International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 1186-1189

Received: 13-05-2019
Accepted: 15-06-2019

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Effect of integrated weed management on weed flora, weed population, weed control efficiency, weed index and economics of linseed (*Linum usitatissimum* L.) under south Gujarat condition

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Abstract
Field experiment was conducted on clayey soil of the college farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during *rabi* season of 2016-2017 to study the effect of integrated weed management on yield, weed flora, weed population, WCE, WI and economics of linseed (*Linum usitatissimum* L.). Production potential, efficient weed control and higher profit in linseed can be achieved by maintaining weed free through hand weeding throughout crop growth period, where labours are easily available. In case of labours scarcity, application of pendimethalin 0.75 kg/ha PE fb 2, 4-D 0.5 kg/ha PoE, 40 DAS was also effective.

Keywords: Economics, isoproturon, linseed, pendimethalin, weed management, 2, 4-D

Introduction
India is one of the leading oilseeds growing country in the world and fourth largest vegetable oil economy next only to USA, China and Brazil. Oilseeds play the second important role in the Indian agricultural economy, next only to food grains in terms of area and production. It is estimated that nine oilseeds namely groundnut, rapeseed, mustard, soybean, sunflower, safflower, sesame, Niger, castor and linseed. The diverse agro-ecological conditions in the country are favourable for growing oilseeds. India is the second largest linseed growing country in the world after Canada and production-wise it ranks fourth in the world after Canada, China, and USA. Among rabi oilseed crops in India, linseed happens to occupy the second position i.e. next to rapeseed-mustard in importance from the view point of area as well as production.

Linseed (*Linum usitatissimum* L.) is a member of Linaceae family and commonly known as alsi, chikna or linseed in India. Linseed plant is considered to be native to India and eastern Mediterranean. Linseed is an important rabi oilseed crop of eastern Uttar Pradesh. The productivity of linseed in UP is 462 kg/ha against national productivity of 408 Kg/ha. It is grown as sole crop on marginal lands under rainfed conditions and also finds place in mixed or intercropping with component crops like wheat, barley, chickpea and mustard. It is also grown as paira or utera crop in rice field. The cultivation of linseed is restricted mostly to marginal and sub marginal land under restricted supply of fertilizer and irrigation, lack of improved varieties and untimely sowing, resulting in low crop yield. There has been continuous decline in linseed area and production in the country so to sustain the linseed production there need to develop agronomic practices to obtain higher crop yield.

Linseed has poor foliage and never forms a canopy; therefore it remains a poor weed competitor throughout its life. Because of slow initial growth and small sized leaves, the crop is highly infested by weeds causing 30-40% yield losses (Mahere *et al*. 2000) [6]. Yield losses to the tune of 49.7% in linseed due to severe infestation of field dodder have been reported. Flax does not compete well with weeds and therefore needs extensive management for effective weed control. Flax does not rapidly cover the soil surface allowing weeds to recruit later in the growing season and out-compete it for nutrients and space.

Pendimethalin is extensively used as pre-emergence herbicide for weed management in linseed field, but the efficacy of pendimethalin fluctuates according to the soil type, moisture regime, and types of weed flora and there is no recommended herbicide for linseed. Therefore, there is

a need to study the efficacy of non-recommended pre and post-emergence herbicides either alone or in combination for efficient management of different weed species in linseed field in South Gujarat region.

Materials and Methods

A field experiment was conducted on plot B-12 of the College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during rabi season of 2016-17. Twelve treatments comprising of weed management practices *viz*.,T_1: Weed Free, T_2: One hand weeding at 20 DAS, T_3: Two hand weeding at 20 and 40 DAS, T_4: Pendimethalin 1.0 kg/ha PE, T_5: Isoproturon 1.0 kg/ha PoE, 20 DAS, T_6: 2,4-D 0.5 kg/ha, PoE, 20 DAS, T_7: Pendimethalin 0.75 kg/ha PE fb Isoproturon 0.75 kg/ha PoE, 40 DAS, T_8: Pendimethalin 0.75 kg/ha fb 2,4-D 0.5 kg/ha PoE, 40 DAS, T_9: Pendimethalin 0.75 kg/ha + One hand weeding at 40 DAS, T_{10}: Isoproturon 0.75 kg/ha PoE, 20 DAS + One hand weeding at 40 DAS, T_{11}: 2,4-D 0.5 kg/ha PoE, 20 DAS + One hand weeding at 40 DAS, T_{12}: Weedy check; were evaluated in randomized block design with three replications. The soil of the experimental field was clayey in texture, low in available nitrogen (254 kg/ha) and medium in available phosphorus (32.67 kg/ha), fairly rich in available potash (430 kg/ha), slightly alkaline in reaction (pH 7.64) and having well drainage with good moisture retention capacity. The Linseed cv. local variety was sown on 23rd November, 2016 and harvested on 10th March 2017. The crop was fertilized with 60 kg N and 30 kg P_2O_5/ha. Observation regarding to the weed parameters i.e. weed flora, weed population at 20,40,60 and at harvest, WI, WCE and also regarding to yield of seeds and stover and economics as gross return, net return and B:C ratio.

