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Studies of weed management practices on weed dynamics and yield of maize (*Zea mays* L.)

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Abstract
A field experiment was conducted at Udaipur during *kharif* 2016 to study the effect of weed management practices on weed dynamics and yield of maize (*Zea mays* L.). The experiment was consisted of ten treatments viz., control, weed free, and alone or sequential application of different herbicides which were replicated thrice in randomized block design (RBD).All the weed control treatments resulted significant reduction in density and dry matter of both grassy as well as broad leaf weeds and total weeds at different growth stages in maize crop. The maximum weed control efficiency were found at 30 (90.97 %)and 60 DAS (81.04 %) by applying atrazine 0.75 kg ha^{-1} +pendimethalin 0.75 kg ha^{-1} PE mixture. Similarly, minimum weed dry matter accumulation was found with pre- emergence application of atrazine 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1} at all growth stages of crop. The yield (grain and stover) of maize were increased significantly under weed free over weedy check while among herbicidal weed control treatments, yield (grain and stover) were maximized under the effect of atrazine 0.75 kg ha^{-1} + pendimethalin0.75 kg ha^{-1} PE mixture.

Keywords: Maize, weed density, weeds dry matter, WCE, weed index, yield

1. Introduction
Maize (*Zea mays* L.) being one of the most important cereal crop of the world and third most important cereal crop of India and has scope to increase the present maize yields. During 2015, it occupied an estimated area of 8.67 m ha area with production of 23.67 m t at an average productivity of 2557 kg ha^{-1}(Govt. of India, 2015) [6]. It can be grown across a wide range of climatic conditions of the world due its wider adaptability. It is mainly a rainfed *Kharif* season crop where weed has become one of the most important yield limiting factors. Maize is generally infested by a wide range of weed flora during early stages of the crop growth which compete for growth resources *viz*., nutrients, moisture, sunlight and space during entire vegetative and early reproductive growth stages of crop. Presence of weeds 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. The most critical period for crop weed competition is first six weeks after sowing of crop because of initial slow growth and wider row spacing of maize, coupled with congenial weather conditions that allow luxuriant weed growth which may reduce yield by 28-100 per cent (Dass *et al.,* 2012) [3]. Hence, management of weeds is considered to be an important factor for achieving higher productivity. Singh *et al.* (1996) [9] mentioned that weed control methods are divided into two groups viz. non-chemical and chemical. The chemical weed control in maize is the best method being used in many developing countries, as it is an effective and relatively less expensive. However, application of single herbicide under diverse and mixed weed flora does not provide satisfactory weed control for the desired period. As most of the crops have a mixed weed population, it is desirable to incorporate the strengths of two or more herbicides into one complementary mixture which having wider and synergetic effect on weed control.

Materials and Methods
A field experiment was conducted to study the effect of weed management practices on weed dynamics and yield of maize (*Zea mays* L.) at the Instructional Farm, Rajasthan College of Agriculture, Udaipur during *Kharif* 2016. The experimental farm is situated at 24º35'N latitude and 73º 42' E longitudes and at an altitude of 582.17 metre above mean sea level. The region falls under agro-climatic zone IV-a (Sub Humid Southern Plain and Aravalli Hills) of the

Rajasthan. The experiment consisted of ten treatments [weed control, weed free, atrazine 1.5 kg ha^{-1} PE, atrazine 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1} PE, atrazine 1.5 kg ha^{-1} PE *fb* 2, 4-D 0.4 kg ha^{-1} PoE at 25 DAS, halosulfuron 0.09 kg ha^{-1} PoE at 25 DAS, atrazine 1.5 kg ha^{-1} PE *fb* halosulfuron 0.09 kg ha^{-1} PoE at 25 DAS, tembotrione 0.12 kg ha^{-1} PoE at 25 DAS, pendimethalin 1.0 kg ha^{-1} PE *fb* atrazine 0.75 kg ha^{-1} + 2,4-D amine 0.4 kg ha^{-1} PoE at 25 DAS, atrazine 1.5 kg ha^{-1} PE *fb* tembotrione 0.12 kg ha^{-1} PoE at 25 DAS]. These ten treatments were replicated thrice in Randomized Block Design.

The experimental field was of even topography with gentle slope and good drainage for determination of physico-chemical properties of experimental plot. The soil of the experimental site wasclay loam in texture slightly alkaline in reaction, medium in available nitrogen andphosphorus, while high in potassium. The maize crop was sown in shallow furrows (4-5 cm deep) by using variety 'PEHM-2' having seed rate of 20 kg $ha^{-1}$with crop geometry of 60 x 25 cm (R x P). The recommended dose of fertilizer was 90 kg N (through urea) and 30 kg P_2O_5 (through SSP), whereas, the 1/3 of the nitrogen and full dose of phosphorus were drilled 5 cm below seeding zone at sowing time and remaining nitrogen was applied in two equal splits at knee high and 50% tasseling stage as top dressing. Pre-emergence herbicides were applied shortly after showing and post-emergence herbicide mainly at 25 DAS of crop. The spraying was performed by knapsack spray with 500 l ha^{-1} of water volume.

