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RESEARCH PAPER

Evaluation of herbicides for efficient weed management in linseed (*Linum usitatissimum* L.)

J. S. SACHIN, N. ANANDA, B. M. CHITTAPUR, M. R. UMESH AND H. VEERESH

Department of Agronomy, College of Agriculture
University of Agricultural Sciences, Raichur - 584 104, Karnataka, India
E-mail: clkananda@gmail.com

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Abstract: A field experiment was conducted during *rabi,* 2020-21 at MARS, UAS Raichur to study the bio-efficacy of herbicides in linseed (*Linum usitatissimum* L.). The study revealed The results revealed that application of pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence was found effective in controlling the weeds with higher growth and yield components consequently higher yield and net returns in linseed that weed free check recorded higher plant height (53.4 cm) at 60 DAS, number of primary branches per plant (4.7) at 60 DAS, number of capsules per plant (44.93), number of seeds per capsule (8.60) which resulted in higher seed yield (957 kg ha^{-1}) and net returns (₹ 32068) as compared to other treatments. In contrast weedy check treatment recorded significantly lower seed yield, with gross/net returns and B:C ratio.

Key words: Bio-efficacy, Herbicide, Linseed, Phyto-toxicity

Introduction

Linseed also referred as flax (*Linum usitatissimum* L.) is a self-pollinated crop widely adapted to temperate climates of the world. It is cultivated as a commercial or subsistence crop in over 30 countries. It is a great source of nutrients and contains 33 to 47 per cent of oil. Linseed oil is used in cooking as well as for industrial uses. Early removal of weeds is necessary to minimize crop losses caused by weed competition. Presently, the conventional method of hand weeding is widely practiced as an effective method of weed management in linseed. But it is costlier, time and labour consuming and tedious. With the advancement of agro techniques, chemical weed control has thus, become an effective and cheap alternative to control weeds.

Herbicides continue to be a key component of weed management programme in conventional linseed production. Linseed is associated with the problem of profused growth of weeds and infestation of heterogeneous weed flora becomes the biggest biological constraint and the success of linseed entirely depends on efficient weed management practices because uncontrolled weeds in linseed can reduce yields to the tune of 52 per cent (Alam *et al.,* 2021) and losses were reported even up to 85 per cent (Singh *et al.,* 2013). Use of pre-emergent herbicides is a vital tool for effective and cost efficient weed management in linseed, which encounters weed competition from the day of germination. When herbicides are used for weed management, selectivity is most important as even the most effective herbicide may be phytotoxic to the linseed plants depending upon the dosage, formulation, proper method and time of application. One time application of any single herbicide may not provide satisfactory management of all types of weeds due to group specific action of many herbicides. Some of the pre- and post-emergence herbicides along with combi-products are registered for early season weed control in different oilseed crops. Among the different pre- and post-emergence herbicides, combi-product like clodinafop + metsulfuron methyl 16 % WP at different doses are reported to provide excellent control of problematic weeds in wheat. Hence, use of effective herbicides at the correct time is critical to achieve optimum flax yields, minimal dockage and high oil quality.

Material and methods

The field experiment was conducted during *rabi* 2020-21 at MARS, UAS Raichur. The soil of the experiment field was deep black clay in texture. The experiment comprised of 11 weed management practices *viz.,* T_1: Weedy check, T_2: Weed free check, T_3: Hand weeding at DAS 20-25 *fb* intercultivation at 40-45 DAS, T_4: Metribuzin 70 % WP @ 250 g *a.i.* ha^{-1} + oxyflourfen 23.5 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence, T_5: Pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence, T_6: Imazethapyr 10 SL @ 75 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence, T_7: Oxyflourfen 23.5 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence, T_8: Metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post- emergence, T_9: Clodinafop-propargyl 15 % WP @ 60 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post- emergence, T_{10}: Clodinafop + metsulfuron methyl 16 % WP @ 64 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence, T_{11}: Oxadiargyl 80 % WP @ 80 g *a.i.* ha^{-1} as pre-emergence. These treatments were laid out in randomized block design with three replications. Pre-emergence herbicides were applied at one day after sowing the crop, post-emergence herbicides were applied at 2-4 leaves stage of weeds using a hand operated knapsack sprayer fitted with flat fan nozzle and at a spray volume of 750 l ha^{-1} (pre-emergence) and 500 l ha^{-1} (post-emergence). Linseed crop (NL-115) was sown at a spacing 30 x 5 cm. The recommended fertilizer dose of 40 kg N, 20 kg P_2O_5 and 20 kg K_2O ha^{-1} was

applied as per package of practices. Weed density was recorded by placing a quadrate of 0.25 m^2 at random in each plot and converted to m^2. The weed density and dry weight data were subjected to transformation $(x+1)^{1/2}$, respectively.

