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Bio-efficacy of pre and post-emergence herbicides on lentil yield, weed control efficiency, weed index, nutrient uptake and economics

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Abstract

Lentil (*Lens culinaris* Medikus) is an important grain legume crop. Among all the biotic factors, weed infestation is being an adverse impact on growth, yield, nutrient uptake and economics due to lentil short stature, low branching, lack of protective canopy and it's unable to smother the weeds. Although, applying pre emergence herbicides, in many situation early weed control herbicides are not that much efficient for attaining higher yields due to lentil is long duration crop and critical weed competition upto 40-60 DAS. Sequence use of pre and post-emergence herbicides and application of early post-emergence herbicides may help in controlling the weeds at later stages of crop growth period. To understand resources distribution in lentil a field experiment was laid out at BAU research farm, Sabour during *Rabi* of 2019-20 in RCBBD replicated thrice with 13 treatments to assess the effect of various pre and post-emergence herbicides in lentil. Out of 13 treatments, weed free treatment produced significantly higher grain yield and haum yield and new generation herbicides application of pendimethalin fb quizalofop-ethyl + imazethapyr and oxyflurofen fb quizalofop-ethyl + imazethapyr were statistically at par with weed free treatment. Weed control efficiency, Weed index, Nutrients uptake and Economics by different weeds treatments were recorded significantly higher in pendimethalin fb quizalofop-ethyl + imazethapyr, oxyflurofen fb quizalofop-ethyl + imazethapyr and imazethapyr + imazomox at 60 DAS and at harvest. Ultimately, it can be concluded that, application of pendimethalin fb quizalofop-ethyl + imazethapyr and oxyflurofen fb quizalofop-ethyl + imazethapyr in lentil brings in enhancing grain yield and achieving more net returns, B:C ratio apart from suppressing the weeds through higher weed control efficiency and lower weed index.

Keywords: Grain yield, weed free, weed control efficiency, weed index, economics, nutrient uptake, pendimethalin, imazethapyr, oxyflurofen and quizalofop-ethyl

Introduction

Lentil (*Lens culinaris* Medikus.), also known as poor man's meat, is one such "superfood" and has the potential to provide daily prebiotic requirements. Compared with cereal food products, prebiotics are found at high levels in lentils. Lentil is one of humanity's oldest crops and is believed first it has been domesticated and cultivated in the Fertile Crescent of the Near East (Sonnante *et al.* 2009) [12]. Lentil is a parts of the world, particularly in parts of Asia continent. Where it represents an important human protein source (Sarker and Erskine 2006) [10]. Lentils exhibit a slow growth rate, particularly early in the growing season, with slow canopy closure (Brand *et al.* 2007, Kirkland *et al.* 2000) [3, 7]. Thus, the lentil canopy is often sparse early in the season and weeds are able to occupy space in the canopy and compete against the lentil crop for resource acquisition (Elkoca *et al.* 2005) [4]. These factors make lentil a weak competitor against weeds, and weed control is major significant limitations in lentil production worldwide (Brand *et al.* 2007) [3]. Yield losses in lentil due to weed competition have been estimated at between 25 and 80% (Ball *et al.* 1997, Boerboom and Young 1995, Swanton *et al.* 1993) [1, 2, 13]. By practicing many agronomic management practices we can increase the yields. To attain higher productivity good weed control during the critical weed competition period is necessary. By practicing the cultural and mechanical methods alone weeds can't be controlled due to lentil short stature, low branching ability, lack of protective canopy it's unable to smother the weeds. Based on effectiveness and economics, weed management methods may depend. Due to non-availability of labour at right time and increased cost for manual labour, the chemical control of weeds plays an important role.

