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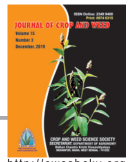

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Bio-efficacy and phytotoxicity of GPH 315 (glufosinate + oxyfluorfen) on weeds of tea

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ABSTRACT

A field experiment was carried out in the established tea orchard located in Panchrukhi block of Kangra district of Himachal Pradesh during kharif seasons of 2018 and 2019 with the objective of evaluating the bio-efficacy and phytotoxicity of a new herbicide combination product GPH 315 containing glufosinate ammonium and oxyfluorfen in tea (Camellia sinensis). The treatments consisted of different doses of this new combination product as well as other herbicides recommended in tea along with standard checks and were tested in randomized block design (RBD) with three replications. Cynodon dactylon, Digitaria sanguinalis, Ageratum conyziodes, Bidens pilosa, Commelina benghalensis and Cyperus rotundus were the major weed species infesting the tea crop during the period of investigation. Application of this combination product GPH 315 @490 + 175 g a.i.ha^{-1}, was statistically similar to the lower dose of 420 + 150 g a.i. ha^{-1}, resulted in significantly lower total weed count as well as total weed dry weight as compared to all other weed control treatments at all the stages of observation. Significantly highest green leaf yield during both the years was obtained in hand weeding treatment though this treatment was statistically similar with the two higher doses of the combination product GPH 315 (490 + 175 g a.i. ha^{-1}and 420 + 150 g a.i. ha^{-1}). No phytotoxic symptoms were observed on tea at any of the doses of GPH 315 and hence this new combination product can be safely used for the effective control of weeds in tea.

***Keywords*:** Bio-efficacy, glufosinate, oxyfluorfen, phytotoxicity, tea, yield

The world famous Kangra tea, made from the tea (*Camellia sinensis*) grown in the Kangra and Mandi districts of Himachal Pradesh, is in great demand worldwide due to its unique colour and flavour. This crop was introduced in these areas by the Britishers in the middle of the nineteenth century and since that time it has played an important role in the economy of the farming populace of these areas. The interest in this tea further increased during the pandemic period after it was found that the chemicals found in this tea are effective in boosting immunity by blocking the viral activity better than the other drugs prevalent in the market. During 2016 there were about 5900 small or large tea gardens covering an area of about 2310 ha with the total production of about 91.86 thousand tonnes. Efforts have been made to increase the area under tea and about 7700 ha area in Chamba District of Himachal Pradesh has been identified as a potential area where this crop can be successfully introduced to improve the livelihood security of the rural population having limited land as well as other resources (Gupta and Verma, 2017). The productivity of the established tea orchards is quiet low (owing to the plethora of reasons) and consequently most of the small and marginal tea growers have abandoned its cultivation. Also with the Government promoting diversification, farmers are shifting to more remunerative options leaving its cultivation. A survey of the tea growing areas was conducted during 2015 which revealed that about 53 per cent of the area under this crop was in a neglected state while the owners abandoned the other 27 per cent.

One of the major reasons for this abject neglect of the established tea orchards is the inadequate returns the farmers get for their efforts and there is an urgent need to reduce the cost involved in the maintenance of these orchards. Therefore, low cost weed management strategy is of paramount importance for the sustainable productivity of tea plantations. Adoption of cultural and ecological methods for managing weeds is of great importance as they are environment friendly and cost effective. However, various herbicides were proven to be the most convenient and effective method for managing weeds (Mirghasemi *et al.*, 2012; Banerjee *et al*., 2018; Ilango *et al.*, 2010). It could minimize soil erosion and eliminate loss of plant nutrients. Many herbicides have been recommended for controlling weeds in tea after extensive screening trials conducted in various tea growing regions of our country. Keeping these things in mind, the present study was conducted to evaluate the bio-efficacy and phytotoxicity of GPH-315 (a new herbicide combination product having glufosinate ammonium 13.4 % SL and oxyfluorfen 4.8%

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EW) against weeds in tea and to study the adverse effect of this herbicide, if any, on the tea crop.

