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Soil Physicochemical Properties as Influenced by Various Weed Management Practices in Winter Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted in *rabi* season 2011-12 and 2012-13 at research farm of Bihar Agricultural College, Sabour, Bhagalpur, Bihar to assess the impact of various weed management practices on physico-chemical properties of soil in winter maize. Experiment consisted of nine treatments *viz*., acetochlor 90% EC at 1.25, 1.875, 2.5, 3.125 l ha^{-1}, atrazine 50% WP at 2.0 kg ha^{-1}, 2,4-DEE 38% EC at 2.65 l ha^{-1}, weedy, weed free and acetochlor 90% EC at 5.0 l ha^{-1} laid out in randomized block design replicated thrice. Results indicated that bulk density, water holding capacity and moisture content of soil did not vary significantly at 45 DAS and harvest of maize due to acetochlor 90% EC and others. Soil pH, EC and organic carbon at 45 DAS and harvest did not differ significantly with acetochlor 90% EC and others. Total nitrogen, available P_2O_5 and K_2O though varied significantly but there was not much variation among herbicides. Herbicide treated plots showed depletion of available N, P and K at harvest over weedy check due to higher nutrient removal by enhanced yield. Soil fertility status after harvest was recorded indicating a reduction in available N, P and K under weed free, acetochlor 90% EC @ 3.125 and 5.0 l ha^{-1} over initial and weedy check. Soil available N was lower in acetochlor 90% EC @ 5.0 l ha^{-1} and at par with its dose 3.125 l ha^{-1}. Soil available P was lowest in acetochlor 90% EC @ 5.0 l ha^{-1}, being at par with acetochlor @ 3.125 and 2.5 l ha^{-1} and was significantly lower over weedy check indicating highest soil available P which was at par with acetochlor 90% EC @ 1.25 and 1.875 l ha^{-1}. Soil available K was lowest in acetochlor 90% EC @ 5.0 l ha^{-1} and similar to rest of its doses except 1.25 l ha^{-1}. It

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showed parity to 2, 4-DEE 38% EC @ 2.65 l ha^{-1} and atrazine 50% WP @ 2.0 kg ha^{-1}, which were significantly lower over weedy check. Weed free plot showed minimum soil available N, P and K.

Keywords: Acetochlor; maize; soil physico-chemical properties; weed management.

1. INTRODUCTION

In Bihar, maize is heavily fertilized and sparsely grown as wide spaced crop having slow initial growth especially in winter favours the emergence and growth of weeds, which led to severe weed infestation which competes the crop for space, moisture, light, carbon dioxide and nutrients which reduced yield and increased the cost of cultivation [1]. *Rabi* maize suffers from severe weed competition and causes yield losses varying from 28-100% [2]. Weeds being the major yield-limiting factor reduced crop yield by 20-40% [3]. Yield losses due to weeds have been reported up to 35% [4].

Several methods such as mechanical, cultural, biological and chemical method are available to minimise the losses caused by weeds. Cultural methods are still useful but are costly, laborious and time-consuming. Hence, farmers are searching alternatives for weed control. Therefore, chemical weed control is an alternative which is quick, more effective, efficient, time and labour saving [5]. Knezevic et al. [6] reported that grain yield was significantly increased by herbicides in maize. These findings are in agreement with those of Rout and Satapathy [7].

Time of application is important for proper control of weeds to increase the efficacy of herbicides. Herbicide seems to be competitive to control weeds at the initial stage. Losses caused by weeds can be reduced by use of selective herbicides but they may be too costly for farmers provided that herbicide-treated weeds are not herbicide resistant [8]. Post emergence herbicides have achieved adequate weed control due to its broad-spectrum activity, excellent crop safety, convenience and flexibility.

To manage the complex weed flora, there is need to evaluate the effect of different herbicides alone and in combination on soil properties either physical or chemical or maybe both of them to have broad spectrum weed control and sustainability of soil health. Keeping these issues in view, the present investigation “Soil physicochemical properties as influenced by various weed management practices in winter maize (*Zea mays* L.)” was undertaken to assess the impact of various herbicides on soil physico-chemical properties.

