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Weed and soil health management in maize (*Zea mays* L.)

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Abstract
A field experiment was conducted at district sultanpur for two consecutive years (2016-17 and 2017-18) to evaluate the efficacy of Halosulfuron methyl to control the *Cyperus rotundus* in Maize. The treatments consisted of new herbicide Halosulfuron methyl (75% WG) @ 52.5 and 67.5 g a.i./ha, applied at 5-6 leaf stage of *Cyperus rotundus* and compared with recommended 2,4-D Ethyl Ester 38% EC (900 g a.i./ha), Atrazine 50% WP (500 g a.i./ha) and two hand weedings at 20 and 35 DAS with untreated control. The results revealed that Halosulfuron methyl 75% WG @ 67.5 g a.i./ha recorded significantly more control of *Cyperus rotundus* recording 80% and 73% during trials in both years. The significantly higher WCE (at 35 DAS) ranging from 93% and 98% was recorded in Halosulfuron methyl 75% WG @ 67.5 g a.i./ha during both years respectively. The grain yield of maize was also found to be maximum in Halosulfuron methyl @ 67.5 g a.i./ha in both the years, recording 65 and 71 q/ha during both years respectively. Halosulfuron methyl 75% WG @ 67.5 g a.i./ha did not show any residual phytotoxicity on succeeding crop of Rapeseeds. Weed management with weedicides improves soil health compare to weeding by manually.

Keywords: Cyperus rotundus, maize (*Zea mays* L.)

Introduction

Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adoptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 150 m. ha. in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 % (782 mt) in the global grain production. The United States of America (USA) is the largest producer of maize contributing nearly 35% of the total production in the world and maize is the driver of the US economy. The USA has the highest productivity (> 9.6 t ha^{-1}) which is double than the global average (4.92 t ha^{-1}) whereas; the average productivity in India is 2.43 t ha^{-1}. Maize is cultivated throughout the year in all states of the country for various purposes including grain, fodder, green cobs, sweet corn, baby corn, pop corn. The predominant maize growing states that contribute more than 80 % of the total maize production are Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9%), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1%), Madhya Pradesh (5.7%) and Himachal Pradesh (4.4%). Hence, the maize has emerged as important crop in the non-traditional regions i.e. peninsular India as the state like Andhra Pradesh which ranks 5th in area (0.79 m ha) has recorded the highest production (4.14 mt) and productivity (5.26 t ha^{-1}) in the country although the productivity in some of the districts of Andhra Pradesh is more or equal to the USA. Weed management with weedicides improves soil health compare to weeding by manually. This is due to incorporation of organic matter in soils.

Weeds are the serious problem in maize as they compete with maize for nutrient and causes yield loss up to 35%. Therefore, timely weed management is needed for achieving higher yield. Due to continuous use of Atrazine in maize fields, the population of grassy and broad leaf weeds has been decreased; whereas the population of *Cyperus* species has increased tremendously. Over the past few years, maize growers in India have experienced the increased infestation of *Motha/Bhada (Cyperus rotundus* L.). This weed possesses predominant basal nut/nutlets just below ground level. One nut produces a chain of nut/nutlets connected with the rhizomes. Nuts can penetrate as deep as 60 centimeter in the soil. During the first month of growth of *Cyperus*, mother tuber can produce four daughter tuber/nuts and in three month the nuts population may reach almost hundred resulting serious weed problem in maize (Stoller and Sweet 1987; Holm *et al.*, 1997; Rao 1968) [3, 5, 6]. There is none herbicide in India which may control this dreaded weed which is a serious problem in maize growers.

Materials and Methods

The experiments were laid out at district sultanpur at farmers fields for two consecutive years (2016-17 and 2017-18). Maize variety Phule Rajarshi was sown on 25- 06-2016 (2016-17) and 30-06-2017 (2017-18) in randomized block design (RBD) consisting four replications. The soil type was sandy loam. Maize sowing was carried over in 5mx5m plots keeping 55cmx25cm spacing (row to row x plant to plant).

