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STUDIES ON THE EFFICACY OF POST-EMERGENCE HERBICIDE FOR CONTROLLING WEED FLORA IN BARLEY (*HORDEUM VULGARE* L.)

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ABSTRACT

An experiment was conducted during Rabi 2022-23 and 2023-24 at Research Farm of Birsa Agricultural University, Kanke, Ranchi, Jharkhand to evaluate the "Studies on the efficacy of post-emergence herbicide for controlling weed flora in barley (*Hordeum vulgare* L.)". The treatments replicated thrice and comprised of weed management practices *viz.*, of (T_1)- Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC), (T_2)-Metsulfuron methyl (20% WG) + Surfactant (0.2%), (T_3)-Carfentrazone (40% DF), (T_4) -Metsulfuron methyl (20% WG) + Carfentrazone (40% DF)+Surfactant (0.2%), (T_5)-2, 4-D-Sodium Salt (80% WP), (T_6)- 2, 4-D-Sodium Salt (80% WP) + Carfentrazone (40% DF), (T_7)-2, 4-D-Ethyl Ester (38% EC), (T_8)-2, 4-D- Ethyl Ester (38% EC) + Carfentrazone (40% DF), (T_9)- Weedy check, (T_{10})-Weed free. At 60 DAS application of Halauxifen-methyl (1.21% EC) + Fluroxypyr (38.9% EC) resulted in minimum total weed density (6.92), total weed dry weight (4.08 g/m^2) and maximum weed control efficiency (88.97) followed by Metsulfuron methyl (20% WG) + Carfentrazone (40% DF) +Surfactant (0.2%). The highest grain yield (3361.90 kg/ha), straw yield (5036.74 kg/ha), biological yield (8398.62 kg/ha) and harvest index (40.03 %) were recorded with application of Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC).

Key words: Barley, Herbicide, weed density, weed dry weight, weed control efficiency, Weed index.

Introduction

Barley (*Hordeum vulgare* L.), a member of the Poaceae family, is one of the most important cereal grains globally, following maize, wheat, and rice. It is used in various industries, primarily for animal feed, malt production (beer, whiskey, and other beverages), and in food products like baby foods, medicinal syrupand coco-malt drinks. Barley is also valued for its nutritional content, offering a rich source of fiber, vitamins and minerals.

Globally, barley is cultivated on approximately 70 million hectares, with a total production of 149.53 million metric tonnes in 2022-2023. In India, barley is grown on around 0.68 million hectares, yielding approximately 1.77 million tonnes of grain with a productivity of 3046kg/ha (Anonymous 2023). India contributes about 1.3% of the world's barley production with key producing states including Uttar Pradesh, Rajasthan, Bihar, Madhya Pradesh, Haryana, Punjab, West Bengal, Himachal Pradesh and Jammu and Kashmir.

Agricultural production results from the interplay of soil, water, fertilizer, climate, and scientific management. A significant challenge in modern agriculture involves balancing diminishing land resources with a growing global population. The sustainable utilization of available land resources without compromising natural ecosystems represents a primary objective. Various factors, such as climatic variations, diseases, pests and weeds significantly impact agricultural production. Barley with its robust growth can face challenges from weeds even under irrigated conditions. Weeds play a critical role in constraining crop productivity by competing with crops for essential resources such as nutrients, soil moisture, solar radiation, and space, ultimately leading to reduced yield and inferior produce quality. Additionally, weeds serve as alternate hosts for insects and pests within the field. The prevalence of weeds fluctuates depending on the crop type, seasonal variations and agricultural management techniques. These factors collectively determine the intensity of competition between crops and weeds (Mishra *et al*., 2016). Barley crops commonly contend with narrow leaves (grasses and sedges) and broad-leaved weeds. Effective weed management practices, essential for maximizing barley yield with minimal input costs have been hindered by a lack of basic knowledge. Chemical weed control methods have become prevalent due to their efficiency though herbicide resistance and shifts in weed flora present ongoing challenges.

The prevalence of weeds in barley fields is influenced by several factors, including crop type, climate, seasonal variations and agricultural practices. In India, weed-induced losses in agriculture are estimated at 33%, which is higher than the losses caused by insects (26%), diseases (20%) and other biotic factors (21%) (Barla *et al.,* 2017). Traditional weed control methods such as hand-weeding were once effective but have become economically unfeasible due to labor shortages, high wages and unfavorable climatic conditions (Pandey *et al.,* 2007). Consequently, farmers have increasingly turned to chemical herbicides to manage weeds which although effective come with their own set of challenges.

