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HERBICIDES IN WEED MANAGEMENT OF MAIZE AND YIELD POTENTIAL OF MAIZE-COWPEA CROPPING SYSTEM IN PUNJAB

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Abstract

A field experiment was conducted at the Division of Agriculture, Lovely Professional University, Jalandhar, and Punjab, India during spring and rabi 2021-22 in a randomized block design with eight weed treatments and three replications. The lowest weed density and biomass, highest weed control efficiency and maize growth parameters, yield characteristics, kernel and straw yields were recorded with post-emergence application of 2, 4-D Na combined with hand weeding at 60 DAS which was statistically at same level as hand weeding Twice (30 & 60 DAS) followed by (fb) pre-emergence application (PE) of Atrazine with Single hand weeding at 30 DAS. Pre-emergence application of pendimethalin combination with single hand weeding at 30 DAS, which was comparable to pendimethalin, showed higher cowpea seed yield, tiller yield and lower total weed density and biomass in subsequent pea tubs) PE closely followed by quizalofop-ethyl applied to cowpea. Based on this study, it was concluded that post-emergence application of 2, 4-D Na combined with one hand weeding at 60 DAS in spring maize and pre-emergence application of pendimethalin combination with single hand weeding at 30 DAS can be used for the most effective weed control to increase the productivity of spring maize followed by summer cowpea cropping system.

Keywords: cropping system; weeds; herbicides; weed index, economics

1. INTRODUCTION

Maize (Zea mays L.) is one of the most important cereals in India, playing a vital role in the agricultural economy as a staple food and fodder for a large proportion of the population and livestock, as well as a raw material for industry. Maize is the second most important cereal in the world in terms of production. Maize is one of the most versatile emerging crops that has wider adaptability in different

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agro-climatic conditions and successful cultivation in different seasons and ecology for different purposes. Worldwide, maize is known as the "queen" of cereals because it has the highest genetic yield potential among cereals. Maize is grown throughout the year across the Indian state for various purposes including grain, fodder, green ears, sweet corn, baby corn, popcorn in peri-urban areas. Punjab is the main growing state of India, an area with a corn crop of 165 thousand hectares with a productivity of 610 thousand tons. Maize productivity in Punjab is about 3697 kg/ha [1]. Maize is very sensitive to weed competition in the early growing season. Corn plant growth in the first 3 to 4 weeks is relatively slow and during this period weeds quickly become established and competitive. Maximum weed competition in corn occurs during the 2- to 6-week post-sowing (WAS) period, indicating the importance of maintaining a weed-free crop during this critical period of weed competition. Yield losses reported for maize due to uncontrolled weed growth ranged from 40 to 60 percent [15]. Among the various biotic and abiotic factors that affect maize production, weed management is the most important factor. Intense weed competition is one of the main constraints to maximizing crop productivity. Currently, there is a global concern about environmental safety and the increasing use of agrochemicals such as herbicides and their persistence in the agroecosystem [4]. In this situation, instead of constant chemical control, seeding early-maturing catch crops in wider row crops such as corn helps quickly cover empty inter-row spaces and keep weeds under control. In addition to reducing weeding costs, intercropping improves the overall productivity of the system. Therefore, to minimize the overuse of herbicides and their adverse effects such as residual toxicity, etc., planting early maturing catch crops such as legumes in wider corn rows provides little room for weed growth and provides significantly higher corn yield.

Cowpea (Vigna unguiculata (L.) cultivated worldwide primarily for seed but also as a vegetable (for leafy greens, green pods, fresh shelled green peas and shelled dried peas), as a cover crop and for forage [2]. It is one of the staple kharif pulses grown in India for grain, fodder and green manure tenacity and commonly known as lobia. Cowpea is also called plant meat because it is rich in protein 19-26% (average 22.5%), carbohydrates 60.3 %, minerals and vitamins. Cowpea can make a very significant contribution to livestock feed on the one hand and supply available nitrogen to the soil on the other, it is a dual-purpose attractive crop mainly in arid and semi-arid ecologies of the world. Cowpea is grown all over the country in small pockets for its food and fodder. It is a deep-rooted crop with good drought tolerance. Now a multi-purpose crop, cowpea can be grown as a single crop, intercrop, catch crop, relay crop, shield grain and green manure crops etc. in sequential/mono-cropping in different agro-ecological regions of the world. During the kharif season, the crop suffers severely due to weeding, resulting in a widespread decline in crop yield. The critical period of weed competition in cowpea was considered to be 20-30 days after sowing, and the appearance of weeds after this period causes a significant reduction in yields [7]. Therefore, the need for weed control should be anticipated during the primary growing age of crops. Although manual weeding is a well-proven effective method of weed control, the unavailability of labor and the costs incurred are very high. In view of the fact, this trial was aimed at discovering a suitable and cost-effective weed management practice to stop weeds in the critical period of crop competition.

