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Evaluation of Herbicide Mixtures for Weed Control in Maize (*Zea mays* L.)

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Abstract A field experiment was carried out to evaluate the tank-mix efficacy of new hydroxy-phenyl pyruvate dioxygenase (4-HPPD) herbicide with atrazine for weed control in maize (*Zea mays* L.) during *kharif* 2014. The experimental field was infested with five grasses, six broad leaved weeds and a sedge. Tank-mix application of topramezone or tembotrione @ 25.2 or 105 g/ha with atrazine @ 250 g/ha along with adjuvants effectively controlled all annual grassey weeds except *Cynodon dactylon* which was bleached but soon recovered after sometime *Cyperus rotundus* was also not very effected, where as it resulted in excellent control of broad leaf weeds. These treatments also recorded highest grain yield and yield attributes on par with hand weeding at 20 and 40 DAS.

Keywords Herbicide mixtures, Maize, Topramezone, Tembotrione, Relative density.

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Introduction

Maize is one of the most important cereal crops in the world's agriculture economy both as food for human being and feed for animals. There are about 100 weed species in 66 genera and 24 plant families known to be problematic for maize in the country (Patel et al. 2006). The magnitude of yield reduction due to infestation of grassy weeds, non-grassy weeds and sedges alone has been reported around 84.4, 31.7 and 21.5%, respectively (Pandey et al. 2001). Chemical weed control is a better supplement to conventional methods and forms an integral part of the modern crop production. Most of the presently available herbicides provide only a narrow spectrum weed control. Many of them have activity only on annual species, while a few are only effective against perennials. Continuous usage of same herbicide or similar herbicides year after year over several years do certainly lead to elimination of sensitive weed species but leave out the tolerant weed species resulting in a gradual buildup of their population. Hence, use of two different chemicals with different mode of action enhanced the efficacy of weed control. Keeping in view the present investigation was carried out to study the bio-efficacy of new hydroxy-phenyl pyruvate dioxygenase (4-HPPD) inhibiting herbicides (topramezone and tembotrione) with atrazine on weed growth and yield of maize.

Materials and Methods

Field experiment was carried out at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendra-

Table 1. Effect of different weed control treatments on relative density (%) in maize at 20 DAS. *Cd-Cynodon dactylon, Ds-Digitaria sanguinalis, Re-Rottboellia exaltata, Cr- Cyperus rotundus,Ph-Parthenium hysterophorus,Cb- Commelina benghalensis, Av-Amaranthus viridis, Eg-Euphorbia geniculata, Tp- Trianthema portulacastrum.*

Sl. No.	Treatments	Grasses				Sedges		BLW				
		Cd	*Ds*	*Re*	Total	*Cr*	*Ph*	*Cb*	*Av*	*Eg*	*Tp*	Total
T_1	Atrazine (1.0 kg/ha) as PE *fb* inter-cultivation at 30 DAS	12.9	0.0	10.4	23.3	63.9	0.0	9.9	0.0	2.9	0.0	12.8
T_2	Topramezone (25.2 g/ha)+MSO (adjuvant) as PoE	17.4	0.0	10.0	27.4	57.3	0.0	10.2	5.0	0.0	0.0	15.3
T_3	Tembotrione (105 g/ha)+stefes mero (adjuvant) as PoE	16.4	0.0	8.4	24.9	57.7	0.0	10.4	5.1	2.0	0.0	17.4
T_4	Topramezone+atrazine, (25.2+250 g/ha)+ stefes mero (adjuvant) tank mix as PoE	10.1	0.0	4.1	14.3	74.5	0.0	7.1	4.2	0.0	0.0	11.3
T_5	Tembotrione+atrazine, (105+250 g/ha)+ stefes mero (adjuvant) tank mix as PoE	11.9	0.0	4.7	16.7	71.2	0.0	8.4	3.8	0.0	0.0	12.2
T_6	Tembotrione (105 g/ha) as PoE	15.8	0.0	7.6	23.4	60.1	0.0	10.8	3.9	1.8	0.0	16.5
T_7	Inter-cropping of maize with cowpea and application of pendimethalin (1.0 kg/ha) as PE	20.1	0.0	8.9	29.0	52.8	0.0	18.3	0.0	0.0	0.0	18.3
T_8	Hand weeding at 20 and 40 DAS	15.4	2.0	16.1	33.5	27.0	5.8	15.0	11.1	5.1	2.7	39.6
T_9	Inter-cultivation at 20 and 40 DAS	16.5	2.4	15.1	34.0	25.9	5.2	14.9	11.8	5.9	2.3	40.1
T_{10}	Unweeded control	17.1	2.9	15.6	35.6	25.8	5.4	16.5	12.0	1.1	3.5	38.6