2. MATERIALS AND METHODS

The experiment was conducted at Bihar Agricultural University, Sabour in 2011-2012 and 2012-13. Maize used in the experiment was laid out in randomized block design with three replications with nine treatments namely, acetochlor 90% EC at 1.25 l ha^{-1}, 1.875 l ha^{-1}, 2.5 l ha^{-1}, 3.125 l ha^{-1} and 5.0 l ha^{-1}, atrazine at 2.0 kg ha^{-1} and 2, 4-Diethyl ester at 1.315 l ha^{-1}, weed free and weedy check. Herbicidal treatments were sprayed after sowing of seed with hand knapsack sprayer. Maize crop was fertilized with 120 kg N ha^{-1}, 75 kg P_2O_5 ha^{-1} and 50 kg K_2O_5 ha^{-1} in the form of urea, di-ammonium phosphate and muriate of potash, respectively. One third of nitrogen and full dose of phosphorus through di-ammonium phosphate and potassium through muriate of potash at basal into the soil during final ploughing. Remaining nitrogen was top- dressed in two equal splits at knee high and tasseling stage in maize rows. Excluding the weed management practice, all the recommended improved package of practices of winter maize was followed in this experiment including general plant protection measures. Prior to sowing, the seeds were treated with carbendazim @ 2 g kg^{-1} seed followed by chlorpyriphos @ 8 ml kg^{-1} seed. Treated seeds were kept under shade for an overnight before sowing in the field. Soil samples collected from each plot after 45 days after sowing and harvest stage of maize were air dried, ground and sieved through 20 mesh sieve. These samples were subjected to analyze for measurement of soil pH (Glass electrode pH meter), EC (Electrical conductivity meter), organic carbon% (Walkley and Black’s rapid titration method), available N (modified Kjeldahl’s method) and K_2O (Flame photometer method) as described by Jackson (1973) and available P_2O_5 (Olsen’s method) as described by Olsen et al. (1954) to determine the nutrient status of the soil after completion of experimentation.

Data for different characters were subjected to statistical analysis adopting the methods appropriate to design [9]. The results were interpreted on the basis of 'F' test and CD between treatments' mean. Whenever F value was significant, CD value was computed for comparison among treatments mean. Data collected was analyzed statistically following standard procedures. Level of significance used in 'F' and 't' test was P=0.05.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Properties of Soil after Application of Treatments during 2011-12

Physical properties: Bulk density, water holding capacity and moisture content of soil did not vary significantly at 45 days after sowing and after harvesting of winter maize due to the application of testing herbicide Acetochlor 90% EC and others (Table 1).

Chemical properties: Soil pH, Electrical conductivity (EC) and organic carbon at 45 days after sowing and harvest stage did not differ significantly with testing herbicide Acetochlor 90% EC and others applied as pre-emergence (Table 2). Soil pH was higher in weed free treatment (T_8) rather than that of the weedy check (T_7). Almost all herbicide treated plots had higher pH as compared to weedy check (T_7) and had lower pH than weed-free treatment (T_8). The data presented in Table 2 showed that total nitrogen, available P_2O_5 and K_2O though varied significantly, but there was not much variation among herbicidal treatments. Herbicide treated and weed free treatment (T_8) showed depletion of available N, P_2O_5 and K_2O after harvest of the crop over a weedy check (T_7). Weed free treatment (T_8) exhibited minimum value of available N, P_2O_5 and K_2O content in soil. These findings are in agreement with those of Rout and Satapathy [7].

Gaurav et al. [10] also reported that among herbicidal treatments, application of atrazine at 1 kg a.i. ha^{-1} PE *fb* 2, 4-D at 30 DAS at 0.5 kg a.i. ha^{-1} PoE recorded highest organic carbon and lower pH and electrical conductivity than other weed management practices. Similarly, weed-free had maximum organic carbon and minimum pH and electrical conductivity than rest of the treatments. Also there were noticeable changes in physico-chemical properties of soil. There was a significant decrease in organic matter and phosphorus content of the soil. Organic matter of soil decreased at the beginning, while phosphorus content decreased. This is consistent with the findings of Ayansina and Oso [11] and has been associated with poor fertility.

