Indian Journal of Weed Science **45**(3): 192–197, 2013

Integrated weed management of lambsquarter and nut sedge in lentil

J. Lhungdim*, Y. Singh, Pramod Kumar and S.K. Chongtham

Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh 221 005

Received: 23 July 2013; Revised: 3 September 2013

ABSTRACT

A field study was conducted during 2010-11 and 2011-12 to evaluate the effect of integrated weed management on two lentil associated weeds *viz*., *Chenopodium* spp., *Cyperus* spp. and economics of the weed management packages. Two hand weedings (HW) at 30 and 45 DAS was the most effective method for containing *Chenopodium* spp. and *Cyperus* spp. counts and dry matter from 60 DAS to harvest. Imazethapyr 2EC and pendimethalin controlled the intensity and corresponding dry matter of *Chenopodium* significantly but poorly affected *Cyperus* which was better suppressed with treatment where mechanical weeding was either a component or as a sole treatment. Among sole herbicides, imazethapyr was the most effective for *Cyperus* and *Chenopodium* weed control whereas, pendimethalin incorporated integrated package was effective on *Chenopodium* while imazethapyr associated integrated system was effective on *Cyperus* weeds. Average weed control efficiency at 75 DAS and crop harvest reflected that two HW was most efficient for control of *Chenopodium* (77.6%) and *Cyperus* (75.3%) followed by pendimethalin 1 kg/ha supplemented with imazathapyr 37.5 g/ha on both the weed species (75.3 and 81.2%), respectively. The effect of sole chlorimuron and quizalofop-ethyl on both the weeds were least, but better than control. Pendimethalin 1 kg/ha *fb* mechanical weeding recorded better yield attributes, highest yield of lentil and cost: benefit ratio (1.37 t/ha and 2.80) but minimum weed index (4.53), next to hand weeding. Hand weeding performed well in all aspects except the lower benefit cost ratio. Hence, integration of pendimethalin 1 kg/ha with mechanical weeding (hoeing) was considered to be the profitable treatment besides being more ecofriendly than chemical-chemical sequential application.

Key words: *Chenopodium*, *Cyperus*, Economics, Grain yield, Herbicides, Lentil

Lentil (*Lens culinaris* Medikus) has become an important food legume crop in the farming and food systems of many countries globally. Its seed is a rich source of protein, minerals, and vitamins for human nutrition, and the straw is a valued animal feed. Its ability in nitrogen and carbon sequestration improves soil nutrient status, which in turn provides sustainability in production systems (Sarker and Erskine 2006). India is the largest producer of lentil and contributes about 32% of lentil production. However India's rank in productivity is low that is, 23rd in the world (Reddy and Reddy 2010). It is a poor competitor due to its short height and slow early growth. Lentil's low competitive ability is compounded when growing season temperatures are low or when moisture is scarce. Increased cost of manual weeding, its poor efficiency and non-availability during critical periods made herbicides very attractive in lentil. Integrated weed management has the potential to restrict weed populations to manageable levels, In adopting any integrated weed control methods, economic factor is the most important and deciding factor.

***Corresponding author:** ginlhungdim@rediffmail.com

MATERIALS AND METHODS

The experimental soil showed organic carbon 0.60%, pH 7.7, electrical conductivity 0.26 ds/m, 216, 26 and 236.46 kg/ha available NPK, respectively. The research field lying at 25^0 18'N latitude and $88^0$36'E latitude at an altitude of 128.93 meters from the mean sea level in the north Gangetic alluvial plains received total rainfall of 14.9 and 34.6 mm during lentil crop seasons of 2010-11 and 2011-12, respectively. Two years weekly mean maximum temperature ranged from 15.3 - 35.8^{0}C and minimum temperature varied from 6.5 to 19.0^0 C. Fertilizer NPKS 20-40-30-15 kg/ha was applied common to all the treatments. Sowing of the crop lentil variety '*HUL 57*' was done on November 15 in both the years. Treatments consisted weedy check (control); weed free; hand weeding 30 DAS and 45 DAS (khurpi aided); mechanical weeding (MW) 30 DAS and 45 DAS (twin wheel hoe); quizalofop-ethyl 50 g/ha 40 DAS; imazethapyr 37.5 g/ha 40 DAS; chlorimuron-ethyl {Pre plant incorporation (PPI)} 4 g/ha; pendimethalin {pre-emergence(PE)} 1 kg/ha; pendimethalin 30 EC + imazethapyr 2 EC (PE) 0.75 kg/ha; pendimethalin 30 EC + imazethapyr 2 EC (PE) 1 kg/ha;

