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Effect of herbicides and their combinations on weeds, productivity and profitability of maize in rainfed sub-tropics of Jammu

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ABSTRACT

A field experiment was conducted at Advanced centre for rainfed agriculture, Rakh Dhiansar of Sher-e- Kashmir University of Agricultural Sciences and Technology of Jammu during the crop growing seasons of 2016 and 2017 to identify the best herbicide option for weed management in maize (*Zea mayz* L.). Fifteen treatments were tested in randomised block design replicated thrice. The post-emergence treatment (PoE) of tembotrione 100 g/ha + atrazine tank mix formulation 750 g/ha at 15-20 days after sowing (DAS) has recorded highest weed control efficiency (93.22 and 93.71% during 2016 and 2017, respectively) followed by tembotrione 100 g/ha + atrazine 500 g/ha at 15-20 days after sowing (DAS) and sequential application of atrazine 1000 g/ha 0-3 DAS *fb* tembotrione 100 g/ha 15-20 DAS. Higher maize grain yield was recorded (3.64 t/ha and 3.74 t/ha during 2016 and 2017, respectively) with weed free which was statically at par with tembotrione 100 g/ha + atrazine 500 g/ha at 15-20 DAS, tembotrione 100 g/ha + atrazine 750 g/ha at 15-20 DAS, tembotrione 100 g/ha + halosulfuron 67.5 g/ha at 15-20 DAS, tembotrione 100 g/ha+ halosulfuron 52.5 g/ha at 15-20 DAS, atrazine 1000 g/ha 0-3 DAS *fb* metribuzin 250 g/ha 15-20 DAS, atrazine 1000 g/ha 0-3 DAS *fb* tembotrione 100 g/ha 15-20. B: C ratio (3.11 and 3.12 in 2016 and 2017 respectively) was high with PoE application of tembotrione 100 g/ha + atrazine 500 g/ha.

INTRODUCTION

Maize is one of the world's most important food crops and it is regarded as "Queen of cereals" because of its high production potential and wider adaptability. In the world, maize is grown over an area of about 168 million hectare with a production of about 945.8 million tonnes (Anonymous, 2016a) and provides food security to a large chunk of population. In India, maize occupies a proud place both as food and feed for animals and it is the third most important food crops after rice and wheat. It is cultivated over an area of 8.90 million hectares with a production of about 23.00 million tonnes and productivity of about 2584 kg/ha (Anonymous 2016b). If the present trend of population growth does not decline, India may need 301 million tonnes of food grains by 2050 AD (Shankaran *et al*. 2005). Maize contributes nearly 9 per cent to the national food basket and more than 100 billion to the agricultural GDP at current prices. In the state of Jammu and Kashmir, maize has special significance because it forms the staple diet of majority of the people living in the state. The total area under maize crop in the state is about 293.86 thousand hectares with the production and productivity of about 360,000 tonnes and 1.78 t/ha, respectively. The state of Jammu and Kashmir has the distinction of being 11th largest maize producing state in the country (Anonymous 2017a). Moreover, in Jammu region, the production and productivity of maize is about 392,900 tonnes and 1800 kg/ha, respectively (Anonymous 2017b), from an area of about 230.69 thousand hectares. Maize provides food to the human beings and feed to the cattle. During recent years, maize is being increasingly used as a feedstock and for the production of bio ethanol. Protecting maize from weeds, pests and diseases is very much essential to avoid heavy losses caused by them in maize yield and gain quality. Weed control is usually most important, as weed interference is a severe problem in maize, especially in the early part of the growing season due to its initial slow growth rate and wider row spacing. Yield losses due to weed infestation vary from 28-93% depending on the type of weed flora and their intensity, stage, nature and duration of crop weed competition (Sharma and

Thakur 1998, Pandey *et al.* 2001) The critical period of crop weed competition in corn range from 1 to 6 weeks after sowing (Dass *et al*. 2012). In order to realize the maximum yield potential of maize, weed management becomes indispensable during this period. Chemical weed management by using pre- or post-emergence herbicides can lead to the efficient and cost effective control of weeds during critical period of crop weed competition, which may not be possible in manual or mechanical weeding due to its high cost of cultivation (Triveni *et al.* 2017). Hence, there is an immense need to find out most suitable herbicidal options for effective weed management in maize. Therefore, this study was undertaken to identify the chemical weed management options in maize (*Zea mays* L.)

