International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

IJBSM June 2023, 14(6):814-823 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR3466a

Research Article Stress Management

DOI: HTTPS://DOI.ORG/10.23910/1.2023.3466a

Bio-Efficacy of Glyphosate Ammonium 79.2% SG against Weeds in Tea (*Camellia sinensis* L.) under Mid-hill Conditions of Himachal Pradesh

Said Agha Tanha, P. Chopra, S. S. Rana, N. Datt, G. Singh and N. Kaur

Dept. of Agronomy, College of Agriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishwavidyalaya, Palampur, Himachal Pradesh (176 062), India

Open Access

Corresponding pankuch@rediffmail.com

0009-0001-6601-6991

ABSTRACT

A field experiment was conducted at the research farm of Department of Tea Husbandry and Technology, CSK HPKV, Palampur, Himachal Pradesh, India during the summer (February–May) and monsoon (June–October) seasons of 2018. The study consists of ten weed control treatments viz. glyphosate ammonium 79.2% SG at 1.089, 2.178 and 4.356 kg ai ha^{-1}, glyphosate ammonium 71% SG at 2.13 kg ai ha^{-1}, paraquat 0.5 kg ha^{-1}, tank mix combination of glyphosate with 2,4-D (Na) at 1.0+0.5 kg ha^{-1}, glyphosate 1.5 kg ha^{-1}, slashing and *in-situ* mulching of weeds before flowering, weed free and weedy check. *Bidens pilosa, Paspalum distichum, Chromolaena adenophorum, Achyranthus aspera* and *Artemisia* sp., were the dominant weeds in both summer and monsoon seasons. Glyphosate ammonium 79.2% SG at 4.356 kg ai ha^{-1} being at par with glyphosate 1.00 kg+2,4-D (Na) 0.5 kg ha^{-1} was quite effective in controlling *Bidens pilosa, Paspalum distichum, Chromolaena adenophorum, Achyranthus aspera, Lantana camara, Ageratum* sp. and *Artemisia* sp. in tea. Lowest count of other weeds (*Hedera helix, Solanum xanthocarpum, Leucas aspera* and *Cynodon dactylon*) was recorded under glyphosate+2,4-D (Na) 1.0 kg +0.5 kg ha^{-1} and glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1}, being comparable to weed free check. Among different weed control treatments, significantly higher green leaf yield of 3767 and 3690 kg ha^{-1} with weed index values of 4.29 and 6.25% was recorded with the application of glyphosate 1.0 kg ha^{-1}+2,4-D (Na) 0.5 kg ha^{-1} and glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1}, respectively which were also statistically similar to weed free check.

KEYWORDS: Tea, glyphosate ammonium, weed control, yield

Citation* (VANCOUVER)*: Tanha et al., Bio-Efficacy of Glyphosate Ammonium 79.2% SG against Weeds in Tea (*Camellia sinensis* L.) under Mid-hill Conditions of Himachal Pradesh. *International Journal of Bio-resource and Stress Management,* 2023; 14(6), 814-823. HTTPS://DOI.ORG/10.23910/1.2023.3466a.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 03rd March 2023 RECEIVED in revised form on 19th May 2023 ACCEPTED in final form on 31st May 2023 PUBLISHED on 17th June 2023

1. INTRODUCTION

Tea (*Camellia sinensis* (L.) Kuntze) is the second most consumed drink in the world after water. Polyphenol *viz.* catechins and theaflavins present in tea have been documented as strong antioxidants and their effectiveness in prevention of cardiovascular diseases, hypertension, diabetes, obesity and alleviation of metabolic syndrome, inhibition of antiviral activity and modulation of immunity (Barooah, 2020; Yang, 2018; Tang et al., 2019). Liu et al., 2015 reported that the presence of unique theaflavin derivatives, amino acid L-theanine has neuroprotective effects that had potent anti-HIV-1 activity and epigallocatechin gallate (EGCG) present in green tea has been shown to inhibit Herpes simplex virus type-1 (HSV-1) (Issack et al., 2008).

India is the world's second-largest producer and consumer of tea, generating more than 1000 million kg from an area of 579.35 thousand hectares (Anonymous, 2023). Among the critical factors limiting optimum productivity, weeds had proved to reduce the yield and quality of tea besides competing for nutrients and moisture (Opeke, 2005; Paul and Pierre, 2012). In the early phases of crop growth, weeds remove 5–6 times more nitrogen, 5–12 times more phosphorus, and 2–5 times more potassium than the beverage crop, creating intense competition for these nutrients and ultimately lowering production (Kumar et al., 2021). Weeds meddle with routine operations in the tea garden and act as an anchorage for some insect and disease pest (Wilson, 2005). Worldwide, tea crop loss due to weeds has been estimated to be about 146 million kg annually which accounts to 14–15% of total production (Rana et al, 2020). Uncontrolled weed growth can cause a loss of tea productivity to the extent of 50–70%. (Deka and Barua, 2015; Singh et al., 2014). Weed infestation and thereby damage to tea is more severe in young tea up to two years before canopy closure and during the period of pruning every three to four years (Kgawa and Fredrick, 2015). Due to the high cost of labour and other inputs like herbicides, managing weeds in tea plantations has become a critical concern (Prematilake et al., 2004; Ilango et al., 2010). Chemical control scores over other methods due to their efficiency, cost effectiveness and ease of operation (Kumar et al., 2014; Rana and Rana, 2016; Mirghasemi et al., 2012). Herbicide use is the primary method for controlling the weed problem in tea (Sarkar and Kabir, 2016). Glyphosate is a commonly used herbicide in agriculture and non-crop area for the management of wide range of weeds and is effective for weed control in tea (Bose et al., 2007). The mechanism of this herbicide is that after getting absorbed by the plant it binds to the enzyme enolpyruvyIshikimate-3-phosphate synthase (EPSPS) and block the activity of the enzyme which comes at the shikimic acid pathway and converts simple carbohydrate precursors into aromatic amino acid and many other metabolites (Kanissery et al., 2019; Devi et al., 2019). It is continuously absorbed by roots, metabolized, and transported into edible tea leaves (Tong et al., 2017). Glyphosate salts perform a variety of important functions. In particular, the salt portion of the formulated product may allow for greater absorption of glyphosate through its more effective penetration into the leaf (Nordby and Hager, 2011; Travlos et al., 2017). Sharma and Singh (2001) showed that the application of glyphosate with ammonium sulfate, significantly increased weed control compared to glyphosate alone. Keeping this in view, a new formulation of ghyphosate i.e. glyphosate ammonium 79.2% SG was tested under the present study for effective control of weeds and achieving higher yield in tea.

