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Effect of Post-Emergence Herbicide -Tembotrione on Yield, Soil Dehydrogenase Activity and Its Phytotoxicity on Maize (*Zea mays* L.) under Mid Hill Conditions of Himachal Pradesh, India

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A B S T R A C T

A field experiment was carried out during kharif 2014 and 2015 at experimental farm of Department of Agronomy, CSK HPKV, Palampur (HP) to evaluate the effect of post emergence herbicide –Tembotrione on yield, soil dehydrogenase activity and its phytotoxicity on maize (*Zea mays* L.) in silty clay loam soil under mid hill conditions of Himachal Pradesh. The experiment was laid out in Randomized Block Design with sixteen treatments replicated thrice. The treatments were three doses of tembotrione (110, 120 and 130 g/ha) with and without surfactant (1000 and 0 ml/ha) at 2 and 3 weeks after sowing and 4 checks [farmer's practice, atrazine 1.5 kg/ha; weed free (atrazine *fb* 2-4, D *fb* hand-weeding if required) and weedy check]. Application of tembotrione 130 g/ha with surfactant at 14 and 21 DAS was comparable to weed free in increasing the grain yield during both the years. Soil dehydrogenase activity in herbicide treated treatments was significantly reduced up to 60 DAS in comparison to later stages. However, the soil dehydrogenase activity was recovered due to degradation of herbicide afterwards. The herbicide was not having any phytotoxic effect on the crop.

Introduction

Maize (*Zea mays* L.) is one of the most important cereals in the world agricultural economy both as a food and fodder crop. It has higher yield potential than any other cereal.

That is why many times it is referred as "miracle crop" or the "queen" of cereals. In India, it is grown over an area of 9.23 m ha with total production of 25.66 m tonnes and average productivity of 25.64 q/ha (Anonymous, 2015).

Maize kernels are used for human consumption, feed for poultry and livestock, extraction of edible oil and also for starch and glucose industry.

Controlling of weeds in maize in the critical period presumes most importance for realizing higher yield. Because weeds emerge fast and grow rapidly competing with the crop severely for growth resources viz., nutrients, moisture, sunlight and space during entire vegetative and early reproductive stages of maize. Further, wide spacing in maize allows faster growth of variety of weed species which reduces the photosynthetic efficiency, dry matter production and distribution to economical parts and there by reduces sink capacity of crop resulting in poor grain yield (Vaid *et al.,* 2010). Labour component in agriculture is becoming scarce, not available at time and prohibitive cost (Dalal and Nandkar, 2010). Under these situations use of herbicides to manage weeds forms an excellent alternative to manual weeding. One alternative tactic based on herbicides to manage weeds may include the use of newly released herbicides with new modes of action. Their effect on soil microflora is also to be studied which is an important consideration in today's agriculture, as lot of emphasis is given on soil health.

Dehydrogenases, as respiratory chain enzymes, play the major role in the energy production of organisms. They oxidize organic compounds by transferring two hydrogen atoms. Dehydrogenases are essential components of the enzyme systems of microorganisms. So dehydrogenase can therefore, be used as an indicator of biological redox systems and as a measure of microbial activity in soil. Under these circumstances, a field experiment was conducted during *kharif 2014* and *2015* to study the effect of tembotrione on maize grain yield, soil dehydrogenase activity and their phytotoxicity on maize.

Materials and Methods

A field experiment was conducted during the rainy seasons of 2014 and 2015 at the experimental farm of Department of Agronomy, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh. The soil of the experimental field was silty clay loam in texture and acidic in reaction. The experiment was laid out in Randomized Block Design with sixteen treatments replicated thrice *viz.* T_1: tembotrione 110 g/ha at 14 DAS, T_2: tembotrione 110 g/ha at 21 DAS, T_3: tembotrione 110 g/ha + surfactant (1000 ml/ha) at 14 DAS, T_4: tembotrione 110 g/ha + surfactant (1000 ml/ha) at 21 DAS,, T_5: tembotrione 120 g/ha at 14 DAS, T_6: tembotrione 120 g/ha at 21 DAS, T_7: tembotrione 120 g/ha + surfactant (1000 ml/ha) at 14 DAS, T_8: tembotrione 120 g/ha + surfactant (1000 ml/ha) at 21 DAS, T_9: tembotrione 130 g/ha at 14 DAS, T_{10}: tembotrione 130 g/ha at 21 DAS, T_{11}: tembotrione 130 g/ha + surfactant (1000 ml/ha) at 14 DAS, T_{12}: tembotrione 130 g/ha + surfactant (1000 ml/ha) at 21 DAS, T_{13}: farmer's practice, T_{14}: atrazine 1500 g/ha as pre-emergence, T_{15}: weed free and T_{16}: weedy check.

