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Effect of Ready Mix Application of Herbicide on Weed Dynamics and Productivity of Maize in Lateritic Belt of West Bengal

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ABSTRACT

Background: Maize, being highly productive and versatile cereal crop, is influenced by various biotic and abiotic stresses. Among biotic stresses, weed infestation is one of the serious concerns in maize cultivation. Weeds can affect maize by competing for light, water and nutrients resulting in yield loss of up to 70% in severe cases.

Methods: A field experiment was conducted during *kharif* season for two consecutive years of 2019 and 2020 in agriculture farm of Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, West Bengal, India. The experiment was laid out in randomized block design and replicated thrice. The experiment comprised of seven weed management treatments *viz*. T1 (tembotrione 9% + atrazine 45% WG @ 1000 g/ha), T2 (tembotrione 9% + atrazine 45% WG @ 1250 g/ha), T3 (tembotrione 9% + atrazine 45% WG @ 1500 g/ha), T4 (Tembotrione 34.4% SC @ 286 ml/ha), T5 (Atrazine 50% WP), T6 (Hand weeding), T7 (Weedy check).

Result: Experimental results revealed that among different herbicide mixtures, tembotrione + atrazine 1500 g/ha was found to be effective in suppressing the weeds growth and found no residual effect on soil chemical and biological properties during both the years of the experiment.

Key words: Atrazine, Maize, Tank mix, Tembotrione, Weed control efficiency, Yield.

INTRODUCTION

Rising temperatures, changing precipitation patterns, increased frequency and intensity of extreme weather events and altered pest and disease dynamics are some of the key challenges faced due to climate change (Gaikwad *et al*., 2022). Maize (*Zea mays* L.) can adapt different climatic conditions under various agroclimatic situations (Erenstein *et al*., 2022). Maize utilizes a highly efficient photosynthetic pathway called C4photosynthesis (Zheng *et al*., 2023). This mechanism enables maize plant to synthesis huge biomass resulting in higher yield potential. Thus, maize cultivation is gaining popularity throughout the world. Globally, maize yields around 987 million metric tons from an area of 182 million hectares (FAOSTAT, 2021). Whereas, in India 31.65 million tons of production is obtained from an area of 9.86 million hectares with an average productivity of 3.21 t/ha (Agriculture Statistics at a Glance, 2022). It plays a crucial role in global food security. Maize is the third major food grain crop grown globally, after wheat and rice (Singh *et al*., 2021). Maize is not only consumed as a food crop but also used for various purposes such as animal feed, biofuels and the production of starch and other derivatives. These versatile uses and market demand of maize crop is encouraging the crop growers to cultivate maize in recent decades (Maitra *et al*., 2019). To meet the demand and to increase the productivity of maize, proper agronomic practices along with providing the crop with stress free environment are essential.

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Among different biotic stresses caused in maize, weed infestation is one of the serious concerns during critical growth stages of the crop. Weeds compete with the crop for space, light, nutrition and soil moisture. Weeds also introduce pathogenic fungus, bacteria and viruses in maize and acts as a host for various insect pests. Depending on the intensity of weed occurrence and key period of weed infestation the yield loss in maize may differ and was reported to be 68.11% (Bada *et al*., 2022, Sharma and Rayamajhi, 2022). Effective weed management is important in maize cultivation to minimize weed competition, maximize crop yield and ensure efficient use of resources (Duary, 2008).

The variation in critical period of crop weed competition is reported to be ranges in between two and six weeks after maize sowing but most critical is found in between 4-7 weeks after sowing.

In the current scenario of labour scarcity, human input has become the costliest in agriculture sector. Further, manual weeding is not effective for controlling weeds in maize. There is very limited scope for mechanical weed management. Under these circumstances, chemical method of weed management is cheaper and effective way for controlling weeds in maize. Introduction of crop selective herbicides are found to be most effective, without harming crop (Zahan *et al*., 2021; Hetta *et al*., 2022). Single use of herbicide often results in development of herbicide resistant weeds and change in weed flora in long terms (Singh and Longkumer, 2021). Therefore, application of one or more herbicides as pre-emergence or post emergence or combination of both, will help to control divergent weed flora like sedges, grasses and broad leaf weeds in maize without causing long term adverse effects. Sole application of atrazine which is a widely used herbicide does not provide effective control of weeds (Upasani *et al*., 2017). Mixing of herbicides for better control of weeds is emerging to tackle the sturdy weed population. Tembotrione is a selective post emergence herbicide which has been found to be effective when used along with atrazine. But it is essential to study the efficacy of tembotrione in different doses against different weed species in maize either alone or in combination with atrazine. Considering the above facts, the experiment was carried out to find the optimum doses and efficacy of individual and combined effect of atrazine and tembotrione in comparison to hand weeding under red and lateritic belt of West Bengal.