Weed control efficiency was calculated by the following formula

$$\text{Weed control efficiency (\%)} = \frac{\text{Total weed dry weight in unweeded plot (g m}^{-2}) - \text{Total weed dry weight in treated plot (g m}^{-2})}{\text{Total weed dry weight in unweeded control plot (g m}^{-2})} \times 100$$

Weed index was calculated by the formula given by Gill and Vijaya Kumar (1992).

$$\text{WI (\%)} = \frac{X-Y}{X} \times 100$$

Results and discussion

Effect of weeds

The major grassy weeds observed in the experiment plot were *Cynodon dactylon* (L.) Pers., *Echinochloa colona* (L.) Link, *Dinebra retroflexa* (Vahl) Panz. and *Chloris barbata* Sw. while *Cyperus rotundus L.,* was the dominant weed among sedges and broad-leaved weeds *viz., Phyllanthus niruri* L., *Parthenium hysterophorus* and *Amaranthus viridis* L. were found dominant. Sivaraj *et al.* (2009) also observed similar weed flora in linseed.

Different herbicidal treatments exhibited significant effect on total weed density and total dry weight at 60 DAS. Weed free check recorded significantly lower total weed density and total dry weight at 60 DAS. In case of herbicides treatments, significantly lower total density and total dry weight of weeds was recorded with the application of oxyflourfen 23.5 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence (3.77 m^{-2} and 3.83 g m^{-2}, respectively,) as compared to weedy check. However, it was found on par with application of metribuzin 70 % WP @ 250 g *a.i.* ha^{-1} + oxyflourfen 23.5 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence (3.84 m^{-2} and 3.92 g m^{-2}, respectively,). Weedy check recorded significantly higher total weed density and total dry weight (7.66 m^{-2} and 7.68 g m^{-2}, respectively,) (Table 1). This might be due to the prevention of biosynthesis of branched chain amino acids, valine, leucine and isoleucine in chloroplasts of susceptible weeds. These herbicides are broad activity and are absorbed by both roots and foliage translocated through both xylem and phloem. The susceptible weeds stop growing after herbicide application and exhibits stuned, interveinal chlorosis, redvenation, purpling, root pruning and gradual death of the weed so that weed density and dry weight of weeds decreases which resulted in good growth of crop. The results of this study were in conformation with the earlier findings of Mishra *et al.* (2003) where in application of pendimethalin as pre-emergence was very effective against weeds

Table 1. Weed control efficiency and weed dynamics as influenced by different weed management practices in linseed at 60 DAS

Treatments	Weed density (m^2)	Weed dry weight (g m^2)	Weed control efficiency (%)	Weed index (%)
T_1: Weedy check	7.66(58.12)	7.68(58.53)	0.00	51.72
T_2: Weed free check	0.71(0.00)	0.71(0.00)	100.0	0.00
T_3: Hand weeding at 20-25 DAS *fb* intercultivation at 40-45 DAS	3.66(12.89)	3.59(10.30)	82.40	3.45
T_4: Metribuzin 70 % WP @ 250 g *a.i.* ha^{-1} + Oxyflourfen 23 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence	3.84(14.21)	3.92(14.90)	74.54	43.05
T_5: Pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* Metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage as post-emergence	3.88(14.53)	3.94(15.02)	74.34	5.33
T_6: Imazethapyr 10 SL @ 75 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence	5.71(32.11)	5.01(24.64)	57.90	22.47
T_7: Oxyflourfen 23.5 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence	3.77(13.73)	3.83(14.18)	75.77	45.04
T_8: Metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence	5.40(28.70)	4.84(22.94)	60.81	19.64
T_9: Clodinafop-propargyl 15 % WP @ 60 g *a.i.* ha^{-1} at 2-3 leaf stage as post-emergence	5.24(26.99)	4.69(21.45)	63.35	17.87
T_{10}: Clodinafop + metsulfuron methyl 16 % WP @ 64 g *a.i.* ha^{-1} at 2-3 leaf stage as post-emergence	3.97(15.27)	4.05(15.94)	72.77	7.31
T_{11}: Oxadiargyl 80 % WP @ 80 g *a.i.* ha^{-1} as pre-emergence	5.96(35.03)	5.30(27.63)	52.79	23.20
S.Em.±	0.23	0.19	3.84	-
C.D. at 5%	0.67	0.59	11.28	-

