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Effects of Chemical and Agronomical Weed Control Treatments on Weed Density, Yield and Yield Parameters of Lentil (*Lens culinaris* L. Cv. Erzurum-89)

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Abstract: This study was conducted in order to investigate the effects of 12 herbicide applications (linuron, prometryn, metribuzin, linuron+prometryn, prometryn+prometryn, metribuzin+prometryn, linuron+fluazifop-p-butyl, prometryn+fluazifop-p-butyl, metribuzin+fluazifop-p-butyl, linuron+quizalofop-p-ethyl, prometryn+quizalofop-p-ethyl and metribuzin+quizalofop-p-ethyl) and hand weeding (once, twice and repeated) in comparison with a weedy control on yield and yield components of lentils (cv. Erzurum-89) in 2000 and 2001 under Erzurum's dry conditions, Turkey. Data were collected on the density and dry weight of weed species, density of lentil, plant height, branch and pod number per plant, 1000-grain weight, seed yield, total biomass yield and harvest index in both years. Weed control applications significantly decreased intensity and dry weight of weeds and increased yield and all yield parameters compared with the unweeded control excepting 1000-grain weight, corresponding increases in yield by 48.3% (metribuzin+quizalofop-p-ethyl) and 74.5% (metribuzin+fluazifop-p-butyl) with significant benefits with chemical herbicides. Pre-emergence+post-emergence combinations, however, gave no clear advantages over single applications of linuron, prometryn and metribuzin. Metribuzin reduced plant stand in wetter conditions of the second year. In conclusion, linuron and prometryn were effective in controlling weeds on lentils without apparent toxic effects. Hand weeding once was also equally effective.

Key words: Lentil, herbicides, weed control, yield, yield parameters

INTRODUCTION

Lentil (*Lens culinaris* L.) is among few legume species adapted well to dry conditions in traditional rainfed cereal based farming system in Turkey. Due to extensive government support for the production of lentils in order to reduce large areas left anually to fallow, its acreage and production have sharply increased over the last two decades. Currently, lentil is grown on 517.000 ha land in dry areas and its production reached 380.000 t[1]. However, long term national yields increased only marginally in consequence of unfavourable cultural practices, especially weed control[2].

Lentils because of their small stature do not grow tall and do not build up a protective canopy to prevent establishment of weeds. Therefore, lentils are poor competitors and good weed control is essential for successful production[3,4]. Lentil growth rates are slow during early stages of vegetative growth and weeds can quickly overgrow the crop if not adequately controlled. Yield losses due to weeds in lentil of 40-80% have been reported[5-7].

Hand weeding is practiced in traditional production areas, but is impractical in the extensive production areas[8,9]. Hand weeding is labour-intensive and therefore an expensive operation when done by hired labour and, if delayed, the operation does not prevent adverse effect of the weeds on crop yield[4]. The use of appropriate herbicides can eliminate this early weed competition and prevent yield losses[3]. It is therefore necessary that effective herbicides should be used to reduce unwanted competition.

This study investigated the efficacy of some herbicide and herbicide combinations in comparison with agronomical weed control under Erzurum conditions.

MATERIALS AND METHODS

This study was carried out on the experimental farm of Atatürk University in Erzurum in Eastern Anatolia (29°55' N and 41°16' E with an altitude at 1850 m a.s.l) in 2000 and 2001 using lentil (*Lens culinaris* cv. Erzurum-89). With an average temperature and total rainfall of 5.7°C and 439.6 mm (Table 1), plant growth in the region is restricted

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Table 1: Climatic data on the experimental site

		Months			Total/Average	
Climatic factors	Years	May	June	July	Growth season	Annual
Total rainfall (mm)	2000	42.0	9.7	4.0	55.7	305.2
	2001	63.2	14.6	36.9	114.7	355.2
	1929-98	73.6	51.1	29.0	153.7	439.6
Average air temperature (°C)	2000	9.8	15.5	22.3	15.9	5.4
	2001	9.8	14.4	19.5	14.6	6.3
	1929-98	10.7	15.0	19.2	15.0	5.7

Table 2: Active ingredients, trade name, application doses and periods of herbicides investigated