2. Materials and Methods

2.1 Area of the Study

The experiment was initiated with furrow-planted Maize in spring of 2020 and completed in Kharif season Cowpea in 2022. Two years of a cropping cycle has been completed in the division farm

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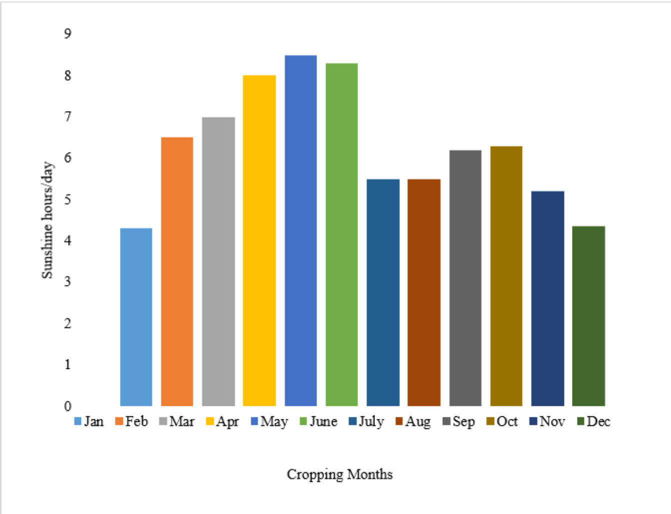
research department Lovely Professional University (LPU), Jalandhar Punjab India. The study was carried out in sandy to clay loam with light grey color. The structure of soil is loose and more fertile. But the soils are lesser in NPK and humus. Base Exchange capacity is low, pH ranges from 7 to 8 with less organic matter (OM).

2.2. Climatic Condition during Cropping Season

Punjab is one of the coolest states in India with a regular every day high temperature of up to 30 degrees centigrade. Some months of the annum is warm to hot at temperatures constantly upstairs 25 degrees centigrade, occasionally up to 39 degrees. The total of hours of sunlight refers to the time when the sun is really visible shown in (fig.1). That is, without any impediment of visibility by clouds, mist or mountains. Through 8-9 hours per day, May is the lightest month in country portion Punjab. Sunshine houses less in the month of December.

(Fig: 1) Hours of sunshine per day at experimental location



2.3. Experimental treatments and design

In maize, test the performance of five herbicides two was (Atrazine and Metribuzin as pre-emergence and Tembotrione, 2,4-D Na and Topramezone as post-emergence) was evaluated by comparing with the 'hand weeding' and 'unwedded' treatments as a check to detect the efficiency and cost-effectiveness of herbicide(s). The study deliberated eight treatments such as T_1 = Atrazine (700 g/ha as pre-emergence), T_2 = Atrazine (500 g/ha as pre-emergence) + One HW, T_3 = Metribuzin (800 g /ha as post-emergence), T_4 = Tembotrione (120 g/ha as post-emergence), T_5 = 2,4-D Na (800 g/ha as post-emergence), T_6 = Topramezone (200 g/ha as post-emergence), T_7 = Hand weeding Twice (manually weeded twice 30 & 60 DAS), and T_8 =Weedy check (no weed control). The experiment was directed in a randomized complete block design (RCB) and replied with three times.

For kharif cowpea, the effectiveness of four herbicides (one pre-emergence herbicide i.e. Pendimethalin; three post-emergence herbicide namely Pendimethalin + 1 HW, Imazethapyr, fb Quizalofop-ethyl, Metolachlor and Quizalofop-ethyl. was evaluated, where 'unwedded', treatments were considered as check. Therefore, treatments were: T_1= Pendimethalin (1.0 kg/ha), T_2 = Pendimethalin (1.0 kg/ha at 30 DAS) + 1 HW, T_3 = Imazethapyr (50 g/ha), T_4 = Quizalofop-ethyl (50 g/ha), T_5 = Metolachlor (1.0 kg/ha), T_6 = Quizalofop-ethyl (40 g/ha), T_7 = Hand weeding (manually

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weeded twice 20 & 40 DAS) and T_8 = Weedy check. The Kharif Cowpea trial was also arranged in the similar experimental field ensuing RCB design with three replications just after harvesting of spring maize.

3. RESULTS AND DISCUSSION

3.1. Impact of Herbicides on Weeds

In Maize, there were eight weed species observed in two years of spring 2021–2022; of these two were grasses. (Commelina benghalensis L., (Cynodon dactylon (L.) Pers) one was sedge (Cyperus rotundus (L.) and four were broadleaved weeds (Chenopodium album (L.), Parthenium hysterophorus (L.), and Cannabis sativus (L.) and Sinapis arvensis (L.)) [10, 12]

Pooled data (Table 1) exposed that species wise and total weed density of grasses, sedges, broad-leaved weeds was reduced substantially by post-emergence application of 2, 4-D Na (800 g/ha) + One HW at 60 DAS (table.) fb Atrazine (500 g/ha) + One HW at 30 DAS, Metribuzin (800 g /ha) The better performance of herbicide was undoubtedly due to the synergistic effect of herbicides with combination of hand weeding subsequent in reduced density as well as biomass of diverse weed species. These results were in close conformity with those of [11]. The highest weed density detected in weedy check among the rest of the treatments. (Table 2) The data revealed that all the weed management treatments significantly reduced dry matter of narrow-leaved, broad-leaved and total dry matter of weeds compared to weedy check. Post-emergence application of 2, 4-D Na (800 g/ha) + One HW at 60 DAS fb Atrazine (500 g/ha) + One HW at 30 DAS recorded the lowest weed biomass alike weedy check. Similar result were found with [17].