The herbicides application practices manage the different weeds timely and effectively, but also it is an effective way in reduction of cost of controlling weeds, irrespective of the situations. Even though farmers applying pre emergence herbicides, in many circumstances early weed control herbicides are not that much efficient for attaining higher yields due to lentil is long duration crop and critical weed competition is upto 40-60 DAS (Days after Sowing). Sequence use of pre and post-emergence herbicides may help in controlling the weeds at later stages of crop growth period. In India only about 15-20% of the lentil cultivated area weeds are controlled by herbicide usage. The crop yields may reduced due to high infestation of weeds during critical growth period hence it is difficult for effective control of weed flora through cultural methods and manual weeding. Beside this, non availability of labour at right time and high wages of labour manual weeding is also problematic in controlling the weeds, by usage of pre and post-emergence herbicide weed control has become the preferred method of weed control for long duration crops like lentil. Considering the effective weed management practices, this research mainly focused to find out best weed control practices to get higher yields and economics of lentil by using 13 herbicidal combinations to reduce crop-weed competition for resources and also to check the treatments with higher weed control

efficiency.

Materials and Methodology

The experiment was conducted during *rabi* season of 2019-20 at Research farm of Bihar Agricultural University, Sabour, Bhagalpur (Bihar). Geographically, Bhagalpur is situated at latitude of 25°15' 40" N and longitude 87°2' 42" E with altitude of 45.75 meters above the mean sea level under middle Gangetic plains of India. The average annual rainfall of this locality is 1167.0 mm, about 75 to 80% of which precipitates during middle of June to middle of October (about 120 days) and there is very scanty rainfall during the remaining period (245 days). Pre-monsoon showers are usually received in the month of May which is the hottest month when average monthly temperature reaches around 36 °C while winter monthly average temperature drops below 10 °C in the month of January. During crop season Nov.-April 2020, minimum and maximum temperature ranged between 5.5 °C to 22.6 °C and 17.3 °C to 36.4 °C, respectively. While the mean relative humidity was in the ranges of 84.9% to 97.8% at 7:00 AM and 55% to 82.4 % at 2:00 PM respectively. Total rainfall received during crop growing season was 118.5 mm. The range of average sunshine hour and evaporation were 1.1 hr. to 8.9 hr. and 0.4 mm to 8.5 mm, respectively.

Table 1: Treatments used in research to control different types of weeds in lentil crop

Treatment	Herbicide name	Dose (g a.i-ha ⁻¹)	Time of application (DAS)
T ₁	Pendimethalin (30% EC)	1000	Pre-em (0-3 DAS)
T ₂	Oxyfluorfen (23.5% EC)	150	Pre-em (0-3 DAS)
T ₃	Quizalofop ethyl (5% EC)	50	Post-em (25-30 DAS)
T ₄	Topramezone (33.6% SC)	40	Post-em (25-30 DAS)
T ₅	Imazethapyr (10% SL)	60	Post-em (25-30 DAS)
T ₆	Propaquizafop (10% EC)	100	Post-em (25-30 DAS)
T ₇	Imazethapyr 35% + Imazamox 35% WG	60	Post-em (25-30 DAS)
T ₈	Quizalofop ethyl (5% EC) + Imazethapyr (10% SL)	60+50	Post-em (25-30 DAS)
T ₉	Clodinafop-propargyl 8% + Na-acifluorfen 16.5% EC	60+50	Post-em (25-30 DAS)
T ₁₀	Pendimethalin (30% EC) fb Quizalofop ethyl (5% EC) + Imazethapyr (10% SL)	1000 fb 60+50	Pre fb Post-em (25-30 DAS)
T ₁₁	Oxyfluorfen (23.5% EC) fb Quizalofop ethyl(5% EC) + Imazethapyr (10% SL)	150 fb 60+50	Pre fb Post-em (25-30 DAS)
T ₁₂	Weed free	-	-
T ₁₃	Weedy check	-	-

Fertility status of the experiment as envisaged through organic carbon (0.52), available nitrogen (224.00 kg/ha⁻¹), phosphorus (39.20 kg/ha⁻¹) and potash (157.00 kg/ha⁻¹) were in available range. Thirteen weed management practices (Table 1) were implemented in a randomized complete block design (RCBD) with three replications. The size of the total experimental plot was 966 m². The variety used for sowing of lentil is HUL-57 with optimum seed rate 35 kg/ha⁻¹ on 18th November, 2019. Seeds were sown at a depth 3-5 cm with spacing of 30 cm inter row spacing. The method of sowing adopted was line sowing opening the soil with furrow placed the seeds and covered with loose soil. The recommended dose of fertilizers is (20:40:00 N:P:K) Kg/ha⁻¹, the source of N and P applied through urea and DAP. The fertilizer was applied as basal application to all the treatment plots. The recommended cultural practices and plant protection measures were followed to raise the healthy crop. Harvesting is done by cutting the plant with sickle above the ground level after attaining the harvesting maturity and most of the pods became dry. In each and every treatment plot five plants were tagged,

