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Tank mix formulation of atrazine and new generation herbicides against complex weed flora of maize (*Zea mays* L.)

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Abstract
A field experiment was conducted on clay loam soil during *kharif*, 2017 at Instructional Agronomy Farm, Rajasthan College of Agriculture, Udaipur to find out the Eeffect of tank mix formulation of atrazine and new generation herbicide against complex weed flora of maize (*Zea mays* L.).
The results of the experiment revealed that the lowest total weed density at 30 DAS was recorded with tank mix application of atrazine0.5 kg/ha+ tembotrione0.125 kg/haPoE at 15 DAS. All the weed control treatments were also found significantly superior in reducing dry matter of monocot, dicot and total weeds compared to weedy check at 30 DAS. The minimum total weed dry matter at this stages (2.85, g/m^2) were observed underatrazine0.5 kg/ha +tembotrione0.125 kg/haPoE at 15 DAS and it was closely followed by atrazine 0.5 kg/ha + topramezone 0.025 kg/haPoE at 15 DAS (3.89, g/m^2). An application of atrazine0.5 kg/ha + tembotrione0.125 kg/haPoE at 15 DAS resulted in maximum weed control efficiency of 96. 99% at 30 DAS. The application of atrazine 0.5 kg/ha +tembotrione0.125 kg/ha as PoE at 15 DAS recorded the tallest plants (47.0 cm) with greatest dry matter accumulation per plant (18.04g) at 30 DAS. The maximum gross and net return (₹98635/ha and ₹71009/ha and benefit cost ratio (2.57) were also obtained under application of atrazine 0.5 kg/ha+ tembotrione 0.125 kg/haPoE at 15 DAS, leading all other treatments significantly behind.

Keywords: Weed dynamics, mixtures, atrazine, tembotrione, post-emergence, maize, net return

Introduction
Maize (*Zea mays* L.) is the third most important cereal in the world; it is one of the most versatile crops having wider adaptability under varied agro-climatic conditions. It is also known as "Queen of Cereals". Maize in India, contribute nearly 9% in the national food basket and more than `100 billion to the agricultural GDP at current price, cultivated on 9.25 m ha area with production of 23.67 m t at a productivity of 2.53 t/ha.In Rajasthan, this crop occupied 0.90 m ha area with production of 1.60 m t and productivity of 1.70 t/ha (Agricultural Statistics at a Glance, 2016) [1]. Bieng rainy season crop, it has high yielding crop but weed infestation is one of the major constraints in cultivation of maize. Maize is infested by a wide range of weed flora; *Commelina benghalensis, Echinochloa colona, Trianthema portulacastrum, Dinebra retroflexa, Amaranthus viridis and Digera arvensis* dominate during the crop growth period. The most critical period for crop-weed competition is first six weeks after planting of crop which may reduce yield by 28-100% (Dass *et al*., 2012).During this period, weeding is essentially required physical and mechanical means are expensive and many times timely operations are not possible due to continuous rains in monsoon season (Chopra and Angiras, 2008) [3].

Materials and Methods
The experiment was carriedout at research farm ofRaasthan college of Agriculture,Udaipur (24°35' N latitude and 73°42' E longitude.an altitude of 582.5 meter above mean sea level).The soil of experimental had low in nitrogen, medium in phosphorus, high in potassium and slightly alkaline and calcarious in nature. The soil of the experimental field was clay loam in texture.The experiment was laid out in randomized block design with 13 treatmentcombination tested were asfollows weedy check, atrazine 0.5 kg/ha at 10 DAS atrazine 0.5 kg/ha at 15 DAS, atrazine 0.5 kg/ha at 20 DAS, atrazine0.5 kg/ha + halosulfuron

0.09, kg/ha at 10 DAS, atrazine0.5 kg/ha + halosulfuron0.09 kg/ha at 15 DAS, atrazine0.5 kg/ha + halosulfuron0.09 kg/ha at 20 DAS, atrazine0.5 kg/ha + tembotrione0.125 kg/ha at 10 DAS, atrazine0.5 kg/ha + tembotrione0.125 kg/ha at 15 DAS, atrazine0.5 kg/ha + tembotrione0.125 kg/ha at 20 DAS, atrazine0.5 kg/ha + topramezone 0.118 kg/ha at 10 DAS, atrazine0.5 kg/ha + topramezone 0.118 kg/ha at 15 DAS and atrazine0.5 kg/ha + topramezone 0.118 kg/ha at 20 DAS. The result were analyzed taking consideration of wed parameters such as as weed density, weed dry matter, weed control effiencieсy and plant parameter such as plant population, plant dry matter, plant height, harvest index and economics like as gross return, net return and B:C ratio.

