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Exogenous application of macronutrient potassium boosting morph-physiological parameter and yield attributes in wheat

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ABSTRACT

The research was carried out using a wheat genotype to assess the foliar impact of applying potassium during a specific growth stage. Various physiological parameters and changes in photosynthetic pigments were analyzed in response to potassium application. The data obtained for different growth parameters over the study period were subjected to statistical analysis to facilitate comparisons. Exposing wheat genotypes to a 0.5% foliar application of potassium resulted in significant enhancements in morphological, biological, photosynthetic pigment and yield attributes parameters when compared to plants grown in a potassium-free environment (Control). This improvement was particularly recorded in terms of the fresh and dry weights of the stem and plant, as well as the levels of chlorophyll 'a,' 'b,' total chlorophyll and yield attributing parameters. The most substantial enhancements in the tested parameters were observed at a potassium concentration of 0.5%. This study establishes that foliar application of potassium at an optimal 0.5% concentration acts as a growth promoter, leading to increased chlorophyll content, yield and ion uptake in wheat. Furthermore, it is advisable to prioritize the use of 0.5% potassium foliar application in the mentioned locations.

Key words: *Wheat, Foliar application, Potassium; Growth, Chlorophyll*

Introduction

Wheat (*Triticum aestivum* L.), commonly known as bread wheat, is an annual grass belonging to the *Poaceae* family. Its origins trace back to the Mediterranean region and Southwest Asia, and it is one of several cultivated wheat species that thrive in temperate climates across the globe. Wheat ranks as the second most widely produced crop worldwide and serves as a crucial staple food for approximately 2 billion people, accounting for 36% of the global population's dietary needs. Additionally, it contributes significantly to dietary protein intake. This cereal is characterized as an annual, self-pollinating plant that is influenced by photoperiodic cues. It thrives in cool-season conditions with long daylight hours. In the marketing year (MY) 2016/17, global wheat production reached 88 million metric tons (MMT), marking a slight increase from the previous year, which was impacted by late-season rains and yielded 86.5 MMT. However, this figure is notably lower than the record harvest of MY 2014/15, which amounted to 95.9 MMT. Revised estimates for MY 2015/16 report a production of 86.5 MMT, according to the Government of India. Wheat plays a pivotal role in global food security, providing 21% of total food calories and supplying 20% of dietary protein to over 4.5 billion individuals worldwide. In light of growing populations and changing dietary preferences, it is projected that the demand for wheat in developing nations will increase by 60% by the year 2050 (Braun *et al.,* 2010). Efforts to boost wheat yield have centered on the development of high-yielding, disease-resistant varieties, as well as improved cultivation practices. This includes strategies such as irrigation and the precise application of macro and micro-nutrients like Potassium and Zinc, either through soil amendments or foliar sprays. In fact, foliar application of these macronutrients has proven to be as effective, if not more so, than traditional soil-based methods in addressing macronutrient deficiencies in subsoil.

Potassium plays a crucial role in the synthesis and transportation of carbohydrates and carbon dioxide, and it is indispensable for the development of robust cell walls in plants. Additionally, potassium has a positive impact on product quality and enhances the efficiency of photosynthesis, thus boosting a plant's resistance to certain diseases. Moreover, potassium is a vital element for the formation of sturdy stalks and larger grains in cereal crops (Khajepour, 1995). As a result, the utilization of potassium through foliar application emerges as a more practical and cost-effective approach, with a specific focus on achieving targeted outcomes, for augmenting both fertilizer efficiency and grain yield. This approach has been supported by previous studies (Farooqi *et al.,* 2012; Eichert and Burkhardt, 2001). Given the aforementioned challenges associated with potassium availability, it becomes imperative to investigate strategies aimed at improving potassium utilization efficiency. The the current investigation, we aimed to assess the influence of foliar potassium application on the growth, photosynthetic pigment and yield attributes performance of wheat in the context of a herbal garden at Maharshi Dayanand University.

Materials and Methods

An experiment entitled the effect of foliar application of Potassium on morpho-physiological aspects of wheat genotypes was conducted in field, Maharshi Dayanand University. One field experiment was carried out at MDU, Rohtak, India (latitude 28º 54′ 0′ N, longitude 76º 34′ 0′ E, Altitude 220m). The experimental site's soil composition consisted of a sandy-loamy texture, predominantly composed of montmorillonite clay. It exhibited low organic matter content, ranging from 0.8% to 0.9%, and had an alkaline pH level ranging from 8.0 to 9.2. The experimental design employed for this study was a Randomized Complete Block Design (RCBD), and the experiment included three replications. Treatment with foliar application of 0.5% K was applied on wheat crop at growing stage. Each plot had 5 rows, 15 cm row spacing and 2m plot length. Seeds were sown in November, at Maharshi Dayanand University respectively. The data underwent statistical analysis using an analysis of variance approach tailored for the Randomized Complete Block Design (RCBD). Foliar application was done at booting stage with 0.5% potassium. First irrigation was given 10 days after sowing. The statistical analysis of the data collected for various parameters followed the methodology recommended by Gomez and Gomez (1984), specifically designed for split-plot designs. At 60 days following seeding, the plants were tested. Plant fresh and dry weight (Stem, Plant), chlorophyll content and yield attributes related parameters were all used to evaluate the crop's performance.