MATERIALS AND METHODS

The field experiment was conducted during the consecutive *kharif* seasons of 2019 and 2020 in agriculture farm of Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, West Bengal, India (23.39°N latitude and 87.42°E longitude). The rainfall during the experimental period (August to November) was 343.6 and 421.8 mm in 2019 and 2020, respectively. The maximum temperature varied from 30.23°C-33.93°C and 28.99°C-33.58°C during both the years, respectively. The mean minimum temperature for two years ranged from 14.49°C-26.76°C and 10.69°C-26.57°C respectively. The mean maximum and minimum relative humidity during the experimentation period ranged from 72.38%-84.67% and 69.46%-84.8% for 2019 and 80.87%-86.93% and 76.94%-84.73% during 2020, respectively. The mean bright sun shine hours recorded/day was between 2.84-7.68 hrs/day and 3.99-7.02 hrs/day for both the years respectively. The soil of the experimental field was sandy loam in texture with soil pH of 5.6 and medium fertility status with low water holding capacity. Maize crop was grown under irrigated condition.

The experiment was laid out in randomised block design and replicated thrice. The treatment comprised of seven weed management treatments *viz* tembotrione + atrazine 1000 g/ha, tembotrione + atrazine 1250 g/ha, tembotrione + atrazine 1500 g/ha, tembotrione 130 g/ha, atrazine 750 g/ha, Hand weeding at 15 DAS and 30 DAS and Weedy Check Maize cultivar '*VBL-55'* was sown at spacing of 60 cm × 25 cm. The crop was fertilized with 150:75:75 kg of N:P_2O_5:K_2O/ha. Full doses of phosphorus and potassium along with half of nitrogen were applied as basal dose at the time of sowing. Remaining half quantity of nitrogen was applied in two equal splits - at knee high stage and pre tasseling stage. All the herbicides were sprayed by knapsack sprayer fitted with flat fan T-jet nozzle using a spray volume of 500 l/ha. T1, T2, T3 and T4 was applied at 18 DAS and T5 was applied at 2 DAS. Weedy check plots remained infested with native population of weeds till harvest.

Data on weed density were recorded from an area enclosed in the quadrant of 0.125 m2 randomly selected at four places in each plot. Weeds were first sun dried for 2-3 days and then oven dried at 70°C till the constant weight was recorded. The weed dry matter obtained was expressed in gram per square meter (g/m^2). Data on weed density and weed dry weight thus obtained were subjected to square root transformation (√+0.5) as wide variations were found. The data obtained on various parameters were tabulated and subjected to analysis of variance techniques as described by Cochran and Cox (1963).

RESULTS AND DISCUSSSION

Weed density and weed dry matter

Data pertaining to weed density and weed dry matter is presented in Table 1 and 2. The maize crop was severely infested with weeds *viz*. *Echinocloa colona*, *Brachiaria ramose, Digitaria sanguinalis, Trianthema portulacastrum, Cleome viscosa, Amaranthus viridis, Cyperus iria.* At 30 DAS, atrazine 2000 g/ha recorded significantly lowest weed density and weed dry matter of dicot as well as monocot weeds, which was statistically at par with tembotrione + atrazine 1500 g/ha. Similar results were also found by Kaur *et al*. (2019). However, at 45 DAS, tembotrione + atrazine 1500 g/ha recorded significantly lowest weed density and weed dry matter accumulation of dicot weeds as well as monocot weeds which was found to be at par with tembotrione + atrazine 1250 g/ha, tembotrione + atrazine 1000 g/ha tembotrione 286 g/ha and atrazine 2000 g/ha. This might have happened probably due to the mode of action of the ready mixture containing tembotrione and atrazine by inhibiting the activity of 4-HPPD enzyme. This enzyme is responsible for the carotenoid formation, which disrupt chlorophyll synthesis as well as photosynthesis and ultimately resulting in mortality of weeds. By controlling weeds population, it helped to minimized the weed competition and increased the nutrient uptake by the maize (Sharma *et al*., 2018; Singh *et al*., 2012; Williams *et al*., 2011).

Table 1: Weed density of monocot dicot and sedges at 30 DAS, 45 DAS and 60 DAS (two years average).