A field experiment was carried out during the *kharif* seasons of 2018 and 2019 in an established tea orchard located in the close vicinity of Palampur (32º6′N latitude and 76º3′E longitude) at an altitude of 1290.8 m above mean sea level. The orchard was owned by a progressive farmer who had planted improved clone of China Hybrid about 25 years back. The soil of the experimental site was acidic in reaction (pH 5.6), silty clay loam in texture with low available nitrogen (270 kg ha^{-1}) and medium in available phosphorus (14.5 kg ha^{-1}) and potassium (150 kg ha^{-1}). Four doses of this new herbicide combination product GPH 315 viz, 350 + 125 g a.i. ha^{-1}, 420 + 150 g a.i. ha^{-1}, 490 + 175 g a.i. $ha^{-1}$and 840 + 300 g a.i. ha^{-1} along with glufosinate ammonium 500 g a.i. ha^{-1}, oxyfluorfen 250 g a.i. ha^{-1}, glyphosate 1230 g a.i. ha^{-1}, hand weeding and weedy check were tested in Randomized Block Design with three replications. The highest dose of the new herbicide GPH 315 (840 + 300 g a.i. ha^{-1}) was used only for the toxicity and residue studies. The herbicide treatments were applied at the active growth stage (3-4 leaves) of weeds using knapsack sprayer fitted with flat fan nozzle along with a spray volume of 500 litre ha^{-1}. Hand weeding was also done twice first on the day of start of experiment (herbicide application) and second 25 days later. Observations were recorded on weed count and weed dry matter at 45 and 75 days after herbicide application and the data so recorded was subjected to square root transformation for statistical analysis. The data from both the years of study was pooled and only the pooled values of weed count and weed dry matter recorded has been given. Green tea leaves were harvested at monthly intervals from all the bushes in a treatment for three months and has been reported as total green tea leaf yield for 3 months. Data on weed count, weed drymatter and green tea leaf yield was subjected to analysis of variance as suggested by Gomez and Gomez (1984) and treatments were compared at 5% level of probability. Weed control efficiency (WCE) was calculated on the basis of data recorded on weed dry weight at 45 and 75 DAA of the treatments as per the formula (Mani *et al.*, 1976) given below:

$$\text{Weed Control Efficiency (\%)} = \frac{\text{WDC - WDT}}{\text{WDC}} \times 100$$

Where WDC= Weed dry weight in untreated control plot (gm^{-2}); WDT= Weed dry weight in treated plot (gm^{-2})

The observations on phytotoxicity (in terms of leaf injury on tip/surface, epinasty, hyponasty, necrosis, stunting, yellowing, wilting and chlorosis) arising due to application of this new herbicide combination product were visually recorded on 1,3, 7, 10 and 15 days after herbicide application and were rated on a scale of 0-10 (0 indicating no injury and 10 rating indicating complete injury).

The experimental orchard was heavily infested with number of weeds which included grasses, broad-leaves and sedges. *Cynodon dactylon*, *Digitaria sanguinalis*, *Ageratum conyziodes*, *Bidens pilosa*, *Commelina benghalensis* and *Cyperus rotundus* were the dominant weeds found in the experimental orchard. In addition *Imperata cylindrica*, *Lantana camara, Chromolaena adenophorum* were also noticed, though in small number.

