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Efficacy of different herbicides on weed flora of berseem (*Trifolium alexandrinum* L.)

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Abstract
A field experiment was conducted to identify the appropriate herbicide for weed control in berseem. Oxyfluorfen @ 0.02, 0.03 and 0.04 kg a.i./ha as pre-emergence; imazethapyr @ 0.05, 0.075, 0.1 kg a.i. /ha as post-emergence and a combination of oxyfluorfen @ 0.03 kg a.i. /ha followed by imazethapyr @ 0.1 kg a.i. /ha after the first cut were tested with weed free and weedy check. Post-emergence application of imazethapyr at twenty days after sowing @ 0.1 kg a.i./ha recorded significantly lowest weed intensity (4.66, 4.43 and 4.14/ m^2), weed dry weight (3.29, 3.24 and 3.15 g/m^2) and highest weed control efficiency (82.49, 79.14 and 70.93 %) than weedy check and other herbicide treatments at first, second and third cut. It resulted in significant increase in growth and yield attributes of berssem. Application of imazethapyr @ 0.1 kg a.i./ha surpassed other treatments except the weed free with respect to green fodder (404.45 q/ha), seed (3.50 q/ha) and straw (25.79 q/ha) yields and generated highest net monetary returns (Rs. 59,336 /ha) and benefit-cost ratio (2.35).

Keywords: Berseem, Fodder yield, Herbicides, Seed yield, Weed control

Introduction

Berseem (*Trifolium alexandrinum* L.) is a premier winter season legume fodder in the Indian subcontinent (Kaushal *et al*., 2003). In India, it is cultivated in an area of around 2 million hectares (Pandey and Roy, 2011). Compared to other forage crops, berseem is very nutritious, succulent and highly palatable to cattle (Mahanta and Karnani, 2010). Weed management is an important factor for enhancing the productivity of berseem because many crop associated weeds like *Cichorium intybus, Coronopus didymus, Rumex dentatus* and *Trifolium resupinatum* compete with main crops for nutrients, water, light and space during early growth period (Thakur *et al.,* 1990). Due to severe weed infestation besides deterioration in fodder quality, 30-40 % loss in green fodder yield of berseem has also been observed earlier (Jain, 1998). Hence, to achieve the full yield potential the crop should be kept weed free up to 35 to 40 days after sowing. Hand weeding and inter-culture operations are effective methods of weed control but they are highly labour intensive (Kauthale *et al*., 2016). The reduced availability of labour in agricultural sector not only enhances the cost of production but also severely limits the timely weeding operations, resulting in reduction of both quality and quantity of fodder and seed. Hence, chemical weeding under such situation appears to be an obvious option for wide spectrum weed control. But very few studies related to herbicide selectivity to berseem and their bio-efficacy against composite weed flora have been documented in the literature. Keeping above aspects in view, present investigation was conducted to test the efficacy of different herbicides to control the weed flora in berseem crop.

Materials and Methods

***Experimental site and design*:** A field experiment was carried out during *Rabi* season of 2015-16 and 2016-17 at Central Research Farm of ICAR-Indian Grassland and Fodder Research Institute, Jhansi. The experimental site contains sandy clay loam soil with neutral pH (7.3), high organic carbon (0.94%), low available nitrogen (159.0 kg/ha) and medium available phosphorus (11.9 kg/ha) and potassium (158.0 kg/ha). The study was conducted in randomized block design with three replications. Seven herbicide treatments *viz*., T_3: oxyfluorfen @ 0.02 kg a.i./ ha; T_4: oxyfluorfen @ 0.03 kg a.i./ha; T_5: oxyfluorfen @ 0.04 kg a.i./ha; T_6: imazethapyr @ 0.05 kg a.i./ha; T_7: imazethapyr @ 0.075 kg a.i./ha; T_8: imazethapyr @ 0.1 kg a.i./ha and T_9: oxyfluorfen @ 0.03 kg a.i./ha followed by imazethapyr @ 0.1 kg a.i./ha were tested after first cut in comparison with weed free (T_2) and weedy check (T_1). The pre-emergence herbicide, oxyfluorfen was sprayed three days after sowing prior to emergence of crop and weed, and the post-emergence herbicide imazethapyr was sprayed at twenty days after sowing. Berseem variety 'Wardan' was sown at seed rate of 20 kg/ha with inter row spacing of 40 cm in the last week of October.

