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Bio-efficacy of herbicides against weed flora of linseed in vertisols of Chhattisgarh plains

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Abstract
Field experiment was conducted during three consecutive *rabi* season of 2013-14, 14-15 and 2015-16 at Research cum Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh 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 *Medicago denticulata, Convolvulus arvensis, Parthenium hysterophorus and other weeds.* The nine weed management treatments consisted of T_1: Weedy check, T_2: Hand weeding twice at 20 and 40 DAS, T_3: Pendimethalin 30 EC @ 1 kg *a.i.* ha^{-1} (PE), T_4: Pendimethalin 30 EC + Imaz 2 EC @ 0.75 kg *a.i.* ha^{-1} (PE), T_5: Pendimethalin 30 EC + Imaz 2 EC @ 1.00 kg *a.i.* ha^{-1} (PE), T_6: Isoproturon @ 1 kg *a.i.* ha^{-1} (PoE), T_7: Clodinafop @ 60 g. *a.i.* ha^{-1} (PoE), T_8: Imazethapyr 10 EC @ 75 g *a.i.* ha^{-1} (PoE), T_9: Imazethapyr 10 EC @ 100 g *a.i.* ha^{-1} (PoE) with the variety of RLC-92. The experiment was laid out in randomized block design with thrice replications. The lowest weed density and dry matter of total weeds at harvest were observed with twice hand weeding treatment (T_2), however among herbicides, the lowest value was observed with the application of Isoproturon @ 1 kg *a.i.* ha^{-1} as PoE (T_6). The growth attributes, seed yield of linseed and weed control efficiency (at harvest) were found highest with twice hand weeding treatment (T_2), however among herbicides, application of Isoproturon @ 1 kg *a.i.* ha^{-1} as PoE (T_6) recorded the higher values. In case of B:C ratio, the application of Isoproturon @ 1 kg *a.i.* ha^{-1} as PoE (T_6) registered the highest value (2.03) among all weed management practices. Hence the alone application of Isoproturon @ 1 kg *a.i.* ha^{-1} as PoE was found most economical herbicide under different weed management practices for linseed in Vertisols of Chhattisgarh plains condition.

Keywords: Bio-efficacy, herbicides, linseed, weed control efficiency

Introduction
Linseed or flax is among the oldest crop plants cultivated for the purpose of oil and fiber. It belongs to the genus Linum and family Linaceae. The botanical name, *Linum usitatissimum* was given by Linnaeus in his book "Species Plantarum" (Linnaeus, 1857) [14]. It is an annual herbaceous plant with shallow root system. The common names flax and linseed are used in North America and Asia, respectively, for L. *usitatissimum*. Oilseed varieties and fiber varieties are specialized development of this species (Millam *et al*., 2005) [16]. Every part of linseed plant is utilized commercially, either directly or after processing. Seed contains 33 to 47 per cent oil. A small quantity is directly used for edible purposes. About 20 per cent of the total oil produced is used at farmer level and the rest 80 per cent oil goes to industries in various forms, such as boiled oil, borated oil, eposidized oil, aluminated oil, urethane oil, isomerized oil etc. Seeds of linseed contain high levels of dietary fibers as well as lignans, an abundance of micronutrients and omega-3 fatty acids. The oil (>66%) is rich in linolenic acid and is a perfect drying oil. The seed of linseed content nutrient value per 100 g is carbohydrates 28.88 g, sugars 1.55 g, fat 42.16 g, protein 18.29 g and dietary fibers 27.39 g (Anonymous, 2013) [3]. Linseed having less branching habit, small leaf area and slow growth during initial growth period, it complete poorly with weeds and often suffers from severe weed competition. Round the globe linseed crop occupies an area of 21.26 lakh ha yielding out 18.67 lakh tones having an average productivity of 877 kg ha^{-1}. Our national production of 1.54 lakh tones is realized from an area of 2.94 lakh ha with low productivity of 525 kg ha^{-1} in world arena. Chhattisgarh occupies an area of 0.29 lakh ha with a production of 0.10 lakh tone and a productivity of 344 kg ha^{-1} (Anonymous, 2018) [4]. An initial growth period of 20-45 days is very critical and season long weed competition has been found to reduce linseed yield to the extent of 30-40% (Mahere *et al.*, 2000) [15] depending on the type and intensity of weed flora. 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) [20]. Though hand weeding is most common but is slow as well as labour intensive and costly hence use of herbicides may be a suitable alternative for managing the weeds for higher returns (Husain, *et al*. 2015) [12]. Hence, the present study was aimed to find out the bio-efficacy of pre and post emergence herbicides for weed flora in linseed in Vertisols of Chhattisgarh plains conditions.

