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Effect of herbicides applied to *kharif* maize on soil physio-chemical properties, microbial population and their residual effect on succeeding wheat crop

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Abstract
The effect of different herbicides *viz.*, atrazine, pendimethalin, 2,4-D, topramezone and tembotrione on soil physio-chemical properties, microbial population and carry over effect on succeeding crop was assessed at AICRP on Weed Management Farm, Anand Agricultural University, Anand during *kharif* seasons of the year 2016. Bacterial, fungal, actinobacterial and PSM populations as well as various soil properties were analyzed. Among physio-chemical properties of the soil, electrical conductivity and available phosphorus in soil were significantly affected due to various herbicidal treatments. Total bacterial, fungal and PSM population decreased initially up to 30 DAS and thereafter, it showed non-significant effect with increase in their number except bacterial population at 60 DAS. In case of total bacteria, significant differences were recorded up to 60 DAS. Actinobacterial population was unaffected due to herbicidal treatment at every interval. Carryover effect of different herbicide applied in preceding maize crop showed non-significant influenced on all the recorded characters of succeeding wheat.

Keywords: herbicide, microorganism, soil properties, carry over effect

Introduction

Weeds are responsible for reduction in yield depending on complex flora and severity of infestation under various field and orchard crops mainly due to competition with crop plants for nutrients, space, light and water. Traditionally weeds are control by tillage operation, but chemical control of weeds using pre and post emergence herbicides is widely used in different crops. However, increased application of herbicides caused for multidisciplinary approach in plant, soil and environment. Soil microorganisms are an important link in soil-plant-herbicide-fauna-man relationships.

Herbicides are incorporated in soil through direct application and indirectly via water or residues of plant and animal origin. After application of herbicides may evaporate (volatilize), washed away through surface runoff, leach into deep soil strata and ground water, inactivated by plants or may be adsorbed in soil in which case they become subject to chemical or microbiological degradation. These herbicides could then accumulate to toxic levels in the soil and may become harmful to soil microorganisms and plant. There is an increasing concern that herbicides not only affect the target organisms (weeds) but also the microbial communities present in soils and these non-target effects may reduce the performance of important soil properties too. Microbial activity measurements appear as good indicators of the degree of pollution of contaminated soils (Kuperman and Margret, 1997) [8]. Further, over application of these chemicals inhibit some of these natural processes, and decreases the performance of the non-target organisms (Subhani *et al*., 2000) [11]. The objective of this work was to study the effect of herbicides belonging to different chemical families and modes of action applied in maize on soil physio-chemical properties, microbial activities as well as their carry over effect on succeeding wheat.

Materials and Methods

With a view to determine the effect of various herbicides applied to *kharif* maize on physio-chemical and microbial properties as well as their residual effect on succeeding wheat crop, present experiment was carried out during *kharif* seasons of the year 2016 at AICRP on Weed Management Farm, Anand Agricultural University, Anand. The soil was sandy loam in texture having low in available nitrogen and medium in available phosphorus and high in potassium.

The experiment was laid out in randomized complete block design with three replications. Twelve treatment comprised *viz.*, T_1: atrazine 1000 g/ha *fb* HW at 40 DAS, T_2: atrazine 500 g/ha + pendimethalin 250 g/ha PE, T_3: atrazine 1000 g/ha PE *fb* 2,4-D 1000 g/ha LPoE, T_4: atrazine 500 g/ha + pendimethalin 250 g/ha PE *fb* 2,4-D 1000 g/ha LPoE, T_5: topramezone 25.2 g/ha EPoE, T_6: tembotrione 120 g/ha EPoE. T_7: topramezone 25.2 g/ha EPoE *fb* IC + HW at 30 DAS. T_8: tembotrione 120 g/ha EPoE *fb* IC + HW at 30 DAS. T_9: topramezone 25.2 + atrazine 500 EPoE *fb* IC + HW at 30 DAS. T_{10}: tembotrione 105 + atrazine 250 g/ha EPoE *fb* IC + HW at 30 DAS. T_{11}: IC + HW at 20 and 40 DAS and T_{12}: Weedy check. The *kharif* maize cv. GM-6 was sown manually keeping the distance of 60 x 20 cm at 20 kg seed/ha during third week of July 2016. The herbicides were applied as per the treatments using Knapsack sprayer fitted with flat fan nozzle by mixing in 500 L of water/ha. The crop was harvested on third week of October.