Recommended dose of fertilizers i.e. 20 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha were applied uniformly.

***Yield attributes and data analysis*:** To harvest the green fodder of berseem the first cutting was taken at 55 days after sowing and subsequent two cuttings were taken at 25 days interval. The yield obtained in three cuttings was summed up to get the total green fodder yield under each treatment. After three cuttings, the crop was left for seed production. To record the dry weight five hundred gram of fresh samples collected during each cut was first sun dried and later oven dried at 65° C to obtain the constant weight. The weed density and dry weight were recorded from each plot in a quadrate of one square meter at the time of first, second and third cut.

Weed data were subjected to square root transformation $\sqrt{(X+0.5)}$ before statistical analysis to normalize data distribution. The weed control efficiency (WCE) was calculated by using the formula:

$$WCE\ (\%) = \frac{DMC - DMT}{DMC} \times 100$$

Where WCE = Weed control efficiency; DMC = Dry mater of weeds in unweeded control; DMT = Dry matter of weeds in a treatment.

The weed index (WI) was worked out using the following formula:

$$WI\ (\%) = \frac{X - Y}{X} \times 100$$

Where, WI = Weed index; X = Yield from weed free plot; Y= Yield from a treated plot.

Benefit cost ratio was calculated by dividing gross returns with the cost of cultivation. The data were analyzed following analysis of variance (ANOVA) technique as per Gomez and Gomez (1984).

Results and Discussion

***Weed flora*:** The berseem crop was infested with several weed species, out of which fifteen weed species were predominant and competed with the main crop during different stages of crop growth. The weed species consisted of one sedge (*Cyperus rotundus*), one grass species (*Poa annua*) and thirteen broad leaf weeds viz., *Anagalis arvensis, Chenopodium album, Cichorium intybus, Coronopus didymus, Eclipta alba, Medicago denticulata, Melilotus alba, Melilotus indica, Physalis minima, Rumex dentatus, Sonchus asper, Spergula arvensis* and *Trifolium resupinatum.* Similar kind of weed flora dominance in berseem was also reported earlier (Tiwana *et al.,* 2002; Kewat *et al.,* 2005).

***Weed density and dry weight*:** Different weed control treatments significantly influenced the density and dry weight of weeds compared to weedy check. The highest weed density (16.26, 14.73 and 11.92/m^2) and dry weight (7.56, 6.81 and 5.63 g/m^2) of weeds at first, second and third cut was recorded in weedy check treatment (Table 1). Among the herbicides pre-emergence application of oxyfluorfen @ 0.02 kg a.i./ha at lowest rate did not control the weed population satisfactorily, but it was effective when applied @ 0.04 kg a.i./ha, even though these treatments could not surpass imazethapyr treatments but they could reduce the weed population in berseem to some extent. The post-emergence application of imazethapyr @ 0.1 kg a.i./ha at twenty days after sowing gave excellent control of weeds and recorded the lowest weed density (4.66, 4.43 and 4.14/m^2) and dry weight (3.29, 3.24 and 3.15 g/m^2) of weeds at first, second and third cut. The high selectivity of imazethapyr to berseem and non-selectivity to complex weed flora of berseem was the reason for better control of weeds with the post-emergence application of imazethapyr @ 0.1 kg a.i./ha. Similar results were also reported by Kumar and Shivadhar (2008) from their studies.

