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RESEARCH PAPER

Effect of 2,4-D Sodium salt 80% WP on growth, productivity and nutrient uptake of *rabi* maize (*Zea mays*)

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Abstract A field investigation was conducted during *rabi* season of 2022 at Varanasi, Uttar Pradesh, to study the effect of 2,4-D Sodium salt 80% WP on growth, productivity and economics of *rabi* maize (*Zea mays* L.). At 60 DAS, 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS found higher plant height, number of leaves, chlorophyll content, leaf area index and plant dry matter over other treatments except weed free and two hand weeding at 20 and 40 DAS. 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS recorded more number of cobs, number of grains, number of grains/row, seed index in comparison to 2,4-D Sodium salt 80% WP 1000 g/ha and 2,4-D Sodium salt 80% WP 750 g/ha. 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS also improved grain and stover yields and higher harvest index with more monetary returns during the study.

Keywords: 2,4-D · Economics · Grain and stover yields · Nutrient uptake

Introduction

Maize is grown over more than193 million hectare of land in 170 countries with a production of 1147.7 million tones and on a larger range of soil, biodiversity, climates and under different management systems (Sanodiya, 2024) Maize has a greater importance in the United States economy with higher productivity (>10 t/ha) than the global average (5.57 t/ha). In India, however, maize productivity is just half (2.96 t/ha) than the average productivity of the rest of the world (Anonymous, 2022). After rice and wheat, maize is India's third most significant cereal crop. It can be produced in a variety of climates, ranging from extreme semi-arid to sub-humid and humid, which predominantly occupies 82% area under cultivation in *kharif* season and nearly 10% in *rabi* season. Broad leaved weeds cause harm to crops in many ways and this happens due to the unusual adaptation characteristics of the weeds and their regeneration ability. Therefore, weed management is the major and important part of crop production (Joshi *et al.*, 2018). At present we have many selective herbicides with different modes of action of weed control in maize. 2,4-D which kills broad leaved weeds after emergence by causing the cells in the tissues that carry water and nutrients to divide and grow without stopping. In view of this we conducted an experiment to find out the best dose of this herbicide for getting higher productivity, nutrient uptake and yields of rabi hybrid maize.

Materials and methods

A field experiment was conducted during *rabi* season of 2022 at AICRP Maize Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The soil was sandy clay loam, with pH 7.40, low in available organic carbon (0.41%), available nitrogen (207.47 kg/ha) and medium in available phosphorous (23.85 kg/ha) and potassium (219.60 kg/ha). The experiment was laid out in a randomized block design, comprising 7 treatments; weedy, two hand weeding at 20 and 40 DAS, Atrazine 50% WP

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1000 g /ha as PE, 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS, 2,4-D Sodium salt 80% WP 1000 g/ha, 2,4-D Sodium salt 80% WP 750 g/ha and weed free replicated thrice. Maize variety 'DHM - 121' was sown manually during the first week of December using the seed rate of 25 kg/ha and 60 × 20 cm row-row and plant-plant spacing. A recommended dose of fertilizer (150 kg N, 70 kg P_2O_5 and 60 kg K_2O) was applied through urea, single super phosphate and muriate of potash. Full dose of phosphorus and potassium were applied as basal application while nitrogen was applied half as basal and remaining half in two equal splits at first top dressing at knee high sand second top dressing at tasseling stages of maize. Application of post-emergence herbicide was done according to the treatments using knap-sack sprayer fitted with flat-fan nozzle using with 300 L water/ha. The crop was raised under irrigated condition recommended package of practices. Biometric characters viz. Growth attributes at 60 DAS and yield attributes and yields (grain and stover) and nutrient uptake of crop were recorded at harvest. Prevailing price of inputs in the market during 2022 were used to calculate the economics of integrated weed management treatments. The net return and benefit: cost ratio (BCR) were calculated by using gross returns (Rs/ha) and cost of cultivation (Rs/ha). The differences within the treatment means were examined by means of "Critical Difference" (CD). Visual phytotoxicity observed at 1, 2, 5, 7 and 10 days after herbicide application based on1-10 scale where 1 = 0-10%, 2 = 11-20%, 3 = 21-30%, 4 = 31-40%, 5 = 41-50%, 6 = 51-60%, 7 = 61-70%, 8 = 71-80%, 9 = 81-90% and 10 = 91-100% indicated that initially there were few phytotoxicity found in maize crop. The decreasing trends of phytotoxicity at various observations dates from 2 to 10 days from herbicide application revealed that with the advancement of the crop growth stages the visual symptoms of phytotoxicity disappear. 2,4-D Sodium salt 80% WP 2000 g/ha at 25 DAS showed higher phytotoxicity as compared to 2,4-D Sodium salt 80% WP 1250 g/ha (Table 1).

