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Economic evaluation of weed control and nitrogen levels in barley (*Hordeum vulgare* L.)

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Abstract
Results of field experiment carried out during *rabi* 2017-18 and 2018-19 at Instructional Farm, Rajasthan College of Agriculture, Udaipur, indicated that various weed-control treatments significantly influenced weed control efficiency, yield and yield attributes of barley (*Hordeum vulgare* L.) and thereby significantly enhanced economic returns. Maximum weed control efficiency of total weeds at harvest was recorded with tank mixture of pinoxaden 40.0 g ha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS(W_5) (88.65%)after weed free treatment. This treatment gave 25.65% and 26.16% more grain and straw yield, respectively on pooled basis compared to weedy check. Maximum yeild attributing characters *viz.* effective tillers per meter row length(80.69), grains per ear (47.23), ear length (6.19 cm), grain weight (1.97 g ear^{-1}) and 1000 grain weight (41.59 g) were observed under tank mixture of pinoxaden 40.0 g ha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS(W_5) after weed free treatment. Maximum net returns (71863 Rs/ha) and BC ratio (2.38) were also observed under this treatment. The net returns and yield as well as yeild attributing characters of the crop were maximum under90 kg N ha^{-1}, however these were found at par with 75 kg N ha^{-1}.Maximum B C ratio (2.23) was recorded under 90 kg N ha^{-1}which was statistically at par with 75 kg N ha^{-1} (2.19).

Keywords: Metsulfuron methyl, Carfentrazone ethyl, Pinoxaden, barley, weeds

Introduction
Barley is an important cereal crop of Rajasthan during *rabi* season. Competition from weeds throughout the crop season reduces barley crop yield by 53.9% depending upon time and intensity of weed infestation (Ram and Singh, 2009) [8]. Hand-weeding was formerly the most widely used and effective method of weed control, but this practice has been abandoned because it is no longer economical (Pandey *et al*., 2007) [7]. Phenoxy herbicides, such as 2, 4-D had been widely used herbicide for control of broad-leaf weeds in barley. However, 2, 4-D use is stage specific and has use restrictions, especially if broad-leaf crop is planted in nearby fields (Swan, 1975). On the other hand resistance of *Phalaris minor* to isoproturon is the most serious case of herbicide resistance (Malik and Singh, 1995) [5]. Therefore, herbicides with alternate mode of action are required to control weeds in barley. Since, no single herbicide controls either all broad-leaf weeds or grassy weeds, hence efforts should be made to use a suitable combination of more than one herbicide to combat noxious weeds and to prevent weed shift. Moreover, herbicide rotation and use of herbicide mixtures are two important strategies to prevent the development of resistant biotypes and problems of weed shift. Another limiting factor in low production of barley is suboptimal application of nitrogenous fertilizer. As factor productivity of cereal crops is declining therefore more inputs are needed to obtain the same yield. Along with it a sizable quantity of nitrogen is taken away by weeds thus it is imperative to use higher doses of nitrogen. In view of these facts present investigation was there foreunder taken to study the impact of weed control and nitrogen levelson economics of barley in terms of net returns and BC ratio.

Materials and Methods
The experiment was conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur during *rabi* season of 2017-18 and 2018-19. The experimental soil was clay loam, slightly alkaline, medium in available nitrogen and phosphorus and high in potassium. The experiment consisted of 8 weed-control treatments, *viz.* metsulfuron-methyl 4.0 gha^{-1} (W_1), carfentrazone-ethyl 20.0 g ha^{-1} (W_2), pinoxaden 40.0 g ha^{-1} (W_3), tank mixture of pinoxaden 40.0 g ha^{-1} + metsulfuron-methyl 4.0 g ha^{-1}(W_4), tank mixture of pinoxaden 40.0 g ha^{-1} + carfentrazone-ethyl 20.0 g ha^{-1} (W_5), tank mixture of metsulfuron-methyl 4.0 g ha^{-1}+