chlorimuron-ethyl (PPI) 4 g/ha *fb* quizalofop-ethyl 50 g/ha 40 DAS; chlorimuron-ethyl (PPI) 4 g/ha *fb* imazethapyr 37.5 g/ha 40 DAS; pendimethalin (PE) 1 kg/ha; quizalofop- ethyl 50 g/ha 40 DAS; pendimethalin (PE) 1 kg/ha *fb* imazethapyr 37.5 g/ha 40 DAS; chlorimuron-ethyl (PPI) 4 g/ha *fb* MW 45 DAS; pendimethalin (PE) 1 kg/ha *fb* MW 45 DAS. Weed samples were collected by placing a quadrate (0.50 x 0.50 m) randomly in each plot at 60, 90 DAS and crop harvest. Data for weed components were subjected to square root transformation $\sqrt{(x+0.5)}$ for uniformity. Data analyses were done with RCBD. The economic analyses were carried out by computing the market price of inputs and outputs of both the experimental seasons prevailing at Varanasi city. The names in parentheses at the end of each herbicides are trade names of the concerned herbicides used in the experiment.

RESULTS AND DISCUSSION

Effect on *Chenopodium*

Chenopodium spp.was effectively controlled by pre-emergence application of pendimethalin 1 kg/ha and pendimethalin 30 EC + imazethapyr 2 EC (PE) that is Pursuit plus at both doses (0.75 and 1 kg/ha) from initial stage (30 DAS). At later stage (60 DAS) and crop harvest, the weed count indicated that, the weed was fairly controlled with imazethapyr 37.50 g/ha and quizalofop-ethyl 50 g/ha. Further weed reduction was observed with sequential application of pre-emergence pendimethalin with either mechanical weeding, imzethapyr or quizalofop-ethyl (Table 1). The finding is in line with Mojeni *et al*. (2005). The better performance of pendimethalin *fb* imazethapyr was also reported by Sasikala *et al.* (2006). Minimum dry matter in *Chenopodium* was correspondingly recorded considering the values taken at 30, 60, 90 DAS and crop harvest (Table 2). The performance of sole herbicide, chlorimuron-ethyl, though not remarkable, was however, better than control. Among the sole herbicides at 60 DAS, pendimethalin 30 EC + imazethapyr 2 EC (PE) 1 kg/ha was next most effective treatment after mechanical weeding twice and two hand weeding. Among the integrated management system, pendimethalin *fb* imazethapyr was the most effective treatment at the same stage. At crop harvest, no sole herbicide was better than two mechanical weeding and twice hand weeding. The vanishing herbicidal effect to the newly emerging weeds and the mechanical action of *Cyperus* removal along with the roots could be attributed to the superiority of two mechanical weeding and hand weeding over herbicides at later stages. Least dry matter was observed in the treatment, pendimethalin 30 EC + imazethapyr 2 EC (PE) 1 kg/ha among sole herbicides at 60 DAS whereas, it was significantly low in pendimethalin *fb* imazethapyr among the integrated weed management systems, respectively. At crop harvest, minimum dry matter of *Cyperus* was recorded with two hand weeding and pendimethalin 30 EC + imazethapyr 2 EC (PE) 1 kg/ha while pendimethalin *fb* mechanical weeding and pendimethalin *fb* imazethapyr which were statistically at par, indicated least dry matter. Carr *et al.* (1997) also supported the finding who reported that minimized weed and dry matter with herbicide supplemented by mechanical weeding/tillage in lentil.

