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Bio-efficacy of herbicides against complex weed flora in linseed (*Linum usitatissimum* L.) in Indo-Gangetic plain of Bihar

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ABSTRACT

Field experiment was conducted during **rabi** seasons of 2012-13 and 2013-14 at Agricultural Research Institute, Patna to find out the bio-efficacy of herbicides for controlling weeds in linseed in comparison to hand weeding twice at 20 and 40 days after sowing. The most predominant weed flora observed in the experimental plots were broad leaf weeds like Rumex dentatus, *Chenopodium album, Polygonum plebejium, Alternenthera sesilis, Physalis minima, Medicago polymorpha* and *Solanum xanthocarpum,* grasses like *Cynodon dactylon, Digitaria sanguinalis* and sedges like *Cyperus rotundus.* The herbicide treatments include pre-emergence application of pendimethalin @ 1000 g a. i./ha, pendimethalin 30 EC + imazethapyr 2 EC @ 750 and 1000 g a. i./ha and post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha, clodinafop 15 WP @ 60 g a. i./ha and imazethapyr 10 SL @ 40, 60, 75 and 100 g a. i./ha. The results showed that application of pendimethalin 30 EC + imazethapyr 2 EC @ 750 and 1000 g a. i./ha as pre-emergence showed inhibitory effect on the linseed seedlings. Safe herbicide pendimethalin 30 EC @ 1000 g a. i./ha recorded lowest weed biomass with highest weed control efficacy (91.5%) which was at par with isoproturon 75 WP @ 1000 g a. i./ha as post-emergence with weed control efficacy of 89.9%. The manually weeded plot recorded the highest seed yield of 1337 kg/ha among all the treatments, whereas maximum seed yield among the herbicide treatments was obtained with post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha (1195 kg/ha), which was found statistically at par with pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha (1177 kg/ha), post-emergence application of imazethapyr 10 SL @ 60 g a. i./ha (1110 kg/ha) and with manually hand weeding twice. In terms of profitability, post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha gave the highest net returns, B : C ratio and incremental B : C ratio than all other weed control treatments.

Key words : Bio-efficacy, herbicides, linseed, weed flora, weed management

INTRODUCTION

Linseed (*Linum usitatissimum* L.) is an oilseed crop of high economic importance because of its medicinal and industrial value, along with its potentiality to be grown as rainfed and partially irrigated areas, as sole and *paira/utera* cropping, under conserved moisture and limited nutrient conditions. In India, linseed is cultivated in about 296 thousand hectares, with a contribution of 193 thousand tonnes to the annual oilseed production of the country, with an average yield of 498 kg/ha (Agricultural Statistics at a Glance, 2014). The low yield of the crop is mainly because of its cultivation under marginal lands and rainfed areas, especially with low externally input condition, by the resource poor farmers in Indo-Gangetic plain of India. At initial crop growth stages of linseed, slow and relatively lower canopy spread leads to high weed infestation, resulting in reduction in yield (Siddesh *et al.*, 2016). The critical crop-weed competition period for linseed is 25-45 days, which accounts for 30-40% reduction in yield (Singh *et al.,* 1992; Mahere *et al.*, 2000). Chhokar *et al.* (2012) reviewed and documented *Rumex dentatus* L., *Polygonum plebejium* R. and *Chenopodium album* L. as

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dominant weed flora in winter crop in Indo-Gangetic plains. The weeds contribute not only to the reduction of yield but also substantially reduce its value and suitability for processing and potential to obtain good quality fibres (Bilalis *et al.,* 2012; Heller *et al.,* 2012). As linseed is a poor competitor against weeds, hence, yield can be improved with weed control measures (Foulk *et al.,* 2004; Harker *et al.*, 2011). Farmers generally adopt hand weeding for controlling weeds in linseed due to its highest weed control efficiency, but it proved to be very laborious and costly (Samant, 2016). Moreover, shortage of labourers, when really on demand, makes it imperative to opt for herbicidal control. Pendimethalin is widely recommended as a pre-emergence herbicide for controlling both grassy and non-grassy weeds in winter crops (Rao and Nagamani, 2007). However, the relative preference of the farmers towards a post-emergence herbicide for managing weeds, after visualizing the prevalence, necessitates further study. Till date, very limited study has been reported to curb the weed population in linseed. In this context, the present study was conducted to study the bio-efficacy of herbicides against complex weed flora in linseed and to assess their impact on the productivity of the crop.

