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Pre-sowing Weed Management of Purple Nutsedge (*Cyperus rotundus*) in a Non-crop Ecosystem

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Purple nutsedge is a perennial, one of the world worst weed, ravages the field continuously throughout the year in the tropical regions. It thrives and dominates under any environmental conditions. Normally weeds compete with the crops for the nutrients, water, space, light and other essential requirements. Inadequate control of weed at appropriate stage is considered as a major constraint for high yield.There is more number of pre-emergence, early post-emergence and post-emergence herbicides coming up in the market with wide spectrum of weed control efficiency. The availability of effective and new herbicides and herbicide combinations in the recent times have led to control of established weeds before crops, so as to reduce their competition with crops and increase the crop yields. With this background, field experiments were carried out to evaluate the effect of different herbicides for control of *Cyperus rotundus* in a non-crop ecosystem in the farmer's field, Chinnankuppam at Dharmapuri district, Tamil Nadu during 2017 to 2018. *Cyperus rotundus* wasfound to bethe predominant weed in the experimental field compared to broad leaved weeds such as *Parthenium hysterophorous* and grasses like *Chloris barbata* and *Cynodon dactylon*. Pre-emergence, early post-emergence and post-emergence herbicides *viz.,* metribuzin, halosulfuron methyl, glyphosate and 2,4-D were applied individually as well as different combination were used for the management of purple nutsedge (*Cyperus rotundus*).Among the herbicides, early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fb post-emergence application of glyphosate at 1.00 kg ha^{-1}resulted in lower *Cyperus* density, dry weight and higher control efficiency followed by early post-emergence application of halosulfuron methyl at 75 g ha^{-1}.

Key words: Purple nutsedge, Herbicides, Weed characters

Purple nutsedge (*Cyperus rotundus* L.), an economically important perennial weed in 52 crops and 92 countries, is classified as the one of the world's worst weed due to its extensive distribution and competitiveness (Holm *et al.*, 1977). Yield of crops are drastically reduced due to interference of the purple nutsedge (*Cyperus rotundus)* throughout the cropping period. Normally weeds compete with the crops for the nutrients, water, space, light and other essential requirements. Inadequate control of weed at appropriate stage is considered as a major constraint for high yield. There is more number of pre-emergence, early post-emergence and post-emergence herbicides coming up in the market with wide spectrum of weed control efficiency. The availability of effective and new herbicides and herbicide combinations in the recent times have led to control of established weeds before crops, so as to reduce their competition with crops and increase the crop yields. This study was carried out for the management of purple nutsedge using different herbicides and their effect in a non-crop ecosystem.

Material and Methods

The field experiment was conducted at Chinnakuppam village, Dharmapuri district with geographical region of 13.20° N latitude and 80.32° E longitude at an altitude of 392 m above mean sea level.A field which has been earlier infested predominantly with *Cyperus rotundus* was selected for the studyduring 2017 to 2018, *rabi* season. The experiment was laid out in randomized block design with nine treatments and three replications. Different herbicides and herbicide combination were used for experiment.The treatments consisted of: T_1 –pre-emergence application of metribuzinat 1.25 kg ha^{-1}; T_2–early post-emergence application of halosulfuron methyl at 75g ha^{-1}; T_3 - post-emergence application of glyphosate at 1.25 kg ha^{-1}; T_4 - post-emergence application of 2,4-D at 1.25 kg ha^{-1}; T_5 - pre-emergence application ofmetribuzinat 1.00 kg ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}; T_6 - early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fb post-emergence application ofglyphosate at 1.00 kg ha^{-1}; T_7-pre-emergence application of metribuzin at 1.00 kg ha^{-1}fb post-emergence application of 2,4-D at 1.00 kg ha^{-1}; T_8 -pre-emergence application of metribuzin at 1.00 kg ha^{-1}+ 2,4-D at 1.00 kg ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}; T_9 - Unsprayed (Control).Pre-emergence herbicide (PE) = applied at 3nd day after weed emergence.Early post-

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emergence herbicide (EPOE) = applied at 2 to 4 leaf stage of weeds *i.e*12th day of weed emergence.Post-emergence herbicide (POE) = applied at 20th dayof weed emergence. All the herbicideswas dissolved in 500 litresof water and sprayed with knapsack sprayer using deflector nozzle.

