Short Communication
Range Mgmt. & Agroforestry 40 (2) : 323-328, 2019
ISSN 0971-2070

Effect of different herbicides on weed control efficiency, fodder and seed yields of berseem (*Trifolium alexandrinum* L.) in central India

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Received: 11th December, 2018 Accepted: 18th November, 2019

Abstract
Berseem (*Trifolium alexandrinum* L.) is an important winter season forage crop, heavily infested with weeds. A multi-location trial was conducted at Jabalpur, Rahuri and Urulikanchan during 2012-15 under All India Coordinated Research Project on Forage Crops to identify the suitable herbicides for weed control in berseem. The different treatment combinations were made with pre-emergence herbicides *viz*., pendimethalin and oxyfluorfen and a post-emergence herbicide, imazethapyr in different proportion along with weedy check (control). Results showed that pre-emergence application of pendimethalin @ 0.4 kg a.i./ha followed by imazethapyr @ 0.1 kg a.i./ha after first cut reduces weed density and dry weight at Jabalpur. However, Oxyfluorfen followed by Imazethapyr @ 0.1 kg a.i./ha was superior in weed control efficiency at Rahuri (66.9%) and Urulikanchan (83.9%). Furthermore, this treatment also increased green fodder and seed yield by 81and 119%, respectively over weedy check across locations. Thus, pre-emergence application of oxyfluorfen followed by imazethapyr @ 0.1 kg a.i./ha after first cut was recommended in central India for better weed control, fodder and seed yields of berseem and higher economic returns.

Keywords: Berseem, Fodder yield, Herbicides, Weed control efficiency, Weed density

Berseem or Egyptian clover (*Trifolium alexandrinum* L.) is an important forage legume of *rabi* season cultivated in about 2 million hectares in India (Muhammad *et al*., 2014). It is widely accepted because of multicut, fast regeneration, high and nutritious fodder yield for livestock from December- April. Congenial soil moisture due to frequent irrigations coupled with suitable temperature as well as better nutrient availability not only increases the fodder production but also provide equal opportunity to weeds to grow simultaneously. Many seasonal weeds along with associated weed common chicory (*Chicorium intybus* L.) poses severe competition with crop for nutrients, light, moisture and space (Tiwana *et al*., 2002). Consequently, weed infestation reduces 20-30% green fodder and 13-37% seed yield in berseem (Vijay *et al*., 2017; Tyagi *et al*., 2018). Maximum crop-weed competition in berseem was recorded at the establishment stage causing lower plant establishment and substantial reduction in forage yield.

Manual removal and frequent inter row cultivation are the usual weed management measures. However, these methods are laborious, expensive and often are partially effective. Herbicides are effective tools in man's eternal struggle with weeds. When properly used, herbicides can safely and effectively accomplish their objective. Chemical weed control is preferred because of its better efficiency along with less cost and time involvement. Moreover, the control is more effective as the weeds even within the rows are killed, which invariably escape, because of morphological similarity to crop during mechanical control. Effective weed control depends on proper selection of herbicide, dose and time of application. Therefore, this study was conducted to find out the most selective and potent herbicide with optimum dose for curbing the menace of weeds in berseem growing areas of India.

Multi-location trials were conducted during 2012-15 at JNKVV, Jabalpur, MPKV, Rahuri and BAIF, Urulikanchan under All India Coordinated Research Project on Forage Crops (AICRP-FC), ICAR-IGFRI, Jhansi. The research locations have semi-arid sub-tropical climate, characterized by hot and dry summer (April-September) and cold winters (October–March). Before starting the experiments, soil samples were collected from 0–15 cm

soil depth using an auger and analyzed in the laboratory. The detailed soil characteristics of experimental sites were also recorded (Table 1). Experiments consisting of 10 treatments (Table 2) were laid out in a randomized complete block design replicated thrice. The gross and net plot size were 4.0 × 3.0 m and 3.4 × 2.4 m, respectively. The berseem variety 'JB-5' at Jabalpur and 'Wardan' at Rahuri and Urulikanchan were sown in rows 30 cm apart by using seed rate of 30 kg/ha in solid rows in November. Uniform dose of 20-80-40 kg/ha N-P_2O_5-K_2O were applied in all treatments at the time of sowing. Herbicides were sprayed with the manually operated knapsack sprayer fitted with flat-fan nozzle at spray volume of 500 litres/ha. Pre-emergence herbicides were sprayed within 3 days of sowing prior to emergence of weed and post-emergence herbicide was applied as per treatment schedule (Table 2). Crop was irrigated at 8-12 days interval as per needs.