3.1.2 Effect of herbicides on weed control efficiency and weed index

Weed control efficiency (WCE) various with different weed control methods at 60 DAS (Table 3). In WCE, total weed dry weight was occupied into account which comprised of different weed species with variable proportions. WCE do not affect the individual weed species. Performance of crop is directly proportional to the WCE and inversely proportional to the weed index. At 60 DAS, the maximum (88.67%) WCE and weed index of grasses and sedges weeds were recorded with the post –emergence application 2, 4-D Na (800 g/ha) + 1 HW at 30 DAS followed by pre-emergence application of Atrazine (500 g/ha) + One HW at 30 DAS. It was caused by lower weed population and total dry weight of weeds in these treatments due to better control of weeds following revelation to PoE application of herbicides [8, 13]. The minimum WCE and higher WI where recorded in weedy check.

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Table 1: Effect of herbicides on species wise and total weed density (no. m^{-2}) at 60 days after sowing of Spring Maize by weed control treatments (pooled data of two years 2021- 2022)

Treatments	Grasses		Sedges	Broadleaf				Total weed density
	C. Benghalensis	C. Dactylon	C. Rotundus	C.Album	P. Hysterophorus	C. Sativus	S. Arvensis	
Atrazine (700 g/ha)	1.65	2.34	1.88	1.63	1.85	1.6	1.53	4.73
	-2.75	-5.51	-3.57	-2.68	-3.45	-2.56	-2.37	-22.41
Atrazine (500 g/ha) + One HW	1.53	2.29	1.72	1.14	1.13	1.2	1.24	4.02
	-2.37	-5.26	-2.98	-1.32	-1.28	(1.44	-1.56	-16.21
Metribuzin (800 g /ha)	1.7	2.55	1.86	1.57	1.79	1.54	1.17	4.73
	-2.89	-6.51	-3.47	-2.49	-3.23	-2.39	-1.39	-22.38
Tembotrione (120 g/ha)	1.57	2.55	3.5	2.61	3.17	3.32	3.47	7.83
	-2.48	-6.55	-12.3	-6.82	-10.1	-11.06	-12.06	-61.39
2,4-D Na (800 g/ha) + One HW	1.02	1.1	1.56	1.07	1.02	1.06	1.09	3.04
	-1.05	-1.21	-2.45	-1.16	-1.05	-1.13	-1.19	-9.25
Topramezone (200 g/ha)	1.76	2.67	2.48	2.21	1.76	2.76	1.98	6.12
	-3.11	-7.16	-6.16	-4.89	-3.11	-7.62	-3.94	-37.5
HW Twice (30 & 60 DAS)	1.11	1.63	2.44	1.21	1.1	1.12	1.06	3.87
	-1.24	-2.68	-6	-1.48	-1.22	-1.26	-1.14	-15.05
Weedy check	3.24	4.56	4.47	4.24	4.8	4.72	4.88	11.78
	-10.55	-20.81	-20.01	-18.04	-23.12	-22.32	-23.9	-138.92
SE (m±)	**0.11**	**0.09**	**0.09**	**0.1**	**0.1**	**0.1**	**0.08**	**0.06**
CD (p = 0.05)	**0.31**	**0.25**	**0.26**	**0.3**	**0.29**	**0.28**	**0.23**	**0.19**

*All values are square root transformed (√x+0.5).

Table 2: Effect of herbicides on species wise and total Weed dry biomass (g m^{-2}) at 60 days after sowing of Spring Maize by weed control treatments (pooled data of two years 2021- 2022)

Treatments	Grasses		Sedges	Broadleaf				Total weed
	C.Benghalensis	C.Dactylon	C. Rotundus	C. Album	P.Hysterophorus	C.Sativus	S. Arvensis	(g/m^2)
Atrazine (700 g/ha)	0.3	0.41	0.44	0.43	0.43	0.45	0.29	1.06
	-0.093	-0.175	-0.2	-0.185	-0.185	-0.206	-0.088	-1.13
Atrazine (500 g/ha) + One HW	0.27	0.33	0.37	0.4	0.41	0.39	0.27	0.95
	-0.077	-0.115	-0.137	-0.163	-0.175	-0.156	-0.078	-0.9
Metribuzin (800 g /ha)	0.33	0.36	0.38	0.42	0.42	0.43	0.29	1
	-0.115	-0.135	-0.148	-0.183	-0.177	-0.185	-0.085	-1.02
Tembotrione (120 g/ha)	0.31	0.75	0.48	0.52	0.47	0.45	0.31	1.31
	-0.099	-0.57	-0.24	-0.275	-0.225	-0.204	-0.099	-1.73
2,4-D Na (800 g/ha)	0.14	0.3	0.33	0.38	0.38	0.32	0.026	0.83
	-0.022	-0.094	-0.115	-0.145	-0.145	-0.103	-0.07	-0.69
Topramezone (200 g/ha)	0.32	0.45	0.4	0.46	0.44	0.41	0.031	1.07
	-0.107	-0.205	-0.163	-0.216	-0.195	-0.173	-0.097	-1.15
HW Twice (30 & 60 DAS)	0.25	0.63	0.34	0.32	0.39	0.33	0.027	0.95
	-0.063	-0.4	-0.117	-0.105	-0.154	-0.114	-0.074	-0.91
Weedy check	0.57	1.45	0.96	1.1	0.97	1.06	0.72	2.58
	-0.325	-2.11	-0.935	-1.215	-0.95	-1.13	-0.52	-6.67
SE (m±)	**0.03**	**0.05**	**0.04**	**0.05**	**0.05**	**0.06**	**0.04**	**0.1**
CD (p = 0.05)	**0.07**	**0.16**	**0.12**	**0.14**	**0.16**	**0.17**	**0.1**	**0.31**

*All values are square root transformed (√x+0.5).