Active ingredients/ Treatments	Trade name	Application doses (ha)	Application periods
Linuron 45%	Linurex	2.1 L	Pre-emergence
Prometryn 500 g/l	Gesegard	2.5 L	Pre-emergence
Metribuzin 70%	Sencor	250 g	Pre-emergence
Linuron+Prometryn	Linurex+Gesegard	2.1 L+1.0 L	Pre-emergence+Post-emergence
Prometryn+Prometryn	Gesegard+Gesegard	2.5 L+1.0 L	Pre-emergence+Post-emergence
Metribuzin+Prometryn	Sencor+Gesegard	250 g+1.0 L	Pre-emergence+Post-emergence
Linuron+Fluazifop-p-butyl	Linurex+Fusilade Super	2.1 L+0.8 L	Pre-emergence+Post-emergence
Prometryn+Fluazifop-p-butyl	Gesegard+Fusilade Super	2.5 L+0.8 L	Pre-emergence+Post-emergence
Metribuzin+Fluazifop-p-butyl	Sencor+Fusilade Super	250 g+0.8 L	Pre-emergence+Post-emergence
Linuron+Quizalofop-p-ethyl	Linurex+Targa Super	2.1 L+1.0 L	Pre-emergence+Post-emergence
Prometryn+Quizalofop-p-ethyl	Gesegard+Targa Super	2.5 L+1.0 L	Pre-emergence+Post-emergence
Metribuzin+Quizalofop-p-ethyl	Sencor+Targa Super	250 g+1.0 L	Pre-emergence+Post-emergence
Hand weeded once	-	-	One month after emergence
Hand weeded twice	-	-	One and two months after emergence
Weeded control	-	-	Repeated after emergence
Unweeded control	-	-	-

to the period between May and October. The second year of experiment received higher and more even distribution of rainfall in the growing months of May, June and July. The experimental soil was a sandy loam with organic matter content ranging between 1.68 and 1.87% and lime content between 0.34 and 0.66% (pH=6.36-6.62). Available P_2O_5 content ranged between 87 and 119 kg ha^{-1} and K_2O content between 1422 and 1596 kg ha^{-1}. Seeds were inoculated with a culture in peat obtained from Soil and Fertilizer Research Institute, Ankara and all plots received 60 kg P_2O_5 ha^{-1} in triple superphosphate form[10].

In the experiment, 16 treatments (Table 2) were investigated in three randomized complete blocks. Sowing was done by hand after mixing seeds with 15% glucose solution and bacterial culture in plots having 6 rows of 5 m length with 20 cm inter row spacing so as to give 350 seeds m^{-2} [11] on 26 April 2000 and 26 April 2001. Pre-emergence herbicides were applied on 27 April 2000 and 28 April 2001 and post-emergence herbicides were applied on 13 June 2000 and 14 June 2001 at the recommended doses (Table 2) with a hand operated shoulder sprayer. No rain was recorded 2 days before or after the herbicide applications. No irrigation or other chemical application was done during the plant growth until harvest. Data on weed species in each plot were collected at the flowering stage of lentil. Weeds were cut from ground level in each plot of 1/2 m^2 area and were taken to the laboratory for separation and dry weight determinations. At the harvest stage, plant density was determined and 10 plants were taken from harvest area of each plot for plant height, branch and pod number measurements. Plots were harvested by hand excluding one row from each side and 50 cm from both ends giving an harvest area of 3.2 m^2 on 26 July 2000 and 28 July 2001. Plants were dried for 2-3 days for 1000-grain weight, seed yield, biomass yield and harvest index measurements.

The data were subjected to analysis of variance using MSTATC Statistical Package and mean values were separated according to Duncan's multiple range test.