2. MATERIALS AND METHODS

The study was carried out during summer (February–May) and monsoon (June–October) seasons of 2018 at the Tea Research Department of Tea Husbandry and Technology, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur. Agro-climatically, the experiment site falls under sub-temperate humid zone of Himachal Pradesh which is characterized by mild summers and cool winters along with high rainfall during monsoon. The experiment site lies between 32.101°N and 76.547°E. In the site selected for experimentation, the tea bushes were top pruned with the help of sickle in the month of December 2017. Recommended dose of N, P_2O_5 and K_2O was 90, 90 and 40 kg ha^{-1} in the form of urea (46%), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively was applied. Whole of the nitrogen, phosphorus and potassium were applied in the month of February. Ten weed control treatments [T_1- Glyphosate ammonium salt 79.2% SG @ 1.089 kg 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 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1}, T_7- Glyphosate @ 1.5 l ha^{-1}, T_8- Slashing & in-situ mulching of weeds before flowering, T_9- Weed free check and T_{10}- Weedy check] were evaluated in randomized block design with three replications. The herbicide application and intercultural operations were carried out as per the treatments in respective plots. Post-emergence application of all the herbicides was done during summer and again during the monsoon season. The crop was managed following all recommended package of practices for tea, except variable treatments.

The species-wise weed count was recorded at their maximum population stage (in weedy check) at 90 days after start of the experiment (DASE) during summer and

30 DASE during monsoon season. The observations on dry matter accumulation by total weeds was taken at same stages. The total number of weeds present in 0.25 m^2 area were selected by using a quadrate of 0.5×0.5 m^2 at random in each plot. The number of total weeds present in the quadrate was counted and expressed in 1 m^2 by multiplying with 4. The total weeds inside each quadrate were uprooted, cleaned and dried in an electric oven for 72 hours maintaining a constant temperature of 70°C. After drying, weight of total weeds was taken and expressed in g m^{-2}. The data on total weed count was subjected to √x+1square root transformation to normalize the distribution. The green leaves from each plot were plucked manually. Two leaves and a bud were plucked from each shoot of the bush from each plot. The green leaf yield (g $bush^{-1}$) obtained per plot was converted to kg ha^{-1}. The total green leaf yield was the sum total of all flushes i.e. early, main and back-end flush The weed Index was calculated as per formulae given below:

Weed index (WI)=(X-Y/ X)×100

X-Yield from weed free

Y-Yield of particular treatment

The data so obtained from field were subjected to statistical analysis as per procedure given by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1. Weed flora

The crop was mainly infested with perennial weeds. The proportion of weed species in the weedy check at their maximum population stage during summer (90 DASE) and monsoon (30 DASE) seasons has revealed that the *Bidens pilosa, Artemesia* sp. and *Paspalum distichum* were the dominant weeds constituting 24.4, 16.5 and 15.3%, respectively, of the total weed population during summer. *Chromolaena adenophorum, Achyranthus aspera, Lantana camara* and *Ageratum* sp. constituted 11.2, 11.2, 7.6 and 5.1%, respectively, of total weed population. The other weeds viz. *Hedera helix*, *Leucas* sp., *Solanum xanthocarpum* and *Cynodon dactylon*etc collectively constituted about 8.6% of total weed flora. Almost similar type of weed flora was present during monsoon. *Bidens pilosa, Artemesia* sp. and *Paspalum distichum* were the dominant weeds constituting 22.2, 16.4 and 15.2%, respectively, of the total weed population. *Chromolaena adenophorum, Achyranthus aspera, Lantana camara* and *Ageratum* sp. constituted 12.3, 10.5, 9.4 and 7.0%, respectively, of total weed population, whereas other weeds had 7.0% proportion. Same type of weed flora was also recorded by Rana et al., 2020 under Palampur conditions.

3.2. Species wise weed count at maximum count stage of weeds during summer season

Weed count of different weeds was significantly influenced due to weed control treatments at their maximum count stage based on population of weeds in weedy check i.e. 90 DASE during summer season. All weed control treatments were significantly superior over weedy check (Table 1).

