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Weed dynamics and performance of lentil as affected by weed management practices under rainfed conditions

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ABSTRACT

The field experiment was conducted at research farm of Tirhut College of Agriculture, Dholi of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar during winter seasons of 2012-13 and 2013-14 to find out the suitable herbicides and their combinations for controlling weeds and improving yield of rainfed lentil (*Lens culinaris*). Study comprised post-emergence application of quizalofop-ethyl 50 g/ha or imazethapyr 37.5 g/ha, pre-plant application of chlorimuron-ethyl 4 g/ha, pre-emergence (PE) application of pendimethalin 300 g/ha, pendimethalin 154 g/ha + imazethapyr 10.5 g/ha (ready-mix), ready-mix pendimethalin 205 g/ha + imazethapyr 14 g/ha (ready-mix), pendimethalin 300 g/ha + hand weeding at 40 DAS, hand weeding twice at 20 and 40 DAS and weedy check. Hand weeding twice at 20 and 40 days after sowing caused the highest reduction (84.6%) in weed population (75.9 and 93.3% in monocot and dicot weeds, respectively) and registered the lowest nutrient depletion (13.6 kg/ha) by weeds. The highest seed yield (1.83 t/ha) obtained with hand weeding twice was 117.4% higher as compared to weedy check. The yield obtained under this treatment was at par with the combined application of pendimethalin 300 g/ha + hand weeding at 40 days after sowing (1.73 t/ha). However, the maximum B: C ratio (3.42) was obtained with application of pendimethalin 205 g/ha + imazethapyr 14 g/ha as PE followed by (*fb*) their lower dose (pendimethalin 154 g/ha + imazethapyr 10.5 g/ha as PE). The chemical weed control was found economically better than hand weeding and weedy check.

INTRODUCTION

Among the numerous pulses grown in India, lentil (*Lens culinaris* Medik.) holds a consequential position because of its wider adaptation to a wide range of climate and soil types. In spite of India's large (30%) share in the global production of lentil, the productivity level in the country is substantially low (678 kg/ha). Weed infestation is one of the major causes of low yield of lentil because this crop has a very weak competitive competency due to minuscule and impotent canopy. Weeds reduce the crop yield through competition for space, light, moisture and plant nutrients. Weeds exhaust the soil depriving the crop of nutrients, particularly nitrogen causing a considerable reduction in yield (Upadhyay *et al*. 2013). The yield loss due to weed infestation can be prevented by effective management of weeds in the field. There is critical crop-weed competition period for every crop when the weeds cause maximum harm by competing with the crop plants (Steckel and Sprague 2004).

Different cultural, physical and chemical methods are often employed to manage the weeds in lentil. Of the various methods, hand weeding is often used for controlling weeds in lentil, but it is labour intensive, time demanding and quite expensive. Herbicide based weed management offers cost effective and timely control of weeds and reduces reliance on labour (Gupta 2003). There is little information available regarding herbicide based weed management in lentil. It is, therefore, imperative to find out the suitable herbicides and their combinations for controlling weeds and improving productivity of lentil.

MATERIALS AND METHODS

A field experiment was conducted for two consecutive winter seasons of 2012-13 and 2013-14 at Tirhut College of Agriculture, Dholi, Bihar (52.18 m altitude, 25.98° N and 85.60° E) under rainfed condition. The soil of the experimental plot was sandy loam in texture having pH 8.1, low in organic carbon (0.25%), available N (182.5 kg/ha), available P (16.6 kg/ha) and medium in available K (122.2 kg/ha). The rainfall received during crop season was 31.5 and 27.8 mm in 2012-13 and 2013-14, respectively. The experiment was laid out in a randomized block design with four replications. Nine treatments of the study comprised, *viz*. quizalofop-ethyl 50 g/ha at 30 days after sowing (DAS), imazethapyr 37.5 g/ha at 30 DAS, chlorimuron-ethyl 4 g/ha as pre-plant incorporation, pendimethalin 300 g/ha as PE, ready-mix of pendimethalin 154 g/ha + imazethapyr 10.5 g/ha (as PE, ready-mix pendimethalin 205 g/ha + imazethapyr 14 g/ha) as PE, pendimethalin 300 g/ha as PE + HW at 40 DAS, hand weeding twice at 20 and 40 DAS and weedy check. The lentil variety '*KLS-218*' was sown during first week of November in both the years in rows 30 cm apart using the seed rate of 35 kg/ha. The plant to plant distance of 10 cm was maintained by thinning at two weeks after sowing. The recommended dose of nutrients (20 kg nitrogen, 50 kg phosphorus and 20 kg potassium/ha) was applied at the time of sowing through di-ammonium phosphate and muriate of potash. Spraying of herbicides as per treatments was done using the knapsack sprayer fitted with flat fan nozzle by using a spray volume of 500 liters/ha.

