Indian Journal of Weed Science (2024) **56**(1): 80–83
http://dx.doi.org/10.5958/0974-8164.2024.00013.3

RESEARCH NOTE

Weed dynamics and maize productivity as influenced by sole and tank mix application of herbicides

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Received: 10 August 2022 | Revised: 12 December 2023 | Accepted: 15 December 2023

ABSTRACT

A field experiment was conducted during rainy season of 2018 in Norman. E. Borlaug. Crop Research Centre of GBPUA&T, Pantnagar with the objective to find the best weed control method among the application of herbicides alone, their tank mix application, sequential application and integration with cultural methods to control the complex weed flora of *Kharif* (rainy) maize and to study its effect on the growth and yield. The experiment was laid out in a randomized block design with three replications and ten treatments, *viz.* atrazine 1.0 kg/ha, tembotrione 120 g/ha, halosulfuron-methyl 67.5 g/ha, atrazine 1.0 kg/ha *fb* halosulfuron-methyl 54 g/ha, atrazine 800 g/ha *fb* halosulfuron-methyl 67.5 g/ha, tembotrione 120 g/ha + halosulfuron-methyl 54 g/ha, tembotrione 96 g/ha + halosulfuron-methyl 67.5 g/ha, atrazine 1.0 kg/ha *fb* one hand weeding at 25 DAS, weed free and weedy check. Among the weed control treatments, pre-emergence application of atrazine 1.0 kg/ha followed by one hand weeding at 25 DAS was the best weed control method which significantly reduced total weed density as well as total dry matter and significantly increased grain and straw yield, weed control efficiency and B:C ratio. This treatment bargained the yield reduction at 3.1% as compared to weedy check (53.1%) reducing the crop-weed competition. Tank mix application of tembotrione 120 g and halosulfuron-methyl 54 g/ha at 3-4 leaf stage of weeds was found to be at par to this treatment.

Keywords: Halosulfuron-methyl, *Kharif* maize, Tank application, Tembotrione, Weed density, Weed dry matter, Weed control efficiency

Maize (*Zea mays*) is one of the most important cereal crops occupying third position in the world after wheat and rice. In India, maize is being cultivated on 9.22 million hectares area, with a production of 28.78 million tonnes and average productivity of 3.12 tonnes per hectare (Nayak *et al.*, 2023). In India major area of maize production falls under *Kharif* (rainy) season which is characterized by heavy rains and high humidity, providing congenial environment for the insect, pest, diseases and weed infestation. Maize crop gets infested with different types of weeds. Some of the grass weeds found in the maize fields of sandy loam soil of Uttarakhand were *Echinochloa colona* L., *Digitaria sanguinalis* L. and *Brachiaria ramosa* L. and broad-leaved weeds were *Phyllanthus niruri* L., *Cleome viscosa* L. and *Trianthema monogyna* L. and *Cyperus rotundus* L. was the most common sedge (Singh *et al.* 2012).

Conventional method of weed control becomes quite difficult and uneconomical in *Kharif* maize due to slushy and hard field conditions as a result of continuous rains and labour scarcity. Hence, chemical method of weed control becomes more feasible, less laborious, cost effective and economical, especially in maize grown in rainy season during June-July (*Kharif*). However, application of sole herbicide under diverse and mixed weed flora does not provide satisfactory weed control (Nath *et al.* 2020). Moreover, continuous usage of same herbicide or similar herbicides year after year results in weed shift as well as herbicide resistance in weed species. So for broad spectrum weed control, use of more than one herbicide should be done, either by mixing them or by using them in temporal variation *i.e.* pre and post-emergence herbicides. Farmers at present are applying atrazine 1.0 kg/ha as pre-emergence herbicide but atrazine is unable to control many weeds such as *Echinochloa colona* and *Cyperus rotundus* (Singh *et al.* 2015). Hence it is necessary to widen the scope of atrazine by applying it with some other herbicides either as mixture or in sequence. Halosulfuron-methyl is a selective, post-emergence herbicide very effective in controlling sedges and some broad-leaf weeds. Kumar (2018) reported that application of halosulfuron-methyl at 67.5 g/ha 15 days after treatment reported significantly less population of *Cyperus rotundus.* Tembotrione is a post-emergence herbicide which inhibits 4-hydroxyphenylpyruvate dioxygenase (HPPD) enzyme and the biosynthesis of

