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Role of weedicides for weed management and improvement in production of berseem (*Trifolium alexandrinum* L.) fodder

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Abstract Berseem (*Trifolium alexandrinum* L.) is an important fodder crop used for feeding cattle across the globe but in Pakistan heavy weeds infestation hampers its production. The most prominent weeds namely *Trianthema partulacastrum* L. and *Digera muricata* L. deteriorate the quality and diminish the quantity of its production. Implication of weedicides for weeds management, improvement in fodder and crude protein yield were investigated. Four weedicides namely, Connect (Atrazine), Panida Grande (Pendimethalin), Dual Gold (S-metolachlor), and Primextra Gold (S-metolachlor + Atrazine) were tested at its four application times i.e., pre-sowing incorporation (0, 2, 4 days before sowing) and pre-emergence (just after sowing). Results revealed that Pendimethalin herbicide showed the best performance amongst all weedicides when used 4 days before sowing, indicating 94.73 % efficiency of weed control and produced maximum fodder yield (108.63 t ha^{-1}), dry matter yield (14.72 t ha^{-1}) and crude protein yield (2.92 t ha^{-1}). Thus, it was concluded that Pendimethalin @ 2.5 L ha^{-1} should be applied at 4 days before sowing for effective control of all types of weeds considered under the current study and to improve the quantity and quality of berseem. Economic analysis showed a maximum benefit-cost ratio of 1.89 for treatments where Pendimethalin herbicide was applied @2.5 liter ha^{-1} four days before sowing.

Keywords: Berseem, Fodder production, Quality of berseem, Weedicides application time, Weed management

Introduction

Berseem (*Trifolium alexandrium* L.) is a major leguminous fodder crop cultivated in South East Asia due to its fast vegetative growth, multi-cut nature, better output and supply of fodder for prolonged period with high palatability

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and maximum nutritive value. It contains about 62 % total digestible nutrients and about 20-21% crude protein (Yadav *et al.,* 2015). Livestock is one of the most important agricultural allied sector sharing approximately 11.22 % towards the gross domestic product (GDP), which is about 60.54 % of the total agriculture share in the GDP (Govt. of Pakistan, 2019). Pakistan is third largest livestock rearing country having population of 196.5 million heads (Economic Survey of Pakistan, 2017-18). The livestock population is increasing at the rate of 4.2% per annum and accordingly its feed requirements are increasing. Regular supply of adequate and nutritious fodder is essential for the promotion and development of livestock. Fodder crops are the main and cheapest source of feed for livestock. However, shortage of fodder production is the major limiting factor for livestock production in the country. The average fodder production in the country is 22.5 t ha^{-1}, which is too low to meet even half of the maintenance requirements of the present livestock population in the country. The deficit estimate variously is 15-30 percent of the requirement in terms of nutrients. In terms of Total Digestible Nutrients (TDN) Pakistan is facing a short of about 25.65 million tones and in terms of Digestible Protein (DP) about 1.58 million tones (Sajid, 2019). Quality fodder is crucial for sustainable livestock production. Currently the quality of berseem fodder is being effected by heavy weeds infestation in most beseem growing areas of Pakistan. There is a substantial gap between the fodder production and requirements, which multiplies during the lean periods of fodder production. The major scarcity periods of fodder are the months of May-June and November-December (FRI, 2019). Fodder production and quality are very low at the farmer's field compared to the potential yield and quality of improved forage cultivars. Hence, there is a dire need to bridge the gap among the fodder requirements and production. The major bottlenecks for higher forage productivity are poor seed quality, lack of knowledge regarding improved production technologies, poor soil health & faultiness in crop husbandry and weed infestation (Zulfiqar *et al.,* 2002). In Pakistan, weed infestation is responsible for huge loss of crop productivity (Matloob *et al*., 2019). Yield reduction from five (5) to 100 % is noted in different crops depending on the weeds density, types, duration of competition and prevailing agro-climatic conditions (Ashiq *et al.,* 2003). Weed competition deteriorates quality of fodder (leaf to stem ratio, palatability, crude protein); whereas, under weed free conditions, forage quality is improved (Gholami *et al*., 2013). Weeds reduce berseem fodder yield to the tune of 30 to 40%, and deteriorate its quality (Jain, 1998). Additionally, seed samples of infested berseem crop contain weeds like *Cichorium intybus* L. and *Sonchus Asper* L. as adulterants since their germination and flowering time coincides with that of berseem. The *C. intybus*