Weed count was recorded by placing four quadrats of size 0.5×0.5 m in each plot and the weeds falling within the frames of the quadrat were counted, recorded and the mean values were expressed in number m^{-2}. The density of grasses, sedges and broad leaved weeds were recorded at before herbicide spraying (BHS) 0th day, 15, 30 and 60 days after herbicide spray (DAHS) and expressed in number m^{-2}. The weed falling within the frames of the quadrats were collected, categorized into grasses, sedges and broad leaved weeds, washed free of soil and shade dried. The collected weeds were later dried in hot-air oven at 80°C for 72 hrs and dry weight of grasses, sedges and broad leaved weeds were recorded separately at BHS (0th day), 15, 30 and 60 DAHS.

Results and Discussion

General weed flora in the experimental field

Weed flora of the experimental field predominantly consisted of two species of grass weeds, one species of broad leaved weeds and one among sedge is presented in Table 1.

Table 1. Weed flora of the experimental field

Botanical name	Common name	Habit	Family
A. Grasses			
Cynodon dactylon , Pers.	Arugampullu (T)	Perennial	Poaceae
	Bermuda grass (E)		
Chloris barbata	Myilkondai pullu (T)	Annual	Poaceae
	Swollen Finger Grass(E)		
Sedges			
**Cyperus rotundus*, Linn.	Korai (T)	Perennial	Cyperaceae
	Purple nut sedge(E)		
Broad leaved weeds			
Parthenium hysterophorous, L.	Visha poondu (T)	Annual	Asteraceae
	Carrot weed (E)		

T-Tamil; E-English; * Predominant weeds

Cyperus rotundus wasfound to bethepredominant weed in the experimental field compared to broad leaved weeds such as *Parthenium hysterophorous* and grasses like *Chloris barbata* and *Cynodon dactylon*. This might be due to the viable weed seed reserves present in the soil; favourable environmental condition like rainfall, low temperature prevailed during that period and soil moisture status which in turn might have lead to dormancy breaking and quick growth of *Cyperus rotundus* in cropped fallow fields.

Table 2. Effect of pre- sowing weed management practices on density (No/m²) of *Cyperus rotundus*

Treatments	*Cyperus rotundus* (No/m²)			
	BHS	15 DAHS	30 DAHS	60 DAHS
T_1 - PE metribuzin at 1.25 kg ha^{-1}	8.51 (70.4)	5.76 (31.2)	5.22 (25.3)	6.00 (34.0)
T_2 - EPOE halosulfuron methyl at 75 g ha^{-1}	8.20 (65.3)	3.90 (13.2)	3.02 (7.1)	2.76 (5.6)
T_3 - POE glyphosate at 1.25 kg ha^{-1}	8.75 (74.5)	5.33 (26.4)	4.25 (16.1)	3.36 (9.3)
T_4 - POE 2,4-D at 1.25 kg ha^{-1}	8.64 (72.6)	6.38 (38.7)	5.44 (27.6)	5.81 (31.8)
T_5 - PE metribuzin at 1.00 kg ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	8.41 (68.7)	4.64 (19.5)	3.92 (13.4)	3.19 (8.2)
T_6 - EPOE halosulfuron methyl at 50 g ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	8.86 (76.5)	3.38 (9.4)	2.47 (4.1)	2.05 (2.2)
T_7 - PE metribuzin at 1.00 kg ha^{-1} fb POE 2,4-D at 1.00 kg ha^{-1}	8.75 (74.6)	4.84 (21.4)	4.18 (15.5)	4.39 (17.3)
T_8 - PE metribuzin at 1.00 kg ha^{-1} + POE 2,4-D at 1.00 kg ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	8.25 (66.1)	4.28 (16.3)	3.39 (9.5)	2.86 (6.2)
T_9 - Unsprayed (Control)	8.51 (70.5)	8.75 (74.6)	8.99 (78.8)	9.30 (84.4)
C.D. (P=0.05)	NS	0.49	0.44	0.45

PE -pre emergence, EPOE -early post emergence, POE - post emergence. BHS- Before herbicide Spray (0 day), DAHS – Day after herbicide spray. Figures in the parenthesis are original values, Data subjected to log transformation (log(x+2)), NS- Not significant

Weed composition in the experimental field

At the time of selection of field, the weed flora composition of different weed species present in the experimental field was observed and recorded. Subsequently absolute and relative density has been worked out and depicted in Fig 1. Among the different weed species present in the experimental field, higher relative density of 90 % was observed for *Cyperus rotundus* followed by grasses (8 %) and broad leaved weeds (2 %) at BHS (0thday).