RESULTS AND DISCUSSION

As an average of both years, *Amaranthus retroflexus* L. (46.8%), *Chenopodium album* L. (35.2%), *Polygonum* spp. (4.9%) and *Convolvulus arvensis* L. (3.3%) were the most dominant broad-leaved weed species in the unweeded control (Table 3). Other species which were of comparatively less density in the plots included *Amaranthus graecizans* L., *Anchusa arvensis* (L.) Bieb., *Centaurea depressa* Bieb., *Chenopodium foliosum* (Moench) Aschers., *Chondrilla juncea* L., *Cirsium arvense* (L.) Scop., *Crambe orientalis* L., *Euphorbia virgata* Waldst. et Kit., *Falcaria vulgaris* Bernh., *Fumaria officinalis* L., *Geranium tuberosum* L., *Hyoscyamus niger* L., *Lactuca serriola* L., *Malva neglecta* Wallr., *Medicago sativa* L., *Myosotis arvensis* (L.) Hill., *Rumex crispus* L., *Salvia* sp., *Sideritis montana* L., *Sisymbrium altissimum* L., *Tragopogon*

Table 3: The intensity of weed (number m^{-2}) and the efficacy of different herbicides and weeding by hand on weed species as an average of 2000 and 2001

Treatments	*A. retroflexus*	*C. album*	*C. arvensis*	Polygonum spp.	Others	Gramineae[1]	Total density	Control (%)[2]
Linuron	13.50	14.50	5.68	1.67	4.32	0.17	39.84	70.6
Prometryn	7.51	5.01	5.66	0.83	2.00	0.67	21.68	84.0
Metribuzin	3.67	0.83	9.34	1.17	0.69	0.00	15.70	88.4
Linuron+Prometryn	12.99	12.16	5.01	1.00	4.68	0.17	36.01	73.4
Prometryn+Prometryn	9.49	6.51	4.17	0.50	3.51	0.17	24.35	82.0
Metribuzin+Prometryn	3.67	1.00	4.49	0.34	3.01	0.50	13.01	90.4
Linuron+Fluazifop-p-butyl	13.51	12.34	6.00	4.50	1.66	0.50	38.51	71.6
Prometryn+Fluazifop-p-butyl	10.99	5.67	4.99	0.50	0.84	0.50	23.49	82.6
Metribuzin+Fluazifop-p-butyl	2.49	1.00	6.18	0.50	3.33	0.17	13.67	89.9
Linuron+Quizalofop-p-ethyl	6.50	8.84	5.02	1.84	2.83	0.67	25.70	81.0
Prometryn+Quizalofop-p-ethyl	6.35	3.51	4.35	0.67	0.68	0.33	15.89	88.3
Metribuzin+Quizalofop-p-ethyl	4.66	1.34	5.34	2.17	2.50	0.00	16.01	88.2
Hand weeded once	20.00	5.34	2.34	0.33	0.68	0.00	28.69	78.8
Hand weeded twice	19.68	5.83	0.17	0.00	0.67	0.00	26.35	80.5
Weeded conrol	5.93	3.34	1.49	0.00	2.19	0.00	12.95	90.4
Unweeded conrol	63.34	47.68	4.51	6.67	12.68	0.50	135.38	-

[1]*Avena fatua* L., *Hordeum vulgare* L. [2]Data not statistically analysed

Table 4: Efficacy of different herbicides and weeding by hand on the dry weight of weeds (g m^{-2})

Treatments	2000	2001	Average	Control(%)[1]
Linuron	45.1b	19.8b	32.5b	66.2
Prometryn	42.6b	1.8b	22.2bc	76.9
Metribuzin	31.9b	1.8b	16.8bc	82.5
Linuron+Prometryn	25.3b	5.5b	15.4bc	84.0
Prometryn+Prometryn	17.8b	2.9b	10.3bc	89.3
Metribuzin+Prometryn	21.4b	6.2b	13.8bc	85.6
Linuron+Fluazifop-p-butyl	40.8b	10.9b	25.9bc	73.0
Prometryn+Fluazifop-p-butyl	19.0b	3.5b	11.2bc	88.3
Metribuzin+Fluazifop-p-butyl	15.4b	0.5b	8.0bc	91.7
Linuron+Quizalofop-p-ethyl	28.1b	10.9b	19.5bc	79.7
Prometryn+Quizalofop-p-ethyl	32.8b	0.1b	16.5bc	82.8
Metribuzin+Quizalofop-p-ethyl	21.1b	7.0b	14.0bc	85.4
Hand weeded once	7.7b	4.9b	6.3bc	93.4
Hand weeded twice	3.1b	0.9b	2.0c	97.9
Weeded control	2.2b	0.6b	1.4c	98.5
Unweeded control	112.1a	80.0a	96.1a	-
Average of herbicide applications	28.4	5.9	17.2	82.1
Average of treatments	29.2a	9.8b	19.5	
LSD Treatment	43.9	22.9	24.6	
LSD Year x Treatment	ns			

Mean values in each column with the same letters are not statistically different at $P < 0.01$. [1]Data not statistically analysed. ns, non significant

bupthalmoides (DC) Boiss. and *Tragopogon dubius* Scop.