Table 1: Effect of treatments on count (No. m^{-2}) of different weeds at 90 DASE during summer season

Treatment	Dose (kg ai ha^{-1})	*Bidens pilosa*	*Chromolaena adenophorum*	*Paspalum distichum*	*Artemisia* sp.	*Lantana camara*	*Ageratum* sp.	*Achyranthus aspera*	Others
Glyphosate ammonium salt 79.2% SG	1.089	3.37 (10.67)	3.40 (10.67)	4.52 (20.00)	5.38 (28.00)	3.61 (12.00)	2.95 (8.00)	4.71 (21.33)	3.61 (12.00)
Glyphosate ammonium salt 79.2% SG	2.178	2.69 (6.67)	2.49 (5.33)	4.07 (16.00)	4.43 (18.67)	3.20 (9.33)	2.49 (5.33)	3.78 (13.33)	2.49 (5.33)
Glyphosate ammonium salt 79.2% SG	4.356	2.69 (6.67)	1.87 (4.00)	3.78 (13.33)	3.73 (13.33)	3.00 (8.00)	2.08 (4.00)	3.37 (10.67)	2.08 (4.00)
Glyphosate ammonium salt 71% SG	2.13	3.20 (9.33)	2.75 (6.67)	4.43 (18.67)	4.70 (21.33)	3.40 (10.67)	2.75 (6.67)	4.43 (18.67)	2.95 (8.00)
Paraquat	0.500	3.75 (13.33)	4.03 (15.33)	5.08 (25.33)	5.49 (29.33)	3.95 (14.67)	3.20 (9.33)	4.72 (21.33)	3.75 (13.33)
Glyphosate+2,4-D (Na)	1.0+0.5	2.75 (6.67)	1.82 (2.67)	3.00 (8.00)	4.10 (16.00)	2.95 (8.00)	2.08 (4.00)	3.61 (12.00)	2.08 (4.00)
Glyphosate	1.5	3.58 (12.00)	2.49 (5.33)	4.10 (16.00)	4.57 (20.00)	3.20 (9.33)	2.49 (5.33)	4.28 (17.33)	2.33 (5.33)

Table 1: continue...

Treatment	Dose (kg ai ha^{-1})	*Bidens pilosa*	*Chromolaena adenophorum*	*Paspalum distichum*	*Artemisia* sp.	*Lantana camara*	*Agera-tum* sp.	*Achyran-thus aspera*	Others
Slashing and *in-situ* mulching of weeds before flowering		4.10 (16.00)	3.37 (10.67)	4.32 (18.67)	4.57 (20.00)	3.78 (13.33)	2.95 (8.00)	4.28 (17.33)	3.40 (10.67)
Weed free check		1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	2.24 (4.0)	1.00 (0.00)	1.00 (0.00)	1.00 (0.0)
Weedy check		8.03 (64.00)	5.49 (29.33)	6.40 (40.00)	6.66 (43.33)	4.57 (20.00)	3.78 (13.33)	5.49 (29.33)	4.86 (22.67)
SEm±		0.34	0.40	0.14	0.21	0.21	0.30	0.22	0.38
LSD (p<0.05)		1.00	1.18	0.98	0.66	0.62	0.87	0.64	1.12

*Values in parentheses are means of original values; Data transformed to square root transformation (√x+1)

Significantly lowest count of *Bidens pilosa* was recorded in weed free check. All the remaining weed control treatments except paraquat 0.5 l ha^{-1} and slashing and *in-situ* mulching of weeds being at par among themselves significantly reduced the count of *Bidens pilosa*.

Tank mix application of glyphosate 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1} and alone application of glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} significantly reduced the count of *Chromolaena adenophorum* which was comparable to weed free check. Glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1}, glyphosate 1.5 l ha^{-1} and glyphosate ammonium 71% at 2.13 kg ai ha^{-1} were the other better treatments which behaved statistically similar to the combination of glyphosate 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1} and glyphosate 1.5 l ha^{-1}.

With respect to *Paspalum distichum*, apart from weed free check, combined application of glyphosate 1.0 l ha^{-1} along with 2,4-D (Na) and glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} behaving statistically similar to each other were proved to be significantly better for controlling this weed. All the remaining weed control treatments except paraquat 0.5 l ha^{-1} were equal to glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1}.

Significantly lowest count of *Artemesia* sp. was found in weed free check. Glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} behaving statistically similar to glyphosate 1.0 l ha^{-1} +2,4-D (Na) 0.5 kg ha^{-1} had significantly lower population of this weed. All remaining weed control treatments except paraquat 0.5 kg ha^{-1} being at par with glyphosate+2,4-D (Na) at 1.0 l+0.5 kg ha^{-1} were the other better treatments to control *Artemesia* sp.

Complete control of *Lantana camara* was achieved in weed free check. All remaining weed control treatments except paraquat 0.5 l ha^{-1}, slashing and *in-situ* mulching of weeds and glyphosate ammonium 79.2% at 1.089 kg ai ha^{-1} being at par among themselves proved significantly superior to control this weed.

Significantly lowest count of *Ageratum* sp. was found in weed free check. Tank mix application of glyphosate 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1}, glyphosate ammonium 79.2% at 4.356 and 2.178 kg ai ha^{-1} and glyphosate ammonium 71% at 2.13 kg ai ha^{-1} behaving statistically similar among themselves were the other better treatments to control this weed.

Achyranthus aspera population was significantly lowest in weed free check. Among other weed control treatments, glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} being at par with tank mix application of glyphosate 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1} and glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} had significantly lower count of this weed. Glyphosate 1.5 l ha^{-1} and slashing and *in-situ* mulching of weeds which remained at par with glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} were found to be the other better treatments in this regard. Paraquat 1.5 kg ha^{-1} was least effective to control *Achyranthus aspera*.

Same trend of treatments as that for controlling *Lantana camara* was followed in respect of others weeds with the difference that slashing and *in-situ* mulching of weeds were better than glyphosate ammonium 79.2% at 1.089 kg ai ha^{-1}. Kumar and Ghosh (2015) also found glyphosate as the best herbicide for controlling weeds in tea. Bose et al. (2007) also reported better results with the use of ammonium salt of glyphosate 71% in tea. Synergestic effect of using 2,4-D in combination with glyphosate for reducing the count of weeds was also reported by Zhang et al. (1995). Through herbicide synergism there was an overall improvement of herbicide combination compared to the activity of each herbicide applied individually

3.3. Species wise weed count at maximum count stage of weeds during monsoon season

Weed control treatments significantly influenced the count of different weeds at maximum count stage of weeds based on weedy check i.e. 30 DASE during monsoon season.