The development of herbicide resistant weeds poses a significant challenge to barley cultivation. To combat this issue, farmers are increasingly using herbicide combinations and rotations. By combining herbicides with different modes of action, they can achieve broader and more effective weed control while reducing the risk of resistance development. Rotating herbicides and using mixtures with varying mechanisms of action are key strategies to mitigate shifting weed dynamics and ensure long-term crop productivity. Integrated weed management strategies such as the use of herbicide combinations, rotations and better knowledge of weed dynamics are crucial to maintaining effective weed control and ensuring sustainable barley production. By adopting these approaches, farmers can protect barley yields, reduce costs and help mitigate the impact of weeds on crop productivity. Keeping these facts in view, an experiment was planned to study the efficacy of alternative post emergence herbicide combinations for weed control in barley.

Materials and Methods

A field experiment was conducted in western section of Research Farm of the Birsa Agricultural University, Kanke, Ranchi (23^{o}17' N latitude, 85^{o}10' E longitude and 625 m above mean sea level), India, during the Rabi seasons of 2022-23 and 2023-24 respectively to evaluate the "Effect of weed management practices on weed density, weed dry weight and weed control efficiency in barley". The barley variety taken for experimentation was "DWRB 137". The experiment was laid out in Randomized Block Design with ten treatments comprising of weed management practices *viz.,* (T_1)- Halauxifen-methyl (1.21% EC) + Fluroxypyr (38.9% EC), (T_2)-Metsulfuron methyl (20% WG) + Surfactant (0.2%), (T_3)-Carfentrazone (40% DF), (T_4) -Metsulfuron methyl (20% WG) + Carfentrazone (40% DF)+Surfactant (0.2%), (T_5)-2, 4-D-Sodium Salt (80% WP), (T_6)- 2, 4-D- Sodium Salt (80% WP) + Carfentrazone (40% DF), (T_7)-2, 4-D-Ethyl Ester (38% EC), (T_8)-2, 4-D- Ethyl Ester (38% EC) + Carfentrazone (40% DF), (T_9)- Weedy check, (T_{10})-Weed free and were replicated thrice. As per treatment, herbicides were applied 35 DAS with the help of knapsack sprayer fitted with a flat-fan nozzle with a spray volume of 500 liters/ha. The Soil of experimental plot was clay loam in texture having organic carbon (4.5g/kg) and nitrogen (216.2 Kg/ha), phosphorous (32.2 Kg/ha), potassium (158.1 Kg/ha) and slightly acidic in nature (pH 5.9). The mean minimum and maximum temperature throughout the cropping season ranged from 3.6^{o}C to 36.1^{o}C respectively during 2022-23, while during 2023-24 the mean minimum and maximum temperature ranged from 3.9ºC to 31.0ºC respectively. Total rainfall recorded during the crop period was 124.4 mm in the first year and 210.4 mm in second year of experimentation. The recommended fertilizer dose applied was 60 kg N: 30 kg P_2O_5: 20 kg K_2O /ha supplied through Urea, Di-ammonium Phosphate and Muriate of potash. Barley was sown manually by using 100 kg/ha seed rate with 20 cm row spacing. The recommended package of practices was applied to all the treatments. All observations on weed density, weed dry weight and weed control efficiency were recorded from the marked area of the net plot. The data obtained from the experiment were put to statistical analysis by adopting an appropriate method of "Analysis of Variance" as suggested by Gomez and Gomez (1976). Critical difference (CD) at 5% level of significance was worked out to determine the difference between the treatments. The weed density, weed dry weight and weed control efficiency were recorded at 30 DAS and 60 DAS. A rectangular iron frame, the quadrate, measuring 25 × 25 cm was placed randomly at two spots in border rows on either side of each plot. Weeds within the quadrate were counted. Thereafter, they were classified into three categories *viz*: grasses, sedges and broad leaves weeds. Weed dry weight was calculated after the weed samples taken for

Table 1: Effect of different herbicide treatments on total weed density (No./m^2) at 30 and 60 DAS in barley (2022-23, 2023-24 and pooled).