The recommended dose of fertilizer and spacing for maize was 120:60:40 NPK kg/ha and 60 cm x 20 cm respectively maintained for all the treatments. Full dose of phosphorus, potassium and half dose of the nitrogen through diammonium phosphate, muriate of potash and urea were applied at the time of sowing and remaining quantity of nitrogen was applied in two splits at knee height and at tasseling stage (as per the recommended package of practices).

The herbicides were applied using Knapsack sprayer fitted with flat fan nozzle by mixing 500 litres of water per ha. Soil samples were collected continued with an interval of 20 days till harvest for estimating dehydrogenase activity. Visual observations were recorded at 7, 14 and 28 days after spraying of herbicides to know the extent of toxicity caused by herbicides on crop by using phytotoxicity rating zero (no toxicity) to ten (100% toxicity) scale (Anonymous., 1981). The phytotoxicity rating was recorded on symptoms - epinasty, hyponasty, necrosis, wilting, vein clearing and stunted growth. Yield was recorded from each net plot area and converted to hectare basis after adjusting moisture and shelling percentage.

The experimental data on soil dehydrogenase activity, yield and yield parameters were subjected to analysis by using Fisher's method of "Analysis of Variance" (ANOVA) as outlined by Panse and Sukhatme (1954). The levels of significance used in "F" and "t" test was at P = 0.05.

Results and Discussion

The weed control treatments significantly affected the number of grains/cob of maize during both the years of study. Treatment T_{15} (Weed free) being statistically at par with T_{11} (Tembotrione 130 g/ha + S at 14 DAS), T_{12} (Tembotrione 130 g/ha + S at 21 DAS) and T_{13} (Farmer's practice) during both the years of experimentation showed significantly higher number of grains/cob. Decrease in number of grains/cob was noticed with increase in weed competition (Singh *et al.*, 2012).

A cursory glance at the data presented in table 1 reveals that the grain yield of maize was significantly affected by different weed control treatments during both the years. All the weed control treatments were significantly superior in increasing the grain yield of maize over weedy check.

T_{15} (Weed free) remaining at par with T_{11} (Tembotrione 130 g/ha + S at 14 DAS), T_{12} (Tembotrione 130 g/ha + S at 21 DAS) and T_{13} (Farmer's practice) gave significantly higher grain yield over rest of the treatments during both the years of study. It was mainly due to minimum crop-weed competition throughout the crop growth period, thus enabling the crop for maximum utilization of nutrients, moisture, light and space which had influence on growth and yield components. The lowest grain yield was noticed in weedy check as a consequence of greatest removal of nutrients and moisture by weeds and severe crop weed competition resulting in poor source and sink development with poor yield components. Weeds in weedy check reduced the grain yield of maize by 56.8 and 55.9 per cent over the best treatment during 2014 and 2015, respectively. The above results could be corroborated with the findings of Singh *et al.*, (2012); Velayutham (2012) and Hooda *et al.*, (2015). The higher grain yield in these treatments could be attributed to improved yield components viz., increased number of grains/cob, higher effective plant population and 1000-grain weight. This improvement in turn was due to improved growth attributes such as higher total dry matter production and distribution in different parts. Thus, the improvement in crop growth and yield components was the consequence of lower crop weed competition, which shifted the balance in favour of crop in utilization of nutrients, moisture, light and space (Akhtar *et al.*, 2015).

The data pertaining to stover yield (Table 1) indicate that all the weed control treatments were significantly superior to weedy check in increasing the stover yield of maize during both the years of study. T_{15} (Weed free) remaining at par with T_{12} (Tembotrione 130 g/ha + S at 21 DAS) gave significant higher stover yield over rest of the treatments during both the years of study.