All weed control treatments were found to be significantly superior over weedy check for controlling different weeds and trend of weed control treatments to control different weeds has been given in Table 2.

Significantly lower population of *Bidens pilosa* was found in weed free check and glyphosate ammonium 79.2% at 4.356 and 2.178 kg ha^{-1}, tank mix application of glyphosate 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1} and glyphosate 1.5 l ha^{-1} were also at par to it. Glyphosate ammonium 79.2% at 1.089, glyphosate ammonium 71% at 2.13 kg ai ha^{-1} and slashing and *in-situ* mulching of weeds being at par with glyphosate 1.5 kg ha^{-1} were the other good treatments. Among different herbicides, paraquat 0.5 l ha^{-1} had maximum count of this weed.

With respect to *Chromolaena adenophorum*, significantly lowest count was recorded in weed free check. Among other treatments, significantly lower count of this weed was recorded under combined application of glyphosate 1.0 l ha^{-1} with 2, 4-D (Na) 0.5 kg ha^{-1}, glyphosate ammonium 79.2% at 4.356 and 2.178 kg ai ha^{-1} and glyphosate ammonium 71% at 2.13 kg ha^{-1}. Glyphosate 1.5 l ha^{-1} and glyphosate ammonium 79.2% at 1.089 kg ai ha^{-1} being at par with the other two higher doses of glyphosate ammonium 79.2% were the other good treatments for controlling this weed. Paraquat 0.5 l ha^{-1} was least effective to control *Chromolaena adenophorum*. Singh et al. (1992) also reported that glyphosate at 1.0 kg ha^{-1} was most effective in checking *Chromolaena odorata* in Himachal Pradesh. Mummigatti (1994) and Doddamani et al. (2001) revealed similar results where application of glyphosate lowered the relative water content, stomatal conductance and transpiration rate with concomitant increase in leaf temperature and resulting in death of weed plants.

Table 2: Effect of treatments on count (No. m^{-2}) of different weeds at 30 DASE during monsoon season

Treatment	Dose (kg ai ha^{-1})	*Bidens pilosa*	*Chromolaena adenophorum*	*Paspalum distichum*	*Artemisia* sp.	*Lantana camara*	*Ageratum* sp.	*Achyranthus aspera*	Others
Glyphosate ammonium salt 79.2% SG	1.089	2.49 (5.33)	3.00 (8.00)	3.58 (12.00)	4.10 (16.00)	2.75 (6.67)	2.95 (8.00)	3.93 (14.67)	2.08 (4.00)
Glyphosate ammonium salt 79.2% SG	2.178	1.41 (1.33)	2.24 (4.00)	2.75 (6.67)	3.37 (10.67)	2.49 (5.33)	2.49 (5.33)	2.95 (8.00)	1.67 (2.67)
Glyphosate ammonium salt 79.2% SG	4.356	1.00 (0.0)	2.24 (4.00)	2.49 (5.33)	3.20 (9.33)	2.49 (5.33)	2.49 (5.33)	2.75 (6.67)	1.00 (0.0)
Glyphosate ammonium salt 71% SG	2.13	2.49 (5.33)	2.49 (5.33)	3.20 (9.33)	3.78 (13.33)	2.75 (6.67)	2.75 (6.67)	3.15 (9.33)	2.49 (5.33)
Paraquat	0.500	3.40 (10.67)	3.58 (12.00)	3.93 (14.67)	4.43 (18.67)	3.40 (10.67)	3.00 (8.00)	4.10 (16.00)	2.95 (8.00)
Glyphosate+2,4-D (Na)	1.0+0.5	1.41 (1.33)	1.82 (2.67)	2.24 (4.00)	2.95 (8.00)	2.08 (4.00)	2.49 (5.33)	2.49 (5.33)	1.41 (1.33)
Glyphosate	1.5	1.82 (2.67)	2.75 (6.67)	3.00 (8.00)	3.37 (10.67)	2.54 (6.67)	2.75 (6.67)	3.20 (9.33)	1.82 (2.67)
Slashing and *in-situ* mulching of weeds before flowering		2.24 (4.00)	3.12 (9.33)	3.00 (8.00)	3.58 (12.00)	3.00 (8.00)	2.24 (4.00)	3.61 (12.00)	2.75 (6.67)
Weed free check		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)	1.00 (0.0)
Weedy check		7.18 (50.67)	5.38 (28.00)	5.96 (34.67)	6.18 (37.33)	4.70 (21.33)	4.10 (16.00)	4.99 (24.00)	4.10 (16.00)
SEm±		0.28	0.26	0.21	0.29	0.39	0.23	0.29	0.37
LSD (p<0.05)		0.82	0.76	0.64	0.88	1.10	0.69	0.86	1.10

*Values in parentheses are means of original values; Data transformed to square root transformation ($\sqrt{x+1}$)

Regarding *Paspalum distichum* , significantly lowest count was recorded in weed free check. Among remaining treatments, significantly lower count was recorded with tank mix application of glyphosate 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1}. However, glyphosate ammonium 79.2% at doses of 4.356 and 2.178 kg ai ha^{-1} were equally effective. Other weed control treatments except, paraquat 0.5 L ha^{-1} and glyphosate ammonium 79.2% at 1.089 kg ai ha^{-1} remaining par with glyphosate ammonium 79.2% at 4.356 and 2.178 kg ai ha^{-1} were the other best treatments in this regard.