Treatment	Monocot			Dicot			Sedges		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1	3.69 (13.11)	4.58 (20.45)	5.49 (29.67)	4.42 (19.03)	5.24 (27.00)	5.90 (34.32)	2.07 (6.34)	2.77 (7.17)	3.30 (10.44)
T_2	3.58 (12.30)	4.39 (18.83)	5.29 (27.48)	4.00 (15.52)	4.88 (23.31)	5.62 (31.14)	2.01 (5.17)	2.73 (6.95)	3.23 (9.92)
T_3	3.47 (11.52)	4.25 (17.57)	5.10 (25.54)	3.70 (13.24)	4.59 (20.60)	5.29 (27.58)	1.87 (4.41)	2.56 (6.06)	3.13 (9.32)
T_4	3.70 (13.22)	4.69 (21.53)	5.64 (31.33)	4.50 (19.73)	5.39 (28.60)	6.13 (37.11)	2.13 (6.58)	2.84 (7.57)	3.34 (10.67)
T_5	3.40 (11.07)	4.73 (21.87)	5.63 (31.20)	4.42 (19.03)	5.38 (28.44)	5.93 (34.70)	2.15 (6.34)	2.87 (7.74)	3.36 (10.78)
T_6	2.83 (7.53)	2.23 (4.47)	2.77 (7.20)	2.73 (7.00)	2.13 (4.07)	2.97 (8.34)	1.41 (2.33)	1.57 (1.96)	1.81 (2.79)
T_7	6.59 (42.93)	8.39 (69.92)	9.58 (91.31)	7.29 (52.71)	8.67 (74.74)	9.72 (93.94)	4.03 (17.50)	5.10 (25.54)	5.51 (29.91)
SEm (+)	0.062	0.115	0.082	0.081	0.103	0.115	0.024	0.053	0.047
LSD	0.190	0.353	0.251	0.250	0.316	0.353	0.075	0.165	0.145

Figures in parentheses are the original values. The data was transformed to √0.5+x before analysis.

Table 2: Weed dry matter of monocot dicot and sedges at 30 DAS, 45 DAS and 60 DAS (two years average).

Treatment	Monocot			Dicot			Sedges		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1	2.41 (5.32)	2.90 (7.93)	3.27 (10.20)	2.25 (4.56)	2.72 (6.91)	3.16 (9.50)	1.59 (2.05)	1.85 (2.92)	2.01 (3.53)
T_2	2.30 (4.80)	2.82 (7.46)	3.20 (9.77)	2.16 (4.19)	2.64 (6.47)	3.08 (8.99)	1.55 (1.91)	1.80 (2.76)	1.96 (3.33)
T_3	2.18 (4.24)	2.73 (6.93)	3.12 (9.23)	2.06 (3.76)	2.56 (6.08)	3.02 (8.61)	1.49 (1.73)	1.75 (2.59)	1.92 (3.18)
T_4	2.63 (6.44)	3.06 (8.88)	3.52 (11.89)	2.41 (5.30)	2.76 (7.12)	3.22 (9.88)	1.65 (2.23)	1.90 (3.10)	2.13 (4.03)
T_5	2.63 (6.40)	3.05 (8.81)	3.47 (11.55)	2.34 (4.98)	2.74 (7.03)	3.21 (9.79)	1.62 (2.13)	1.89 (3.06)	2.12 (4.00)
T_6	1.98 (3.42)	1.54 (1.87)	2.12 (4.01)	1.62 (2.14)	1.46 (1.66)	1.86 (2.97)	1.08 (0.68)	0.93 (0.37)	1.18 (0.90)
T_7	5.97 (35.13)	6.86 (46.66)	7.52 (56.05)	5.54 (30.18)	6.41 (40.69)	7.25 (52.05)	3.55 (12.14)	4.09 (16.27)	4.46 (19.38)
SEm (+)	0.054	0.087	0.052	0.044	0.033	0.048	0.054	0.061	0.055
LSD	0.165	0.267	0.159	0.137	0.101	0.146	0.165	0.187	0.171

Figures in parentheses are the original values. The data was transformed to √0.5+x before analysis.

However, with regard to sedges, hand weeding recorded significantly lowest density and dry matter accumulation of density and dry matter accumulation of *Cyperus iria*. Among the herbicide treatments, tembotrione + atrazine 1500 g/ha was found the best in treatment at initial stage. But at later stages, the increase in doses of tembotrione + atrazine did not affect the weed density and weed dry matter accumulation significantly and were at par with atrazine 2000 g/ha and tembotrione 286 ml/ha applied alone.