can regenerate its vegetative shoots along with berseem after subsequent cuts (Rao, 2008). Parasitic weeds such as *Cuscuta campestris* also infest berseem crop.

In Pakistan, berseem is the most important cultivated fodder crop of Rabi season that comprises the months from October-March i.e., winter season. It is largely used as green forage crop and as pallets hay during off-season periods (Nigam *et al.*, 2010). When berseem crop is sown during the second fortnight of September to cover the November-December fodder scarcity period, many seasonal weed species namely *Cyperus rotundus* L., *Trianthema partulacastrum* L., *C. intybus*, and *Digera muricata* L. also emerge in great numbers and compete with berseem crop for nutrients, light, moisture and space (Tiwana *et al.*, 2002; Wasnik *et al.*, 2017). The highest competition among weeds and berseem has been recorded at the early stage of plant growth due to which establishment of plants decreases and considerable reduction (25-30 %) occurs in the forage yield (Tiwana *et al.*, 2002; Alfred, 2012). Kantwa *et al.* (2019) also reported that growth of weeds in berseem at its establishment stages resulted in lower plant establishment subsequently reduced forage yield. Weeds infestation decreases yields of fresh fodder and seed to the tune of 20 to 30% and 13 to 37% respectively (Vijay *et al.,* 2017; Tyagi *et al.,* 2018). Chemical weed control has proved an efficient approach in controlling weeds in field crops. Kantwa *et al.* (2019) reported that green fodder and seed yield of berseem is increased upto 81 and 119% respectively by the application of weedicides. Nevertheless, contrary to the cereals, their use in fodders is limited and very few herbicide molecules are actually used. Meager information is available on the comparative performance of different weedicides in berseem especially with reference to their application window. Keeping in view the agro-economic significance of berseem as a fodder crop, the current study was conducted to study the role of various weedicides and their time of application in managing weeds and improving the quality and yield of berseem fodder. The study also aimed to optimize the time of their pre-emergence and post-sowing application.

Materials and methods

Site description

The experiment was carried out at research farm of Fodder Research Institute, Sargodha, which is located between 32.1233 ° North and 72.6805 ° East; with elevation of 190 m above mean sea level (msl), during two winter seasons (2017-18 and 2018-19) to ascertain the most suitable herbicide and its

application time for weed control in early sown berseem. Soil of experimental site was loam having organic matter 0.71%, pH 7.8, total Nitrogen (N) 0.062%, available phosphorous (P) 7.41 mg kg^{-1}, available potassium (K) 167.33 mg kg^{-1} and saturation percentage of 37.8%.

Experimental design

The experiment was laid out in randomized complete block design (RCBD) with split plot arrangements having four replications. Time of applications were kept in main plots and weedicides were assigned to the sub plots.