Table 3. Effect of pre-sowing weed management practices on dry weight (g/m^2) of *Cyperus rotundus*

Treatments	*Cyperus rotundus* dry weight (g/m^2)			
	BHS	15 DAHS	30 DAHS	60 DAHS
T_1 - PE metribuzin at 1.25 kg ha^{-1}	3.75 (12.10)	3.32 (9.02)	3.20 (8.22)	3.48 (10.13)
T_2 - EPOE halosulfuron methyl at 75 g ha^{-1}	3.64 (11.22)	2.92 (6.51)	2.71 (5.34)	2.37 (3.62)
T_3 - POE glyphosate at 1.25 kg ha^{-1}	3.85 (12.83)	3.31 (8.94)	3.03 (7.21)	2.83 (6.02)
T_4 - POE 2,4-D at 1.25 kg ha^{-1}	3.83 (12.65)	3.63 (11.15)	3.33 (9.08)	3.45 (9.91)
T_5 - PE metribuzin at 1.00 kg ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	3.72 (11.81)	3.12 (7.73)	2.95 (6.72)	2.80 (5.83)
T_6 - EPOE halosulfuron methyl at 50 g ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	3.91 (13.30)	2.83 (6.01)	2.63 (4.93)	2.13 (2.55)
T_7 - PE metribuzin at 1.00 kg ha^{-1} fb POE 2,4-D at 1.00 kg ha^{-1}	3.86 (12.92)	3.18 (8.10)	3.00 (7.01)	3.06 (7.34)
T_8 - PE metribuzin at 1.00 kg ha^{-1} + POE 2,4-D at 1.00 kg ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	3.67 (11.44)	3.04 (7.23)	2.84 (6.05)	2.72 (5.42)
T_9 - Unsprayed (Control)	3.78 (12.28)	4.40 (17.32)	4.49 (18.16)	4.59 (19.03)
C.D. (P=0.05)	0.32	0.28	0.26	0.26

a. *PE -pre emergence, EPOE -early post emergence, POE - post emergence. BHS- Before herbicide Spray (0 day), DAHS – Day after herbicide spray. Figures in the parenthesis are original values.* Data subjected to log transformation (log(x+2))

***Cyperus rotundus* density**

The data on *Cyperus rotundus* density recorded before herbicide spraying (BHS) 0th day and at 15, 30 and 60 days after herbicide spraying (DAHS) are presented in Table 2.Before herbicide spraying (BHS) 0th day, *Cyperus* weed density was recorded in all the treatment plots. The weed density in different treatment did not differ significantly before spraying. Similarly, Mritunjay Kumar (2018) reported that before herbicide spray (Pre-treatment) the density of *Cyperus rotundus* did not vary significantly among the treatments.

Table 4. Effect of pre-sowing weed management practices on control efficiency (%) of *Cyperus rotundus*

Treatments	*Cyperus rotundus* control efficiency (%)		
	15 DAHS	**30 DAHS**	**60 DAHS**
T_1 - PE metribuzin at 1.25 kg ha^{-1}	47.92	54.73	46.76
T_2 - EPOE halosulfuron methyl at 75 g ha^{-1}	62.41	70.59	80.97
T_3 - POE glyphosate at 1.25 kg ha^{-1}	48.38	60.29	68.36
T_4 - POE 2,4-D at 1.25 kg ha^{-1}	35.62	50.00	47.92
T_5 - PE metribuzin at 1.00 kg ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	55.36	62.99	69.36
T_6 -EPOE halosulfuron methyl at 50 g ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	65.30	72.85	86.60
T_7 - PE metribuzin at 1.00 kg ha^{-1} fb POE 2,4-D at 1.00 kg ha^{-1}	53.23	61.39	61.42
T_8 - PE metribuzin at 1.00 kg ha^{-1} + POE 2,4-D at 1.00 kg ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	58.25	66.68	71.51
T_9 - Unsprayed (Control)	-	-	-

b. *PE -pre emergence, EPOE -early post emergence, POE - post emergence. DAHS – Day after herbicide spray, Data not statistically analysed*

At 15 DAHS, *Cyperus* weed density was significantly lower in early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fb post-emergence application of glyphosate at 1.00 kg ha^{-1}followed by early post-emergence application of halosulfuron methyl at 75 g ha^{-1} and pre-emergence application of metribuzin at 1.00 kg ha^{-1} + 2,4-D at 1.00 kg ha^{-1} fb post-emergence application of glyphosate at 1.00 kg ha^{-1} while within the treatment, higher *Cyperus* was conspicuously higher in post-emergence application of 2,4-D at 1.25 kg ha^{-1} which was on par with pre-emergence application of metribuzinat 1.25 kg ha^{-1}. Similar trend was followed at 30 and 60 DAHS.

