



Study on effective weed management in Indian mustard (*Brassica juncea* L.)

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Abstract

A field experiment was conducted at, College of Agriculture, Nagpur during *Rabi* 2011-2012 and 2012-13 in RBD with three replications. Among the ten treatments weed-free practice was the most effective weed control method throughout the crop growth period of mustard during both the year of experimentation and in pooled results also. Pendimethalin @ 1.0 kg a.i./ha (PE), Oxadiargyl @ 0.09 kg a.i. ha⁻¹ (PE), Oxyflurofen @ 0.15 kg a.i. ha⁻¹ (PE), Isoproturon @ 1.0 kg a.i. ha⁻¹ (PE) and Clodinafop @ 0.06 kg a.i. ha⁻¹ POE (25-30 DAS) were at par and recorded seed yield in decreasing order. All other treatments recorded significantly higher seed yield compared to un-weeded check except Trifluralin @ 0.75 kg a.i. ha⁻¹ (PPI) and Isoproturon @ 1.0 kg a.i. ha⁻¹ POE (25-30 DAS). But from weed control point of view isoproturon PE recorded better weed control efficiency throughout the crop growth period, followed by oxadiargyl PE and pendimethalin PE. Amongst the herbicide treatments Oxadiargyl @ 0.09 kg a.i. ha⁻¹ (PE) recorded highest seed yield followed by Isoproturon @ 1.0 kg a.i. ha⁻¹ (PE), Oxyflurofen @ 0.15 kg a.i. ha⁻¹ (PE), and Clodinafop @ 0.06 kg a.i. ha⁻¹ POE (25-30 DAS). Similar trend of weed index in increasing order was recorded. On the basis of NMR, weed free check (2 hand weeding at 20 DAS and 40 DAS) was superior followed by oxadiargyl PE, clodinafop POE and oxyflurofen PE which were at par with weed free check and all these were significantly superior over weedy control. Hence based on two years data it is recommended to follow the two hand weedings at 20 and 40 DAS. But under scarcity of labour and saving time, either the pre-emergence application of pendimethalin (30 EC) @ 1.0 kg a.i. ha⁻¹ or oxadiargyl @ 0.09 kg a.i. ha⁻¹ or oxyflurofen @ 0.15 kg a.i. ha⁻¹ or post emergence application of clodinafop @ 0.06 kg a.i. ha⁻¹ at 25-30 DAS is recommended for control of broad leaved weeds.

Keywords: Economy, herbicide, Indian mustard, weed control

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] crop growth in early stage is very slow. Therefore weeds which emerge before crop offer severe competition and results in low yield. Therefore it is very important to keep the crop weed free in early stage for a month. Thus control of weeds is very necessary for getting higher yield. Traditionally the weeds are controlled by manual weeding. There is scarcity of labour for weeding and also the wages for the laborers for weeding are increasing day by day. Thus the cost of cultivation is increasing and the manual weeding is time consuming. With the herbicidal control there is possibility of saving in time and saving in money with

effective weed control. There are few herbicides that can be used as pre-emergence or post emergence. However, there is less information of these herbicides and their doses against weeds in mustard. Herbicidal control is one of the potent means of controlling the weeds. Fluchloralin, pendimethalin and isoproturon are the most common herbicides used in oilseeds and recently some new herbicides have also been found effective. The farmers are using the herbicide under shortage of labour and time. Considering these aspects, the present study was planned to study the effect of herbicides on growth, yield attributes, seed yield and economics of Indian mustard crop, and to explore the effective herbicides for effective weed control in Indian mustard.