nagar, Hyderabad situated at an altitude of 542.6 m above mean sea level (MSL) at $18^0 50'$ N latitude and $77^0 53'$ E longitude during *kharif* 2014. The soil of the experimental field was sandy loam in texture with pH of 7.6 low in available nitrogen (255 kg/ha), medium in available phosphorus (25 kg/ha) and potassium (263 kg/ha). The experiment was laid out in randomized block design (RBD) with ten treatments and three replications comprising of atrazine 50% WP @ 1.0 kg/ha as pre-emergence *fb* inter-cultivation at 30 DAS, topramezone 33.6% SC @ 25.2 g/ha along with methylated seed oil (adjuvant), tembotrione 42% SC@ 105 g/ha along with stefes mero (adjuvant), topramezone + atrazine@ 25.2 + 250 g/ha with methylated seed oil, tembotrione + atrazine 105 + 250 g/ha with stefes mero, tembotrione 42% SC @ 105 g/ha, inter-cropping of maize with cowpea and pendimethalin 30% EC @ 1.0 kg/ha as pre-emergence, hand weeding at 20 and 40 DAS, inter-cultivation at 20 and 40 DAS and unweeded control. Total 30 plots were laid out in the field with the plot size of 5.4 m ×4.0 m maize hybrid DHM-117 were dibbled manually at 60 cm between and 20 cm within the line @ 25 kg seed/ha during the first week of July. All the pre and post-emergence herbicides were applied as per treatment using knapsack sprayer fitted with flat fan nozzle by mixing in 500 L of water ha^{-1}. After sowing of the seed immediately a light irrigation was given to the crop for uniform germination and next day the herbicide was spray as per the treatment. Fertilizer @ 180:60:60 kg of N, P_2O_5 and K_2O/ha in the form of urea, di-ammonium phosphate and muriate of potash was applied, entire dose of P_2O_5, $^1/_3$ of N, $^1/_2$ of K_2O were applied as basal. Nitrogen was applied in two more splits at knee height stage and at tasseling stage along with $^1/_2$ of K_2O. The package of recommended practices was adopted to maintain the crop. The observations of weed density and their dry matter were taken randomly from 0.25 m^2 quadrat at 2 spots from each treatment and data were transformed to square root before their statistical analysis.

$$\text{Relative density (\%)} = \frac{\text{Density of individual species in a treatment}}{\text{Total density of all the species in that treatment}}$$

Results and Discussion

Twelve weed species were observed in the experimental plots comprising of *Cynodon dactylon, Digitaria sanguinalis, Dactyloctenium aegyptium, Echinocloa* spp, *Rottboellia exaltata* among the grasses *Parthenium hysterophorus, Commelina benghalensis, Amaranthus viridis, Euphorbia*

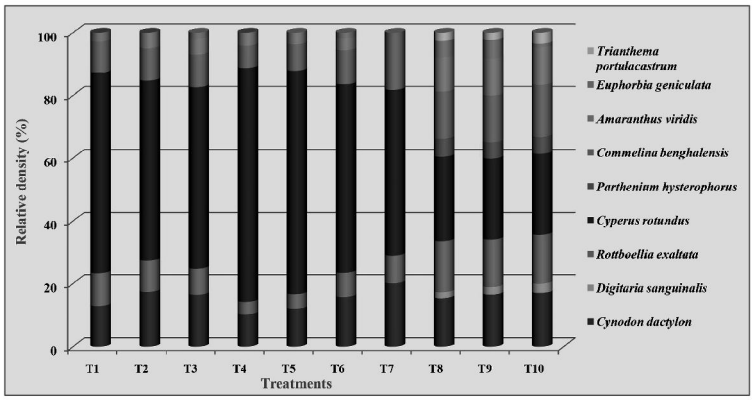

Fig. 1. Effect of different weed control treatments on relative density (%) in maize at 20 DAS.

geniculata, Digera arvensis L. and *Trianthema portulacastrum* L. among the broad leaf weeds and sedge *Cyperus rotundus.*

Effect on weeds

At 20 DAS (Table 1, Fig. 1) tank mix application of topramezone+atrazine@ 25.2 + 250 g/ha+MSO asPoE recorded higher (74.5%) relative density of *Cyperus rotundus* and lower relative density of grasses (14.3%) and broad leaf weeds (11.3%). Relative densities of sedges, grasses and broad leaf weeds in tembotrione + atrazine @ 105 + 250 g/ha + stefes mero as PoE was 71.2%, 16.7% and 12.2% respectively.

