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Effect of Herbicidal Weed Management Strategies on Weed Dynamics and Yield of Lentil

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ABSTRACT: Lentil is an important *Rabi* pulse crops of India. Weeds are unwanted plants and adversely affected the yield of lentil. Keeping the view of seriousness of weeds a field experiment was conducted to evaluate weed management strategies on weed dynamics and yield of lentil during the *Rabi* season 2021-22 at Research area, Bihar Agricultural University, Sabour, Bhagalpur, India. The experiment was comprised with ten weed management practices carried out in randomized block design. Lentil variety HUL 57 was sown and herbicides applied at pre and post emergence. Lentil crop was infested with diverse types of weed flora and dominated with *Vicia sativa, Vicia hirsuta, Chenopodium album, Anagallis arvensis, Solanum nigrum, Cynodon dactylon, Dactyloctenium aegyptium, Phalaris minor* and *Cyperus rotundus.* Weed density, weed dry weight of grassy, broad leaf weeds as well as total weeds were recorded lowest value in weed management practice with metolachlor (50% EC) @ 1.0 kg a.i. ha^{-1} pre emergence followed by one hand weeding at 25 days after sowing. Minimum weed index, maximum weed control efficiency, highest number of branches plant^{-1}, number of pod plant^{-1}, number of seeds pod^{-1}, test weight, maximum grain yield (1.62 t ha^{-1}) and haulm yield (2.54 t ha^{-1}) were observed by metolachlor (50% EC) @ 1.0 kg a.i. ha^{-1} pre emergence followed by one hand weeding at 25 days after sowing. However, all weed management strategies showed more grain and haulm yield as compared to weedy check.

Keywords: Lentil, weed index, herbicide, weed control efficiency, yield.

INTRODUCTION

Lentil (*Lens culinaris* Medik.) is an important and economical *Rabi* season pulse crop of India. Seed of lentil is a good source of protein, minerals and vitamins. It provides human nutrition and straw contains a valued animal feed. It has ability for nitrogen and carbon sequestration adds to soil fertility (Sarker and Erskine 2006). India is the highest producer of lentil and contributing about 32% of world production. The global lentil production is decreasing due to several biotic and abiotic factors. Weeds are biotic stress and play an important role for poor productivity of lentil. Canopy of lentil is often sparse during early season and weeds are capable for occupying space in canopy and compete with the crop of lentil for resource acquisition (Elkoca *et al.*, 2005). These conditions compose lentil as a weak competitor toward weeds thus weed management is an important limitations for production of lentil worldwide (Brand *et al*., 2007). Infestation of weed is one of the restraining factors for achieving optimum production of lentil. Among various crop management practices, weed management strategies have key importance for reducing 20 to 30 % losses in grain yield (Tanveer and Ali 2003). Weed decreases production by competing with lentil plants for their space, water, sunlight and nutrients. Insufficient weed management may reduce the yield 40-66 % of lentil. Considering the above facts, this study focused for finding best weed control strategies effective on the weed dynamics of lentil crop by applying ten herbicides combinations for reducing crop-weed competition for resources. Ahlawat *et al*. (1981) found that most critical period for weed competition in lentil was first 4-8 weeks. Weed management strategies including application of herbicides and other tools, can found more beneficial and economical for lentil crop. According to Barros *et al*. (2018) weed management practices keep the weed community at an adequate level somewhat keep crop totally free from weeds. For realizing potential crop yield, proper weed management is essential (Punia *et al.*, 2017). Weed control strategies often require a combination of mechanical, cultural and chemical measures to hindrance for herbicide resistance and diminish the herbicidal load in the agro-ecosystem (Verma *et al.*, 2017). Earlier findings have been conducted by using herbicides like quizalofop-ethyl and Imazethapyr as post-emergence and pendimethalin as pre-emergence (Singh *et al*., 2014).