carfentrazone-ethyl 20.0 g ha^{-1} (W_6) all applied at 35 DAS, weed free (W_7) and weedy check (W_8) in main plots and 3 nitrogen levels *viz.* 60 kg N ha^{-1} (N_1), 75 kg N ha^{-1} (N_2) and 90 kg N ha^{-1} (N_3) in sub plots. The experiment was laid out in split plot design with 3 replications. Barley variety "RD 2035" was sown at 22.5 cm row spacing using 100 kg ha^{-1} seed on 15th and 19th November and harvested on 12 and 23 march in respective seasons. Application of 60 kg N and 20 kg P_2O_5 ha^{-1}was done through Urea and DAP, respectively, as recommended dose of fertilizer. As per treatment, full dose of phosphorus and 1/2 dose of nitrogen was applied through DAP and urea, respectively (after adjusting the amount of N available through DAP) at the time of sowing by drilling in furrows 5 cm below the seeding depth. The remaining ½ dose of nitrogen was applied through urea as topdressing in two equal splits *i.e.* at first and second irrigation. The size of the gross and net plots were 5.0 m x 3.15 m and 4 m x2.7mrespectively. As per treatment, herbicides (metsulfuron-methyl, carfentrazone-ethyl and pinoxaden) were sprayed 35 DAS, when there was sufficient moisture in the soil. Yield data on crops and dry weight of weeds were recorded at harvest. Observations on various parameters were taken following standard procedures.

Result and Discussion

In two years field study, barley was mainly infested with mixed flora of narrow and broad-leaved weeds *viz. Phalaris minor* Retz, *Avena fatua* (L.), *Cynodon dactylon* (L.) Pers., *Cyperusrotundus* (L.) among narrow-leaved weeds & *Chenopodium album*, *Chenopodium murale*, *Convolvulus arvensis* (L.), *Fumaria parviflora* Lam., *Melilotus indica* (L.) and *Anagalis arvensis* (L.) among broad-leaved weeds.

Weed control efficiency

Weed control efficiency fluctuated to a great extent under the influence of various weed control treatments. Weed control efficiency was highest under the tank mixture of pinoxaden 40.0 g ha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS(W_5) (88.65%) after weed free treatment (89.91%). The respective weed control efficiency observed under tank mixture of pinoxaden 40.0 g ha^{-1} + metsulfuron-methyl 4.0 g ha^{-1}(W_4) and tank mixture of metsulfuron-methyl 4.0 g ha^{-1}+ carfentrazone ethyl 20.0 g ha^{-1} 35 DAS (W_6) treatment were 87.63 and 62.98% respectively on pooled basis. It is manifested that amongst herbicides, tank mixture of pinoxaden 40.0 g ha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS(W_5) was superior to rest of treatments in respect of weed control efficiency. The higher weed control efficiency of tank mixture of pinoxaden 40.0 gha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS (W_5) over sole application of herbicides could be due to broad spectrum control of weeds (both narrow-leaved and broad-leaved weeds) by mixing two herbicides of different mode of action, so the efficacy of this herbicide in suppressing the weed growth is increased. This resulted in the efficient control of weeds and lower dry matter production of weeds. The results corroborate with the findings of, Shoeran *et al.* (2013) [11], Katara *et al.* (2012) [2], Khippal *et al.* (2016) [3] and Singh *et al*. (2017) [13].