Berseem was harvested from each plot at 5–7 cm height using a serrated sickle for better regrowth. The first cutting was done 55 days after sowing (DAS) and subsequent two cuttings were done at about 30 days intervals. The yield from three cuttings was summed up to get the total green forage yield under each treatment. The crop was left for seed production after the third cutting and given light irrigations until flowering and seed setting. Crop was harvested in the month of May and the seed yield was recorded. The quadrate of 0.25 m^2 (0.5 m × 0.5 m) was randomly placed at three places in each plot and total weed count was recorded. The weed samples were weighed fresh and oven dried at 65°C for 72 hours for dry matter (DM) determination. The weed control efficiency (WCE) was calculated using following formula-

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

Where, WCE = Weed control efficiency in percent; DWC = Dry weight of weeds in control plot; and DWT = Dry weight of weeds in treated plot.

All data were analyzed using analysis of variance (ANOVA) to evaluate differences between treatments, and the means were separated using the Fisher's Protected LSD test at the 5% level of significance using GenStat Version 18 (VSN International, Oxford, UK). Because of significant differences between years, data were not combined and were presented separately for years. The weed density and dry weight data were subjected to square-root transformation $[\sqrt{(x + 0.5)}]$ before analysis.

Weed flora was highly diverse due to different soil types, climate and locations. At Jabalpur centre, major weeds were *Cichorium intybus*, *Medicago denticulata*, *Coronopus didymus* etc. while at Rahuri, *Parthenium hysterophorus*, *Celosia argentia*, *Euphorbia geniculata*,

Table 1. Soil characteristics (0–15 cm depth) of the experimental sites

Soil characteristics	Jabalpur	Rahuri	Urulikanchan
Texture class	Sandy clay loam	Clay	Sandy clay
pH	7.5	8.1	7.9
EC (dS/m)	0.45	0.35	0.27
Organic carbon (g/kg)	6.2	3.9	3.6
$KMnO_4$ oxidizable N (kg/ha)	236	144	130
0.5 M $NaHCO_3$ extractable P (kg/ha)	17	12	32
1 N Neutral NH_4OAc- extractable K (kg/ha)	360	504	222

Table 2. Details of treatments applied in berseem field

Symbol	Treatment	Dose (a.i. kg/ha)	Time of application
T1	Weedy check (Control)	-	-
T2	Pendimethalin	0.30	Pre-emergence
T3	Pendimethalin	0.40	Pre-emergence
T4	Pendimethalin	0.50	Pre-emergence
T5	Oxyfluorfen	0.10	Pre-emergence
T6	Imazethapyr	0.10	Immediate after 1st and 2nd cut
T7	Oxyfluorfen – Imazethapyr	0.10 and 0.10	Pre-emergence *fb* immediately after 1st cut
T8	Pendimethalin – Imazethapyr	0.30 and 0.10	Pre-emergence *fb* immediately after 1st cut
T9	Pendimethalin – Imazethapyr	0.40 and 0.10	Pre-emergence *fb* immediately after 1st cut
T10	Pendimethalin – Imazethapyr	0.50 and 0.10	Pre-emergence *fb* immediately after 1st cut

Treatments T7 to T10 are combination of 2 herbicides applied separately; fb*:* followed by

Cichorium intybus, *Amaranthus viridis*, *Cynodon dactylon* and *Cyperus rotundus* were dominant weeds. *Parthenium hysterophorus*, *Echinochloa colonum*, *Cynodon dactylon*, *Cyperus rotundus*, *Commelina benghalensis*, *Amaranthus viridis*, *Portulaca oleraceae* were major weeds infesting the berseem field at Urulikanchan. Similar kind of weed flora dominance was also reported earlier (Pathan *et al.*, 2013; Wasnik *et al.*, 2017).