Soil pH, electrical conductivity and organic carbon were not significantly varied due to different herbicidal treatments at 45 days of sowing and at harvest of crop (Table 1). Herbicide-treated plots showed depletion of available N, P & K after harvest of the crop over weedy check due to higher nutrient removal by enhanced crop yield.

Data obtained from Table 2 observed that soil fertility status at harvest of crop indicated reduction in available N, P and K in soil under weed free, acetochlor 90% EC @ 3.125 & 5.0 l ha^{-1} over its initial value and weedy check. Soil available N content was of lower value in acetochlor 90% EC @ 5.0 l ha^{-1} and at par with its lower dose 3.125 l ha^{-1}. Amongst herbicidal treatments, soil available P was lowest in acetochlor 90% EC @ 5.0 l ha^{-1}, which was at par with acetochlor 90% EC @ 3.125 & 2.5 l ha^{-1} and was significantly lower over weedy check indicating highest soil available P which was statistically at par with acetochlor 90% EC @ 1.25 & 1.875 l ha^{-1}. Amongst herbicidal treatments, soil available K was lowest in acetochlor 90% EC @ 5.0 l ha^{-1} and similar to rest of its doses except 1.25 l ha^{-1}. It also showed parity to 2, 4-Diethyl ester 38% EC @ 2.65 l ha^{-1} and atrazine 50% WP @ 2.0 kg ha^{-1}, which were significantly lower over weedy check. Weed free plot showed the minimum value of available N, P and K content in soil (Table 2).

3.2 Physico-chemical Properties of Soil after Application of Treatments during 2012-13

Physical properties: The bulk density, water holding capacity and moisture content of soil did not vary significantly at 45 days after sowing and after harvest of winter maize due to application of testing herbicide Acetochlor 90% EC and others (Table 3).

Chemical properties: The soil pH, Electrical conductivity (EC) and organic carbon at 45 DAS and harvest stage were not significantly affected by the testing herbicide Acetochlor 90% EC and others applied as pre-emergence (Table 3). The data presented in Table 4 clearly showed that available nitrogen, available P_2O_5 and K_2O varied significantly due to different herbicides use but there was not much variation amongst herbicidal treatments.

Table 1. Effect of different treatments on bulk density, moisture content and water holding capacity of soil during 2011-12

Treatment	Bulk density (g cc^{-1})		Moisture content (%)		Water holding capacity (%)	
	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest
T_1-Acetochlor 90% EC @ 1.25 l ha^{-1}	1.34	1.36	13.62	14.24	42.37	45.11
T_{2-} Acetochlor 90% EC @ 1.875 l ha^{-1}	1.36	1.38	13.67	14.20	42.64	44.74
T_{3-} Acetochlor 90% EC @ 2.5 l ha^{-1}	1.37	1.39	13.69	14.15	42.77	44.87
T_{4-} Acetochlor 90% EC @ 3.125 l ha^{-1}	1.35	1.34	13.26	14.28	42.81	44.95
T_{5-} Atrazine @ 2 kg ha^{-1}	1.35	1.34	13.29	14.32	41.94	44.28
T_{6-} 2,4-Diethyl ester 38% EC @ 2.65 l ha^{-1}	1.34	1.36	14.32	14.46	41.90	44.76
T_{7-} Weedy check	1.36	1.37	13.94	14.56	42.27	46.30
T_{8-} Weed free	1.37	1.35	12.60	14.61	42.95	46.24
T_{9-} Acetochlor 90% EC @ 5.0 l ha^{-1}	1.35	1.33	13.21	14.37	42.85	44.57
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Initial value	1.32		13.12		44.39	

Table 2. Effect of different treatments on soil pH, EC, available N, P and K during 2011-12