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Table 3: Influence of herbicides on kinds of, total weed control efficiency at 60 days after sowing and WI (%) of Spring Maize by weed control treatments (pooled data of two years 2021 – 2022

Treatments	Grasses		Sedges	Broadleaf				Total weed control efficiency	WI (%)
	C.Benghalensis	C.Dactylon	C. Rotundus	C. Album	P.Hysterophorus	C.Sativus	S. Arvensis		
Atrazine (700 g/ha)	71.23	91.73	78.61	85.63	80.1	81.88	82.83	81.79	5.84
Atrazine (500 g/ha) + One HW	74.83	94.58	85.28	87.44	81.14	86.06	84.52	85.33	4.15
Metribuzin (800 g /ha)	74.31	93.63	84.15	85.93	81.35	83.67	83.96	83.64	4.93
Tembotrione (120 g/ha)	69.33	72.52	74.33	78.87	76.04	82.36	81.32	72.83	9
2,4-D Na (800 g/ha)+ 1 HW at 30 DAS	93.08	95.54	84.73	88.64	84.27	90.85	86.79	88.67	0
Topramezone (200 g/ha)	67.16	90.31	82.55	83.23	79.16	84.87	81.69	81.48	7.25
HW Twice (30 & 60 DAS)	80.47	87.05	87.47	91.65	83.43	89.82	86.03	83.48	0.79
Weedy check	0	0	0	0	0	0	0	0	44.95
SE (m±)	-	-	-	-	-	-	-	-	**0.47**
CD (p = 0.05)	-	-	-	-	-	-	-	-	**1.43**

*All values are square root transformed (√x+0.5).

Fig: 2 Weed species wise Weed control efficacy (%) (Maize 2021-2022)

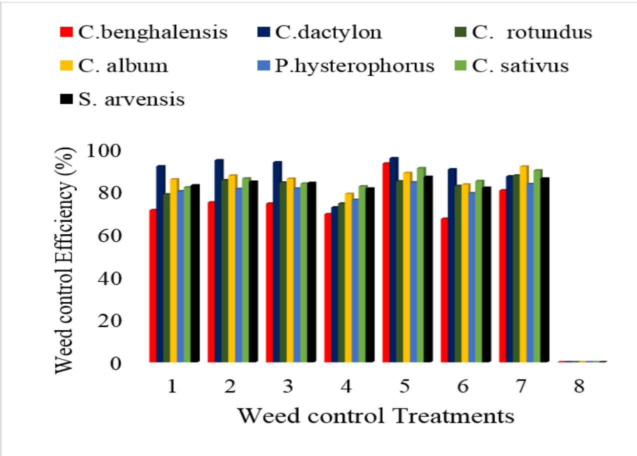

Fig: 3 Overall Weed control efficiency and Weed Index (%) (Maize-2021-2022)

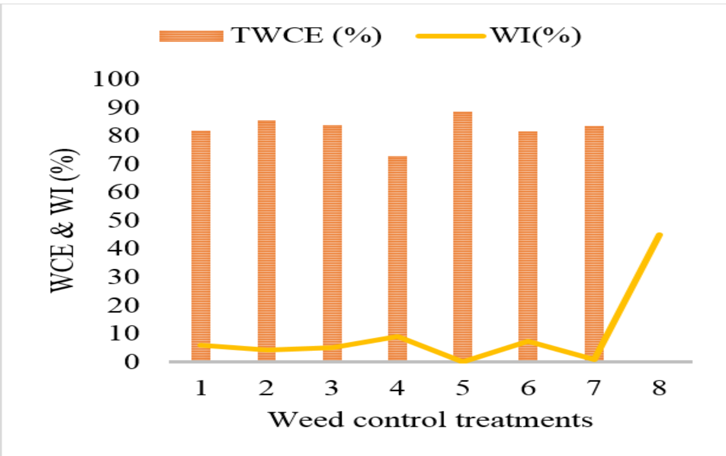

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Fig: 4 Species wise Weed control efficacy (%) (Cowpea-2021-2022)