Effect on *Cyperus*

Cyperus spp. was the most difficult to kill and the most populous weed in lentil during *Rabi* season. The initial period of growth and development was not remarkably observed with pre- emergence application of either pendimethalin, pendimethalin 30 EC + imazethapyr 2 EC (PE) or pre-plant incorporation of chlorimuron-ethyl (Table 1). Except at 30 DAS (first weed count taken before first hand weeding), the treatment, two hand weeding 30 and 45 DAS was the most effective treatment right from 60 DAS to crop harvest. Among the sole herbicide, sole application of imazethapyr, quizalofop-ethyl, chlorimuron-ethyl, pendimethalin and pendimethalin 30 EC + imazethapyr 2 EC (PE) were in the order of better performance for controlling *Cyperus* weed. However, they were all better than control. At initial stage, chlorimuron-ethyl applied as PPI was the only herbicide significantly affecting growth of *Cyperus* better than control. The finding was in conformity with Sharma and Raghuvanshi (1999) who reported that, chlorimuron-ethyl controlled sedges effectively. Little or no effect was observed with pendimethalin and pendimethalin + imazethapyr on the *Cyperus*. Amongst the integrated system, chlorimuron-ethyl applied as PPI and mechanical weeding showed minimum weed count at 60 DAS and 90 DAS while at crop harvest, it was minimum with pendimethalin *fb* mechanical weeding. However, least dry matter of *Cyperus* at the same crop stage was recorded in the treatments, chlorimuron-ethyl *fb* imazethapyr and pendimethalin *fb* imazethapyr at 90 DAS and crop harvest (Table 2). Weedy check exhibited maximum weed count and dry matter. In either case, imazethapyr was involved in the reduction of *Cyperus* count and dry matter accumulation. The result was also corroborated by Kumar (2008).

Weed control efficiency

Weed control efficiency (WCE) in *Chenopodium* recorded at 90 DAS and crop harvest indicated that hand

Table 1. Effect of IWM on weed count of *Chenopodium* and *Cyperus* at different crop growth stages (pooled mean of two years)