MATERIALS AND METHODS

A field experiment was conducted at Advanced Centre for Rainfed Agriculture, Rakh Dhiansar of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during the *Kharif* seasons of 2016 and 2017. The soil of the experimental site was sandy loam in texture with neutral soil reaction (pH-6.9), electric conductivity-0.17 dS/m and low in organic carbon content (0.30%). Availability of nitrogen, phosphorus and potassium in the experimental site were low (166.5 kg/ha), medium (14.7 kg/ha) and medium (115.6 kg/ha), respectively. Total rainfall received during crop season was 636 mm and 576.50 mm in 2016 and 2017, respectively with mean maximum temperature varies from 31.6^{0}C to 35.2^{0}C in 2016 and 2017 and mean minimum temperatures varies from 11.5 ^{0}C to 27.8^{0}C, during 2016 and mean maximum temperature varies from 24.4 ^{0}C to 35.4 ^{0}C and mean minimum temperatures varies from 13.2 ^{0}C to 24.5^{0}C during 2017.

Experiment was conducted in a randomized block design with three replications. Treatments include tembotrione 100 g/ha 15-20 days after seeding (DAS), halosulfuron 67.5 g/ha 15-20 DAS, atrazine 1000 g/ha 0-3 g/ha, atrazine 750 g/ha 15-20 DAS, atrazine 500 g/ha 15-20 DAS, tembotrione + atrazine 100 + 500 g/ha 15-20 DAS, tembotrione + atrazine 100 + 750 g/ha 15-20 DAS, tembotrione + halosulfuron 100 + 67.5 g/ha 15-20, tembotrione + halosulfuron 100 + 52.5 g/ha 15-20 DAS, halosulfuron + atrazine 67.5 + 500 15-20 DAS, atrazine *fb* 2,4-D 1000 *fb* 500 0-3 DAS and 15-20 DAS, atrazine *fb* metribuzin 1000 *fb* 250 0-3 DAS and 15-20 DAS, atrazine *fb* tembotrione 1000 *fb* 100 0-3 DAS and 15-20 DAS, weed free and weedy check. Maize composite "*Mansar"* was sown on 30.06.2016 and 28.06.2017, during 2016 and 2017, respectively at 60 x 20 cm spacing. Before sowing, field was thoroughly ploughed and levelled. The crop was fertilized evenly irrespective of treatments with 60:40:20 kg NPK/ha with N in three equal split doses. Pre-emergence herbicides were applied within two days after sowing. Post-emergence herbicides were applied at 15-20 DAS. All the herbicides were used after making the spray volume of 500 L/ha. Weed density was recorded at 60 DAS by using a quadrat of 0.5 x 0.5 m size from the centre of the plot. The entire weeds inside the quadrat were uprooted and cut close to the transition of root and shoot in each plot and collected for dry matter accumulation (biomass). The samples were first dried in sun and then kept in oven at 70 ± 2°C. The dried samples were weighed and expressed as biomass (g/m^2). Cost of cultivation, gross returns, net returns and benefit cost ratio for each treatment were calculated by taking into consideration of total costs incurred and returns obtained. Square root transformation was done for weed density and weed biomass by using the formula $(\sqrt{x+1})$. Weed control efficiency (WCE), weed index (WI) were calculated using formulae as suggested by Mishra and Mishra (1997) and Raju (1998).

RESULTS AND DISCUSSION

Weed flora

In the experimental site, sedges weeds were dominant compared to the grasses and broad-leaved weeds *Echinochloa colona, Digitaria sanguinalis, Acrachne racemosa, Eragrostis tenella, Eleusine aegyptium* were the major grassy weeds and *Cyperus rotundus and Cyperus iria* were the dominant sedge weeds. *Amaranthus viridis* and *Solanum nigrum* were the major broad-leaved weed species during both the years of study.