Grassy and broad leaf weed density was taken at 30 and 60 DAS from randomly selected spot in the plots by using a quadrat of 0.5 x 0.5 m and then expressed as no m^{-2}. The data were subjected to square root transformation $\sqrt{X + 0.5}$ to normalize their distribution (Gomez and Gomez, 1984) [5]. Weed dry matter were recorded at 30, 60 DAS and at harvest by drying of weed under shade for 24 hours followed by oven drying at 65^0C to a constant weight and was expressed in g m^{-2}. Weed control efficiency (%) was computed by using following formula (Mani *et al*., 1973) [7]:

$$\text{WCE} = \frac{\text{Dry weight of weeds in unweeded control plot (g m}^{-2}\text{)} - \text{Dry weight of weeds in treated plot (g m}^{-2}\text{)}}{\text{Dry weight of weeds in unweeded control plot (g m}^{-2}\text{)}} \times 100$$

Weed index was computed by using the formula (Gill and Kumar, 1969) [4].

$$\text{WI (\%)} = \frac{X-Y}{X} \times 100$$

Where X= Yield from weed free plot (kg ha^{-1})

Y= Yield from the treated plot for which WI is to be worked out (kg ha^{-1}).

Result and Discussion

The results obtained from the present investigation are presented in Table 1, 2 and 3.

Weed density

A perusal of data in Table 1revealed that all herbicide treatments either alone or mixture or sequential application caused marked reduction in weed density of grassy and broadleaf weeds at all growth stages. The trend of effects of weed control treatments was not similar for broadleaf and grassy weeds. In respect of grassy weeds, pre-emergence application of atrazine 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1}significantly reduced the maximum weed density as 6.67 m^{-2} and 7.67 m^{-2} at 30 and 60 DAS respectively, compared to other weed control treatments due to selective nature of herbicide and were quite effective in controlling grasses and broad leaved weeds which significantly reduced weed population at early stages of crop and at later period crop gives smothering effect on weed and better performance of these herbicides might be due to longer persistence effect. In case of broad leaf weeds, atrazine 0.75 kg ha^{-1}+pendimethalin 0.75 kg ha^{-1} reduced maximum weed density (5.17 m^{-2}) at 30 DAS due to better effect of pre-emergence application, but sequential applicationof atrazine 1.5 kg ha^{-1} PE *fb* 2, 4-D 0.4 kg ha^{-1}PoE at 25 DAS reduce maximum weed density at 60 DAS (28.67 m^{-2}) because of better effect of 2, 4-D and persistency of atrazine. These results are in conformity with Ali *et al*., (2014) [1]. Also found that treated plots result highly significant reduction in weeds density as compared to that of weedy check due to mortality of weeds by weed control practices.

Weed dry matter

Data (Table 2) showed that compared to weedy check, significant reduction in weed dry matter were observed by different weed control treatments. Application of atrazine 0.75 kgha^{-1} + pendimethalin 0.75 kg ha^{-1} PE brought greatest reduction in grassy weed dry matter at 30, 60 DAS and at harvest(3.27, 3.53 and 4.57 g m^{-2}, respectively). Similarly, broad leaf weed dry matter was also reduced maximum (3.09 g m^{-2}) with mixture of atrazine 0.75 kgha^{-1} + pendimethalin 0.75 kg ha^{-1} PE at 30 DAS but at 60 DAS and at harvest minimum broad leaf weed dry matter (11.50 and 5.30 g m^{-2}) was found with sequential application of atrazine 1.5 kg ha^{-1} PE *fb* 2, 4-D 0.4 kg ha^{-1}PoE at 25 DAS due to better effect of 2, 4-D in controlling of broad leaf weed population.

Weed control efficiency

The data clearly explained (Table 2) that the pre-emergence application of atrazine 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1} gave (90.97 and 81.05 per cent) higher degree of control of total weeds at 30 DAS and 60 DAS, respectively. Mixtures comprising of such herbicides result in higher weed control, if their interaction is synergistic or additive. This can be reasoned for reduced weed density and weed dry matter under the effect of these herbicides.

Weed index

Weed index is negatively correlated with weed control efficiency, if better weed control is achieved by any treatments corresponds to lower weed index, so lower weed index (5.77 per cent) was achieved by mixture of atrazine 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1}. Similar results were reported by Shantveerayya and Agasimani (2012) [8] that application of either atrazine or butachlor followed by 2, 4-D recorded lower weed density, weed dry weight and higher WCE in crop.