Significantly lowest count of grassy weeds was observed with the application of higher dose of new herbicide combination product (GPH 315) 490 + 175 g a.i. ha^{-1} at both the stages of observation (Table 1) though this treatment behaved statistically similar with hand weeding and application of this product (GPH 315) at a lower dose of 420 + 150 g a.i. ha^{-1}. Application of both the herbicides, that are part of this combination product, alone were less effective in controlling the grassy weeds indicating the synergistic effect of these herbicides, when used in combination. Significantly highest weed count of grassy weeds was observed in weedy check. Application of glyphosate alone was also not as effective in controlling grassy weeds in tea as compared to this herbicide combination product though it was equally effective as application of glufosinate ammonium and oxyfluorfen alone.The count of broad leaved weeds as well as sedges also behaved in an almost similar manner with hand weeding treatment resulting in significantly lowest count. However, this treatment was at par with the two higher doses of new herbicide combination product GPH 315 (490 + 175 g a.i. ha^{-1} and 420 + 150 g a.i. ha^{-1}) at all the stages of observation. Significantly highest weed count of both broad leaved weeds and sedges was reported from the weedy check. Also the lowest dose of new herbicide combination product (350 + 125 g a.i. ha^{-1}) was as effective as the use of both the constituents alone (glufosinate ammonium 500 g a.i. ha^{-1} and oxyfluorfen 250 g a.i. ha^{-1}) as well as glyphosate (1230 g a.i. ha^{-1}).

Weed dry weight also followed the similar trend (Table 2) with significantly lowest dry weight of all the three types of weeds observed in the hand weeding treatment with the exception of weed dry weight of sedges at 45 days after application (DAA), at which stage application of herbicide combination (GPH 315) 490 + 175 g a.i. ha^{-1} recorded lowest dry weight of sedges. Further, hand weeding treatment was at par with the application of GPH 315 at the higher doses of490 +

Table 1: Effect of weed control treatments on weed count (No./m^2) at different stages in tea (pooled data of two years)

Treatment	Dose g a.i.ha^{-1}	Weeds population (No.m^{-2})					
		Grassy weeds		Broad leaf weeds		Sedges	
		45 DAA*	75 DAA	45 DAA	75 DAA	45 DAA	75 DAA
GPH 315	350+125	3.25 (10.07)	4.09 (16.25)	3.54 (12.01)	4.42 (19.02)	1.93 (3.21)	2.22 (4.45)
GPH 315	420+150	2.25 (4.58)	3.08 (8.98)	2.41 (5.32)	2.96 (8.28)	1.18 (0.89)	1.70 (2.38)
GPH 315	490+175	1.96 (3.36)	2.91 (7.98)	2,21 (4.39)	2.84 (7.55)	1.18 (0.89)	1.61 (2.08)
Glufosinate Ammonium 13.5 % SL	500	3.34 (10.68)	4.34 (18.31)	3.61 (12.56)	4.45 (19.32)	1.94 (3.27)	2.36 (5.05)
Oxyfluorfen 23.5 % EC	250	3.20 (9.77)	4.32 (18.16)	3.58 (12.31)	4.42 (19.02)	2.09 (3.86)	2.22 (4.45)
Glyphosate 41 % SL	1230	3.39 (10.98)	4.50 (19.78)	3.80 (13.96)	4.20 (17.17)	2.01 (3.56)	2.16 (4.16)
Hand weeding		2.03 (3.86)	2.97 (8.34)	2.10 (3.92)	2.75 (7.06)	1.05 (0.60)	1.51 (1.78)
Weedy check		5.60 (30.88)	6.67 (44.04)	5,84 (33.63)	6.61 (43.24)	2.63 (6.41)	3.04 (8.72)
SEm (±)		**0.17**	**0.22**	**0.19**	**0.22**	**0.08**	**0.09**
LSD (0.05)		**0.48**	**0.64**	**0.55**	**0.64**	**0.23**	**0.27**

**DAA – days after application; #Values in the parenthesis are the means of original value. Data transformed to square root* $\left(\sqrt{x+0.5}\right)$ *transformation*

Table 2: Effect of weed control treatments on weed dry weight (g/m^2) at different stages in tea (pooled data of two years)