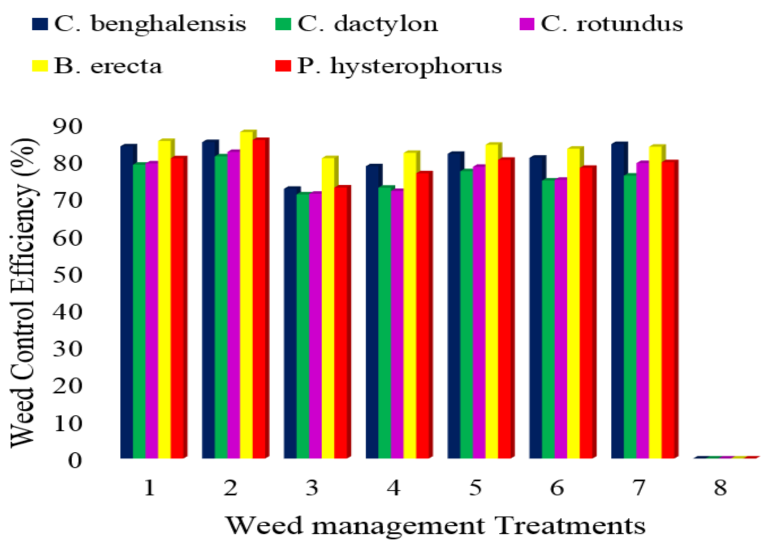
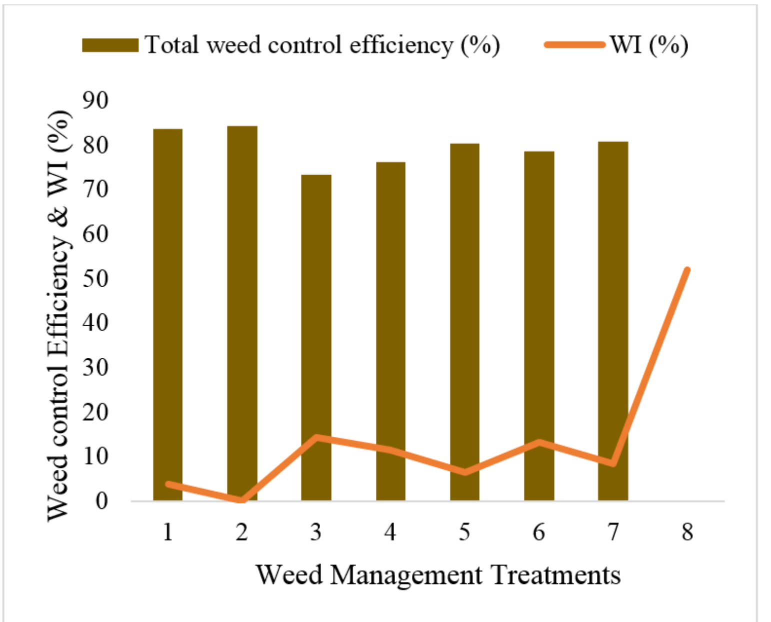


Fig: 5 Aggregate Weed control efficiency and Weed Index (%) (Cowpea-2021-2022)



3.2 Effect of herbicides on spring Maize

Pooled data (Table 4) revealed that all the weed management treatments significantly higher crop stand (cm) recorded in the post-emergence application of 2,4-D Na (800 g/ha) + One HW at 60 DAS fb Atrazine (500 g/ha) + One Hand weeding at 30 DAS. Less number of plants hectare^{-1} were observed in pre- emergence application of Metribuzin (800 g /ha) [16]. A comparatively lesser number of plants per hectare was recorded in the weed check (control) treatment but it did not bring a significant difference in plant population than all other treatments during both the years .All weed control

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treatments were significantly superior to untreated check in influencing plant height during 2021-2022. Controlling weeds is important in obtaining desired plant stand as evident from higher plant population under all treatments over the untreated check. The post-emergence application of 2, 4-D Na (800 g/ha) + One HW at 60 DAS fb Atrazine (500 g/ha) + One Hand weeding at 30 DAS resulted in taller maize plants among the rest of the treatments. Similar results have also been observed by [8, 19]. 60 days after sowing weed management method significantly affected the silking in maize. The maximum silking is observed in the combine application of 2, 4-D Na (800 g/ha) + One HW at 60 DAS fb Atrazine (500 g/ha) + One Hand weeding at 30 DAS. Significantly more number of days taken to 50% silking was recorded with the weedy check treatment as compared to all other treatments.

Table.4 Effect of herbicides on growth characters of Spring Maize at 60 DAS by weed control treatments (pooled data of two years 2021-2022)

Treatments	Plant count (No. m^{-2})	Plant tallness (cm)	Silking (50%)
Atrazine (700 g/ha)	9.5	91.97	80.27
Atrazine (500 g/ha) + One HW	9.0	96.75	84.67
Metribuzin (800 g /ha)	8.5	93.96	81.86
Tembotrione (120 g/ha)	8.0	90.79	76.71
2,4-D Na (800 g/ha) + One HW	9.5	98.50	87.16
Topramezone (200 g/ha)	8.5	93.72	80.74
HW Twice (30 & 60 DAS)	8.5	97.48	84.82
Weedy check	8.5	85.71	69.21
SE (m±)	**0.42**	**0.56**	**0.54**
CD (p = 0.05)	**1.26**	**1.71**	**1.63**

3.3 Effect of herbicides on yield and yield characteristics and economics of spring corn

Data (table 5) of a higher level of revenue attributes, viz. Number of ears/plant, number of rows of grain/cob and Weight of grain/cob (g) were recorded with post-emergence application of 2,4-D Na (800 g/ha) + one HW at 60 DAS fb Atrazine (500 g/ha) + one-handed weeding at 30 DAS. The improvement in yield attributes in the above treatment was primarily due to less weed competition during the weed competition period due to better post-emergence weed control, 2,4-D Na (800 g/ha) + one HW at 60 DAS. This was consistent with the findings of [19].