Soil physico-chemical properties: For assessment of physio-chemical properties of soil, samples were drowned after harvest of maize crop from each plot and the same were used for analysis purpose.

Soil microbial properties: Representative soil samples were collected from each plot before sowing, at 30 and 60 DAS as well as at harvest. All the soil samples were analyzed for total soil bacteria, fungi, actinomycets and phosphate solubilizing microbial (PSM) populations using standard methodology as under. For total count, soil samples were serially diluted and inoculated on respective agar media *i.e.* for bacteria nutrient agar, for fungi MRB agar, for actinomycetes, actinomycets agar and for PSM, PKVK agar medium were used. After incubation microbial count in terms of CFU was recorded (Bera and Ghosh, 2014) [3].

Residual effect: To know the residual effect of herbicides applied to maize, after harvesting of the maize crop without disturbing the layout each plot were manually prepared for sowing of succeeding crop. Succeeding wheat crop was sown in each plot during *rabi* season with adopting all the recommended package of practices. The observation on plant stand (%) at 15 DAS, plant height (cm), grain and straw yield were recorded and data were used for analysis. Data on various observations during the experiment period was statistically analyzed as per the standard procedure developed by Cochran and Cox (1957) [6].

Result and Discussion

Effect on soil physico-chemical properties

The data regarding various phsyco-chemical properties of soil *viz.*, pH, organic carbon, available nitrogen and available potassium were analyzed after harvest of maize exhibited non significant differences (Table 1). The non significant effect on percentage of organic matter content in soil may be due to the short term nature of the exposure period for the herbicides treatment. Adomako and Akyeampong (2016) [2] also noted that percentage organic matter of the control and the various herbicide treatments did not differ much with the mean values of baseline determination. However, electrical conductivity and available phosphorus in soil were significantly affected due to various treatments. Though the results was non significant but numerically higher organic carbon and available nitrogen were recorded under application of topramezone + atrazine 25.2 + 500 g/ha EPoE *fb* IC + HW at 30 DAS as compared to rest of the treatments. Significantly higher electrical conductivity (0.45 dS/m) and available phosphorous in soil (56 kg/ha) were recorded under atrazine + pendimethalin (500+250 g/ha) PE *fb* 2,4-D 1000 g/ha LPoE.

Effect on soil microbial properties

The effect of applied herbicides on soil microbial population was determined based on the growth and number (CFU/gm soil) of bacteria, fungi, actinomycets and PSM colonies on their respective medium (Table 2).

Significant difference was recorded in total bacterial count due to different weed management practices at 30 and 60 DAS, while the difference became non-significant at harvest (Table 2). The activity of total bacterial count was significantly altered at 30 and 60 DAS due to different weed management practices in maize. Significantly the highest total bacterial count (97 x 10^5 CFU/g soil) was recorded under treatment IC + HW at 20 & 40 DAS. This may be due to interculturing operation allows pulverization of soil and better soil aeration which ultimately increase the microbial population in the soil (Bhale *et al.*, 2012) [5]. Further, it was observed that weedy check, application of tembotrione + atrazine 105 + 250 g/ha EPoE *fb* IC + HW at 30 DAS, topramezone 25.2 g/ha EPoE *fb* IC + HW at 30 DAS, tembotrione 120 g/ha EPoE *fb* IC + HW at 30 DAS and topramezone + atrazine 25.2 + 500 g/ha EPoE *fb* IC + HW at 30 DAS statistically at par with each other but found significantly superior over rest of the treatment. The superiority of the treatments might be attributed to IC + hand weeding operation. Total bacterial count was severely affected in treatments receiving application of atrazine 1000 g/ha PE *fb* 2,4-D 1000 g/ha LPoE and atrazine + pendimethalin (500+250 g/ha) PE *fb* 2,4-D 1000 g/ha LPoE as compared to other treatments. At 60 DAS, total bacterial count was significantly affected but similar trend was recorded as observed at 30 DAS. The toxic effect of some of the herbicide was observed for a short period after its application, while in other herbicide treatments the effect was found for long period because inabilities of the organisms to degrade the particular herbicide in due course of time. Ramesh and Nadanassababady (2005) [9] also found significant differences in population of soil bacteria, fungi and actinomycets, shortly after application of herbicides *i.e.* 5 days after sowing as compared to their population before herbicide application.

