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INFLUENCE OF PRE AND POST EMERGENCE HERBICIDE APPLICATION ON WHEAT (*TRITICUM AESTIVUM L.)*

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ABSTRACT:

Objective: The study aimed to evaluate the impact of different herbicide concentrations, applied before and after wheat emergence, on its growth and production.
Methods: The field experiment conducted during the Rabi season of 2024 at Dev Bhoomi Uttarakhand University Crop Research Farm, the experiment used a randomized block design replicated three times. It compared herbicide treatments: T7 (Imazapyr at 25g a.i. ha^{-1} pre-emergence), T4 (Metsulfuron at 4g a.i. ha^{-1} pre-emergence), and T6 (Bispyribac sodium at 18g a.i. ha^{-1} 18 days post-emergence) with manual weeding to assess their effectiveness in weed control and their impact on wheat growth and production.
Results: Treatments T7, T4, and T6 were found to be equally effective as manual weeding and significantly superior to other weed management strategies. Additionally, these herbicide treatments improved weed control measures, thereby enhancing wheat growth and production. **Conclusion:** The study highlighted the importance of herbicide application timing in influencing weed control efficacy, wheat growth, and yield outcomes. Herbicides were identified as essential tools in modern agriculture, crucial for effective weed management and achieving optimal crop yields. The research provided insights into maximizing wheat yield and quality through strategic herbicide use.

Keywords: *Triticum aestivum* L., Herbicide, Yield, Growth, Harvest index

1. Introduction

Wheat (*Triticum aestivum* L.) is a vital global cereal crop, crucial for food security and economic stability. Weed infestation poses significant challenges in wheat cultivation, competing for essential resources such as light, nutrients, and water, which reduces yields and quality[1]. Effective weed management is essential, with herbicides playing a key role. Herbicides are categorized into pre-emergence and post-emergence types. Pre-emergence herbicides like pendimethalin, flufenacet, and metribuzin create a soil barrier to prevent weed germination, while post-emergence herbicides such as Mesosulfuron-methyl, Iodosulfuron, and 2,4-D target actively growing weeds[1,2]. Combining both types offers optimal weed control, addressing both early and late-emerging weeds.

In India, wheat production for 2023-24 is projected at 112 million tonnes, an increase from 104 million tonnes in the previous year. Productivity stands at approximately 37.8 qha^{-1}, despite challenges like excess rainfall (https://www.fitchsolutions.com/bmi/agribusiness/india-wheat-production-forecast-2023/24-held-unchanged-despite-recent-excess-rainfall-risks-tilted-toward-downside-18-03-2024). Uttarakhand, contributing 1.51% of the national production, faces lower productivity (1.9 tha^{-1}) due to rainfed conditions in its mountainous regions. The state 0.4 million hectares yield 0.8 million tonnes over the past five years.

Physical weed control methods are laborious and costly due to the high cost of labor, draft animals, and equipment. Additionally, these methods cannot efficiently manage weeds purely due to crop mimicry[3]. Chemical weed management methods are the most effective, useful, and time-saving means of reducing early weed competition and crop production injuries[4]. However, reliance on herbicides is limited due to certain weed species becoming resistant and the development of inter- and intra-specific variations. Not all types of weeds are controlled by a single herbicide, and repeated use of a single herbicide can lead to weed shifts and herbicide resistance. The presence of diverse weed flora necessitates the combined use of chemical control measures, showing the need for the rotation or sequential application of herbicides with diverse modes of action to control complex weed flora in wheat. Tank-mix or pre-mix use of different herbicide chemistries or successive application of pre- and post-emergence herbicides has shown effective weed control. In addition to managing mixed weed flora, the combined use of herbicides may help manage herbicide resistance problems. Consequently, the current study was undertaken to investigate optimizing weed management strategies.

2. Materials and Methods

2.1. Experimental Site

The trial was conducted at the Crop Research Farm of Dev Bhoomi Uttarakhand University in Dehradun, Uttarakhand, during the Rabi season of 2023–2024. During this period, summer temperatures ranged from 35 to 39 ^{o}C, while winter temperatures dropped to 0.5 ^{o}C. The area received an annual average rainfall of 1040.4 mm, with most precipitation occurring between November and April.