Treatments

Treatments consisted of four weedicides and four application times. Four weedicides comprising Connect (Atrazine @ 1073 g ha^{-1}), Panida Grande (Pendimethlin @ 1088 g ha^{-1}), Dual Gold (S-metolachlor @ 1440 g ha^{-1}) and Primextra Gold (S-metolachlor @ 600 g ha^{-1} + (Atrazine & others) @525 g ha^{-1}) were applied two days before sowing (2 DBS), four days before sowing (4 DBS) & just before sowing (JBS) as pre-plant incorporation (PPI) and just after sowing (JAS) as pre-emergence application. A weedy check (control) was also maintained for comparison. Field selected for experiment was preferred where huge quantities of weed seeds were fallen during prior season resulting in diverse weed seed bank. The size of each experimental unit was kept as 3 m × 6 m. Berseem variety (Super late) was sown in standing water in the last week of September during both years. Five cuts were taken each at the time when fodder attained 60 cm height each year. The weedicides, Atrazine @ 2.5 L ha^{-1}, Pendimethalin @ 2.5 L ha^{-1}, dual gold @ 1.5 L ha^{-1} and Primextra gold @ 1.5 L ha^{-1} were applied according to requirements. Fertilizer Nitrophos (NP) dose containing 57-57 kg ha^{-1} was applied in half nitrogen (N) and full Phosphorus (P) at sowing and rest of half N after 25 days of sowing.

Data collection and recording

Data on weed management and crop growth parameters were recorded as per predefined plan. After setting up of treatments and sowing of crop, daily observations were taken on number of days after sowing to start of weed emergence, main crop germination, completion of germination, weedy seedlings start to die and complete mortality in all treatments. Data on plant

population and weed density (spp. wise) was also noted after twenty-five (25) days of sowing, with the help of (1m x 1m) quadrate.

Data on total weed density (m^{-2}), plant population (m^{-2}) and dry weight of weeds (g m^{-2}) were collected after 25 days of sowing. Berseem crop was harvested for 1st cut after 55 days of sowing on attaining the height of 60 cm and each subsequent cuttings were obtained when the plants attained the height of 60 cm. At this stage number of tillers m^{-2} were counted for the first cut of fodder by randomly selected from each treatment. Total fodder yield of five cuts (ton ha^{-1}), dry matter yield and crude protein yield (t ha^{-1}) were weighed at harvest. The number of weeds with their species were also recorded. After counting, the weeds were uprooted and weighed, then, oven dried at 70 ℃ till removal of all moisture and recorded the dry weight (g-m^{-2}) of total weeds. Crude protein was estimated using recommended procedure (AOAC, 1990). Weed control efficiency percentage was find out by the formula:

$$WCE\ (\%) = \frac{\text{Total weed in weedy check} - \text{weeds in respective treatment}}{\text{total weeds in weedy check}}\ X(100)$$

Economic return was determined according to prevailing market rate for cost of cultivation and gross income.

Statistical analysis

All the recorded data were analyzed statistically using Fisher's analysis method of variance (ANOVA). The entire data and means of treatments were compared with LSD (least significant difference test) at probability level 5% (Montgomery, 2013).

Results

General crop husbandry

Observation on germination and growth parameters of weeds and crop showed that the germination started after two days of sowing and completed in three days under all treatments. Next day weedy seedlings were started to die and all seedlings completely died in all treatments (4 DBS, 2 DBS, JBS and JAS) where Pendimethalin was applied. However, seedlings started to die after 12 days of sowing (i.e., after application of the second irrigation) where Atrazine, Dual gold and Primextra were applied. Almost all seedlings died in all treatments in 15 days after sowing. Data on plant population and weed

density (spp. wise) recorded after twenty-five (25) days of sowing showed that the weeds namely; *Trianthema portulacastrum, Digera muricata, Cichorium intybus* and *Cyperus rotundus* were prominent in the experimental fields.

Weed density

Effect of weedicides and their time of application on weed (density m^2) were recorded as presented in Tables 1 and 2. Interactive effect of weedicides and their time of application on weeds density were found significant. Data indicated that maximum number of all weeds i.e., *Trianthema portulacastrum* (127 plants), *Digera muricata* L. (18 plants) *Cichorium intybus* (13 plants), *Cyprus rotundus* (15 plants) and total weeds density of 173 plants m^{-2} were found in the weedy check treatment. This weed infestation (density of plants m^{-2}) was followed by dual gold applications JBS (96 plants m^{-2}) and JAS (56 plants m^{-2}), Pendimethalin JBS (5 plants m^{-2}), 4 DBS (10 plants m^{-2}) and dual gold 2 DBS (110 plants m^{-2}). Whereas the lowest weeds density was observed in all treatments where Pendimethalin was applied.