A total of 12 herbicide applications and 3 hand weeding treatments (once, twice and repeated) were tested for these weed species control in lentil (Table 2). The existing weed population was significantly affected by applied treatments. All of the herbicide treatments were effective on *Amaranthus retroflexus* L., *Chenopodium album* L., *Polygonum* spp. and the other weed species, but ineffective on *Convolvulus arvensis* L. when compared with the unweeded control (Table 3). The efficacy of herbicides tested was rated in comparison with the control as <40% is weak, 40-70% medium, 70-90% good, >90% excellent[12]. Thus, weed control efficiency was excellent under metribuzin+prometryn (90.4%) whereas metribuzin+fluazifop-p-butyl (89.9%), metribuzin (88.4%), prometryn+quizalofop-p-ethyl (88.3%), metribuzin+quizalofop-p-ethyl (88.2%), prometryn (84.0%), prometryn+fluazifop-p-butyl (82.6%), prometryn+prometryn (82.0%), linuron+quizalofop-p-ethyl (81.0%), linuron+prometryn (73.4%), linuron+fluazifop-p-butyl (71.6%) and linuron (70.6%) were of relatively good efficacy (Table 3). Hand weeding once, twice and repeated provided 78.8, 80.5 and the 90.4% weed control, respectively when compared with the unweeded control.

In other studies metribuzin was reported to effectively control (>90%) broad-leaved annual weed species in lentil[3,13,14]. In Sudan, prometryn, pendimethalin and prometryn+oxyfluorfen applications significantly reduced intensity of weeds between 91 and 99% compared with the unweeded control[4]. Under Spain's conditions the best weed control results in lentil were obtained using prometryn, trifluralin, methabenzthiazuron and linuron[15].

All cultural and chemical weed control treatments markedly reduced weed dry weight as compared with the unweeded control in both years (Table 4). However, soil moisture affected efficiency of the herbicides investigated. Relatively balanced and higher rainfall received in 2001 (Table 1), as an average of herbicide applications, herbicidal effectiveness was greater (92.6%) compared with dry conditions experienced in 2000 (74.7%). Other researchers[3,16] also reported that dry conditions reduced the effectiveness of herbicides and weed control might be poor. Total weed dry weight mass was 96.1 g m^{-2} in the control plots with no herbicide spraying or hand weeding compared with 17.2 g m^{-2} in herbicide sprayed plants on average (Table 4). Thus, herbicidal control of weeds was 82.1% on average. In terms of dry weed mass metribuzin+fluazifop-p-butyl was more effective (91.7%) followed by prometryn+prometryn (89.3%), prometryn+fluazifop-p-butyl (88.3%), metribuzin+prometryn (85.6%), metribuzin+quizalofop-p-ethyl (85.4%) and the others. Hand weeding once, twice

Table 5: Effect of herbicides and hand weeding on plant density, plant height, branch and pod number per plant of lentil