Table 2. Effect of different weed control treatments on relative density (%) in maize at 40 DAS. *Cd-Cynodon dactylon, Ds-Digitaria sanguinalis, Dae- Dactyloctenium aegyptiacum, Ec- Echinocloa* sps, *Re- Rottboellia exaltata, Cr- Cyperus rotundus, Ph-Parthenium hysterophorus, Cb-Commelina benghalensis, Av- Amaranthus viridis, Eg-Euphorbia geniculata, Da- Digera arvensis, Tp- Trianthema portulacastrum.*

Sl. No.	Treatments	Grasses						Sedges		BLW					
		Cd	*Ds*	*Dae*	*Ec*	*Re*	Total	*Cr*	*Ph*	*Cb*	*Av*	*Eg*	*Da*	*Tp*	Total
T_1	Atrazine (1.0 kg/ha) as PE *fb* intercultivation at 30 DAS	21.4	5.9	0.0	9.0	6.9	43.2	32.5	6.9	12.8	0.0	0.0	0.0	4.6	24.3
T_2	Topramezone (25.2 g/ha)+ MSO (adjuvant) as PoE	18.0	1.3	0.0	2.2	7.7	29.2	43.4	4.0	13.0	1.3	2.5	2.5	4.0	27.4
T_3	Tembotrione (105 g/ha)+ stefes mero (adjuvant) as PoE	19.7	0.0	1.4	0.0	7.7	28.8	41.8	3.8	13.2	3.4	2.8	2.8	3.5	29.5
T_4	Topramezone+atrazine, (25.2+ 250 g/ha)+MSO (adjuvant) tank mix as PoE	15.9	0.0	0.0	0.0	7.1	22.9	60.6	3.2	10.7	0.0	0.0	0.0	2.5	16.5
T_5	Tembotrione+atrazine, (105+ 250 g/ha)+stefes mero (adjuvant) tank mix as PoE	17.5	0.0	0.0	0.0	6.1	23.6	56.2	5.4	11.0	0.0	0.0	0.0	3.8	20.2
T_6	Tembotrione (105 g/ha) as PoE	15.9	0.0	1.2	0.0	7.9	25.0	43.0	5.3	13.9	4.5	2.9	2.9	2.5	32.0
T_7	Inter-cropping of maize with cowpea and application of pendimethalin (1.0 kg/ha) as PE	22.3	2.9	0.0	0.0	5.4	30.7	45.7	2.5	13.4	1.7	2.6	2.6	0.8	23.6
T_8	Hand weeding at 20 and 40 DAS	18.6	0.0	0.0	0.0	13.0	31.7	42.0	0.0	6.4	3.2	8.3	8.3	0.0	26.3
T_9	Inter-cultivation at 20 and 40 DAS	12.6	11.8	0.0	0.0	9.1	33.5	41.8	0.0	9.1	3.0	6.3	6.3	0.0	24.7
T_{10}	Unweeded control	15.5	3.2	1.7	2.7	13.6	36.7	27..6	4.8	13.6	9.7	1.8	1.8	4.2	35.8

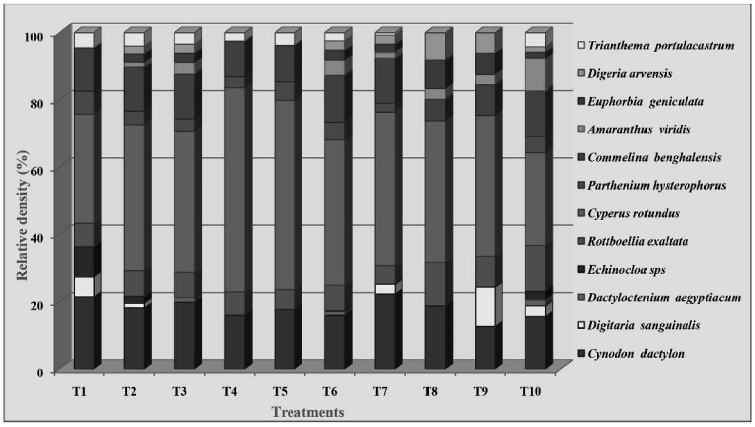

Fig. 2. Effect of different weed control treatments on relative density (%) in maize at 40 DAS.