Growth parameter

The fresh weights (FW) of the stem and plant were found by separating them. The stem and plant were dried at 70 °C for 48 hours and then weighed to calculate out their dry weight (DW).

Chlorophyll Content

Chlorophyll content is estimated by the non-destructive method described by Hiscox and Israelstam (1979) using dimethyl sulphoxide (DMSO). For estimating of photosynthetic pigment, 100 mg of fresh harvested young fully expanded leaf from top was taken in the test tube containing 3 ml of DMSO. These tubes were then placed in an oven at 60 °C for 2 hours to facilitate the extraction of the pigment. After incubation, tubes were cooled to the room temperature and absorbance of these pigment extract was read at 645 and 665 nm as a described by Kaloyereas (1958) on a computer aided spectrophotometer running a multiple wavelength program. DMSO was used as blank.

Calculation of different pigments were made according to Welburn (1994).

Chl 'a' = (μg/ml) = $12.19\ A_{665} - 3.45\ A_{645}$

Chl 'b' = (μg/ml) = $21.99\ A_{645} - 5.32\ A_{665}$

Quantities of these pigments were calculated in ug/g tissue fresh weight.

Total chlorophyll content = Chl 'a' + Chl 'b'

Yield attributes

During the harvest period, twenty sentinel plants were randomly selected from each plot to assess yield characteristics, i. e. Spike length, number of spikelet/spike, number of grains per spike, 1000 seed weight, grain yield/ plant.

Statistical analysis

ANOVA was used to analyse the collected data for the two variables, and the results shown in the figures are the mean values of three replica. The Tukey's HSD post hoc test ($p \leq 0.05$) was utilized to identify significant differences between treatment means through multiple comparisons. Utilizing the program Origin Pro 2023, the statistics' graphical representation was produced.

Results

Fresh and Dry weight of Stem

The analyzed data (Fig.1A, B) regarding fresh and dry weight of wheat showed significant effect of potassium spray on this parameter. Compared to the control, fresh weight of stem was increased upto by 60.34% in HD-3086 and 54.89% in WH-1105 at 0.5% K foliar application. Similarly, the dry weights of stem were increased by up to 28.96 % in WH 542 and 23.67 % in DBW 88 in wheat genotypes compared to control. Minimum increase were observed in fresh and dry weight of stem in HD 2967 and HD 3086 upto by 19.94%, 15.87%. The FW, DW of wheat varieties were greatly enhanced when foliar application of potassium were given at growth stage (Figure 1A,B). Such effects of K foliar application, macronutrient K might be due to their critical role in crop growth involving in photosynthesis, enzymic activity, osmo-regulation and their importance to achieving higher fresh weight. However out of five genotypes, HD 3086 showed highest increased in fresh weight of stem as compared to rest four genotype of wheat.

Fresh and Dry weight of Plant

The analysis of variance (Fig. 2 A, B) revealed that the plant FW and DW had significantly affected by foliar application of 0.5% K (once time spray) at growing stage. Data in Fig. 2 A,B clearly demonstrate that, in comparison to control plants, the fresh and dry weight of wheat, gradually increased with 0.5% K application upto by 51.76% in HD 3086 and 54.20% in WH 1105 with respect to control. Minimum increase were observed in mainly two genotype of wheat, WH 542 (15.77%) and HD 3086 (14.07%) with 0.5%K foliar application compared to