2.2. Soil

The soil in the experimental field originated from alluvial deposits, had a sandy loam texture, and was slightly alkaline with a pH of 7.6 (measured using the 1:2.5 soil suspension method by Jackson, 1973) [5]. It was well-drained with uniform topography. The electrical conductivity was 0.45 dSm-1 (measured using the same method). The soil contained 0.24% organic carbon (determined by Walkley and Black rapid titration method, 1934)[6]. Available nitrogen was present at 237 kg/ha (measured using the alkaline permanganate method by Subbiah and Asija, 1956)[7], and available phosphorus as sodium bicarbonate-extractable P was 19.60 kg/ha (measured by Olsen's calorimetric method[8].

2.3. Experimental Design

The research employed a randomized block design with 12 treatment combinations, each replicated three times. Within each replication, treatments were randomly assigned to 36 plots, specifying various layout specifications and other factors.

2.4. Details of Treatments:

Treatments	
T1	Control
T2	Two hand weeding
T3	Sulfosulfuron@ 25g a.i. ha^{-1}
T4	Metsulfuron@ 4g a.i. ha^{-1}
T5	Salfomet sulfuron at 16 g a.i. ha^{-1}
T6	Bispyribac sodium at 18 g a.i. ha^{-1}
T7	Imazapyrat 25ga.i. ha^{-1}

2.4. Sowing

Clean seeds of wheat variety PBW-154 were sown at a row distance of 20 cm, with a seeding rate of 100 kg/ha using a seed drill. The crop was sown on November 28, 2023.

2.5. Hand weeding

Hand weeding was conducted twice, at 20 and 40 days after sowing, according to the treatment specifications, to remove weeds manually.

2.6. Herbicides application

The herbicides Sulfosulfuron at 25 gha^{-1} and Metsulfuron at 4 g/ha were applied post-emergence at 30 days after sowing (DAS) of wheat, according to the treatments. Application was carried out using a knapsack sprayer equipped with a flat-fan nozzle, delivering a spray volume of 250 Lha^{-1} of water.

2.7. Data Collection

2.7.1. Harvest index (%)

The recovery of grains in total dry matter was considered as harvest index, expressed in percentage. It has been calculated by following formula:

$$\text{Harvest Index (\%)} = [\text{Seed Yield (q ha}^{-1}) / \text{Biological Yield (q ha}^{-1})] \times 100$$

2.8. Statistical analysis

The data collected for various characteristics underwent statistical analysis using Fisher's method of analysis of variance (ANOVA). Critical difference (CD) values were calculated when the 'F' test was found significant at the 5% level. Correlation matrices using SRPLOT (http://www.bioinformatics.com.cn/en?keywords=heatmap) was employed to visually summarize the data, highlighting key features and their interrelationships.

3. Results and Discussion

3.1. Growth attributes

The study analyzed variations in plant population, plant height, root length, dry weight, and number of tillers per plant among different weed management treatments at 60 and 90 days after sowing (DAS). Significant differences were observed in these parameters across different intervals. Two hand weeding at 25 and 45 DAS (T2) resulted in the highest plant population at 30 DAS. Imazapyr (25g a.i. ha^{-1} as pre-emergence) showed comparable results to T2 at 25 and 45 DAS. Treatments T7 (Imazapyr at 25g a.i./ha as pre-emergence), T4 (Metsulfuron at 4g a.i. ha^{-1} as pre-emergence), and T6 (Bispyribac sodium at 18g, 18 days as post-emergence) showed significant differences among each other at 30, 60, and 90 DAS. The control treatment (T1) consistently had the lowest plant population at all stages. T2 also recorded the maximum plant height, root length, dry weight, and number of tillers per plant at 30, 60, and 90 DAS. Imazapyr (T7) was comparable to T2 across these stages **(Table 1 and Fig. 1)**. This was attributed to the effective weed management practices, particularly hand weeding at critical stages, which minimized competition for nutrients, moisture, and space, promoting vigorous crop growth. Overall, these findings underscored the importance of effective weed management in enhancing crop performance and yield, as supported by previous research[9-11].