***Weed control efficiency*:** At first, second and third cut highest weed control efficiency (82.49, 79.14 and 70.93%) was registered with imazethapyr application @ 0.1 kg a.i./ha followed by imazethapyr @ 0.075 kg a.i./ha (74.36 and 69.79%) at first and second cut. This might be due to requirement of higher dose of herbicide to kill broad spectrum weeds. The dose @ 0.1 kg a.i./ha reduced the weed density and weed dry weight significantly and thereby enhanced the weed control efficiency. With imazethapyr application highest weed control efficiency in berseem and lucerne were also achieved earlier by different workers (Kumar and Shivadhar, 2008; Revathi *et al.,* 2012).

***Weed index*:** The weed index varied greatly due to various weed control treatments. The weedy check treatment recorded maximum weed index (27.61 and 43.81%) for green fodder and seed yield. While lower weed index (5.70 and 8.27%) for green fodder and seed yield was observed under post-emergence application of imazethapyr @ 0.1 kg a.i./ha followed by the imazethapyr treatment @ 0.075 kg a.i./ha (Table 2). This might be due to the control of both grassy and broad-leaved weeds which provided favorable condition to enhance the crop growth and yield. These results are akin to those reported by Pathan *et al.* (2013).

Table 1. Density, dry weight and control efficiency of weeds as influenced by different weed control treatments in berseem

Treatments	Weed density (No. /m²)			Weed dry weight (g/m²)			Weed control efficiency (%)			
	I Cut	II Cut	III Cut	I Cut	II Cut	III Cut	I Cut	II Cut	III Cut	Mean
Weedy check	*16.26 (263.33)	14.73 (216.17)	11.92 (141.00)	*7.56 (56.17)	6.81 (45.53)	5.63 (30.79)	0.00	0.00	0.00	0.00
Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	100.00	100.00	100.00	100.00
Oxyfluorfen @ 0.02 kg a.i./ha	14.69 (214.83)	13.84 (190.67)	10.93 (118.50)	6.18 (37.18)	5.54 (32.29)	4.79 (21.92)	33.80	29.08	28.82	30.57
Oxyfluorfen @ 0.03 kg a.i./ha	14.32 (204.17)	13.62 (184.50)	10.52 (109.67)	5.96 (34.49)	5.50 (26.92)	4.56 (19.80)	38.59	40.88	35.71	38.39
Oxyfluorfen @ 0.04 kg a.i./ha	13.92 (192.83)	13.24 (174.33)	9.67 (92.50)	5.47 (28.92)	4.92 (23.17)	4.30 (17.50)	48.52	49.12	43.17	46.93
Imazethapyr @ 0.05 kg a.i./ha	6.26 (38.17)	5.91 (34.00)	5.32 (27.33)	4.73 (21.39)	4.55 (19.75)	4.02 (15.19)	61.91	56.63	50.67	56.41
Imazethapyr @ 0.075 kg a.i./ha	5.46 (29.00)	5.14 (25.50)	4.69 (21.00)	3.92 (14.40)	3.84 (13.76)	3.52 (11.40)	74.36	69.79	62.98	69.04
Imazethapyr @ 0.100 kg a.i./ha	4.66 (20.83)	4.43 (18.67)	4.14 (16.17)	3.29 (9.83)	3.24 (9.50)	3.15 (8.95)	82.49	79.14	70.93	77.52
Oxyfluorfen @ 0.03 kg a.i./ha *fb* imazethapyr @ 0.100 kg a.i./ha after first cut	14.51 (209.67)	7.75 (59.33)	5.23 (26.33)	6.05 (35.65)	4.38 (18.21)	3.39 (10.51)	36.53	60.01	65.86	54.13
SEm±	0.18	0.18	0.14	0.12	0.18	0.08	-	-	-	-
CD (P=0.05)	0.55	0.55	0.42	0.35	0.53	0.24	-	-	-	-

*Values are $\sqrt{(x + 0.5)}$ transformed and original values are in parenthesis

Table 2. Weed index, berseem growth parameters and yield attributes as influenced by different weed control treatments