Weed density and dry weight were significantly influenced by different herbicide treatments (Table 3). Among locations, maximum weed density was observed at Jabalpur (227/m^2) followed by Urulikanchan (134/m^2) and Rahuri (101/m^2) in weedy check plot. However, highest weed dry weight was recorded at Rahuri (206.4 g/m^2) followed by Jabalpur and Urulikanchan. Application of different herbicides reduced weed density and dry weight across locations. Among herbicidal treatments, application of pendimethalin @ 0.4 kg a.i. /ha followed by imazethapyr @ 0.1 kg a.i./ha was found to be highly effective in reducing the density (20/m^2) and dry weight (26.8 g/m^2) of weeds at Jabalpur. However, Oxyfluorfen @ 0.1 kg a.i./ha followed by imazethapyr @ 0.1 kg a.i./ha was more efficient treatment in reducing the weed density and dry weight at Rahuri and Urulikanchan. The high selectivity of herbicides to berseem and non-selectivity to weeds was the reason for better control of weeds.

Treatments had significant effect on weed control efficiency in berseem (Fig 1). At Jabalpur, highest weed control efficiency was computed under pendimethalin 0.3 kg a.i./ha (80.8%) followed by pendimethalin 0.4 kg a.i./ha. However, application of oxyfluorfen (0.1 kg a.i./ ha)– imazethapyr (0.1 kg a.i./ha) was superior in weed control efficiency at Rahuri (66.9%) and Urulikanchan (83.9%). The higher weed control efficiency might be due to reduced total dry weight of weeds in pendimethalin 0.3 kg a.i./ha at Jabalpur and oxyfluorfen (0.1 kg a.i./ha)– imazethapyr (0.1 kg a.i./ha) at Rahuri and Urulikanchan as compared to weedy check (Table 3). Kumar *et al.* (2018) also managed more than 80% weeds in berseem through application of pendimethalin at 0.3 kg a.i./ ha. However, Wasnik *et al*. (2017) noticed highest weed control efficiency with Imazethapyr @ 0.1 kg a.i./ha.

Table 3. Weed density and dry weight as influenced by treatments at different locations (pooled data of three years)†

Treatments	Weed density (No./m^2)			Weed dry weight (g/m^2)		
	Jabalpur	Rahuri	Urulikanchan	Jabalpur	Rahuri	Urulikanchan
Weedy check (control)	15.1	10.1	11.6	11.4	14.4	5.48
	(227.0)	(100.6)	(134.0)	(129.3)	(206.4)	(29.1)
Pendimethalin (0.3 kg/ha)	6.4	8.8	9.0	5.0	13.0	4.22
	(40.0)	(77.2)	(79.7)	(24.8)	(167.2)	(16.8)
Pendimethalin (0.4 kg/ha)	7.2	8.8	9.3	5.2	12.9	3.76
	(52.0)	(76.8)	(84.7)	(26.6)	(164.4)	(13.1)
Pendimethalin (0.5 kg/ha)	8.8	8.8	9.7	7.8	12.8	3.92
	(73.7)	(76.2)	(92.7)	(60.0)	(163.0)	(14.4)
Oxyfluorfen (0.1 kg/ha)	8.2	6.5	8.3	7.3	9.9	3.62
	(66.7)	(41.1)	(68.3)	(52.4)	(96.4)	(12.2)
Imazethapyr (0.1 kg/ha)	7.1	5.8	10.5	7.1	8.9	3.70
Oxyfluorfen (0.1 kg/ha) –	(49.3)	(32.7)	(110.0)	(49.9)	(77.9)	(12.7)
Imazethapyr (0.1 kg/ha)	6.2	5.3	7.1	6.5	8.3	2.39
Pendimethalin (0.3 kg/ha) –	(38.3)	(26.9)	(50.0)	(42.3)	(68.3)	(4.7)
Imazethapyr (0.1 kg/ha)	6.8	7.3	8.6	6.4	10.8	3.42
Pendimethalin (0.4 kg/ha) –	(46.3)	(52.1)	(73.7)	(41.1)	(116.3)	(10.8)
Imazethapyr (0.1 kg/ha)	4.5	6.9	10.0	5.2	10.7	3.73
Pendimethalin (0.5 kg/ha) –	(20.0)	(46.7)	(100)	(26.8)	(113.4)	(12.9)
Imazethapyr (0.1 kg/ha)	8.9	6.8	10.6	7.2	10.6	3.67
	(79.0)	(45.4)	(112.3)	(51.9)	(112.0)	(12.5)
SEm±	0.15	0.08	0.21	0.17	0.11	0.14
LSD (p=0.05)	0.46	0.25	0.64	0.51	0.33	0.41