those plants harvested separately for record of post-harvest observations. Later net area was harvested, after harvesting the plants are allowed to sundry in their respective plots. After sun drying, the plot wise produce was done through threshing, winnowing and cleaning operations manually, followed by weighing the produce as haulm yield and seed yield treatment wise in terms of kg plot⁻¹ and then converted into t ha⁻¹ (tone per ha). From grain and haulm yield, harvest index (HI) was calculated. The five numbers of plants was selected at random in each plot to take nutrient uptake, yield attributes and yield. The herbicides were sprayed with the help of a hand-operated Knapsack sprayer fitted with flat fan nozzle using 500 liters of water ha⁻¹. For weeds, nutrient content (%) was multiplied to their corresponding total dry weights (kg/ha⁻¹) at harvest and nutrient uptake of weeds was represented as kg/ha⁻¹.

Results and Discussion

Grain yield, Haulm yield and HI

Data on grain yield, haulm yield and HI in lentil crop under different herbicidal treatments was mentioned under Table 2.

In this experiment, the results explored that Weed free treatment (Grain yield: 1.59 t/ha; Haulm yield: 2.50 t/ha), pendimethalin fb quizalofop-ethyl + imazethapyr (Grain yield: 1.50 t/ha; Haulm yield: 2.30 t/ha) and oxyfluorfen fb quizalofop-ethyl + imazethapyr (Grain yield: 1.47 t/ha; Haulm yield: 2.28 t/ha) recorded highest grain yield and haulm yield that has been statistically on par with each other and was slightly higher than the majority of weed control treatments. The lowest haulm yield (1.80 t/ha) and seed yield (1.00 t/ha) of lentil was noted under weedy check (T13) because of greater removal of available moisture and nutrients by the weeds and severe weed crop competition resulted into weak

source and sink development along with retarded yield attributes and greater weed index. The data on harvest index (HI) under the influence of different weed control treatments in lentil showed that there was no significant impact of treatments for weed control on harvest index. However, maximum HI was recorded in T10 (39.3%) treatment followed by the treatments T11 (39.1%) and T12 (38.9%). The treatments Weedy check (35.7%), imazethapyr + imazomox (36.2%) and Propaquizafop (35.8%) treated plots produced lower HI. These results are consistent with the findings of Kavaliauskaite and Bobinas (2006) [6].

Table 2: Influence of different weed control treatments on grain yield (t ha⁻¹), haulm yield (t ha⁻¹) and harvest index (%) in lentil

Treatment	Grain yield (t ha ⁻¹)	haulm yield (t ha ⁻¹)	Harvest index (%)
T ₁	1.27	2.14	37.4
T ₂	1.26	2.09	37.5
T ₃	1.13	1.94	36.8
T ₄	1.29	2.14	37.6
T ₅	1.23	2.03	37.6
T ₆	1.09	1.95	35.8
T ₇	1.04	1.83	36.2
T ₈	1.40	2.24	38.4
T ₉	1.35	2.16	38.5
T ₁₀	1.49	2.30	39.3
T ₁₁	1.47	2.28	39.1
T ₁₂	1.59	2.50	38.9
T ₁₃	1.00	1.80	35.7
SEm ±	0.04	0.07	0.01
CD (P=0.05)	0.13	0.22	NS

Weed control efficiency (%) and Weed index (%)