	Plant density (number m^{-2})			Plant height (cm)			Branch number $plant^{-1}$			Pod number $plant^{-1}$		
Treatments	2000	2001	Average	2000	2001	Average	2000	2001	Average	2000	2001	Average
Linuron	213.3	250.0a	231.7a	23.3a	20.8cd	22.1ab	3.7a-d	5.5abc	4.6a-d	10.7a-d	13.5cd	12.1cd
Prometryn	210.0	258.3a	234.2a	23.2a	22.0a-d	22.6ab	3.0b-e	5.3abc	4.2bcd	9.2b-e	14.4c	11.8cd
Metribuzin	211.7	158.3b	185.0c	23.3a	22.7abc	23.0ab	4.6a	6.9ab	5.7a	13.1ab	19.1ab	16.1a
Linuron+Prometryn	215.0	281.7a	248.3a	22.3ab	21.6bcd	21.9ab	2.5cde	5.5abc	4.0cd	8.5cde	12.3cd	10.4de
Prometryn+Prometryn	216.7	266.7a	241.7a	22.6ab	21.9a-d	22.2ab	3.5a-d	5.4abc	4.4a-d	10.9a-d	14.6c	12.7c
Metribuzin+Prometryn	218.3	156.7b	187.5c	21.1b	22.9abc	22.0ab	2.3de	6.0ab	4.2bcd	8.1de	18.9ab	13.5bc
Linuron+Fluazifop-p-butyl	215.0	270.0a	242.5a	23.0a	23.1ab	23.0ab	2.7b-e	4.2bc	3.4de	9.1b-e	10.9d	10.0e
Prometryn+Fluazifop-p-butyl	208.3	266.7a	237.5a	22.4ab	21.5bcd	21.9ab	4.6a	5.3abc	5.0abc	13.9a	13.1cd	13.5bc
Metribuzin+Fluazifop-p-butyl	220.0	158.3b	189.2c	23.5a	23.0abc	23.3a	4.1ab	6.8ab	5.5ab	12.4abc	18.1b	15.2ab
Linuron+Quizalofop-p-ethyl	210.0	245.0a	227.5ab	23.1a	21.7bcd	22.4ab	3.4a-d	4.9abc	4.2bcd	9.5b-e	14.5c	12.0cd
Prometryn+Quizalofop-p-ethyl	218.3	271.7a	245.0a	21.9ab	21.9a-d	21.9ab	3.3a-e	5.8abc	4.6a-d	9.6b-e	14.9c	12.2cd
Metribuzin+Quizalofop-p-ethyl	221.7	166.7b	194.2c	22.2ab	24.0a	23.1a	2.3de	7.5a	4.9abc	8.9cde	21.4a	15.2ab
Hand weeded once	221.7	266.7a	244.2a	22.9a	21.5bcd	22.2ab	3.6a-d	4.8abc	4.2bcd	10.7a-d	13.7cd	12.2cd
Hand weeded twice	215.0	285.0a	250.0a	21.9ab	22.3a-d	22.1ab	3.3a-e	5.5abc	4.4a-d	11.7a-d	14.5c	13.1c
Weeded control	205.0	248.3a	226.7ab	22.2ab	23.3ab	22.7ab	3.9abc	5.4abc	4.6a-d	11.7a-d	14.1c	12.9c
Unweeded control	223.3	233.3a	228.3ab	21.0b	20.1d	20.6c	1.9e	3.3c	2.6e	5.9e	7.2e	6.6f
Average	215.2b	236.5a	225.8	22.5	22.1	22.3	3.3b	5.5a	4.4	10.3b	14.7a	12.5
LSD Year x Treatment	46.1			-			1.59			3.16		
Source	F-test											
Year (Y)	-	-	**	-	-	ns	-	-	*	-	-	**
Treatment (T)	ns	**	**	*	*	**	**	**	**	**	**	**
YxT	-	-	**	-	-	ns	-	-	*	-	-	**

Table 6: Effect of herbicides and hand weeding on 1000-grain weight, seed yield, total biomass yield and harvest index of lentil