Table 5. Effect of pre-sowing weed management practices on density (No m^{-2}) of other weeds

Treatments	Density (No m^{-2})							
	Grasses				Broad leaved weeds			
	BHS	15 DAHS	30 DAHS	60 DAHS	BHS	15 DAHS	30 DAHS	60 DAHS
T_1 - PE metribuzin at 1.25 kg ha^{-1}	2.66	2.41	2.10	1.82	1.82	1.41	1.41	1.41
	(5.1)	(3.8)	(2.4)	(1.3)	(1.3)	(0.0)	(0.0)	(0.0)
T_2 - EPOE halosulfuron methyl at 75 g ha^{-1}	1.41	1.41	1.41	1.41	1.87	2.07	2.51	2.83
	(0.0)	(0.0)	(0.0)	(0.0)	(1.5)	(2.3)	(4.3)	(6.0)
T_3 - POE glyphosate at 1.25 kg ha^{-1}	1.41	1.41	1.41	1.41	1.79	1.41	1.41	1.41
	(0.0)	(0.0)	(0.0)	(0.0)	(1.2)	(0.0)	(0.0)	(0.0)
T_4 - POE 2,4-D at 1.25 kg ha^{-1}	1.84	2.32	2.47	2.79	1.84	1.41	1.41	1.41
	(1.4)	(3.4)	(4.1)	(5.8)	(1.4)	(0.0)	(0.0)	(0.0)
T_5 - PE metribuzin at 1.00 kg ha^{-1} fb POE	1.41	1.41	1.41	1.41	1.76	1.41	1.41	1.41
glyphosate at 1.00 kg ha^{-1}	(0.0)	(0.0)	(0.0)	(0.0)	(1.1)	(0.0)	(0.0)	(0.0)
T_6 - EPOE halosulfuron methyl at 50 g ha^{-1}	1.87	2.41	2.68	2.97	1.41	1.41	1.41	1.41
fb POE glyphosate at 1.00 kg ha^{-1}	(1.5)	(3.8)	(5.2)	(6.8)	(0.0)	(0.0)	(0.0)	(0.0)
T_7 - PE metribuzin at 1.00 kg ha^{-1} fb POE	1.79	2.14	2.28	2.66	1.41	1.41	1.41	1.41
2,4-D at 1.00 kg ha^{-1}	(1.2)	(2.6)	(3.2)	(5.1)	(0.0)	(0.0)	(0.0)	(0.0)
T_8 - PE metribuzin at 1.00 kg ha^{-1} + POE 2,4-D at 1.00 kg ha^{-1} fb POE glyphosate	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41
at 1.00 kg ha^{-1}	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
T_9 - Unsprayed (Control)	2.83	3.19	3.39	3.61	2.92	3.27	3.48	3.71
	(6.0)	(8.2)	(9.5)	(11.0)	(6.5)	(8.7)	(10.1)	(11.8)
SEd	0.04	0.05	0.06	0.07	0.04	0.05	0.06	0.07
C.D (P=0.05)	0.10	0.12	0.13	0.15	0.09	0.11	0.13	0.15

PE -pre emergence, EPOE -early post emergence, POE - post emergence. BHS- Before herbicide Spray (0th day), DAHS – Days after herbicide spray. Figures in the parenthesis are original values

Mritunjay Kumar (2018) also suggested that after 15 and 30 days of treatment, significantly minimum *Cyperus rotundus* density was recorded in halosulfuron methyl 75% WG @ 67.5 g ha^{-1} and significantly less density of *Cyperus rotundus* was recorded in halosulfuron methyl 75% WG @ 52.5 g ha^{-1} treatment in comparison to atrazine 50% WP and untreated control.

At all the stages of observation, *Cyperus* weed density was higher in unsprayed control than all other treatments at 15, 30 and 60 DAHS respectively.