Treatment	Dose g a.i.ha^{-1}	Weeds dry weight (g m^{-2})					
		Grassy weeds		Broad leaf weeds		Sedges	
		45 DAA*	75 DAA	45 DAA	75 DAA	45 DAA	75 DAA
GPH 315	350+125	3.75 (13.72)	4.82 (22.95)	3 80 (14.02)	4.81 (22.79)	2.07 (3.85)	2.74 (7.06)
GPH 315	420+150	2.88 (7.97)	3.54 (12.16)	2.67 (6.71)	3.30 (10.44)	1.32 (1.29)	2.25 (4.62)
GPH 315	490+175	2.80 (7.43)	3.40 (11.28)	2.53 (5.99)	3.13 (9.44)	1.28 (1.20)	2.20 (4.39)
Glufosinate Ammonium 13.5 % SL	500	3.67 (13.15)	5.02 (24.93)	4.00 (15.66)	4.80 (22.74)	2.28 (4.82)	2.78 (7.32)
Oxyfluorfen 23.5 % EC	250	3.66 (13.09)	5.10 (25.74)	4.01 (15.77)	4.65 (21.30)	2.38 (5.35)	2.86 (7.82)
Glyphosate 41 % SL	1230	3.67 (13.16)	5.32 (28.15)	3.95 (15.29)	4.64 (21.19)	2.51 (6.02)	3.19 (9.79)
Hand weeding		2.70 (6.92)	3.38 (11.04)	2.36 (5.18)	3.04 (8.82)	1.35 (1.39)	2.16 (4.23)
Weedy check		6.92 (47.70)	7.61 (57.68)	6.46 (41.57)	7.30 (53.17)	3.77 (14.05)	4.73 (22.05)
SEm (±)		**0.20**	**0.26**	**0.19**	**0.24**	**0.11**	**0.14**
LSD (0.05)		**0.58**	**0.75**	**0.55**	**0.70**	**0.32**	**0.41**

**DAA – days after application; #Values in the parenthesis are the means of original value. Data transformed to square root* $\left(\sqrt{x+0.5}\right)$ *transformation*

Table 3: Effect of weed control treatments on weed control efficiency after herbicide application (pooled data of two years)

Treatment	Dose g a.i. ha^{-1}	Weed control efficiency (%)					
		45 DAA*			75 DAA		
		Grassy weeds	Broad leaf weeds	Sedges	Grassy weeds	Broad leaf weeds	Sedges
GPH 315	350+125	71.23	66.29	72.60	60.21	57.14	67.97
GPH 315	420+150	83.30	83.86	90.85	78.92	80.36	79.04
GPH 315	490+175	84.42	85.59	91.46	80.44	82.24	80.11
Glufosinate Ammonium 13.5 % SL	500	72.43	62.33	65.73	56.78	57.24	66.80
Oxyfluorfen 23.5 % EC	250	72.57	62.08	61.92	55.37	59.94	64.53
Glyphosate 41 % SL	1230	72.41	63.23	57.19	51.20	60.15	55.59
Hand weeding	-	85.49	87.55	90.11	80.87	83.42	80.83
Weedy check	-						

**DAA – days after application*

175 g a.i. ha^{-1} and 420 + 150 g a.i. ha^{-1}. Application of glufosinate ammonium, oxyfluorfen as well as glyphosate were equally effective in controlling all the types of weeds in tea orchard at both stages and were statistically at par with the lowest dose of GPH 315 (350 + 125 g a.i. ha^{-1}). Effective reduction in weed dry matter with the application of herbicide combination product as compared to their application alone indicates the synergistic effect of use of glufosinate ammonium and oxyfluorfen together. Flint and Barrett (1989) had also reported additive and synergistic effect of mixture of herbicides. Kabir *et al.* (1991), Kumar and Ghosh (2015) and Devi *et al.* (2019) had also reported the effectiveness of glyphosate for managing weeds in tea. Significantly highest weed dry weight was observed in weedy check where weeds were not controlled.