Treatments	Total weed density (No./m^2)					
	30 DAS			60 DAS		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1- Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC)	10.92 (125.25)	11.12 (130.1)	11.32 (127.69)	6.62 (45.77)	6.87 (49.06)	6.92 (47.42)
T_2-Metsulfuronmethyl (20% WG) + Surfactant (0.2%)	11.28 (126.78)	11.38 (129.0)	11.33 (127.93)	8.49 (71.6)	9.00 (80.47)	8.75 (76.04)
T_3- Carfentrazone(40% DF)	11.10 (122.74)	10.88 (117.9)	10.99 (120.34)	8.89 (78.46)	9.43 (88.37)	9.16 (83.42)
T_4-Metsulfuronmethyl (20% WG) + Carfentrazone (40% DF)+Surfactant (0.2%)	11.26 (126.32)	11.60 (134.0)	11.43 (130.20)	7.28 (52.53)	7.11 (50.05)	7.20 (51.29)
T_5- 2, 4-D-Sodium Salt(80% WP)	10.68 (113.56)	10.80 (116.0)	10.74 (114.81)	8.76 (76.27)	8.78 (76.66)	8.77 (76.47)
T_6- 2, 4-D- Sodium Salt (80% WP) + Carfentrazone (40% DF)	11.54 (134.45)	11.31 (129.2)	11.50 (131.83)	7.87 (62.23)	8.21 (67.87)	8.10 (65.05)
T_7- 2, 4-D-Ethyl Ester (38% EC)	11.40 (129.51)	11.45 (130.6)	11.43 (130.06)	8.83 (77.43)	8.95 (79.60)	8.89 (78.52)
T_8- 2, 4-D- Ethyl Ester (38% EC) + Carfentrazone (40% DF)	11.91 (141.28)	11.87 (140.4)	11.89 (140.86)	7.71 (58.9)	7.89 (61.72)	7.80 (60.31)
T_9- Weedy check	12.14 (146.79)	12.23 (149.1)	12.18 (147.97)	13.97 (194.73)	14.62 (213.3)	14.30 (204.05)
T_{10}- Weed free	11.33 (127.85)	11.52 (132.1)	11.42 (130.02)	1.53 (1.85)	1.30 (1.19)	1.42 (1.52)
SEm±	0.48	0.46	0.42	0.37	0.42	0.38
CD (p=0.05)	NS	NS	NS	1.12	1.26	1.14
CV%	7.35	7.10	6.45	8.20	8.94	8.25

*Data outside Paranthesis were transformed to √(X+0.5) before analysis.

recording observation on weed density were sun dried to remove any excess moisture present on the surface of weeds and then oven dried at 60°C ± 5°C for 48 hours. The data were subjected to square root transformation $\sqrt{x+0.5}$ to normalize their distribution. The weed control efficiency was calculated on the basis of reduction in dry matter production in treated plot in comparison with the control plot and expressed in percentage.

Weed control efficiency

$$WCE = \frac{DMC\text{-}DMT}{DMC} \times 100$$

Where,

DMC= dry matter production of weeds per unit area in control plots,

DMT = dry matter production of weeds per unit area in the treated plots,

WCE = expressed in percentage.

Weed Index

Weed index is defined as the magnitude of yield reduction due to the presence of weeds in comparison to weed free plot. Weed index was calculated by using the following formula:

$$WI = \frac{X\text{-}Y}{X} \times 100$$

Where,

X= yield from weed free plot,

Y= yield from treated plot for which WI is calculated,

WI= Weed Index.

Results and Discussion

Weed flora

The experimental field was infested with a diversity of weed flora. Throughout the cropping period, broad-leaved weeds predominated in the experimental area, followed by grasses and sedges were recognized as *Trifolium repens*, *Coronopus didymus* L., *Anagallis arvensis* L., *Chenopodium album* L. and *Rumex obtusifolius*. Under the grasses *Cynodon dactylon* L., *Avena fatua* and *Digitaria sanguinalis* were found most dominant. These results are also in conformity with Singh

Table 2: Effect of different herbicide treatments on total weed dry weight (g/m²) at 30 and 60 DAS in barley (2022-23, 2023-24 and pooled).