Yield

Data presented in Table 2 revealed that in comparison to uncontrolled weeds, weed free tended to increases the yield (grain & stover) of maize. Herbicides application for weed control either alone or mixtures or in sequence resulted in significant increase in yield (grain & stover) of maize as compared to weedy check. Herbicide mixture comprising of atrazine 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1} PE gave the maximum yield (grain & stover) over weedy check, while remained at par to weed free and atrazine 1.5 kg ha^{-1} PE fb 2,4-D 0.4 kg ha^{-1} PoE at 25 DAS and found significantly superior over rest of the treatments. It was further concluded that atrazine 1.5 kg ha^{-1} PE *fb* 2, 4-D 0.4 kg ha^{-1} PoE at 25 DAS, atrazine 1.5 kg ha^{-1} PE *fb* tembotrione 0.12 kg ha^{-1} PoE at 25 DAS, atrazine 1.5 kg ha^{-1} PE, pendimethalin 1.0 kg ha^{-1} PE *fb* atrazine 0.75 kg ha^{-1}+ 2,4-D amine 0.4 kg ha^{-1} PoE at 25 DAS and atrazine 1.5 kg ha^{-1} PE *fb* halosulfuron 0.09 kg ha^{-1} PoE at 25 gave significant higher yield (grain & stover) whereas remained statistically superior over weedy check. Weed control by halosulfuron 0.09 kg ha^{-1} PoE at 25 DAS, gave significant increase in yield (grain & stover) of maize over weedy check, however, it was significantly inferior to rest of treatment except tembotrione 0.12 kg ha^{-1} PoE at 25 DAS. The increment in yield (grain & stover) of maize were obtained due to tembotrione 0.12 kg ha^{-1} PoE at 25 DAS was the least and significantly inferior to rest of the treatments. The better expression of yield (grain & stover) in the crop plants were might be due to poor resurgence frequency and growth of weeds as evident from weed dry matter studies in these plots. It is well established fact that least crop-weed competition during critical phases of crop growth exerts an important regulation function on complex process of yield formation due to better availability of water, space and nutrient. The results are in close conformity with the findings of Sinha *et al.* (2005) [10]. The pronounced effect of atrazine 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1} PE increased the grain and stover yield in respective value of 4510.67 kg ha^{-1} and 6989.00 kg ha^{-1} (Table 2) as compared to weedy check due to significant reduction in weed dry matter, there by reduction in crop weed competition which proved congenial environment to the crop for better expression of vegetative and reproductive potential. Similar results were also reported for improvement in yield by Channabasavanna *et al.*, (2015) [2].

Correlation and regression

Data (Table 3) showed that a negative significant correlation were observed between total weed dry matter accumulation and crop dry matter at 30, 60 DAS and at harvest with the respective values of r = -0.873**, - 0.829** and -0.802** because of higher weed density increase crop weed competition and weed dry matter. Negative significant correlation were observed between yield and weed dry matter accumulation and crop dry matter at 30, 60 DAS and at harvest with the respective values of r= -0.903**, - 0.900**, - 0.891 and -0.908**. Various authors have also reported improvement in yield with reduced weed density and dry matter (Sunitha *et al.*, 2010 and Channabasavanna *et al.*, 2015) [11, 2].

Conclusion

The experimental evidences warrant the following specific conclusion which may be adopted for better control of weed flora in maize during *Kharif* season. Among the different weed management practices adopted and yield, the mixture application of atrazine 0.75 kg ha^{-1} + pendimethalin 0.75 kg ha^{-1} PE mixture proved superior in reduction of weed density, dry matter and weed index and enhances weed control efficiency along with yield (grain and stover) of maize, whereas a negative significant correlation were observed between total weed dry matter accumulation and crop dry matter at different stages of crop growth.