	1000-grain weight (g)			Seed yield (kg ha^{-1})			Total biomass yield (kg ha^{-1})			Harvest index (%)		
Treatments	2000	2001	Average	2000	2001	Average	2000	2001	Average	2000	2001	Average
Linuron	42.0	52.1	47.0	671.7a	853.3a	762.5a	2098.7cde	2879.7de	2489.2abc	32.0a	29.6de	30.8a-d
Prometryn	42.8	53.8	48.3	463.3bc	945.7a	704.5a	1775.7g	2968.3cde	2372.0bcd	26.1b-e	31.9bcd	29.0de
Metribuzin	42.4	49.7	46.1	663.7ab	853.0a	758.3a	2061.3de	2463.0ef	2262.2cd	32.2a	34.6ab	33.4a
Linuron+Prometryn	41.4	50.8	46.1	518.3ab	864.3a	691.3a	1896.3fg	2889.0de	2392.7bcd	27.3bcd	29.9de	28.6def
Prometryn+Prometryn	42.7	49.8	46.3	620.7ab	968.3a	794.5a	2412.3a	3146.3ab	2779.3a	25.7de	30.8cde	28.3def
Metribuzin+Prometryn	42.2	49.7	46.0	558.3ab	893.7a	726.0a	2174.3bcd	2558.7def	2366.5bcd	25.7de	34.9ab	30.3b-e
Linuron+Fluazifop-p-butyl	42.1	50.8	46.5	592.3ab	836.3a	714.3a	2124.3b-e	3092.0abc	2608.2abc	27.9bcd	27.0e	27.5ef
Prometryn+Fluazifop-p-butyl	42.0	50.3	46.2	708.3a	826.0ab	767.2a	2382.3a	2838.0e	2610.2abc	29.7a-d	29.1de	29.4cde
Metribuzin+Fluazifop-p-butyl	42.8	50.4	46.6	698.7a	895.0a	796.8a	2403.7a	2492.0ef	2447.8abc	29.1a-d	35.9a	32.5ab
Linuron+Quizalofop-p-ethyl	42.4	50.8	46.6	579.3ab	909.0a	744.2a	2219.7bc	2986.7cde	2603.2abc	26.1cde	30.4cde	28.3def
Prometryn+Quizalofop-p-ethyl	43.6	51.1	47.4	560.7ab	926.0a	743.3a	1969.3ef	2958.7cde	2464.0abc	28.5a-d	31.3bcd	29.9b-e
Metribuzin+Quizalofop-p-ethyl	41.7	49.9	45.8	541.3ab	812.3ab	676.8a	1857.3fg	2308.7f	2083.0d	29.1a-d	35.2ab	32.2abc
Hand weeded once	42.4	51.8	47.1	609.7ab	916.0a	762.8a	1989.7ef	2996.3bcd	2493.0abc	30.6ab	30.6cde	30.6a-e
Hand weeded twice	39.9	50.3	45.1	589.7ab	988.7a	789.2a	2232.3bc	3137.7ab	2685.0ab	26.4b-e	31.5bcd	29.0de
Weeded control	41.4	51.2	46.3	683.0a	972.0a	827.5a	2275.0ab	3154.3a	2714.7ab	30.0abc	30.8cde	30.4a-e
Unweeded control	40.7	50.7	45.7	304.0c	609.0b	456.5b	1309.3h	2167.0f	1738.2e	23.2e	28.1de	25.7f
Average	42.0b	50.8a	46.4	585.2b	879.3a	732.2	2073.9b	2814.8a	2444.3	28.1b	31.4a	29.8
LSD Year x Treatment	-			-			441.2			3.76		
Source	F–test											
Year (Y)	-	-	**	-	-	**	-	-	**	-	-	**
Treatment (T)	ns	ns	ns	**	**	**	**	**	**	**	**	**
YxT	-	-	ns	-	-	ns	-	-	*	-	-	**

Mean values in each column with the same letters are not statistically different at $P < 0.05$. *$P < 0.05$; ** $P < 0.01$. ns, non significant

and repeated provided 93.4, 97.9 and 98.5% weed dry weight control, respectively when compared with the unweeded control. Hand weeding once was almost as effective in controlling weeds as herbicide applications, hand weeding twice and repeated. Other researchers also reported that hand weeding once controlled weeds effectively in lentil[17-19].

As an average of both years, except for 1000-grain weight, weed control treatments significantly affected all the parameters investigated (Table 5 and 6). Variation occured, however, between years. Except for plant height, relatively low rainfall in May, June and July of the first year (Table 1) reduced all the parameters compared with the second year. Except for plant height, 1000-grain weight and seed yield, year x treatment interaction was significant.

In the first year of experiment, plant density ranging between 205.0 and 223.3 number m^{-2} depending on the treatments was not affected by weed control treatments. However, metribuzin had toxic effect in relatively wet conditions of the second year. Therefore, metribuzin and metribuzin+post-emergence applications significantly

reduced plant density between 32.9% (metribuzin+quizalofop-p-ethyl) and 36.9% (metribuzin+prometryn) compared with the weeded control (Table 5). Under wet conditions and on soils with minimal organic matter, metribuzin may leach deeper into the profile and cause crop injury[3,14].