Treatment	30 DAS		60 DAS		90 DAS		Harvest	
	Chem.	*Cyperus*	*Chem.*	*Cyperus*	*Chem.*	*Cyperus*	*Chem.*	*Cyperus*
HW 30 DAS and 45 DAS	37.33	41.67	1.17	6.67	4.33	15.83	4.50	12.67
	(6.15)	(6.49)	(1.29)	(2.68)	(2.20)	(4.04)	(2.24)	(3.63)
MW 30 DAS and 45 DAS	36.33	50.50	1.67	12.33	7.33	16.17	7.83	13.58
	(6.07)	(7.14)	(1.47)	(3.58)	(2.80)	(4.08)	(2.89)	(3.75)
Quizalofop-ethyl 50 g/ha 40 DAS	38.67	43.50	12.17	34.33	10.17	29.17	19.00	20.17
	(6.26)	(6.63)	(3.56)	(5.90)	(3.27)	(5.45)	(4.42)	(4.55)
Imazethapyr 37.5 g/ha 40 DAS	36.00	47.00	9.83	13.33	8.50	21.33	9.50	17.50
	(6.04)	(6.89)	(3.21)	(3.72)	(3.00)	(4.67)	(3.16)	(4.24)
Chlorimuron-ethyl 4 g/ha (PPI)	21.67	46.67	31.50	43.17	32.83	31.67	26.33	25.17
	(4.71)	(6.87)	(5.66)	(6.61)	(5.77)	(5.67)	(5.18)	(5.07)
Pendimethalin 1 g/ha (PE)	1.17	43.83	3.50	69.50	4.83	48.50	6.50	29.50
	(1.29)	(6.66)	(2.00)	(8.37)	(2.31)	(7.00)	(2.65)	(5.48)
Imazethaspyr 0.75 kg/ha (PE)*	1.20	42.83	3.33	72.83	5.17	43.00	6.33	25.33
	(1.30)	(6.58)	(1.96)	(8.56)	(2.38)	(6.60)	(2.61)	(5.08)
Pendimethalin + imazethapyr (PE) 0.75 kg/ha	1.00	49.83	3.00	68.83	4.83	42.33	5.50	25.50
	(1.22)	(7.09)	(1.87)	(8.33)	(2.31)	(6.54)	(2.45)	(5.10)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* quizalofop-ethyl 50 g/ha 40 DAS	22.00	40.67	8.33	28.83	10.53	27.67	8.17	21.00
	(4.74)	(6.42)	(2.97)	(5.42)	(3.32)	(5.31)	(2.94)	(4.64)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* imazethapyr 37.5 g/ha 40 DAS	23.33	41.17	9.00	23.00	6.83	24.50	7.00	16.50
	(4.88)	(6.45)	(3.08)	(4.85)	(2.71)	(5.00)	(2.74)	(4.12)
Pendimethalin 1 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha 40 DAS	1.17	44.17	1.67	23.67	4.83	30.83	6.17	17.67
	(1.29)	(6.68)	(1.47)	(4.92)	(2.31)	(5.60)	(2.58)	(4.26)
Pendimethalin 1 g/ha (PE) *fb* imazethapyr 37.5 g/ha 40 DAS	1.27	48.83	1.50	18.17	5.00	19.67	5.00	15.33
	(1.33)	(7.02)	(1.41)	(4.32)	(2.35)	(4.49)	(2.35)	(3.98)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* MW 45 DAS	24.67	39.50	12.17	11.17	17.00	19.33	18.67	19.83
	(5.02)	(6.32)	(3.56)	(3.42)	(4.18)	(4.45)	(4.38)	(4.51)
Pendimethalin 1 g/ha (PE) *fb* MW 45 DAS	1.55	48.83	2.17	14.83	5.17	20.83	4.83	14.00
	(1.43)	(7.02)	(1.63)	(3.92)	(2.38)	(4.62)	(2.31)	(3.81)
Weedy check (control)	38.17	55.67	63.83	100.50	57.17	69.67	43.17	47.33
	(6.22)	(7.49)	(8.02)	(10.05)	(7.59)	(8.38)	(6.61)	(6.92)
Weed free	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
LSD (P = 0.05)	0.44	0.58	0.35	0.49	0.55	0.56	0.40	0.46

*Pre-mixed product of pendimethalin 30 EC and imazethapyr 2 EC; PE - Pre-emergence; MW - Mechanical weeding. Data on weeds are subjected to transformation $\sqrt{(x+0.5)}$. Figures within parentheses are square root transformed values and outside the parentheses are original values.

weeding twice at 30 and 45 DAS and pendimethalin *fb* mechanical weeding which were statistically at par were most effective followed by pendimethalin 1 kg/ha that was statistically non-significant with pendimethalin + imazethapyr 0.75 and 1 kg/ha. At crop harvest, the maximum WCE on *Chenopodium* was observed with the treatment, hand weeding twice at 30 and 45 DAS closely followed by pendimethalin *fb* imazethapyr (Table 3). Among the treatments, maximum weed control efficiency in *Chenopodium* spp. evaluated at 90 DAS and crop harvest (average) was registered with pendimethalin 1 kg/ha *fb* imazethapyr 37.50 g/ha after hand weeding that was statistically at par with pendimethalin *fb* mechanical weeding. Among the sole herbicide applications at 90 DAS, highest WCE in *Chenopodium* spp. was associated with two hand weeding, pendimethalin and pendimethalin + imazethapyr, which were statistically at par and in *Cyperus* spp., it was with two hand weeding and pendimethalin *fb* imazethapyr. At crop harvest, highest WCE in both the weeds was observed in the treatment, two hand weeding and pendimethalin *fb* imazethapyr. The result indicated that, pendimethalin supplemented with either imzethapyr or mechanical weeding was on average, the most efficient treatment in controlling both the weeds. Similar reports were communicated by Punia *et al*. (2011) on high WCE with pre-emergence *fb* post-emergence (imazethapyr) and pendimethalin *fb* mechanical weeding by Patel *et al.* (2012) in pendimethalin *fb* intercultivation, respectively.