Materials and Methods

A field experiment was conducted at College of Agriculture, Nagpur during *rabi* 2011-2012 and 2012-13 in randomized block design with ten treatments and three replications. The soil of experimental field was clayey, moderately high in organic carbon (0.63%), low in available nitrogen (261.3 kg ha⁻¹) and phosphorus (22.4 kg ha⁻¹) and high in available potassium (359 kg ha⁻¹) with pH 7.17. Chemical composition of the soil viz., organic carbon was estimated by Walkley and Black method (Jackson, 1967), Available N (kg ha⁻¹) by Alkaline permanganate method (Subbiah and Asija, 1956), Available P₂O₅ (kg ha⁻¹) by Olsen's method (Jackson, 1967), Available K₂O (kg ha⁻¹) by Neutral normal ammonium acetate method (Jackson, 1967) and pH using glass electrode pH meter (Jackson, 1967). The treatments were viz., T₁ - Pendimethalin @ 1.0 kg a.i. ha⁻¹ PE, T₂ - Oxadiargyl @ 0.09 kg a.i. ha⁻¹ PE, T₃ - Trifluralin @ 0.75 kg a.i. ha⁻¹ PPI, T₄ - Oxyfluorfen @ 0.15 kg a.i. ha⁻¹ PE, T₅ - Quizalofop @ 0.06 kg a.i. ha⁻¹ POE (25-30 DAS), T₆ - Clodinafop @ 0.06 kg a.i. ha⁻¹ POE (25-30 DAS), T₇ - Isoproturon @ 1.0 kg a.i. ha⁻¹ PE, T₈ - Isoproturon @ 1.0 kg a.i. ha⁻¹ POE (25-30 DAS), T₉ - Weedy Check (Un-weeded control) and T₁₀ - Weed-free (2 weeding at 20 DAS and 40 DAS). The spacing was 30 cm x 10 cm with fertilizer dose of 50:40:00 NPK kg ha⁻¹. The crop variety Pusa bold was used. Slight infestation of aphid was noticed. The herbicide treatment application not showed any adverse effect on crop except isoproturon PE treated plot which initially shown some chlorotic patches on border of leaves of mustard plant. The weed count was recorded in one square meter area periodically and presented stage wise. The observation on growth and yield attributes and yield were recorded by the standard procedure and economics was worked out.

Results and Discussion

Effect on weeds of Indian mustard crop

Effect on monocot weeds: The data (table 1) revealed that there was no significant effect of all the weed control treatments on monocot weed population at 30 and 60 DAS during both the year

of investigation. DRMR (2013) Bharatpur also reported non control of monocot weed due to trifluralin and isoproturon which support the present findings.

Effect on dicot weeds: At 30 DAS pendimethalin PE, oxadiargyl PE, oxyfluorfen PE and isoproturon PE recorded significantly lesser dicot weeds over unweeded control and were at par with weed free treatment during both the year of experimentation. At 60 DAS compared to unweeded control all the weed control treatments recorded significantly lesser dicot weed population except quizalofop @ 0.06 kg a.i. ha⁻¹ POE (25-30 DAS) and were at par with weed free check during both the year of investigation (table 1), consequently showing better weed control. This might be due to their ability to control the dicot weeds.

Effect on total weed population: At 30 DAS, weed-free check recorded significantly less and least total weed population (table 1). However, pre-emergence application of isoproturon, pendimethalin, oxadiargyl and pre-plant incorporation of trifluralin also showed at par total weed population with weed free, but all these treatments along with oxyfluorfen PE recorded significantly lesser total weed count over unweeded control indicating control of weed population, i.e. all the herbicide applied as pre-emergence showed weed control during both the year of experimentation. At 60 DAS except quizalofop all the treatments recorded significantly less number of total weeds m⁻² than weedy check and weed free was at par with these herbicides except quizalofop during both the years. DRMR (2013) Bharatpur also reported significantly lesser weed population due to weed free check which supports the present findings.

Effect on weed dry matter: At 30 DAS the weed dry matter (table 2) was least due to pre-emergence application of isoproturon and except the post emergence application treatments (viz., quizalofop, clodinafop and isoproturon) all other herbicidal treatments recorded significantly less weed dry matter over unweeded check during both the year of experimentation. Thus lower weed dry matter in these treatments might be due to lower total weed