Treatments	Total weed dry weight (g/m²)					
	30 DAS			60 DAS		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1- Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC)	5.98 (37.23)	6.17 (39.71)	6.24 (38.47)	3.95 (14.96)	4.10 (17.26)	4.08 (16.11)
T_2-Metsulfuronmethyl (20% WG) + Surfactant (0.2%)	6.27 (38.81)	6.41 (40.65)	6.34 (39.73)	5.48 (29.47)	5.65 (31.41)	5.56 (30.44)
T_3- Carfentrazone(40% DF)	6.08 (36.42)	6.26 (38.73)	6.17 (37.58)	5.50 (29.72)	5.68 (31.72)	5.59 (30.72)
T_4-Metsulfuronmethyl (20% WG) + Carfentrazone (40% DF)+Surfactant (0.2%)	5.98 (35.32)	6.30 (39.17)	6.14 (37.25)	4.28 (17.80)	4.49 (19.70)	4.39 (18.75)
T_5- 2, 4-D-Sodium Salt(80% WP)	6.06 (36.22)	6.41 (40.58)	6.24 (38.40)	5.24 (26.99)	5.63 (31.19)	5.44 (29.09)
T_6- 2, 4-D- Sodium Salt (80% WP) + Carfentrazone (40% DF)	5.95 (35.39)	6.34 (40.30)	6.19 (37.85)	5.26 (27.58)	5.55 (30.72)	5.45 (29.15)
T_7- 2, 4-D-Ethyl Ester (38% EC)	6.03 (35.91)	6.42 (40.69)	6.23 (38.30)	5.45 (29.23)	5.69 (31.83)	5.57 (30.53)
T_8- 2, 4-D- Ethyl Ester (38% EC) + Carfentrazone (40% DF)	5.96 (35.07)	6.31 (39.34)	6.14 (37.21)	4.72 (21.74)	4.98 (24.26)	4.85 (23.00)
T_9- Weedy check	6.40 (40.48)	6.59 (42.88)	6.49 (41.68)	12.00 (143.47)	12.20 (148.38)	12.10 (145.93)
T_{10}- Weed free	5.98 (35.27)	6.27 (38.80)	6.13 (37.04)	0.85 (0.22)	0.83 (0.19)	0.84 (0.21)
SEm±	0.27	0.29	0.29	0.26	0.29	0.30
CD (p=0.05)	NS	NS	NS	0.77	0.88	0.91
CV%	7.97	8.08	8.17	8.61	9.39	9.93
*Data outside Paranthesis were transformed to √(X+0.5) before analysis.						

et al., (2023) and Jaiswal *et al.*, (2020).

Effect of weed management practices on total weed density of barley

Pooled data showed that total weed density (Table 1) at 60 DAS was recorded significantly lowest in Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC) (6.92) followed by Metsulfuron methyl (20% WG) + Carfentrazone (40% DF) +Surfactant (0.2%) (7.20) and 2,4-D- Ethyl Ester (38% EC) + Carfentrazone (40% DF) (7.80)butsignificantly highest in weedy check (14.30). Better control of weeds in Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC) at 60 DAS was due to

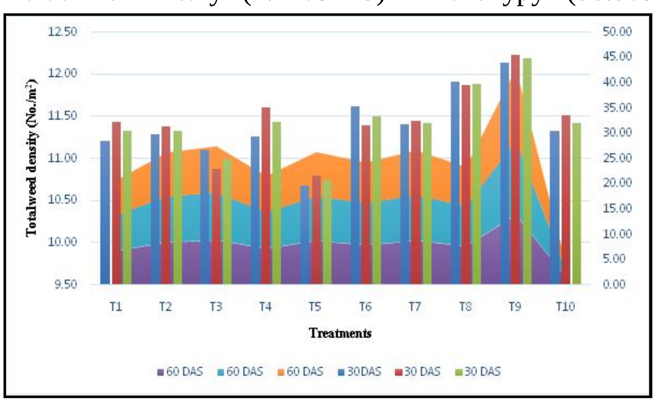

Fig. 1: Effect of weed management practices on total weed density (No./m²) of barley. (***This figure clearly shows that Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC) (T_1) recorded minimum weed density (No./m²) during 2022-23 and 2023-24 respectively.***)