Result and Discussion

Weed flora

Predominant weed flora observed in the experimental field is *Echinochloa crusgalli* L. Beauv, *Cynodon dactylon* L. Pers as a monoct weed. In case of dicot weeds *Euphorbia mudarosptiensis*, Digera arvensis Forsk, Convolvulus arvensis L., *Euphorbia hirta* L., *Physalis minima* L. Portulaca oleracea and sedges weed severe growth of *Cyperus rotundus* L.

Effect of herbicides on weed population

Periodically weed population of monocot, dicot and sedge weeds recorded from one square meter area at 20, 40, 60 DAS and at harvest are furnished in Table 1. All weed management treatments significantly reduced the population of weeds compared to weedy check (T_{12}).

Among the different treatments tried, treatment T_1 (weed free) recorded significantly lowest number of monocot, it was found that, at 20 DAS, application of pendimethalin at higher dose of 1.0 kg/ha, controlled significantly higher monocot weeds (1.88), which was at par with pendimenthalin @ 0.75 kg/ha fb one hand weeding carried out at 40 DAS (2.32). Significantly poor control of monocot was found under the treatment T_{11} (4.79). At 40 DAS, significantly lower monocot weeds population was recorded under treatment T_5 (1.90) in which post emergence application of isoproturon at 20 DAS was done @ 1.0 kg/ha, which was at par with one hand weeding at 20 DAS(T_2, 2.23) and two hand weeding at 20 and 40 DAS(T_3, 2.35). Significantly higher number of monocot (6.03) was recorded under the treatment of weedy check (T_{12}). At 60 DAS, significantly lower monocot weeds population recorded under treatment T_3 (1.82), in which two hand weeding at 20 and 40 DAS, which was at par with T_9 (1.91) pre emergence application of pendimethalin 0.75 kg/ha followed by one hand weeding at 40 DAS, T_{11} (1.91), T_7 (2.06), T_{10} (2.14). Significantly higher number of monocot (6.61) was recorded under the treatment of weedy check (T_{12}) at 60 DAS. In case of monocot weeds population at harvest, significantly lower monocot weeds were recorded under treatment T_3 (1.82), which was at par with T_7 (1.90), T_9 (1.91), T_{10} (1.91) and T_{11} (1.99), while treatment T_{12} recorded significantly highest number of monocot weeds (6.35).

Dicot weeds population at 20, 40, 60 DAS and at harvest was significantly influenced by various weed management treatments. Treatment of weed free (T_1) recorded significantly lowest number of dicot weeds per square metre compared to rest of the treatments. Application of higher dose of pendimethalin @ 1.0 kg/ha (T_4) recorded significantly lower dicot weeds at 20 and 40 DAS (1.99 and 2.47 respectively), but at 20 DAS of weeds counting, application of pendimethalin 0.75 kg/ha with one hand weeding at 40 DAS was found at par with T_4, while at 40 DAS of weed counting, T_2 (2.71), T_3 (2.92), T_6 (2.98) and T_{11} (3.03) were at par with T_4. Significantly highest weeds population of dicot weeds at 20 and 40 DAS was found under weedy check (T_{12}, 4.65 and 5.74). At 60 DAS, significantly lower dicot weeds population recorded under treatment T_8 (2.05), in which pre emergence application of pendimethaline 0.75 kg/ha followed by post emergence application of 2-4 D at 40 DAS @ of 0.5 kg/ha, which was at par with T_{10} (2.06), in which post emergence application of isoproturon 0.75 kg/ha at 20 DAS followed by one hand weeding at 40 DAS, T_{11} (2.28), T_9(2.31), T_3(2.37), T_6 (2.75). Significantly highest number of diocot (6.11) was recorded under the treatment of weedy check (T_{12}) at 60 DAS. At harvest, significantly lower dicot weeds were recorded under treatment T_8 (2.36), which was at par with T_3 (2.30), T_9 (2.37), T (2.80) and T_6 (2.97), while treatment T_{12} recorded significantly highest number of monocot weeds (5.86).