Table 1. Phytotoxicity evaluation of 2, 4- D in *rabi* maize at 1, 2, 5, 7 and 10 days after herbicide application

Treatment	Yellowing					Stunting					Necrosis					Epinasty				
	1	2	5	7	10	1	2	5	7	10	1	2	5	7	10	1	2	5	7	10
Weedy check	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
2,4-D Sodium salt 80% WP 1250 g/ha	4	4	3	3	3	0	0	0	0	0	6	5	4	3	3	1	2	2	1	1
2,4-D Sodium salt 80% WP 2000 g/ha	10	5	5	3	3	0	0	0	0	0	10	8	7	5	4	2	2	2	2	2

Scale 0–10 where: 0=0%, 1, 1–10%; 2, 11–20%; 3, 21–30%; 4, 31–40%; 5, 41–50%; 6, 51–60%; 7, 61–70%; 8, 71–80%; 9, 81–90%; 10, 91–100%

Result and discussion

At 60 DAS, numbers of leaves (10.6) were recorded higher in Atrazine 50% WP 1000 g/ha as PE in comparison 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS (10.3) and 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS (9.6) and all were found statistically similar to each other

(Table 2). Plant height followed the trend: Atrazine 50% WP 1000 g /ha as PE (24.2 cm) followed by 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS (23.4 cm) and both were found statistically similar to each other. Plant height was observed more in 2,4-D Sodium salt 80% WP1000 g/ha at 25 DAS (9.6 cm) followed by 2,4-D Sodium salt 80% WP750 g/ha at 25 DAS (8.3 cm) and both were recorded statistically at par to each other. Chlorophyll content was recorded higher in atrazine 50% WP 1000 g /ha (39.3) as PE in comparison of 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS (38.6). Leaf area index were found higher in 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS (0.40) as compared to 2,4-D Sodium salt 80% WP1000 g/ha at 25 DAS (0.38) and both were recorded statistically similar to each other. Dry weight was recorded more in 2,4-D Sodium salt 80% WP1250 g/ha at 25 DAS (5.2 g/plant) as compared to 2,4-D Sodium salt 80% WP1000 g/ha at 25 DAS (4.7 g/plant). This study was collaborated with Pasha *et al.* (2012).

NPK uptake by grains were recorded higher in hand weeding twice at 20 and 40 DAS (61.2, 18.3 and 16.4 kg/ha) in comparison of Atrazine 50% WP 1000 g /ha as PE (52.7, 15.3 and 13.7 kg/ha) followed by 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS (47.1, 13.9 and 12.4 kg/ha), 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS (40.8, 11.8 and 10.5 kg/ha) and 2,4-D Sodium salt 80% WP750 g/ha at 25 DAS (29.6, 8.6 and 7.2 kg/ha) (Table 2). Nitrogen and potassium uptake by stover were recorded higher in hand weeding twice at 20 and 40 DAS (27.8 and 84.6 kg/ha) in comparison of Atrazine 50% WP 1000 g /ha as PE (24.2 and 73.1 kg/ha). N and K uptake in 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS (22.1 and 68.3 kg/ha) were observed higher as compared to 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS (19.2 and 60.1 kg/ha) and both were recorded statistically at par to each other. Phosphorus uptake by stover was found higher in hand weeding twice at 20 and 40 DAS (13.3 kg/ha) as compared to Atrazine 50% WP 1000 g /ha as PE (11.1 kg/ha). Phosphorus uptake was recorded more in 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS (10.8 kg/ha) as compared to 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS (9.2 kg/ha). This might be due to higher grain yield in manual weeding plots and similar results were corroborated by Sinodiya *et al.* (2014).

Number of cobs per plant was found higher in 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS as compared

Table 2. Effect of herbicidal treatments on number of leaves/plant, plant height (cm), chlorophyll content, leaf area index, plant height (cm) at 60 DAS and nutrient uptake by grain and stover in *rabi* maize

Treatments	Numbers of leaves/ plant	Plant height (cm)	Chlorophyll content (SPAD value)	Leaf area index	Plant dry weight (g/plant)	Nutrients uptake by grains (kg/ha)			Nutrients uptake by stover (kg/ha)		
						N	P	K	N	P	K
Weedy check	7.6	21.6	32.9	0.33	3.4	17.6	4.9	3.9	9.9	4.1	32.0
Hand weeding twice at 20 and 40 DAS	11.0	25.2	40.3	0.42	5.4	61.2	18.3	16.4	27.8	13.3	84.6
Atrazine 50% WP 1000 g /ha as PE	10.6	24.2	39.3	0.41	5.2	52.7	15.3	13.7	24.2	11.1	73.1
2,4-D Sodium salt 80% WP 750 g/ha at 25 DAS	8.3	22.6	35.0	0.35	4.5	29.6	8.6	7.2	15.2	6.8	46.6
2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS	9.6	23.0	36.6	0.38	4.7	40.8	11.8	10.5	19.2	9.2	60.1
2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS	10.3	23.4	38.6	0.40	5.2	47.1	13.9	12.4	22.1	10.8	68.3
Weed free	13.3	25.5	43.0	0.43	5.7	74.1	22.0	19.7	32.2	16.1	97.9
SEm±	0.37	0.41	0.01	0.03	0.14	1.06	0.31	0.28	0.62	0.32	1.90
CD (P=0.05)	1.14	1.25	0.03	0.09	0.44	3.23	0.96	0.85	1.89	0.96	5.77

to 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS and both were observed statistically at par with each other. Number of grains rows per cobs was recorded higher in hand weeding twice at 20 and 40 DAS in comparison to Atrazine 50% WP 1000 g /ha as PE, 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS and 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS and all were found statistically similar to each other. 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS possessed more number of grain rows per cobs as compared to 2,4-D Sodium salt 80% WP 750 g/ha at 25 DAS and both were found statistically similar to each other. Number of grains per row was found higher in 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS in comparison to 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS and both were observed statistically similar with each other. Seed index was recorded higher in hand weeding twice at 20 and 40 DAS in comparison to Atrazine 50% WP 1000 g /ha as PE followed by 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS, 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS and all were found statistically at par to each other (Table 3). The similar findings were also reported by Sanodiya *et al.* (2013).