Keeping plots weed free had resulted in significantly lowest count of *Artemesia and Ageratum* sp. For significantly reducing the count of these two weeds, all the treatments except glyphosate ammonium 79.2% at 1.089 kg ai ha^{-1} and paraquat 0.5 kg ha^{-1}, were equally effective.

For controlling *Lantana camara* effectively, combined application of glyphosate 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1} performed statistically similar to hand weeding twice. However, all other herbicides except paraquat 0.5 kg ha^{-1} were at par with tank mix application of glyphosate 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1}.

Weed free check had resulted in significantly lowest count of *Achyranthus aspera*. Among remaining treatments, tank mix application of glyphosate 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1} being at par with glyphosate ammonium 79.2% at 4.356 and 2.178 kg ai ha^{-1} and glyphosate ammonium 71% at 2.13 kg ai ha^{-1} was proved to be better and was followed by glyphosate 1.5 kg ha^{-1}.

For controlling other weeds, all weed control treatments except glyphosate ammonium 79.2% at 1.089 kg ai ha^{-1}, slashing and *in-situ* mulching of weeds and paraquat 0.5 l ha^{-1} were equally effective.

Glyphosate in combination with 2,4-D resulted in an increase in the metabolical activity, improving glyphosate transport and eventually leading to effective control of different weeds (Flint and Barrett, 1989). Better efficacy to control predominant infestation of broad-leaved weeds with ammonium salt of glyphosate (Excel Mera 71 SG) at 2.89 g litre^{-1} of water has also been reported by Ilango et al. (2010). Similar type of results with ammonium salt of glyphosate was also reported by Bose et al. (2007). For controlling weeds, Bautista et al., 2021 also found no antagonistic effect of tank mix application of glyphosate with 2,4-D.

3.4. Total weed count

Data on the effect of treatments on the total weed count at different stages have been given in Table 3. Total weed count was significantly influenced by different weed control treatments at all stages of observation. Significantly lowest count of total weed was recorded in weed free check during both the season.

During summer season, there was decline in the total weed count from initial due to the effect of herbicides at 30 DASE. Thereafter, there was gradual increase in count of weeds from 30–90 DASE because of emergence of many weeds. Whereas, in weedy check, increasing trend in the total weed count was noticed from initial to 90 DASE. In weed control treatments, combination of glyphosate 1.0 l ha^{-1} with 2,4-D (Na) 0.5 kg ha^{-1} being at par with glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} resulted in significantly lower count of total weeds at all stages of

Table 3: Effect of treatments on total weed count (No m^{-2}) at different time intervals during summer and monsoon season in tea

Treatment	Dose (kg ai ha^{-1})	Summer season				Monsoon season			
		Initial	30 DASE	60 DASE	90 DASE	30 DASE	60 DASE	90 DASE	120 DASE
Glyphosate ammonium salt 79.2% SG	1.089	13.60 (184.00)	9.36 (86.67)	9.98 (98.67)	11.11 (122.67)	8.69 (74.67)	8.72 (76.00)	7.46 (54.67)	7.25 (52.00)
Glyphosate ammonium salt 79.2% SG	2.178	13.78 (189.33)	7.08 (49.33)	7.72 (58.67)	9.00 (80.00)	6.69 (44.00)	7.00 (48.00)	5.72 (32.00)	5.11 (25.33)
Glyphosate ammonium salt 79.2% SG	4.356	13.54 (182.67)	6.18 (38.67)	6.95 (48.00)	8.04 (64.00)	6.08 (36.00)	6.13 (37.33)	5.41 (29.33)	5.32 (28.00)
Glyphosate ammonium salt 71% SG	2.13	13.24 (174.67)	7.40 (54.67)	8.61 (73.00)	10.05 (100.00)	7.88 (61.33)	7.72 (58.67)	6.58 (42.67)	6.80 (45.33)
Paraquat	0.500 l	13.39 (178.67)	10.37 (106.67)	11.32 (127.33)	11.49 (142.00)	9.98 (98.67)	10.03 (100.00)	8.22 (66.67)	7.95 (62.67)
Glyphosate+2,4-D (Na)	1.0l+0.5	13.23 (174.67)	5.20 (26.67)	6.70 (44.00)	7.89 (61.33)	5.72 (32.00)	6.18 (37.33)	4.79 (22.67)	4.71 (21.33)
Glyphosate	1.5 l	13.74 (188.00)	7.43 (54.67)	8.14 (65.33)	9.56 (90.67)	7.35 (53.33)	7.62 (57.33)	6.18 (37.33)	5.74 (32.00)
Slashing and *in-situ* mulching of weeds before flowering		14.61 (212.67)	8.54 (72.00)	9.57 (90.67)	10.74 (114.67)	8.05 (64.00)	8.77 (76.00)	7.62 (57.33)	7.17 (50.67)

Table 3: Continue...

Treatment	Dose (kg ai ha^{-1})	Summer season				Monsoon season			
		Initial	30 DASE	60 DASE	90 DASE	30 DASE	60 DASE	90 DASE	120 DASE
Weed free check		13.14 (172.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Weedy check		13.82 (190.67)	14.45 (208.00)	14.82 (218.67)	16.22 (262.00)	15.12 (228.00)	14.67 (214.67)	13.15 (172.00)	12.73 (161.33)
SEm±		0.43	0.44	0.28	0.22	0.25	0.35	0.38	0.41
LSD (P=0.05)		NS	1.32	0.84	0.65	0.91	1.19	1.11	1.15

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

observation. Glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} was the next better treatment for reducing the count of total weeds, behaving statistically similar to glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} at 30 and 60 DASE. At 30 DASE, glyphosate ammonium 71% at 2.13 kg ai ha^{-1} and glyphosate 1.5 kg ha^{-1} also behaved in a similar fashion for reducing the count of total weeds. Paraquat 1.5 kg ha^{-1} was the least effective treatment for reducing the total weed count, but significantly superior over weedy check at all stages of observation.

