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Full Research Article

Influence of Herbicides on Phytotoxicity and Soil Dehydrogenase Enzyme Activity in Chickpea (*Cicer arietinum* L.)

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Abstract

A field experiment was conducted at Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh (C.G.), India, during *rabi* season of 2013-14 to find out effective herbicide in chickpea. Results revealed that among the herbicidal treatments, post-emergence application of metribuzin @ 250 g a.i. ha^{-1} and early post-emergence application of oxyfluorfen @ 125 g a.i. ha^{-1} has recorded phytotoxicity on chickpea plants at 3, 7 and 10 days after spraying of herbicides and resulted in 62.26 and 53.19% reduction in yield, respectively, over hand weeding twice. The significantly minimum dehydrogenase activity was also observed under post-emergence application of metribuzin @ 250 g a.i. ha^{-1} and early post-emergence application of oxyfluorfen @ 125 g a.i. ha^{-1}. Whereas, among the herbicides, pre-emergence application of pendimethalin @ 1000 g a.i. ha^{-1} resulted in significantly higher dehydrogenase activity of experimental field. Hand weeding twice at 25 and 45 DAS and pre-emergence tank mix application of oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} were most appropriate in reducing the density and dry weight of weeds with the weed control efficiency of 90.43 and 74.31%, respectively. Further, the significantly higher yield attributes, seed yield, stover yield and harvest index registered under hand weeding twice at 25 and 45 DAS, followed by the treatment of oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} as pre-emergence. Net return and B:C ratio was also recorded maximum under pre-emergence tank mix application of oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1}.

1. Introduction

Chickpea (*Cicer arietinum* Linn.) is an important winter season pulse crop and a key source of protein. It plays an important role in human nutrition for large population in the developing world. It leaves substantial amount of residual nitrogen for subsequent crops and adds plenty of organic matter to maintain and improve soil health and fertility. Chickpea is most important pulse crop of India in terms of both area and production. In India, chickpea is grown over an area of 8.52 mha with production of 8.83 mt and average productivity of 1036 kg ha^{-1} (Anonymous, 2014). In spite of the importance of this crop in our daily diet and in agricultural production system, the productivity of this crop is very low in India as well as in Chhattisgarh. The yield and productivity of chickpea is influenced by various production constraints such as biotic and abiotic factors. Among various barriers, poor weed management is one of the most important yield limiting factors in chickpea. Chickpea is poor competitor to weeds because of slow growth rate and limited leaf development at early stage of crop growth and establishment, if weed management is neglected under these conditions, resulting in yield loss of 40 to 87% (Solh and Pala, 1990; Chaudhary et al., 2005). A critical period of 30 to 60 days is considered to be the crucial for crop-weed competition in chickpea (Kumar and Singh, 2010). Hand or manual weeding though very effective and commonly adopted in India is expensive, tedious, time consuming and many a times become uneconomic. In recent years, herbicide have been developed and found promising tool in weed management. Weed management with herbicides is an effective, quick in action, and time saving (Ahmed et al., 2005). Herbicide treatment gave 50–64% weed control with considerable increase in yield (Bhalla et al., 1998). But, there is no recommended herbicide for chickpea. Many herbicides show phytotoxicity on chickpea. Therefore, there is a need to study the efficacy of non recommended pre and post-emergence herbicides either alone or in combination for efficient weed management in chickpea which is to be safe for chickpea. The microbial activity plays a vital role in soil fertility, soil productivity and soil structure. The turnover and mineralization of organic substances, nutrient transformation and cyclic of organic wastes in soil are all dependent on the metabolic functions of soil microorganisms. Dehydrogenase is an indicator of overall microbial activity, because it occurs inter-cellularly in all living microbial cells and is linked with microbial oxydoreduction processes. Keeping all the facts in view, a research trial was conducted to find out the effective and economical herbicides and their combination for weed management in chickpea.