Effect on weeds

At 60 DAS Weed free recorded significantly lesser total weed density and biomass (**Table 1**). Among herbicide treatments, total weed density and biomass was least with tembotrione 100 g/ha + atrazine 750 g/ha at 15-20 DAS, which was statistically at par with tembotrione 100 g/ha + atrazine 500 g/ha at 15-20 DAS, atrazine 1000 *fb* tembotrione 100 g/ha), tembotrione 100 g/ha + halosulfuron 67.5 g/ha at 15-20 DAS, tembotrione 100 g/ha + halosulfuron 52.5 g/ha at 15-20 DAS) and atrazine 1000 g/ha *fb* metribuzin 250 g/ha. The better performance of combination of herbicides was probably due to the synergestic effect of two herbicides with same or different modes or sites of action resulting in reduced density as well as biomass of differnt weed species (Singh *et al.* 2015). These results were in close conformity with those of Rao *et*

al. (2009) and Yakadri *et al.* (2015). The higher WCE at 60 DAS was recorded with tembotrione100 g/ha + atrazine 750 g/ha at 15-20 DAS which was followed by tembotrione100 g/ha + atrazine 500 g/ha at 15-20 DAS and tembotrione100 g/ha + halosulfuron 67.5 g/ha at 15-20 DAS. The lowest weed index was observed with tembotrione100 g/ha + atrazine 750 g/ha at 15-20 DAS followed by tembotrione 100 g/ha + atrazine 500 g/ha at 15-20 DAS and atrazine 1000 *fb* tembotrione 100 g/ha) during both the years of experimentation during 2016 and 2017 (**Table 2**).

Effect on crop

Weed management treatments significantly affected the growth and yield attributing characters of maize. At 60 DAS, significantly higher plant height (176.48 cm) was recorded with weed free treatment, which was statistically at par with treatment atrazine 1000 g/ha *fb* metribuzin 250 g/ha, tembotrione100 g/ha + halosulfuron 52.5 g/ha at 15-20 DAS, atrazine 1000 g/ha 0-3 DAS *fb* 2,4-D 500 g/ha at 15-20 DAS, halosulfuron 67.5 g/ha + atrazine 500 g/ha at 15-20 DAS, atrazine 1000 g/ha at 0-3 DAS, tembotrione 100 g/ha at 15-20 DAS) and halosulfuron 67.5 g/ha at 15-20 DAS (**Table 3**). The numbers of grains/cobs and 1000 grain weight were higher in weed free which was stastically at par with tembotrione100 g/ha + atrazine 750 g/ha at 15-20 DAS, tembotrione 100 g/ha + halosulfuron 67.5 g/ha at 15-20 DAS, tembotrione100 g/ha + atrazine 500 g/ha at 15-20 DAS, atrazine 1000 *fb* tembotrione 100 g/ha (**Table**

Table 1. Effect of different weed management treatments on total weed density and biomass in maize