During monsoon, as compared to summer season, there was a decreasing trend in the combined count of weeds up to 30 DASE which remained almost same up to 60 DASE and thereafter gradually decreased. However, the differences were not too much marked. In weedy check, decreasing trend in the total weed count was noticed from 30–120 DASE. In this season, besides, weed free check, significantly lower count of total weeds was recorded with tank mix application of glyphosate 1.0 kg ha^{-1} along with 2,4-D (Na) 0.5 kg ha^{-1}and glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} at all stages. Glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} at all stages of observation except 30 DASE and glyphosate 1.5 kg ha^{-1} at 120 DASE were also at par to these treatments in reducing the total weed count. Similar to summer season, among herbicide treatments, highest weed count was recorded in plots treated with paraquat 1.5 kg ha^{-1}. Therefore, 2,4-D could be used either as a component of a formulation or in a tank-mix with glyphosate. IIango et al. (2010) and Bose et al. (2007) found effective control of weeds with the use of ammonium salt of glyphosate 71%. Onsando (1992) and Devi et al., 2019 also found glyphosate as an effective herbicide in tea. Saikia et al., 2013; Blouin et al., 2004 also reported that in 2,4-D and glyphosate combination, each herbicide have improved the performance of the other and thus increased the herbicide's performance versus their alone application.

3.5. Total weed dry matter

The data for dry matter accumulation by total weeds was taken at their maximum dry matter stage (in weedy check) i.e. 90 DASE during summer and 30 DASE during monsoon season. It was revealed from data presented in Table 4 that during both the seasons, the tank mix combination of glyphosate 1.0 l ha^{-1} along with 2,4-D (Na) 0.5 kg ha^{-1} being at par with glyphosate ammonium 79.2% at 4.356 kg and 2.178 kg ai ha^{-1} resulted in significantly lower dry matter accumulation by total weeds. During summer, the glyphosate 1.5 l ha^{-1} also behaved statistically similar to these said treatments, however, during monsoon glyphosate ammonium 71% at 2.13 kg ai ha^{-1} and glyphosate 1.5 l ha^{-1} were statistically similar to only glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1}. Apart from weedy check, higher dry matter accumulation by total weeds was recorded in plots treated with paraquat 0.5 l ha^{-1} during both the seasons.

The tank mix combination of glyphosate along with 2,4-D was found to be most effective in reducing the dry weight of weeds. Flint and Barrett (1989) also reported additive or synergistic effect of this mixture to control field bindweed due to greater accumulation of herbicides in the roots of weeds. Similar results have been found for controlling Canada thistle (*Cirsium arvense*) and honeywine milkweed (*Ampelamus albidus*) by Moshier (1980) and Belles et al. (1980), respectively. Kumar and Ghosh (2015) reported better control of weeds with the application of glyphosate in tea crop.

3.6. Green leaf yield of tea

The data on effect of different weed control treatments on green leaf yield of tea have been given in Table 4. The data revealed that combined application of glyphosate 1.0 L ha^{-1} along with 2,4-D (Na) 0.5 kg ha^{-1} being at par with glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} had significantly higher green leaf yield, which was statistically similar to hand weeding check. The per cent increase in the green tea leaf yield due to glyphosate+2,4-D (Na) 1.0 l+0.5 kg ha^{-1} and glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} was 37.08 and 34.28%, respectively, over weedy check, while, it was 43.23%with weed free check.

Table 4: Effect of treatments on total green leaf and made tea yield (kg ha^{-1})

Treatment	Dose (kg ai ha^{-1})	Total weed dry matter (g m^{-2})			Green leaf yield (kg ha^{-1})	WI (%)
		Initial	Summer 90 DASE	Monsoon 30 DASE		
Glyphosate ammonium salt 79.2% SG	1.089	13.60 (184.00)	11.11 (122.67)	8.69 (74.67	3268	16.97
Glyphosate ammonium salt 79.2% SG	2.178	13.78 (189.33)	9.00 (80.00)	6.69 (44.00)	3690	6.25
Glyphosate ammonium salt 79.2% SG	4.356	13.54 (182.67)	8.04 (64.00)	6.08 (36.00)	3389	13.90
Glyphosate ammonium salt 71% SG	2.13	13.24 (174.67)	10.05 (100.00)	7.88 (61.33)	3254	17.33
Paraquat	0.500 l	13.39 (178.67)	11.49 (142.00)	9.98 (98.67)	2995	23.91
Glyphosate+2,4-D (Na)	1.0 l+0.5	13.23 (174.67)	7.89 (61.33)	5.72 (32.00)	3767	4.29
Glyphosate	1.5 l	13.74 (188.00)	9.56 (90.67)	7.35 (53.33)	3423	13.03
Slashing and *in-situ* mulching of weeds before flowering		14.61 (212.67)	10.74 (114.67)	8.05 (64.00)	3110	20.99
Weed free check		13.14 (172.00)	1.00 (0.00)	1.00 (0.00)	3936	0.00
Weedy check		13.82 (190.67)	16.22 (262.00)	15.12 (228.00)	2748	30.18
SEm±		0.43	0.22	0.25	168	
LSD (p=0.05)		NS	0.65	0.91	497	