Because of low cost of herbicide, T_{14} (Atrazine 1500 g/ha) resulted in highest marginal benefit cost ratio. Next to this treatment, T_{12} (Tembotrione 130 g/ha + S at 21 DAS) resulted in higher marginal benefit cost ratio followed by T_{11} (Tembotrione 130 g/ha + S at 14 DAS) and T_{10} (Tembotrione 130 g/ha at 21 DAS) during both the years. T_{15} (Weed free) had low marginal benefit cost ratio followed by T_{13} (Farmer's practice).

Table.1 Effect of treatments on grains/cob, grain yield (q/ha), stover yield (q/ha) and marginal benefit cost ratio (MBCR) of maize

Treatments	Dose (g/ha)	TOA (DAS)	Grains/cob		Grain yield (q/ha)		Stover yield (q/ha)		MBCR	
			2014	2015	2014	2015	2014	2015	2014	2015
Tembotrione	110	14	246.2	250.1	31.8	33.3	60.1	62.2	5.0	5.1
Tembotrione	110	21	250.6	254.3	32.2	34.1	60.9	63.0	5.2	5.5
Tembotrione+S	110+1000	14	252.7	257.0	32.8	34.6	62.0	64.1	5.5	5.7
Tembotrione+S	110+1000	21	256.1	261.5	33.3	35.3	63.1	65.3	5.8	6.1
Tembotrione	120	14	260.3	265.3	35.5	37.3	66.9	69.2	6.3	6.5
Tembotrione	120	21	263.1	268.0	36.1	37.9	68.6	70.7	6.6	6.8
Tembotrione+S	120+1000	14	264.8	271.5	36.9	38.4	70.1	72.3	7.0	7.1
Tembotrione+S	120+1000	21	270.5	274.8	37.7	39.1	72.1	74.2	7.5	7.5
Tembotrione	130	14	273.1	279.0	39.0	40.4	75.0	77.1	7.4	7.5
Tembotrione	130	21	277.7	284.7	39.5	41.4	78.1	80.1	7.8	8.0
Tembotrione+S	130+1000	14	282.1	287.5	41.4	43.0	79.9	82.0	8.6	8.6
Tembotrione+S	130+1000	21	287.2	291.2	43.6	45.2	82.5	84.6	9.4	9.5
Farmer's practice	-	15 & 35	284.0	288.7	42.2	44.1	80.2	82.3	6.8	6.2
Atrazine	1500	Pre	263.2	266.0	37.0	38.7	71.4	73.5	21.4	19.6
Weed free	-	-	289.9	295.1	46.1	47.4	88.2	90.3	7.7	7.1
Weedy check	-	-	225.2	228.7	19.9	20.9	39.6	41.8	-	-
CD (P=0.05)			10.2	9.9	4.8	4.6	6.6	6.8	-	-

TOA: Time of application, DAS: Days after sowing

Table.2 Effect of treatments on phytotoxicity ratings recorded at different days after spraying of tembotrione in maize

Treatments	Dose (g/ha)	TOA (DAS)	Phytotoxicity ratings (Days after spraying)					
			7		14		21	
			2014	2015	2014	2015	2014	2015
Tembotrione	110	14	0	0	0	0	0	0
Tembotrione	110	21	0	0	0	0	0	0
Tembotrione+S	110+1000	14	0	0	0	0	0	0
Tembotrione+S	110+1000	21	0	0	0	0	0	0
Tembotrione	120	14	0	0	0	0	0	0
Tembotrione	120	21	0	0	0	0	0	0
Tembotrione+S	120+1000	14	0	0	0	0	0	0
Tembotrione+S	120+1000	21	0	0	0	0	0	0
Tembotrione	130	14	0	0	0	0	0	0
Tembotrione	130	21	0	0	0	0	0	0
Tembotrione+S	130+1000	14	0	0	0	0	0	0
Tembotrione+S	130+1000	21	0	0	0	0	0	0
Farmer's practice	-	15 & 35	0	0	0	0	0	0
Atrazine	1500	Pre	0	0	0	0	0	0
Weed free	-	-	0	0	0	0	0	0
Weedy check	-	-	0	0	0	0	0	0