Table 1. Effect of different treatment combination on growth parameters of wheat

Treatments	Treatment Combination	Plant population (No. /running m)	Plant height (cm)	Root length (cm)	Plant dry weight (g)	Number of tillers plant^{-1}
T_1	Control	9.42	110.02	72.53	185.94	12.16
T_2	Two hand weeding at 25 and 45 DAS	10.46	128.03	84.94	210.46	14.85
T_3	Sulfosulfuron at 25g a.i. ha^{-1} pre emergence	9.62	117.73	78.10	193.53	13.66
T_4	Metsulfuron at 4g a.i. ha^{-1} as pre emergence	9.82	120.24	79.77	197.66	13.95
T_5	Salfometsulfuron 16g a.i. ha^{-1} as post emergence	9.69	118.60	78.68	194.95	13.76
T_6	Bispyribac sodium at 18g, 18day as post emergence	9.72	118.97	78.92	195.56	13.80
T_7	Imazapyr at 25g a.i.ha^{-1} as pre –emergence	9.98	121.98	80.48	199.42	14.41
F-test		S	S	S	S	S
SED ±		0.22	3.73	2.87	5.13	0.39
CD at 5%		0.49	8.12	6.26	11.18	0.85

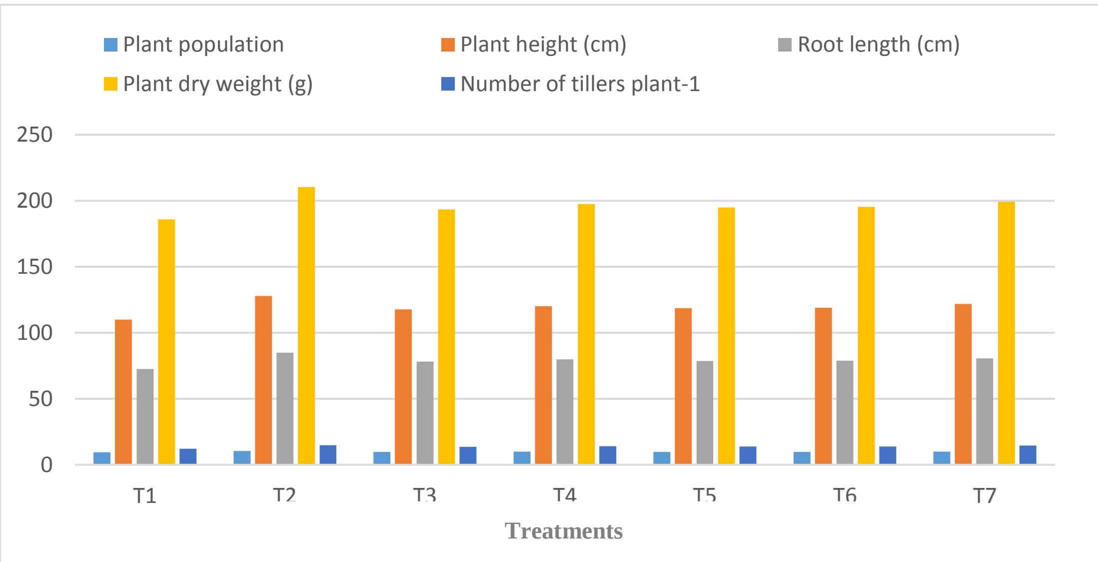


Figure 1. Effect of different treatment combination on growth parameters of wheat

3.2. Yield Attributes

The study analyzed various yield parameters of wheat under different weed management treatments. Significant differences were observed in the number of ears per square meter, number of seeds per ear, test weight, grain yield, and stover yield. T2 (two hand weedings at 25 and 45 DAS) consistently recorded the highest number of ears per square meter, statistically comparable to T7 (Imazapyr at 25g a.i./ha as pre-emergence) and significantly superior to other treatments. The number of seeds per ear mirrored the trend observed in the number of ears across treatments. While test weight showed no significant variation among the weed management treatments, T2 exhibited higher test weight compared to other treatments. This improvement in yield attributes in T2 was attributed to enhanced vegetative and reproductive characteristics facilitated by effective weed management practices. In contrast, T1 (control) consistently showed the lowest values across all yield attributes, likely due to inadequate nutrient availability resulting in poor yields. Both seed and stover yields were significantly influenced by the weed management practices. T2 demonstrated the highest seed yield, statistically comparable to T7 and superior to other treatments. Similarly, T2 also exhibited the highest stover yield. These findings were consistent with prior research [12-14]. The study also found that T2 had the highest harvest index, indicating efficient conversion of non-seed biomass into grain. This efficiency was attributed to optimal nutrient availability and reduced competition for resources, which promoted overall growth and yield parameters. Overall, the results underscored the critical role of effective weed management practices, particularly hand weeding at crucial growth stages, in enhancing wheat yield and harvest efficiency.