Table 1. Effect on monocot, diacot and total weed count m⁻²

Treatments	*Monocot weed count m ⁻² at			*Diacot weed count m ⁻² at			*Total weed count m ⁻² at					
	2011-12		2012-13	2011-12		2012-13	2011-12		2012-13			
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS		
Pendimethalin (30 EC) @ 1.0 kg a.i./ha (PE)	2.6(7)	2.3(5)	0.7(0.0)	7.1(7.0)	6.0(40)	8.1(75)	4.2(24.0)	4.4(18.7)	6.6(47)	8.4(80)	4.2(24.0)	5.1(25.7)
Oxadiazyl @ 0.09 kg a.i. ha ⁻¹ (PE)	2.3(5)	2.6(7)	1.2(1.0)	2.1(2.0)	6.0(39)	8.0(65)	5.1(25.3)	4.4(18.7)	6.4(43)	8.5(71)	5.2(26.3)	4.5(20.7)
Trifluralin @ 0.75 kg a.i. ha ⁻¹ (PPI)	3.0(9)	2.3(5)	2.3(5.0)	1.6(1.3)	8.7(78)	8.0(70)	5.7(33.7)	5.0(24.7)	9.3(87)	8.4(75)	6.2(38.7)	5.1(26.0)
Oxyfluorfen @ 0.15 kg a.i. ha ⁻¹ (PE)	5.1(34)	1.6(2)	1.1(0.7)	0.6(0.3)	7.9(73)	6.5(43)	5.0(30.3)	4.4(19.0)	10.3(107)	6.7(45)	5.1(31.0)	4.4(19.3)
Quizalofop @ 0.06 kg a.i. ha ⁻¹ (25-30 DAS)	3.3(11)	1.9(3)	2.4(5.7)	1.4(1.3)	11.8(141)	9.1(84)	8.7(81.3)	5.5(29.7)	12.3(153)	9.3(87)	9.0(87.0)	5.6(31.0)
Clodinafop @ 0.06 kg a.i. ha ⁻¹ (25-30 DAS)	5.3(37)	2.1(6)	2.0(4.0)	1.9(7.7)	10.8(138)	8.0(67)	9.1(86.0)	4.3(18.3)	12.5(175)	8.4(73)	9.3(90.0)	5.1(26.0)
Isoproturon @ 1.0 kg a.i. ha ⁻¹ (PE)	4.5(20)	2.8(8)	2.0(4.3)	4.9(5.0)	4.3(20)	4.5(20)	5.5(30.3)	4.4(18.7)	6.3(40)	5.3(28)	5.8(34.7)	4.9(23.7)
Isoproturon @ 1.0 kg a.i. ha ⁻¹ (25-30 DAS)	4.2(18)	1.7(3)	3.3(6.0)	1.7(1.7)	10.4(109)	8.2(70)	6.0(38.7)	4.6(20.7)	11.2(127)	8.4(73)	6.3(44.7)	4.7(22.3)
Weedy check (No Weeding)	5.4(29)	2.7(7)	2.2(11.0)	4.7(8.7)	13.5(186)	11.8(140)	9.4(88.7)	6.3(40.0)	14.6(216)	12.1(147)	10.0(99.7)	6.9(48.7)
Weed free (2 W at 20 & 40 DAS)	3.2(10)	1.5(2)	0.7(0.0)	2.8(4.0)	5.1(26)	7.9(62)	2.2(4.7)	3.5(12.0)	6.0(36)	8.1(65)	2.2(4.7)	4.0(16.0)
CD (p=0.05)	NS	NS	NS	NS	4.98	3.45	3.51	1.25	4.01	3.28	3.65	1.45