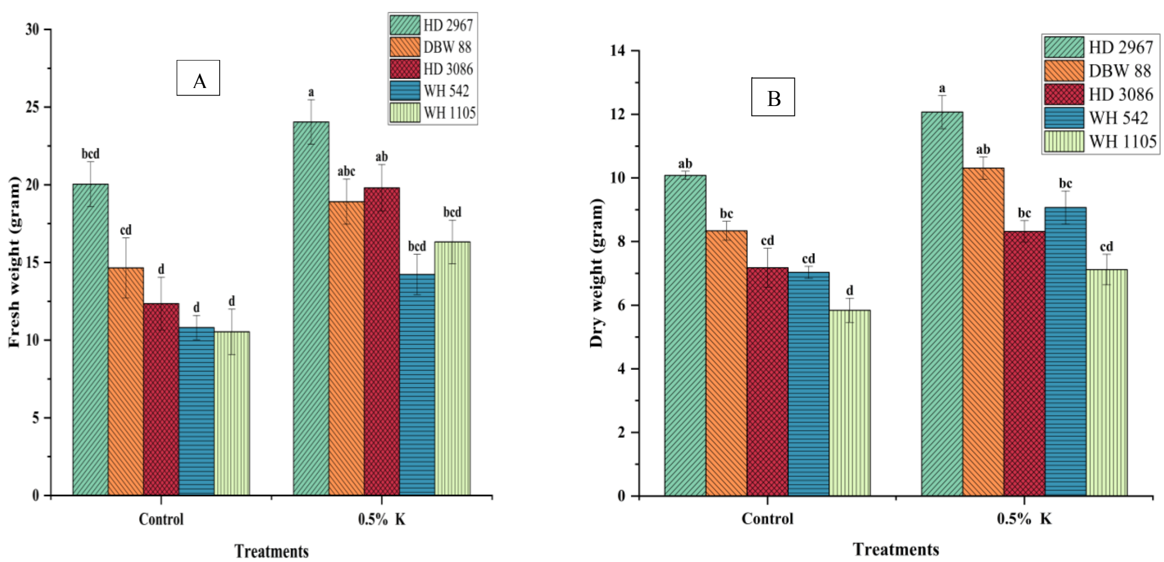


Fig. 1. Effect of Foliar spray of potassium on Wheat genotypes including parameters Fresh weight of Stem (A), and Dry weight of stem (B). Each value is the average across three replicates, with standard error calculated. Each bar with a distinct letter was significantly different across treatments ($p \leq 0.05$); means SE; two-way ANOVA; Tukey's post hoc test.

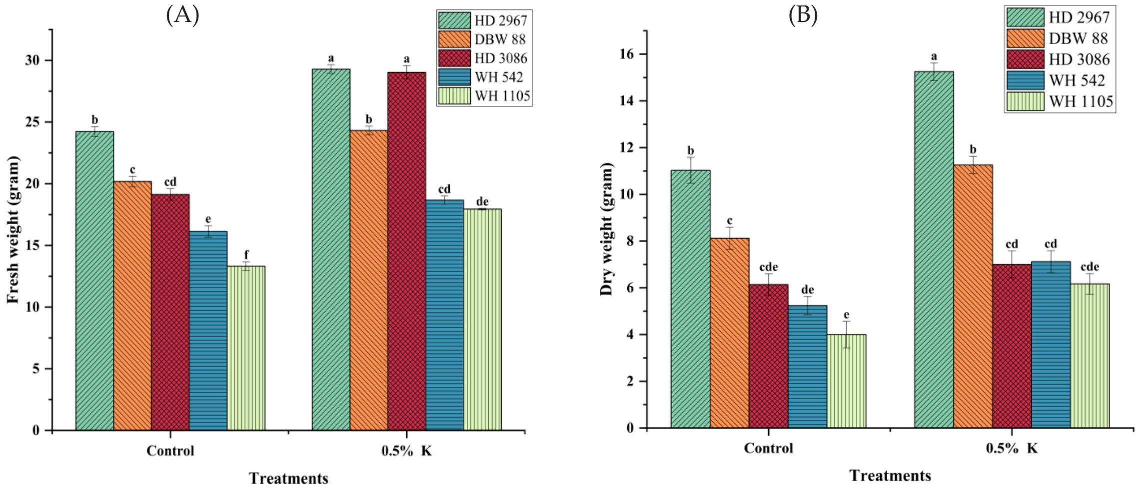


Fig. 2. Effect of Foliar spray of potassium on Wheat genotypes including parameters Fresh weight of plant (A), and Dry weight of plant (B). Each value is the average across three replicates, with standard error calculated. Each bar with a distinct letter was significantly different across treatments ($p \leq 0.05$); means SE; two-way ANOVA; Tukey's post hoc test.

control plants. Foliar application of potassium enhanced the fresh and dry weight of total plant parts. Data recorded from different treatments were subjected to analysis, revealing significant differences among wheat genotypes. This could potentially be attributed to the crop's enhanced nutrient uptake via foliar application, subsequently leading to an increase in the dry weight of the Plants.

Photosynthetic pigment

Data present in Fig. 3, A, showed that chl 'a' content of genotype HD 2967 and DBW 88 were higher and followed by HD 3086, WH 542 and WH 1105 at control condition. In 0.5% foliar spray, genotype WH 1105(47.84%) show significantly increase in Chl 'a' content. Foliar spray of 0.5% K show positive effect on some wheat genotypes. Data present in Fig. 3, B, evinces of chlorophyll 'b' was higher in genotype HD 2967 at control conditions. Genotype WH 1105 showed greatly increase its content (40.01%) followed by WH 542 (37.14%), HD 2967(23.33%), DBW 88(20.00%) than other genotypes. Similarly trend were obtained with total chlorophyll content, it also increased with foliar application of 0.5% potassium application (Fig. 3,C). Highest increased were obtained in WH 542(37.53%) followed by HD 3086 (36.24%), DBW 88(33.91%). Minimum increase were obtained in WH 1105 upto by 26.67% with compared to control. However out of five genotypes, WH 542 showed highest increased in total chlorophyll content of leaves as compared to rest four genotype of wheat.