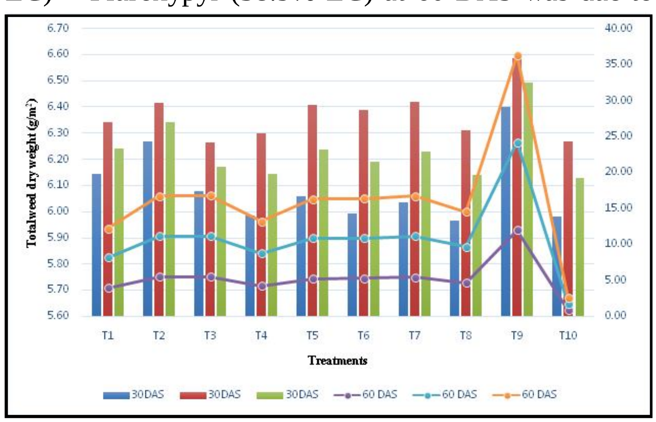

Fig. 2: Effect of weed management practices on total weed dry weight (g/m²) of barley. (***This figure clearly shows that Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC) (T_1) recorded minimum weed dry weight (g/m²) during 2022-23 and 2023-24 respectively.***)

Table 3: Effect of different herbicide treatments on weed control efficiency (%) and weed index in barley (2022-23, 2023-24 and pooled).

Treatments	Weed control efficiency (%) 60 DAS			Weed Index (%)
	2022-23	2023-24	Pooled	Pooled
T_1- Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC)	89.57	88.36	88.97	7.00
T_2-Metsulfuronmethyl (20% WG) + Surfactant (0.2%)	77.3	78.83	78.07	29.41
T_3- Carfentrazone(40% DF)	79.28	78.62	78.95	32.54
T_4-Metsulfuronmethyl (20% WG) + Carfentrazone (40% DF) +Surfactant (0.2%)	87.59	86.72	87.16	17.21
T_5- 2, 4-D-Sodium Salt (80% WP)	81.18	78.97	80.08	27.06
T_6- 2, 4-D- Sodium Salt (80% WP) + Carfentrazone (40% DF)	80.77	79.29	80.03	20.25
T_7- 2, 4-D-Ethyl Ester (38% EC)	79.62	78.54	79.08	23.12
T_8- 2, 4-D- Ethyl Ester (38% EC) + Carfentrazone (40% DF)	84.84	83.65	84.25	19.82
T_9- Weedy check	0.00	0.00	0.00	43.17
T_{10}- Weed free	99.84	99.87	99.86	0.00
SEm±	3.05	3.03	3.04	0.87
CD (p=0.05)	9.06	9.01	9.04	2.60

herbicide mixture provides a broader spectrum of weed control than a single herbicide. Probably this mixture of chemicals might have acted as a catalyst to enhance the weed control ability of the herbicides. These results are also consistent with the findings of Ram *et al.,* (2020) and Mukherjee D. (2020).

Effect of weed management practices on total weed dry weight of barley

Results of pooled analysis (two-year experimentation) revealed that total weed dry weight (Table 2) was significantly observed least in weed free (0.84). Among herbicide treatments Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC) at 60 DAS (4.08 g/m^2) was recorded minimum weed dry weight over all the treatments which was at par with Metsulfuron methyl (20% WG) + Carfentrazone (40% DF) +Surfactant (0.2%) (4.39 g/m^2) and 2,4-D- Ethyl Ester (38% EC) + Carfentrazone (40% DF) (4.85 g/m^2) however weedy check (12.10 g/m^2) at 60 DAS reported maximum total weed dry weight. The weed free treatment consistently showed the lowest weed dry weight throughout the growing period. This could be due to manual weed control at 35 and 60 DAS. Application of Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC) was effective in controlling weeds as compared to the rest of the treatments as the herbicides controlled broad leaved weed, narrow and sedges owing to synergetic enhancement. Herbicide combinations in general were better than the sole application of herbicides in efficiency reducing the

Table 4: Effect of different herbicide treatments on grain yield, straw yield, biological yield and harvest index of barley (pooled).