NS= Non significant

*Square root (0.5+original value) transformed value

Figures in parenthesis are original values

Table 2. Effect on weed control efficiency and weed dry matter

Treatments	Weed control efficiency (%) at DAS						Weed dry matter g m ⁻² at DAS							
	2011-12		2012-13		Pooled		2011-12		2012-13		Pooled			
	60	Harvest	30	Harvest	60	Harvest	60	Harvest	30	Harvest	60	Harvest		
Pendimethalin @ 1.0 kg a.i./ha(PE)	54	27	68	46	69	50	37	131	59	10.9	6.2	23.5	71.0	32.6
Oxadiazyl	80	55	74	8	77	54	4	129	81	9.8	10.6	16.6	69.4	45.8
@ 0.09 kg a.i. ha ⁻¹ (PE)	66	64	69	32	68	48	40	102	57	13.8	5.7	25.8	57.9	31.4
Trifluralin	52	80	81	48	67	64	42	56	47	10.6	6.8	32.5	33.3	26.9
@ 0.75 kg a.i. ha ⁻¹ (PPI)	34	49	20	1	18	30	26	81	65	18.2	7.8	55.9	81.6	36.4
Oxyflurofen	23	63	46	16	20	62	42	105	44	8.2	7.2	60.0	56.6	25.6
@ 0.15 kg a.i. ha ⁻¹ (PE)	77	86	69	73	75	70	44	28	40	9.4	9.3	18.3	24.7	17.2
Quizalofop	30	53	52	35	33	60	42	86	39	20.3	7.8	53.2	70.9	23.4
@ 0.06 kg a.i. ha ⁻¹ (25-30 DAS)	0	0	0	0	0	0	0	122	81	31.0	11.5	76.5	152.7	46.3
Clodinafop	78	72	46	95	87	72	49	27	81	1.5	5.6	14.3	43.4	24.8
@ 1.0 kg a.i. ha ⁻¹ (30 DAS)	-	-	-	-	-	-	-	50	122	17.36	5.4	33.7	63.7	0.0
Isoproturon	-	-	-	-	-	-	-	-	-	-	-	-	-	-
@ 1.0 kg a.i. ha ⁻¹ (PE)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isoproturon	-	-	-	-	-	-	-	-	-	-	-	-	-	-
@ 1.0 kg a.i. ha ⁻¹ (30 DAS)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weedy check	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(No Weeding)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weed free	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(2 W at 20 & 40DAS)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CD	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(p=0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-

NS= Non-significant

Table 3. Effect on growth and yield attributes of Indian mustard

Treatments	Plant height (cm)		No. of branches plant ⁻¹		No. of siliqua plant ⁻¹		Seed yield plant ⁻¹ (g)		Test weight (1000) g					
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13				
	Pooled		Pooled		Pooled		Pooled		Pooled					
Pendimethalin @ 1.0 kg a.i.ha ⁻¹ (PE)	145	140	142	3.9	3.9	130	127	129	2.50	5.24	3.87	4.6	4.0	4.3
Oxadiargyl @ 0.09 kg a.i. ha ⁻¹ (PE)	149	156	152	4.7	4.7	148	120	134	2.90	4.66	3.78	4.8	3.4	4.1
Trifluralin @ 0.75 kg a.i. ha ⁻¹ (PPI)	160	164	162	5.0	4.9	117	102	110	2.10	4.52	3.31	4.2	3.8	4.0
Oxyfluorfen @ 0.15 kg a.i. ha ⁻¹ (PE)	145	154	149	4.5	4.5	133	121	127	2.50	4.68	3.59	4.8	4.4	4.6
Quizalofop @ 0.06 kg a.i. ha ⁻¹ (25-30 DAS)	150	160	155	5.1	4.6	111	114	113	1.90	3.67	2.79	4.3	3.6	4.0
Clodinafop @ 0.06 kg a.i. ha ⁻¹ (25-30 DAS)	148	153	150	4.9	4.5	137	101	119	2.30	4.45	3.38	4.7	3.3	4.0
Isoproturon @ 1.0 kg a.i. ha ⁻¹ (PE)	150	171	160	4.7	4.6	133	121	127	2.60	4.61	3.61	4.6	3.8	4.2
Isoproturon @ 1.0 kg a.i. ha ⁻¹ (30 DAS)	144	159	152	4.5	4.4	125	104	115	2.20	3.2	2.70	4.3	3.6	4.0
Weedy check (No Weeding)	151	163	157	4.4	4.4	108	93	101	1.60	3.14	2.37	4.2	3.4	3.8
Weed free (2 W at 20 & 40DAS)	153	149	151	4.3	4.7	160	142	151	3.30	5.94	4.62	4.6	3.7	4.2
CD (p=0.05)	NS	NS	NS	NS	NS	27.7	21.9	24.8	0.85	1.35	1.10	-	-	-

NS= Non-significant

count. Higher weed dry matter in post emergence application treatment might be due to non application of treatment at this stage. However, at 60 DAS though pre-emergence application of isoproturon recorded least weed dry matter, all the herbicidal treatments along with weed free check also recorded statistically at par dry matter indicating the better weed control as evidenced by the lower total weed count in same treatment. At harvest weed dry matter was not influenced significantly. Similar trend of results was also found under pooled mean. Buttar and Aulakh (2003) also reported lowest weed dry matter with 1.00 kg a.i. trifluralin ha⁻¹ and higher weed control efficiency which supports the present finding.