In case of sedges, significantly lowest sedges were found under weed free treatment. Among the different treatments, application of pendimethalin 1.0 kg/ha significantly highest control of sedges (1.91) over rest of treatments at 20 DAS. At 40 DAS, treatment of two hand weeding, each at 20 and 40 DAS (1.58) showed significantly lower sedges population, which was at par with one hand weeding at 20 DAS (T_2,1.91) and post emergence application of isoproturon 0.75 kg/ha at 20 DAS followed by one hand weeding carried out at 40 DAS (2.16). Significantly higher sedges were found under weedy check (T_{12}, 4.31). In case of 60 DAS and at harvest, treatment T_{10} in which post emergence application of isoproturon 0.75 kg/ha at 20 DAS was done followed by one hand weeding carried out at 40 DAS (1.62 and 1.63) recorded significantly lower sedges population, which was at par with T_5, in which only post emergence application of isoproturon was done at higher rate of 1.0 kg/ha (1.90 and 1.91, respective period), while only T_3 was at par (1.97) at 60 DAS. The treatment T_{12} recorded significantly highest number of sedges (4.43, 4.65) at 60 DAS and at harvest. Similar effect was also observed by Giriyapla *et al*. (2016) [1] and Mane *et al*. (2017) [7].

Effect on weed dry weight, weed control efficiency and weed index

Among the different treatments (Table 2), significantly the highest dry weight of total weeds was recorded under weedy check treatment (T_{12}). However, it was found that, among the different herbicidal weed management treatments, treatment T_8 in which pre emergence application of pendimethalin 0.75 kg/ha fb 2,4-D @ 0.50 kg/ha as post emergence at 40 DAS,

recorded significantly lower dry weight of weeds at 60 DAS (2.41 g/m^2) and at harvest (10.1 kg/ha), which was at par with the treatment T_3 (2.60 g/m^2 and 10.7 kg/ha, respectively) in which two hand weeding each at 20 and 40 DAS were carried out, T_9 (2.83 g/m^2 and 11.3 kg/ha, respectively) in which pre application of pendimethalin @ 0.75 kg/ha + one hand weeding at 40 DAS recorded at 60 DAS and at harvest, while T_7 was at par only at 60 DAS (2.93g/m^2). Similar results were also reported by Kumar *et al*. (2012) [5] and Jain and Jain (2016) [2].

Various weed management treatment showed better weed control efficiency. The highest weed control efficiency was achieved at harvest of crop was 100 per cent under weed free treatment (T_1) followed by treatments T_8 (75.72 %) in which, pre-emergence application of pendimethalin 0.75 kg/ha fb 2,4-D 0.5 kg/ha PoE at 40 DAS was done. Second highest WCE (72.61 %) was obtained with the application of two hand weeding at 20 and 40 DAS (T_3) followed by T_9 (69.00 %). The higher weed control efficiency under weed management treatments might be due to periodical removal of germinated weeds by hand weeding or herbicidal control resulted in remarkable reduction in weed population and ultimately less dry weight of weeds was recorded under these treatments. In case of weed index, it was found lowest under weed free treatment (T_1), followed by treatment T_8 (0.2 %) in which, application of pendimethalin 0.75 kg/ha fb 2,4-D 0.5 kg/ha PoE, 40 DAS followed by the treatment T_9 (6.1 %), T_3 (6.9 %) in which two hand weeding carried out at 20 and 40 DAS. This might be due to effective weed control achieved under these weed management treatments in terms of reduced biomass of weeds and higher weed control efficiency. These finding collaborate the results of Kalhapure *et al*. (2013) [3] and Giriyapla *et al*. (2016) [1].

Table 1: Effect of different weed management treatment on monocot, dicot and sedges population in linseed.