The data on the application of herbicides on the weed control efficiency (WCE) recorded at 45 and 75 days after herbicide application (Table 3) revealed that maximum weed control efficiency for the control of all the three types of weeds at both the stages was recorded with hand weeding treatment with the exception of sedges at 45 DAS at which stage application of this new herbicide combination product (GPH 315) 490 + 175 g a.i. ha^{-1} showed highest weed control efficiency. Among the herbicide treatments, GPH 315 application at 490 + 175 g a.i. $ha^{-1}$and 420 + 150 g a.i. ha^{-1}gave the highest efficiency for controlling all types of weeds in tea. The efficiency data so recorded indicates the superiority of this combination product for controlling weeds in tea as compared to the application of the constituents alone and the earlier recommended herbicide glyphosate.

No phytotoxicity symptoms regarding epinasty, hyponasty, vein clearing, necrosis, leaf tip and surface injury and wilting of plants were observed on tea due to the application of this new combination product even at the higher dose of 840 + 300 g a.i. ha^{-1} at all the stages of observation (1,3,5,7, 10 and 15 DAA) indicating that this herbicide can be safely applied in tea (Table 4). The results are in close conformity with the findings of Cheramgoi *et al.* (2015) and Kumar *et al.* (2017).

The data on the effect of different weed control treatments on the tea leaf yield recorded on a monthly basis as well as totalled over a period of three months has been given in Table 5. Significantly highest total tea leaf yield was recorded in the hand weeding treatment during both the years though it was at par with GPH 315 applied at 490 + 175 g a.i. ha^{-1} as well as 420 + 150 g a.i. ha^{-1}. Similar results had also been reported by Patra *et al.* (2016). On the contrary significantly lowest tea leaf yield was obtained in the weedy check treatment. Paul and Pierre (2012) have also reported lower green leaf yield in weedy check treatment as compared to the other weed control treatments.

From the present study it can be concluded that this new herbicide combination product having glufosinate ammonium and oxyfluorfen can safely be recommended at the dose of 490 + 175 g a.i. ha^{-1} and 420 + 150 g a.i. ha^{-1} for managing weeds in an established tea orchard.

Table 4: Phytotoxicity effect of GPH 315 on tea crop

Treatment	Dose	Observations recorded after 1, 3, 5 ,7, 10 and 15 DAA																							
		Leaf injury on tip/ surface						Epinasty						Hyponasty						Necrosis					
	g a.i. ha^{-1}	1	3	5	7	10	15	1	3	5	7	10	15	1	3	5	7	10	15	1	3	5	7	10	15
GPH 315	420 + 150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GPH 315	840 + 300	0	0	0	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	0	0	0	0

**Values of both the years were 0 (zero)*

Table 5: Effect of weed control treatments on the green leaf yield of tea

Treatment	Dose g a.i. ha^{-1}	Green leaf yield (qha^{-1})							
		2018				2019			
		July	August	September	Total	July	August	September	Total
GPH 315	350+125	9.68	8.37	7.18	25.23	8.25	8.15	7.64	24.04
GPH 315	420+150	10.68	8.95	8.67	28.30	9.34	9.41	8.57	27.32
GPH 315	490+175	11.02	10.13	8.97	30.12	9.85	9.70	8.92	28.47
Glufosinate Ammonium 13.5 % SL	500	9.67	8.47	7.03	25.17	9.24	7.30	7.59	24.13
Oxyflourfen 23.5 % EC	250	8.11	8.99	7.33	24.43	9.42	7.08	7.91	24.41
Glyphosate 41 % SL	1230	8.48	7.46	6.71	22.65	8.06	8.06	7.36	23.48
Hand weeding	-	10.73	9.43	10.12	30.28	9.58	9.83	9.27	28.68
Weedy check (untreated control)	-	7.58	7.22	5.38	20.18	7.79	7.77	5.97	21.53
SEm (±)	**-**	**0.35**	**0.31**	**0.40**	**1.33**	**0.46**	**0.45**	**0.41**	**1.31**
LSD (0.05)	**-**	**1.06**	**0.94**	**0.85**	**2.16**	**0.98**	**0.97**	**0.87**	**2.04**

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