2. Materials and Methods

The field experiment was conducted at the Instructional Cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh (C.G.), India, during *rabi* season of 2013−14. The soil of experimental field was in texturally clay, neutral in pH, low in nitrogen, medium in phosphorus and high in potassium contents. The experimental field had an even topography with a good drainage. The soil samples were drawn from each replication of the experimental plot to a depth of 0−30 cm before sowing of crop. The experiment was laid out in Randomized Complete Block Design with three replications. The treatments consisted of eleven weed management practices viz, pendimethalin @ 1000 g a.i. ha^{-1} at 2 DAS (T_1), pendimethalin @ 1250 g a.i. ha^{-1} at 2 DAS (T_2), pendimethalin @ 1500 g a.i. ha^{-1} at 2 DAS (T_3), pendimethalin (extra) 38.7 CS @ 1000 g a.i. ha^{-1} at 2 DAS (T_4), oxyfluorfen @ 125 g a.i. ha^{-1} at 2 DAS (T_5), metribuzin @ 250 g a.i. ha^{-1} at 2 DAS (T_6), oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} at 2 DAS (T_7), oxyfluorfen @ 125 g a.i. ha^{-1} at 12 DAS (T_8), metribuzin @ 250 g a.i. ha^{-1} at 20 DAS (T_9), control (T_{10}) and hand weeding twice at 25 and 45 DAS (T_{11}). The chickpea variety JG-130 was grown as test crop. The crop was sown on 25th November by seed cum fertilizer drill in rows at 30 cm apart with seed rate of 80 kg ha^{-1} and harvested in second week of March. A basal application of 20 kg N, 50 kg P_2O_5 and 30 kg ha^{-1} K_2O was given uniformly through DAP and MOP in all the experimental plots. Herbicides were applied as pre-emergence, early post-emergence and post-emergence by using knapsack sprayer fitted with flat fan nozzle by mixing in 500 l of water ha^{-1} as treatments^{-1}.

To count the weed population m^{-2} in different plots, 0.25 m^2 quadrate was thrown at four random places in each plot at 20, 40, 60 DAS and at harvest and subjected to square root $\sqrt{x+0.5}$ transformation and statistically analyzed. Total dry matter production by weeds was also recorded by oven-dried at 60°C for 48 hr and dry matter was weighted on electronic balance in g m^{-2}. Weed dry matter was subjected to square root of transformation i.e. $\sqrt{x+0.5}$ and statistically analyzed. Dehydrogenase activity in terms of triphenyl formazone (TPF) of experimental soil was measured by using UV/VIS Spectrophotometer with the wavelength of 485 nm at 50 DAS and at harvest. The procedure to evaluate the dehydrogenase activity of soil described by (Klein et al., 1971). Phytotoxicity of herbicides on chickpea was observed by quantitative visual assessment at 1, 3, 7 and 10 days after spraying of herbicides by using rating scale 0−10. All the yield attributing characters viz. number of pods, number of seed, 100 seed weight and seed yield, stover yield, harvest index and weed index of chickpea crop were also recorded and economics in terms of net return and benefit cost ratio were calculated with prevailing rates.

3. Results and Discussion

3.1. Weed density and dry matter production

Different weed management practices significantly influenced the density and dry matter production of total weeds. Hand weeding twice at 25 and 45 DAS recorded significantly lowest weed density and dry matter production of weeds than all other treatments at all the stages (Table 1). The results were in agreement with the findings of Patel et al. (2006), Kumar et al. (2008); Singh et al. (2008); Sadiq et al. (2011). However, among the herbicidal treatments, significantly lower total weed density and dry matter was recorded under metribuzin @ 250 g a.i. ha^{-1} as post-emergence and oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} as pre-emergence, which were at par to each other and were significantly superior over rest of the treatments. The highest weed density and dry matter production was recorded under the control plot. Control plot resulted higher weed population due unhindered growth of weeds at all the growth stages of crops. Similar results were observed by (Aslam et al., 2007; Buttar et al., 2008; Chaudhary et al., 2011; Sadiq et al., 2011), Poonia and Pithia (2013).

Hand weeding twice at 25 and 45 DAS recorded highest weed control efficiency, followed by metribuzin @ 250 g a.i. ha^{-1} as post-emergence, oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} as pre-emergence and metribuzin @ 250 g a.i. ha^{-1} as pre-emergence. These results are in accordance with the findings of Sharma (2009), Bhutada and Bhale (2013). Whereas, minimum weed index was registered under hand weeding twice at 25 and 45 DAS, followed by oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} as pre-emergence and metribuzin @ 250 g a.i. ha^{-1} as pre-emergence and maximum weed index (74.36%) was noticed under control plot.