MATERIALS AND METHODS

A field experiment was carried out at Research area of Bihar Agricultural University, Sabour, Bhagalpur, Bihar during *Rabi* season, 2021-22. Geographically, Sabour is situated at latitude of 25°15′40″ North and longitude 87°2′ 42″ East with altitude of 45.75 meters above mean sea level in Gangetic plains of the India. The experiment was conducted in RBD comprising ten treatments in three replications as depicted in Table 1. Size of experimental plot was 540 m^2 with lentil variety HUL-57 with seed rate of 35 kg ha^{-1} on 21st November, 2021. Seeds sown at depth 3-5 cm having spacing 30 cm and inter row spacing with application of recommended dose of fertilizers 20:40:00 N, P, K kg ha^{-1}. Cultural practices and plant protection measures were applied to raise the healthy lentil crop. After sun dried produce gone through threshing followed by winnowing and cleaning and weighing the produce *viz*., yield of haulm and yield of seed treatment in terms of kg $plot^{-1}$ and converted into ton ha^{-1}. Grain and straw yield harvest index (HI) was also calculated. Number of weeds was taken from three places randomly in each plot by applying quadrant with size of 50 cm x 50 cm afterward samples were further dried in the hot air oven at temperature 70±2 °C for the period of 48 hours or till constant weight attained than dry weight of weed was calculated in gm^{-2}. Total five plants were selected randomly in each plot to record crop growth characters and yield. Herbicides were sprayed by the hand-operated Knapsack sprayer with flat fan nozzle with the capacity of 500 litres of water ha^{-1}.

Table 1: Treatments of control applied for different types of weeds in lentil crop.

Treatments	Name of herbicide	Dose (gm a.i. ha^{-1})	Application time (DAS)
T_1	Weedy check/Untreated/ Control	-	-
T_2	Hand weeding at 20 DAS	-	20DAS
T_3	Mechanical method by hand grubber	-	-
T_4	Pendimethalin (30% EC)	1000	PE (0-3 DAS)
T_5	Isoproturon (75%WP)	750	PoE (20-25 DAS)
T_6	Pendimethalin (30% EC) + isoproturon (75%WP)	1000 + 750	PE (0-3 DAS) *fb* PoE (20-25 DAS)
T_7	Pendimethalin (30% EC) + imazethapyr (10% SL)	720 + 30	PE (0-3 DAS) *fb* PoE (20-25 DAS)
T_8	Pendimethalin (30% EC) + imazethapyr (10% SL)	960 + 40	PE (0-3 DAS) *fb* PoE (20-25 DAS)
T_9	Metolachlor (50% EC) + one hand weeding	1000	PE (0-3 DAS) + (25DAS)
T_{10}	Metolachlor (50% EC) + quizalofop-ethyl (5% EC)	1000 + 50	PE (0-3 DAS) *fb* PoE (20-25 DAS)

Weed dynamics was counted at interval of 30 DAS to harvest in an area of 0.25m^2(size of quadrate) selected randomly and calculated in per square meter (m^{-2}). Later original value was transformed to the square root values ($\sqrt{X+1}$) subjected to statistical analysis. Analysis of dry weight of weed which was present within the quadrate area and uprooted at the intervals of 30 days after sowing to harvest and subjected to drying in sun followed by drying in hot air oven at temperature 65-70˚C till constant weight observed and recorded (gm^{-2}). Data were subjected to square root transformation value ($\sqrt{X+1}$) and further analysed statistically.

Weed control efficiency was calculated on 60 DAS and harvest on the dry weight basis by applying formula given by the Mani *et al.* (1976).

$$\text{WCE}(\%) = \frac{\text{Dry matter of weeds in weedy check} - \text{Dry matter of weeds in treated plot}}{\text{Dry matter of weeds in weedy check}} \times 100$$

Weed index is reduction in the yield due to infestation of weed. It is estimated by using formula given by the Gill and Kumar (1969).

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

Where,

X- Yield of the weed free plot (kg ha^{-1})

Y-Yield of the treated plot (kg ha^{-1})

Plants selected for the growth studies were applied for recording observations on following components of yield. Branches raised from main shoot were computed of five randomly picked plants from all the treatment plots at 30, 60, 90 DAS and at the time of harvest. Average value were calculated with five plants and uttered as number of the branches $plant^{-1}$. Number of pods $plant^{-1}$, matured pods were separated from the five tagged sample plants in the net plot counted and average taken as number of pods $plant^{-1}$. Seeds from the representative pods separated by the hand threshing and calculated, mean number of seeds period was calculated by dividing the number of seeds by number of pods. Seed samples from produce of each treatment taken at randomly and thousand seeds from samples were counted, weighed and it was expressed in gram 1000 $seed^{-1}$. Pods from every net plot accorded for the treatment threshed, cleaned and seed weight was calculated. Finally seed yield $plot^{-1}$ was converted into yield ha^{-1} by multiplying with correct conversion factor. Haulm yield was determined by the subtracting seed yield from biological yield of each plot under the particular treatment. The values were converted into haulm yield ha^{-1} by using the same conversion factor applied for seed yield ha^{-1}.