Spike Length, No. of spikelets /Spike, No. of grains/Spike

The yield potential of wheat crops hinges on the length of their spikes, with a greater number of grains per spike attributed to increased spike length. Upon analysis of the data (Fig. 4 A), it is evident that foliar spraying with 0.5 K has a positive impact on ear length. Furthermore, the application of potassium (K) through foliar spray significantly enhances spike length, particularly when applied during the vegetative stage. Fig. 4 A clearly demonstrate that, in comparison to control plants, the spike length, gradually increased with 0.5% K application upto by 30.67 % in HD 3086 and 26.17 % in WH 1105 with respect to control. Minimum increase were observed in mainly two genotype of wheat, WH 542 (15.74%) and DBW 88 (23.92%) with 0.5% K foliar application compared to control plants. Similarly trend were obtained with number of spikelet/spike and number of grains/ spike in wheat genotypes. The production potential of a crop is significantly influenced by the quantity of spikelets present on each spike. No. of spikelets/spike were increased upto 33.09% in HD 2967 and 25.89% in WH 1105 (Fig.4 B). Minimum increase were recorded in WH 542 (19.71%) and DBW (23.27%) compared to control plants. Production potential of any crop depends on its number

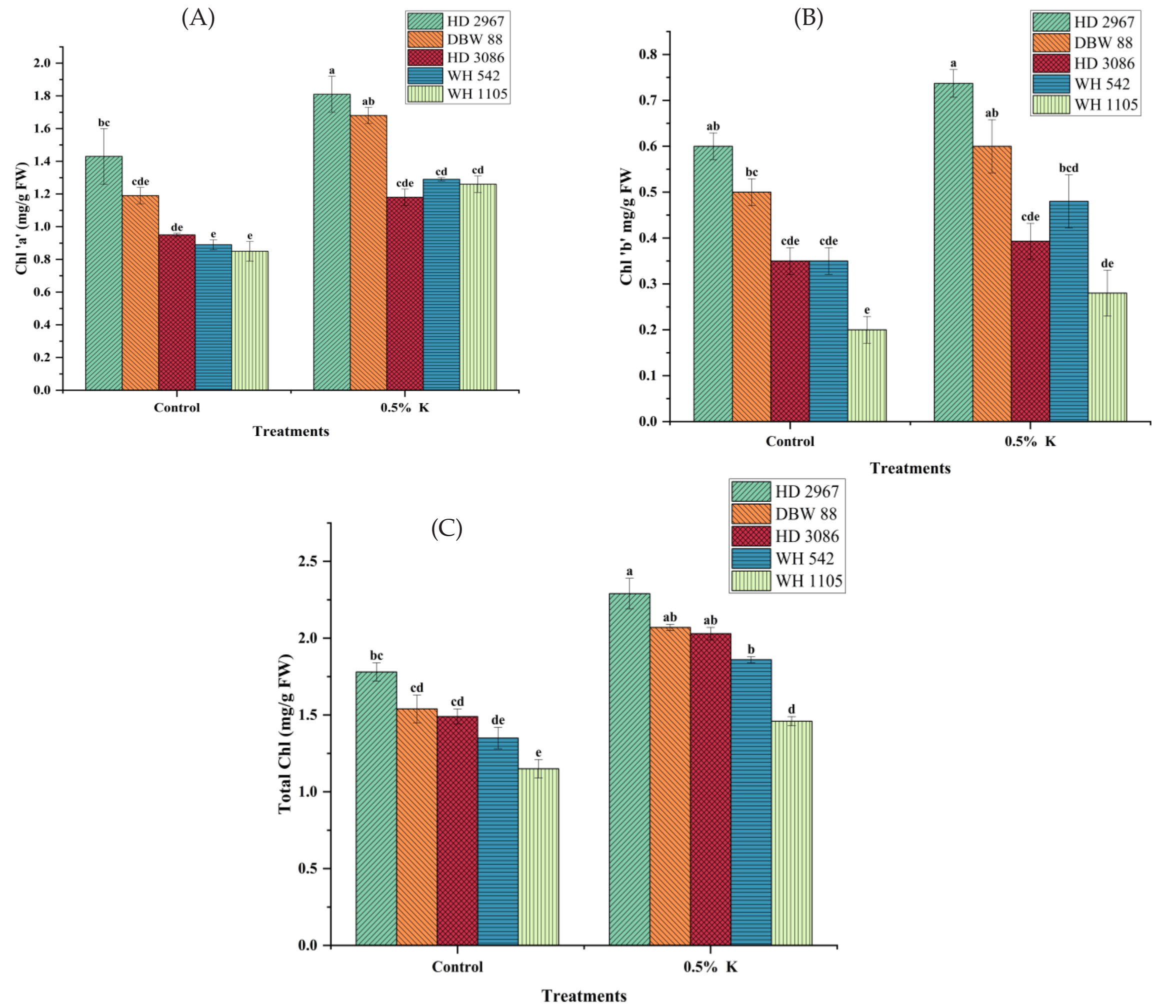


Fig. 3. Effect of Foliar spray of potassium on Wheat genotypes including parameters Chl 'a' (A), Chl 'b' (B) and total Chl (C). Each value is the average across three replicates, with standard error calculated. Each bar with a distinct letter was significantly different across treatments ($p \leq 0.05$); means SE; two-way ANOVA; Tukey's post hoc test.

of grains per spike that play vital role in the economic yield of the crop. No. of grains per spike were maximum increased in WH 1105(30.05%) and minimum were recorded in DBW 88(18.46%) shown as Fig. 4 C. Foliar application of potassium enhanced the spike length, no. of spikelets and no. of grains per spike in wheat genotypes. Data recorded from different treatments were subjected to analysis, revealing significant differences among wheat genotypes. This could potentially be attributed to the crop's enhanced nutrient uptake via foliar application, subsequently leading to an increase in yield related parameters.