Materials and Methods

A field experiment was conducted at Research cum Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (21°4′ N latitude, 81°35′ E longitude and 290.20 metres above mean sea level) under Chhattisgarh plains during three consecutive *rabi* season of 2013-14, 2014-15 and 2015-16 to study the bio-efficacy of herbicides in reducing weed dynamics and increasing productivity of linseed. The experiment was conducted in randomized block design with nine treatments replicated thrice. The treatment details are Weedy check (T_1), Hand weeding twice at 20 and 40 DAS (T_2), Pendimethalin 30 EC @ 1 kg *a.i.* ha^{-1} (Pre-emergence) (T_3), Pendimethalin 30 EC + Imazphtyre 2 EC @ 0.75 kg *a.i.* ha^{-1} (Pre-emergence) (T_4), Pendimethalin 30 EC + Imazphtyre 2 EC @ 1.00 kg *a.i.* ha^{-1} (Pre-emergence) (T_5), Isoproturon @ 1 kg *a.i.* ha^{-1} at 2-3 leaf stage of weeds (T_6), Clodinafop @ 60 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds (T_7), Imazphtyre 10 EC @ 75 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds (T_8) and Imazphtyre 10 EC @ 100 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds (T_9). The linseed variety RLC-92 was sown on mid of November of each year of experimentation at 30 cm row spacing. 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^{-1}. The observation of weed density and biomass (dry weight) was recorded at Initial (20 DAS) and at harvest with the help of quadrate (1×1 m^2) and the data were subjected to square root transformation ($\sqrt{x+0.5}$) prior to statistical analysis. Transformation of weed data and statistical analysis was fallowed as per Gomez and Gomez (1984) [10].

Results and Discussion

Effect of weed management practices on weed density and biomass

The most predominant weed flora observed in the experimental plot were broad leaf weeds like *Medicago denticulate, Convolvulus arvensis*, *Parthenium hysterophorus* and others weeds spp. etc. The weed density and biomass of *Medicago denticulata*, *Convolvulus arvensis*, *Parthenium hysterophorus* and others were recorded at initial stage and at harvest (Table 1). The total weed density and biomass was significantly influenced by different weed management treatments during both the stages of observation. At initial stage, minimum total weed density and biomass was observed with the application of Pendimethalin 30 EC + Imaz 2 EC @ 1.00 kg *a.i.* ha^{-1} as PE (T_5) followed by Pendimethalin 30 EC + Imaz 2 EC @ 0.75 kg *a.i.* ha^{-1} as PE (T_4) and Pendimethalin 30 EC @ 1 kg *a.i.* ha^{-1} as PE (T_3). 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 20 DAS. Superiority of pendimethalin compared to other herbicides in linseed was also earlier reported by Chopra and Paul (2015) [6] in Himachal Pradesh. 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) [18] and Younesabadi *et al*. (2014) [23] in field pea and also Ram *et al*. (2012) [19] in Rajmash.

However, at harvest stage, significantly lowest total weed density and biomass was recorded under the hand weeding twice at 20 and 40 DAS (T_2), which was significantly superior over other treatments, while, among the herbicidal treatments, application of Isoproturon @ 1 kg *a.i.* ha^{-1} as PoE (T_6) controlled optimum total weed density and biomass. The highest total weed density and biomass was observed with weedy check treatment at both the stages of observation. The superiority of isoproturon in controlling diverse weed flora in winter crops was also reported by Yadav *et al*. (1995) [22] in Indian mustard and Gupta (1998) [11] and Acharya *et al.* (2017) [1] in linseed.