Weed control efficiency was calculated at 30 DAS using the following formula (Mani *et al*., 1968) [6].

The harvest index of both crops were calculated by dividing the economic yield (grain yield) by biological yield and expressed as percentage (Donald and Hamblin, 1976) [5].

Results and Discussion

Effect on weeds

The data reflected that proportion of density of monocot to dicot weeds in weedy check plots at 30 DAS 1:0.31. Likewise the dry matter record in corresponding plots revealed that the monocot versus dicot weed proportion was 1:0.32 at 30 DAS. The magnitude of existence of monocot and dicot weeds indicated that the crop suffered stress from a mixed flora of weeds.

The results (Table 3). indicated that all herbicide treatments either alone or tank mix application caused marked reduction in weed density and dry matter of monocot, dicot and total weeds at 30 DAS. However, the trend of effects of weed control treatments was not similar for monocot and dicot weeds. Among weed control treatments, minimum weed density, weed dry matter of monocots, dicots and total weeds was observed under atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 15 DAS. *Commelina benghalensis, Echinochloa colona, Trianthema portulacastrum, Dinebra retroflexa, Amaranthus viridis and Digera arvensis* were effectively controlled by post-emergence tank mix application of atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 15 DAS. The results corroborate the findings of Stanzen *et al.* (2016) [12] and Rana *et al.* (2017) [8]. The greatest weed control efficiency of monocots, dicots and total weeds (96.89, 97.32 and 96.99% resectively) was acquired by mixture of atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 15 DAS.

Effect on crop

Plant population of maize was not significantly affected by weed control treatments. It was clear from data in (Table 2) that combination of herbicide and herbicide alone have no significant influence on plant population at 30 DAS.The post-emergence application of atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 15 DAS recorded the highest plant height at 30 DAS (47.0 cm) which was higher torest of the treatments. Compared to weedy check,this weed control treatments resulted in 39.3% increase in plant height. The maximum dry matter was accumulated by plants when weeds were controlled by atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 15 DAS (18.04 g/plant). However, the statistical analysis revealed that it was at par with atrazine0.5 kg/ha + topramezone 0.118 kg/ha at 15 DAS (17.83 g/plant), atrazine0.5 kg/ha + topramezone 0.118 kg/ha at 20 DAS (17.05 g/plant), atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 20 DAS (17.00 g/plant), atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 10 DAS (16.53 g/plant) and atrazine0.5 kg/ha + topramezone 0.118 kg/ha at 10 DAS (16.33 g/plant). The resultalso have been reportedby Singh *et. al.* (2012) [4], Rao *et al.* (2009) [9], Nazreen and Subramanyam (2017) [7].

Table 2: Effect of herbicides on weed dry matter in Maize at 30 DAS

Treatment	Weed dry matter (g/m^2)					
	Echinochloa colona	***Dinebra retroflexa***	***Digera arvensis***	***Commelina benghalensis***	***Trianthema Portulacastrum***	***Amaranthus Viridis***
Weedy check	47.73	16.26	14.48	8.11	4.70	3.71
Atrazine0.5 kg ha^{-1} at 10 DAS	3.83	4.72	1.09	3.42	1.33	0.97
Atrazine0.5 kg ha^{-1} at 15 DAS	5.38	6.95	1.81	4.19	1.56	1.68
Atrazine0.5 kg ha^{-1} at 20DAS	6.29	7.21	3.75	4.84	1.64	2.47
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 10 DAS	3.11	4.46	0.85	2.89	0.89	1.55
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 15 DAS	3.86	3.93	1.54	3.42	1.58	1.84
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 20 DAS	7.03	6.15	2.27	4.07	1.87	2.15
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 10 DAS	1.22	1.06	0.00	1.76	1.49	0.97
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 15 DAS	0.80	0.70	0.00	0.75	0.44	0.18
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 20 DAS	0.84	0.93	0.57	0.96	0.90	0.77
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 10 DAS	1.22	1.06	0.20	1.81	1.34	0.86
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 15 DAS	0.81	0.72	0.35	0.84	0.84	0.33
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 20DAS	1.15	1.05	0.55	1.51	1.14	1.02
SEm ±	0.52	0.14	0.13	0.15	0.04	0.10
LSD(P=0.05)	1.51	0.40	0.37	0.43	0.13	0.29