Glyphosate 1.5 l ha^{-1}, glyphosate ammonium 79.2% at 4.356 kg ai ha^{-1} and glyphosate ammonium 71% at 2.13 kg ai ha^{-1} behaving statistically at par to glyphosate+2,4-D (Na) 1.0 l+ 0.5 kg ha^{-1} were the other better treatments for green leaf yield. Decreased crop-weed competition for resources (sunlight, nutrients and space) due to effective control of weeds through these herbicides resulted in significant improvement in growth which ultimately contributed to higher green tea yield. Among herbicide treatments, the lowest green leaf yield was recorded with paraquat 0.5 l ha^{-1}. Lowest green leaf yield was recorded from the weedy check treatment among all treatments. Bose et al. (2007) and Rana et al. (2020) also reported higher tea yield with the use of glyphosate alone and ammonium salt of glyphosate 71% at 3.0 kg ai ha^{-1}, respectively. Tanha et al. (2022) also reported higher made tea yield and net returns with combined application of glyphosate at 1.0 l ha^{-1} with 2,4-D (Na) at 0.5 kg ha^{-1} and alone application of glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1}.

3.7. Weed index

Weed index refers to the reduction in crop yield due to the presence of weed in comparison to weed free plots and used to assess the efficacy of herbicides or weed control treatments. Lesser the weed index, better the efficacy of a herbicide. It is evident from Table 4 that lowest weed index (4.29) was achieved with the tank mix application of glyphosate 1.0 l ha^{-1}along with 2,4-D (Na) 0.5 kg ha^{-1}, indicating its superiority among all the weed control treatments and were followed by glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} and glyphosate 42 SL at 1.5 l ha^{-1} having weed index of 6.25 and 13.03%, respectively. Highest value of weed index i.e. 30.18% was recorded in weedy check. Weed Index values of all other herbicide treatments except paraquat 0.5 l ha^{-1} ranged below 17.33%.

4. CONCLUSION

Tea crop was infested with a diverse weed flora in both summer and monsoon seasons. Maximum yield in weed free conditions apprised that the presence of weeds significantly affected the tea yield. Among different treatments, by effective control of different weeds, application of glyphosate ammonium 79.2% at 2.178 kg ai ha^{-1} being at par with tank mix application of glyphosate along with 2,4-D (Na) @ 1.0 kg+0.5 kg ha^{-1} resulted in significantly higher green leaf yield of tea. Thus depending upon availability of chemicals, any one of the said options can be chosen as a good alternative to hand weedings for weed control in tea.

5. REFERENCES

Anonymous, 2023. Tea Board of India. State wise tea growers and tea area. Available from https://www.teaboard.gov.in/pdf/STATE_WISE_TEA_GROWERS_AND_TEA_AREA_pdf7864.pdf and State/region wise and month wise tea production data for the year 2022 Available https://www.teaboard.gov.in/pdf/Production_Data_for_2022_2022_23_Provisional_doc_pdf1423.pdf. Accessed on 31st May, 2023.

Barooah, A.K., 2020. Black tea antiviral activity & boosting immunity. Tea Research Association Tocklai Tea Research Institute, Jorhat, 1–14.

Bautista, C.P., Cruz-Hipolito, H.E., Cruz, R.A., Vazquez-Garcia, J.G., Yanniccari, M., De Prado, R., 2021. Comparison of premix glyphosate and 2,4-D formulation and direct tank mixture for control of *Conyza canadensis* and *Epilobium ciliatum*. Environmental Pollution 281, 117013.

Belles, W.S., Wattenbarger, D.W., Lee, G.A., 1980. Herbicidal control of Canada thistle (*Cirsium arvense* L. Scop.) In: Proceedings of Western Weed Science Society 33, 134

Blouin, D.C., Webster, E.P., Zhang, W., 2004. Analysis of synergistic and antagonistic effects of herbicides using nonlinear mixed-model methodology. Weed Technology 18, 464–472.

Bose, A., Ravikumar, 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, 2–6th October 2007, Colombo, Sri Lanka, 565–567.

Deka, J., Barua, I.C., 2015. Weeds of tea fields and their control. In: National seminar on Plant Protection in Tea: Recent Advances organized by Tea Research Association, TOCKLAI, Jorhat in association with Tea Improvement Consortium, National working group in Plant Protection in Tea w.e.f. Feb., 26–7, 2015 at Jorhat, Assam.

Devi, N.M., Kundu, C.K., Bera, P.S., Panda, S., Das, S., 2019. Evaluation of glyphosate 41% SL to control weeds in tea at Terai region of West Bengal. Journal of Crop and Weed 15(3), 213–219.

Doddamanni, M.B., Mummigatti, U.V., Nadagoudar, B.S., Chetti, M.B., 2001. Influence of chemical and conventional methods of weed control on *Chromolaena odorata*. In: Sankaran, K.V. (Ed.), Alien weeds in moist Tropical Zones: Banes and Benefits. KFRI, 139–142.

Flint, J.L., Barrett, M., 1989. Effect of glyphosate combinations with 2,4–D or dicamba on field bindweed (*Convolvulus arvensis*). Weed Science 37, 12–18.

Gomez, K.A., Gomez, A.A., 1984. Statistical procedure for agricultural research (2nd Edn.). Wiley Inter Science, New York, USA, 680.

Ilango, R.V.J., Durairaj, J., Mohan, K.P., 2010. Evaluation of excel Mera–71 for the control of *Commelina* species. Newsletter – UPASI Tea Research Foundation 20(2), 20–25.