MATERIALS AND METHODS

A field experiment was conducted during **rabi** seasons of 2012-13 and at 2013-14 at Agricultural Research Institute, Bihar Agricultural University, Lohiya Nagar, Patna, Bihar, to study the bio-efficacy of herbicides in reducing weed dynamics and increasing productivity of linseed. The location is situated on a medium land situation at 25°30' N latitude, 85°15' E longitude and an elevation of 57.8 m above mean sea level, with vertisol soil, clayee texture, 7.2 pH, 0.36% organic carbon, 20.5 kg/ha available P_2O_5 and 190 kg/ha available K_2O. The total rainfall during the cropping period was 26.4 and 55.6 mm in 2012-13 and 2013-14, respectively (Fig. 1).

The experiment was laid out in a randomized block design with 11 treatments and 3 replications. The treatments consisted of hand weeding twice at 20 and 40 days after sowing (DAS), pendimethalin 30 EC @ 1000 g a. i./ha, pendimethalin 30 EC + imazethapyr 2 EC @ 750 g a.i./ha, pendimethalin 30 EC+imazethapyr 2 EC @ 1000 g a. i./ha, isoproturon 75 WP @ 1000 g a. i./ha, clodinafop @ 60 g a. i./ha, imazethapyr 10 SL @ 40 g a. i./ha, imazethapyr 10 SL @ 60 g a. i./ha, imazethapyr 10 SL @ 75 g a. i./ha and imazethapyr 10 SL @ 100 g a.i./ha, along with weedy check. The experiment was conducted by sowing seeds of the variety Shekhar at 25 × 5 cm^2 spacing. The field was fertilized with N, P_2O_5 and K_2O @ 80, 30 and 20 kg/ha, respectively. Half of N (40 kg), full of P_2O_5 and K_2O were applied at final land preparation before sowing. Half of N (40 kg) was applied as first top dressing at 30 DAS. All the

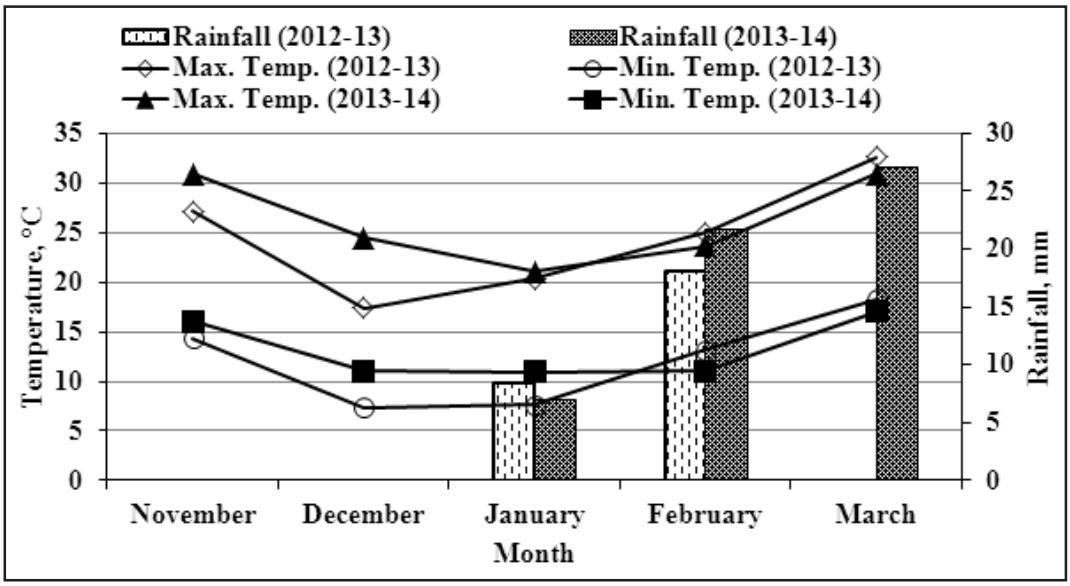

Fig. 1. Maximum temperature, minimum temperature and rainfall during linseed cropping period of 2012-13 and 2013-14.