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plastoquinone and subsequently carotenoid pigment formation and chlorophyll disruption (Porter *et al*. 2005). It controls broad as well as grass weeds. Tank mix application of tembotrione with lower dose of atrazine has been reported to be more effective providing broad spectrum weed management than their sole application. So, there is a need to evaluate alternate post-emergence herbicide which can provide broad spectrum weed control in maize in Indian situation. Hence, an experiment was undertaken to find out the most effective and economic herbicide and its optimum dose for minimizing the menace of weeds in *Kharif* maize.

The field experiment was conducted during the *Kharif* season of 2018 in the D-3 block of NE Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology (GBPU&T), Pantnagar. Soil type at the experimental site was clay loam in texture, almost neutral in reaction (pH- 7.2) and medium in organic carbon (0.57%). Available N, P and K content in soil was 211.5, 21.3 and 192.5 kg/ha, respectively. Hybrid maize variety '*NMH – 589*' (*Suvarna*) was sown on 27th June, 2018 at spacing of 60 × 20 cm and harvested on 9th October, 2018. Crop was fertilized with 120: 60:40 kg/ha of N, P and K, respectively. Herbicides were sprayed using 750 litres of water per hectare for pre-emergence herbicides (atrazine) and 500 litres of water per hectare for post-emergence herbicides with the help of Maruti foot sprayer fitted with flat fan nozzle. In weed free plots, weeds were removed with the help of khurpi (hand operated small spade) as and when required to keep the plot free from weeds. Weedy plot remained infested with the native weed population throughout the crop growing season. Data on weed density and dry matter, crop growth and yield were recorded. Weed control efficiency and weed index were calculated. Weed data were square root transformed before statistical analysis.

Total weed density and dry matter

The experimental field was infested with 14 weeds species which consisted 5 grass weeds, 8 broad-leaved weeds and 1 sedge. The major weed flora of the field consists of three grass weeds, *viz. Echinochloa colona, Dactyloctenium aegyptium, Digitaria sanguinalis*, three broad-leaf weeds *viz.*, *Celosia argentea, Trianthema monogyna* and *Cyperus rotundus* as a major sedge. *Cyperus rotundus* was the major weed of the maize field which contributed 33.5, 38.9 and 39.7 per cent of the total weed density at 30th, 60th and 90th day stage of the crop growth, respectively. Similar findings regarding the highest density of *Cyperus rotundus* in the maize field has also been reported by Shaik and Subramanyam (2017) and Dey *et al.* (2018).

The highest density of total weeds was recorded at 30th day stage in weedy check, which decreased at later stages (**Table 1**). Similar results of higher weed infestation at 30th day stage of maize have also been reported by Gupta *et al*. (2017) and Zimdahl (2004). All the weed control measures caused significant reduction in the density and dry weight of total weeds over weedy check (**Table 1**). Pre-emergence

Table 1. Effect of different treatments on weed density and dry matter of total weeds; weed control efficiency (WCE) at different crop growth stages and weed index (WI) in maize