Relative weed density

Relative weed density of monocots, dicot and sedges were affected by various weed management methods (Table 3). Generally, dicots recorded highest relative density (RD) among other weeds in both the years. Dicots recorded the highest RD for all the weed management practices (30-52%) followed by monocot (30-45%) and sedges (13-19%). Relative weed densities of monocots were lower than the dicot and sedges had the lowest relative weed density. Only in T5, monocot RD exceeded 50% at 30 DAS. RD of monocots increased with increase in days after sowing, whereas dicot RD reduced to some extent. The herbicide combination of atrazine and tembotrione are effective in controlling the sedges most effectively followed by monocots and dicots. The results corroborate with findings of Gharsiram *et al*. (2022).

Weed control efficiency

Weed control efficiency (WCE) at 30, 45 and 60 DAS recorded significant impact on different weed management practices (Table 4). Hand weeding (T6) recorded significantly highest weed control efficiency at 30, 45 and 60 DAS which might be due to weed free environment at the critical growth stages of maize, whereas among the herbicidal treatments, maximum weed control efficiency at all the stages for monocot, dicot and sedges was observed with tembotrione + atrazine 1500 g/ha followed by tembotrione + atrazine 1250 g/ha (T2). The lower dose of tembotrione + atrazine 1000 g/ha were found relatively less effective compared to tembotrione + atrazine 1500g/ha and tembotrione + atrazine 1250 g/ha but significantly better than tembotrione 286 ml/ha, atrazine 2000 g/ha and weedy check. Such results recorded might be due to the fact that the herbicide tembotrione and atrazine ready mixture effectively controlled the weeds, minimized the weed competition and thereby increased the nutrient uptake by the plants and less dry matter accumulation in weeds (Sharma *et al*., 2018; Chhokar *et al*., 2020).

Yield

All the weed control treatments resulted in significant increase in maize yield compared to weedy check during both the years (Table 5). Among the herbicidal treatments, tembotrione + atrazine 1500 g/ha recorded significantly higher yield (44.68 and 44.13 q/ha) among the herbicidal treatments. Increase in yield in might be attributed due to effective weeds control. The lowest yield (26.55 and 24.20 q/ha) was obtained in the weedy check control treatment. A similar trend was observed for stover yield and biological yield of maize with respect to weed management practices. Grain yield enhancement percentage over weedy check was

Table 3: Relative weed density of monocot, dicot and sedges at 30 DAS, 45 DAS and 60 DAS (two years average).

Treatment	Monocot			Dicot			Sedges		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1	34.1	37.4	39.9	49.5	49.4	46.1	16.5	13.1	14.0
T_2	37.3	38.4	40.1	47.0	47.5	45.4	15.7	14.2	14.5
T_3	39.5	39.7	40.9	45.4	46.6	44.2	15.1	13.7	14.9
T_4	33.4	37.3	39.6	49.9	49.6	46.9	16.6	13.1	13.5
T_5	30.4	37.7	40.7	52.2	49.0	45.3	17.4	13.3	14.1
T_6	44.7	42.6	39.3	41.5	38.8	45.5	13.8	18.7	15.2
T_7	37.9	41.1	42.4	46.6	43.9	43.7	15.5	15.0	13.9

Table 4: Weed control efficiency of monocot dicot and sedges at 30 DAS, 45 DAS and 60 DAS (two years average).

Treatment	Monocot			Dicot			Sedges		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1	84.95	83.06	81.83	84.72	82.98	81.67	27.67	82.07	27.24
T_2	86.42	84.07	82.61	85.97	84.07	82.70	28.09	83.08	27.54
T_3	88.03	85.16	83.60	87.41	85.05	83.42	28.59	84.12	27.83
T_4	81.65	80.81	78.79	83.91	82.42	80.97	27.21	80.96	26.40
T_5	81.87	80.98	79.39	82.77	82.59	81.15	27.35	81.22	26.48
T_6	88.75	96.02	92.85	93.01	96.03	94.29	31.48	97.73	31.74
T_7	84.95	83.06	81.83	84.72	82.98	81.67	27.67	82.07	27.24
SEm (+)	0.054	0.087	0.052	0.044	0.033	0.048	0.054	0.061	0.055
LSD	0.165	0.267	0.159	0.137	0.101	0.146	0.165	0.187	0.171

also found highest in tembotrione 1500 g/ha and lowest for weed control through atrazine 2000 g/ha spray. Further, the results corroborate with findings of Chhokar *et al*. (2020), Sharma *et al*. (2018) and Kumar *et al*., (2017), Raghuwanshi *et al.,* (2023).

Soil chemical properties

Soil pH, soil EC, organic carbon, available nitrogen, available phosphorus and available potassium at crop harvest did not vary significantly and was comparable from initial values when tembotrione + atrazine 1500, 1250 and 1000 g/ha and other treatments were applied in the maize (Table 6). The results revealed that there was non-significant influence of herbicides on nutrient availability of the post-harvest soils. Omar *et al*. (2020) also reported non-significant difference in the soil chemical properties might be due to the fact that the experiment was carried only for two seasons which did not show the residual effect of herbicides.