Harvest index is calculated by ratio of the economic yield to biological yield under the particular treatment and expressed in percentage and computed by using formula given by Nichiporovich (1967).

$$\text{Harvest index}(\%) = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Where the Biological yield = Grain yield + Haulm yield

RESULTS AND DISCUSSION

The weed flora were collected, identified and grouped as grasses, sedges and broad-leaved weeds in experimental plot during the year 2021-22. The broad-leaved weeds were found in the lentil field *viz*., *Vicia sativa* L, *V. hirsuta* L, *Anagallis arvensis* L, *Chenopodium album* L, *and Solanum nigrum*. Grasses namely *Phalaris minor*, *Dactyloctenium aegyptium* L and *Cynodon dactylon* L *were observed*. Common sedge in lentil was *Cyperus rotundus*. Weeds population (No. m^{-2}) at different growth stages namely 30, 60, 90 DAS and at the time of harvest which influenced by the different weed management strategies are presented in the Table 2-5. Density of grasses (No. m^{-2}) at the different growth stages like 30, 60, 90 DAS and at the time of harvest was significantly influenced by the different herbicidal strategies in lentil crop. For weed management practices at 30 DAS, treatment with metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by 1 hand weeding at 25 DAS exhibited significantly lowest population of grassy weeds (1.20 m^{-2}). Hand weeding at the time of 20 DAS resulted in lowest population of grassy weeds (3.50 m^{-2}). Hand weeding at the time 20 DAS resulted in lowest weed population of the sedge weeds (17.50 m^{-2}). Density of broad-leaved weeds at the time of 90 DAS by application of metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by 1 hand weeding 25 DAS exhibited significantly lowest population of broad-leaved weeds. Density of total weeds (No. m^{-2}) at the time of 60 DAS, application of the metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by 1 hand weeding at 25 DAS exhibited significantly least population of the total weeds (6.10 m^{-2}). Total dry weight of the weeds (g m^{-2}) at the time of 30 DAS, application of the metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by 1 hand weeding at the time of 25 DAS showed significantly least total dry weight of weeds (0.85 m^{-2}). Hand weeding at the time of 20 DAS resulted in minimum total dry weight of weeds (34.82 g m^{-2}). The weed control efficiency (%) at the time of 60 DAS, application of the metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by 1 hand weeding at the time of 25 DAS showed significantly maximum weed control efficiency (98.47%). Weed Index (%) was influenced by the different herbicidal applications in the lentil crop (Table 7). Treatment with metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by one hand weeding at the time of 25 DAS showed significantly highest number of the branches plant $^{-1}$ (10.96). Highest number of pods plant^{-1} showed by the metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by one hand weeding at the time of 25 DAS exhibited maximum number of pod^{-1} (75.86) and number of seed pod^{-1} and test weight (Table 8). Seed yield (1.62 t ha^{-1}) was found highest by the application of metolachlor @ 1.0 kg a.i. ha^{-1} followed by one hand weeding at time of 25 DAS. Haulm yield and harvest index were also found maximum (Table 9) with the application of metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by one hand weeding at the time of 25 DAS.

Table 2: Effect of weed management strategies on population of grassy weeds at various growth stages.

Treatments	Population of the grassy weed (No. m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	3.49(11.30)	4.74(21.50)	6.40(40.00)	5.89(33.70)
T_2	2.08(3.50)	1.92(2.70)	2.50(5.30)	2.12(3.60)
T_3	2.87(7.30)	3.35(10.30)	4.33(17.80)	4.07(15.60)
T_4	3.09(8.60)	2.88(7.30)	3.80(13.50)	3.80(13.50)
T_5	3.19(9.20)	3.11(8.70)	4.28(17.40)	3.98(14.90)
T_6	2.93(7.80)	2.60(5.80)	3.41(10.70)	3.41(10.70)
T_7	2.48(5.20)	2.50(5.30)	3.03(8.20)	3.04(8.30)
T_8	2.37(4.76)	2.25(4.20)	2.89(7.40)	2.91(7.50)
T_9	1.47(1.20)	1.38(1.00)	1.83(2.40)	1.74(2.10)
T_{10}	2.33(4.60)	2.17(3.80)	2.62(6.00)	2.26(4.20)
SEm±	0.09(0.47)	0.06(0.30)	0.09(0.61)	0.05(0.22)
CD (P=0.05)	0.27(1.41)	0.20(0.91)	0.27(1.84)	0.16(0.67)

*Values in the parentheses are original values

Table 3: Effect of weed management strategies on population of sedge weeds at various growth stages.