Significantly the highest total soil fungal population (5.1 x 10^3 CFU/g soil) and PSM population (98 x 10^3 CFU/g soil) were observed under IC + HW at 30 and 40 DAS (Table 2). Whereas, application of atrazine 1000 g/ha PE *fb* 2,4-D 1000 g/ha LPoE, atrazine + pendimethalin (500+250 g/ha) PE *fb* 2,4-D 1000 g/ha LPoE, tembotrione 120 g/ha EPoE and topramezone 25.2 g/ha EPoE at par with each other and recorded significantly the lowest total fungi population at 30 DAS. These results indicated that certain fungal species are benefitted/less affected by application of herbicide while others are inhibited. Further, it was observed that, total fungi and PSM populations were significantly affected up to 30 DAS, while at 60 DAS and at harvest it was found non-significant. These results showed retardant effects of herbicide treatments initially on fungal growth, but after acclimatization with surroundings and degradation of herbicide molecules, the fungi quickly regained its population density at 60 DAS shown non-significant effect of treatments (Abbas *et al*., 2015) [1]. For PSM population, in soil most of phosphate solubilization is performed by fungi. So, it can be directly correlated with effect on fungal population. This results confirm with the results of Adomako and Akyeampong (2016) [2] they noted a cumulative score of 7 for a particular fungus by atrazine treatment compared to 4 score for the baseline determination.

All the microbial parameters i.e. total bacteria, total fungi and total PSM were significantly influenced by different weed management practices adopted in maize except total actinobacteria (Table 2). Total actinomycets population was not affected due to robust nature of the organisms and capabilities to produce different metabolites and to degrade different of agrochemicals (Dhanasekaran *et al*., 2010) [7].

At harvest, effect of weed management practices showed non-significant effect for all microbial parameters. Initially, from the day of herbicide application to 30 DAS microbial properties were affected significantly but after 30 DAS gradual buildup in population was recorded, may be due to herbicide degradation and microbial acclimatization to surroundings leads to increase in microbial activity and after 60 DAS to time of harvest stabilize by neutralizing ill effects of herbicides. At harvest, all microbial parameter found to decrease in comparison to 60 DAS, because of maturity of the crop, limited water activity as well as limited secretion of root exudates in the rhizospheric region of the plant. These results are in conformity with the results of Tyagi *et al*. (2018) [12] in maize crop. Similarly, Bera and Ghosh (2013) [4] reported that soil microorganisms are able to degrade herbicides and utilize them as a source of biogenic elements for their own physiological processes. However, immediately after application of herbicides showed toxic effects on microorganisms, reducing their population and activity before they take part in degradation. Later on, after acclimatization with surroundings, microorganisms take part in a degradation process and degrade organic molecules of herbicides provide carbon rich substrates, which helps in maximizing the microbial population in the soil. Abbas *et al*. (2015) [1] reported that, overall bacteria, actinomycetes and fungi populations showed decreasing trend with herbicide application up to the day 30 and then increasing trend was observed till day 60. They have also recorded decrease in dehydrogenase and alkaline phosphatase activities was experienced with herbicide application up to day 7 thereafter, the activities of these enzymes showed increasing tendency up to day 60.