Table 2. Effect of IWM on dry matter (g/m²) of *Chenopodium* and *Cyperus* at different crop growth stages (pooled mean of two years)

Treatment	30 DAS		60 DAS		90 DAS		Harvest	
	Cheno.	*Cyperus*	*Cheno.*	*Cyperus*	*Cheno.*	*Cyperus*	*Cheno.*	*Cyperus*
HW 30 DAS and 45 DAS	2.13	4.87	2.13	3.83	5.17	9.12	11.50	6.20
	(1.78)	(2.32)	(1.66)	(2.08)	(2.74)	(3.10)	(3.34)	(2.59)
MW 30 DAS and 45 DAS	2.33	4.15	2.50	5.67	17.00	13.53	18.50	10.75
	(1.86)	(2.16)	(1.78)	(2.48)	(2.84)	(3.75)	(4.34)	(3.35)
Quizalofop-ethyl 50 g/ha 40 DAS	2.27	6.10	9.07	7.72	32.47	15.93	23.70	12.72
	(1.69)	(2.57)	(3.01)	(2.87)	(4.19)	(4.05)	(4.83)	(3.64)
Imazethapyr 37.5 g/ha 40 DAS	2.83	5.90	4.43	6.65	26.53	14.47	18.40	10.12
	(1.80)	(2.53)	(2.27)	(2.67)	(4.09)	(3.87)	(4.51)	(3.26)
Chlorimuron-ethyl 4 g/ha (PPI)	1.67	6.25	10.90	10.65	25.90	25.30	24.40	20.28
	(1.53)	(2.60)	(3.32)	(3.34)	(4.47)	(5.08)	(5.06)	(4.56)
Pendimethalin 1 g/ha (PE)	0.40	6.27	2.53	13.50	5.87	26.00	14.40	23.88
	(1.06)	(2.60)	(1.98)	(3.74)	(2.70)	(5.15)	(3.75)	(4.94)
Imazethapyr 0.75 kg/ha (PE)*	0.93	5.63	2.23	13.35	9.93	24.72	13.33	26.33
	(1.17)	(2.48)	(1.93)	(3.72)	(2.43)	(5.02)	(3.65)	(5.18)
Pendimethalin 30 EC + imazethapyr (PE) 0.75 kg/ha	0.73	6.10	3.00	12.92	6.67	22.58	13.20	20.40
	(1.10)	(2.57)	(1.93)	(3.66)	(2.54)	(4.80)	(3.66)	(4.57)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* quizalofop-ethyl 50 g/ha 40 DAS	2.50	6.70	8.37	10.55	24.40	17.07	20.33	13.93
	(1.64)	(2.68)	(3.01)	(3.32)	(4.55)	(4.19)	(4.34)	(3.80)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* imazethapyr 37.5 g/ha 40 DAS	2.47	7.30	2.50	6.23	33.67	14.02	15.67	9.73
	(1.85)	(2.79)	(1.93)	(2.59)	(3.93)	(3.81)	(4.17)	(3.20)
Pendimethalin 1 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha 40 DAS	0.87	6.98	2.57	8.13	15.50	15.13	14.17	9.75
	(1.07)	(2.74)	(2.04)	(2.94)	(3.35)	(3.95)	(3.73)	(3.20)
Pendimethalin 1 g/ha (PE) *fb* imazethapyr 37.5 g/ha 40 DAS	0.70	5.70	2.17	6.88	11.27	12.50	13.03	7.93
	(1.13)	(2.49)	(1.83)	(2.72)	(2.44)	(3.61)	(3.60)	(2.90)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* MW 45 DAS	2.50	5.98	5.73	7.87	36.83	18.00	21.53	12.45
	(1.69)	(2.55)	(3.07)	(2.89)	(3.81)	(4.30)	(4.64)	(3.60)
Pendimethalin 1 g/ha (PE) *fb* MW 45 DAS	0.90	5.90	3.63	5.23	7.67	14.37	12.67	9.92
	(1.11)	(2.53)	(2.08)	(2.39)	(2.54)	(3.86)	(3.60)	(3.23)
Weedy check (control)	2.83	8.92	27.27	22.13	59.40	55.53	41.87	45.18
	(1.73)	(3.07)	(4.75)	(4.76)	(6.95)	(7.49)	(6.91)	(6.76)
Weed free	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
LSD (P =0.05)	0.17	0.29	0.33	0.57	0.56	0.57	0.69	0.59