Table 2. Effect of different treatment combination on yield parameters of wheat

Treatments	**Treatment Combination**	**Number of ear / m^2 (No.)**	**Number of seeds ear^{-1} (No.)**	**Test weight**	**Grain yield (qha^{-1})**	**Stover yield (qha^{-1})**
T_1	Control	69.35	43.09	41.39	31.73	41.67
T_2	Two hand weeding at 25 and 45 DAS	77.61	43.49	49.55	33.76	43.03
T_3	Sulfosulfuron at 25g a.i. ha^{-1} pre emergence	71.37	43.21	43.00	32.26	41.77
T_4	Metsulfuron at 4g a.i. ha^{-1} as pre emergence	72.89	43.27	44.56	31.99	42.10
T_5	Salfometsulfuron 16g a.i. ha^{-1} as post emergence	71.89	43.23	43.54	31.82	41.73
T_6	Bispyribac sodium at 18g, 18day as post emergence	72.12	43.24	43.77	31.86	41.80
T_7	Imazapyr at 25g a.i.ha^{-1} as pre-emergence	74.60	43.33	45.90	32.09	42.97
F-test		S	S	S	S	S
SED ±		1.63	0.08	1.67	0.32	0.74
CD at 5%		3.56	0.17	3.65	0.70	1.62