Treatment	Dose (g/ha)	Weed density (no./ m^2)			Total weed dry matter (g/m^2)			WCE (%)			WI (%)
		30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	
Atrazine	1000	12.36 (152.0)	11.23 (125.3)	9.00 (80.0)	5.35 (27.70)	8.17 (69.95)	6.93 (47.11)	65.5	70.6	68.1	32.8
Tembotrione	120	9.07 (81.3)	7.98 (62.7)	6.50 (41.3)	3.54 (11.76)	5.82 (32.89)	4.64 (20.56)	85.4	86.2	86.1	20.3
Halosulfuron	67.5	13.10 (170.7)	11.53 (132.0)	9.43 (88.0)	6.69 (46.15)	13.66 (165.33)	9.58 (90.95)	42.6	30.6	38.5	43.8
Atrazine *fb* halosulfuron	1000 *fb* 54	6.38 (52.0)	5.97 (34.7)	4.27 (17.3)	2.96 (8.09)	5.16 (25.63)	3.69 (12.66)	89.9	89.2	91.4	12.5
Atrazine *fb* halosulfuron	800 *fb* 67.5	9.43 (88.0)	7.98 (62.7)	6.40 (40.0)	4.42 (18.70)	7.08 (63.35)	5.86 (36.88)	76.7	73.4	75.0	31.3
Tembotrione+ halosulfuron	120 + 54	5.38 (28.0)	4.27 (17.3)	3.00 (8.0)	2.13 (3.56)	3.59 (11.91)	2.37 (4.75)	95.6	95.0	96.8	9.4
Tembotrione + halosulfuron	96 + 67.5	7.81 (60.0)	6.30 (38.7)	5.00 (24.0)	3.50 (11.30)	6.09 (36.12)	4.52 (19.46)	85.9	84.8	86.8	17.2
Atrazine *fb* 1 hand weeding at 25 DAS	1000	1.0 (0.0)	3.96 (14.7)	1.92 (2.7)	1.0 (0.0)	2.23 (3.9)	1.41 (0.99)	100	98.3	99.3	3.1
Weed free		1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	100	100	100	0.0
Weedy check		17.73 (318.7)	15.24 (238.7)	13.00 (174.7)	8.90 (80.36)	16.11 (238.3)	12.04 (147.8)	0.0	0.0	0.0	53.1
LSD (p=0.05)		2.66	1.81	1.3	1.38	3.24	1.75	-	-	-	-

application of atrazine 1.0 kg/ha followed by one hand weeding at 30 DAS was found to be the most effective treatment in controlling the weeds in maize crop. The next treatment in order was tank mix application of tembotrione 120 g and halosulfuron-methyl 54 g/ha applied at 3-4 leaf stage of weeds which was at par with pre-emergence application of atrazine 1.0 kg/ha *fb* halosulfuron-methyl 54 g/ha. Alone application of atrazine 1.0 kg/ha or tembotrione 120 g/ha or halosulfuron-methyl 67.5 g/ha were not found as effective as their tank mix application. Lowest total weed density and dry matter accumulation in pre-emergence application of atrazine 1.0 kg/ha followed by one hand weeding at 25 DAS has also been reported by Abdullah *et al*. (2016) and Deshmukh *et al*. (2014). This could be due to integrated weed management involving pre-emergence application of atrazine 1.0 kg/ha which led to inhibition of weed germination at initial stage of crop and hand weeding at later stage which completely controlled the late germinating weeds from further growth as reported by Gopinath and Kundu (2008). Lower density and dry matter accumulation of total weeds in tank mix application of tembotrione 120 g and halosulfuron-methyl 54 g/ha at 3-4 leaf stage of weed might be due to efficient control of grass and non-grass weeds with post-emergence application of tembotrione 120 g/ha and sedges with halosulfuron methyl 54 g/ha. Similar results of effective control of grass and non-grass weeds with the application of tembotrione 120 g/ha and sedges with halosulfuron methyl 67.5 g/ha has also been reported by Yadav *et al*. (2018) and Kumar (2018), respectively.

Weed control efficiency and weed index

Highest WCE was recorded under weed free condition at all the stages of crop growth, which was closely followed by pre-emergence application of atrazine 1.0 kg/ha followed by one hand weeding at 25 DAS. Similar result was obtained by Kumar *et al.* (2015). The next in order which recorded maximum WCE was with tank mix application of tembotrione 120 g and halosulfuron-methyl 54 g/ha at 3-4 leaf stage of the weeds, which was closely followed by pre-emergence application of atrazine 1.0 kg/ha *fb* halosulfuron-methyl 54 g/ha. Application of halosulfuron-methyl 67.5 g/ha at 3-4 leaf stage of weeds recorded lowest WCE at all the stages of crop growth. In weedy check, the highest yield reduction (53.1%) was reported out of crop-weed competition. Among the combination treatments, the lowest weed index was obtained in atrazine 1.0 kg/ha *fb* 1 hand weeding at 25 DAS (3.1%) followed by tembotrione 120 g and halosulfuron-methyl 54 g/ha at 3-4 leaf stage of the weeds (9.4%) and atrazine 1000 g/ha *fb* halosulfuron 54 g/ha (12.5%) whereas, among the sole application of herbicide treatments, tembotrione 120 g/ha was able to restrict the yield loss at 20.3% followed by atrazine 1000 g/ha (32.8%) and halosulfuron-methyl 67.5 g/ha (43.8%).