3.4. Economic Analysis

A grower's preference for any herbicide depends mostly on the efficacy and economics of weed control. In general, the cost of physical weeding is much higher than that of chemical weed control, which inspires many farmers to replace expensive and unpleasant manual weeding with herbicides. Considering the economics of different treatments, net cash returns were found to be high with post-emergence treatment of 2, 4-D Na (800 g/ha) + one HW at 60 DAS fb Atrazine (500 g/ha) + One hand weeding at 30 DAS. Through both years. Based on average benefit: cost ratio 2, 4-D Na (800 g/ha) + One HW at 60 DAS was strictly followed by Atrazine (500 g/ha) + One Hand weeding at 30 DAS, Metribuzin (800 g /ha) as pre-emergence. Minimum net cash returns, benefit: cost ratio was under control due to higher weed population and minimum yield. This result confirms the findings of [16, 20, 14, 4 and 5] who reported higher yields when using this combination of herbicides in conservatively grown maize.

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Table 5: Impact of herbicides on yield and yield attributes and economics of spring Maize2021-2022

Treatments	No. of cobs/plant	No. of kernel rows /cob	Weight of kernel /cob (g)	Seed yield Kg ha^{-1}	Straw yield (kg ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
Atrazine (700 g/ha)	1.67	14.96	72.75	4338	4338	73746	30355	1.70
Atrazine (500 g/ha) + One HW	2.13	15.37	80.14	4415	4425	75074	30645	1.69
Metribuzin (800 g /ha)	1.88	15.07	77.71	4380	4394	74475	31284	1.73
Tembotrione (120 g/ha)	1.62	14.48	70.45	4192	4222	71294	28080	1.65
2,4-D Na (800 g/ha)	2.60	16.50	86.22	4607	4659	78371	33287	1.74
Topramezone (200 g/ha)	1.71	15.01	75.62	4273	4312	72681	28378	1.64
HW Twice (30 & 60 DAS)	2.32	16.00	82.68	4570	4665	77794	29823	1.63
Weedy check	1.51	13.77	59.81	2536	2917	43494	2623	1.06
SE (m±)	**0.19**	**0.40**	**0.59**	**96.94**	**95.72**	**-**	**-**	**-**
CD (p = 0.05)	**0.57**	**1.22**	**1.78**	**294.01**	**290.35**	**-**	**-**	**-**

3.4 Result of herbicides on Weeds in Kharif Cowpea

Five different weed species were observed in Cowpea in two kharif years 2021-2022; of these two were grasses. (Commelina benghalensis (L.), (Cynodon dactylon (L.) Pers) one was sedge (Cyperus rotundus (L.) and two were broadleaf weeds. (Boerhavia erecta (L.) and Parthenium hysterophorusI (L.))[18].

Among treatments, weed density and weed biomass were statistically higher in the unwedded control. This was due to the uncontrolled growth of weeds during the growth period of the intact crop. Lower weed density and weed biomass (Table 6) was recorded at 40 DAS cowpea with pre-emergence application of Pendimethalin (1.0 kg/ha) + 1 hand weeding at 30 DAS fb HW (20 & 40 DAS) which was on par with Quizalofop-ethyl (40 g/ha). Weed control recorded the significantly highest density and biomass of grasses, sedges and broadleaf weeds in the subsequent vine. [3] Pendimethalin (1.0 kg/ha) also reported as pre-emergent has been found to be promising in reducing weed biomass.

Weed control efficiency in cowpea was significantly affected by weed control treatment, where all treatments resulted in increased weed control efficiency and minimum weed index compared to the weed control. (Table8). Highest value of WCE (84.29 %) was obtained from pre-emergence application of Pendimethalin (1.0 kg/ha) + 1 hand weeding at 30 DAS followed by Pendimethalin (1.0 kg /ha) PE. during weeding control, the minimum weed control efficiency and the maximum weed index are monitored. This may be due to lower weed density and weed dry matter production, which resulted in successful weed growth arrest over these treatments. [3] It also reports higher weed control efficiency with pre-emergence application of pendimethalin and post-emergence application of metolachlor.

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Table 6 : Effect of herbicides on species wise and total weed density (no. m^{-2}) at 40 days after sowing of Cowpea by weed control treatments (pooled data of two years 2021- 2022)