Isaack, C.E., Wen, G.Y., Xu, W., Jia, J.H., Rohan, L., Corbo, C., DiMaggio, V., Jenkins, E.C., Hillier, S., 2008. Epigallocatechin gallate inactivates clinical isolates of herpes simplex virus. Antimicrobial Agents and Chemotherapy 52, 962–970.

Kanissery, R., Gairhe, B., Kadyampakeni, D., Batuman, O., Alferez, F., 2019. Glyphosate: Its environmental persistence and impact on crop health and nutrition. Plants 8(11), 499, doi: 10.3390/plants8110499

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. Bio-efficacy 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 w.e.f. 13–16 October, 2015, 377.

Kumar, S., Rana, S.S., Angiras, N.N., Ramesh, 2014. Weed management in tea with herbicides mixture. Indian Journal of Weed Science 46, 353–357.

Kumar, S., Sharma, N., Manuja, S., Parita, Bhalla, T., 2021. Bio-efficacy and phytotoxicity of glyphosate 41% SL on weed flora of tea and its effect on soil microbial activities. Himachal Journal of Agricultural Research 47(2), 235–238.

Liu, S.M., Huang, H.H., 2015. Assessments of antioxidant effect of black tea extract and its rationals by erythrocyte haemolysis assay, plasma oxidation assay and cellular antioxidant activity (CAA) assay. Journal of Functional Foods 18, 1095–1105.

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.

Moshier, L.J., 1980. Response of honeyvine milkweed

(*Ampelamus albidus*) to herbicide applications. Weed Science 28, 722–724.

Mummigatti, U.C., 1994. Effect of herbicides, growth conditions and carriers on physiological, biochemical and anatomical changes in Eupatorium (*Chromolaena odorata*). Ph.D. Thesis submitted to the University of Agricultural Sciences, Dharwad.

Nordby, D.E., Hager, A.G., 2011. Herbicide formulations and calculations: Active ingredient or acid equivalent, a weed fact sheet. In: Integrated pest management handbook, University of Illinois, Champaign, IL, USA.

Opeke, K.L., 2005. Tropical commodity tree crops (2nd Edn.). Spectrum house, Ring road, Ibadan, Nigeria, 436–440.

Paul, B.V.D., Pierre, B.J., 2012. Evaluation of the efficacy of herbicides in tea (*Cammelia sinensis*) production in Rawada. International Journal of Applied Agriculture Research 7, 197–202.

Peiris, H.M.P., Nissanka, S.P., 2015. Affectivity of chemical weed control in commercial tea plantations: a case study in hapugastenne estate, maskeliya, Sri Lanka. Procedia Food Science 6, 318–322.

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 Biology and Management 4, 239–248.

Rana, S.S., Kumar, R., Kumar, S., Sharma, N., Badiyala, D., 2020. Evaluation of glyphosate against weeds and phytotoxicity, productivity and soil quality parameters in tea (*Camellia sinensis* O. kuntze). Journal of Research in Weed Science 3(1), 90–100.

Rana, S.S., Rana, M.C., 2016. Principles and practices of weed management. Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, 138. DOI 10.13140/RG.2.2.33785.47207.

Saikia, S., Bhuyan, R.P., Saikia, G.K., 2013. Evaluation of selectivity and persistence of glyphosate and its combinations with 2,4-D for weed control in mature tea. Pestology 37(1), 31–34.

Sarkar, S., Kabir, S.E., 2016. Studies on the impact of commonly used herbicides on beneficial soil microbes in Terai tea plantation, West Bengal, India. Annals of Plant Sciences 5(1), 1254–1260.

Sharma, S.D., Singh, M., 2001. Surfactants increase toxicity of glyphosate and 2,4-D to Brazil Pusley. Horticulture Science 36(4), 726–728.

Singh, C.M., Mohantry, R.K., Kumar, S., 1992. Biology and control of *E. adenophorum* in Himachal Pradesh. Indian Journal of Weed Science 24, 62–64.

Singh, R.D., Sud, R.K., Pal, P.K., 2014. Integrated weed management in plantation crops. In: Chauhan, B.S., Mahajan, G. (Eds.), Recent advances in weed management. Springer, 255–280.

Tang, G., Meng, X., Gan, R., Zhao, C., Liu, Q., Feng, Y., Li, S., Wei, X., Atanasov, A.G., Corke, H., Li, H., 2019. Health functions and related molecular mechanisms of tea components: an update review. International Journal of Molecular Sciences 20, 6196, doi:10.3390/ijms20246196.

Tanha, S., Chopra, P., Rana, S.S., Singh, G., 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.). Journal of Crop and Weed 18(3), 78–85.

Tong, M., Gao, W., Jiao, W., Zhou, J., Li, Y., He, L., Hou, R., 2017. Uptake, translocation, metabolism, and distribution of glyphosate in nontarget tea plant (*Camellia sinensis* L.). Journal of Agricultural and Food Chemistry 65, 7638–7646.

Travlos, I., Cheimona, N., Bilalis, D., 2017. Review-Glyphosate efficacy of different salt formulations and adjuvant additives on various weeds. Agronomy 7, 60. doi:10.3390/agronomy7030060.

Wilson, S.W., 2005. Keys to the families of flugoromorpha with emphasis on plant hoppers of potential economic importance in the Southeastern United States (Hemiptera:Auchenorhyncha). Florida Entomologist 88, 464–481.

Yang, C.S., 2018. The potential role of tea in combating chronic diseases. In: Sharma, V.S., Gunasekhare, M.T.K. (Eds.), Global tea science current status and future needs. Burleigh Dodds Science Publication, 427–451.

Zhang, J., Hamill, A.S., Weaver, S.E., 1995. Antagonism and synergism between herbicides: Trends from previous studies. Weed Technology 9, 86–90.