Treatment	Soil pH		EC (ds m^{-1})		% Organic C		Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})	
	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest
T_1-Acetochlor @ 1.25 l ha^{-1}	7.3	7.4	0.29	0.28	0.575	0.576	220.6	205.0	33.7	28.6	226.8	155.8
T_{2-} Acetochlor @ 1.875 l ha^{-1}	7.5	7.5	0.29	0.28	0.580	0.583	220.4	198.9	33.6	28.4	222.3	153.7
T_{3-} Acetochlor @ 2.5 l ha^{-1}	7.5	7.5	0.28	0.27	0.582	0.585	211.8	190.3	27.6	22.6	217.3	151.6
T_{4-} Acetochlor @ 3.125 l ha^{-1}	7.6	7.6	0.28	0.28	0.579	0.582	209.8	188.7	25.9	20.6	215.9	150.8
T_{5-} Atrazine @ 2 kg ha^{-1}	7.1	7.2	0.26	0.23	0.579	0.581	216.5	197.2	32.3	26.6	220.9	153.5
T_{6-} 2,4-Diethyl ester @ 2.65 l ha^{-1}	7.1	7.1	0.27	0.23	0.584	0.586	212.1	190.8	31.2	25.8	219.6	151.9
T_{7-} Weedy check	7.2	7.3	0.28	0.28	0.576	0.579	237.2	220.4	35.1	30.8	229.3	160.3
T_{8-} Weed free	7.8	7.7	0.27	0.25	0.522	0.526	206.3	185.6	24.3	19.7	209.8	141.6
T_{9-} Acetochlor @ 5.0 l ha^{-1}	7.6	7.6	0.29	0.26	0.575	0.578	207.1	187.5	25.5	20.5	212.5	150.2
CD (P=0.05)	NS	NS	NS	NS	NS	NS	19.6	12.4	1.8	2.5	12.6	3.8
Initial value	7.4		0.29		0.562		198.0		24.2		158.8	

Table 3. Effect of different treatments on bulk density, moisture content and water holding capacity of soil during 2012-13

Treatment	Bulk density (g/cc)		Moisture content (%)		Water holding capacity (%)	
	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest
T_1-Acetochlor 90% EC @ 1.25 l ha^{-1}	1.38	1.40	13.68	14.21	42.69	45.29
T_{2-} Acetochlor 90% EC @ 1.875 l ha^{-1}	1.40	1.41	13.74	14.16	42.78	44.63
T_{3-} Acetochlor 90% EC @ 2.5 l ha^{-1}	1.41	1.42	13.77	14.10	42.92	44.70
T_{4-} Acetochlor 90% EC @ 3.125 l ha^{-1}	1.39	1.38	13.35	14.26	42.99	44.87
T_{5-} Atrazine 50% WP @ 2 kg ha^{-1}	1.38	1.37	13.38	14.35	41.95	44.35
T_{6-} 2,4-Diethyl ester 38% EC @ 2.65 l ha^{-1}	1.38	1.39	14.34	14.43	41.87	44.68
T_{7-} Weedy check	1.39	1.40	13.90	14.51	42.54	46.38
T_{8-} Weed free	1.40	1.38	12.87	14.57	43.15	46.30
T_{9-} Acetochlor 90% EC @ 5.0 l ha^{-1}	1.39	1.37	13.30	14.38	43.07	44.51
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Initial value	1.36		13.35		45.01	

Table 4. Effect of different treatments on soil pH, EC, available N, P and K during 2012-13