Grain, Stover and biological yield

All the weed control treatments significantly increased grain, straw and biological yields compared to weedy check on pooled basis. The pronounced effect of increased yield was observed with tank mixture of pinoxaden 40.0 g ha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS(W_5). This resulted in increase in grain, straw and biological yield by 20.43%, 20.73% and 20.61% respectively compared to weedy check. However, this treatment was closely followed by tank mixture of pinoxaden 40.0 g ha^{-1} + metsulfuron-methyl 4.0 g ha^{-1}(W_4). The increase in yield under various weed control treatments may be due to the fact that economic yield is a function of dry matter production and efficiency to translocate photosynthates from assimilatory area to sink to accumulate in different plant parts and ultimately on yield attributing traits. The yield attributing characters namely effective tillers per meter row length, grains per ear, ear length, grain weight per ear and 1000-grain weight were significantly increased under weed control treatments as compared to weedy check which resulted into increased yield. During experimentation the grain, straw and biological yield of barley increased significantly with increasing level of nitrogen from 60 to 75 kg ha^{-1} resulted in significant increase in grain, straw and biological yields and further increase in the dose of nitrogen could not affect all these parameters at significant level. This treatment recorded grain, straw and biological yield as 4238, 6710 and 10948 kg ha^{-1}, respectively and the corresponding increase of all these parameters were 7.13, 7.11 and 7.12 per cent over 60 kg N ha^{-1}. Application of 75 kg N ha^{-1} significantly improved yield attributes (effective tillers per meter row length, grains ear^{-1}, ear length, grain weight per ear and 1000 grain weight) and grain, straw and biological yield. Increase in these parameters might be due to the fact that there was better availability of nutrients and metabolites due to increased photosynthetic efficiency, synchronized to meet demand for growth and development of each yield attribute. The observed results under present investigation are in close agreement with the findings of Singh *et al.* (2013) [12], Kumar *et al.* (2013) [5] and Jat *et al*., (2014) [1] and Puniya *et al.* (2015) [8].

Yield Attributes

Application of various weed control treatments tended to increase yield attributes like effective tillers per meter row length, grains ear^{-1}, ear length, grain weight per ear and 1000 grain weight significantly over weedy check. After weed free treatment maximum number of effective tillers per meter row length, grainsear^{-1}, ear length, grain weight per ear and 1000 grain weight were recorded under tank mixture of pinoxaden 40.0 g ha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS (W_5) on pooled basis, which was statistically at par with tank mixture of pinoxaden 40.0 g ha^{-1} + metsulfuron-methyl 4.0 g ha^{-1} (W_4). Compared to weedy check (61.63, 35.80, 4.71 cm, 1.15g ear^{-1} and 31.84 g) the respective per cent increase in these parameters owing to tank mixture of pinoxaden 40.0 gha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS was 23.62, 24.20, 23.91, 41.62 and 23.44 per cent, respectively on pooled basis. Different fertility levels significantly enhanced all the yield attributes on pooled basis. All the yield attributes (effective tillers per meter row length, grains ear^{-1}, ear length, grain weight per ear and 1000 grain weight) were significantly increased with nitrogen application from 60 to 75 kg ha^{-1} during both years as well as on pooled basis. Further increase in nitrogen level failed to affect the yield attributes significantly. The corresponding per cent increase of all these parameters owing to 75kg N ha^{-1} was 5.72, 5.74, 5.86, 13.81 and 7.00 compared to 60 kg N ha^{-1}. The better

expression of yield attributes in herbicide treated plots might be due to poor resurgence frequency and growth of weeds in these treatments. Hence, weeds were unable to compete with the crop plant for different growth factors. The observed results are in close conformity with findings of Khippal *et al.* (2016) [3], Sasode *et al.* (2017) [10] and Kaur *et al.* (2017) [3]. Improvement in yield attributes occurred when weeds were controlled during critical growth period, which bought down competition and created congenial micro-environment for better establishment and growth of the crop. The increased grain and straw yields and thereby biological yield were obviously the results of better weed control which rendered favourable condition like increased availability of nutrient, moisture, light and other factor to the crop plant, which resulted in better growth and higher dry matter production of plants. Enhanced values of yield attributing characters were the outcome of these effects.

Table 1: Effect of weed control and nitrogen levels on yield attributes at harvest (pooled data of 2 years)