recommended agronomic and plant protection measures were adopted to raise the crop.

All the herbicides were applied as per the protocol of application time using knapsack sprayer fitted with flat fan nozzle at a spray volume of 500 l/ha. The observation of weed density was recorded at 30 and 60 DAS with the help of quadrate of 1×1 m^2 and the data were subjected to square root transformation prior to statistical analysis. The observation of weed dry matter weight was recorded at 60 DAS.

Weed control efficiency (WCE) was determined by the following formula :

$$WCE\ (\%) = \frac{WDC - WDT}{WDC} \times 100$$

Where, WCE=Weed control efficiency, WDC=Dry matter accumulation by weeds in un-weeded plot (g/m^2) and WDT=Dry matter accumulation by weeds in herbicide treated plots (g/m^2).

Weed Index (WI) was determined by the following formula :

$$WI\ (\%) = \frac{YH - YT}{YH} \times 100$$

Where, WI=Weed index, YH=Seed yield (kg/ha) in hand weeded plot and YT=Seed yield (kg/ha) in treated plot.

The growth and yield attributing characters like plant height, primary branches/plant, capsules/plant, seeds/capsule, test weight and seed yield of linseed were recorded during both the years of the experiment. The economic performance of the treatments was evaluated in terms of gross returns, net profit and benefit : cost (B : C) ratio and incremental benefit : cost ratio (IBCR), taking the cost of inputs and market value of the produce for the respective years. The IBCR was determined by the following formula :

$$IBCR = \frac{\text{Added net returns}}{\text{Added cost of cultivation}} \times 100$$

The data were statistically analyzed applying the techniques of analysis of variance and the significance of different sources of variations were tested by error mean square of Fisher Snedecor's 'F' test at probability level 0.05 (Cochran and Cox, 1977).

RESULTS AND DISCUSSION

Weed Flora

The most predominant weed flora observed in the experimental plots were : broad leaf weeds like *Rumex dentatus, Chenopodium album, Polygonum plebejium, Alternenthera sesilis, Physalis minima, Medicago polymorpha* and *Solanum xanthocarpum,* grasses like *Digitaria sanguinalis* and sedges like *Cyperus rotundus*. The intensity of weed infestation varied between the years with more weed infestation found in second year i. e. 2013-14, due to high rainfall during the cropping season. Among these, the highest weed density of 90.9% was recorded for broad-leaved weeds, followed by sedges (5.7%) and grasses (3.4%) at 60 days after sowing (DAS). Similar type of observation was recorded at Madhya Pradesh, India, where maximum weed density of 67.7% was recorded for dicots, followed by only 18% for monocots. Among the broad leaf weeds, *R. dentatus, C. album* and *P. plebejium* dominated the field during both the years of study.

Crop Toxicity

Regular visual field observation revealed that pendimethalin 30 EC+ imazethapyr 2 EC @ 750 and 1000 g a. i./ha as pre-emergence showed inhibitory effect on the linseed seedlings, resulting in reduction in plant density of linseed, in both the years of experimentation. Similarly, slightly phytotoxicity effect up to seven days after application was recorded for post-emergence application of imazethapyr @ 100 g a. i./ha, but after that period, the plants recovered from phytotoxicity.