Yield, yield attributes and economics of *Kharif* maize

Uncontrolled growth of weeds in weedy check plot resulted in 53.1 and 49.6% reduction in grain and stover yield of maize, respectively when compared to weed free plot (**Table 2**). The grain as well as stover yield was severely reduced due to the weed- crop competition. Reduction in maize yield by 27-60% due to season long weed competition has also been reported by Kumar *et al.* (2015) and Jat *et al.* (2012). Among the weed control treatments, pre-emergence application of atrazine 1.0 kg/ha followed by one hand weeding at 25 DAS and tank mix application of tembotrione 120 g and halosulfuron-methyl 54 g/ha at 3-4 leaf stage of weeds yielded at par with weed free plot. Different yield attributing characters *viz*., number of grains/row and number of grains/cobs in plots treated under these treatments was also at par with those under weed free condition. Significantly higher grain yield in pre-emergence application of atrazine 1.0 kg/ha followed by one hand weeding at 25 DAS has also been reported by Abdullah *et al*. (2016), Deshmukh *et al*. (2014) and Dixit and

Table 2. Effect of different treatments yield attributes, yield and economics of *Kharif* maize

Treatment	Dose (g/ha)	No. of grains/ row	No. of grains/cob	Grain yield (t/ha)	Stover yield (t/ha)	B:C ratio
Atrazine	1000	23.3	284.3	4.3	7.8	1.4
Tembotrione	120	25.5	339.2	5.1	9.4	1.7
Halosulfuron	67.5	21.1	242.7	3.6	6.6	0.9
Atrazine *fb* halosulfuron	1000 *fb* 54	26.2	356.3	5.6	9.9	1.9
Atrazine *fb* halosulfuron	800 *fb* 67.5	23.4	294.8	4.4	8	1.3
Tembotrione+ halosulfuron	120 + 54	26.9	371.2	5.8	10.2	1.8
Tembotrione + halosulfuron	96 + 67.5	25.6	340.5	5.3	9.6	1.6
Atrazine *fb* 1 hand weeding at 25 DAS	1000	28.2	394.8	6.2	11.2	2.1
Weed free		28.7	407.5	6.4	11.5	1.4
Weedy check		18.9	207.9	3	5.8	0.8
LSD (p=0.05)		4.4	72.8	0.7	1.5	

Gautam (1994). Higher crop yield in treatments where tank mix application of post-emergence herbicides might be due to broad spectrum weed control, which reduced the crop weed competition and led to increased crop growth and thereby increased the nutrient uptake by crop and ultimately higher grain and stover yield. Similar reports of increased nutrient uptake and yield of maize has been reported by Singh *et al.* (2005), Chopra and Angiras, (2008) and Shrinivas *et al.* (2014). Halosulfuron-methyl 67.5 g/ha at 3-4 leaf stage alone produced lowest grain yield. Application of both tembotrione 120 g/ha and halosulfuron-methyl 67.5 g/ha alone as post emergence produced lower yield than their tank mix application. The reduction in grain yields in plot treated with halosulfuron-methyl 67.5 g/ha at 3-4 leaf stage was particularly due to its very less effect on grass weeds and broad leaved weeds and tembotrione 120 g/ha on *Cyperus rotundus*.

The highest B: C ratio was recorded in pre-emergence application of atrazine 1.0 kg/ha followed by one hand weeding at 25 DAS. The next in line was pre-emergence application of atrazine 1.0 kg/ha *fb* halosulfuron-methyl 54 g/ha which was closely followed by tank mix application of tembotrione 120 g and halosulfuron-methyl 54 g/ha at 3-4 leaf stage of weeds. However the lowest B: C ratio was recorded in weedy check. Higher grain yield and lower cost of cultivation might have been responsible for the corresponding higher net returns and ultimately to higher B: C ratio. These weed control measures were more remunerative than weedy check with regard to net monetary returns hence gave higher B: C ratio. These results are in line with the findings of Roy *et al.*, (2008).

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