The observation on weed density and biomass were recorded at 60 days after sowing from an area enclosed in the quadrat of 0.25 m^2 randomly selected at two places in each plot. Weed data were subjected to square root transformation before statistical analysis. Weed mortality (%) of treated plots were calculated by using the formula.

$$\text{Weed Moratlity} = \frac{\text{Weed density in control plot} - \text{Weed density in treated plot}}{\text{Weed density in control plot}} \times 100$$

Weed growth rate (WGR) was calculated by using the formula and is expressed as gram of dry matter of weed produced per day per square meter.

$$\text{WGR} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are dry biomass of plant (g/m^2) at time t_1 and t_2, respectively.

Observations on plant biomass, yield, nutrient uptake and protein content in seeds were recorded at the time of harvesting. The NPK uptake in kg/ha by seed and stover of lentil crop was calculated by multiplying yields of seed or stover with their respective nutrient content, while protein content in seed at maturity was worked out by multiplying nitrogen content of seed at maturity with 6.25 (AOAC, 1960). Economics was computed on the basis of prevailing market rates of produce and agro-inputs. Net returns was calculated by subtracting cost of cultivation from gross returns and benefit: cost ratio was worked by dividing the gross returns by the cost of cultivation.

RESULTS AND DISCUSSION

Effect on weeds

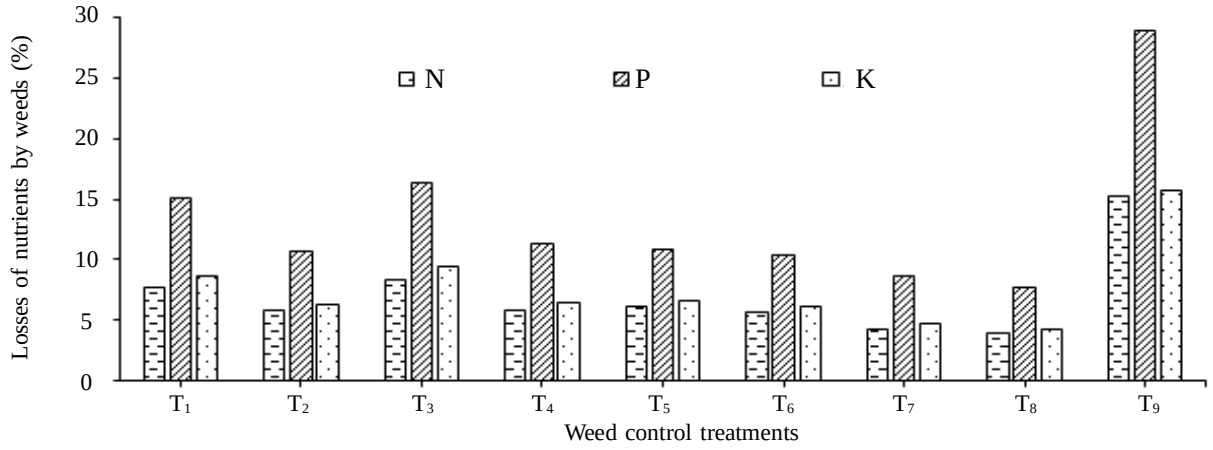
Weed flora: The prominent weeds recorded in the experimental field were *Cynodon dactylon* (L.) Pers and *Cyperus rotundus* L. among monocots and *Anagallis arvensis* L., *Cannabis sativa* L., *Chenopodium album* L. and *Parthenium hysterophorus* L. among dicot weeds. Weed species of comparatively less density in the field included *Avena fatua* L., *Argemone mexicana* L., *Cirsium arvense* L., *Convolvulus arvensis* L., *Fumaria parviflora* L., *Lathyrus aphaca* L., *Melilotus indica* L., *Phalaris minor* Retz., *Solanum nigrum* L. and *Vicia sativa* L.