Table 1. Effect of weedicides on weeds density (m^{-2}) spp. wise (*Trianthema partulacastrum* (T. P) and *Digera muricata* (D. M) (values are means of two years data)

Weedicides	**T. P. Density (m^{-2})**					**D. M. density (m^{-2})**				
	Time of application									
	4DBS	2DBS	JBS	JAS	Means	4DBS	2DBS	JBD	JAS	Means
Control	127.4 a	127.4 a	127.4 a	127.4 a	127.4 a	18.25 a	18.25 a	18.25 a	18.25 a	18.25 a
Atrazine	3.75 f	4.13 f	5.37 f	2.50 f	3.94 d	2.75 defg	2.37 efg	4.63 bc	3.75 cd	3.37 b
Pendimethalin	1.38 f	1.25 f	1.63 f	1.37 f	1.41 d	1.0 hi	1.87 gh	0.00 i	0.50 i	0.84 c
Dual gold	63.75 c	91.37 b	97.5 b	23.70 e	69.08 b	3.12 defg	2.75 defg	2.37 efg	5.50 b	3.44 b
Primextra	53.67 d	65.37 c	53.75 d	27.75 e	50.14 c	3.62 cde	2.25 fgh	4.00 cd	3.50 cdef	3.34 b
Means	49.98 b	57.89 a	57.12 a	36.53 c		5.748 b	5.5 c	5.85 b	6.30 a	
LSD for time/ weedicides			2.3156		4.6380		0.1691			0.7194
LSD for interaction			8.6100				1.2978			

Table 2. Effect of weedicides on weeds density (m^{-2}) spp. wise, *Cichorium intybus* (C. I), *Cyperus rotundus* (C. R) (values are means of two years data)

Weedicides	**C. I. Density (m^2)**					**C. R. Density (m^{-2})**				
	Time of application									
	4DBS	2DBS	JBS	JAS	Means	4DBS	2DBS	JBS	JAS	Means
Control	12.87 a	12.87 a	12.87 a	12.87 a	12.87 a	15.00 a	15.00 a	15.00 a	15.00 a	15.00 a
Atrazine	4.00 cd	1.00 f	1.25 f	3.00 de	2.313 c	3.50 ghi	6.50 c	6.35 cd	3.00 hi	4.84
Pendimethalin	1.38 f	1.00 f	0.50 f	1.37 f	1.06 d	5.37 cde	3.75 fgh	4.50 efg	1.37 j	3.75
Dual gold	3.00 de	4.86 bc	2.87 e	5.00 bc	3.93 b	10.00 b	10.30 b	5.25 de	5.00 ef	7.64 b
Primextra	2.60 e	0.375 f	5.25 b	2.50 e	2.68 c	10.12 b	5.00 ef	6.37 cd	2.50 ij	5.998 c
Means	4.77 ab	4.02 c	4.55 b	4.95 a		8.798 a	8.110 b	7.495 c	5.375 d	
LSD for time/ weedicides		0.3073			0.5610		0.3741			0.6374
LSD for interaction		1.049					1.199			

Table 3. Effect of weedicides on total weeds density (m^{-2}) and weeds control efficiency (%) (values are means of two years data)