DAS: Days after sowing, *a.i.*: Active ingredient, *fb*: Followed by, CS: Capsulated suspension
EC: Emulsifiable concentrate, SL: Soluble liquids, WP: Wettable powder, Original grassy weed count (x) data were transformed into √X+0.5*
Figures in parenthesis indicate original values

Weed free check recorded significantly higher weed control efficiency at 60 DAS. In case of herbicides treatments, application of oxyflourfen 23.5 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence recorded significantly higher weed control efficiency (75.77 %) and it was found on par with application of metribuzin 70 % WP @ 250 g *a.i.* ha^{-1} + oxyflourfen 23.5 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence (74.54 %) (Table 1). These results were supported by the findings of Giriyapla *et al.* (2016) and Alam *et al.* (2021) who observed higher weed control efficiency due to pre-emergence application of metribuzin 70 % WP @ 250 g *a.i.* ha^{-1} oxyflourfen 23.5 % EC @ 125 g *a.i.* ha^{-1} .

Among the herbicides treatments, significantly lower weed index was recorded with application of pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* metsulfuron methy 120 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence (5.33 %). However, it was found on par with the application of clodinafop + metsulfuron methyl 16 % WP @ 64 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence (7.31 %). Weedy check recorded significantly higher weed index (51.72 %) (Table 1). These findings were similar with Bilalis *et al.* (2012) and Husain *et al.* (2015) who concluded that application of clodinafop @ 60 g ha^{-1} or 80 g ha^{-1} (POE) could be an alternative to hand weeding carried out twice for weed management in irrigated linseed.

Effect on growth and yield of linseed

All the growth and yield attributes were significantly higher under application of pre and post emergent herbicides. Weed free check treatment recorded significantly superior growth and yield attributes as compared to other treatments including weedy check. Among herbicidal treatments, significantly higher plant height (51.5 cm), number of primary branches (4.3), number of capsules per plant (39.91) and number of seeds per capsule (8.03) was recorded with application of pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* metsulfuron methy 120 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence at 60 DAS. However, it was found on par with application of clodinafop + metsulfuron methyl 16 % WP @ 64 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence (Table 2). This might be attributed to initial vigorous crop growth restricted the growth of weeds that has indirectly boosted the plants to record higher growth parameters and also characteristics of better utilization of solar energy and nutrients during plant growth which has contributed for an increased growth of crop and also weed control by different treatments which resulted into less or nearly no crop weed competition for nutrients, light, moisture and space which leads to higher accumulation of photosynthesis. Thus, it clearly indicates that increased weed population adversely affect the yield parameters in linseed. Mishra *et al.* (2005) and Amandeep and Walia (2007) also observed similar results wherein post-emergence application of clodinafop (60 g ha^{-1}) *fb* 2,4-D (0.5 kg ha^{-1}) significantly reduced uptake of N, P and K by both *Phalaris minor* and broadleaf weeds.

Among herbicidal application treatments, significantly higher seed and straw yield was recorded with application of pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence (906 and 2348 kg ha^{-1}, respectively). However, it was found at par with application of clodinafop +

Table 2. Growth and yield parameter of linseed as influenced by different weed management practices.

Treatments	Plant height (cm)	Number of primary branches	Number of capsules per plant	Number of seeds per capsule
T_1: Weedy check	24.9	2.4	22.61	5.33
T_2: Weed free check	53.4	4.7	44.93	8.60
T_3: Hand weeding at 20-25 DAS *fb* intercultivation at 40-45 DAS	52.8	4.5	40.82	8.41
T_4: Metribuzin 70 % WP @ 250 g *a.i.* ha^{-1} + Oxyflourfen 23 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence	34.6	2.7	26.03	6.33
T_5: Pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* Metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage as post-emergence	51.5	4.3	39.91	8.03
T_6: Imazethapyr 10 SL @ 75 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence	40.7	3.1	31.63	7.02
T_7: Oxyflourfen 23.5 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence	31.7	2.6	25.39	6.17
T_8: Metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence	42.4	3.3	33.26	7.16
T_9: Clodinafop-propargyl 15 % WP @ 60 g *a.i.* ha^{-1} at 2-3 leaf stage as post-emergence	43.2	3.4	34.49	7.30
T_{10}: Clodinafop + metsulfuron methyl 16 % WP @ 64 g *a.i.* ha^{-1} at 2-3 leaf stage as post-emergence	49.1	4.2	39.83	7.86
T_{11}: Oxadiargyl 80 % WP @ 80 g *a.i.* ha^{-1} as pre- emergence	40.1	2.9	30.83	6.98
S.Em.±	1.67	0.21	1.75	0.42
C.D. at 5%	4.90	0.61	5.13	1.24