Effect of Treatments on Weed Density

The pooled data of weed density of both the years at 30 DAS revealed that all the pre-emergence herbicides recorded significant reduction in weed density compared to weedy check (Table 1). The maximum reduction of weed density at 30 DAS was recorded against pre-emergence application of pendimethalin 30 EC+imazethapyr 2 EC @ 1000 g a. i./ha (96.5%), followed by pendimethalin 30 EC+imazethapyr 2 EC @ 750 g a. i./ha (95.4%) and pendimethalin @ 1000 g a. i./ha (93.8%), compared to weedy check, which were superior to hand weeding treatment with a value of 89.6%, as there was only one hand weeding operation done up to 30 DAS and the second

Table 1. Effect of treatments on weed density, weed biomass and weed control efficiency

Treatment	Time of application	Rate (@ a. i./ha)	Weed density at 30 DAS/m^2 (Pooled)				Weed density at 60 DAS/m^2 (Pooled)				Weed biomass at 60 DAS (g/m^2) (Pooled)	WCE (%)
			G	S	B	Total	G	S	B	Total		
Weedy check	-	-	1.99	2.03	8.24	8.67	2.00	2.51	9.60	10.09	29.56	0.0
Hand weeding twice			(3.50)	(3.67)	(68.17)	(75.33)	(3.50)	(5.83)	(93.17)	(102.5)		
at 20 & 40 DAS	-	-	1.05	1.34	2.47	2.86	0.97	1.34	1.93	2.37	0.91	96.9
			(0.67)	(1.33)	(5.83)	(7.83)	(0.50)	(1.33)	(3.33)	(5.17)		
Pendimethalin	Pre	1000 g.	0.88	0.97	2.04	2.24	0.88	1.36	3.12	3.39	2.52	91.5
			(0.33)	(0.50)	(3.83)	(4.67)	(0.33)	(1.50)	(9.33)	(11.17)		
Pendimethalin 30 EC+Imazethapyr 2 EC	Pre	750 g.	0.97	1.05	1.64	1.98	0.88	1.22	2.37	2.64	1.19	95.9
			(0.50)	(0.67)	(2.33)	(3.50)	(0.33)	(1.00)	(5.33)	(6.67)		
Pendimethalin 30 EC+Imazethapyr 2 EC	Pre	1000 g.	0.80	1.05	1.45	1.75	0.80	1.20	1.89	2.20	0.85	97.1
			(0.17)	(0.67)	(1.83)	(2.67)	(0.17)	(1.00)	(3.33)	(4.50)		
Isoproturon	Post	1000 g.	1.86	1.69	8.22	8.55	0.97	1.41	2.54	2.92	2.96	89.9
			(3.00)	(2.50)	(67.83)	(73.33)	(0.50)	(1.67)	(6.50)	(8.67)		
Clodinafop	Post	60 g.	1.95	1.93	7.67	8.08	0.80	2.15	8.30	8.55	22.86	22.7
			(3.33)	(3.33)	(58.83)	(65.50)	(0.17)	(4.17)	(70.00)	(74.33)		
Imazethapyr	Post	40 g.	2.02	1.63	8.45	8.80	1.34	1.85	6.07	6.45	14.35	51.5
			(3.67)	(2.33)	(71.50)	(77.50)	(1.33)	(3.00)	(37.50)	(41.83)		
Imazethapyr	Post	60 g.	2.00	1.77	7.88	8.27	1.28	1.45	5.38	5.67	11.83	61.7
			(3.67)	(2.67)	(62.17)	(68.50)	(1.17)	(1.83)	(29.33)	(32.33)		
Imazethapyr	Post	75 g.	1.77	1.80	8.41	8.74	1.03	1.50	5.07	5.34	9.64	69.1
			(2.83)	(3.00)	(70.33)	(76.17)	(0.67)	(1.83)	(26.0)	(28.50)		
Imazethapyr	Post	100 g.	1.84	1.98	8.34	8.73	1.20	1.22	4.61	4.83	7.66	74.1
			(3.17)	(3.50)	(69.67)	(76.33)	(1.00)	(1.00)	(22.00)	(24.00)		
S. Em±			0.127	0.129	0.271	0.263	0.10	0.15	0.53	0.34	1.881	
C. D. (P=0.05)			0.361	0.365	0.769	0.746	0.29	0.42	1.51	0.97	5.344	