Treatment	Total weed density (no. /m^2) 60 DAS		Total weed biomass (g/m^2) 60 DAS	
	2016	2017	2016	2017
Tembotrione 100 g/ha at 15-20 DAS	7.21(51.0)	6.89(46.6)	7.09(49.3)	6.13(36.7)
Halosulfuron 67.5 g/ha at 15-20 DAS	9.11(82.0)	8.55(72.2)	9.06(81.0)	8.33(68.3)
Atrazine 1000 g/ha at 0-3 DAS	8.31(68.0)	7.87(61.0)	8.10(64.7)	7.36(53.3)
Atrazine 750 g/ha at 15-20 DAS	9.91(97.3)	9.41(87.8)	9.89(97.0)	9.32(86.0)
Atrazine 500 g/ha at 15-20 DAS	10.58(111.0)	10.10(101.0)	10.64(112.3)	10.16(102.3)
Tembotrione 100 g/ha + atrazine 500 g/ha at 15-20 DAS	4.20(16.7)	4.22(16.8)	4.16(16.3)	2.76(6.7)
Tembotrione 100 g/ha + atrazine 750 g/ha at 15-20 DAS	4.12(16.0)	3.83(13.7)	3.74(13.0)	2.28(4.3)
Tembotrione 100 g/ha + halosulfuron 67.5 g/ha at 15-20 DAS	5.66(31.0)	5.41(28.3)	5.60(30.3)	5.09(25.0)
Tembotrione 100 g/ha+ halosulfuron 52.5 g/ha at 15-20 DAS	6.00(35.0)	5.80(32.7)	6.08(36.0)	5.28(27.0)
Halosulfuron 67.5 g/ha + atrazine500 g/ha at 15-20 DAS	7.19(50.7)	6.97(47.5)	6.85(46.0)	6.58(42.3)
Atrazine1000 g/ha 0-3 DAS *fb*2,4-D 500 g/ha at 15-20 DAS	6.90(46.7)	6.77(44.8)	6.63(43.0)	5.97(34.7)
Atrazine 1000 g/ha 0-3 DAS *fb* metribuzin 250 g/ha at 15-20 DAS	5.10(25.0)	4.96(23.7)	4.79(22.0)	3.79(13.3)
Atrazine 1000 g/ha 0-3 DAS *fb* tembotrione 100 g/ha at 15-20 DAS	4.16(16.3)	4.26(17.2)	4.03(15.3)	2.63(6.0)
Weed free	1.00(0)	1.41(1.0)	1.00(0.)	1.00(0)
Weedy check	13.17(172.7)	12.38(152.4)	14.11(198.3)	13.36(177.7)
LSD (p=0.05)	0.34	0.48	0.48	0.49

The data were subjected to $(\sqrt{x+1})$ transformation; Figures in the parentheses are original values

Table 2 Effect of different weed management treatments on maize grain and stover yield, weed control efficiency and weed index

Treatment	Grain yield (t/ha)		Stover yield (t/ha)		WCE 60 DAS		WI	
	2016	2017	2016	2017	2016	2017	2016	2017
Tembotrione 100 g/ha at 15-20 DAS	2.93	3.03	6.16	6.22	66.5	66.1	19.6	19.0
Halosulfuron 67.5 g/ha at 15-20 DAS	2.74	2.84	5.00	5.06	56.3	55.8	24.8	24.1
Atrazine 1000 g/ha at 0-3 DAS	2.89	2.93	5.92	5.95	54.0	54.7	20.6	21.6
Atrazine 750 g/ha at 15-20 DAS	2.17	2.28	4.58	4.69	35.7	36.4	40.5	39.0
Atrazine 500 g/ha at 15-20 DAS	2.14	2.27	4.31	4.36	29.6	29.5	41.3	39.4
Tembotrione 100 g/ha + atrazine 500 g/ha at 15-20 DAS	3.52	3.62	7.34	7.39	92.5	93.3	3.3	3.2
Tembotrione 100 g/ha + atrazine 750 g/ha at 15-20 DAS	3.54	3.64	7.35	7.40	93.2	93.7	2.6	2.5
Tembotrione 100 g/ha + halosulfuron 67.5 g/ha at 15-20 DAS	3.48	3.52	7.19	7.26	86.7	86.9	4.5	6.0
Tembotrione 100 g/ha + halosulfuron 52.5 g/ha at 15-20 DAS	3.47	3.50	7.08	7.10	83.6	85.0	4.9	6.5
Halosulfuron 67.5 g/ha+ atrazine500 g/ha at 15-20 DAS	2.78	2.91	6.09	6.15	68.0	68.1	23.7	22.2
Atrazine1000 g/ha 0-3 DAS *fb*2,4-D 500 g/ha at 15-20 DAS	2.92	3.02	6.04	6.13	68.5	69.6	19.8	19.3
Atrazine 1000 g/ha 0-3 DAS *fb* metribuzin 250 g/ha at 15-20 DAS	3.37	3.50	6.86	6.92	78.7	80.6	7.5	6.5
Atrazine 1000 g/ha 0-3 DAS *fb* tembotrione 100 g/ha at 15-20 DAS	3.52	3.63	7.33	7.39	81.0	81.6	3.4	3.1
Weed free	3.64	3.74	7.82	7.90	100.0	100.0	-	-
Weedy check	1.96	2.06	3.61	3.68	-	-	46.3	44.9
LSD (p=0.05)	0.44	0.41	1.06	0.941				