1000 seed weight, Grain yield per plant

The 1000-grain weight plays a vital role in determining the overall wheat yield. An examination of the data (Fig. 5A) revealed that applying a foliar spray containing 0.5% potassium (K) had a noteworthy impact on the 1000-grain weight. The external application of potassium led to a significant enhancement in the 1000-grain weight across all wheat genotypes. The most substantial increase was observed in the HD 3086 genotype, with an improvement of 14.65%, while the DBW 88 genotype showed the smallest increase at 10.59%. The crop produced heaviest grains when it affected with potassium foliar treatment. The different varieties exhibited an insignifi-

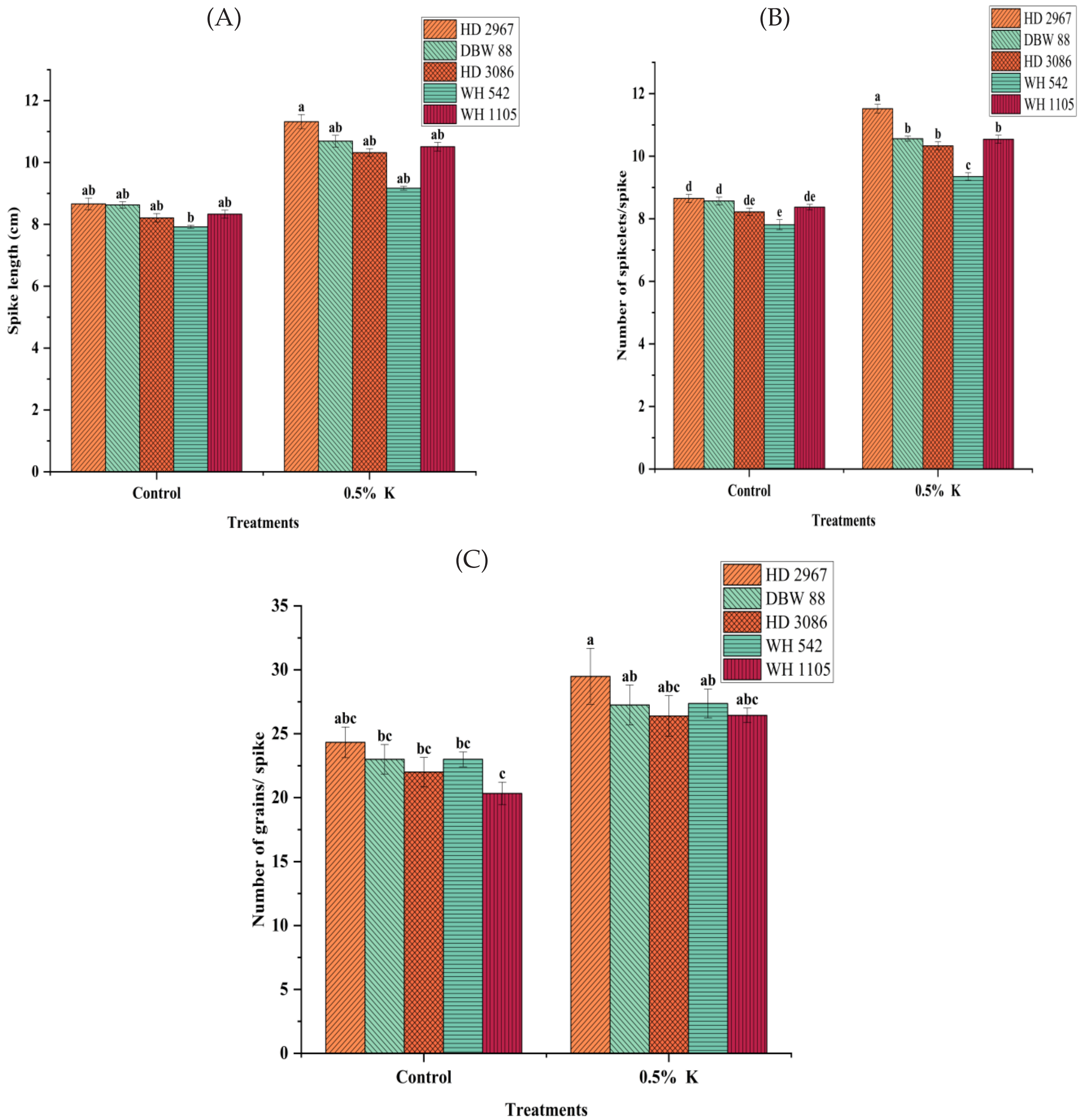


Fig. 4. Effect of Foliar spray of potassium on Wheat genotypes including parameters Spike length (A), Number of spikelet per spike (B) and Number of grains per spike (C). Each value is the average across three replicates, with standard error calculated. Each bar with a distinct letter was significantly different across treatments ($p \leq 0.05$); means SE; two-way ANOVA; Tukey's post hoc test.

cant response. Furthermore, there was no significant interaction between the genotypes and the external application of potassium (K) in relation to the 1000-grain weight. The ultimate grain yield is the culmination of the impacts of various yield components that develop under the specific treatment conditions. The data presented in Figure 5B clearly show that the foliar application of 0.5% potassium (K) had a noticeable impact on grain yield per plant in various wheat genotypes. The most substantial increase in grain yield was observed in HD 3086 (49.71%) and WH 542 (44.77%). Conversely, the smallest increase was recorded in HD 2967 (27.32%) when the crop was grown under standard irrigation conditions with K supply. However out of five genotypes, HD 2967 showed highest 1000 grain weight and grain yield/ plant in wheat as compared to rest four genotype of wheat.