Treatments	Weed index (%)		Berseem dry weight (g)			Plant height at harvest (cm)	No. of effective tillers/m²	No. of heads /m²	No. of seeds /head	Test weight (g)
	Green fodder yield	Seed yield	I Cut	II Cut	III Cut					
Weedy check	27.61	43.81	34.92	43.00	51.42	42.67	225.50	606.00	61.67	2.79
Weed free	0.00	0.00	47.52	55.17	64.50	57.59	306.77	728.00	98.33	3.37
Oxyfluorfen @ 0.02 kg a.i./ha	23.06	38.38	36.48	44.82	53.08	47.61	238.83	635.00	65.68	2.82
Oxyfluorfen @ 0.03 kg a.i./ha	19.44	33.92	37.33	46.16	54.51	48.67	242.33	647.33	67.34	2.86
Oxyfluorfen @ 0.04 kg a.i./ha	15.87	30.15	39.20	47.43	56.09	50.22	249.82	661.67	70.69	2.99
Imazethapyr @ 0.05 kg a.i./ha	13.58	24.29	40.49	49.02	57.67	50.83	260.67	674.50	73.00	3.03
Imazethapyr @ 0.075 kg a.i./ha	9.75	15.36	43.00	50.63	59.59	53.22	271.00	695.17	81.36	3.07
Imazethapyr @ 0.100 kg a.i./ha	5.70	8.27	44.58	52.68	62.02	56.10	291.07	713.54	90.99	3.18
Oxyfluorfen @ 0.03 kg a.i./ha *fb* imazethapyr @ 0.100 kg a.i./ha after first cut	11.93	18.69	37.50	48.23	58.82	51.78	265.00	678.44	75.00	3.04
SEm±	-	-	0.44	0.46	0.49	0.86	3.36	4.21	2.33	0.10
CD (P=0.05)	-	-	1.33	1.38	1.47	2.60	10.16	12.74	7.03	0.31

***Growth parameters*:** The berseem dry weight recorded at first, second and third cut and plant height at harvest was significantly influenced by various weed control treatments. Berseem dry weight recorded at all the three cuts (47.52, 55.17 and 64.50 g) and plant height recorded at harvest (57.59 cm) was maximum under weed-free treatment followed by post-emergence application imazethapyr @ 0.1 kg a.i./ha (Table 2). The significant reduction in weed density and dry weight of weeds under treatments weed free and application of imazethapyr @ 0.1 kg a.i./ha led to better availability of nutrients and eventually resulted in increased plant height and dry weight of berseem.

Yield attributes and yield: The maximum values of yield attributes, no. of effective tillers (306.77 /m^2), no. of heads (728.00 /m^2) and no. of seeds/head (98.33) were recorded under weed-free treatment (Table 2). This result was in line with the findings of Kewat *et al.* (2005), Mishra (2012) and Jha *et al.* (2014). Among all the herbicides treatments application of imazethapyr @ 0.1 kg a.i./ha at twenty days after sowing recorded maximum no. of effective tillers (291.07 /m^2), no. of heads (713.54 /m^2) and no. of seeds/head (90.99). However, test weight recorded under weed-free treatment were at par with post-emergence application of imazethapyr @ 0.1 kg a.i./ ha. The significantly highest green fodder (428.89 q/ha), seed (3.81 q/ha) and straw yield (28.05 q/ha) of berseem were recorded with weed-free treatment (Table 3). The weed-free condition provided a competition-free environment to crop from weeds for light, nutrients and moisture, which led to increased growth of the crop and thereby increase in nutrient uptake by increasing the green fodder, seed and straw yield of berseem. Pathan *et al.* (2013) and Jha *et al.* (2014) obtained similar results. Among two herbicides post-emergence application of imazethapyr @ 0.1 kg a.i./ha recorded significantly highest green fodder (404.45 q/ha), seed (3.50 q/ha) and straw (25.79 q/ha) yields. The selective mode of imazethapyr to berseem and nonselective mode against grassy, broad leaves and sedges weeds gave the efficient weed control during the critical period of crop-weed competition, which translated in higher growth and yield attributing characters. The increase in berseem green fodder and seed yield by imazethapyr application was also observed by Prajapati *et al.* (2015) and Kauthale *et al.* (2016). Among pre-emergence herbicides, application of oxyfluorfen @ 0.04 kg a.i./ha recorded highest green fodder (360.83 q/ha), seed (2.66 q/ha) and straw (21.44 q/ha) yields. These results were at par with pre-emergence application of oxyfluorfen @ 0.03 kg a.i./ha. However, the yields obtained under oxyfluorfen applied treatments were comparatively lower than imazethapyr applied treatments. This was probably be due to poor efficacy of oxyfluorfen @ 0.02 kg a.i./ha against complex weed flora at lower dose and phytotoxicity on the berseem plants at increased dosage of 0.04 kg a.i./ha resulting in the reduction in berseem green fodder and seed yield. Phytotoxic effect on rice seedlings due to oxyfluorfen application at higher dose was also reported by Abraham *et al.* (2010).