The higher relative density of *Cyperus rotundus* (sedge) in these treatments was due to the effective control of broad leaf weeds like *Parthenium hysterophorus, Euphorbia geniculata* and *Trianthema portulacastrum;* grasses *Digitaria sanguinalis* and *Rottboellia exaltata* with zero predominance and presence of very few number of broad leaf weeds like *Commelina benghalensis* and *Amaranthus viridis;* grasses *Cynodon dactylon* and *Rottboellia exaltata*. Relative density of *Cyperus rotundus* in tank mix of topramezone + atrazine @ 25.2 + 250 g/ha without adjuvant was 57.3% and *Cynodon dactylon* was 17.4% which is comparatively lower than the treatments where adjuvants were mixed with the herbicide this is due to relative pre-dominance of higher number *Rottboellia exaltata* 10% and broad leaf weeds like *Commelina benghalensis* and *Amaranthus viridis* with 10.2% and 5.0% as a result of this the predominance of *Cyperus rotundus* and *Cynodon dactylon* was less in this treatments where as pre-emergence application of atrazine @ 1.0 kg/ha was very effective in controlling the broad leaf weeds with zero predominance of *Parthenium hysterophorus* and *Amaranthus viridis* and lower relative density of *Commelina benghalensis* and *Euphorbia geniculata* (9.9 and 2.9%). Unweeded control recorded relative density of grasses, sedges and broad leaf weeds was 35.6%, 25.8% and 38.6% respectively.

At 40 DAS (Table 2, Fig. 2) *Cyperus rotundus* was found to be most predominant weed with relative density varying from 32.5% to 60. 6% in different weed control treatments.Relative density of broad leaf weeds in different weed control treatments varied from 16.6% to 32.0%. Relative density of *Cynodon dactylon* and *Cyperus rotundus* in topramezone + atrazine @ 25.2 + 250 g/ha + MSO was 15.9% and 60.6%whereas in tembotrione + atrazine @ 105 + 250 g/ha + stefes mero as PoE the densities were 17.5% and 56.2%. *Digitaria sanguinalis, Dactyloctenium aegyptium, Echinocloa* spp, *Amaranthus viridis, Euphorbia geniculata, Digera arvensis* were totally controlled in these treatments. Combined relative density of *Cyperus rotundus* and *Cynodon dactylon* was 76.5% and 73.7% in tank mix of topramezone and tembotrione with atrazine respectively, indicating relative predominance of perennial weeds compared to annual grasses and BLW. *Commelina benghalensis* was the third most predominant weed with relative density of 10.7% and 11.0% in tank mix application of topramezone and tembotrione with atrazine and adjuvants respectively. Sole application of topramezone and tembotrione without atrazine resulted in reduced relative density of sedges (43.4% and 41.8%) compared to atrazine tank mix treatments. However, relative predominance of BLWs increased in these treatments indicating effectiveness of atrazine in controlling BLW. Application of atrazine as PE (1.0 kg/ha) *fb* IC at 30 DAS was effective in controlling of broad leaf weeds like *Amaranthus viridis, Euphorbia geniculata, Digera*

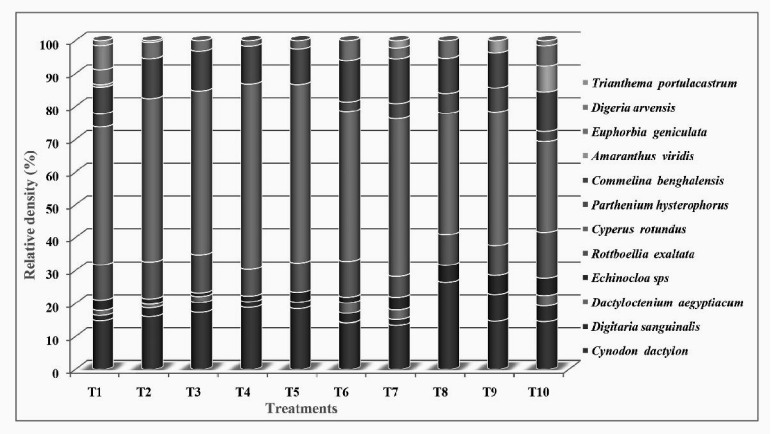

Fig. 3. Effect of weed control treatments on relative density (%) of maize at 60 DAS.