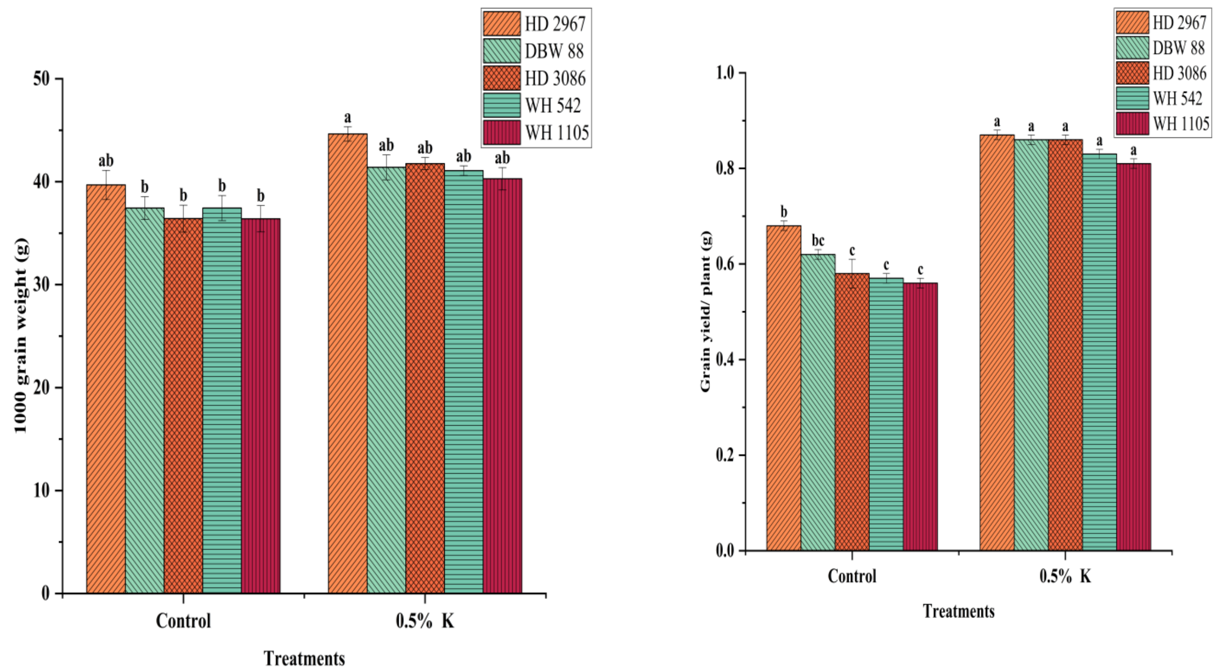
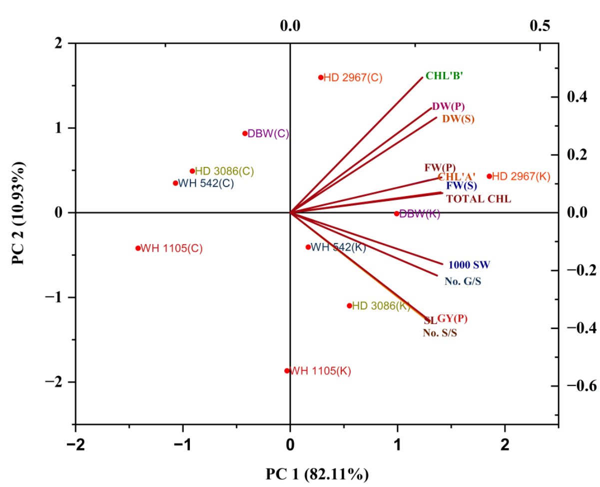


Fig. 5. Effect of Foliar spray of potassium on Wheat genotypes including parameters 1000 grain weight (A), Grain yield per plant (B). Each value is the average across three replicates, with standard error calculated. Each bar with a distinct letter was significantly different across treatments (p≤ 0.05); means SE; two-way ANOVA; Tukey's post hoc test.

Response of various parameters to the treatments: The biplot shows the values of various parameters under different genotypes- treatment combinations. In this biplot PC 1 explained 82.11% and PC 2 explained 10.93%, a total sum of square of the variations about 93.04%. The following points are presented by the biplot:

(1) PC 1 divides the biplot into two groups: the foliar spray of potassium (K) for each genotype on the right side, and the control (C) for each genotype on the left side of the biplot. However, the 0.5% foliar potassium sprays (K) are present on the right side of the biplot representing the positive effect compared to control.