***Cyperus rotundus* dry weight**

The data on *Cyperus rotundus* weed dry weight was recorded at BHS (0th day), 15, 30 and 60 DAHS and are presented in Table 3.At 15 DAHS, dry weight of *Cyperus rotundus* was significantly lower with early post-emergence application of halosulfuron methyl at 50 g ha^{-1} fb post-emergence application of glyphosate at 1.00 kg ha^{-1} which was on par with early post-emergence application of halosulfuron methyl at 75 g ha^{-1}. Both the treatments recorded 6.01, 6.51 g/m^2 of *Cyperus* dry weight, respectively. Post-emergence application of 2,4-D at 1.25 kg ha^{-1} recorded higher *Cyperus* dry weight than other treatments but lesser than unsprayed control.At 30 DAHS, early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fb post-emergence application ofglyphosate at 1.00 kg ha^{-1} was on par with early post-emergence application of halosulfuron methyl at 75 g ha^{-1} and pre-emergence application ofmetribuzin at 1.00 kg ha^{-1} + 2,4-D at 1.00 kg ha^{-1} fb post-emergence application of glyphosate at 1.00 kg ha^{-1}. The above treatments recorded 4.93, 5.34 and 6.05 g m^{-2} of *Cyperus* dry weight respectively. At 60 DAHS, early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1} recorded lower *Cyperus* dry weight (2.55g/m^2) followed by early post-emergence application of halosulfuron methyl at 75 g ha^{-1}. However higher *Cyperus* dry weight was registered in unsprayed control (19.03 g/m^2).Dry weed bio-mass (g/m^2) of *Cyperus rotundus* was minimum and significantly less in halosulfuronmethyl 75% WG @ 67.5 g ha^{-1}, after 30 days of treatments was also reported Mritunjay Kumar (2018).

***Cyperus rotundus* control efficiency**

The efficiency of treatments on control of *Cyperus rotundus* in terms of dry weight in comparison to control plot was worked out and presented in Table 4. At 15 DAHS, higher *Cyperus* control efficiency of 65.30 per cent was obtained with early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fb post-emergence application of glyphosate at 1.00 kg ha^{-1} followed by early post-emergence application of halosulfuron methyl at 75 g ha^{-1} (62.41 per cent). Lower *Cyperus* control efficiency of 35.62 per cent was obtained with post-emergence application of 2,4-D at 1.25 kg ha^{-1}.

Table 6. Effect of pre- sowing weed management practices on dry weight (g.sq.m^{-1}) of other weeds

Treatments	Dry weight (g.sq.m^{-1})							
	Grasses				Broad leaved weeds			
	BHS	15 DAHS	30 DAHS	60 DAHS	BHS	15 DAHS	30 DAHS	60 DAHS
T_1 - PE metribuzin at 1.25 kg ha^{-1}	1.68 (0.81)	1.61 (0.60)	1.54 (0.37)	1.49 (0.21)	1.53 0.35)	1.41 (0)	1.41 (0)	1.41 (0)
T_2 -EPOE halosulfuron methyl at 75 g ha^{-1}	1.41 (0)	1.41 (0)	1.41 (0)	1.41 (0)	1.57 (0.47)	1.65 (0.72)	1.83 (1.36)	1.97 (1.90)
T_3 - POE glyphosate at 1.25 kg ha^{-1}	1.41 (0)	1.41 (0)	1.41 (0)	1.41 (0)	1.54 (0.38)	1.41 (0)	1.41 (0)	1.41 (0)
T_4 - POE 2,4-D at 1.25 kg ha^{-1}	1.49 (0.22)	1.59 (0.54)	1.63 (0.65)	1.71 (0.92)	1.56 (0.44)	1.41 (0)	1.41 (0)	1.41 (0)
T_5 -PE metribuzin at 1.00 kg ha^{-1} fb POE Glyphosate at 1.00 kg ha^{-1}	1.41 (0)	1.41 (0)	1.41 (0)	1.41 (0)	1.53 (0.34)	1.41 (0)	1.41 (0)	1.41 (0)
T_6 - EPOE halosulfuron methyl at 50 g ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	1.50 (0.24)	1.61 (0.60)	1.68 (0.82)	1.75 (1.07)	1.41 (0)	1.41 (0)	1.41 (0)	1.41 (0)
T_7 -PE metribuzin at 1.00 kg ha^{-1} fb POE 2,4-D at 1.00 kg ha^{-1}	1.48 (0.18)	1.55 (0.41)	1.58 (0.50)	1.68 (0.81)	1.41 (0)	1.41 (0)	1.41 (0)	1.41 (0)
T_8 -PE metribuzin at 1.00 kg ha^{-1} + POE 2,4-D at 1.00 kg ha^{-1} fb POE glyphosate at 1.00 kg ha^{-1}	1.41 (0)	1.41 (0)	1.41 (0)	1.41 (0)	1.41 (0)	1.41 (0)	1.41 (0)	1.41 (0)
T_9 - Unsprayed (Control)	1.71 (0.92)	1.82 (1.32)	1.89 (1.56)	1.97 (1.87)	2.00 (2.01)	2.07 (2.29)	2.10 (2.41)	2.17 (2.72)
SEd	0.28	0.01	0.01	0.02	0.01	0.02	0.02	0.03
C.D (P=0.05)	NS	0.03	0.03	0.04	0.04	0.04	0.05	0.06