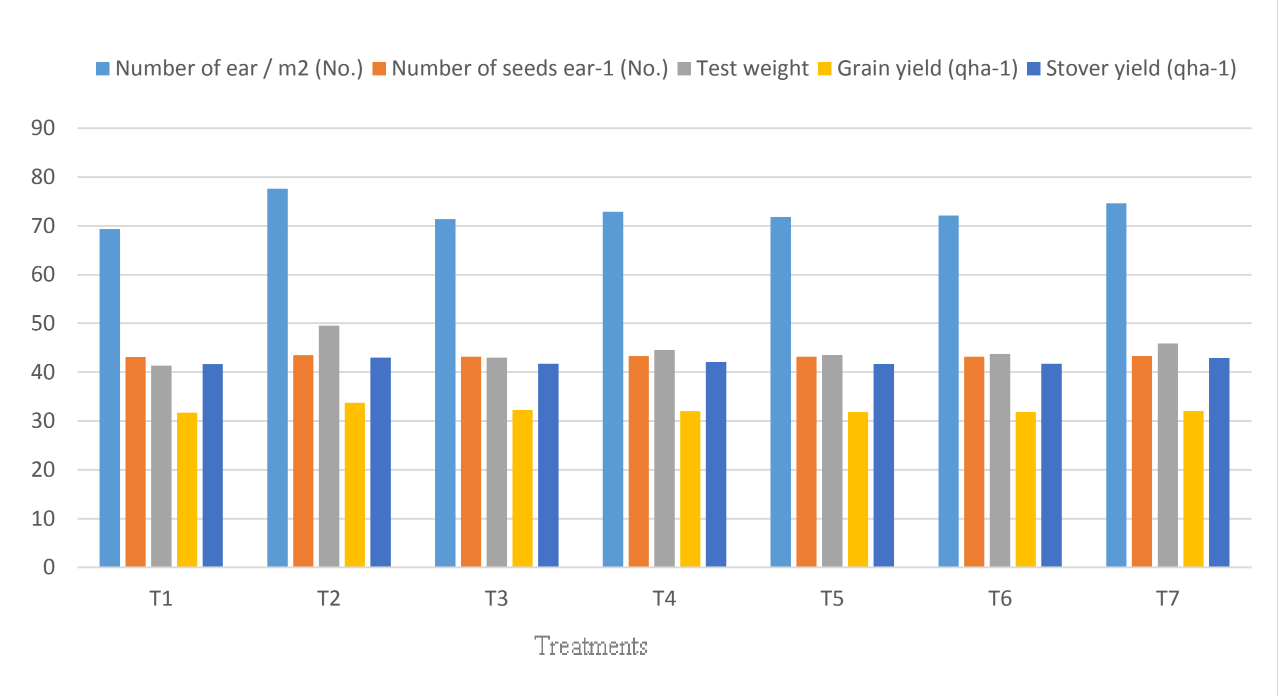


Figure 2. Effect of different treatment combination on yield parameters of wheat

3.3. Effect of different treatments on weed management practices on crop yield and weed characteristics

The study investigated the impact of different weed management practices on crop yield and weed characteristics. Harvest index, a measure of crop productivity, showed no significant variation among treatments, with the highest values observed under T2 (two hand weeding at 30 and 60 DAS) and the lowest under T1 (control). Weed density varied significantly across treatments, with T2 (two hand weeding at 25 and 45 DAS) exhibiting the lowest density. T7 (Imazapyr at 25g a.i. ha^{-1} as pre-emergence) had weed density similar to T2, whereas T4 (Metsulfuron at 4g a.i. ha^{-1} as pre-emergence) and T6 (Bispyribac sodium at 18g, 18 days as post-emergence) differed significantly from each other. T1 (control) had the highest weed density among all treatments. Similarly, weed dry weight showed significant variation, with T2 recording the least amount of weed biomass. Treatments T7, T4, and T6 differed significantly in weed dry weight, while T1 exhibited the highest weed biomass. Weed control efficiency, an indicator of the effectiveness of weed management practices, was highest in T2, followed by significant differences among T7, T4, and T6. T1 demonstrated the lowest weed control efficiency. Maximum weed index, which combines weed density and dry weight, was highest in T2, statistically comparable to T7. Treatments T4 and T6 showed significant differences from each other, with T1 having the lowest weed index. Overall, the results emphasize the efficacy of various weed management strategies, particularly hand weeding at critical growth stages, in influencing weed characteristics and optimizing crop yield [15-17]. These findings contribute to the understanding of integrated weed management approaches that can enhance agricultural sustainability and productivity.

Table 3. Effect of different treatments on number of Harvest Index (%), Weed density (No. m^{-2}), Weed dry weight (g), Weed control efficiency (%) and Weed Index (%) at different treatments.

Treatments	Treatment Combination	Harvest Index(%)	Weed density (No. m^{-2})	Weed dry weight	Weed control efficiency	Weed Index (%)

				(g)	(%)	
T1	Control	34.99	6.75 (45.12)	4.96 (24.13)	37.51	7.94
T2	Two hand weeding at 25 and 45 DAS	35.33	6.54 (44.38)	3.42 (11.36)	40.25	11.64
T3	Sulfosulfuron at 25g a.i. ha^{-1} pre emergence	34.91	4.12 (16.46)	3.94 (15.04)	-	-
T4	Metsulfuron at 4g a.i. ha^{-1} as pre emergence	35.16	6.68 (44.12)	3.90 (14.70)	38.90	8.89
T5	Salfometsulfuron 16g a.i. ha^{-1} as post emergence	35.23	6.72 (44.72)	3.93 (14.91)	38.11	8.30
T6	Bispyribac sodium at 18g, 18day as post emergence	35.24	6.69 (44.25)	3.91 (14.75)	38.76	7.97
T7	Imazapyr at 25g a.i.ha^{-1} as pre – emergence	34.49	6.65 (43.79)	3.75 (13.58)	39.44	8.67
F-test		NS	S	S	S	S
SED ±		0.76	0.09	0.07	1.57	1.84
CD at 5%		-	0.19	0.16	3.42	4.01