(2) The two genotypes under control conditions showed little difference as they are placed close to each other on the biplot. They were characterized by having relatively high levels for the indicators placed on the left side (such as HD 3086 (C), WH 542), and relatively low levels for those placed on the right side (HD 2967(K),HD 3086 (K),DBW (K)) of the biplot. The opposite can be said for the potassium foliar spray treatments. Therefore, the control and foliar spray of potassium on wheat genotypes showed contrasting physiological states in the terms of the two sets of indicators.

(3) PC2 appeared to have separated the genotypes under control and foliar application of potassium conditions. WH 542 under K (WH 542(K), HD 3086 under K (3086(K), WH 1105 under K (WH 1105(K))DBW under K (DBW(K)) are placed on the upper right of the biplot, characterized by relatively high levels of 1000 seed

weight, number of grains per spike, spike length, grain yield per plant, number of spikelet per spike. In contrast, genotype HD 2967(K) is placed in the lower right of the biplot, characterized by relatively high levels of Chl'A', Chl'B', total Chl, Spm, Apx, FW(S), DW(S), FW(P), DW(P) etc. This suggested that the foliar application of potassium are positive indicator for wheat genotype.

Boxplot of wheat genotypes under 0.5K and control condition

In our analysis, we compared the performance of five different wheat genotypes (DBW 88, HD 2967, HD 3086,WH 542,WH 1105 using boxplots. Each boxplot represented the distribution of data points for a specific genotype. We observed that HD2967, one of the five genotypes, outperformed the other four genotypes. Specifically, the median of HD2967 was significantly higher than the medians of the other genotypes, indicating better performance. Additionally, HD2967 exhibited less variability, as evidenced by the narrower box in its boxplot. Furthermore, there were fewer or less extreme outliers in the HD2967 data, suggesting a more consistent performance. These findings are consistent with the conclusion that HD2967 excels in the specific characteristic under consideration. Further statistical tests support this conclusion. Therefore, HD2967 is recommended for closer observation or potential adoption in future wheat breeding programs.

Discussion

Exogenous application of 0.5% K, when given separately to wheat genotypes, enabled the plants in the current research study to the reversal of altered growth and physiological -biochemical processes. These findings were reported in the present study.

Foliar application of 0.5 % K has Promoting effect on stem and total plant fresh weight. Potassium significantly increased fresh and dry weight of stem and complete plant and these results were supported with findings obtained by Celik Hakam *et al.* (2010), who reported that potassium levels has positive effects on the dry weight of Maize. The involvement of potassium in light utilization during photosynthesis and other metabolic processes contributed to an expansion of leaf area and enhanced water efficiency, which was evident in the morphological and yield components (Sharma and Agarwal, 2002). In present investigation, genotypes of wheat showed that fresh and dry weight of stem increased with K foliar application. In a study conducted by Wang *et al.* (2013), it was found that adjusting the utilization of potassium fertilizer could enhance the total dry mass production of stems under conditions of salt and drought stress. This improvement was observed when compared to the use of lower concentrations of potash fertilizers. Similarly, Yagmur *et al.* (2007) reported positive effects of potassium application on mitigating salinity-related issues. Their research demonstrated that potassium application alleviated the adverse effects of salinity on both

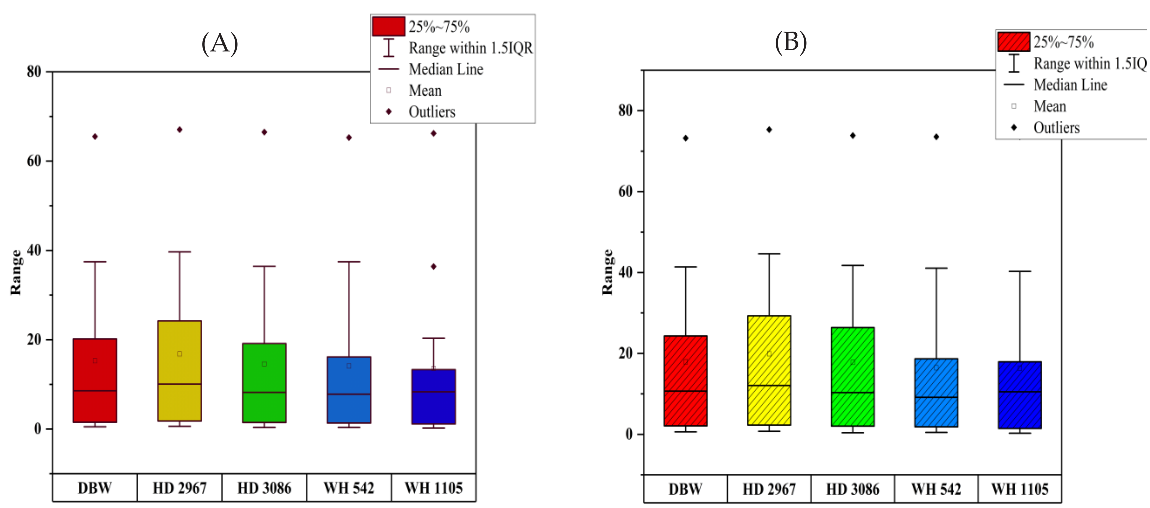


Fig. 6. Effect of 0.5%K spray(B) on wheat with respect to control (A) plants in five genotypes of Wheat. Boxplot represent the range, horizontal bar in each box shows median. Whiskers shows the range and dots represent outliners.