3.2. Phytotoxicity of herbicides on chickpea plants

Among the herbicides, pre-emergence application of pendimethalin @ 1000 g a.i. ha^{-1}, pendimethalin @ 1250 g a.i. ha^{-1}, pendimethalin @ 1500 g a.i. ha^{-1}, pendimethalin (extra) @1000 g a.i. ha^{-1}, oxyfluorfen @ 125 g a.i. ha^{-1}, metribuzin @

Table 1: Density and dry matter accumulation of total weeds as influenced by different weed management practices at different growth stages

Weed management Practices	Dose (g a.i. ha^{-1})	Density of total weeds (No. m^{-2})			Dry matter of total weeds (g m^{-2})			Weed control efficiency (%)
		40 DAS	60 DAS	At harvest	40 DAS	60 DAS	At harvest	
T_1-Pendimethalin as PE	1000	9.83 (96.33)	11.11 (123.00)	12.07 (145.33)	7.10 (49.94)	11.78 (138.43)	15.79 (249.71)	34.66
T_2-Pendimethalin as PE	1250	8.72 (75.67)	9.82 (96.00)	11.26 (126.33)	6.43 (40.83)	10.92 (118.78)	14.36 (205.88)	46.13
T_3-Pendimethalin as PE	1500	8.45 (71.00)	9.04 (81.33)	10.82 (117.00)	6.02 (35.77)	10.49 (109.58)	13.18 (173.36)	54.64
T_4-Pendimethalin (extra) as PE	1000	10.89 (118.33)	11.54 (133.00)	13.10 (171.33)	7.37 (53.86)	12.62 (158.84)	16.48 (274.06)	28.29
T_5-Oxyfluorfen as PE	125	9.51 (90.00)	10.15 (102.67)	11.72 (137.00)	6.57 (42.94)	11.26 (126.30)	14.94 (223.00)	41.65
T_6-Metribuzin as PE	250	7.95 (62.67)	8.64 (74.33)	9.40 (88.00)	5.28 (27.42)	9.51 (90.07)	12.34 (152.00)	60.23
T_7-Oxyfluorfen+ Metribuzin as PE	125+350	7.25 (52.33)	7.96 (63.00)	8.52 (72.33)	4.72 (21.81)	7.68 (58.46)	9.91 (98.19)	74.31
T_8-Oxyfluorfen as early PoE	125	11.31 (128.00)	12.61 (158.67)	13.88 (192.33)	7.63 (58.08)	12.89 (166.10)	16.69 (278.31)	27.18
T_9-Metribuzin as PoE	250	7.02 (49.00)	7.77 (60.00)	8.40 (70.00)	4.35 (18.42)	7.76 (58.20)	9.87 (97.05)	74.61
T_{10}-Control	-	13.43 (182.33)	15.16 (233.33)	16.47 (275.33)	10.54 (110.66)	15.85 (250.95)	19.56 (382.18)	-
T_{11}- Hand weeding twice at 25 and 45 DAS	-	3.56 (12.33)	4.49 (19.67)	5.49 (29.67)	2.43 (5.45)	4.22 (17.34)	6.09 (36.59)	90.43
SEm±		0.44	0.51	0.53	0.20	0.24	0.52	-
CD (p=0.05)		1.28	1.52x	1.57	0.60	0.70	1.52	-

Figures in the parentheses are original values; data were transformed through $\sqrt{x + 0.5}$ which are given in bold; PE: Pre-emergence; DAS: Days after sowing, PoE: Post-emergence, g ha^{-1}: gram ha^{-1}

250 g a.i. ha^{-1} and oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} were found to be safe herbicides on chickpea and phytotoxic symptoms were not seen throughout its growth period from germination to harvest (Table 2). Whereas, oxyfluorfen @ 125 g a.i. ha^{-1} and metribuzin @ 250 g a.i. ha^{-1} when applied as early post-emergence and post-emergence, respectively, showed adverse effects on chickpea crop. Light yellow discoloration on leaves was observed in 3 days after spraying of oxyfluorfen @ 125 g a.i. ha^{-1} as early post-emergence and metribuzin @ 250 g a.i. ha^{-1} as post-emergence, and scorching was also observed with the spraying of metribuzin @ 250 g a.i. ha^{-1} applied as post-emergence. However, these symptoms vanished and crop was normal by 20 days after herbicide application.