Treatment	Soil pH		EC (ds/m)		% Organic C		Available N (kg/ha)		Available P_2O_5 (kg/ha)		Available K_2O (kg/ha)	
	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest
T_1-Acetochlor @ 1.25 l ha^{-1}	7.2	7.3	0.29	0.26	0.572	0.577	221.6	198.5	23.5	21.7	187.3	158.5
T_{2-} Acetochlor @ 1.875 l ha^{-1}	7.3	7.3	0.29	0.27	0.578	0.581	215.8	194.0	23.1	20.5	178.4	153.0
T_{3-} Acetochlor @ 2.5 l ha^{-1}	7.3	7.3	0.28	0.26	0.579	0.582	210.3	189.2	21.5	20.2	178.0	151.3
T_{4-} Acetochlor @ 3.125 l ha^{-1}	7.3	7.3	0.28	0.27	0.578	0.581	208.1	187.5	20.8	18.8	176.3	150.7
T_{5-} Atrazine @ 2 kg ha^{-1}	7.1	7.2	0.26	0.23	0.576	0.579	213.7	192.7	22.7	21.9	184.2	156.1
T_{6-} 2,4-Diethyl ester @ 2.65 l ha^{-1}	7.1	7.1	0.27	0.25	0.581	0.583	213.1	191.8	21.8	19.7	183.1	154.2
T_{7-} Weedy check	7.1	7.2	0.27	0.27	0.574	0.578	228.3	207.8	25.3	24.3	189.6	159.8
T_{8-} Weed free	7.4	7.4	0.27	0.25	0.529	0.534	204.2	185.3	20.4	18.3	172.0	143.6
T_{9-} Acetochlor @ 5.0 l ha^{-1}	7.4	7.3	0.29	0.28	0.574	0.578	206.2	186.4	20.6	18.7	175.4	150.4
CD (P=0.05)	NS	NS	NS	NS	NS	NS	5.2	4.8	2.0	2.0	10.5	1.9
Initial value	7.43		0.26		0.576		195.6		25.0		152.1	

Gaurav et al. [10] reported that all the weed management treatments recorded the highest N, P, K, S and Zn availability in soil than weedy check. Weed free had more N, P, K, S and Zn availability in soil, which was closely followed by atrazine 1 kg a.i. ha^{-1} PE *fb* 2, 4-D at 0.5 kg a.i. ha^{-1} PoE, atrazine at 1.0 kg a.i. ha^{-1} *fb* one hand weeding at 30 DAS and pendimethalin at 1.0 kg a.i. ha^{-1} PE *fb* one hand weeding at 30 DAS. Whereas, weedy check had less N, P, K S, and Zn availability in soil due to higher weed dry weight and poor crop yield.

Soil pH, electrical conductivity and organic carbon were not significantly varied due to different herbicidal treatments at 45 days of sowing and at harvest of the crop (Table 3). Herbicide treated plots showed depletion of available N, P & K after harvest of crop over weedy check due to higher nutrient removal by enhanced crop yield. Data obtained from Table 4 observed that soil fertility status at harvest of crop indicated a reduction in available N, P and K in soil under weed free, acetochlor 90% EC @ 3.125 & 5.0 l ha^{-1} over its initial value & weedy check. Soil available N content was lower in acetochlor 90% EC @ 5.0 l ha^{-1} being at par with its dose 3.125 & 2.5 l ha^{-1}. Soil available P content was lowest in acetochlor 90% EC @ 5.0 l ha^{-1}, which was at par with acetochlor 90% EC @ 3.125, 2.5 & 1.875 l ha^{-1} and was significantly lower over weedy check. Among herbicidal treatments, soil available K was lowest in acetochlor 90% EC @ 5.0 l ha^{-1} and similar to rest of its doses. It also showed parity to 2, 4-Diethyl ester 38% EC @ 2.65 l ha^{-1} and atrazine 50% WP @ 2.0 kg ha^{-1}, which were significantly lower over the weedy check. Weed free plot showed the minimum value of available N, P and K content in soil (Table 4). This is consistent with the findings of Ayansina and Oso [11]. This might be attributed to the lingering effects of the herbicides in the experimental plots [12] and the physicochemical changes caused to the soil by use of herbicides [11,13,14]. Studies conducted by Myers et al. [12] showed that herbicides persisted in soil longer than previously reported, and so the effects of the herbicides applied during first phase of the study can easily extend to the second phase of the study.

4. CONCLUSION

The present study results indicated that bulk density, water holding capacity and moisture content of soil did not vary significantly at 45 days and harvest of maize due to acetochlor 90% EC and others. Soil pH, EC and organic carbon at 45 days and harvest did not differ significantly with acetochlor 90% EC and others. It might be concluded that there was no any detrimental ill effects of applying acetochlor and other herbicides in winter maize in controlling obnoxious weeds very effectively and maintaining sustaining of soil fertility and crop productivity in the context of climate change scenario.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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