Treatments		Monocot weed population (m^2)				Dicot weed population (m^2)				Sedges weed population (m^2)			
		At 20 DAS	At 40 DAS	At 60 DAS	At Harvest	At 20 DAS	At 40 DAS	At 60 DAS	At Harvest	At 20 DAS	At 40 DAS	At 60 DAS	At Harvest
T_1	Weed free	-	-	-	-	-	-	-	-	-	-	-	-
T_2	One hand weeding at 20 DAS	4.51 (19.30)	2.23 (4.00)	3.86 (14.00)	4.04 (15.30)	5.03 (24.33)	2.71 (6.33)	3.63 (12.30)	3.51 (11.30)	4.43 (18.70)	1.91 (2.67)	2.75 (6.67)	3.04 (8.33)
T_3	Two hand weeding at 20 and 40 DAS	4.19 (16.66)	2.35 (4.67)	1.82 (2.33)	1.82 (2.33)	4.89 (23.00)	2.92 (7.67)	2.37 (4.67)	2.30 (4.33)	4.55 (20.33)	1.58 (1.67)	1.97 (3.00)	2.51 (5.67)
T_4	Pendimethalin 1.0 kg/ha PE	1.88 (2.67)	2.87 (7.33)	4.16 (16.30)	4.04 (15.30)	1.99 (3.00)	2.47 (5.33)	3.63 (12.30)	3.90 (14.30)	1.91 (2.67)	3.15 (9.00)	3.55 (11.60)	3.38 (10.60)
T_5	Isoproturon 1.0 kg/ha PoE, 20 DAS	4.25 (17.19)	1.90 (2.67)	2.38 (4.67)	2.40 (5.00)	4.96 (23.67)	4.53 (19.60)	4.96 (23.60)	5.13 (25.30)	3.91 (14.3)	2.38 (4.67)	1.90 (2.67)	1.91 (2.67)
T_6	2,4-D 0.5 kg/ha, PoE, 20 DAS	3.98 (15.00)	3.91 (14.33)	4.51 (19.30)	4.30 (17.60)	4.99 (24.00)	2.98 (8.00)	2.75 (6.67)	2.97 (8.00)	4.24 (17.00)	4.17 (16.60)	4.71 (21.30)	4.61 (20.30)
T_7	Pendimethalin 0.75 kg/ha PE fb Isoproturon 0.75 kg/ha PoE, 40 DAS	2.72 (6.67)	3.20 (9.33)	2.06 (3.33)	1.90 (2.67)	2.70 (6.33)	4.24 (17.00)	3.61 (12.30)	3.79 (13.60)	3.13 (9.00)	3.44 (11.00)	2.15 (3.67)	2.49 (5.33)
T_8	Pendimethalin 0.75 kg/ha fb 2,4-D 0.5 kg/ha PoE, 40 DAS	2.81 (7.00)	3.26 (9.67)	2.74 (6.67)	2.75 (6.67)	2.73 (6.67)	3.77 (13.30)	2.05 (3.32)	2.36 (4.62)	3.41 (10.66)	3.35 (10.30)	3.73 (13.00)	3.91 (14.30)
T_9	Pendimethalin 0.75 kg/ha + One hand weeding at 40 DAS	2.32 (4.42)	3.04 (8.33)	1.91 (2.67)	1.91 (2.67)	2.44 (5.00)	4.16 (16.30)	2.31 (4.38)	2.37 (4.67)	3.26 (9.66)	3.86 (14.00)	2.15 (3.67)	2.06 (3.33)
T_{10}	Isoproturon 0.75 kg/ha PoE, 20 DAS + One hand weeding at 40 DAS	4.54 (19.67)	2.70 (6.33)	2.14 (3.67)	1.91 (2.68)	4.68 (21.00)	4.65 (20.60)	2.06 (3.37)	2.80 (7.00)	3.73 (13.00)	2.16 (3.67)	1.62 (1.67)	1.63 (1.68)
T_{11}	2,4-D 0.5 kg/ha PoE, 20 DAS + One hand weeding at 40 DAS	4.79 (22.00)	3.73 (13.00)	1.91 (2.67)	1.99 (3.00)	4.83 (22.33)	3.03 (8.33)	2.28 (4.33)	2.94 (7.67)	3.80 (13.70)	4.04 (15.33)	2.75 (6.67)	2.50 (5.33)
T_{12}	Weedy check	4.40 (18.33)	6.03 (35.30)	6.61 (42.60)	6.35 (39.30)	4.65 (20.67)	5.74 (32.00)	6.11 (36.33)	5.86 (33.30)	4.20 (16.66)	4.31 (17.60)	4.43 (18.60)	4.65 (20.60)
	S.Em. ±	0.21	0.18	0.15	0.17	0.18	0.21	0.23	0.20	0.22	0.20	0.15	0.22
	C.D at 5 %	0.65	0.55	0.46	0.53	0.57	0.64	0.71	0.62	0.68	0.61	0.46	0.70
	C.V. %	10.50	10.27	8.69	10.2	8.54	10.21	12.75	10.7	11.06	11.51	9.32	13.8

*Data in parenthesis indicate actual value and $\sqrt{X+1}$ transformed value of weeds those outside.