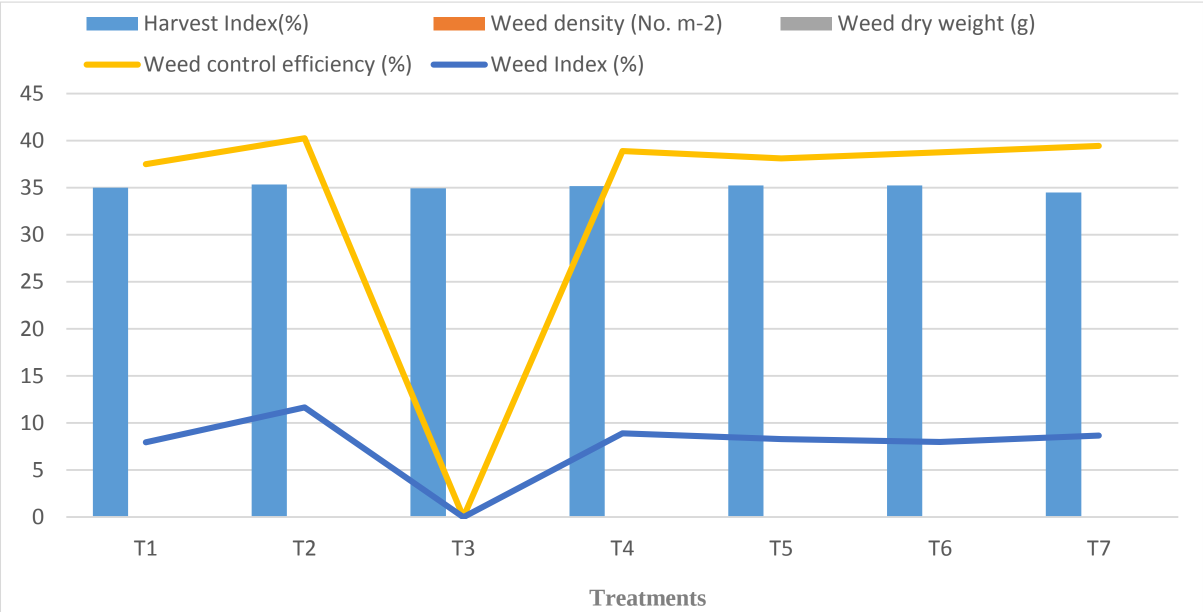
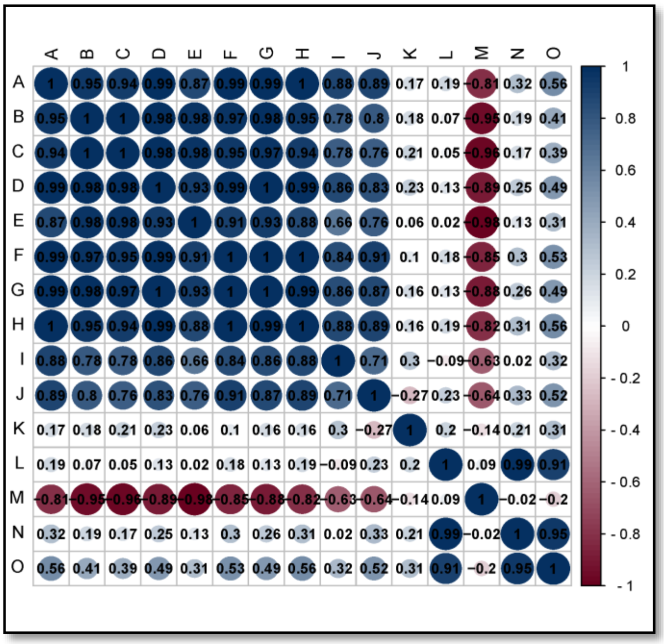


Figure 3. Effect of different treatments on number of Harvest Index(%), Weed density (No. m^{-2}), Weed dry weight (g), Weed control efficiency (%) and Weed Index (%)at different treatments.

3.4. Correlation matrices relationships between various plant parameters

(a)



(b)