Pre : Pre-emergence, Post : Post-emergence, G : Grassy weeds, S : Sedge weeds, B : Broad leaf weeds and WCE : Weed control efficacy. Figures in parentheses indicate original values.

hand weeding operation was not yet applied. This showed the highest efficacy of pre-mixed combi-product of pendimethalin 30 EC + imazethapyr 2 EC, in controlling early flush of diverse weed flora in linseed up to 30 DAS. This result is attributed to the fact that pendimethalin inhibits cell division and cell elongation which led to death of weeds shortly after germination, coupled with the inhibitory effect of imazethapyr which hampered synthesis of branched chain amino acids in susceptible weed species, leading to disruption in DNA and protein synthesis and ultimately killing them shortly after application. This result is in accordance with the findings of Ram *et al.* (2011) and Younesabadi *et al.* (2014) in field pea and also Ram *et al.* (2012) in Rajmash. However, both the treatments showed inhibitory effect on emergence of linseed crop by reducing the plant population.

There was no significant difference in weed density between post-emergence herbicides and weedy check, as the post-emergence herbicides were not applied at 30 DAS. At 60 DAS, the lowest grassy weed density among the safe herbicides was recorded for post-emergence application of clodinafop 15 WP @ 60 g a. i./ha (0.8/m^2), which was found statistically at par with pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha (0.88/m^2), post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha (0.97/m^2) and also with hand weeding twice (0.97/m^2). The lowest grassy weed density, as obtained for clodinafop, was mainly due to its effectiveness in controlling grassy weeds through its Acetyl CoA carboxylase inhibitory action (Das, 2015).

The pooled data of sedge weed density of both the years revealed that among the safe herbicides, the lowest value (1.36/m^2) was recorded with pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha, which did not differ significantly with post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha (1.41/m^2), imazethapyr 10 SL @ 60 g a. i./ha (1.45/m^2) and imazethapyr 10 SL @ 75 g a. i./ha (1.50 m^2) and was in turn found at par with hand weeding twice, with value of 1.93/m^2 (Table 1).

With respect to the weed density of broad leaf weeds, the lowest density among the safe herbicides was recorded with post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha (2.54/m^2) which was found at par with pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha (3.12/m^2) and hand weeding twice with values of 1.93/m^{-2} (Table 1). The lowest total weed density by post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha and pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha was due to their effectiveness in controlling dominating broad leaf weeds like *R. dentatus* and *C. album*. Similar type of finding of 100% control of *R. dentatus* by isoproturon was earlier reported by Yaduraju and Das (2006). The pooled data of total weed density at 60 DAS revealed lowest density among all treatments for hand weeding twice, with values of 2.37/m^2, which was found at par with isoproturon 75 WP @ 1000 g a. i./ha (2.92/m^2), but differed significantly with all other treatments. Among the safe herbicides, isoproturon 75 WP @ 1000 g a. i./ha, being the most effective herbicide was found statistically at par with pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha (3.39/m^2). The superiority of isoproturon in controlling diverse weed flora in winter crops was also reported by Yadav *et al.* (1995) in Indian mustard and Gupta (1998) in linseed.

Effect of Treatments on Weed Biomass and Weed Control Efficiency

The pooled data of total weed biomass at 60 DAS for both the years showed that among the safe herbicide treatments, lowest weed biomass of 2.52 g/m^2, with highest WCE of 91.5%, obtained with pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha, which was found at par with isoproturon 75 WP @ 1000 g a. i./ha as post-emergence with values of 2.96 g/m^2 and WCE of 89.9%, followed by post-emergence application of imazethapyr 10 SL @ 100 g a. i./ha with values of 7.66 g/m^2 and WCE of 74.1%. The result of isoproturon is in agreement with that reported by Yadav *et al.* (1995) in Indian mustard and Yaduraju and Das (2006) in wheat. Similarly, the result of higher WCE with lowest biomass of weeds by pendimethalin in canola was earlier supported by Chaudhry *et al.* (2011). Though the combination of pendimethalin 30 EC+imazethapyr 2 EC @ 1000 g a. i./ha and 750 g a. i./ha recorded lowest total weed biomass with highest WCE, both the treatments resulted toxicity to the seeds and seedlings of linseed crop, thereby inhibiting seedling emergence of linseed and significant decrease in linseed plant population.