Effect of weed management practices on growth parameters and yield of linseed

Dry matter accumulation (g plant^{-1}) and plant height (cm) were recorded at 30, 60, 90 DAS and presented in Table 2. The higher dry matter accumulation was registered under hand weeding twice at 20 and 40 DAS (T2) at 60 and 90 DAS, which was at par with all the treatments except the treatment of weedy check at 60 DAS and application of Pendimethalin 30 EC @ 1 kg *a.i.* ha^{-1} as PE (T_3) and weedy check treatment at 90 DAS. While, non-significant difference was observed among weed management practices at 30 DAS. The lowest dry matter accumulation of linseed plant^{-1} was observed with weedy check treatment. Data related to plant height at 30 DAS revealed that significantly higher plant height was observed under hand weeding twice at 20 and 40 DAS (T2) but it was found at par with all treatments except Clodinafop @ 60 g. *a.i.* ha^{-1} as PoE (T_7) and weedy check. Whereas, at 60 and 90 DAS, significantly higher dry matter accumulation plant^{-1} was registered under hand weeding twice at 20 and 40 DAS (T2) which was found at par with application of Isoproturon @ 1 kg *a.i.* ha^{-1} as PoE (T_6) and Imazphtyre 10 EC @ 75 g *a.i.* ha^{-1} as PoE (T_8). The lowest plant height was observed with weedy check treatment. Data pertaining to yield of linseed under different treatments are presented in Table 2 and reveals that amongst weed management practices, hand weeding twice (T_2) registered significantly higher seed yield (1257 kg ha^{-1}) than others but it was statistically at par with the application of Isoproturon @ 1 kg *a.i.* ha^{-1} as PoE (T_6) and Imazethapyr 10 EC @ 75 g *a.i.* ha^{-1} as PoE (T_8). The minimum seed yield was recorded under weedy check (T_1) plot due to unhindered growth of weeds. This result is in accordance with the findings of Angiras *et al*. (1991) [2], Dange *et al.* (2007) [7], Devendra *et al.* (2016) [8] and Chhaganiya *et al*. (2018) [5].

Effect of weed management practices on quality of linseed

The highest oil yield (454 kg ha^{-1}) was recorded with the treatment of twice hand weeding at 20 and 40 DAS (T2) followed by application of Isoproturon @ 1 kg *a.i.* ha^{-1} as PoE, T_6 (432 kg ha^{-1}) and Imazethapyr 10 EC @ 75 g *a.i.* ha^{-1} as PoE, T_8 (414 kg ha^{-1}). The higher oil yield received under this treatment was due to the higher seed yield recorded under this treatment which directly responsible for higher oil yields. There was no significant effect on oil content due to various weed management treatments (Table 2). The maximum oil

content was observed in the treatment of twice hand weeding at 20 and 40 DAS (T2). This might be due to oil content is mainly a genetic character which cannot be manipulated by agronomic practices. The higher oil yield recorded with two hand weeding may be due to deleterious effect of weedicides on crop development as well as nutrient supply from soil to plant reported by Husain *et al.* (2015) [12]. Similar results also reported by Jain and Agarwal (1998) and Mishra *et* al. (2003) [17]. Significant reduction in yield by weeds (37.9%) in linseed crop was also observed by Tomar *et al.* (1990) [21].

Effect of weed management practices on B:C ratio, weed control efficiency and weed index

In terms of profitability, post-emergence application of Isoproturon @ 1 kg *a.i.* ha^{-1} (T_6) gave the highest B: C ratio than all other weed control treatments and lowest was computed with weedy check treatment. Reduction in dry weight of weed accumulation leads to maximization of weed control efficiency. The highest weed control efficiency was computed with the application of Pendimethalin 30 EC + Imaz 2 EC @ 1.00 kg *a.i.* ha^{-1} as PE (T_5) at initial stage that is due to pre-emergence effect of herbicide. However, hand weeding twice at 20 and 40 DAS (T2) recorded the highest weed control efficiency (71.68%) which was followed by post-emergence application of Isoproturon @ 1 kg *a.i.* ha^{-1} (T_6) and Imazethapyr 10 EC @ 75 g *a.i.* ha^{-1} (T_8) having weed control efficiency of 53.26 and 41.69 per cent at harvest, respectively. While, minimum weed index (0.00%) was recorded under the treatment of weedy check plot. The lowest weed index was computed with the application of Isoproturon @ 1 kg *a.i.* ha^{-1} as PoE (T_6) followed by Imazethapyr 10 EC @ 75 g *a.i.* ha^{-1} as PoE (T_8). While, maximum weed index (37.5%) was recorded under the weedy check plot (Table 2). Frisen and Freer (1991) [9] reported that only pre emergence herbicides application was less effective and allow weed competition in later stages, therefore along with cultural practices (hoeing or weeding) or post emergence herbicides gave maximum weed control efficiency.