Treatments	Population of the sedge weed (No. m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	5.19(26.00)	6.24(38.00)	7.14(50.00)	6.58(42.40)
T_2	4.02(15.30)	4.30(17.50)	4.35(18.00)	3.99(15.00)
T_3	5.13(25.40)	5.15(25.60)	5.95(34.50)	5.31(27.30)
T_4	4.81(22.20)	4.96(23.70)	5.69(31.50)	5.13(25.40)
T_5	5.06(24.70)	5.07(24.80)	5.72(31.80)	5.27(26.80)
T_6	4.49(19.20)	4.71(21.30)	5.56(30.00)	4.70(21.10)
T_7	4.42(18.60)	4.53(19.60)	4.72(21.30)	4.46(18.90)
T_8	4.31(17.70)	4.46(18.90)	4.56(19.90)	4.29(17.50)
T_9	1.85(2.50)	2.02(3.10)	2.29(4.30)	2.04(3.20)
T_{10}	4.14(16.20)	4.39(18.40)	4.51(19.40)	4.15(16.30)
SEm±	0.10(0.84)	0.11(1.08)	0.11(1.09)	0.11(0.95)
CD (P=0.05)	0.31(2.54)	0.33(3.24)	0.33(3.27)	0.32(2.84)

*Values in the parentheses are original values

Table 4: Effect of weed management strategies on population of broad-leaved weeds at various growth stages.

Treatments	Population of the broad-leaved weed (No. m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	6.02(35.30)	7.45(54.60)	8.69(74.60)	7.63(57.30)
T_2	3.37(10.40)	3.11(8.70)	3.15(9.00)	2.72(6.50)
T_3	5.54(29.80)	4.74(21.50)	6.04(35.60)	5.70(31.60)
T_4	5.33(27.50)	4.44(18.80)	5.06(24.70)	4.67(20.90)
T_5	5.43(28.50)	4.50(19.30)	5.52(29.50)	4.76(21.70)
T_6	5.05(24.56)	3.84(13.80)	4.66(20.80)	4.28(17.40)
T_7	4.93(23.40)	3.78(13.30)	4.38(18.20)	3.81(13.60)
T_8	3.65(12.40)	3.65(12.40)	3.82(13.60)	3.42(10.80)
T_9	1.77(2.20)	1.71(2.00)	2.13(3.60)	2.01(3.10)
T_{10}	3.51(11.40)	3.21(9.40)	3.36(10.40)	2.84(7.20)
SEm±	0.10(0.86)	0.10(0.81)	0.10(0.79)	0.14(1.02)
CD (P=0.05)	0.32(2.58)	0.32(2.44)	0.31(2.38)	0.43(3.05)

*Values in the parentheses are original values

Table 5: Effect of weed management practices on population of total weeds at different growth stages.

Treatments	Density of the total weeds (No. m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	8.57(72.60)	10.72(114.10)	12.86(164.60)	11.59(133.40)
T_2	5.49(29.20)	5.46(28.90)	5.77(32.30)	5.10(25.10)
T_3	7.96(62.50)	7.64(57.40)	9.42(87.90)	8.68(74.50)
T_4	7.70(58.30)	7.12(49.80)	8.40(69.70)	7.79(59.80)
T_5	7.96(62.40)	7.33(52.80)	8.92(78.70)	8.02(63.40)
T_6	7.24(51.56)	6.47(40.90)	7.90(61.50)	7.08(49.20)
T_7	6.94(47.20)	5.52(31.26)	6.97(47.70)	6.46(40.80)
T_8	5.97(34.86)	6.03(35.50)	6.47(40.90)	6.06(35.80)
T_9	2.59(5.90)	2.63(6.10)	3.34(10.30)	3.03(8.40)
T_{10}	5.74(32.20)	5.70(31.60)	6.05(35.80)	5.34(27.70)
SEm±	0.12(1.37)	0.28(2.85)	0.10(1.39)	0.13(1.40)
CD (P=0.05)	0.38(4.11)	0.85(8.55)	0.32(4.17)	0.39(4.21)

*Values in the parentheses are original values

Table 6: Effect of the weed management strategies on total dry weight of weeds at various growth stages.

Treatments	Total dry weight of weeds (g m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1	2.90(7.47)	8.15(65.55)	13.00(168.14)	13.65(185.38)
T_2	1.92(2.76)	3.08(8.55)	5.05(24.55)	5.98(34.82)
T_3	2.70(6.32)	5.47(28.93)	9.45(88.37)	10.50(109.37)
T_4	2.57(5.68)	4.52(19.54)	7.64(57.48)	8.84(77.28)
T_5	2.68(6.24)	4.77(21.77)	8.07(64.27)	10.17(102.49)
T_6	2.42(4.88)	4.16(16.39)	6.37(39.63)	8.57(72.48)
T_7	2.12(3.57)	3.81(13.54)	5.97(34.69)	8.20(66.37)
T_8	1.95(2.87)	3.43(10.81)	5.32(27.35)	7.16(50.27)
T_9	1.35(0.85)	1.40(1.00)	1.46(1.22)	1.91(2.72)
T_{10}	1.95(2.84)	3.21(9.34)	5.18(25.88)	6.45(40.65)
SEm±	0.08(0.38)	0.08(0.65)	0.09(0.87)	0.07(1.07)
CD (P=0.05)	0.25(1.14)	0.26(1.95)	0.29(2.61)	0.23(3.20)

Table 7: Effect of the weed management strategies on weed control efficiency and weed index at different growth stages.