Effect of Treatments on Crop Growth and Yield Attributes of Linseed

The pooled data of growth and yield attributing characters viz., plant height, primary branches/plant, capsules/plant, seeds/capsule and test weight of linseed were significantly influenced by different weed management treatments (Table 2). Hand weeding recorded taller plants (53.2 cm), with more number of primary branches/plant (4.73), capsules/plant (39.55), seeds/capsule (8.03), due to reduced weed competition for resources like sunlight, nutrients and space, resulting in significant increase in higher seed yield of linseed. Among the safe herbicide treatments, the highest number of capsules/plant was recorded with isoproturon 75 WP @ 1000 g a.i./ha as post-emergence with value of 35.90, which did not differ significantly with imazethapyr 10 SL @ 60 g a. i./ha (33.68) and was in turn at par with hand weeding. The highest number of seeds/ capsule, among the safe chemicals, was obtained with imazethapyr 10 SL @ 60 g a. i./ha (7.79), followed by pendimethalin 30 EC (7.70) and isoproturon 75 WP (7.53). With respect to test weight, isoproturon 75 WP @ 1000 g a. i./ha and imazethapyr 10 SL @ 60 g a. i./ha resulted in highest test weight of 6.82 g each.

Effect of Treatments on Seed Yield of Linseed

Data on seed yield of linseed of both the years of experimentation showed higher seed yield in 2012-13 as compared to 2013-14, due to more weeds, more rainfall and high incidence of linseed rust in the second year under unfavourable weather conditions during the cropping season. The pooled data of both the years clearly revealed a loss of seed yield of 31.4% in weedy check treatment, with a seed yield of 917 kg/ha, compared to hand weeding twice, being the highest yielder, with an yield of 1337 kg/ha. Among the safe herbicides, without any phytotoxicity, isoproturon 75 WP @ 1000 g a. i./ha as post-emergence registered highest seed yield (1195 kg/ha), which was found statistically at par with pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha (1177 kg/ha) and post-emergence application of imazethapyr 10 SL @ 60 g a. i./ ha (1110 kg/ha), and was in turn found no significant difference with hand weeding twice. The higher seed yield, among the safe herbicides, by post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha might be due to its effectiveness in controlling broad spectrum of weeds of linseed, up to critical period of crop-weed competition. This was in conformity with the earlier recommendation of controlling weeds by post-emergence application isoproturon at 2-3 leaf stage of weeds (Singh *et al.,* 1996).

Among the pre-emergence herbicides, pendimethalin 30 EC @ 1000 g a. i./ha registered highest seed yield, surpassing combination product of pendimethalin 30 EC+ imazethapyr 2 EC @ 750 g a. i./ha and 1000 g a.i./ha, which recorded lesser seed yield, due to its inhibitory effect on emergence of seedlings. Superiority of pendimethalin compared to other herbicides in linseed was also earlier reported by Chopra and Paul (2015) in Himachal Pradesh. The lowest seed yield among the safe herbicides was recorded with post-emergence application of clodinafop @ 60 g a. i./ha (940 kg/ha), followed by imazethapyr 10 SL @ 40 g a. i./ha (947 kg/ha). The lowest seed yield with post-emergence application of clodinafop @ 60 g a. i./ha might be due to its inability in controlling broad leaf weeds, thereby giving scope to weeds for competition with the crop. Similarly, imazethapyr 10 SL @ 40 g a. i./ha, as post-emergence failed to control weeds at the given low concentration, thereby registering lesser seed yield of linseed. With respect to weed index, among the herbicide treatments the highest value of 30.3% was recorded with post-emergence application of isoproturon @ 1000 g a. i./ha.