Weedicides	**Total weeds density (m^{-2})**					**Weeds control efficiency (%)**				
	Time of application									
	4DBS	2DBS	JBS	JAS	Means	4DBS	2DBS	JBS	JAS	Means
Control	173.38 a	173.38 a	173.38 a	173.38 a	173.38 a	-	-	-	-	-
Atrazine	14.00 ef	14.00 ef	16.63 e	12.25 ef	14.22 d	91.93	91.93	90.41	92.93	91.8
Pendimethalin	9.13 ef	7.88 ef	6.63 ef	3.38 f	6.75 e	94.73	95.46	96.18	97.99	96.09
Dual gold	79.75 c	109.75 b	108.00 b	47.50 d	86.25 b	53.96	37.03	37.76	72.62	50.22
Primextra	70.00 c	73.25 c	68.38 c	35.00 d	61.91 c	59.70	57.92	60.01	79.82	64.36
Means	69.25 b	75.65 a	74.80 a	54.30 c		75.08	70.58	71.09	85.78	
LSD for time/ weedicides		4.072			7.012					

LSD interactive effect =13.189

Weed control efficiency (%age) and weeds dry weight (g m^{-2})

The results revealed that interactive effect of weedicides and time of application showed significant differences on weed control efficiency (WCE) percentage and weed dry weight (WDW) (Table 3). Treatments of Pendimethalin pre-plant incorporation (PPI) 4 DBS, 2 DBS, JBS and JAS showed higher WCE (94.73, 95.46, 96.18 and 97.98 %) respectively, which are statistically higher as compared to all other treatments. Minimum WCE (37.03 %) was observed in the treatment where Dual gold was applied 2 DBS. Highest weeds dry weight (31.37 g m^{-2}) was recorded in weedy check and lowest (0.27 g m^{-2}) in treatment where Pendimethalin was applied JAS.

Plant density (m^{-2}) and number of tillers (m^{-2})

Interactive effect of treatments indicated significant differences ($p<0.05$) on plant density 25 days after sowing (DAS) and number of tillers at first harvest (Table 4). Highest plant density (427 plants m^{-2}) was observed in treatment where Pendimethalin was applied 4 DBS, which was statistically at par with weedy check (411 plants m^{-2}) and lowest plant density (0.00 plants m^{-2}) was recorded where Atrazine was applied JBS. Highest number of tillers (671 tillers m^{-2}) were achieved by the application of Pendimethalin 4 DBS, which was followed by Pendimethalin 2 DBS (636 tillers m^{-2}) as compared to the weedy check (365 tillers m^{-2}). Rest of the treatments produced less number of tillers as compared to weedy check.

Forage yield and dry matter (t ha^{-1})

It was observed that forage yield and dry matter indicated significant interactive effects of treatments on fresh fodder and dry matter yield (Table 5). Higher values of both parameters were obtained by the application of Pendimethalin (4 DBS, 2 DBS and JBS) as compared to all other treatments. In all treatments of Pendimethalin, forage and dry matter yield was gradually decreased as the time between sowing and pre-plant incorporation was decreased. The maximum green forage yield (108.63 t ha^{-1}) and dry matter (14.72 t ha^{-1}) was observed when Pendimethalin was applied 4 DBS, which was statistically at par with application of Pendimethalin 2 DBS and JBS. Increase of 41.31 t ha^{-1} and 58.62 t ha^{-1} in fodder and dry matter yields respectively were observed with the application of Pendimethalin 4 DBS over weedy check.

Table 4. Effect of weedicides on plants density (m^{-2}) 25 DAS, and Av. No. of tillers (m^{-2}) at harvesting (values are means of two years data)

Weedicides	**Plants density (m^{-2}) 25 DAS**					**Av. No of tillers (m^{-2}) at harvest**				
	Time of application									
	4DBS	2DBS	JBS	JAS	Means	4DBS	2DBS	JBS	JAS	Means
Control	410.6 a	410.6 a	410.6 a	410.6 a	410.6 a	365.0 d	365.0 d	365.0 d	365.0 d	365.0 b
Atrazine	139.5 e	33.5 h	0.00 i	0.00 i	43.25 e	231.3 fg	78.75 j	0.00 k	0.00 k	78.75 d
Pendimethalin	426.7 a	386.1 b	350.0 c	0.00 i	290.7 b	670.5 a	636.3 b	496.3 c	0.00 k	451.3 a
Dual gold	142.4 e	131.8 e	100.0 f	0.00 i	93.56 d	247.5 f	206.3 h	176.3 i	0.00 k	157.5 c
Primextra	246.7 d	135.4 e	66.13 g	0.00 i	112.06 c	273.7 e	221.3 gh	166.3 i	0.00 k	165.3 c
Means	273.2 a	219.5 b	185.4 c	82.13 d		359.0 a	301.5 b	241.7 c	73.00 d	
LSD for time & weedicides	5.604				11.384	10.402				9.559
LSD for interactive effect	21.1120					19.9890				