Treatments	Weed control efficiency (%)		Weed index (%)
	60 DAS	At harvest	
T_1	0.00	0.00	37.03
T_2	86.95	81.21	3.08
T_3	55.86	41.00	32.71
T_4	70.19	58.31	24.07
T_5	66.78	44.71	27.16
T_6	74.99	60.90	19.13
T_7	79.34	64.19	17.90
T_8	83.50	72.88	13.58
T_9	98.47	98.53	0.00
T_{10}	85.75	78.07	6.79
SEm±	1.43	2.13	1.98
CD (P=0.05)	4.30	6.39	5.95

Table 8: Effect of weed management practices on the yield attributes at different growth stages.

Treatments	Number of branches plant^{-1}	Number of pods plant^{-1}	Number of seeds pod^{-1}	Test weight (g)
T1	7.86	44.56	1.77	23.30
T2	10.77	75.72	2.77	23.32
T3	8.72	50.71	1.84	22.65
T4	8.67	58.82	1.97	22.92
T5	8.50	54.05	1.92	22.81
T6	9.47	61.52	2.15	22.41
T7	9.73	62.88	2.43	23.00
T8	10.15	69.36	2.48	23.02
T9	10.96	75.86	2.84	23.42
T10	10.45	72.52	2.61	23.16
SEm±	0.52	2.15	0.48	1.27
CD (P=0.05)	1.55	6.46	NS	NS

Table 9: Effect of the weed management strategies on the grain yield, haulm yield and harvest index at various growth stages.

Treatments	Grain yield (t ha^{-1})	Haulm yield (t ha^{-1})	HI (%)
T1	1.02	1.63	38.49
T2	1.57	2.48	38.76
T3	1.09	1.73	38.65
T4	1.23	1.94	38.80
T5	1.18	1.88	38.56
T6	1.31	2.04	39.10
T7	1.33	2.10	38.77
T8	1.40	2.22	38.67
T9	1.62	2.54	38.94
T10	1.51	2.35	39.11
SEm±	0.08	0.10	0.91
CD (P=0.05)	0.26	0.30	NS

Density of weeds increased up to 60 DAS and afterward a decreasing trend was ecorded, irrespective of weed management strategies. It might be a fact at later stages, growth of weeds decreased due to the senescence and complete life cycle which resulted in decreased weed density. Among weed management practices, use of metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by one hand weeding at the time of 25 DAS most effectively managed grassy weeds, sedges, broad leaved weed and total weeds. Similar findings were reported by Meena and Jadon (2009); Manjunath *et al.* (2010); Sharma *et al*. (2012); Punia *et al.* (2015). Dry matter of the total weeds (g m^{-2}) use of the metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by one hand weeding at the time of 25 DAS might be due to the broad spectrum activities of herbicides. Similar findings were obtained by Rajib *et al*. (2014); Chandrakar *et al*. (2016); Kumar *et al.* (2016). Weed control efficiency and weed index were significantly decreased by the application of metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by one hand weeding at 25 DAS. It might be herbicide's persistence and broad-spectrum mode of action on weeds, which allowed managing weeds more successfully than other herbicides. This treatment, further led to better weed index might be largely due to better grain yield of the crop on account of better weed control efficiency. Similar trends were also found by Padmaja (2015); Pandey (2015); Baldev *et al*. (2011); Khope *et al*. (2011).

CONCLUSIONS

Weed management strategies by metolachlor (50% EC) and one hand weeding after 25 DAS was found better in term of growth yield 38 % higher yield and weed control. Afterward hand weeding at 20 DAS, metolachlor @ 1.0 kg a.i. ha^{-1} PE followed by @ 0.05 kg a.i. ha^{-1} PoE and pendimethalin @ 960 g a.i. ha^{-1} PE followed by the imazethapyr @ 40 g a.i. ha^{-1} PoE also found to be better in terms of suppression of different weeds in lentil. However, all weed management practices in lentil was found effective in reducing weed population, weed growth and better yield than weedy check in lentil crop.

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