Weed control efficiency (WCE): The pooled data (Table 2) at 30 DAS showed more than 50 % WCE with all the pre-emergence and pre-plant application of herbicide and also with weed free. At 60 DAS all the pre-emergence herbicide applied and post emergence application of clodinafop and isoproturon along with weed free treatments recorded more than 50% weed control efficiency, thus indicating better weed control. This might be due to lower weed dry matter compared to un-weeded check. The pre-emergence application of isoproturon showed continuous weed suppression from 30 days to harvest (75, 70 and 44% at 30, 60 DAS and at harvest respectively) while oxadiargyl PE, pendimethalin PE and oxyflurofen PE showed weed control from 30 to 60 DAS, but isoproturon POE and clodinafop POE showed better weed control at 60 DAS only. This behavior of herbicide towards the weed control might be due to its time of application. Nepalia and Jain (2000) also reported control of weed dry matter by oxyflurofen, pendimethalin, isoproturon similar to that of hand weeding. These results are in line with present findings. Sharma and Jain (2002) also reported significant weed dry matter reduction due to isoproturon PE @ 1 kg a.i. ha⁻¹ which support the present findings.

Effect on the mustard crop

Effect on growth and yield attributes: The plant height and number of branches plant⁻¹ at harvest was not significantly influenced by the weed control treatments during both the years as well as

in pooled results. Number of siliquae plant⁻¹ was the maximum and significantly superior due to weed-free check (151) followed by application of oxadiargyl PE (134), oxyflurofen PE (127) and isoproturon PE (127) and all these recorded significantly more number of siliquae plant⁻¹ during both year and in pooled results. Among the herbicidal treatments oxadiargyl PE recorded maximum and significantly higher number of siliquae plant⁻¹. This might be due to better crop condition due to lower weed population. The mean of two years showed numerically highest test weight due to oxyflurofen PE and was followed by the pendimethalin PE and isoproturon PE.

Pooled mean of seed yield plant⁻¹ was significantly higher due to weed-free check as compared to all other treatments. However oxadiargyl PE, isoproturon PE, pendimethalin PE and oxyflurofen PE were at par with weed-free check. This might be due to more test weight and higher number of siliquae plant⁻¹ which further might have enhanced due to better crop growth and effective weed control. Sharma and Jain (2002) also reported the higher number of seeds per siliqua and number of siliquae per plant and 1000-seed weight for the weed-free control, followed by hand weeding at 30 and 45 DAS which support the present findings.

Yield study: The pooled data showed that, the weed-free check recorded maximum and significantly higher seed yield (601.7 kg ha⁻¹) over other treatments and oxadiargyl PE (598.9 kg ha⁻¹), oxyflurofen PE (574.9 kg ha⁻¹), isoproturon PE (574.3 kg ha⁻¹) and clodinafop POE (567.5 kg ha⁻¹) were at par and recorded seed yield in decreasing order. Compared to un-weeded check, all these treatments were recorded significantly higher yield ha⁻¹. Among the herbicide treatments, oxadiargyl PE (598.9 kg ha⁻¹), oxyflurofen PE (574.9 kg ha⁻¹), isoproturon PE (574.3 kg ha⁻¹) and clodinafop POE (567.5 kg ha⁻¹) recorded significantly higher yield over weed free. The increased seed yield ha⁻¹ in these treatment might be the cumulative effect of more number of siliquae plant⁻¹, more test weight and more seed yield (g) plant⁻¹ as well as higher weed control efficiency and lower total weed count as evidenced from the data creating the situation of