3.3. Dehydrogenase enzyme activity of experimental field

Dehydrogenase activity (μg TPF h^{-1} g^{-1} soil) of chickpea field was influenced significantly due to different weed management practices (Table 3). At 50 DAS, significantly higher dehydrogenase activity was measured under the treatment of control plot, which was at par with the treatment of hand weeding twice at 25 and 45 DAS, pendimethalin @ 1000 g a.i. ha^{-1} as pre-emergence, pendimethalin @ 1250 g a.i. ha^{-1} as pre-emergence and pendimethalin (extra) @ 1000 g a.i. ha^{-1} as pre-emergence, respectively. At harvest, significantly higher dehydrogenase activity was measured under the treatment of control plot, which was comparable with treatment of hand weeding twice at 25 and 45 DAS and pre-emergence application of herbicides, pendimethalin @ 1000 g a.i. ha^{-1}, pendimethalin @ 1250 g a.i. ha^{-1}, pendimethalin (extra) @ 1000 g a.i. ha^{-1}, pendimethalin @ 1500 g a.i. ha^{-1}, metribuzin @ 250 g a.i. ha-

Table 2: Herbicidal phytotoxicity effects on chickpea at 1, 3, 7 and 10 DAA as influenced by different weed management practices

Weed management practices	Dose (g a.i. ha^{-1})	Herbicidal phytotoxicity effects on chickpea							
		Yellowing (DAA)				Scorching (DAA)			
		1	3	7	10	1	3	7	10
T_1-Pendimethalin as PE	1000	0	0	0	0	0	0	0	0
T_2-Pendimethalin as PE	1250	0	0	0	0	0	0	0	0
T_3-Pendimethalin as PE	1500	0	0	0	0	0	0	0	0
T_4-Pendimethalin (extra) as PE	1000	0	0	0	0	0	0	0	0
T_5-Oxyfluorfen as PE	125	0	0	0	0	0	0	0	0
T_6-Metribuzin as PE	250	0	0	0	0	0	0	0	0
T_7-Oxyfluorfen+Metribuzin as PE	125+350	0	0	0	0	0	0	0	0
T_8-Oxyfluorfen as early PoE	125	0	2	6	3	0	0	0	0
T_9-Metribuzin as PoE	250	0	6	9	8	0	8	8	6
T_{10}-Control	-	0	0	0	0	0	0	0	0
T_{11}- Hand weeding twice at 25 and 45 DAS	-	0	0	0	0	0	0	0	0

DAA: Days after application of herbicide

Table 3: Dehydrogenase activity (µg TPF h^{-1} g^{-1} soil) of rhizosphere soil as affected by weed management practices of chickpea

Weed management practices	Dose (g a.i. ha^{-1})	Dehydrogenase activity (µg TPF h^{-1} g^{-1} soil)	
		50 DAS	At harvest
T_1-Pendimethalin as PE	1000	62.26	25.93
T_2-Pendimethalin as PE	1250	61.13	25.39
T_3-Pendimethalin as PE	1500	59.24	24.73
T_4-Pendimethalin (extra) as PE	1000	60.59	25.10
T_5-Oxyfluorfen as PE	125	57.64	23.94
T_6-Metribuzin as PE	250	58.27	24.12
T_7-Oxyfluorfen+Metribuzin as PE	125+350	57.21	23.45
T_8-Oxyfluorfen as early PoE	125	52.73	21.36
T_9-Metribuzin as PoE	250	53.57	22.13
T_{10}-Control	-	68.27	28.13
T_{11}-Hand weeding twice at 25 and 45 DAS	-	64.37	27.24
SEm±		2.79	2.26
CD (p=0.05)		8.24	4.71

[1], oxyfluorfen @ 125 g a.i. ha^{-1}, oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1}, respectively. The minimum dehydrogenase activity was measured under oxyfluorfen @ 125 g a.i. ha^{-1} as early post-emergence followed by metribuzin @ 250 g a.i. ha^{-1} as post-emergence. The minimum dehydrogenase activity under these treatments might be due to herbicidal toxic effects on microbial population.