Table 1: Grassy and broad leaf weed density at 30 and 60 DAS in maize

Treatments	Grassy weed (m^{-2})		Broad leaf weed (m^{-2})	
	30 DAS	60 DAS	30 DAS	60 DAS
Control (weedy)	136.00	152.67	52.00	63.27
Weed free	2.33	4.33	1.00	2.67
Atrazine1.5 kg ha^{-1} PE	9.67	11.67	35.33	44.67
Atrazine 0.75 kg ha^{-1}+pendimethalin 0.75 kg ha^{-1} PE	6.67	7.67	5.17	31.32
Atrazine 1.5 kg ha^{-1} PE fb 2, 4-D 0.4 kg ha^{-1} PoE at 25 DAS	12.67	14.00	30.33	28.66
Halosulfuron 0.09 kg ha^{-1} PoE at 25 DAS	40.00	42.00	38.33	36.67
Atrazine 1.5 kg ha^{-1} PE fb halosulfuron 0.09 kg ha^{-1} PoE at 25 DAS	9.00	12.33	25.67	35.33
Tembotrione 0.12 kg ha^{-1} PoE at 25 DAS	114.33	118.00	36.00	46.00
Pendimethalin 1.0 kg ha^{-1} PE *fb* atrazine 0.75 kg ha^{-1} + 2,4-D amine 0.4 kg ha^{-1} PoE at 25 DAS	89.00	92.00	23.00	29.67
Atrazine 1.5 kg ha^{-1} PE *fb* tembotrione 0.12 kg ha^{-1} PoE at 25 DAS	8.00	11.33	40.33	48.00
SEm±	2.27	2.79	2.18	2.09
CD 5%	6.75	8.29	6.46	6.20

Table 2: Dry matter and weed control efficiency of weeds at 30, 60 DAS and at harvest and weed index and grain yield in maize

Treatments	Grassy weed dry matter (g m^{-2})			Broad leaf weed dry matter (g m^{-2})			Weed control efficiency (%)		Weed index	Grain yield (kgha^{-1})	Stover yield (kgha^{-1})
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS			
Control (weedy)	51.80	63.33	61.33	19.13	25.47	23.40	0.00	0.00	69.87	1443.33	1636.00
Weed free	2.07	2.77	2.43	1.05	2.25	1.03	95.61	94.26	0.00	4792.33	7137.00
Atrazine1.5 kg ha^{-1} PE	6.17	8.27	7.40	13.40	17.60	15.70	72.43	70.74	20.72	3781.33	5560.00
Atrazine 0.75 kg ha^{-1}+pendimethalin 0.75 kg ha^{-1} PE	3.27	3.53	4.57	3.09	13.30	13.03	90.97	81.05	5.77	4510.67	6989.00
Atrazine 1.5 kg ha^{-1} PE fb 2, 4-D 0.4 kg ha^{-1} PoE at 25 DAS	5.80	7.90	7.17	8.23	11.50	5.30	80.21	78.17	19.37	3841.33	5966.33
Halosulfuron 0.09 kg ha^{-1} PoE at 25 DAS	42.17	50.23	48.27	16.35	15.85	14.20	17.43	25.07	28.11	3423.33	5084.00
Atrazine 1.5 kg ha^{-1} PE fb halosulfuron 0.09 kg ha^{-1} PoE at 25 DAS	6.53	8.13	7.23	15.40	19.50	18.10	69.11	69.15	22.72	3673.00	5550.33
Tembotrione 0.12 kg ha^{-1} PoE at 25 DAS	44.20	50.60	49.00	12.17	16.43	15.13	20.51	24.07	46.29	2593.67	3501.33
Pendimethalin 1.0 kg ha^{-1} PE *fb* atrazine 0.75kg ha^{-1} + 2,4-D amine 0.4 kg ha^{-1} PoE at 25 DAS	26.07	45.90	43.93	7.02	13.77	11.23	53.57	32.46	26.13	3526.33	5266.33
Atrazine 1.5 kg ha^{-1} PE *fb* tembotrione 0.12 kg ha^{-1} PoE at 25 DAS	4.40	8.17	7.00	11.37	16.20	14.67	77.77	72.56	19.85	3838.67	5897.00
SEm±	0.99	0.92	0.92	0.58	0.66	0.69	1.71	1.53	2.75	138.10	182.40
CD 5%	2.93	2.73	2.75	1.73	1.96	2.06	5.08	4.55	8.18	410.32	541.94

Table 3: Correlation coefficient and regression equation showing relationship between independent variable (X) and dependent variable (Y)

SNo	Dependent variable (Y)	Independent variable (X)	Correlation coefficient (r)	Regression equation (Y = a + bx)
1	Grain yield (kg ha^{-1})	Weed DMA at 30 DAS	-0.903**	Y= 4618.727-35.916x
2	Grain yield (kg ha^{-1})	Weed DMA at 60 DAS	-0.900**	Y= 4770.982-30.661x
3	Grain yield (kg ha^{-1})	Weed DMA at harvest	-0.891**	Y= 4690.963-31.032x
4	Stover yield (kg ha^{-1})	Weed DMA at 30 DAS	-0.908**	Y= 7118.211-62.049x
5	DMA at 30 DAS	Weed DMA at 60 DAS	-0.873**	Y= 19.662-0.081x
6	DMA at 60 DAS	Weed DMA at 60 DAS	-0.829**	Y= 66.414-0.169x
7	DMA at harvest	Weed DMA at 60 DAS	-0.802**	Y= 212.411-0.183x

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