Higher grain and stover yields were obtained under hand weeding twice at 20 and 40 DAS (4.8 and 5.8 t/ha) followed by Atrazine 50% WP 1000 g /ha as PE (4.1 and 5.0 t/ha), 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS (3.7 and 4.7), 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS (3.3 and 4.1) and 2,4-D Sodium salt 80% WP750 g/ha at 25 DAS (2.4 and 3.2). Similar results were found by Mandi *et al.* (2019). The harvest index in different weed management system followed the trend : hand weeding twice at 20 and 40 DAS (45.5) *fb* Atrazine 50% WP 1000 g /ha as PE (45.2), 2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS (44.5), 2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS (44.1) and 2,4-D Sodium salt 80% WP 750 g/ha at 25 DAS (42.7) and all were found statistically similar to each other. This might be due to better growth parameters and better yield parameters i.e., number of cobs per plant, number of grain rows per cob, number of grains per row and seed index (Table 2 & 3).

Amongst the different weed management treatments higher gross (41.7 $\times 10^3$ Rs./ha) and net return (5.74 $\times 10^3$ Rs./ha) were obtained in hand weeding twice 20 and 40 DAS followed by Atrazine 50% WP 1000 g/ha as PE (12.6 and 7.43 $\times 10^3$ Rs./ha), 2,4-D Sodium salt 80% WP 1250

Table 3. Effect of herbicidal treatments on number of cobs, number of grains/row, seed index, grain and stover yields, harvest index, weed index and economics of *rabi* maize

Treatment	Cobs/ plant	Grain rows/ cob	Grains/ row	Seed index (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Gross return ($\times 10^3$ Rs/ha)	Net return ($\times 10^3$ Rs/ha)	Benefit : Cost
Weedy check	2.4	10.9	22.1	30.9	1.4	2.3	39.2	41.7	5.74	1.16
Hand weeding twice at 20 and 40 DAS	3.2	15.5	31.6	36.4	4.8	5.8	45.5	12.6	7.43	2.42
Atrazine 50% WP 1000 g /ha as PE	3.0	15.4	30.3	35.2	4.1	5.0	45.2	10.9	7.13	2.89
2,4-D Sodium salt 80% WP 750 g/ha at 25 DAS	2.4	13.7	25.9	33.6	2.4	3.2	42.7	65.0	2.77	1.74
2,4-D Sodium salt 80% WP 1000 g/ha at 25 DAS	2.7	14.7	28.4	34.7	3.3	4.1	44.1	87.5	5.01	2.34
2,4-D Sodium salt 80% WP 1250 g/ha at 25 DAS	2.9	15.2	29.3	34.9	3.7	4.7	44.5	99.9	6.25	2.67
Weed free	3.4	16.2	33.1	37.7	5.8	6.7	46.4	15.1	8.78	2.39
SEm±	0.06	0.29	0.65	0.36	0.83	1.30	0.98	-	-	-
CD (P=0.05)	0.20	0.90	1.98	1.11	2.54	3.94	2.99	-	-	-

g/ha at 25 DAS (99.9 and 6.25 $\times 10^3$ Rs./ha), 2,4-D Sodium salt 80% WP1000 g/ha at 25 DAS (87.5 and 5.01 $\times 10^3$ Rs./ha) and 2,4-D Sodium salt 80% WP750 g/ha at 25 DAS (65.0 and 2.77$\times 10^3$ Rs./ha). The maximum B-C ratio was possessed by Atrazine 50% WP 1000 g /ha as PE followed (2.89) by 2,4-D Sodium salt 80% WP1250 g/ha at 25 DAS (2.67), hand weeding twice at 20 and 40 DAS (2.42), 2,4-D Sodium salt 80% WP1000 g/ha at 25 DAS (2.34) and 2,4-D Sodium salt 80% WP750 g/ha at 25 DAS (1.74). The possible reason behind it that higher economic yield and lower cost of cultivation. Similar findings supported by Kumar *et al*. (2023).

Conclusion

Based on the present study it can be concluded that 2,4-D Sodium salt 80% WP 1250 g/ha 25 DAS was found effective in improving growth in *rabi* hybrid maize and recorded higher net return with B-C ratio of (2.67). Thus, for higher yield and nutrient uptake of *rabi* maize 2,4-D Sodium salt 80% WP 1250 g/ha 25 DAS can be suggested under Agro climatic condition of Varanasi, Uttar Pradesh.

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