Weed density: The mean density of monocot and dicot weeds at 60 DAS was significantly reduced by the application of herbicides alone as well as by their combination as ready mix and by integration of pendimethalin with HW (**Table 1**). Hand weeding twice at 20 and 40 DAS caused the highest mortality of monocot and dicot weeds (88.8% and 93.2%, respectively) followed by integration of pendimethalin 300 g/ha with hand weeding at 40 DAS (72.4% and 89.3%, respectively). The PE application of ready mix pendimethalin 205 g/ha + imazethapyr 14 g/ha, pendimethalin 154 g/ha + imazethapyr 10.5 g/ha and pendimethalin 300 g/ha alone were less effective in controlling monocot weeds, but were more effective in controlling the dicot weeds (90.2%, 86.6% and 81.8%, respectively) over control. The application of imazethapyr 37.5 g/ha (PoE), quizalofop-ethyl 50 g/ha post-emergence (PoE) and chlorimuron-ethyl 4 g/ha (pre-plant incorporation) alone proved much better for controlling the monocot weeds to the tune of 62.9%, 60.3% and 59.0%, respectively than pre-emergence herbicides. However, these herbicides failed to control the dicot weeds. Earlier, Manjunath *et al.* (2010) reported effective control of broad-leaved

weeds like *Chenopodium album*, *Melilotus alba*, *Solanum nigrum*, *etc*. with ready mix pendimethalin + imazethapyr or pendimethalin alone in lentil. Sharma *et al.* (2012) reported excellent weed control in soybean with hand weeding twice followed by the treatment comprising integration of imazethapyr with hand weeding.

Weed dry biomass: Hand weeding, integrated weed control measures and herbicidal treatments significantly reduced the weed dry biomass as compared to weedy check (**Table 1**). Hand weeding twice recorded the lowest weed dry biomass (8.50 g/ m^2). Pre-emergence application of ready mix herbicides (pendimethalin 205 g/ha + imazethapyr 14 g/ha, pendimethalin 154 g/ha + imazethapyr 10.5 g/ ha) or pendimethalin 300 g/ha alone resulted in lower weed dry biomass (27.3 - 30.5 g/m^2) compared with PoE application of imazethapyr 37.5 g/ha or quizalofop-ethyl 50 g/ha or pre-plant incorporation of chlorimuron-ethyl 4 g/ha (41.7 - 56.3 g/m^2). The lower weed count and weed dry biomass in these treatments might be due to broad-spectrum control of weeds. Kumar *et al.* (2016) also reported reduction in number of weeds, duration of weed growth and lower dry matter of weeds with integrated weed control measures compared to the weedy check in lentil.

Weed growth rate: All the weed control treatments registered significantly lower growth rate of weeds as compared to weedy check (**Table 1**). Pre-emergence application of pendimethalin 300 g/ha + HW at 40 DAS resulted in the lowest weed growth rate (0.150 g/day/m^2) which was at par with HW twice (0.161 g/ day/m^2). Among the herbicides, imazethapyr 37.5 g/ ha recorded the lowest weed growth rate (0.217 g/ day/m^2) which was significantly lower as compared to rest of the herbicide treatments. The reduction in



T_1 – quizalofop-ethyl 50 g/ha at 30 DAS; T_2 – imazethapyr 37.5 g/ha at 30 DAS; T_3 – chlorimuron-ethyl 4 g/ha as pre-plant; T_4 – pendimethalin 300 g/ha as PE; T_5 – pendimethalin 154 g/ha + imazethapyr 10.5 g/ha as PE; T_6 – pendimethalin 205 g/ha + imazethapyr 14 g/ha as pre-em; T_7 – pendimethalin 300 g/ha as PE + HW at 40 DAS; T_8 – two hand weeding at 20 and 40 DAS; T_9 – weedy check.

Figure 1. Major soil nutrients depletion by weeds under different weed control treatments

Table 1. Weed density and weed mortality in lentil as affected by different weed control treatments at 60 days after sowing