Cheno. Spp. - Chenopdium species; *fb* - followed by; DAS - Days after sowing; Quiza.- Quizalofop-ethyl; Imaze. - Imazethapyr; Chlori. - Chlorimuron-ethyl; *pre-mixed product of pendimethalin 30 EC and imazethapyr 2 EC; PE - Pre-emergence; MW - Mechanical weeding; Data on weeds are subjected to transformation $\sqrt{(x+0.5)}$. Figures within parentheses are square root transformed values and outside the parentheses are original values.

Effect on yield attributes

Among the treatments (Table 3), hand weeding twice at 30 and 45 DAS, mechanical weeding twice at 30 and 45 DAS and pendimethalin *fb* mechanical weeding at 45 DAS were in the increasing order of branches/plant with statistically non significance among them. The mechanical loosening of the soil, effective broad-leaved weed control at the initial stage and favourable soil environment due to the soil structural alteration could be attributed to the increased effective branches. The finding is in line with Muhammad (2010) who reported that, hand hoeing gave more branches in chickpea. Pod counts/plant was maximum in two hand weeding, pendimethalin *fb* mechanical weeding and pendimethalin *fb* imzethapyr treatments. The pod number in each plant had a positive correlation with the branches. More production of effective branches, better weed control of weeds and soil friability as a result of inter cultivation (mechanical weeding with twin wheel hoe) could be attributed to high pod count/plant. The result showed that, pod yield has been increased with the application of pendimethalin which was a component in both the best performing treatments. More pods with pendimethalin application was also reported by Rana (2002).

Table 3. Effect of IWM on WCE of *Chenopodium* and *Cyperus*, yield attributes, yield and economics of lentil (pooled mean of two years)

Treatment	WCE (%) at 90 DAS		WCE (%) at crop harvest		At crop harvest				Net returns (x10^3 `/ha)	BCR
	Cheno podium	*Cyperus*	*Cheno podium*	*Cyperus*	Branch/ plant	Pods/ plant	Yield (t/ha)	WI (%)		
HW 30 DAS and 45 DAS	77.0	83.7	73.2	86.2	8.12	65.07	1.39	2.81	56.07	2.53
MW 30 DAS and 45 DAS	69.6	75.6	61.0	76.2	7.22	58.88	1.30	8.89	51.90	2.44
Quizalofop-ethyl 50 g/ha 40 DAS	61.1	71.3	43.3	71.6	6.17	42.33	1.02	28.76	39.67	2.15
Imazethapyr 37.5 g/ha 40 DAS	65.1	73.8	52.1	77.6	6.52	50.93	1.11	21.95	44.78	2.57
Chlorimuron-ethyl 4 g/ha (PPI)	39.8	54.4	37.6	54.9	5.58	37.25	1.01	29.35	39.89	2.34
Pendimethalin 1 g/ha (PE)	74.8	53.1	68.0	47.0	6.83	58.35	1.04	26.86	41.07	2.25
Imazethapyr 0.75 kg/ha (PE)*	74.8	55.5	68.9	41.6	6.83	59.20	1.15	19.33	46.23	2.54
Pendimethalin + imazethapyr (PE) 0.75 kg/ha	74.4	59.2	70.1	54.7	6.67	60.05	1.19	16.41	47.95	2.56
Chlorimuron-ethyl 4 g/ha (PPI) *fb* quizalofop-ethyl 50 g/ha 40 DAS	57.6	69.3	61.9	69.2	6.25	52.75	1.03	27.64	40.16	2.12
Chlorimuron-ethyl 4 g/ha (PPI) *fb* imazethapyr 37.5 g/ha 40 DAS	62.3	74.7	61.1	78.4	5.93	55.92	1.09	23.43	43.50	2.41
Pendimethalin 1 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha 40 DAS	73.4	72.8	67.5	78.4	6.33	57.87	1.22	14.84	48.32	2.39
Pendimethalin 1 g/ha (PE) *fb* simazethapyr 37.5 g/ha 40 DAS	77.0	77.5	71.3	82.4	6.78	61.15	1.29	9.33	52.50	2.72
Chlorimuron-ethyl 4 g/ha (PPI) *fb* MW 45 DAS	52.2	67.5	50.0	72.3	6.48	54.07	1.07	25.23	41.90	2.25
Pendimethalin 1 g/ha (PE) *fb* MW 45 DAS	75.7	74.2	70.4	78.2	7.63	62.33	1.36	4.51	55.59	2.80
Weedy check	0.0	0.0	0.0	0.0	4.17	24.48	0.62	56.21	13.98	0.85
Weed free	100.0	100.0	100.0	100.0	8.30	68.88	1.42	0.00	55.20	2.06
LSD (P=0.05)	-	-	-	-	1.13	8.53	0.15	0.00	-	-