Effect of Treatments on Economics of Linseed

The pooled net returns over two years showed highest value of Rs. 24,372 obtained by post-emergence application of isoproturon 75 WP @ 1000 g a.i./ha, followed by hand weeding twice (Rs. 24,073) and pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha (Rs. 22,583). With respect to pooled B : C ratio of both the years, the highest value of 1.33 was obtained with post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha, followed by pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha (1.20) and post-emergence application of imazethapyr 10 SL @ 60 g a. i./ha (1.11). The highest incremental B : C ratio (IBCR), among all the treatments, was obtained with post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha with values of 13.36, followed by pre-

Table 2. Effect of treatments on growth, yield parameters and economics of linseed

Treatment	Time of application	Rate (@ a. i./ha)	Plant height (cm)	Primary branches/ plant	Capsules/ plant	Seeds/ capsule	Test weight (g)	Seed yield (kg/ha)			Weed index (%)	Net returns (Rs./ha)	B : C ratio	IBCR
								2012-13	2013-14	Pooled				
Weedy check	-	-	52.70	3.17	23.45	6.48	6.22	1048	785	917	0.0	14882	0.85	0.00
Hand weeding twice at 20 & 40 DAS	-	-	55.60	4.73	39.55	8.03	7.11	1449	1225	1337	45.8	24073	1.02	1.51
Pendimethalin	Pre	1000 g	53.20	3.92	30.80	7.70	6.66	1365	988	1177	28.4	22583	1.20	5.57
Pendimethalin 30 EC+Imazethapyr 2 EC	Pre	750 g	51.85	3.33	28.00	7.30	6.23	998	975	986	7.5	15944	0.81	0.34
Pendimethalin 30 EC+Imazethapyr 2 EC	Pre	1000 g	50.75	3.45	26.27	7.17	6.55	678	942	810	-11.7	9580	0.46	-2.37
Isoproturon	Post	1000 g	52.53	3.83	35.90	7.53	6.82	1284	1106	1195	30.3	24372	1.33	13.36
Clodinafop	Post	60 g	52.03	3.77	24.17	6.90	6.06	1076	805	940	2.5	14600	0.79	-0.22
Imazethapyr	Post	40 g	53.55	3.90	28.47	7.12	6.21	1020	874	947	3.3	15306	0.83	0.03
Imazethapyr	Post	60 g	54.05	4.07	33.68	7.79	6.82	1145	1074	1110	21.0	20936	1.11	4.38
Imazethapyr	Post	75 g	53.43	4.03	30.53	7.45	6.63	1141	996	1069	16.6	19037	0.99	2.52
Imazethapyr	Post	100 g	52.33	3.70	24.07	7.45	6.34	1058	924	991	8.1	15810	0.81	0.36
S. Em±			0.912	0.22	1.572	0.328	0.157	55.4	51.5	83.6	-	-	-	-
C. D. (P=0.05)			2.590	0.62	4.465	NS	0.446	163.6	152.0	237.4	-	-	-	-

Pre : Pre-emergence, Post : Post-emergence and IBCR : Incremental B : C ratio.

emergence application of pendimethalin 30 EC @ 1000 g a. i./ha (5.57).

CONCLUSION

The most predominant weed flora observed in the experimental plot were broad leaf weeds like *R. dentatus, C. album, P. plebejium,* grasses like *C. dactylon, D. sanguinalis* and sedges like *C. rotundus*, causing a loss of seed yield of 31.4% in weedy check treatment. Based on the results, it can be concluded that herbicide-based weed management through post-emergence application of isoproturon 75 WP @ 1000 g a. i./ha was found to be the most effective and economic herbicide, in controlling weed flora and improving seed yield of linseed, followed by pre-emergence application of pendimethalin 30 EC @ 1000 g a. i./ha, in Indo-Gangetic plain of Bihar.

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