PE -pre emergence, EPOE -early post emergence, POE - post emergence. BHS- Before herbicide Spray (0 day), DAHS – Day after herbicide spray. NS- Non-significant

Figures in the parenthesis are original values,

Early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1} continued to result in higher *Cyperus* control efficiency of 72.85 per cent, whereas the lower *Cyperus*control efficiency was obtained in post-emergence application of 2,4-D at 1.25 kg ha^{-1} (50.0 per cent) at 30 DAHS. Similar trend was noticed at 60 DAHS also.All the stages of observation, halosulfuronmethyl at 67.5, 75.0 and 150.0 g ha^{-1} gave 96.4 to 97.0 % control of *C. rotundus*. Comparatively *C. rotundus* density increased in atrazine applied plot followed by 2,4-D treatment (12.5 %) and 21.5 % increase in untreated check over pre-treatment density was earlier reported by Mehar Chand *et al*. (2013).

Other weeds characters

Grass weeds density

The data on grass weed density recorded before herbicide spraying (BHS) 0th day and at 15, 30 and 60 days after herbicide spraying (DAHS) are presented in Table 5. The grass weed density was significantly affected by different weed control treatments.

Before herbicide spraying (0th day), grass weed density was significantly lower in early post-emergence application of halosulfuron methyl at 75 g ha^{-1} and it was on par with post-emergence application of glyphosate at 1.25 kg ha^{-1}, pre-emergence application of metribuzin at 1.00 kg ha^{-1} fb post-emergence application of glyphosate at 1.00 kg ha^{-1}and pre-emergence application of metribuzin at 1.00 kg ha^{-1} + 2,4-D at 1.00 kg ha^{-1} fb post-emergence application of glyphosate at 1.00 kg ha^{-1}

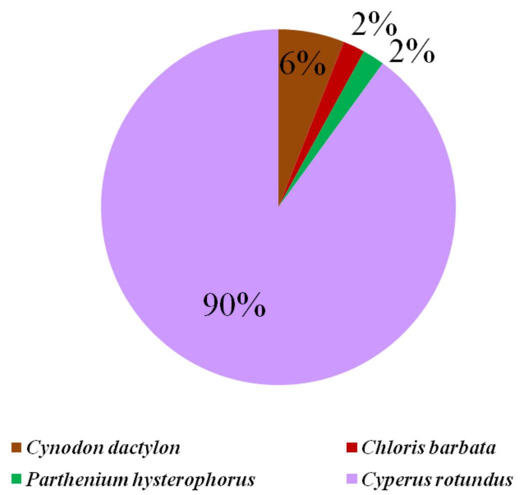

Fig.1 Relative density of predominant weed species in the experimental field

At 15 DAHS, there was reduction in grass weed density significantly lower in early post-emergence application of halosulfuron methyl at 75 g ha^{-1} which was on par with post-emergence application of glyphosate at 1.25 kg ha^{-1}, pre-emergence application of metribuzin at 1.00 kg ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}and pre-emergence application of metribuzin at 1.00 kg ha^{-1} + 2,4-D at 1.00 kg ha^{-1} fb post-emergence application of glyphosate at 1.00 kg ha^{-1}. The same trend was followed in 30 and 60 DAHS. However, the higher grass weed density was registered in unsprayed control.The findings are in line with the observation made by Barros *et al.* (2007). They have reported that the sulfuronyl urea herbicides at the dose of 0.4 kg ha^{-1} recommended by the manufacturer, to obtain sufficient control of the grass weeds.