Table 3: Effect of treatments on weed density (No./m^2), weed dry matter (g/m^2) and weed control efficiency (%) at 30 DAS in maize

Treatments	Weed density*			weed dry matter			weed control efficiency		
	Monocot weeds	Dicot weeds	Total weeds	Monocot weeds	Dicot weeds	Total weeds	Monocot weeds	Dicot weeds	Total weeds
Weedy check	11.75 (137.50)	6.67 (43.95)	13.49 (181.45)	72.11	22.90	95.01	0.00	0.00	0.00
Atrazine0.5 kg ha^{-1} at 10 DAS	4.83 (22.80)	2.63 (6.43)	5.45 (29.23)	11.97	3.39	15.35	83.40	85.20	83.85
Atrazine0.5 kg ha^{-1} at 15 DAS	5.66 (31.50)	3.19 (9.65)	6.45 (41.15)	16.52	5.05	21.57	77.08	77.94	77.29
Atrazine0.5 kg ha^{-1} at 20DAS	5.96 (35.00)	3.94 (15.00)	7.11 (50.00)	18.34	7.85	26.20	74.56	65.71	72.43

Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 10 DAS	4.52 (19.93)	2.61 (6.30)	5.17 (26.22)	10.45	3.29	13.74	85.47	85.65	85.52
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 15 DAS	4.67 (21.35)	3.14 (9.39)	5.59 (30.74)	11.21	4.96	16.17	84.44	78.34	82.97
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 20 DAS	5.78 (32.88)	3.53 (12.00)	6.74 (44.87)	17.24	6.29	23.54	76.05	72.51	75.22
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 10 DAS	2.87 (7.71)	2.28 (4.72)	3.59 (12.43)	4.04	2.46	6.50	94.39	89.26	93.16
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 15 DAS	2.18 (4.27)	1.29 (1.17)	2.44 (5.44)	2.24	0.62	2.85	96.89	97.32	96.99
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 20 DAS	2.39 (5.21)	2.18 (4.27)	3.16 (9.47)	2.73	2.24	4.97	96.21	90.20	94.76
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 10 DAS	2.88 (7.82)	2.25 (4.59)	3.59 (12.40)	4.10	2.40	6.49	94.31	89.51	93.17
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 15 DAS	2.24 (4.53)	1.83 (2.92)	2.81 (7.44)	2.37	1.52	3.89	96.71	93.38	95.90
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 20DAS	2.75 (7.08)	2.39 (5.20)	3.57 (12.28)	3.71	2.71	6.42	94.85	88.15	93.23
SEm ±	0.05	0.07	0.06	0.51	0.16	0.50	NA	NA	NA
LSD(P=0.05)	0.16	0.20	0.18	1.50	0.47	1.47			

(*$\sqrt{x+0.5}$ Transformed values and Data in parenthesis are original values);NA: Not analysed

Ecnomics

Compared to weedy check, all the weed management treatments resulted in significantly higher gross andnet returns from the maize crop. However, the magnitude increase in net returns varied. The maximum net return (₹71009/ha) were realised by applying atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 15 DAS, which was 243.2% higher over weedy check. Net returns obtain through this treatments were higher over rest of the treatments which was at par with atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 20 DAS (₹66433/ha), atrazine0.5 kg/ha + topramezone 0.118 kg/ha at 10 DAS (₹ 65026/ha), atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 10 DAS (₹64813/ha), at 15 DAS (₹61710/ha) and 20 DAS (₹ 60938/ha). The data revealed that all the herbicides applied either singly or as mixtures resulted in significantly high net returns over weedy check. Further, these herbicide mixtures applications gave significantly higher net returns over other applied herbicides.

The economic analysis of treatments in term of B C ratio revealed that all the weed control treatments tended to surpass weedy check. Alike net returns, the highest B C ratio (2.57) was obtained by controlling the weeds through atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 15 DAS. However, the B C ratio obtained through atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 20 DAS (2.40), atrazine0.5 kg/ha + topramezone 0.118 kg/ha at 10 DAS (2.35), atrazine 0.5 kg/ha + tembotrione0.125 kg/ha at 10 DAS (2.35) were at par. The weedy check lagged behind rest all the herbicidal weed control treatments. This is in accordance with findings of Sivamurugan *et al*. (2017) [11] and Akhtar *et al.* (2017) [2].