Table 5: Yield of maize as influenced by weed management practices (two years average).

Treatment	Yield (quintal/ha)			Percentage increase in yield above control (%)
	Grain yield	Stover yield	Biological yield	
T_1	40.11	45.26	85.36	58.2
T_2	43.18	46.58	89.76	70.4
T_3	44.41	47.18	91.59	75.3
T_4	41.03	45.78	86.80	61.7
T_5	37.39	45.81	83.19	47.4
T_6	47.66	52.36	100.02	88.1
T_7	25.39	28.00	53.39	0
SEm (+)	1.2	0.7	NA	NA
LSD	3.624	2.204		

Table 6: Chemical properties of experimental soil at crop harvest (average of two years).

Treatments	pH		EC (ds/m)		OC (%)		Available N (kg/ha)		Available P_2O_5 (kg/ha)		Available K_2O (kg/ha)	
	BS	AH	BS	AH	BS	AH	BS	AH	BS	AH	BS	AH
T_1	5.6	5.6	0.16	0.15	0.35	0.32	253.3	249.8	22.1	22.1	113.6	112.8
T_2	5.6	5.7	0.14	0.17	0.32	0.34	253.1	252.0	21.4	23.7	113.0	113.6
T_3	5.6	5.7	0.15	0.16	0.34	0.33	252.2	254.2	23.0	22.4	113.3	113.0
T_4	5.7	5.6	0.16	0.16	0.34	0.34	251.6	248.2	23.7	22.8	113.7	113.0
T_5	5.7	5.6	0.14	0.15	0.33	0.32	254.3	247.5	22.1	23.1	110.7	113.7
T_6	5.6	5.7	0.14	0.14	0.32	0.34	253.5	248.3	22.6	22.6	112.7	113.8
T_7	5.6	5.5	0.15	0.17	0.34	0.34	253.1	250.5	22.9	22.1	113.4	115.4
SEM (+)	0.06	0.08	0.04	0.04	0.05	0.05	2.43	3.13	1.06	0.96	2.08	2.65
LSD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

BS: Before sowing; AH: After harvesting; OC: Organic carbon.

Table 7: Microbial population of experimental soil before crop sowing and at crop harvest (average of two years).

Treatments	Total Bacteria (CFU 1 × 10^6/g soil)		Fungi (CFU 1 × 10^4/g soil)		Actinomycetes (CFU 1 × 10^5/g soil)	
	BS	AH	BS	AH	BS	AH
T_1	3.48	7.94	1.26	3.30	1.98	5.46
T_2	3.70	6.80	1.23	2.75	1.85	5.46
T_3	3.43	5.45	1.24	2.57	1.95	3.39
T_4	3.58	6.76	1.39	3.78	1.68	5.40
T_5	3.44	6.55	1.44	3.53	1.81	3.52
T_6	3.56	8.40	1.42	3.94	1.93	5.56
T_7	3.47	8.35	1.46	3.96	1.94	5.68
SEM (+)	0.60	1.73	0.24	1.39	0.24	0.81
LSD	NS	NS	NS	NS	NS	NS

BS: Before sowing; AH: After harvesting; CFU: Colony forming units.

Soil microbial properties

The impact of the testing herbicide, tembotrione + atrazine 1500, 1250, 1000 g/ha and other treatments on soil microflora - total bacteria, fungi and Actinomycetes as recorded before crop sowing and after harvest of the crop did not vary among themselves (Table 7). After application of different doses of the herbicide tembotrione + atrazine there were non-significant variations in bacterial population (*Pseudomonas fluorescens, Bacillus* spp.) between the treated and non-treated plots at crop harvest and found similar colony formation unit (CFU) in weed check, hand weeding and herbicide treatments. The population were recorded higher than initial values before crop sowing. Similar findings were observed for both fungi and actinomycetes. The result clearly showed that there was no toxicity of herbicides sprayed separately or in combination in maize fields. Sripriya *et al*. (2022) also reported that application of tembotrione alone at lower doses did not affect the microbial population in the experimental soils.

CONCLUSION

Different weed management practices found a significant influence on weed dynamics and yield of maize. Though the hand weeding performed well in terms of less weed density and dry matter, it was not cost effective. In this regards, the experiment concludes that application of tembotrione + atrazine 1500 g/ha has been found to be best pre-mix herbicide for efficient control of mixed flora of weeds and realizing higher productivity of maize farmers for the red and lateritic belt of West Bengal.

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