Carryover effect on wheat

The data pertaining to carryover effect of different herbicide applied in preceding maize crop showed non significant influenced on all the recorded characters of wheat (Table 3). Reddy *et al*. (2012) [10] observed that atrazine applied at 0.25 to 0.5 kg/ha as pre-emergence and pendimethalin 0.5 kg/ha as pre-emergence in maize did not leave any residues in the soil. Thus, the results clearly indicated that herbicides applied alone or their mixtures in maize were found to be safe for succeeding crop might be due to detoxification of herbicides in soil, which do not adversely affect the growth of succeeding crop in terms of plant height, dry weight of plants and yields of wheat.

Table 1: Effect of weed management practices on physico-chemical properties of soil at harvest of maize

S. No.	Treatment	Soil pH	Soil EC (dS/m)	Organic Carbon (%)	Available Nitrogen (kg/ha)	Available Phosphorus (P_2O_5) (kg/ha)	Available potassium (K_2O) (kg/ha)
T_1	Atrazine 1000 g/ha PE *fb* HW at 40 DAS	7.99	0.36	0.41	520	46	174
T_2	Atrazine + Pendimethalin (500+250 g/ha) PE	7.99	0.44	0.40	504	49	153
T_3	Atrazine 1000 g/ha PE *fb* 2,4-D 1000 g/ha LPoE	7.98	0.44	0.41	504	43	184
T_4	Atrazine + Pendimethalin (500+250 g/ha) PE *fb* 2,4-D 1000 g/ha LPoE	7.86	0.45	0.46	562	56	213
T_5	Topramezone 25.2 g/ha EPoE	8.20	0.39	0.41	480	43	174
T_6	Tembotrione 120 g/ha EPoE	7.92	0.42	0.42	463	41	200
T_7	Topramezone 25.2 g/ha EPoE *fb* IC + HW at 30 DAS	8.03	0.29	0.41	507	44	170
T_8	Tembotrione 120 g/ha EPoE *fb* IC + HW at 30 DAS	8.06	0.36	0.41	511	49	178
T_9	Topramezone + atrazine 25.2 + 500 g/ha EPoE *fb* IC + HW at 30 DAS	7.92	0.39	0.44	553	52	197
T_{10}	Tembotrione + atrazine 105 + 250 g/ha EPoE *fb* IC + HW at 30 DAS	7.84	0.36	0.42	523	52	189
T_{11}	IC + HW at 20 and 40 DAS	7.97	0.29	0.43	546	52	203
T_{12}	Weedy check	8.01	0.38	0.41	435	41	158
	S. Em. ±	0.06	0.01	0.01	51.0	1.69	12.7
	CD (P=0.05)	NS	0.05	NS	NS	4.98	NS
	CV %	1.5	8.5	6.2	17.3	6.2	12.1

Table 2: Effect of weed management practices on soil microbial properties in maize

S. No.	Treatment	Total Bacterial Count (10^5 CFU/g soil)			Total Fungi (10^3 CFU/g soil)			Total Actinobacteria (10^3 CFU/g soil)			Total PSM (103 CFU/g soil)		
		Initial: 55 X 10^5			Initial: 40 X 10^3			Initial: 60 X 10^3			Initial: 72 X 103		
		30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1	Atrazine 1000 g/ha PE *fb* HW at 40 DAS	38	97	82	45	106	53	90	224	112	84	129	90
T_2	Atrazine + Pendimethalin (500+250 g/ha) PE	39	96	81	49	105	52	86	214	109	86	128	90
T_3	Atrazine 1000 g/ha PE *fb* 2,4-D 1000 g/ha LPoE	25	95	80	28	105	52	85	216	110	79	129	90
T_4	Atrazine + Pendimethalin (500+250 g/ha) PE *fb* 2,4-D 1000 g/ha LPoE	25	96	81	29	108	54	84	211	108	81	128	90
T_5	Topramezone 25.2 g/ha EPoE	35	97	82	32	111	55	87	217	108	80	127	89
T_6	Tembotrione 120 g/ha EPoE	35	96	81	31	110	55	86	215	107	81	128	89
T_7	Topramezone 25.2 g/ha EPoE *fb* IC + HW at 30 DAS	69	104	84	52	108	54	87	216	108	87	130	91