Table 3. Effect of different weed management treatments on number of grains/cob, 1000- grain weight plant height, net return and B: C ratio in maize

Treatment	No. of grains/cob		1000- grain weight (g)		Plant height (cm) 60 DAS		Net returns (x10^3 `/ha)		B:C ratio	
	2016	2017	2016	2016	2016	2017	2016-17	2017-18	2016-17	2017-18
Tembotrione 100 g/ha at 15-20 DAS	383	385	164.3	164.3	164.3	166.0	33.12	34.31	2.62	2.65
Halosulfuron 67.5 g/ha at 15-20 DAS	346	349	159.9	159.9	159.9	160.2	25.52	26.65	2.10	2.13
Atrazine 1000 g/ha at 0-3 DAS	380	384	166.0	166.0	166.0	162.3	33.14	33.36	2.70	2.68
Atrazine 750 g/ha at 15-20 DAS	325	329	155.7	155.7	155.7	156.0	20.32	21.76	2.05	2.10
Atrazine 500 g/ha at 15-20 DAS	282	285	150.7	150.7	150.7	151.4	19.54	21.11	2.02	2.07
Tembotrione 100 g/ha + atrazine 500 g/ha at 15-20 DAS	543	547	174.0	174.0	174.0	178.2	43.62	44.73	3.11	3.12
Tembotrione 100 g/ha + atrazine 750 g/ha at 15-20 DAS	551	555	176.3	176.3	176.3	179.9	44.73	44.80	3.10	3.11
Tembotrione 100 g/ha + halosulfuron 67.5 g/ha at 15-20 DAS	544	547	174.4	174.4	174.4	175.0	38.75	38.99	2.57	2.56
Tembotrione 100 g/ha + halosulfuron 52.5 g/ha at 15-20 DAS	538	539	171.8	171.8	171.8	173.0	39.28	39.39	2.66	2.63
Halosulfuron 67.5 g/ha + atrazine500 g/ha at 15-20 DAS	391	363	166.7	166.7	166.7	167.9	27.83	29.42	2.19	2.23
Atrazine1000 g/ha 0-3 DAS *fb* 2,4-D 500 g/ha at 15-20 DAS	360	396	170.4	170.4	170.4	171.4	33.21	34.37	2.66	2.68
Atrazine 1000 g/ha 0-3 DAS *fb* metribuzin 250 g/ha at 15-20 DAS	403	405	171.8	171.8	171.8	172.9	40.86	42.40	3.01	3.04
Atrazine 1000 g/ha 0-3 DAS *fb* tembotrione 100 g/ha at 15-20 DAS	539	544	173.8	173.8	173.8	174.2	42.94	44.17	3.01	3.03
Weed free	553	557	176.5	176.5	176.5	180.3	19.48	20.63	1.41	1.43
Weedy check	268	270	144.5	144.5	144.5	144.9	16.22	17.49	1.87	1.92
LSD (p=0.05)	49	52	18.8	18.8	18.8	21.2				

3). Martin *et al.* (2011) observed that yield attributes of maize were higher when atrazine was applied along with tembotrione as PoE.

Economic

Preference of any herbicides by the farmers mainly depends on the weed control efficiency and economics. Currently, the cost of manual weeding is much higher than the chemical weed control, which encourages many farmers for switching over to herbicides from expensive and tiresome manual weeding. The net returns were found to be higher with tembotrione 100 g/ha + atrazine 750g/ha followed by tembotrione 100 g/ha + atrazine 750 g/ha and atrazine 1000 g/ha *fb* tembotrione 100g/ha during both years. Further, the benefit: cost ratio was higher for tembotrione 100 g/ha + atrazine 500 g/ha during both the years (3.11 and 3.12, respectively) tembotrione 100 g/ha + atrazine 750 kg/ha and atrazine 1000 g/ha *fb* tembotrione 100 g/ha during both years. (**Table 3**).

It may be concluded that post-emergence application of tembotrione 100 g/ha + atrazine 500 g/ha at 15-20 DAS was on effective method of managing weeds, improving maize grain yield and ensured better economic returns in maize crop grown in the rainfed area of Jammu.

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