Table 4. Effect on yield, harvest index and weed index of Indian mustard

Treatments	Seed yield (kg ha ⁻¹)			Stover yield (q ha ⁻¹)			Harvest index (%)			Weed Index (%)		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
	Pendimethalin @ 1.0 kg a.i./ha (PE)	606.4	597	601.7	40.3	40.63	40.5	13.1	12.8	13.0	22.6	11.92
Oxadiargyl @ 0.09 kg a.i. ha ⁻¹ (PE)	666.7	531	598.9	41.7	33.35	37.5	13.8	13.7	13.8	14.9	21.63	18.01
Trifluralin @ 0.75 kg a.i. ha ⁻¹ (PPI)	513.8	515	514.4	29.2	29.45	29.3	15	14.9	15.0	34.4	24.02	29.58
Oxyfluorfen @ 0.15 kg a.i. ha ⁻¹ (PE)	616.7	533	574.9	31.9	28.25	30.1	16.2	15.9	16.1	21.2	21.32	21.30
Quizalofop @ 0.06 kg a.i. ha ⁻¹ (25-30 DAS)	486.8	418	452.4	23.6	20.24	21.9	17.1	17.1	17.1	37.8	38.29	38.06
Clodinafop @ 0.06 kg a.i. ha ⁻¹ (25-30 DAS)	615	520	567.5	30.6	26.34	28.5	16.7	16.5	16.6	21.5	23.28	22.31
Isoproturon @ 1.0 kg a.i. ha ⁻¹ (PE)	622.5	526	574.3	40.3	33.61	37.0	13.4	13.5	13.5	20.5	22.38	21.38
Isoproturon @ 1.0 kg a.i. ha ⁻¹ (25-30 DAS)	475.6	389	432.3	27.8	21.14	24.5	14.6	15.7	15.2	39.3	42.64	40.80
Weedy check (No Weeding)	358.6	358	358.3	19.4	19.82	19.6	15.6	15.5	15.6	54.2	47.14	50.95
Weed free (2 W at 20 & 40DAS).	782.9	678	730.5	38.9	34.03	36.5	16.8	16.6	16.7	0.0	0.00	0.00
P=0.05	169.7	153	161.4	16.84	9.63	13.2	-	-	-	-	-	-

NS= Non-significant

Table 5. Effect on economics of Indian mustard

Treatments	GMR (Rs ha ⁻¹)			NMR (Rs ha ⁻¹)			B:C ratio		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
	Pendimethalin @ 1.0 kg a.i. /ha (PE)	18192	17906	18049	9092	7719	8406	2.0	1.8
Oxadiazyl @ 0.09 kg a.i. ha ⁻¹ (PE)	20000	15934	17967	11844	6691	9268	2.5	1.7	2.1
Trifluralin @ 0.75 kg a.i. ha ⁻¹ (PPI)	15413	15446	15430	7429	6375	6902	1.9	1.7	1.8
Oxyflurofen @ 0.15 kg a.i. ha ⁻¹ (PE)	18500	15995	17248	9405	5813	7609	2.0	1.6	1.8
Quizalofop @ 0.06 kg a.i. ha ⁻¹ (25-30 DAS)	14604	12546	13575	5144	1999	3572	1.5	1.2	1.4
Clodinafop @ 0.06 kg a.i. ha ⁻¹ (25-30 DAS)	18450	15598	17024	10150	6211	8181	2.2	1.7	1.9
Isoproturon @ 1.0 kg a.i. ha ⁻¹ (PE)	18675	15781	17228	9042	5061	7052	1.9	1.5	1.7
Isoproturon @ 1.0 kg a.i. ha ⁻¹ (30 DAS)	14267	11661	12964	4634	941	2788	1.5	1.1	1.3
Weedy check (No Weeding)	10758	10745	10752	3498	2398	2948	1.5	1.3	1.4
Weed free (2 W at 20 & 40DAS)	23488	20330	21909	14308	10063	12186	2.6	2.0	2.3
CD (p=0.05)	5091	4590	4841	5091	4590	4841	-	-	-

NS= Non-significant GMR= Gross monetary returns, NMR= Net monetary returns

lesser crop weed competition without any side effect. Yadav *et al.* (2004) also found highest seed yield with weed-free treatment and trifluralin PPI. Similarly Chauhan *et al.* (2005) found higher seed yield with two hand weeding and oxyflurofen PE over weedy check. Singh and Sinsinwar (2002) also found increase in seed yield with weed-free treatment and isoproturon PE over weedy check. These results are in line with the findings of present investigation. The ICAR-Directorate of Rapeseed Mustard Research, Bharatpur in annual reports also reported better yield due to weed free treatment followed by isoproturon PE (DRMR, 2011).