Effect on grain yield

Hand weeding (HW) twice at 30 and 45 DAS (Khurpi aided hand pulling) showed superior effect next to weed free. Kaur *et al*. (2009) also confirmed the same result when HW in lentil was done at 25 and 45 DAS. Among the treatments (Table 3), two hand weeding gave maximum yield followed by pendimethalin with sequential mechanical weeding (hoeing with twin wheel hoe) which was statistically at par with pendimethalin *fb* imazethapyr. Twice hand weeding and weed free were statistically showing non-significant difference among them, while two HW and pendimethalin *fb* MW were at par. The latter, further showed its insignificance with pendimethalin *fb* imazethapyr in the grain yield. Among the treatments, Chlorimuron-ethyl sole registered the least yield but was higher that weedy check. Imazethapyr recorded maximum yield among the sole post emergence herbicides. Similar report was communicated by Anonymous (2009).

Weed index

Weed index is per cent reduction in grain yield due to weeds as compared to total yield of weed free treatment. Weedy check resulted in yield reduction to the tune of 56% (Table 3). The yield reduction was possibly due to the high intensity of weeds that robbed off the nutrient supply, sunlight and water besides limited space for comfortable crop growth and development. Among the treatments, chlorimuron-ethyl alone applied as PPI and sole quizalofop-ethyl applied as post emergence resulted in highest yield loss next to control. There was little loss in two hand weeding and no loss in weed free. Pendimethalin *fb* mechanical hoeing was the integrated system of weed management that showed lowest yield reduction after two hand weeding. Effective weed control with reduced weed flora and biomass could be attributed to the better performance in avoiding yield loss. Among the sole applied herbicides, imazethapyr at both doses (0.75 and 1 kg/ha) showed least yield reduction.

Economics

Cost incurred in single application of herbicides was comparatively less, but the low yield resulted in low net return and BCR. Weed free and two hand weeding were highest in yield and net return, but due to higher cost of cultivation associated, the net return and BCR correspond-

ingly were low. Comparison between single herbicides indicated that, pendimethalin + imazethapyr (Pursuit plus) was the most profitable herbicide. Among the chemical-chemical sequential application, pendimethalin *fb* imazethapyr was the best option as it fetched a fair net return and high BCR. Pendimethalin *fb* mechanical weeding (hoeing) reflected highest net returns and BCR which may be the best choice for integrated weed management. Similar profitability with the treatment in lentil was also reported by Kalpana (2010). Under pendimethalin *fb* mechanical hoeing, comparatively low cost of the herbicide, lesser labour with more weeding coverage area in a short time particularly under sandy soils and rainfed condition may be reasons for profitability of the system.