T_8	Tembotrione 120 g/ha EPoE *fb* IC + HW at 30 DAS	68	103	83	53	107	53	88	218	109	87	131	91
T_9	Topramezone + atrazine 25.2 + 500 g/ha EPoE *fb* IC + HW at 30 DAS	68	103	83	51	107	53	86	215	107	86	130	91
T_{10}	Tembotrione + atrazine 105 + 250 g/ha EPoE *fb* IC + HW at 30 DAS	69	102	82	52	109	54	87	217	109	87	131	91
T_{11}	IC + HW at 20 and 40 DAS	97	106	86	67	114	57	92	229	114	98	138	97
T_{12}	Weedy check	74	103	83	51	113	56	86	215	110	87	127	88
S. Em. ±		2.5	1.9	1.9	1.7	2.7	1.4	1.6	3.7	1.9	2.3	2.1	1.6
CD (P=0.05)		7.5	5.5	NS	5.1	NS	NS	NS	NS	NS	6.7	NS	NS
CV %		8.2	3.3	4.0	6.7	4.3	4.6	3.3	2.9	3.1	4.6	2.8	3.0

Table 3: Growth and yield parameters of wheat as influenced by weed management treatments in preceding maize crop

S. No.	Treatment	Plant stand 15 DAS (No./m row)	Plant height (cm)			Grain yield (t/ha)	Straw yield (t/ha)
			30 DAS	60 DAS	harvest		
T_1	Atrazine 1000 g/ha PE *fb* HW at 40 DAS	53.4	32.9	68.9	1.05	4.95	8.06
T_2	Atrazine + Pendimethalin (500+250 g/ha) PE	52.5	33.9	68.0	1.05	4.73	7.88
T_3	Atrazine 1000 g/ha PE *fb* 2,4-D 1000 g/ha LPoE	52.9	33.9	71.2	1.04	5.01	8.21
T_4	Atrazine + Pendimethalin (500+250 g/ha) PE *fb* 2,4-D 1000 g/ha LPoE	53.7	34.2	70.3	1.01	4.81	8.04
T_5	Topramezone 25.2 g/ha EPoE	54.4	34.0	71.7	1.04	4.86	7.70
T_6	Tembotrione120 g/ha EPoE	53.0	34.9	69.1	1.04	4.81	7.54
T_7	Topramezone 25.2 g/ha EPoE *fb* IC + HW at 30 DAS	52.0	32.9	69.0	1.01	5.03	8.05
T_8	Tembotrione 120 g/ha EPoE *fb* IC + HW at 30 DAS	51.2	32.9	69.5	0.993	5.06	7.82
T_9	Topramezone + atrazine 25.2 + 500 g/ha EPoE *fb* IC + HW at 30 DAS	51.6	33.7	69.1	1.02	5.04	8.23
T_{10}	Tembotrione + atrazine 105 + 250 g/ha EPoE *fb* IC + HW at 30 DAS	50.5	34.9	68.4	1.07	4.82	7.83
T_{11}	IC + HW at 20 and 40 DAS	50.5	32.3	70.9	0.968	4.83	7.67
T_{12}	Weedy check	50.3	33.9	69.2	1.01	4.77	7.23
S. Em. ±		2.39	0.78	0.87	0.04	0.16	0.25
CD (P=0.05)		NS	NS	NS	NS	NS	NS
CV %		7.9	4.0	2.2	6.9	5.6	5.5

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