The Maize crop was raised by following packages and practices recommended by SMS, Soil Science, KVK, Kushinagar, other than use of herbicides. Foliar application of Halosulfuron Methyl 75% WG (Sempra) was given after 20 days of sowing at 5-6 leaf stage of *Cyperus rotundus*. Spray volume was 575 litre / ha. Spray was done by using knapsack sprayer fitted with flat fan nozzle. Cropping pattern was kept maize- Rapseeds in the both years. Observations on *Cyperus rotundus* weed count, before spray (pre-treatment) and after 20 and 33 days of spray treatment was recorded. Dry weed bio-mass and weed control efficiency were recorded after 33 days of spray treatment of Halosulfuron Methyl 75% WG (Sempra). Grain yield (q/ha) was recorded at harvest during both the years. During both the years, the observation on phytotoxicity in maize was recorded after 20 days of application of Halosulfuron Methyl 75% WG (Sempra) at normal and double dose of Halosulfuron Methyl 75% WG (Sempra). The treatments details are given in tables 1-3. Rapseeds crop was sown as follow-up crop in the same plots in which Halosulfuron Methyl 75% WG (Sempra) and other herbicides were sprayed on maize crop during the Kharif cropping seasons during both the. Observations were recorded with regard to its germination and yield. The observations on visual phytotoxicity symptoms were also recorded in follow-up Rapseed crop

Table 1: Effect of different herbicides against *Cyperus rotundus* in Maize (2016-17 and 2017-18)

Treatment	Dose/ha		Number of *Cyperus rotundus*/ sq.m									
			Pre-treatment		18DAT				33DAT			
	A.I. (g)	Formulation (g)	2016-17	2017-18	2016-17	2017-18	% control over pre-treatment 2016-17	% control over pre-treatment 2017-18	2016-17	2017-18	% control over pre-treatment 2016-17	% control over pre-treatment 2017-18
Halosulfuron Methyl 75% WG (Sempra)	52.5	70	190	230	85	97	55.26	57.82	75	87	60.52	62.17
Halosulfuron Methyl 75% WG (Sempra)	67.5	90	210	210	42	57	80.00	72.82	4	6	98.09	97.14
2,4-D Ethyl Easter 38% EC	900	2.38	205	200	43	47	79.94	76.50	163	140	20.48	30.00
Atrazine 50% WP	500	1000	195	205	185	204	5.00	0.48	190	206	2.56	-0.48
Farmer Practice	2 hand weeding (at 18 and 30 days after sowing)		208	220	211	218	-1.44	0.90	218	219	-4.80	0.45
Untreated control			200	215	202	216	-1.00	-0.46	205	220	-2.50	-2.32
SEm±			0.32	0.37	0.30	0.35			0.35	0.41		
CD 5%			NS	NS	1.02	1.06			1.07	1.25		

Results and Discussion

Bio-efficacy of halosulfuron methyl 75% WG (Sempra) against *Cyperus rotundus*

Before spray (Pre-treatment) the population of *Cyperus rotundus* varied from 190 to 208/ sq.m. in 2016-17 while in 2017-18 the population of *Cyperus rotundus* varied from 210 to 230/ sq.m. among the treatments. The number of *Cyperus rotundus* did not vary significantly among the treatments (Table 1). After twenty days of treatment, significantly minimum *Cyperus rotundus* population was recorded in Halosulfuron Methyl 75% WG (Sempra) @ 67.5 g a.i/ha, while the maximum population of *Cyperus rotundus* was recorded in farmer practice in both the years. However, significantly less population of *Cyperus rotundus* was recorded in Halosulfuron Methyl 75% WG (Sempra) @ 52.5 g a.i./ha treatment in comparison to Atrazine 50% WP, farmer practice and untreated control. 2, 4-D Ethyl Easter 38% EC also recorded significantly less *Cyperus rotundus* in comparison to Atrazine 50% WP, farmer practice and Untreated Control. The percent control over pre-treatment was higher in Halosulfuron Methyl 75% WG (Sempra) (80%) @ 67.5 g a.i/ha and 2,4-D Ethyl Easter (79.94%) 38% EC @ 900 g a.i/ha in 2012-13 while in the same treatments in 2017-18 there was 72.82% and 76.50% mortality of *Cyperus rotundus* respectively (Table 1). After 33 days of treatment Halosulfuron Methyl 75% WG (Sempra) @ 67.5 g a.i./ha recorded minimum and significantly less population of *Cyperus rotundus* as