Data related to weed control efficiency (%) and weed index (%) which was affected by different herbicidal treatments in lentil crop are presented in Table 3. It was observed that the herbicidal activity i.e., weed control efficiency of herbicides was increased gradually and at time of harvest, there was slight declination was noticed in WCE. The weed control efficiency (%) was recorded maximum in weed free (T12) treatment (100%) at 60 DAS and at time of harvest and it was significantly higher compared to all other treatments. Next to weed free treatment, the treatments namely T7 (84.27% at 60 DAS), T10 (88.43% at 60 DAS and 80.93% at harvest) and T11 (87.49% at 60 DAS and 79.64% at harvest) showed higher weed control efficiency (%) and these treatments were

statistically at par with each other. These observations were in close proximity with findings of (Prachand *et al.* 2015) [8]. Weed index indicates percent reduction in grain yield due to crop-weed competition. So, the treatment with lesser weed index is considered to be more productive in nature. Among all the weed control treatments, weed free (T12) treatment produced zero weed index and the treatments T8 (11.92%), T10 (6.17%) and T11 (7.62%) produced significantly lower weed index and were statistically at par with each other. Weedy check (36.84%), propaquizofop (31.26%) (T6) and imazethapyr + imazomox (34.41%) (T7) were recorded significantly higher weed index and these treatments were statistically at par with each other. This finding is closer to the findings of (Rao 2010) [9].

Table 3: Influence of different weed control treatments on weed control efficiency (%) and weed index (%) in lentil

S. No.	Weed Control Efficiency (%)		Weed Index (%)
	60 DAS	At Harvest	
T ₁	69.51	62.42	19.62
T ₂	66.30	60.99	20.78
T ₃	67.98	45.31	28.54
T ₄	76.84	66.28	18.74
T ₅	71.99	61.05	22.66
T ₆	59.86	47.02	31.26
T ₇	84.27	74.30	34.41
T ₈	81.74	75.50	11.92
T ₉	73.75	63.59	14.68
T ₁₀	88.43	80.93	6.17
T ₁₁	87.49	79.64	7.62
T ₁₂	100.00	100.00	0.00
T ₁₃	0.00	0.00	36.84
SEm ±	1.477	1.532	2.517
CD (P=0.05)	4.338	4.497	7.391

Nutrient Uptake by Weeds

Nitrogen uptake

The uptake of nitrogen by weeds have been presented in table 4 and recorded as minimum (0.00 kg/ha⁻¹) and maximum (32.36 kg/ha⁻¹) with weed free (T₁₂) and weedy check (T₁₃), respectively. Among the herbicide treatments, the minimum uptake (5.54 kg/ha⁻¹) was recorded with pendimethalin *fb* quizalofop-ethyl + imazethapyr @ 1000 *fb* 60 + 50 g a.i/ha⁻¹ (T₁₀) which was at par with oxyflurofen *fb* quizalofop-ethyl + imazethapyr @ 150 *fb* 60 + 50 g a.i/ha⁻¹ (T₁₁) (6.0 kg/ha⁻¹) and was significantly lower over rest of the treatments. Similar results was noticed by (Singh, 1993) [11].

Phosphorus uptake

The maximum (6.40 kg/ha⁻¹) and the minimum (0.00 kg/ha⁻¹) uptake of phosphorus by weeds were recorded with weedy check (T₁₃) and weed free (T₁₂), respectively. Among the herbicidal treatments, the minimum uptake of phosphorus (1.15 kg/ha⁻¹) was recorded with pendimethalin *fb* quizalofop-ethyl + imazethapyr @ 1000 *fb* 60 + 50 g a.i/ha⁻¹ (T₁₀) which was at par with imazethapyr + imazamox @ 60 g a.i/ha⁻¹ at 20 DAS (T₇), quizalofop-ethyl + Imazethapyr @ 60 + 50 g a.i/ha⁻¹

¹ at 20 DAS (T₈) and oxyflurofen *fb* quizalofop-ethyl + imazethapyr @ 150 *fb* 60 + 50 g a.i/ha⁻¹ (T₁₁) and was significantly lower over rest of the treatments and presented in table 4.

Potassium uptake

The uptake of potassium by weeds at harvest ranged between 0.00 to 26.34 kg/ha⁻¹. The minimum uptake of potassium (0.00 kg/ha⁻¹) was recorded with weed free treatment (T₁₂). Among the herbicide treatments, the minimum K uptake (4.67 kg/ha⁻¹) was found with pendimethalin *fb* quizalofop-ethyl + imazethapyr @ 1000 *fb* 60 + 50 g a.i/ha⁻¹ (T₁₀) which was at par with oxyflurofen *fb* quizalofop-ethyl + imazethapyr @ 150 *fb* 60 + 50 g a.i/ha⁻¹ at 20 DAS (T₁₁). This is because of minimizing the weed density and lowers the crop weed competition in weed free treatment leads to minimum depletion of nutrients by weeds and it's the way for maximum utilization and uptake of nutrients by the crop at different stages to till harvest and this obviously leads to more dry matter accumulation in seeds and haulm and also higher N, P and K concentrations in seeds and haulm, similar results was noticed by (Singh, 1993) [11].