Table 3. Green fodder, seed and straw yield and economics of berseem as influenced by different weed control treatments

Treatments	Yield (q/ha)			Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	Benefit cost ratio
	Green fodder	Seed	Straw				
Weedy check	310.47	2.14	14.75	41757	69284	27526	1.66
Weed free	428.89	3.81	28.05	55022	111475	56453	2.03
Oxyfluorfen @ 0.02 kg a.i./ha	329.97	2.35	17.21	42574	75237	32663	1.77
Oxyfluorfen @ 0.03 kg a.i./ha	345.51	2.52	19.39	42877	80132	37255	1.87
Oxyfluorfen @ 0.04 kg a.i./ha	360.83	2.66	21.44	43244	84541	41297	1.95
Imazethapyr @ 0.05 kg a.i./ha	370.66	2.88	21.97	43169	89213	46044	2.07
Imazethapyr @ 0.075 kg a.i./ha	387.06	3.22	23.26	43639	96612	52973	2.21
Imazethapyr @ 0.100 kg a.i./ha	404.45	3.50	25.79	44041	103377	59336	2.35
Oxyfluorfen @ 0.03 kg a.i./ha *fb* imazethapyr @ 0.100 kg a.i./ha after first cut	377.74	3.10	22.25	44438	93376	48937	2.10
SEm±	5.32	0.07	0.70	-	-	-	-
CD (P=0.05)	16.09	0.20	2.12	-	-	-	-

Prevailing price of berseem: Green fodder: Rs. 100/q; Seed: Rs.158/kg; Straw: Rs. 300/q

Economics: All the weed control treatments had proven superiority in terms of monetary returns over the weedy check. The weed-free treatment recorded the highest gross returns (Rs. 1,11,475 /ha), followed by imazethapyr application @ 0.1 kg a.i./ha at twenty days after sowing (Rs. 1,03,377 /ha). Among herbicides, the highest net returns (Rs. 59,336 /ha) as well as benefit cost ratio (2.35) were recorded under post-emergence application of imazethapyr @ 0.1 kg a.i./ha. In the present experiment, even though maximum yield was obtained in weed-free (hand weeding), the benefit-cost ratio was low due to high labour cost (discourages its usage). However, the application of weedicide imazethapyr @ 0.1 kg a.i./ha not only increased the yield compared to other treatments and weedy check, but it had better monetary returns due to high benefit cost ratio. Kumar and Shivadhar (2008) also reported similar findings in berseem with a pre-emergence application of imazethapyr @ 0.1 kg a.i./ha.

Conclusion

The study indicated that application of imazethapyr @ 0.100 kg a.i./ha at 20 days after sowing was the most remunerative and effective herbicide treatment for controlling the complex weed flora in berseem.

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