compared to the remaining treatments in both the year. 2,4-D Ethyl Easter 38% EC gave good control of *Cyperus*

rotundus after 15 days of treatments but after 30 days new plants of *Cyperus rotundus* germinated resulting only 20.48% control during 2016 and 30% during 2017 as against 98.09 and 97.14% in halosulfuron methyl 75% WG (Sempra) @ 67.5 g a.i./ha, respectively (Table 1). The previous workers have also reported that halosulfuron methyl herbicide controls *Cyperus rotundus* by killing the underground nuts (Stoller and Sweet 1987; Holm *et al.*, 1997; Rao 1968; Chand *et al.*, 2014) [2, 4, 6, 7]. Amrein and Gerber (1985) [1] reported that the sulfonylurea herbicides are rapidly absorbed by the foliage as well as by the roots of *Cyperus rotundus*.

Dry weed bio- mass and weed control efficiency

Dry weed bio-mass (g/sq. m) of *Cyperus rotundus* was minimum and significantly less in Halosulfuron Methyl 75% WG (Sempra) @ 67.5 g a.i./ha, after 33 days of treatments as compared to the remaining treatments in both the years (Table 2). Weed control efficiency (%) in

Halosulfuron Methyl 75% WG (Sempra) @ 67.5 g a.i./ha was 98.38% and 97.67% after 33 days in 2016 and 2017, respectively. Halosulfuron Methyl 75% WG (Sempra) @ 52.5 g a.i./ha was the next effective treatment recording 69.04% and 64.03% weed control efficiency in 2016 and 2017 respectively. 2,4-D Ethyl Easter 38% EC @ 900 a.i./ha was moderately effective and Atrazine 50% WP @ 500 g a.i./ha was ineffective against *Cyperus rotundus* (Table 2).

Farmer practice, having two hand weeding, after 20 and 33 days of sowing was also not effective in controlling *Cyperus rotundus* as only 17.88 and 12.91% weed control efficiency was recorded in 2016 and 2017, respectively (Table 2). Johari *et al*, (2012) [4] also reported minimum dry weed bio mass and maximum weed control efficiency in Sempra 75% WG @ 67.5 g a.i./ha + Metribuzin 70% WP @ 750 g a.i./ha in Sugarcane crop.

Table 2: Dry weed bio-mass, weed control efficiency and yield in different herbicidal treatments (2016-17 and 2017-18)

Treatment		Dose/ha	Dry weed bio-mass (g/sq m) 30 DAT		Weed control efficiency (%) 30 DAT		Yield (q/ha)	
	A.I. (g)	Formulation (g)	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Halosulfuron Methyl 75% WG (Sempra)	52.5	70	13.00	15.79	69.04	64.03	50.70	51.90
Halosulfuron Methyl 75% WG (Sempra)	67.5	90	0.68	1.02	98.38	97.67	65.90	70.70
2,4-D Ethyl Easter 38% EC	900	2.38	26.71	24.80	36.40	43.50	53.80	55.50
Atrazine 50% WP	500	1000	33.30	36.02	20.71	20.22	41.80	43.40
Farmer Practice	2 hand weeding (at 18 and 30 days after sowing)		34.49	38.23	17.88	12.91	54.40	56.90
Untreated control	42.00		43.90		40.70		42.80	
SEm±	0.19		0.18		3.73		2.78	
CD 5%	0.59		0.55		10.83		8.06	