stem and leaf dry weights. Cao and Tibbittis (1991) found that different potassium concentration gave significant shoot dry weight and dry matter accumulation in potato plants after harvest. In present investigation showed that chlorophyll content was increased with 0.5% K foliar application. Lower concentration of Zn and phosphorus increased chl. content in wheat (Alam *et al.,* 2002). The application of MOP and anti-transpirant improved the concentration of chlorophyll over control. However Chl 'b' and total Chl 'a+b' and their ratio didnot show any increase on MOP and anti-transparent over control (Barman, 2011). Romheld and EL- Fouly (1999) also represented that efficiency of foliar application is higher than of soil fertilization. The presence of sufficient zinc is associated with the production of carbonic anhydrase enzyme, as noted by Abou-EL-Nour in 2002. Carbonic anhydrase plays a crucial role in photosynthesis. When potassium was applied, there was a positive impact on photosynthetic pigments, including Chl 'a,' Chl 'b,' and carotenoids. This increase in chlorophyll pigments aligns with findings from previous studies conducted by Quary *et al*. (2006) and Broadly *et al*. (2007). However, it's worth noting that foliar application of potassium can have a negative effect on chlorophyll content, potentially due to the antagonistic relationship between potassium and magnesium. Reduced magnesium levels in plant leaves often lead to the inhibition of chlorophyll biosynthesis. Zinc-deficient leaves typically appear light green, reflecting their lower chlorophyll concentration, as demonstrated by Hisamitsu *et al*. 2001.

In the current investigation, we observed a significant enhancement in grain yield and various yield components as a result of foliar application of potassium (K). Our findings align with those of Goud *et al.* (2014), who reported similar outcomes in chickpea, where potassium application led to increased yield and related attributes such as 100-grain weight, biological yield, and grain yield. Additionally, Ganga *et al.* (2014) also corroborated our results, indicating that the application of potassium resulted in higher 100-seed weight, seeds per pod, biological yield, and grain yield. Regarding foliar potassium (K) application, we observed improvements in various yield-related characteristics. The enhanced yield and associated attributes can be attributed to increased nutrient availability, K supply, growth hormones, micronutrients, phytohormones, growth-promoting substances such as ascorbic acid, phenols, and minerals, as well as cytokinins and gibberellic acid derived from Multi-Layer Extract (MLE) (Makkar *et al*., 2007). These findings align with the research of Chattha *et al.* (2015) and Yasmeen *et al.* (2018), who similarly reported increased grain weight and grain yield following K application. Additionally, Mathew (2016) and Ahmad *et al.* (2016) demonstrated improved crop yields through the utilization of MLE. Our research findings align with previous studies. Afzal *et al*. (2015) observed improved wheat yield with the application of 3% MLE during tillering and booting stages, which is consistent with our results. Similarly, Yasmeen *et al*. (2018) reported increased boll weight, biological yield, and lint yield in cotton with combined foliar K application, supporting our findings. Organic fertilizer application, as demonstrated by Abd El-Fattah *et al.* (2022), enhances soil fertility and crop productivity under stress conditions, which is in line with our observations. Our results also resonate with the research conducted by Ben Mimoun and Marchand (2013), who noted a 12% and 16% yield increase in apples and pears, respectively, in response to foliar potassium application compared to untreated trees.

Haggag *et al.* (2016) found that various treatments, including potassium citrate foliar application, effectively increased the yield of 'Canino' apricot trees compared to the control group, a result that complements our findings. Moreover, Vijay *et al.* (2017) indicated that foliar applications of potassium nitrate and potassium sulphate significantly boosted the yield of 'Jaffa' sweet oranges compared to water spray as a control. In a similar vein, Jawandha *et al.* (2017) reported an improvement in plum tree fruit yield through foliar application of potassium nitrate, further supporting our research outcomes.

Conclusion

The foliar application of 0.5% K solution at booting stage influences significantly the morpho physiological, biochemical and yield attributes performances of wheat. Therefore foliar application of 0.5% K solution (once time), i.e. at growing stage is recommended for best growth of wheat under agro-climate zone of Rohtak. The genotype HD 2967 showed maximum increased under 0.5% K foliar application while WH1105 was exerted minimum increase in morpho-physiological and biochemical in wheat. Foliar application of K at all critical stages improved all the growth parameters, photosynthetic and yield attributes pigments being more responsive.

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Author contributions: All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Neha Yadav. The first draft of the manuscript was written by Neha Yadav. Review and editing are performed by Heena, Ajay Kumar, Mamta Sawariya. Supervision are performed Sunder Singh Arya. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declarations

Conflict of interest: The authors declare there is no conflict of interest.

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