†Data were subjected to square-root $\sqrt{(x + 0.5)}$ transformation before analysis and original values are shown in parenthesis

Table 4. Fodder and seed yield of berseem as influenced by treatments at different locations (pooled data of three years)

Treatments	Green fodder yield (t/ha)				Dry matter yield (t/ha)				Seed yield (kg/ha)			
	Jabalpur	Rahuri	Urulik-anchan	Mean	Jabalpur	Rahuri	Urulik-anchan	Mean	Jabalpur	Rahuri	Urulik-anchan	Mean
Weedy check (Control)	27.1	30.0	13.7	23.6	3.49	4.94	2.26	3.57	140	148	177	155
Pendimethalin (0.3 kg/ha)	50.6	25.5	21.0	32.4	6.91	4.10	2.93	4.65	352	120	265	246
Pendimethalin (0.4 kg/ha)	51.8	24.2	18.3	31.4	7.10	3.85	2.62	4.52	374	116	253	248
Pendimethalin (0.5 kg/ha)	57.4	23.1	16.3	23.3	8.06	3.63	2.30	4.67	447	113	236	265
Oxyfluorfen (0.1 kg/ha)	60.2	29.6	23.6	37.8	8.40	4.81	3.26	5.49	459	143	297	300
Imazethapyr (0.1 kg/ha)	53.9	41.6	18.9	38.1	7.46	6.90	2.74	5.70	426	182	268	292
Oxyfluorfen (0.1 kg/ha) – Imazethapyr (0.1 kg/ha)	61.6	33.2	33.4	42.7	8.77	5.49	5.07	6.44	500	162	358	340
Pendimethalin (0.3 kg/ha) – Imazethapyr (0.1 kg/ha)	53.5	28.9	26.7	36.4	7.38	4.67	4.09	5.38	398	143	311	284
Pendimethalin (0.4 kg/ha) – Imazethapyr (0.1 kg/ha)	50.5	27.8	22.5	33.6	7.80	4.38	3.47	5.22	427	136	279	281
Pendimethalin (0.5 kg/ha) – Imazethapyr (0.1 kg/ha)	60.7	26.9	19.6	35.7	8.59	4.14	2.80	5.18	505	124	264	298
Mean	52.7	29.1	21.4		7.40	4.69	3.15		403	139	271	
LSD (p=0.05)		Location	0.57			Location	0.19			Location	11.8	
		Treatment	2.34			Treatment	0.20			Treatment	11.9	
		L × T	3.87			L × T	0.36			L × T	21.8	

