.

Mishra, A. and Tosh, G.C. 1979. Chemical weed control studies of dwarf wheat. *J. Res.Orissa Univ. Agric. Sci. Technol.,***10**: 1-6.

Mitra, A. and Neelanjana. 1991. Indian tea industry: Problems and Policies. *Econ. Political Weekly,* **26**(48): 153-156.

Nguyen, D.B., Rose, M.T., Rose, T.J., Stephen, G.M. and Zwieten L. 2016. Impact of glyphosate on soil microbial biomass and respiration: A meta-analysis. *Soil Biol. Biochem.,* **92**: 50-57.

Olsen, S.R., Cole, C.W., Watanable, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with $NaHCO_3$. *US Dept. Agric. Cir.,***939**: 19-23.

Opeke, K.L. 2005. *Tropical commodity tree crops*. Second edition, Spectrum house, Ring road, Ibadan, Nigeria. pp. 436-440.

Paul, B.V.D. and Pierre, B.J. 2012. Evaluation of the efficacy of herbicides in tea (*Cammelia sinensis*) production in Rawada. *Int. J. Appl. Agric. Res.,* **7**(3): 197-202.

Prematilake, K.G., Froud-Williams, R.J. and 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. Management,* **4**(4): 239-248.

Rajkhowa, D.J., Bhuyan, R.P. and Barua, I.C. 2005. Evaluation of Carfentrazone-ethyl 40 DF and glyphosate as tank mixture for weed control in tea. *Indian J. Weed Sci.,* **37**(1&2): 157-158.

Rana, S.S. and Rana, M. C. 2016. *Principles and Practices of Weed Management*. Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, 138pages. (DOI: 10.13140/RG.2.2.33785.47207)

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the determination of available N in soils. *Curr. Sci.,***25**(1): 259-260.

Vance, E.D., Brookes, P.C. and Jenkinson, D.S. 1987. An extraction method for measuring soil microbial biomass C. *Soil Biol. Biochem.,* **19**(6): 703-707.