Table 5. Effect of weedicides on fodder yield (t ha^{-1}) and dry matter yield (t ha^{-1}) (values are means of two years data)

Weedicides	**Fodder yield (t ha^{-1})**					**Dry matter yield (t ha^{-1})**				
	Time of application									
	4DBS	2DBS	JBS	JAS	Means	4DBS	2DBS	JBD	JAS	Means
Control	76.87 c	76.87 c	76.87 c	76.87 c	76.87 a	9.283 d	9.283 d	9.283 d	9.283 d	9.283 b
Atrazine	36.23 e	17.97 g	0.00 h	0.00 h	76.87 a	4.733 f	2.387 h	0.00 i	0.00 i	1.780 d
Pendimethalin	108.6 a	105.9 a	90.67 b	0.00 h	76.32 a	14.72 a	14.21 b	12.11 c	0.00 i	10.26 a
Dual gold	39.12 e	35.80 e	30.84 f	0.00 h	26.44 c	5.06 f	4.74 f	3.95 g	0.00 i	3.438 c
Primextra	47.18 d	37.60 e	28.20 f	0.00 h	13.55 d	5.820 e	4.933 f	3.825 g	0.00 i	3.644 c
Means	61.60 a	54.84 b	45.33 c	15.37 d		7.923 a	7.109 b	5.833 c	1.856 d	
LSD for time & herbicides	2.083				1.58	0.3215				0.2235
LSD interactive effect	1.5715					0.5123				

Crude protein yield (t ha^{-1})

The results revealed that interactive effect of treatments indicated significant differences on production of crude protein (Table 6). Highest crude protein yield (2.913 t ha^{-1}) was observed when Pendimethalin was applied 4 DBS, followed by application of Pendimethalin 2 DBS (2.813 t ha^{-1}), which was statistically higher than weedy check (1.683 t ha^{-1}). All other weedicides gave lower crude protein yield because of reduction in total dry matter yield that may be due to phytotoxicity effect. Thus, it was observed that crude protein production was inversely related to production of dry matter.

Table 6. Effect of weedicides on weeds dry weight (g m^{-2}) and crude protein (t ha^{-1}) (values are means of two years data)

Weedicides	**Weeds dry weight (g m^{-2})**					**Crude protein yield (t ha^{-1})**				
	Time of application									
	4DBS	2DBS	JBS	JAS	Means	4DBS	2DBS	JBD	JAS	Means
Control	31.37 a	31.37 a	31.37 a	31.37 a	31.37 a	1.683 d	1.683 d	1.68 3 d	1.68 3 d	1.683 b
Atrazine	1.26 h	1.12 h	1.33 h	0.98 h	1.17 d	0.92 5 f	0.467 5 h	0.00 0 i	0.00 0 i	0.3481 d
Pendimethalin	0.82 h	0.63 h	0.53 h	0. 27 h	0.56 d	2.91 3 a	2.813 b	2.40 3 c	0.00 0 i	2.032 a
Dual gold	12.76 c	16.46 b	11.88 cd	5.23 g	11.58 b	0.94 0 f	0.883 f	0.72 5 g	0.00 0 i	0.6369 c
Primextra	9.80 e	10.26 de	7.63 f	3.85 g	7.88 c	1.05 8 e	0.905 f	0.71 3 g	0.00 0 i	0.6687 c
Means	11.20 b	11.96 a	10.55 c	8.34 d						
LSD for time & weedicides	0.5577				1.0725	0.056				0.0444
LSD for interactive effect	1.9971					0.0970				