Table 1: Effect of herbicides on weed density in Maize at 30 DAS

Treatment	Weed density (No./m^2)					
	Echinochloa colona	***Dinebra retroflexa***	***Digera Arvensis***	***Commelina benghalensis***	***Trianthema Portulacastrum***	***Amaranthus Viridis***
Weedy check	9.56 (91.00)	5.61 (31.00)	5.33 (27.88)	4.00 (15.50)	3.07 (8.93)	2.77 (7.15)
Atrazine0.5 kg ha^{-1} at 10 DAS	2.79 (7.30)	3.08 (9.00)	1.60 (2.06)	2.64 (6.50)	1.75 (2.55)	1.52 (1.83)
Atrazine0.5 kg ha^{-1} at 15 DAS	3.28 (10.25)	3.71 (13.25)	1.99 (3.45)	2.91 (8.00)	1.87 (3.00)	1.92 (3.20)
Atrazine0.5 kg ha^{-1} at 20DAS	3.53 (12.00)	3.77 (13.75)	2.77 (7.15)	3.12 (9.25)	1.91 (3.15)	2.28 (4.70)
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 10 DAS	2.53 (5.93)	3.00 (8.50)	1.46 (1.64)	2.45(5.50)	1.48 (1.69)	1.86 (2.98)
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 15 DAS	2.80 (7.35)	2.83 (7.50)	1.84 (2.90)	2.66 (6.50)	1.87 (3.02)	1.99 (3.48)
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 20 DAS	3.73 (13.40)	3.50 (11.73)	2.20 (4.33)	2.87 (7.75)	2.02 (3.57)	2.15 (4.11)
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 10 DAS	1.68 (2.33)	1.59 (2.02)	0.71 (0.00)	1.96 (3.36)	1.84 (2.88)	1.53 (1.84)
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 15 DAS	1.42 (1.52)	1.35 (1.33)	0.71 (0.00)	1.39 (1.43)	1.15 (0.83)	0.91 (0.35)
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 20 DAS	1.45 (1.60)	1.51 (1.78)	1.25 (1.08)	1.53 (1.83)	1.49 (1.73)	1.40 (1.47)
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 10 DAS	1.68 (2.33)	1.59 (2.03)	0.90 (0.38)	1.99 (3.46)	1.75 (2.55)	1.47 (1.66)
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 15 DAS	1.43 (1.55)	1.37 (1.38)	1.00 (0.67)	1.45 (1.60)	1.46 (1.63)	1.06 (0.63)
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 20DAS	1.64 (2.20)	1.58 (2.00)	1.25 (1.07)	1.84 (2.88)	1.63 (2.15)	1.56 (1.98)
SEm ±	0.06	0.04	0.10	0.05	0.02	0.06
LSD(P=0.05)	0.17	0.11	0.30	0.14	0.07	0.18

(*$\sqrt{x+0.5}$ Transformed values and Data in parenthesis are original values)

Table 4: Effect of herbicides on plant population, plant height (cm), plant dry matter (g/plant) at 30 DAS and economics of maize

Treatment	Weed dry matter (g/m^2)					
	Plant population	**Plant height**	**Plant dry matter**	**Gros return (₹/ha^1)**	**Net return (₹/ha^1)**	**BC ratio**
Weedy check	58938	33.7	11.33	43788	20690	0.90
Atrazine0.5 kg ha^{-1} at 10 DAS	61839	45.1	12.27	73340	49332	2.05
Atrazine0.5 kg ha^{-1} at 15 DAS	62668	46.1	13.80	64380	40372	1.68
Atrazine0.5 kg ha^{-1} at 20DAS	62875	44.2	14.17	67605	43597	1.82
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 10 DAS	62461	35.6	7.33	61819	30311	0.96
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 15 DAS	60388	35.3	7.27	62369	30861	0.98
Atrazine0.5 kg ha^{-1}+ Halosulfuron0.09 kg ha^{-1} at 20 DAS	60595	39.0	7.53	69143	37635	1.19
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 10 DAS	62156	43.5	16.53	92439	64813	2.35
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 15 DAS	62633	47.0	18.04	98635	71009	2.57
Atrazine0.5 kg ha^{-1}+ Tembotrione0.125 kg ha^{-1} at 20 DAS	61412	41.9	17.00	94059	66433	2.40
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 10 DAS	61612	39.0	16.33	92677	65026	2.35
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 15 DAS	62057	41.9	17.83	89361	61710	2.23
Atrazine0.5 kg ha^{-1}+ Topramezone 0.025 kg ha^{-1} at 20 DAS	58026	44.3	17.05	88589	60938	2.20
SEm ±	1403	1.5	0.59	3789	3789	
LSD(P=0.05)	NS	4.5	1.73	11061	11061	

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