Treatments	Grasses		Sedges	Broadleaf		Total weed density (no. m^{-2})
	C. Benghalensis	C. Dactylon	C. Rotundus	B. Erecta	P. Hysterophorus	
Pendimethalin (1.0 kg /ha)	1.31 (1.72)	1.52 (2.34)	2.24 (5.03)	1.15 (1.34)	1.30 (1.71)	3.48 (12.16)
Pendimethalin (1.0 kg./ha) + 1 HW	1.05 (1.11)	1.07 (1.15)	1.43 (2.05)	1.00 (1.02)	0.74 (0.56)	2.29 (5.26)
Imazethapyr (50 g/ha)	1.74 (3.04)	1.69 (2.86)	2.45 (6.04)	2.68 (7.22)	2.49 (6.22)	5.04 (25.41)
Quizalofop-ethyl (50 g/ha)	1.71 (2.94)	1.62 (2.64)	2.96 (8.82)	1.52 (6.37)	2.30 (5.31)	5.14 (26.42)
Metolachlor (1.0 kg/ha)	1.59 (2.54)	1.38 (1.92)	1.4 (3.06)	1.88 (3.54)	1.48 (2.22)	3.50 (12.30)
Quizalofop-ethyl (40 g/ha)	1.31 (1.73)	1.24 (1.54)	1.59 (2.53)	1.24 (1.54)	1.14 (1.32)	2.88 (8.31)
HW (20 & 40 DAS)	1.10 (1.22)	1.15 (1.34)	1.44 (2.09)	0.70 (0.50)	1.10 (1.22)	2.52 (6.38)
Weedy check	2.77 (7.72)	2.59 (6.73)	1.53 (20.58)	3.37 (11.38)	3.29 (10.84)	7.54 (56.92)
SE (m±)	**0.095**	**0.11**	**0.11**	**0.12**	**0.12**	**0.13**
CD (p = 0.05)	**0.29**	**0.34**	**0.34**	**0.35**	**0.38**	**0.36**

*All values are square root transformed (√x+0.5).

Table 7: Effect of herbicides on species wise and total weed dry biomass (no. m^{-2}) at 40 days after sowing of cowpea by weed control treatments (pooled data of two years 2021- 2022)

Treatments	Grasses		Sedges	Broadleaf		Total weed dry biomass
	C. Benghalensis	C. Dactylon	C. Rotundus	B. Erecta	P. Hysterophorus	
Pendimethalin (1.0 kg /ha)	0.27 (0.077)	0.26 (0.072)	0.99 (0.99)	0.23 (0.054)	0.21 (0.046)	0.55 (0.303)
Pendimethalin (1.0 kg./ha) + 1 HW	0.26 (0.072)	0.25 (0.064)	0.28 (0.079)	0.21 (0.046)	0.18 (0.033)	0.54 (0.296)
Imazethapyr (50 g/ha)	0.36 (0.132)	0.31 (0.099)	0.37 (0.138)	0.26 (0.071)	0.25 (0.064)	0.70 (0.503)
Quizalofop-ethyl (50 g/ha)	0.32 (0.103)	0.30 (0.093)	0.36 (0.134)	0.26 (0.072)	0.23 (0.055)	0.67 (0.451)
Metolachlor (1.0 kg/ha)	0.29 (0.087)	0.27 (0.078)	0.32 (0.103)	0.24 (0.058)	0.21 (0.046)	0.68 (0.473)
Quizalofop-ethyl (40 g/ha)	0.30 (0.092)	0.29 (0.086)	0.34 (0.120)	0.24 (0.061)	0.22 (0.052)	0.63 (0.404)
HW (20 & 40 DAS)	0.27 (0.074)	0.28 (0.082)	0.31 (0.099)	0.23 (0.060)	0.21 (0.048)	0.60 (0.362)
Weedy check	0.69 (0.48)	0.58 (0.342)	0.69 (0.48)	0.74 (0.55)	0.48 (0.235)	1.37 (1.90)
SE (m±)	**0.03**	**0.02**	**0.03**	**0.03**	**0.02**	**0.06**
CD (p = 0.05)	**0.09**	**0.07**	**0.08**	**0.09**	**0.06**	**0.17**

*All Figures are subjected to transformed values to square root (√x+0.5)

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Table 8: Effect of herbicides on species wise, total weed control efficiency (no. m^{-2}) at 40 days after sowing and WI (%) of cowpea by weed control treatments (pooled data of two years 2021-2022)

Treatments	Grasses		Sedges	Broadleaf		Total weed control efficiency (%)	WI (%)
	C. Benghalensis	C. Dactylon	C. Rotundus	B. Erecta	P. Hysterophorus		
Pendimethalin (1.0 kg /ha)	83.82	78.91	79.24	85.28	80.65	83.60	3.87
Pendimethalin (1.0 kg./ha) + 1 HW	84.97	81.14	82.32	87.66	85.54	84.29	0.00
Imazethapyr (50 g/ha)	72.42	70.94	71.09	80.66	72.78	73.23	14.30
Quizalofop-ethyl (50 g/ha)	78.49	72.74	71.85	82.08	76.60	76.04	11.48
Metolachlor (1.0 kg/ha)	81.83	77.15	78.34	84.26	80.22	80.20	6.45
Quizalofop-ethyl (40 g/ha)	80.78	74.64	74.86	83.21	78.08	78.51	13.29
HW (20 & 40 DAS)	84.45	75.96	79.34	83.73	79.58	80.74	8.34
Weedy check	00.00	00.00	00.00	00.00	00.00	00.00	52.00
SE (m±)	-	-	-	-	-	-	
CD (p = 0.05)	-	-	-	-	-	-	