Weed control treatments significantly affected plant height, branch and pod number per plant in both years. As an average of both years, unweeded control had the lowest plant height, branch and pod number per plant and all of the weed control treatments significantly increased above parameters compared with the unweeded control (Table 5). However, the effect of the weed control treatments on branch and pod number per plant significantly changed between years. In wet conditions of the second year, reduction of plant density depending on the toxic effect of metribuzin reflected to branch and pod number per plant and consequently treatments having metribuzin had the highest branch and pod number values (Table 5). In sowing density studies, it was reported that branch and pod number per plant increased depending on the reduction of plant density[20-22]. As an average of years, 1000-grain weight ranging between 45.1 and 48.3 g showed unsignificant differences among the weed control treatments (Table 6).

All herbicidal and cultural weed control treatments significantly increased seed and total biomass yields compared with the unweeded control. Seed yield increases in herbicide applications ranged between 48.3% (metribuzin+quizalofop-p-ethyl) and 74.5% (metribuzin+fluazifop-p-butyl) over the unweeded control (456.5 kg ha^{-1}). However, pre-emergence+post-emergence combinations gave no significant yield increases compared with single applications of linuron, prometryn and metribuzin (Table 6) possibly due to the high levels of broad-leaved weed species in the experimental fields (Table 3). Fluazifop-p-butyl and quizalofop-p-ethyl which are used post-emergence to control grass weed in broad-leaved crops do not have any effect on broad-leaved weed species[23] and therefore, they do not increase seed yield in fields where broad-leaved weed species are dominant[16]. Hand weeding once gave seed yield similar to chemical applications, hand weeding twice and weeded control (Table 6). In other studies hand weeding once which controlled weeds effectively and produced grain yield almost equal to herbicide applications was also found to be sufficient for lentil[17-19]. Total biomass yield was the highest in prometryn+prometryn application (2779.3 kg ha^{-1}) and the lowest in the unweeded control (1738.2 kg ha^{-1}) as an average of both years. Except for metribuzine and metribuzin+quizalofop-p-ethyl, all herbicide applications gave total biomass yields similar to the weeded control (Table 6). However, the effects of metribuzin alone and metribuzin+post-emergence applications on total biomass yield significantly changed between years. Although all herbicide applications having metribuzin significantly increased total biomass yield compared with the unweeded control in the first year, these applications gave total biomass yields similar to the unweeded control depending on the toxic effect of metribuzin in relatively wet conditions of the second year.

As an average of years, the effect of weed control treatments on harvest index was significant. The unweeded control had the lowest harvest index (25.7%). Except for linorun+prometryn, prometryn+prometryn, linuron+fluazifop-p-butyl and linuron+quizalofop-p-ethyl, weed control treatments gave significantly higher harvest index values than the unweeded control (Table 6). But, the effect of treatments on harvest index significantly changed between years. Reduction of plant densitiy and total biomass yield depending on the toxic effect of metribuzin in the wet conditions of the second year was compensated with increasing of harvest index and metribuzin alone and metribuzin+post-emergence treatments had the highest harvest index values. (Table 6). Therefore, reduction of plant density did not have any negative effect on seed yields in the treatments having metribuzin, except for metribuzin+quizalofop-p-ethyl giving seed yield similar to the unweeded control in the second year of experiment (Table 6). This finding is in agreement with that of Kantar *et al.*[24] who reported that higher harvest index compensated yield disadvantages at lower plant densities in lentil.

In conclusion, two years of trials showed that herbicide applications considerably increased lentil yields compared with the unweeded control under Erzurum's dry conditions. However, pre-emergence+post-emergence combinations gave no significant yield increases compared with the single applications of linuron, prometryn and metribuzin. On the other hand, metribuzin which controlled weeds effectively had toxic effect and significantly reduced plant density in relatively wet conditions of the second year. Thus, it was concluded that linuron and prometryn alone which considerably increased seed yield compared with the unweeded control and had no toxic effect were appropriate for weed control in lentil. Furthermore, hand weeding once may equally be effective in controlling weeds subject to economical availability of labour.

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