Table 4: Uptake of nutrients (N, P and K) by weeds (kg/ha⁻¹) as influenced by different weed control treatments

S. No.	Uptake of Nutrients by Weeds					
	Concentration (%)			Uptake (kg/ha)		
	N	P	K	N	P	K
T ₁	1.59	0.27	1.31	11.82	1.98	9.77
T ₂	1.60	0.28	1.32	12.30	2.12	10.18
T ₃	1.62	0.29	1.34	17.56	3.08	14.48
T ₄	1.56	0.26	1.27	10.40	1.71	8.50
T ₅	1.61	0.29	1.34	12.36	2.19	10.31
T ₆	1.62	0.30	1.35	17.04	3.19	14.15
T ₇	1.62	0.23	1.35	8.20	1.16	6.85
T ₈	1.53	0.29	1.25	7.40	1.42	6.06
T ₉	1.57	0.26	1.30	11.26	1.84	9.35
T ₁₀	1.46	0.30	1.24	5.54	1.15	4.67
T ₁₁	1.49	0.30	1.25	6.00	1.22	5.04
T ₁₂	1.44	0.29	1.23	0.00	0.00	0.00
T ₁₃	1.63	0.32	1.33	32.36	6.40	26.34
SEm ±	-	-	-	0.516	0.093	0.427
CD (P=0.05)	-	-	-	1.516	0.273	1.252

Studies on the Economics of Weed Control in Lentil

Cost of Cultivation

Data on cost of cultivation as influenced by different weed control treatments have been presented in Table 5.

It is evident from the data presented in Table 5 that maximum cost of cultivation (Rs. 32273 ha⁻¹) was incurred under weed free treatment (T₁₂). Among herbicide treatments, highest cost of cultivation (Rs. 30363 ha⁻¹) was recorded under topramezone 40 g a.i/ha⁻¹ (T₄) followed by with pendimethalin *fb* quizalofop-ethyl + imazethapyr @ 1000 *fb* 60 + 50 g a.i/ha⁻¹ (T₁₀) and oxyflurofen *fb* quizalofop-ethyl + imazethapyr @ 150 *fb* 60+50 g a.i/ha⁻¹ (T₁₁).

Gross Returns

It is evident from the data in Table 5, that the highest gross return of Rs. 88751 ha⁻¹ was recorded under weed free treatment (T₁₂) and lowest gross return of Rs. 57032 ha⁻¹ was recorded under weedy check (T₁₃). Among herbicide treatments, highest gross return of Rs. 83070 ha⁻¹ was recorded under pendimethalin *fb* quizalofop-ethyl + imazethapyr @

1000 *fb* 60 + 50 g a.i/ha⁻¹ (T₁₀) which was statistically at par with oxyflurofen *fb* quizalofop-ethyl + imazethapyr @ 150 *fb* 60 + 50 g a.i/ha⁻¹ (T₁₁) and quizalofop-ethyl + imazethapyr @ 60+50 g a.i/ha⁻¹ (T₈) and was found significantly superior over rest of the treatments.

Net Returns

Data on net return calculated from gross returns and cost of cultivation for each treatment as influenced by different weed control treatments has been presented in Table 5.

The data revealed that significantly highest net return of Rs. 56478 ha⁻¹ was accrued when weed free treatment (T₁₂) was applied which was statistically at par with pendimethalin *fb* quizalofop-ethyl + imazethapyr @ 1000 *fb* 60+50 g a.i/ha⁻¹ (T₁₀), oxyflurofen *fb* quizalofop-ethyl + imazethapyr @ 150 *fb* 60+50 g a.i/ha⁻¹ (T₁₁) and quizalofop-ethyl + imazethapyr @ 60+50 g a.i/ha⁻¹ (T₈) and clodinafop-propargyl + Sodium-acifluorfen @ 60 g a.i/ha⁻¹ POE (T₉) and was significantly superior over rest of the treatments. This result is in conformity with the findings of Jha *et al.* (2014) [5].