Economic analysis

The pooled data regarding total costs, gross & net income and benefit cost ratio (BCR) of different treatments was analyzed and estimated the economic viability of all agronomic practices as presented in Table 7. The data revealed that significantly highest gross income (Rs. 407362 ha^{-1}), net income (Rs. 192196 ha^{-1}) and BCR (1.89) were recorded from the treatment of Pendimethalin 4 DBS, which was statistically at par with Pendimethalin 2 DBS, followed by weedy check with gross income (Rs. 288262 ha^{-1}), net income (Rs. 85094 ha^{-1}) and BCR (1.42).

Table 7. Economic comparison of different weedicides and their applications time

Weedicides	Total Cost (000 Rs ha^{-1})				Grass income (000 Rs ha^{-1})				Net return (000 Rs ha^{-1})				Benefit cast ratio			
	4DBS	2DBS	JBS	JAS	4DBS	2DBS	JBS	JAS	4DBS	2DBS	JBS	JAS	4DBS	2DBS	JBS	JAS
Control	203	203	2003	203	288	288	2888	288	78	78	78	78	1.42	1.42	1.42	1.42
Atrazine	194	188	1000	100	136	67	0	0	-58	-121	-1000	-100	0.70	0.36	0	0
Pendimethalin	215	214	2100	100	407	397	3400	0	192	183	1300	-100	1.89	1.85	1.62	0
Dual gold	196	195	1933	101	147	134	1161	0	-49	-60	-77	-101	0.75	0.69	0.60	0
Primextra	198	195	1992	101	177	141	1006	0	-21	-54	-87	-101	0.90	0.72	0.55	0

Discussion

From the current investigation, it was observed that early sown berseem crop faced competition with infestation of several weeds of which major weeds were *Trianthema portulacastrum, Digera muricata* L., *Cichorium intybus and Cyprus rotundus.* Pathan and Kamble (2012) and Tyagi *et al*. (2018) reported the same weeds found in their investigation and they further reported reduction in berseem yield to the tune of 23-30 % due to weed infestation. Joshi and Bhilare (2006) and Alfred (2012), also reported these major weeds present in berseem field and found that these weeds compete with berseem for essential nutrients, light, space and moisture. Kewat *et al.* (2005); Vijay *et al*. (2017) and Tyagi *et al.* (2018) also reported that weeds infestation decreased forage and seed yield of Berseem upto 20-30% and 13-37 % respectively.

It was found that application of weedicides especially Pendimethalin showed positive effect in weed control and all crop growth characters were influenced significantly by the application of weedicides. Naik *et al.* (2018); Menon *et al.* (2016); Deivasigamani (2016) and Singh *et al*. (2012) reported in their studies that pre- and post- emergence application of herbicides help in eradication of most of the weeds, however, taking different time periods after sowing. They also observed that weeds died after 25 days of sowing and at harvest of crop for fodder. Priyanka *et al.* (2017) reported similar findings that Pendimethalin and Oxadiargyl showed 75% control over weeds in pre-

emergence application. Leroux *et al.* (2005) also reported mortality in fodder pearl millet with the pre-emergence application of S-metolachlor benoxacor at recommended dose. However, some other researchers reported differently.

In the treatment of Pendimethalin application, 4 DBS gave higher number of plant m^{-2} and lower number of weeds as compared to other herbicide treatments while most weed infestation was recorded in weedy check. It was found that maximization of fodder yield was dependent of improvement in growth characters such as plant density, number of tillers, dry matter, crude protein (%) and fodder yield. This might be due to less number of weeds m^{-2} and phytotoxic effect as compared to weedy check and other herbicide treatments. Pathan and Kamble (2012) and Pathan *et al*. (2013) that dry weight of weeds (g m^{-2}) was statistically higher in weedy check than all other treatments and lowest dry weight of weeds (g m^{-2}) was noted in Pendimethalin treatment reported similar findings. The phytotoxicity of weedicides influenced berseem plant density up to 100% when applied as Post emergence, JAS (Priyanka *et al.,* 2017).