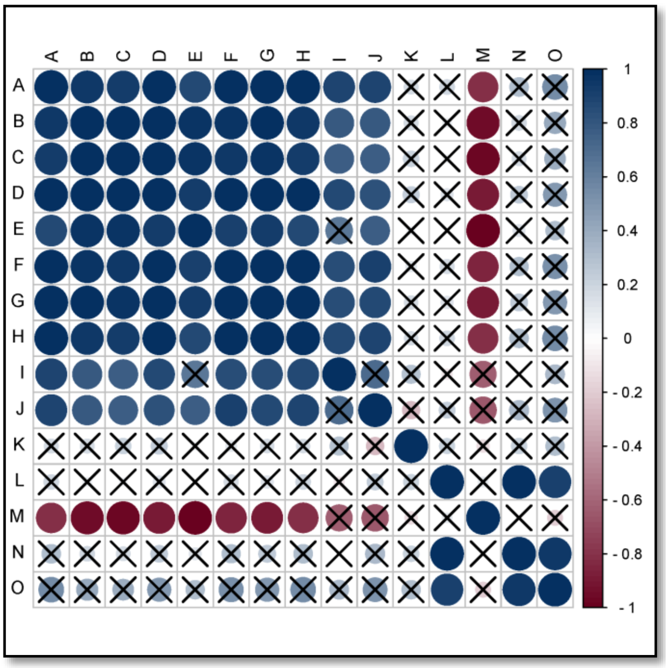


Figure 4 (a & b): Correlation matrices showing the relationships between various plant parameters including: Plant Population (A), Plant Height (B), Root Length (C), Plant Dry Weight (D), Number of Tillers per Plant (E), Number of Ears per m² (F), Number of Seeds per Ear (G), Test Weight (H), Grain Yield (I), Stover Yield (J), Harvest Index (%) (K), Weed Density (L), Weed Control Efficiency (M and N), and Weed Index (O).

The correlation matrices in Figures 1 and 2 visualize the relationships between various plant parameters labeled from A to O, including: Plant Population (A), Plant Height (B), Root Length (C), Plant Dry Weight (D), Number of Tillers per Plant (E), Number of Ears per m² (F), Number of Seeds per Ear (G), Test Weight (H), Grain Yield (I), Stover Yield (J), Harvest Index (%) (K), Weed Density (L), Weed Dry Weight (M), Weed Control Efficiency (N), and Weed Index (O). Each cell in these matrices represents the correlation between a pair of parameters[18]. The size and color of the circles indicate the strength and direction of the correlation: larger circles denote stronger correlations, blue circles represent positive correlations, and red circles indicate negative correlations. The color intensity reflects the correlations strength, with darker shades representing stronger relationships. Each cell also contains a numerical value for the correlation coefficient, which ranges from -1 (perfect negative correlation) to 1 (perfect positive correlation), with 0 indicating no correlation. The color bar on the right side of the matrix shows the gradient from -1 (red) to +1 (blue).

In both figures, parameters A, B, C, D, E, F, G, and H show strong positive correlations with each other. This is indicated by large, dark blue circles, suggesting that these parameters tend to increase together. For example, Plant Population (A) and Plant Height (B) have a strong positive correlation, implying that as the plant population increases, plant height tends to increase as well. This trend is consistent across these highly correlated parameters, suggesting they are likely influenced by similar factors or conditions. Conversely, parameter M (Weed dry weight) exhibits strong negative correlations with several other parameters, including A, B, C, D, E, F, G, H, I, J, K, and L. This is shown by large red circles and negative correlation coefficients (e.g., -0.81 between A and M, -0.96 between C and M). These negative correlations suggest that as Weed dry weight increases, the values of these other parameters decrease. This could indicate that effective weed control might negatively impact these plant growth parameters, possibly due to reduced competition for resources among weeds. Some parameters, such as K (Harvest Index) and N (Weed control efficiency), exhibit weak or near-zero correlations with others, indicating no significant relationship. For instance, the correlation between K and N is weak, suggesting that these parameters do not have a clear linear relationship. Parameter N, however, shows a strong positive correlation with parameter O (Weed Index), indicating that these two parameters are closely related.

The matrices help identify which parameters could be good predictors for each other in a model. Strong correlations suggest redundancy, where one parameter might be removed to simplify the model. On the other hand, weak correlations indicate independence, providing unique information. By examining the size, color, and numerical values in each cell, these matrices provide valuable insights for data analysis. This information is crucial for making informed decisions on variable selection and exploring potential causal relationships. Understanding these patterns is a valuable tool in exploratory data analysis, helping to identify relationships that may warrant further investigation.

4. Conclusion

Based on this study, effective weed management significantly enhances wheat growth and yield parameters. Manual weeding, particularly two applications at critical stages, demonstrated optimal results in plant height, tiller count, and yield attributes. Herbicide treatments, specifically T7 (Imazapyr at 25g a.i. ha^{-1} pre-emergence), T4 (Metsulfuron at 4g a.i. ha^{-1} pre-emergence), and T6 (Bispyribac sodium at 18g a.i. ha^{-1} post-emergence), proved equally effective as manual weeding, improving weed control efficiency and reducing weed density and biomass. These findings underscore the importance of timing and selection in herbicide applications to maximize wheat yield and quality. They contribute to integrated weed management strategies crucial for sustainable agriculture, addressing challenges like herbicide resistance and environmental impact. Future research should explore additional variables affecting herbicide efficacy to refine these strategies further.

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