arvensis but grasses and sedges were not controlled effectively by atrazine indicating that it was less effective against grasses and sedges. Similar observation was reported by Praveen and Murthy (2005). Unweeded control recorded 36.7% relative density of grasses *(Cynodon dactylon, Digitaria sanguinalis, Dactyloctenium aegyptiacum, Rottboellia exaltata)* 27.6% of *Cyperus rotundus* and 35.8% of broad leaf weeds *(Parthenium hysterophorus, Commelina benghalensis, Amaranthus viridis, Euphorbia geniculata, Digera arvensis, Trianthema portulacastrum).*

At 60 DAS (Table 3, Fig. 3) predominance of perennial weeds was more compared to annual weeds due to poor control of *Cyperus rotundus* and *Cynodon dactylon,* similar to that at 40 DAS. Tank mix application of topramezone and tembotrione @ 25.2 and 105 g/ha with atrazine (250 g/ha) along with adjuvant recorded zero relative density of Dactyloctenium aegyptium, 1.7% and 1.9% relative density of *Digitaria sanguinalis,* 8.1% and 8.9% of *Rottboellia exaltata* which was lower compared to application of topramezone and tembotrione alone without atrazine. This might be due to the residual effect of atrazine in tank mix application with topramezone and tembotrione which resulted in lower relative density.

Effect on yield attributes and yield of maize

Hand weeding carried out at 20 and 40 DAS (Table 4) recorded more number of cobs/ha, girth of cob, cob weight, highest number of grains per cob, 100 seed weight followed by topramezone + atrazine @ 25.2 + 250 g/ha + MSO as PoE which was on par with tembotrione + atrazine @ 105 + 250 g/ha + stefes mero as PoE, atrazine as PE @ 1.0 kg/ha *fb* IC at 30 DAS and IC at 20 and 40 DAS. Lowest was recorded in unweeded control. The increase in the yield attributes is due to the lower weed competition which resulted better growth and development of maize which led to higher photosynthetic activities that resulted in the production of enough assimilates for subsequent translocation from vegetative parts to developing grains. Similar observation was made by Nadiger et al. (2013). In general, twice hand weeding at 20 and 40 DAS recorded highest grain yield of 6580 kg ha^{-1} i.e. 60.5% increase over the unweeded control and was on par with topramezone + atrazine @ 25.2 + 250 g/ha + MSO as PoE with 59.6% increase, tembotrione + atrazine @ 105 + 250 g/ha + stefes mero as PoE (6282 kg/ha) with 58.7% over the unweeded control. These findings were substantiating with the results of Madhavi et al. (2014) and Paradkar and Tiwari (2014), who reported that efficiency of maize crop to partition the dry matter in to its economic yield was highest in tank mix application of HPPD inhibiting herbicides with atrazine. Whereas, inter-cropping with cowpea and application of pendimethalin @ 1.0 kg/ha as PE recorded 44.9% yield increase over unweeded control the yield reduction in inter-cropping treatment compared to other treatments is due to the competi-

Table 3. Effect of different weed control treatments on relative density (%) in maize at 60 DAS. *Cd-Cynodon dactylon, Ds-Digitaria sanguinalis, Dae- Dactyloctenium aegyptiacum, Ec- Echinocloa* sps., *Re- Rottboellia exaltata, Cr-Cyperus rotundus, Ph- Parthenium hysterophorus, Cb-Commelina benghalensis, Av-Amaranthus viridis, Eg-Euphorbia geniculata, Da- Digera arvensis, Tp- Trianthema portulacastrum.*