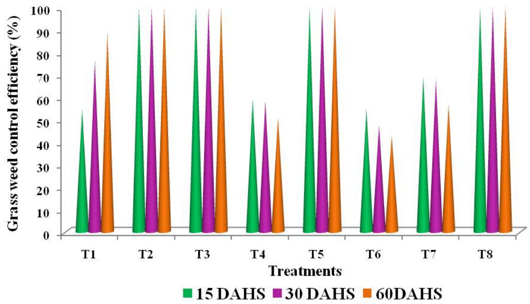

Fig.2 Effect of pre-sowing weed management practices on control efficiency (%) of grass weeds

Broad leaved weeds density

The data on broad leaved weed density recorded at BHS (0th day), 15, 30 and 60 DAHS are presented in Table 5.With regard to broad leaved weeds, application of different herbicides significantly influenced the density of broad leaved weeds at all the stages of observation. Before herbicide spraying (0th day), early post-emergence application of halosulfuron methyl at 50 g ha^{-1}+post-emergence application of glyphosate at 1.00 kg ha^{-1}, pre-emergence application ofmetribuzinat 1.00 kg ha^{-1} + 2,4-D at 1.00 kg ha^{-1} +post-emergence application of glyphosate at 1.00 kg ha^{-1} and pre-emergence application ofmetribuzinat 1.00 kg ha^{-1}fbpost-emergence application of 2,4-D at 1.00 kg ha^{-1} recorded lower broad leaved weed density. At 15 DAHS, broad leaved weed density was higher in unsprayed control and it was followed by early post-emergence application of halosulfuron methyl at 75 g ha^{-1} .The lower BLW density was noticed in post-emergence application of 2,4-D at 1.25 kg ha^{-1} and it was on par with pre-emergence application of metribuzin at 1.25 kg ha^{-1}, post-emergence application of glyphosate at 1.25 kg ha^{-1}, pre-emergence application ofmetribuzinat 1.00 kg ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1},early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}, pre-emergence application of metribuzinat 1.00 kg ha^{-1} fbpost-emergence application of 2,4-D at 1.00 kg ha^{-1}, pre-emergence application of metribuzin at 1.00 kg ha^{-1} + 2,4-D at 1.00 kg ha^{-1} fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}. The same trend was followed in 30 and 60 DAHS.Higher number of 2.33 broad leaf weeds m^{-2} were noticed in trifluralin treated plots, whereas zero (no weed) broad leaf weeds m^{-2} were recorded in plots treated with 2,4–D were reported by Punia *et al.*(2004).

Grass weeds dry weight

The data on grass weed dry weight was recorded at 15, 30 and 60 DAHS and are presented in Table 6.At 15 DAHS, dry weight of grass weeds was significantly lower in early post-emergence application of halosulfuron methyl at 75 g ha^{-1} which was on par post-emergence application of glyphosate at 1.25 kg ha^{-1}, pre-emergence application of metribuzin at 1.00 kg ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}and pre-emergence application of metribuzin at 1.00 kg ha^{-1} + 2,4-D at 1.00 kg ha^{-1} fbpost-emergence application of glyphosate at 1.00 kgha^{-1}. All the other treatments recorded higher dry weight but lower than unsprayed control.Similar trend was noticed at 30 DAHS and 60 DAHS also.This finding was in accordance with earlier reports Hossain *et al*. (2018) that post-emergence application followed by pre emergence herbicide reduced total grass weed dry weight by at least 97 per cent.

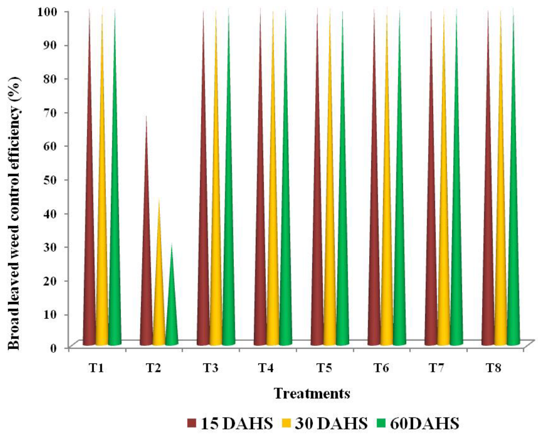

Fig.3 Effect of pre-sowing weed management practices on control efficiency (%) of broad leaved weeds

Broad leaved weeds dry weight

The data on broad leaved weed dry weight was recorded at BHS (0th day), 15, 30 and 60 DAHS and are presented in Table 6. Before herbicide spraying (0th day), broad leaved weed dry weight was significantly lower in early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fb post-emergence application of glyphosate at 1.00 kg ha^{-1} and it was on par with pre-emergence application of metribuzin at 1.00 kg ha^{-1}fbpost-emergence application of 2,4-D at 1.00 kg ha^{-1} and pre-emergence application of metribuzin at 1.00 kg ha^{-1} + 2,4-D at 1.00 kg ha^{-1} fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}.