	Yield attributes				
Treatment	**Effective tillers/mrl**	**Grains/ ear**	**Ear length (cm)**	**Grain weight (g/ear)**	**1000 grain weight (g)**
Weed management					
Metsulfuron methyl 4.0 g ha^{-1} (W_1)	73.74	42.99	5.53	1.58	36.60
Carfentrazone ethyl 20.0 g ha^{-1} (W_2)	74.67	43.61	5.73	1.68	38.41
Pinoxaden 40.0 g ha^{-1} (W_3)	73.27	41.41	5.42	1.47	35.33
Pinoxaden 40.0 g ha^{-1} + Metsulfuron methyl 4.0 g ha^{-1} (W_4)	79.57	46.53	6.10	1.89	40.07
Pinoxaden 40.0 g ha^{-1} + Carfentrazone ethyl 20.0 g ha^{-1} (W_5)	80.69	47.23	6.19	1.97	41.59
Metsulfuron methyl 4.0 g ha^{-1} + Carfentrazone ethyl 20.0 g ha^{-1} (W_6)	74.98	43.12	5.65	1.65	38.13
Weed free (W_7)	84.58	49.36	6.48	2.04	43.37
Weedy check (W_8)	61.63	35.80	4.71	1.15	31.84
SEm±	1.48	0.98	0.10	0.03	0.72
CD (P=0.05)	4.28	2.83	0.30	0.09	2.09
Nitrogen (kg ha^{-1})					
60 (N_1)	72.10	41.81	5.46	1.52	36.13
75(N_2)	76.23	44.21	5.78	1.73	38.66
90(N_3)	77.85	45.09	5.90	1.77	39.27
SEm±	0.57	0.32	0.04	0.01	0.24
CD (P=0.05)	1.62	0.91	0.13	0.04	0.68

Table 2: Effect of weed control and nitrogen levels on yield, economics and weed control efficiency of barley at harvest (pooled data of 2 years)

Treatment					
Weed control	**Grain yield**	**Straw yield**	**Net returns**	**BC ratio**	**Weed control efficiency (%)**
Metsulfuron methyl 4.0 g ha^{-1} (W_1)	4068	6110	61969	2.17	59.40
Carfentrazone ethyl 20.0 g ha^{-1} (W_2)	4120	6342	62886	2.17	59.61
Pinoxaden 40.0 g ha^{-1} (W_3)	3868	6492	57553	1.95	23.46
Pinoxaden 40.0 g ha^{-1} + Metsulfuron methyl 4.0 g ha^{-1} (W_4)	4348	6767	67378	2.27	87.63
Pinoxaden 40.0 g ha^{-1} + Carfentrazone ethyl 20.0 g ha^{-1} (W_5)	4557	7296	71863	2.38	88.65
Metsulfuron methyl 4.0 g ha^{-1} + Carfentrazone ethyl 20.0 g ha^{-1} (W_6)	4181	6708	64446	2.20	62.98
Weed free (W_7)	4598	7340	69214	2.05	89.91
Weedy check (W_8)	3626	5783	53438	1.92	0.00
SEm±	97	158	1996	0.07	
CD (P=0.05)	280	456	5782	0.20	
Nitrogen (kg ha^{-1})					
60 (N_1)	3956	6264	58985	2.00	
75(N_2)	4238	6710	65102	2.19	
90(N_3)	4318	6841	66693	2.23	
SEm±	44	82	889	0.03	
CD (P=0.05)	125	231	2511	0.09	

Net returns and BC ratio

Maximum net returns and BC ratio were fetched undertank mixture of pinoxaden 40.0 g ha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS(W_5)with corresponding values of `71863 $ha^{-1}$ and 2.38 and thus, compared to weedy check the net return in this treatment was increased by `18425 ha^{-1} on mean basis. The lowest investment under application of tank mixture of pinoxaden 40.0 g ha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS with good economic (grain) yield might be the reason for higher net monetary returns and BC ratio.Net return under nitrogen levels was increased with increase in its dose from 60 to 75 kg $ha^{-1}$and further increase in its level could not significantly enhance the net returns. Application of 75 kg N ha^{-1} enhanced net return by `6117 ha^{-1} over 60 kg N ha^{-1}. BC ratio of 2.19 was reported with this treatment. The higher net returns and BC ratio obtained under this treatment was as a result of higher grain yield and comparatively less cost of cultivation involved under this treatment.

On the basis of two years investigation on barley under the influence of weed control treatments and nitrogen levels, it can be concluded that tank mixture of pinoxaden 40.0 g ha^{-1} and carfentrazone ethyl 20.0 g ha^{-1} 35 DAS resulted in highest

yield and economic returns.

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