Treatment	Weed density (no./m^2)				Weed dry biomass (g/m^2)	Weed growth rate ($g/day/m^2$)
	Monocots	Mortality (%)	Dicots	Mortality (%)		
Quizalofop-ethyl 50 g/ha at 30 DAS	5.57(30.7)*	60.34	12.42(153.7)	17.68	6.93(47.5)	0.53
Imazethapyr 37.5 g/ha at 30 DAS	5.40 (28.7)	62.93	12.27(150.0)	19.64	6.50(41.7)	0.22
Chlorimuron-ethyl 4 g/ha as pre-plant incorporation	5.67 (31.7)	59.05	12.63(59.0)	68.39	7.54(56.3)	0.88
Pendimethalin 300 g/ha as PE	6.07 (36.3)	53.02	5.87(34.0)	81.79	5.57(30.5)	0.78
Pendimethalin 154 g/ha + imazethapyr 10.5 g/ha as PE	5.93(34.7)	55.17	5.05(25.0)	86.61	5.36(28.2)	0.69
Pendimethalin 205 g/ha + imazethapyr 14 g/ha as PE	5.87(34.0)	56.03	4.34(18.3)	90.18	5.27(27.3)	0.68
Pendimethalin 300 g/ha as PE + HW at 40 DAS	4.67(21.3)	72.42	4.53(20.0)	89.29	3.46(11.5)	0.15
Two HW at 20 and 40 DAS	4.38(8.7)	88.79	3.63(12.7)	93.21	3.00(8.5)	0.16
Weedy check	8.82(77.3)	-	13.68(186.7)	-	8.60(73.5)	1.99
LSD (p=0.05)	0.241	-	0.212	-	0.14	0.32

*Original figures in parentheses were subjected to square-root transformation $\sqrt{x+0.5}$ before statistical analysis. PE - Pre-emergence; HW - Hand-weeding; DAS - Days after sowing

rate of weed growth under these treatments might be attributed to lower weed population and weed biomass.

Nutrient depletion by weeds: The average initial value of available N, P and K in soil were 182.5, 16.6 and 122.2 kg/ha, respectively. All the weed control practices reduced the depletion of NPK by weeds over weedy check (**Figure 1**). Hand weeding twice registered the lowest per cent depletion of nutrients by weeds (15.2% N, 28.9% P and 15.7% K) which was *fb* the treatment comprising PE application of pendimethalin 300 g/ha + HW at 40 DAS. Amongst the herbicides, the nutrient losses through weeds was less in ready mix pendimethalin 205 g/ha + imazethapyr 14 g/ha *fb* imazethapyr 37.5 g/ha, ready mix pendimethalin 154 g/ha + imazethapyr 10.5 g/ha and pendimethalin 300 g/ha alone. Better weed control (number and dry matter of weeds) at critical period of crop-weed competition resulted in lesser depletion of nutrients by weeds (Kumar *et al*. 2016, Younesabadi *et al*. 2013).

Effect on crops

Plant biomass: Weed management practices registered significant differences in plant biomass (**Table 2**). Hand weeding twice recorded the highest plant biomass (492 g/m^2) which was significantly more than that obtained with weedy check and at par with all other treatments. The results confirmed the finding of Ram *et al.* (2011).

Seed yield: All the weed control treatments resulted in significantly higher seed yield than the weedy check (**Table 2**). The highest seed yield (1.83 t/ha) obtained with hand weeding twice registered significant increase of 117.4% over weedy check, but was at par with all other treatments. Pendimethalin 300 g/ha + hand weeding at 40 DAS (1.73 t/ha) and ready-mix pendimethalin 205 g/ha + imazethapyr 14 g/ha (1.67 t/ha) or pendimethalin 154 g/ha + imazethapyr 10.5 g/ha (1.60 t/ha) resulted in yield increase of 105.8%, 98.4% and 90.1%, respectively over weedy check. The efficient weed control measures reduced weed density and weed dry biomass resulting in the improvement in yield attributes and ultimately in crop yield. Similar results were obtained by Kumar *et al.* (2016) in lentil and Chander *et al*. (2014) in soybean.

Nutrient uptake by crop: All the weed control treatments significantly differed with weedy check for uptake of NPK by the crop (**Table 3**). The maximum nutrient uptake by the crop was recorded with hand weeding twice (124.1, 17.7 and 59.1 kg/ha of N, P and K, respectively) and was significantly higher than rest of the weed control treatments. The lowest nutrient uptake was registered under weedy check (72.70, 7.72 and 32.20 kg/ha of N, P and K, respectively). Higher plant dry biomass and higher nutrient content in plants contributed to higher uptake of nutrients. Venkateshwarulu (1984) also observed higher nutrient uptake under the conditions of lesser crop-weed competition.

Protein content: Except application of chlorimuron-ethyl 4 g/ha as pre-plant and quizalofop-ethyl 50 g/ha at 30 DAS, all the weed control treatments resulted in significantly higher protein content in seed than weedy check (**Table 3**). The maximum protein content obtained with hand weeding twice (25.2%) was at par with pendimethalin 300 g/ha + hand weeding at 40 DAS (25.0%) and significantly higher over rest of the weed control treatments. Among the herbicides, the pre-emergence herbicidal treatments were statistically at par with each other and significantly superior over post-emergence and pre-plant incorporated herbicides. The higher protein content in these treatments might be due to the higher uptake of nitrogen by plants and their conversion into amino acid under conditions of reduced crop-weed competition (Gronle *et al*. 2015).