3.4. *Yield attributes and yield of chickpea*

Hand weeding twice at 25 and 45 DAS resulted in higher yield attributes of chickpea viz. number of pods $plant^{-1}$, number of seeds pod^{-1} and 100 seed weight, followed by pre-emergence application of oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} (Table 4). But, number of seeds pod^{-1} and 100 seed weight did not influence significantly due to various weed management practices.

Significantly highest seed and stover yield registered under the treatment of hand weeding twice at 25 and 45 DAS, however, it was at par with the pre-emergence treatment of oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} and metribuzin @ 250 g a.i. ha^{-1}. The minimum seed yield and stover yield was recorded under control treatment. Among other herbicidal treatments, combination of oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} as pre-emergence recorded 73.10% higher seed yield over control plot.

The maximum harvest index (43.80%) was estimated under hand weeding twice at 25 and 45 DAS, but, it was at par with the pre-emergence application of oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1}, metribuzin @ 250 g a.i. ha^{-1} as, pendimethalin @ 1500 g a.i. ha^{-1} as, pendimethalin @ 1250 g a.i. ha^{-1} as, oxyfluorfen @ 250 g a.i. ha^{-1}, pendimethalin @ 1000 g a.i. ha^{-1} as and pendimethalin (extra) @ 1000 g a.i. ha^{-1}, respectively and minimum was recorded under control plot. Similar results were observed by Tewari and Tiwari (2004); Chaudhary et al. (2005); Hassan and Khan (2007).

3.5. *Economics*

Table 4: Effect of weed management practices on yield attributes, yield and economics of chickpea

Weed management practices	Pods plant^{-1} (no.)	100 Seed wt (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)	Weed Index (%)	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
T_1- Pendimethalin @ 1000 g a.i. ha^{-1} PE	39.78	25.89	1091.18	1527.66	41.11	38.12	32735	8599	1.36
T_2- Pendimethalin @ 1250 g a.i. ha^{-1} PE	40.23	26.15	1325.34	1741.54	42.27	24.84	39760	15430	1.63
T_3- Pendimethalin @ 1500 g a.i. ha^{-1} PE	44.10	26.26	1380.44	1794.57	42.87	21.71	41413	16761	1.68
T_4- Pendimethalin (extra) 38.7% CS @ 1000 g a.i. ha^{-1} PE	37.45	26.19	1080.17	1512.23	40.36	38.74	32404	6249	1.24
T_5- Oxyfluorfen @ 125 g a.i. ha^{-1} PE	40.00	26.02	1242.70	1690.07	41.90	29.52	37280	13638	1.58
T_6- Metribuzin @ 250 g a.i. ha^{-1} PE	45.23	26.36	1515.43	1939.75	43.17	14.05	45462	22115	1.95
T_7- Oxyfluorfen+Metribuzin @ 125+350 g a.i. ha^{-1} PE	47.78	26.66	1680.83	2117.84	43.49	4.67	50424	25882	2.05
T_8- Oxyfluorfen @ 125 g a.i. ha^{-1} early post-emergence	31.22	25.72	825.34	1320.55	38.46	53.19	24760	1118	1.05
T_9- Metribuzin @ 250 g a.i. ha^{-1} PoE	27.89	25.21	665.51	1091.44	37.88	62.26	19965	-3381	0.86
T_{10}- Control	25.78	25.20	452.07	759.47	37.31	74.36	13561	-8869	0.60
T_{11}- Hand weeding twice at 25 and 45 DAS	50.45	27.15	1763.25	2145.75	43.80	-	52897	25461	1.93
SEm±	2.03	1.08	84.29	108.13	1.41	-	-	-	-
CD (p=0.05)	5.98	NS	248.65	318.97	4.15	-	-	-	-

The net return and benefit:cost ratio was recorded highest under pre-emergence application of oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1}. However, minimum net returns and benefit:cost ratio was obtained under control plot.

4. Conclusion

Post-emergence application of metribuzin and early post-emergence application of oxyfluorfen showed phytotoxicity on chickpea plants with low dehydrogenase activity. But, the pre-emergence tank-mix application of oxyfluorfen+metribuzin @ 125+350 g a.i. ha^{-1} would be an appropriate combination of herbicides for reducing the weed competition in chickpea and resulted in higher grain yield and B:C ratio without any phytotoxic effect. Whereas, the dehydrogenase activity of experimental field was highest under pendimethalin @ 1000 g a.i. ha^{-1} as pre-emergence.

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