DAS: Days after sowing, *a.i.*: Active ingredient, *fb*: Followed by, CS: Capsulated suspension
EC: Emulsifiable concentrate, SL: Soluble liquids, WP: Wettable powder

Table 3. Seed yield and economics as influenced by different weed management practices in linseed

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	BC ratio
T_1: Weedy check	452	1501	22600	10218	1.83
T_2: Weed free check	957	2417	47850	32068	3.03
T_3: Hand weeding at 20-25 DAS *fb* intercultivation at 40-45 DAS	924	2386	46200	32407	3.35
T_4: Metribuzin 70 % WP @ 250 g *a.i.* ha^{-1} + Oxyflourfen 23 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence	545	1609	27250	12450	1.84
T_5: Pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* Metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage as post-emergence	906	2348	45300	30836	3.13
T_6: Imazethapyr 10 SL @ 75 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence	742	2031	37100	22968	2.63
T_7: Oxyflourfen 23.5 % EC @ 125 g *a.i.* ha^{-1} as pre-emergence	526	1549	26300	12446	1.90
T_8: Metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence	769	2048	38450	25550	2.98
T_9: Clodinafop-propargyl 15 % WP @ 60 g *a.i.* ha^{-1} at 2-3 leaf stage as post-emergence	786	2072	39300	25729	2.90
T_{10}: Clodinafop + metsulfuron methyl 16 % WP @ 64 g *a.i.* ha^{-1} at 2-3 leaf stage as post-emergence	887	2327	44350	30255	3.15
T_{11}: Oxadiargyl 80 % WP @ 80 g *a.i.* ha^{-1} as pre-emergence	735	2023	36750	22988	2.69
S.Em.±	33	86	1560	1560	0.11
C.D. at 5%	98	251	4587	4587	0.33

DAS: Days after sowing, *a.i.*: Active ingredient, *fb*: Followed by, CS: Capsulated suspension
EC: Emulsifiable concentrate, SL: Soluble liquids, WP: Wettable powder

metsulfuron methyl 16 % WP @ 64 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence (887 and 2327 kg ha^{-1}, respectively) (Table 3). Significantly lower grain yield and straw yield was recorded with weedy check (452 and 1501 kg ha^{-1}, respectively). The enhanced yields under these treatments was due to control of weeds which helped in enhancing the availability of nutrients, space, sunlight and water resulting in better growth and development of crop plants.. Ganvit *et al.* (2019) and Jitendra *et al.* (2000) also observed significantly higher seed yield of linseed with pre-emergence application of pendimethalin @ 1.0 kg ha^{-1}.

Weed free check recorded significantly higher gross returns (₹ 47850) as compared to all other treatments. Among herbicide treatment, application of pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence (₹ 45300) as compared to other treatments and it was found at par with clodinafop + metsulfuron methyl 16 % WP @ 64 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence (₹ 44350). Whereas, lower gross returns was observed with weedy check (₹ 22600) due to poor yield (Table 3).

Significantly lower net returns were recorded in weedy check (₹ 10218) as compared to all other treatments. Among herbicidal application treatments, significantly higher net returns was recorded with application of pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence (₹ 30836) and it was found at par with clodinafop + metsulfuron methyl 16 % WP @ 64 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence (₹ 30255).

Significantly higher BC ratio was recorded with application of clodinafop + metsulfuron methyl 16 % WP @ 64 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence (3.15) (Table 3). The lower BC ratio (1.83) was obtained in the weedy check plot. Herbicide technology offers an alternative method of selective and economical control of weeds right from the beginning, giving crop an advantage of good start and competitive superiority and found to be cheaper than hand weeding for effective management of weeds and economic returns in linseed. These results were in conformity with the findings of Puhup and Dwivedi (2019) who reported that application of metsulfuron-methyl @ 4 g ha^{-1} as post-emergence was found superior in respect of various growth and yield attributes *viz.* plant height, dry matter, number of pods plant^{-1}, 100 seed weight, highest seed yield and straw yield of linseed.

Conclusion

The results revealed that application of pendimethalin 38.7 % CS @ 750 g *a.i.* ha^{-1} as pre-emergence *fb* metsulfuron methyl 20 % WP @ 4 g *a.i.* ha^{-1} at 2-3 leaf stage of weeds as post-emergence was found effective in controlling the weeds with higher growth/yield component coupled with grain yield and net returns in linseed consequently higher yield and net returns in linseed.

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