Inference can be drawn from the outcome of the present study that, one herbicide as pre-emergence (pendimethalin 1 kg/ha) supplemented by one mechanical weeding (hoeing with twin wheel hoe) 45 DAS could be the best option under integrated weed management in lentil under rainfed conditions under sandy soils. The finding can be justified with the fact that, pendimethalin was an excellent herbicide for control of weeds propagated by seeds and mechanical hoeing that created favourable environment for microorganisms through weed incorporation and decomposition in the soil besides uprooting the weeds. quizalofop-ethyl 50 g/ha 40 DAS; imazethapyr 37.5 g/ha 40 DAS; chlorimuron-ethyl {Pre plant incorporation (PPI)} 4 g/ha; pendimethalin {pre-emergence (PE)} 1 kg/ha; pendimethalin 30 EC + imazethapyr 2 EC (PE) 0.75 kg/ha; pendimethalin 30 EC + imazethapyr 2 EC (PE) 1 kg/ha; chlorimuron-ethyl (PPI) 4 g/ha *fb* quizalofop-ethyl 50 g/ha 40 DAS; chlorimuron-ethyl (PPI) 4 g/ha *fb* imazethapyr 37.5 g/ha 40 DAS; pendimethalin (PE) 1 kg/ha; quizalofop- ethyl 50 g/ha 40 DAS; pendimethalin (PE) 1 kg/ha (Stomp) *fb* imazethapyr 37.5 g/ha 40 DAS; chlorimuron-ethyl (PPI) 4 g/ha *fb* MW 45 DAS; pendimethalin (PE) 1 kg/ha *fb* MW 45 DAS. Weed samples were collected by placing a quadrate (0.50 x 0.50 m) randomly in each plot at 60, 90 DAS and crop harvest. Data for weed components were subjected to square root transformation $\sqrt{(x+0.5)}$ for uniformity. Data analyses were done with RCBD. The economic analyses were carried out by computing the market price of inputs and outputs of both the experimental seasons prevailing at Varanasi city. The names in parentheses at the end of each herbicides are trade names of the concerned herbicides used in the experiment.

REFERENCES

Anonymous. 2009. Screening of post-emergence herbicides in lentil (*Lens culinaris*), p. 77. In: *Annual Report of AICRP on MULLaRP* (2008-09).

Carr PM, Martin GB and Harris JD. 1997. Post-plant tillage provides limited weed control in flax, lentil and spring wheat. North Dakota Agricultural Research. [*http://www.ag.ndsu.nodak.edu/ndagres/ndagres.htm*]

Kalpana R. 2010. Evaluation of integrated weed management package for soybean. In: *Proceedings of 15th Agronomy Conference*, 15-18 November, 2010, Lincoln, New Zealand.

Kumar N. 2008. Post-emergence herbicides for pulses. *Indian Institute of Pulses Research Newslette* **19**(4): 2.

Mojeni HK, Zadeh HMA, Hosseini NM and Peighambari SA. 2005. Efficiency of either single or integrated application of different herbicides on lentil (*Lens culinaris). Iranian Journal of Agricultural Sciences* **36**(1): 209-218.

Patel BD, Patel RB and Shah SN. 2012. Integrated weed management in cluster bean, pp. 1067-1068. In: *Extended Summaries of the 3rd International Agronomy Congress*, Vol. 3 held on November 26-30, 2012. New Delhi.

Punia SS, Singh S and Yadav D. 2011. Bioefficacy of imazethapyr and chlorimuron-ethyl in cluster bean and their residual effect on succeeding *Rabi* Crops. *Indian Journal of Weed Science* **43**(1&2): 48-53.

Rana SS. 2002. Integrated weed management in pea (*Pisum sativum* L.) under Sangla valley conditions of Himachal Pradesh. *Indian Journal of Weed Science* **34** (3&4): 204-207.

Sasikala B, Kumari CR, Obulamma U and Reddy CR. 2006. Effect of chemical weed control on yield and economics of rabi groundnut. *Journal of Research ANGRAU* **34**(3): 70-73.

Sarker A and Erskine W. 2006. Recent progress in the ancient lentil. *Journal of Agricultural Science* **144**(1): 19-29.

Sharma PB and Raghuwanshi PS. 1999. Chlorimuron-ethyl: a promising herbicide against sedges and broad-leaved weeds in soybean. *Indian Journal of Weed Science* **31**(3&4): 133-137.