Benefit- Cost Ratio

Data on benefit: cost ratio calculated from net return and cost of cultivation of each treatment as influenced by different weed control treatments have been presented in Table 5.

Data revealed that effect of different weed control treatments was found significant on benefit: cost ratio. Highest B:C ratio was found (2.05) in clodinafop-propargyl + sodium-acifluorfen @ 60 g a.i/ha⁻¹ POE (T₉) which was statistically at

par with pendimethalin fb quizalofop-ethyl + imazethapyr @ 1000 fb 60 + 50 g a.i/ha⁻¹ (T₁₀), oxyfluorfen fb quizalofop-ethyl + imazethapyr @ 150 fb 60 + 50 g a.i/ha⁻¹ (T₁₁) and quizalofop-ethyl + imazethapyr @ 60 + 50 g a.i/ha⁻¹ (T₈), oxyfluorfen @ 150 g a.i/ha⁻¹ as PE (T₂) and pendimethalin @ 1000 g a.i/ha⁻¹ as PE (T₁) and was found significantly superior over rest of the treatments.

Table 5: Influence of different weed control treatments on economics of lentil

S. No.	Treatments	Cost of cultivation (Rs. ha ⁻¹)	Gross returns (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	B:C ratio
T ₁	Pendimethalin @ 1000 g a.i/ha ⁻¹ PE	25328	71837	46509	1.84
T ₂	Oxyfluorfen @ 150 g a.i/ha ⁻¹ PE	24728	70723	45995	1.86
T ₃	Quizalofop-ethyl @ 50 g a.i/ha ⁻¹ at 20-25 DAS	25763	64117	38354	1.49
T ₄	Topramezone @ 40 g a.i/ha ⁻¹ at 20-25 DAS	30363	72495	42132	1.39
T ₅	Imazethapyr @ 50 g a.i/ha ⁻¹ at 20-25 DAS	24913	68985	44072	1.77
T ₆	Propaquizafop @ 100 g a.i/ha ⁻¹ at 20-25 DAS	25413	62040	36627	1.44
T ₇	Imazethapyr + Imazamox @ 60 g a.i/ha ⁻¹ at 20-25 DAS	25224	59024	33800	1.34
T ₈	Quizalofop-ethyl + Imazethapyr @ 60+50 g a.i/ha ⁻¹ at 20-25 DAS	27073	78335	51262	1.89
T ₉	Clodinafop-propargyl + Sodium-acifluorfen @ 60 g a.i/ha ⁻¹ at 20-25 DAS	24827	75611	50784	2.05
T ₁₀	Pendimethalin @ 1000 g a.i/ha ⁻¹ PE fb Quizalofop-ethyl + Imazethapyr @ 60+50 g a.i/ha ⁻¹ at 20-25 DAS	28438	83056	54618	1.92
T ₁₁	Oxyfluorfen @ 150 g a.i/ha ⁻¹ PE fb Quizalofop-ethyl + Imazethapyr @ 60+50 g a.i/ha ⁻¹ at 20-25 DAS	27838	81601	53763	1.93
T ₁₂	Weed free	32273	88751	56478	1.75
T ₁₃	Weedy check	23963	57032	33069	1.38
	SEm ±	-	2354.63	2354.72	0.09
	CD (P=0.05)	-	6913.61	6913.87	0.26

Conclusion

Based on the results of the field trials, it can be concluded that using herbicides like pendimethalin fb quizalofop-ethyl + imazethapyr and oxyfluorfen fb quizalofop-ethyl + imazethapyr in lentils increases grain yield, increases nutrient uptake, net returns, and B:C ratio in addition to suppressing weeds through improved weed control efficiency and a lower weed index. The amount of nutrients (N, P, and K) weeds absorb as a result of these herbicidal applications is minimal. By successfully managing weeds, these herbicides reduced crop weed competition, which in turn increased chickpea nutrition uptake and decreased weed nutrient intake.

Future Scope: Long term trail must be conducted for new herbicides and its impact on the crop ecology very closely.

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