Treatments	Pooled Grain Yield (kg/ha)	Pooled Straw Yield (kg/ha)	Pooled Biological Yield (kg/ha)	Pooled Harvest Index (%)
T_1- Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC)	3361.9	5036.74	8398.62	40.03
T_2- Metsulfuron methyl (20% WG) + Surfactant (0.2%)	2537.6	4071.87	6609.44	38.39
T_3- Carfentrazone(40% DF)	2427.2	3912.51	6339.72	38.29
T_4- Metsulfuron methyl (20% WG) + Carfentrazone (40% DF) +Surfactant (0.2%)	2991.2	4702.46	7693.68	38.88
T_5- 2, 4-D-Sodium Salt (80% WP)	2621.8	4136.47	6758.29	38.79
T_6- 2, 4-D- Sodium Salt (80% WP) + Carfentrazone (40% DF)	2871.3	4582.54	7453.79	38.52
T_7- 2, 4-D-Ethyl Ester (38% EC)	2770.6	4419.08	7189.72	38.54
T_8- 2, 4-D- Ethyl Ester (38% EC) + Carfentrazone (40% DF)	2895.4	4526.47	7421.88	39.01
T_9- Weedy check	2042.7	3158.39	5201.12	39.27
T_{10}- Weed free	3605.9	5476.23	9082.14	39.70
SEm±	138.75	159.24	255.5	1.44
CD (p=0.05)	412.25	473.13	759.22	NS
CV%	8.57	6.28	6.15	6.44

total weed dry weight. These findings are consistent with Sivran *et al.,* (2020).

Effect of weed management practices on weed control efficiency

Reduction in dry weight of weed accumulation leads to maximization of weed control efficiency (pooled data in Table 3) with the application of Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC) at 60 DAS recorded the highest weed control efficiency (88.97 %) which was followed by treatment Metsulfuron methyl (20% WG) + Carfentrazone (40% DF) +Surfactant (0.2%) having weed control efficiency of (87.16 %). This was due to mixing two different types of herbicides created a broad spectrum of weed control, effectively targeting a wider range of weed species. Weed control efficiency may be improved as a result of decreasing weed counts and dry weight. These findings are in agreement with those of Tomar *et al.,* (2023), Negi and Chopra (2015) and Choudhary *et al.,* (2021).

Effect of weed management practices on weed Index

The results of the effects of treatments on weed index have been represented in (Table 3). The weed index helps us to describe the decreased yield due to the presence of weeds in comparison with weed free plots. The weed index ranges from 7.00 to 43.17 under different treatments. The treatment Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC) recorded the lowest weed index (7.00 %) followed by treatment Metsulfuron methyl (20% WG) + Carfentrazone (40% DF) +Surfactant (0.2%) (17.21%). Whereas, weedy check showed maximum weed index (43.17%) which experienced the most significant weed growth and loss of grain yield. These findings agreed with those of Kamboj *et al.,* (2017).

Effect of weed management practices on yield of barley

All the weed management treatments significantly increased grain, straw and biological yields compared to weedy check on pooled basis (Table 4) after weed free treatment the pronounced effect of increased yield was observed with Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC). The highest grain yield (3361.9 kg/ha), straw yield (5036.74 kg/ha) and biological yield (8398.62 kg/ha) was observed with Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC) which was at par with Metsulfuron methyl (20% WG) + Carfentrazone (40% DF) +Surfactant (0.2%). The better yield in the above treatments might be due to their higher weed control efficiency, higher crop biomass and poor growth of weed. Various weed control strategies significantly boosted seed yield as compared to the weedy control. This could be due to improved weed protection paired with reduced weed population and improved yield contributing features in these treatments. The cumulative effects of yield components contribute to the final yield buildup. The higher seed output in the mentioned treatments is due to the barley crop's effective utilization of moisture, nutrients, light, and space in the absence of weed competition. These findings are in confirmation with Singh *et al.*, (2017) and Meena *et al.*, (2021). The significant increase in straw yield due to nitrogen fertilization may be ascribed to its direct influence on dry matter accumulation per meter row length at various stages of crop growth and indirectly increased vegetative and reproductive parameters. Biological yield is a function of grain and straw yield. Thus, significant increase in biological yield could be ascribed to significant increase in grain and straw yield. These results are in support with the findings of Verma *et al.,* (2018) and Ram *et al.,* (2023).

Conclusion

On the basis of two years of experimentation, it can be concluded that Halauxifen- methyl (1.21% EC) + Fluroxypyr (38.9% EC) recorded the minimum number of total weed density, total weed dry weight and maximum weed control efficiency followed by the post application of Metsulfuron methyl (20% WG) + Carfentrazone (40% DF) + Surfactant (0.2%).

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