Table 2. Effect of different weed control treatments on growth, yield and economics of lentil

Treatment	Plant biomass (g/m^2) at harvest	Yield (t/ha)	Total cost of cultivation (x10^3 `/ha)	Gross returns (x10^3 `/ha)	B:C ratio
Quizalofop-ethyl 50 g/ha at 30 DAS	398	1.45	10.73	32.63	3.04
Imazethapyr 37.5 g/ha at 30 DAS	404	1.50	10.92	35.72	3.27
Chlorimuron-ethyl 4 g/ha as pre-plant incorporation	365	1.37	10.10	30.60	3.03
Pendimethalin 300 g/ha as PE	416	1.46	11.36	37.26	3.28
Pendimethalin 154 g/ha + imazethapyr 10.5 g/ha as PE	420	1.60	11.53	38.63	3.35
Pendimethalin 205 g/ha + imazethapyr 14 g/ha as PE	433	1.67	11.94	40.84	3.42
Pendimethalin 300 g/ha as PE + HW at 40 DAS	443	1.73	12.67	40.17	3.17
Two HW at 20 and 40 DAS	492	1.83	13.40	38.60	2.88
Weedy check	305	0.84	8.23	23.53	2.86
LSD (p=0.05)	168	0.48	-	-	-

PE- Pre-emergence; HW,- Hand-weeding; DAS- Days after sowing

Table 3. Effect of different weed control treatments on nutrient (N, P, K) uptake by seed and stover of lentil

Treatment	Nutrient uptake by crop (kg/ha)						Protein content in seed (%)
	N		P		K		
	Seed	Stover	Seed	Stover	Seed	Stover	
Quizalofop-ethyl 50 g/ha at 30 DAS	56.3	39.2	5.8	5.6	12.8	31.1	24.2
Imazethapyr 37.5 g/ha at 30 DAS	58.5	39.7	6.1	6.1	13.4	31.6	24.4
Chlorimuron-ethyl 4 g/ha as pre-plant	52.6	35.2	5.3	4.3	11.6	27.5	24.1
Pendimethalin 300 g/ha as PE	61.7	40.8	6.9	6.5	14.5	32.5	24.7
Pendimethalin 154 g/ha + imazethapyr 10.5 g/ha as PE	63.2	41.2	7.2	6.8	15.4	33.1	24.8
Pendimethalin 205 g/ha + imazethapyr 14 g/ha as PE	66.2	42.4	7.5	6.9	16.2	34.4	24.8
Pendimethalin 300 g/ha as PE + HW at 40 DAS	69.2	43.5	8.1	7.5	17.1	35.1	25.0
Two HW at 20 and 40 DAS	73.6	50.5	8.8	8.9	18.5	40.6	25.2
Weedy check	43.2	29.5	4.2	3.6	9.3	23.0	24.1
LSD (p=0.05)	6.85	4.91	0.98	1.02	2.04	3.70	0.25

Pre-plant - Pre-plant incorporation; PE- Pre-emergence; HW- Hand-weeding; DAS - Days after sowing

Economics

Hand weeding twice resulted in the highest cost of cultivation (` 13404/ha) *fb* combined use of pendimethalin 300 g/ha + HW at 40 DAS (` 12673/ ha). The cost of cultivation in case of herbicidal treatments was low in comparison to manual weed control and integrated approaches.

The influence of all the weed control treatments on gross return and B:C ratio were well marked as they registered significantly higher gross returns and B:C ratio over weedy check (**Table 2**). The maximum gross returns (` 40842/ha) and B:C ratio (3.42) were obtained with the ready-mix pendimethalin 205 g/ha + imazethapyr 14 g/ha, *fb* integrated treatment of pendimethalin 300 g/ha + HW at 40 DAS and ready-mix pendimethalin 154 g/ha + imazethapyr 10.4 g/ha . It may be due to higher seed and stover yield as a result of high weed control efficiency coupled with lesser cost of herbicide under these treatments.

Based on the results of present investigation, it was concluded that PE application of ready-mix pendimethalin 205 g/ha + imazethapyr 14 g/ha offers a cost effective and profitable weed management in lentil under rainfed condition.

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