Table 1: Effect of weed management practices on weed density and biomass at initial and harvest stage of linseed (Mean data of three years)

Treatment	Weed density (m^{-2}) and biomass (g m^{-2}) at initial stage										Weed density (m^{-2}) and biomass (g m^{-2}) at harvest									
	Medicago denticulata		*Convolvulus arvensis*		*Parthenium hysterophorus*		Other weeds		Total weeds		*Medicago denticulate*		*Convolvulus arvensis*		*Parthenium hysterophorus*		Other weeds		Total weeds	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
T_1:Weedy check	5.38 (30.9)	4.04 (17.0)	2.08 (4.4)	1.91 (3.60)	4.78 (4.9)	2.80 (4.78)	1.87 (3.8)	1.69 (2.8)	12.14 (43.9)	9.90 (28.2)	5.44 (31.3)	5.52 (31.8)	3.24 (11.0)	3.05 (9.49)	3.32 (11.0)	4.89 (23.6)	6.69 (5.0)	2.94 (8.4)	14.27 (58.3)	16.39 (73.3)
T_2:Hand weeding at 20 and 40 DAS	4.49 (21.1)	3.34 (11.2)	1.59 (2.2)	1.45 (1.66)	4.76 (4.0)	2.74 (4.76)	1.56 (2.3)	1.36 (1.6)	10.39 (29.)	8.42 (19.2)	2.08 (4.)	2.18 (4.5)	1.49 (2.0)	1.37 (1.62)	1.89 (3.9)	2.79 (8.2)	1.95 (1.6)	1.34 (2.3)	6.73 (11.5)	7.69 (16.6)
T_3: Pendimethalin 30 EC @ 1 kg *a.i.* ha^{-1} (PE)	3.85 (15.2)	2.89 (8.2)	1.75 (2.9)	1.51 (2.02)	2.58 (3.7)	1.98 (2.58)	1.65 (2.7)	1.53 (2.0)	9.23 (24.)	7.66 (14.8)	4.70 (22.4)	4.75 (23.0)	3.18 (9.9)	3.01 (9.08)	2.43 (5.6)	3.61 (12.7)	5.96 (3.8)	2.70 (8.1)	12.25 (41.8)	14.06 (52.9)
T_4: Pendimethalin 30 EC + Imaz 2 EC @ 0.75 kg *a.i.* ha^{-1} (PE)	4.13 (17.6)	2.93 (8.6)	1.75 (2.8)	1.58 (2.23)	2.81 (4.5)	2.12 (2.81)	1.45 (2.4)	1.25 (1.4)	9.45 (27.)	7.54 (15.0)	4.26 (18.26)	4.18 (17.9)	2.96 (8.5)	2.82 (8.15)	2.58 (7.0)	3.66 (14.2)	7.22 (5.0)	3.01 (9.4)	12.00 (38.8)	13.67 (49.6)
T_5: Pendimethalin 30 EC + Imaz 2 EC @ 1.00 kg *a.i.* ha^{-1} (PE)	3.47 (12.5)	2.53 (6.3)	1.55 (2.4)	1.45 (1.97)	3.20 (4.7)	2.16 (3.20)	1.65 (2.7)	1.43 (1.8)	8.84 (22.2)	7.28 (13.3)	4.17 (17.6)	4.05 (16.7)	3.03 (8.9)	2.83 (7.95)	2.23 (5.0)	3.31 (11.3)	6.82 (4.2)	3.09 (9.4)	11.57 (35.6)	13.29 (45.4)
T_6:Isoproturon @ 1 kg *a.i.* ha^{-1} (PoE)	4.85 (24.0)	3.49 (12.1)	2.11 (4.4)	1.89 (3.42)	2.79 (4.5)	2.09 (2.79)	1.53 (2.2)	1.36 (1.6)	10.58 (34.9)	8.50 (19.9)	3.64 (13.1)	3.40 (11.4)	2.59 (6.4)	2.50 (6.18)	2.15 (4.5)	2.94 (8.8)	5.38 (3.6)	2.57 (7.1)	10.30 (27.6)	11.40 (33.5)
T_7: Clodinafop @ 60 g *a.i.* ha^{-1} (PoE)	4.92 (25.4)	3.50 (12.3)	2.15 (4.9)	1.87 (3.53)	4.08 (6.1)	2.47 (4.08)	1.80 (3.7)	1.57 (2.5)	11.34 (40.1)	9.03 (22.5)	4.14 (17.7)	3.99 (16.3)	2.94 (8.3)	2.77 (7.84)	2.44 (5.7)	3.45 (11.6)	7.80 (5.6)	3.09 (10.0)	11.85 (37.3)	13.31 (45.8)
T_8: Imazethapyr 10 EC @ 75 g *a.i.* ha^{-1} (PoE)	4.89 (25.2)	3.48 (12.4)	2.03 (4.4)	1.91 (3.77)	4.23 (6.9)	2.57 (4.23)	1.79 (3.5)	1.55 (2.4)	11.28 (40.0)	9.03 (22.8)	4.20 (17.8)	3.98 (15.7)	2.77 (7.3)	2.61 (6.78)	2.21 (4.7)	3.29 (10.6)	5.83 (4.4)	2.59 (7.2)	11.21 (34.3)	12.46 (40.4)
T_9: Imazethapyr 10 EC @ 100 g *a.i.* ha^{-1} (PoE)	4.90 (24.7)	3.53 (12.4)	1.81 (3.3)	1.67 (2.77)	3.89 (6.6)	2.43 (3.89)	1.65 (2.8)	1.41 (1.8)	10.79 (37.3)	8.58 (20.9)	4.26 (18.1)	3.99 (15.6)	2.65 (6.6)	2.55 (6.51)	2.28 (5.1)	3.17 (10.5)	7.36 (4.9)	2.95 (9.8)	11.39 (34.7)	12.65 (42.5)
SEm±	0.28	0.18	0.20	0.17	0.51	0.22	0.18	0.13	0.33	0.20	0.28	0.30	0.26	0.28	0.21	0.28	0.15	0.16	0.50	0.59
CD (P=0.05)	0.83	0.54	NS	NS	1.50	0.65	NS	0.39	0.99	0.60	0.84	0.89	0.78	0.83	0.61	0.82	0.46	0.47	1.48	1.76