TOA: Time of application, DAS: Days after sowing

Table.3 Effect of treatments on dehydrogenase activity in soil

Treatment	**Dose (g/ha)**	**TOA (DAS)**	**Dehydrogenase activity (µg TPF/g/h)**											
			20 DAS		**40 DAS**		**60 DAS**		**80 DAS**		**100 DAS**		**At harvest**	
			2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
Tembotrione	110	14	2.65	2.70	2.57	2.59	2.47	2.51	3.15	3.18	3.27	3.32	3.17	3.21
Tembotrione	110	21	2.78	2.84	2.70	2.73	2.59	2.64	3.17	3.20	3.30	3.35	3.22	3.26
Tembotrione+S	110+1000	14	2.56	2.61	2.49	2.52	2.38	2.42	3.12	3.15	3.25	3.30	3.15	3.18
Tembotrione+S	110+1000	21	2.72	2.78	2.64	2.67	2.53	2.58	3.16	3.20	3.30	3.35	3.20	3.23
Tembotrione	120	14	2.53	2.58	2.46	2.49	2.36	2.40	3.11	3.14	3.24	3.29	3.14	3.17
Tembotrione	120	21	2.64	2.70	2.56	2.58	2.46	2.49	3.17	3.20	3.30	3.35	3.20	3.22
Tembotrione+S	120+1000	14	2.48	2.52	2.41	2.44	2.31	2.35	3.06	3.09	3.18	3.24	3.09	3.12
Tembotrione+S	120+1000	21	2.58	2.63	2.51	2.52	2.40	2.44	3.14	3.18	3.27	3.32	3.17	3.20
Tembotrione	130	14	2.41	2.46	2.34	2.37	2.24	2.29	3.00	3.04	3.12	3.18	3.03	3.06
Tembotrione	130	21	2.53	2.59	2.46	2.49	2.36	2.40	3.09	3.12	3.21	3.26	3.11	3.14
Tembotrione+S	130+1000	14	2.37	2.42	2.30	2.33	2.21	2.24	2.98	3.01	3.09	3.14	3.00	3.03
Tembotrione+S	130+1000	21	2.49	2.54	2.42	2.45	2.32	2.36	3.04	3.07	3.16	3.21	3.06	3.09
Farmer's practice	-	15 & 35	2.92	2.97	3.01	3.05	3.14	3.18	3.22	3.28	3.33	3.38	3.29	3.33
Atrazine	1500	Pre	2.53	2.57	2.46	2.49	2.35	2.39	3.10	3.13	3.22	3.27	3.12	3.14
Weed free	-	-	2.51	2.56	2.44	2.47	2.34	2.38	3.07	3.10	3.19	3.24	3.09	3.13
Weedy check	-	-	2.84	2.89	2.96	2.99	3.07	3.12	3.20	3.24	3.30	3.35	3.24	3.27
CD (P=0.05)	-	-	0.17	0.17	0.19	0.19	0.28	0.28	NS	NS	NS	NS	NS	NS

TOA: Time of application, DAS: Days after sowing

This might be due to high cost of cultivation and high cost of weed control under these treatments.

The data on effect of treatments on soil dehydrogenase activity have been embodied in table 3. The data depicted in table 3 showed that all the weed control treatments significantly influenced the dehydrogenase activity in soil up to 60 DAS during both the years.

The results of this experiment showed a decreased activity of dehydrogenase for applied herbicide concentrations at higher doses from 20 to 60 DAS. There was an increase in the enzyme activity from the 60th to the 100th day in all the treatments.

From the studies, it appears that the enzyme activity was reduced by the harmful activity of herbicides from 20 to 60 DAS. However, at later stages of the crop growth (60, 80 and 100 DAS), there was a drastic increase in the activity of dehydrogenase enzyme in the plots treated with tembotrione, atrazine and weed free. So, the harmful effect of these herbicides might have been reduced by microbial degradation at later stages of crop growth. Similar results were obtained by Shukla *et al.*, (1997).

The herbicide (tembotrione) used in the present investigation did not caused any phytotoxic effect on maize in terms of epinasty, hyponasty, necrotic symptoms, stunted growth and wilting at 7, 14 and 28 days after spraying because of the selective nature of the herbicide to maize (Table 2). The results are in conformity with Hatti *et al.*, (2014).

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