At 15 DAHS, dry weight of broad leaved weed was significantly lower in pre-emergence application of metribuzin at 1.25 kg ha^{-1} and it was on par with post-emergence application of glyphosate at 1.25 kg ha^{-1}, post-emergence application of 2,4-D at 1.25 kg ha^{-1}, pre-emergence application ofmetribuzinat 1.00 kg ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}, early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}, pre-emergence application ofmetribuzinat 1.00 kg ha^{-1}fbpost-emergence application of 2,4-D at 1.00 kg ha^{-1} andpre-emergence application of metribuzin at 1.00 kg ha^{-1} + 2,4-D at 1.00 kg ha^{-1} fbpost-emergence application of glyphosate at 1.00 kg ha^{-1} . Higher broad leaved weed dry weight was recorded in unsprayed control which was followed by early post-emergence application of halosulfuron methyl at 75 g ha^{-1} .Similar trend was noticed in 30 DAHS and 60 DAHS also. The results are confirmative with the findings of Mehar Chand *et al*. (2013), who have reported that none of the doses of halosulfuron methyl affected the dry weight of grass as well as broad leaved weeds but atrazine (PE) followedby 2,4-D gave effective control of grasses andbroad leaved weeds.

Grass weeds control efficiency

The efficiency of pre-sowing weed management treatments on control of grass weed in terms of dry weight in comparison to control plot was worked out and presented in Fig 2.Significantly higher grass weed control efficiency was registered in early post-emergence application of halosulfuron methyl at 75 g ha^{-1} at 15 DAHS which was followed by post-emergence application of glyphosate at 1.25 kg ha^{-1}, pre-emergence application of metribuzinat 1.00 kg ha^{-1} fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}and pre-emergence application of metribuzinat 1.00 kg ha^{-1} + 2,4-D at 1.00 kg ha^{-1} fb post-emergence application of glyphosate at 1.00 kg ha^{-1}. Lowergrass weed control efficiency of 54.54 per cent was obtained with early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fbpost-emergence application ofglyphosate at 1.00 kg ha^{-1} and pre-emergence application ofmetribuzinat 1.25 kg ha^{-1} at 15 DAHS.At 30 and 60 DAHS, early post-emergence application of halosulfuron methyl at 75 gha^{-1} significantly recorded the higher weed control efficiency which was closely followed by post-emergence application of glyphosate at 1.25 kg ha^{-1}, pre-emergence application ofmetribuzin at 1.00 kg ha^{-1} fbpost-emergence application of glyphosate at 1.00 kgha^{-1} and pre-emergence application of metribuzin at 1.00 kg ha^{-1} +2,4-D at 1.00 kg ha^{-1} fbpost-emergence application of glyphosate at 1.00 kg ha^{-1}. The lower weed control efficiency was obtained with early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1} and pre-emergence application of metribuzin at 1.25 kg ha^{-1}.Results are in corroboration with the findings of Suganthi *et al*. (2013) who have reported that at 60 and 90 DAP also the higher weed control efficiency was obtained with combination at early post-emergence application of halosulfuron methyl at 180 g ha^{-1} which recorded the control efficiency of 66.73 and 83.15%, respectively.

Broad leaved weeds control efficiency

The efficiency of treatments on control of broad leaved weed in terms of dry weight in comparison to control plot was worked out and presented in Fig 3.At 15 DAHS, early post-emergence application of halosulfuron methyl at 75 g ha^{-1} recorded lower weed control efficiency of 68.55 per cent. Similar trend was noticed at 30 and 60 DAHS also. Higher control efficiency of broad leaved weeds was found in 2,4-D amine(67.14 %) form as reported by Hossain *et al*. (2018).

Conclusion

From the results of the present study, it can be concluded that, early post-emergence application of halosulfuron methyl at 50 g ha^{-1}fbpost-emergence application of glyphosate at 1.00 kg ha^{-1} was found significant in reducing the *Cyperus* density, dry weight and increase the control efficiency.

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