Figures in parentheses are original, transformed to values $\sqrt{x + 0.5}$, PE: Pre-emergence, PoE: Post-emergence

Table 2: Effect of weed management practices on growth, yield, quality parameter, B:C ratio, WCE and WI of linseed (Mean data of three years)

Treatment	Dry matter (g $plant^{-1}$)			Plant height (cm)			Yield (kg ha^{-1})	Quality parameter		B:C ratio	Weed control efficiency (WCI)		Weed index % (WI)
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS		Oil content (%)	Oil yield (kg ha^{-1})		Initial	At harvest	
T_1:Weedy check	0.4	1.5	4.3	19.3	40.4	55.9	785	35.7	280	1.07	0.00	0.00	37.5
T_2:Hand weeding at 20 and 40 DAS	0.5	2.3	5.5	22.3	50.6	70.4	1257	36.1	454	1.79	31.89	71.68	00.0
T_3: Pendimethalin 30 EC @ 1 kg *a.i.* ha^{-1} (PE)	0.5	1.8	4.6	22.2	44.8	62.1	989	35.7	353	1.41	22.79	29.18	21.3
T_4: Pendimethalin 30 EC + Imaz 2 EC @ 0.75 kg *a.i.* ha^{-1} (PE)	0.5	1.9	4.8	21.9	45.4	62.0	1006	35.9	361	1.50	46.63	33.52	20.0
T_5: Pendimethalin 30 EC + Imaz 2 EC @ 1.00 kg *a.i.* ha^{-1} (PE)	0.5	1.8	4.8	22.0	46.0	62.3	1044	35.9	375	1.55	52.72	39.55	16.9
T_6:Isoproturon @ 1 kg *a.i.* ha^{-1} (PoE)	0.5	2.2	5.3	20.9	47.4	67.8	1200	36.0	432	2.03	29.37	53.26	04.5
T_7: Clodinafop @ 60 g *a.i.* ha^{-1} (PoE)	0.4	1.8	4.8	19.5	45.1	64.3	1037	35.6	369	1.57	20.28	32.07	17.5
T_8: Imazethapyr 10 EC @ 75 g *a.i.* ha^{-1} (PoE)	0.5	2.2	5.1	19.9	47.2	66.7	1153	35.9	414	1.84	18.99	41.69	08.3
T_9: Imazethapyr 10 EC @ 100 g *a.i.* ha^{-1} (PoE)	0.4	1.9	5.0	20.3	45.6	65.3	1116	35.6	397	1.69	25.90	39.22	11.2
SEm±	0.03	0.14	0.22	0.82	1.37	1.65	40.43	0.33	-	-	-	-	-
CD (P=0.05)	NS	0.42	0.68	2.45	4.12	4.95	121.21	NS	-	-	-	-	-

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