Grain yield

During 2016-17, halosulfuron methyl 75% WG (Sempra) @ 67.5 g a.i./ha recorded maximum and significantly more grain yield in comparison to remaining herbicidal treatments and control. 2,4-D Ethyl Easter 38% EC and farmer practice (two hand weedings at 20 and 33 days after sowing) recorded next highest yield and both were at par with each other and significantly superior than control and halosulfuron methyl 75% WG (Sempra) @ 52.5 g a.i./ha (Table 2). During 2017-18, halosulfuron methyl 75% WG (Sempra) @ 67.5 g a.i./ha recorded maximum and significantly more grain yield in comparison to remaining herbicidal treatments and control. Farmer practice (two hand weedings at 20 and 33 days after sowing), 2,4-D Ethyl Easter 38% EC and Halosulfuron Methyl 75% WG (Sempra) @ 52.5 g a.i./ha recorded next higher yield and all the three were at par with each other. Atrazine 50% WP was at par with control (Table 2).

Table 3: Effect of herbicidal treatments on follow-up crop rapeseed during experimentation

Treatment		Dose/ha	Germination (%)		Yield (q/ha)	
	a.i. (g)	Formulation (g)	2016	2017	2016	2017
Halosulfuron Methyl 75% WG (Sempra)	52.5	70	93	89	14.90	15.10
Halosulfuron Methyl 75% WG (Sempra)	67.5	90	95	92	15.00	15.25
Halosulfuron Methyl 75% WG (Sempra)	135.0	180	96	94	15.40	15.40
2,4-D Ethyl Easter 38% EC	900	2.38	90	93	15.25	14.90
Atrazine 50% WP	500	1000	94	90	15.10	15.10
Farmer Practice	2 hand weeding (at 18 and 30 days after sowing)		93	93	15.30	15.20
Untreated control	94			92	15.20	15.15
SEm±	4.78			6.78	1.42	0.97
CD 5%	NS			NS	NS	NS

Effect of halosulfuron methyl 75% WG (Sempra) on follow-up mustard crop

It was observed that none of the herbicidal treatments of halosulfuron methyl 75% WG (Sempra), even double dose did not show any adverse affect of halosulfuron methyl 75% WG (Sempra) on the germination and yield of mustard crop, which was sown in the same plots where the herbicidal treatments were given during Kharif 2016-17 and 2017-18.

There was no difference in crop growth and vigour in any of the treatments during both the year (Table 3). No phytotoxicity was observed in mustard crop at any stage during both the years (Table 3). halosulfuron methyl 75% WG (Sempra) @ 67.5 g a.i./ha was found significantly more effective against the *Cyperus rotundus*, recording 98.09% and 97.14% control after 33 days of treatments during 2016-17 and 2017-18, respectively. Significantly less dry weed bio-mass of 0.68 and 1.02 g/sq.m in 2016-17 and 2017-18, respectively in the treatment halosulfuron methyl 75% WG (Sempra) @ 67.5 g a.i./ha was recorded, in comparison to remaining treatments. Halosulfuron methyl 75% WG (Sempra) @ 67.5 g a.i./ha recorded 98.38 and 97.67% weed control in 2016-17 and 2017-18 respectively. Maximum and significantly more grain yield of 65.90 q/ha and 70.70 q/ha was recorded in 2016-17 and 2017-18, respectively. Halosulfuron methyl 75% WG (Sempra) at different doses did not show any adverse effect on maize crop and also on follow-up rapseed crop. Halosulfuron methyl 75% WG (Sempra) foliar application @ 67.5 g a.i./ha (90 g/ha) is recommended to farmers of U.P. for *Cyperus rotundus* control in maize.

Conclusions

Weed management with weedicides improves soil health compare to weeding by manually. This is due to incorporation of organic matter in soils. Weedicides are more economical than farmers practices (Mannual weeding).

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