Results revealed that pre plant incorporation of Pendimethalin 4 DBS statistically was at par with 2 DBS and showed statistically higher WCE with higher fodder yield as compared to other treatments. The maximum WCE in the treatment of Pendimethalin might be due to complete mortality of weeds and consequently decrease in weeds dry weight as compared to the weedy check. These research findings were similar to the findings of Tiwana *et al*. (2002); Pathan and Kamble (2012); Pathan *et al.* (2013). Kumar *et al.* (2018) who observed that more than 80 percent weeds can be managed in berseem by the application of Pendimethalin at rate of 0.3 kg ai ha^{-1}. Prajapati *et al*. (2015) also observed that weed dry weight significantly decreased with application of Pendimethalin and Imazethapyr resulting in high WCE.

The results of the study also revealed that weedicides have significant influence on the number of tillers m^{-2} after 55 days of sowing at harvest of crop. The means of treatment revealed that highest number of tillers were achieved by the application of Pendimethalin (PPI) 4 DBS, which was followed by Pendimethalin (PPI) 2 DBS and weedy check. Application of Pendimethalin 4 DBS produced maximum yield, that might be due to efficient control on weed density. In absence of weeds, berseem crop used maximum resources and established well due to which produced higher number of tillers m^{-2}. These research findings were in line with Malik *et al*. (2009) who stated that by controlling broad leave weeds, number of tillers significantly increased. Kantwa *et al.* (2019) also reported that the competition between crop and weeds in berseem at establishment stage resulted in lower plants density and substantial reduction in fodder tonnage. The two years pooled data depicted that

weedicides treatments significantly influenced all cuttings of forage yield. The treatment, which suppressed more weeds produced significantly higher fodder and dry matter production over the weedy check and the treatments where plant density decreased might be due to phytotoxicity of weedicides. Maximum crude protein yield were noted from the plot where Pendimethalin @ 2.5 L ha^{-1} PPI 4DBS was applied. These findings are in line with the findings of Tiwana *et al.* (2002) who stated that Butachlor @ 1-2 kg ai ha^{-1} significantly increased the fresh fodder and dry matter production of berseem while crude protein productivity exhibited superiority with Pendimethalin treatments over the weedy check. Kantwa *et al.* (2019) reported that green fodder and seed yield of Berseem increased 81 and 119 % respectively with the application of herbicide over weedy check. The increase in this parameter might be due to reduction in weed density and competition due to which crop uptakes more nutrients. Dhar *et al.* (2006) and Rao *et al*. (2007) reported similar findings. The maximum fodder yield was recorded under treatment where Pendimethalin PPI 4 DBS, which resulted in maximum gross income and highest net income followed by weedy check. All other weedicides treatments showed lower gross income and B.C.R. This may be due to phytotoxic effect of weedicides as well as higher competitive influence on growth and production resulted in less return. These research findings are similar to the findings of Kumar *et al*. (2012), Mishra *et al*. (2012) and Thakur *et al*. (2016).

Berseem is fodder is heavily infested with weeds especially, *Trianthema partulacastrum* L. and *Digera muricata* L. These weeds caused substantial yield and quality losses in berseem and grew vigorously on the expense of berseem growth. Reduction in yield and quality of barseem increased when suitable doses of weedicides were applied at appropriate time. Therefore, it is concluded that Pendimethalin @ 2.5 L ha^{-1} should be applied at 4 days before sowing for better chemical control of *T. partulacastrum*, *D. muricata* and other weeds in berseem efficiently and to avoid quality and yield losses of berseem.

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