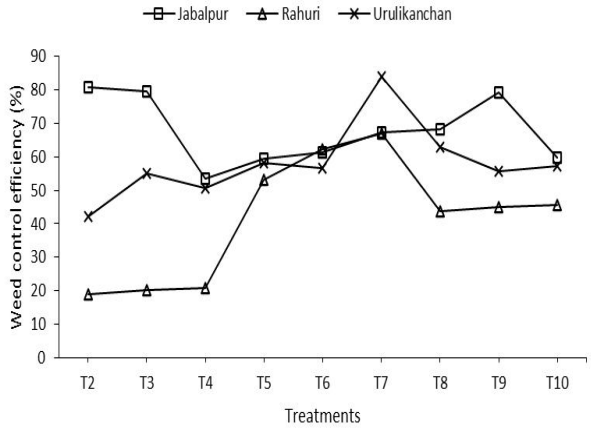

Fig 1. Weed control efficiency of treatments at different locations

Location, treatment and location × treatment effect significantly (P<0.05) influenced fodder and seed yields of berseem (Table 4). Higher green and dry matter yield were recorded at Jabalpur followed by Rahuri and Urlikanchan. Application of oxyfluorfen (0.1 kg a.i./ha) – imazethapyr (0.1 kg a.i./ha) produced higher green and dry matter yield at Jabalpur and Urulikanchan. However, imazethapyr (0.1 kg a.i./ha) resulted in higher yield at Rahuri. It was observed that pendimethalin associated treatments were phytotoxic to berseem in Rahuri had produced less forage and seed yield as compared to un-weeded control (Table 4). Mishra (2012) also recorded fifty per cent reduction in berseem population upon pre-emergence application of pendimethalin. Across the locations, higher green and dry fodder yield were recorded in oxyfluorfen (0.1 kg a.i./ha) – imazethapyr (0.1 kg a.i./ ha) followed by imazethapyr (0.1 kg a.i./ha). This treatment produced about 81% higher green and dry fodder yield of berseem than un-weeded control. The selective action of the imazethapyr and oxyfluorfen might be the reason of better control of weeds which ultimately resulting in very meagre competition of weeds to crop in respect to moisture, space, sunlight and nutrition reflected in improving yields. These results were in agreement with the earlier findings (Kumar and Dhar, 2008; Pathan *et al*., 2013; Wasnik *et al*., 2017).

Net monetary returns and benefit to cost ratio (BCR) of different treatments were worked out (Table 5). In general, the net return and BCR were higher at Jabalpur followed by Urulikanchan and Rahuri. Maximum net return was observed in oxyfluorfen (0.1 kg a.i./ha)– imazethapyr (0.1 kg a.i./ha) at Jabalpur (Rs 124495/ha) and Urulikanchan (Rs 106219/ha). However, imazethapyr (0.1 kg a.i./ha) gave highest economic return and BCR at Rahuri. Across the locations, maximum net return (Rs 87934/ha) and BCR (3.04) were also observed in oxyfluorfen (0.1 kg a.i./ ha)– imazethapyr (0.1 kg a.i./ha). Higher net return and BCR were realized due to higher fodder and seed yields.

On the basis of three years study at different locations of berseem growing areas, it was concluded that pre-emergence application of Oxyfluorfen @ 0.1 kg a.i/ha followed by imazethapyr @ 0.1 kg a.i/ ha after first cut reduced weed infestation, improved fodder and seed yields of berseem and profitability.

Table 5. Effect of weed control treatments on economics of berseem at different locations (pooled data of three years)

Treatments	Net returns (Rs/ha)				Benefit to cost ratio			
	Jabalpur	Rahuri	Urulik-anchan	Mean	Jabalpur	Rahuri	Urulik-anchan	Mean
Weedy check (control)	31508	29920	27152	29527	2.02	1.70	1.58	1.77
Pendimethalin (0.3 kg/ha)	91244	20289	67654	59729	4.09	1.54	2.58	2.74
Pendimethalin (0.4 kg/ha)	95495	17788	58101	57128	4.20	1.47	2.39	2.69
Pendimethalin (0.5 kg/ha)	111956	14963	49156	58692	4.44	1.39	2.17	2.67
Oxyfluorfen (0.1 kg/ha)	114584	28471	75062	72706	4.20	1.69	2.57	2.82
Imazethapyr (0.1 kg/ha)	98796	48966	52376	66713	4.08	2.09	2.01	2.73
Oxyfluorfen (0.1 kg/ha)– Imazethapyr (0.1 kg/ha)	124495	33088	106219	87934	4.47	1.70	2.96	3.04
Pendimethalin (0.3 kg/ha)– Imazethapyr (0.1 kg/ha)	95928	24571	85811	68770	3.93	1.58	2.78	2.76
Pendimethalin (0.4 kg/ha)– Imazethapyr (0.1 kg/ha)	104539	22157	68769	65155	4.30	1.52	2.45	2.76
Pendimethalin (0.5 kg/ha)– Imazethapyr (0.1 kg/ha)	121809	18765	58737	66437	4.56	1.45	2.24	2.75

Acknowledgement

The financial support for this study under AICRP on Forage Crops, ICAR-Indian Grassland and Fodder Research Institute, Jhansi is duly acknowledged.

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