Herbicide pendimethalin PE recorded significantly higher stover yield (40.6 q ha^{-1}) followed by oxadiargyl PE, isoproturon PE and weed free and all these recorded significantly higher stover yield over unweeded control (19.4 kg ha^{-1}) Increase in stover yield of mustard might be due to luxurious crop growth and less crop weed competition. Bazaya *et al.* (2004) and Sharma and Jain (2002) with weed-free treatment also reported more stover yield over unweeded control which support the present findings. The average values for the two years showed that, highest harvest index was recorded by quizalofop PE (17.1%) followed by clodinafop POE and oxyflurofen PE. Lower harvest index was shown by pendimethalin PE (13.1%).

Weed Index: The pooled data of two years indicated that pre-emergence application of pendimethalin showed least weed index (17.6 %) compared to weed free check followed by pre-emergence application of isoproturon (21.4%), pre-emergence application of oxyflurofen (21.3%), post-emergence application of clodinafop (22.3%) and pre-emergence application of oxadiargyl (18.0%). All the herbicidal treatments showed lower and better weed index than the un-weeded control. Thus all the herbicide was effective in controlling weed with different intensity.

Economic study: The pooled mean indicated that the weed-free control recorded maximum gross monetary return (Rs 21909 ha^{-1}) followed by oxadiargyl PE (Rs 17967 ha^{-1}), oxyflurofen PE (Rs 17248 ha^{-1}), isoproturon PE (Rs 17228 ha^{-1}) and

clodinafop (Rs 17024 ha^{-1}) all these recorded significantly higher values of GMR over unweeded control. When compared to weed free treatment the above treatment except clodinafop PE, all other recorded at par GMR. The higher GMR might be due to more yields in these treatments.

The net monetary return (NMR) also showed trend similar to gross monetary return where the weed-free check recorded maximum NMR (Rs 12186 ha^{-1}) and was followed by oxadiargyl PE (Rs 9268 ha^{-1}), clodinafop POE (Rs 8181 ha^{-1}) and oxyflurofen PE (Rs 7609 ha^{-1}) and all these recorded significantly higher NMR over unweeded control. Also application of this herbicide showed at par NMR with weed free treatment. This might be due to more yields and comparatively less herbicide cost. The lowest NMR (Rs 10758 ha^{-1}) was recorded due to un-weeded control. Yadav (2004) also reported lowest NMR (Rs 9312 ha^{-1}) due to un-weeded check at Morena.

The data on benefit cost ratio showed that weed-free check recorded highest B:C ratio (2.27) and this was followed by oxadiargyl PE (2.09) and clodinafop POE (1.94). Pendimethalin PE (1.88), oxyflurofen PE (1.80) and similar trend was also observed in NMR, thus indicating the most economical and beneficial weed control method. This might be due to comparative higher yield coupled with lower herbicide cost. Bazaya *et al.* (2004) also found highest B:C ratio with weed-free treatment.

Conclusion

Weed-free check recorded highest gross monetary return (GMR), net monetary return (NMR) and benefit cost (B:C) ratio and this was followed by oxadiargyl PE and clodinafop POE, pendimethalin PE and oxyflurofen PE. Similar trend was also observed in GMR and NMR, thus indicating the most economical and beneficial weed control methods. The same treatments also found better weed control efficiency and lower weed count. Hence based on two years data it is recommended to follow the two hand weeding at 20 and 40 DAS. But under scarcity of labour and saving time, either the pre-emergence application of pendimethalin (30 EC) @ 1.0 kg a.i. ha^{-1}

oroxadiargyl @ 0.09 kg a.i. ha⁻¹ or oxyflurofen @ 0.15 kg a.i. ha⁻¹ or post emergence application of clodinafop @ 0.06 kg a.i. ha⁻¹ at 25-30 DAS is recommended for control of broad leaved weeds. This recommendation will hold well in all the rapeseed-mustard growing areas of country. The frequency of post emergence application of herbicide need to be tested for further better weed control in mustard under irrigated as well as dry land condition.

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