Table 2: Effect of weed management treatments on dry weight of weeds, WCE, WI, yield and economics in linseed.

Treatments		Dry weight of weeds		WCE	WI	Yield(kg/ha)		Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C Ratio
		At 60 DAS (g/m^2)	At harvest (kg/ha)			Seed	Stover				
T_1	Weed free	-	-	100	0.0	1420	2962	19442	99992	80550	4.14
T_2	One hand weeding at 20 DAS	31.46	181.97	55.9	32.7	0955	1646	18018	67179	49161	2.73
T_3	Two hand weeding at 20 and 40 DAS	5.98	113.19	72.6	06.9	1321	2708	19086	93035	73949	3.87
T_4	Pendimethalin 1.0 kg/ha PE	19.97	160.55	61.1	16.9	1181	2337	17782	83114	65332	3.67
T_5	Isoproturon 1.0 kg/ha PoE, 20 DAS	24.26	330.76	19.9	31.0	0979	1958	16610	68945	52335	3.15
T_6	2,4-D 0.5 kg/ha, PoE, 20 DAS	29.06	189.58	54.1	31.8	0969	1864	16332	68203	51871	3.18
T_7	Pendimethalin 0.75 kg/ha PE fb Isoproturon 0.75 kg/ha PoE, 40 DAS	7.63	159.72	61.3	08.7	1297	2465	17742	91283	73541	4.15
T_8	Pendimethalin 0.75 kg/ha fb 2,4-D 0.5 kg/ha PoE, 40 DAS	4.91	100.34	75.7	0.2	1417	2872	17582	99741	82159	4.67
T_9	Pendimethalin 0.75 kg/ha + One hand weeding at 40 DAS	7.13	128.12	69.0	6.1	1334	2576	18450	93872	75422	4.09
T_{10}	Isoproturon 0.75 kg/ha PoE, 20 DAS + One hand	13.26	164.93	60.1	26.4	1045	2090	17560	73591	56031	3.19

	weeding at 40 DAS										
T_{11}	2,4-D 0.5 kg/ha PoE, 20 DAS + One hand weeding at 40 DAS	17.50	153.12	62.9	28.1	1021	1997	17400	71893	54493	3.13
T_{12}	Weedy check	31.99	413.33	-	56.2	622	851	15882	43710	27828	1.75

Selling price: 1. Seed per kg 70 ₹ 2. Stover per kg 0.20 ₹

Economics

Economics is the major consideration of farmers, while taking a decision regarding the adoption of the recently developed new technology. Hence the gross realization, net realization and benefit cost ratio were computed for different weed management treatments. Data presented in (Table 2) revealed that maximum gross returns of (₹ 99992/ha) was realized under the treatment T_1 (weed free), followed by treatment T_8 (₹ 99741/ha) and T_9 (₹ 93872/ha). The higher seed yields recorded under these treatments might be responsible for higher gross return. However, the maximum net returns (₹ 82159/ha) and B: C ratio (4.67) was accrued under the treatment T_8 followed by T_1. The lowest gross return, net return and B: C was accrued under the treatment T_{12} (₹ 43710/ha, ₹ 27828/ha and 1.75 respectively). So higher gross returns along with the lowest cost under T_1, T_8, T_9 treatments might be responsible for higher net return and B: C ratio. These findings are in close vicinity with those reported by Kumar and Nagaich (2013) in linseed, Husain *et al*. (2015) and Giriyapla *et al*. (2016) [1].

Conclusion

Based on results of the field experiment, it seems quite logical to conclude that production potential, higher profit and effective weed control in linseed can be achieved by maintaining weed free through hand weeding throughout crop growth period, where labours are easily available. In case of labours scarcity, application of pendimethalin 0.75 kg/ha PE fb 2,4-D 0.5 kg/ha PoE, 40 DAS was also equally effective.

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