Sl. No.	Treatments	Grasses					Sedges			BLW					
		Cd	*Ds*	*Dae*	*Ec*	*Re*	*Total*	*Cr*	*Ph*	*Cb*	*Av*	*Eg*	*Da*	*Tp*	*Total*
T_1	Atrazine (1.0 kg/ha) as PE *fb* inter-cultivation at 30 DAS	14.8	1.6	1.6	3.1	10.7	31.8	42.0	4.0	8.1	0.8	4.6	7.2	1.6	26.2
T_2	Topramezone (25.2 g/ha) + MSO (adjuvant) as PoE	16.0	2.7	1.1	1.6	11.2	32.7	49.8	0.0	12.1	0.0	4.9	0.5	0.0	17.5
T_3	Tembotrione(105 g/ha) + stefes mero (adjuvant) as PoE	17.4	2.9	1.8	1.1	11.6	34.9	49.7	0.0	12.2	0.0	3.2	0.0	0.0	15.4
T_4	Topramezone+atrazine, (25.2+250 g/ha)+ MSO (adjuvant) tank mix as PoE	18.9	1.7	0.0	1.7	8.1	30.4	56.4	0.0	11.5	0.0	1.7	0.0	0.0	13.2
T_5	Tembotrione+atrazine, (105+250 g/ha) + stefes mero (adjuvant) tank mix as PoE	18.5	1.9	0.0	3.0	8.9	32.3	54.3	0.0	10.8	0.0	2.6	0.0	0.0	13.4
T_6	Tembotrione (105 g/ha) as PoE	14.2	2.9	3.1	1.8	10.9	32.8	45.6	2.9	12.7	0.0	6.0	0.0	0.0	21.6
T_7	Inter-cropping of maize with cowpea and application of pendimethalin (1.0 kg/ha) as PE	13.4	1.8	2.9	3.8	6.4	28.3	48.0	4.5	13.7	0.0	3.2	0.0	2.3	23.7
T_8	Hand weeding at 20 and 40 DAS	26.4	0.0	0.0	5.3	9.2	40.9	37.0	6.0	10.8	0.0	5.3	0.0	0.0	22.1
T_9	Inter-cultivation at 20 and 40 DAS	14.7	8.1	0.0	5.8	9.0	37.6	40.7	7.3	10.7	3.7	0.0	0.0	0.0	21.7
T_{10}	Unweeded control	14.5	4.8	3.1	5.3	12.9	40.6	27.8	3.0	11.9	6.0	6.0	3.7	1.6	32.2

tion for space, light, water and nutrients as intercrop was having shading effect, curtailed the efficient utilization of natural resources and restricted the growth of maize from initial stages to harvest which resulted in lower yield and yield attributes. Similar findings were observed by Haque et al. (2008) and Hussain et

Table 4. Effect of different weed control treatments on yield attributes in maize.

Sl. No.	Treatments	No. of cobs ($000ha^{-1}$)	Length of cob (cm)	Girth of cob (cm)	Grain rows	Grains in a row	Grain number /cob	Test weight (g)	Cob weight (g)	Grain yield (kg/ha)
T_1	Atrazine (1.0 kg/ha) as PE *fb* inter-cultivation at 30 DAS	73.9	15.00	15.47	13.6	26.8	364.48	24.7	133.1	5721
T_2	Topramezone (25.2 g/ha)+ MSO (adjuvant) as PoE	72.2	13.83	14.58	13.2	26.5	349.8	24.4	123.1	4992
T_3	Tembotrione (105 g/ha) + stefes mero (adjuvant) as PoE	70.2	13.43	14.43	13.2	26.3	347.16	24.1	120.6	4834
T_4	Topramezone + atrazine, (25.2+250 g/ha) + MSO (adjuvant) tank mix as PoE	75.1	15.53	15.84	14.0	27.4	383.6	25.4	148.3	6436
T_5	Tembotrione + atrazine, (105+250 g/ha) + stefes mero (adjuvant) tank mix as PoE	74.1	15.23	15.73	13.6	27.3	371.28	25.2	145.7	6282
T_6	Tembotrione (105 g/ha) as PoE	71.2	13.32	14.17	13.2	24.2	319.4	21.6	116.5	4527
T_7	Inter-cropping of maize with cowpea and application of pendimethalin (1.0 kg/ha) as PE	70.1	13.30	13.54	12.8	24.0	307.2	21.2	104.8	(4711) (MEY)
T_8	Hand weeding at 20 and 40 DAS	76.5	15.90	16.76	14.4	28.2	406.1	26.1	167.8	6580
T_9	Inter-cultivation at 20 and 40 DAS	72.6	15.00	15.23	13.2	26.7	352.4	24.3	130.2	5486
T_{10}	Unweeded control	66.3	12.80	12.07	12.0	19.2	230.4	18.2	98.7	2594
	SEm (±)	0.76	0.95	0.2	0.63	0.19	8.17	0.17	9.59	120.3
	CD (0.05%)	2.3	NS	0.68	NS	0.65	25.2	0.54	28.7	360.3

al. (2008).

Conclusion

Based on the findings emerged out from the present investigation, use of herbicide mixtures along with adjuvants as post-emergence application rather than a single herbicide is more effective in weed control in *kharif* maize or if laborers are available easily then twice hand weeding done at 20 and 40 DAS was also found to be effective for weed control.

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