3.5 Influence of herbicides on cowpea

The collected data (Table 9) revealed that all weed treatments significantly higher no. crop stands m^{-2} shown in the pre-emergence application of Pendimethalin (1.0 kg./ha) + 1 hand weeding at 30 DAS pre-emergence application of Pendimethalin (1.0 kg./ha) PE. The lowermost plants count per m^{-2} were saw in weedy check. Among the treatments, the weed density was statistically higher in unwedded check. This was due to uncontrolled weed growth throughout the crop growing season, the highest plant height was recorded in the pre-emergence application of Pendimethalin (1.0 kg/ha) + 1 hand weeding at 30 DAS fb pre-emergence application of Pendimethalin (1.0 kg/ha) PE. The lowest plant height was recorded in the weed control. Our results confirm those of [9]. Different weed control treatments significantly affected the number of branches per plant 40 days after sowing. The highest number of branches per plant was recorded with pre-emergence application of Pendimethalin (1.0 kg/ha) + 1 hand weeding at 30 DAS pre-emergence application of Pendimethalin (1.0 kg/ha) PE compared to weeding control.

Table 9: Effect of herbicides on growth characteristics at 60 days after sowing of kharif cowpea with weed control treatments (cumulative data for two years 2021-2022)

Treatments	Plant count (No. m^{-2})	Plant tallness (cm)	No. of twigs m^{-2}
Pendimethalin (1.0 kg /ha)	28.5	53.02	1.82
Pendimethalin (1.0 kg./ha) + 1 HW	29	53.935	2.835
Imazethapyr (50 g/ha)	29	48.55	1.38
Quizalofop-ethyl (50 g/ha)	27	49.5	1.435
Metolachlor (1.0 kg/ha)	26	51.49	2.13
Quizalofop-ethyl (40 g/ha)	28.5	50.485	1.83
HW (20 & 40 DAS)	28	50.47	2.09
Weedy check	28	44.705	1.33
SE (m±)	**0.74**	**0.60**	**0.22**
CD (p = 0.05)	**2.24**	**1.83**	**0.65**

3.6 Effect of herbicides on yield and yield characteristics and economics of kharif cowpea

Different weed control treatments significantly affected the yield characteristics i.e. pods/plant, seeds/pod and Test weight (g) shown in (Table 10) were significantly increased in the absence of crop-

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weed competition caused by pre-emergence application. of Pendimethalin (1.0 kg/ha) + 1 hand weeding at 30 DAS closely followed by Pendimethalin (1.0 kg /ha) PE. The significantly lowest seed yield was observed under weed control [18]. The result of economic analysis of weed management practices revealed that the maximum net returns, benefit-cost ratio recorded with pre-emergence application of Pendimethalin (1.0 kg/ha) + 1 hand weeding at 30 m DAS followed by Pendimethalin (1.0 kg/ha) PE and minimum with Imazetapyr (50 g/ha). [9] A higher benefit: cost ratio was also achieved with pendimethalin in cowpea.

Table 10: Influence of herbicides on yield and yield characteristics and finances of cowpea (2021-2022)

Treatments	No. of shells/ plant	No. of seeds/ shell	Test weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Cost of production (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
Pendimethalin (1.0 kg /ha)	15.24	16.12	85.305	745	1430	33923	63277	29354	1.84
Pendimethalin (1.0 kg./ha) + HW	15.85	16.37	85.70	775	1453	35698	65771	30073	1.87
Imazethapyr (50 g/ha)	12.17	13.815	82.38	664	1213	33308	54997	21689	1.66
Quizalofop-ethyl (50 g/ha)	13.27	14.915	83.11	686	1298	33319	58199	24880	1.75
Metolachlor (1.0 kg/ha)	14.78	15.775	84.66	728	1395	35816	61789	25973	1.73
Quizalofop-ethyl (40 g/ha)	12.46	14.245	82.895	672	1235	33298	56958	23660	1.71
HW (20 & 40 DAS)	14.38	15.35	83.295	712	1353	39130	60414	21284	1.55
Weedy check	11.75	12.77	80.775	372	1102	32030	32157	127	0.97
SE (m±)	**0.48**	**0.58**	**0.55**	**38.27**	**58.04**	-	-	-	-
CD (p = 0.05)	**1.45**	**1.75**	**1.68**	**116.09**	**176.05**	-	-	-	-

4. CONCLUSION

This study revealed that post-emergence application of 2, 4-D Na (800 g/ha) + One hand weeding at 60 DAS fb Atrazine (500 g/ha) + One hand weeding at 30 DAS. They were the most effective weed treatments, effectively controlling weeds and increasing productivity of spring corn and subsequent cowpeas. In kharif cowpea, for higher productivity, profitability and effective weed control, pre-emergent application of Pendimethalin (1.0 kg/ha) + 1 hand weeding at 30 DAS closely followed by Pendimethalin (1.0 kg/ha) PE. These treatments can be used for effective weed control in corn and cowpea during labor shortages and without any residual effect on the following cowpea

Credit authorship contribution statement

Pratap J Khose: formal analysis, Methodology, Investigation. **Dr. Sandeep Menon:** Supervision, Softwere, Project admistration.

L.S Vyvahare: Resources, Data curation, validation. **Pawan Thorhate, Kiran Yadav and Bhumi Reddy Divyavani:** Writing-review& editing, Writing-original draft, Supervision.

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