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Evaluation of performance and yield of modern wheat cultivars through foliar nutrition strategies for sustainable agricultural development

Md. Masud Rana[1]
Md. Mejbah Uddin[2]
Md. Aminul Hoque[3+]
Most. Serajam Monira[4]

[1,2,3,4]*Department of Agronomy & Agricultural Extension, University of Rajshahi, Rajshahi-6205, Bangladesh.*
[1]*Email: mrana64196@gmail.com*
[2]*Email: mejbah155@gmail.com*
[3]*Email: aminulh2@yahoo.com*
[4]*Email: munira3672@gmail.com*


(+ Corresponding author)

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ABSTRACT

This research investigates the evaluation of performance and yield of modern wheat cultivars through foliar nutrition strategies for sustainable agricultural development. The research. This research, conducted from November 2022 to March 2023 at the University of Rajshahi, evaluated the impact of reduced fertilizer through foliar feeding on two advanced wheat cultivars using a randomized complete block design with five treatments: T_1 (control), T_2 (1500 ml liquid fertilizer per hectare), T_3 (2500 ml liquid fertilizer per hectare), T_4 (1500 ml liquid fertilizer with 2.5 kg urea per hectare as spray), and T_5 (1500 ml liquid fertilizer with 2.5 kg urea and 1.5 kg muriate of potash per hectare as spray). The study found that the highest plant height (97.86 cm), chlorophyll content (48.20 mg m^{-2}), and yield attributes, including plant height (99.36 cm), total tillers per plant (8.057), productive tillers per plant (5.000), productive spikelets per spike (18.610), spike length (15.777 cm), 1000 grain yield (41.183 g), grain yield (3.247 t ha^{-1}), straw yield (7.738 t ha^{-1}), biological yield (10.985 t ha^{-1}), and harvest index (29.558%), were achieved with T_5. The study aimed to assess the efficacy of modern wheat varieties under reduced fertilizer conditions, highlighting the potential for sustainable wheat fertilizer management, particularly under drought conditions.

Contribution/Originality: The results of this study enhance our understanding of the performance of advanced heat-tolerant wheat varieties for drought-prone regions in Bangladesh.

1. INTRODUCTION

Wheat is one of the most important cereal crops and a staple food for millions of people. Among the major crops for consumption, wheat ranked second to rice in terms of overall production (Meherunnahar, Chowdhury, Hoque, Satter, & Islam, 2018). For approximately two billion people globally, constituting 36% of the world's population, it serves as the paramount staple food, and twenty percent of the daily calories consumed by approximately 55% of the worldwide population come from wheat (Yadav et al., 2021). In the 2022-2023 years, Bangladesh produced a total of 1.1 million metric tons of wheat on 310 thousand hectares of agricultural land, according to the (USDA (United States Department of Agriculture), 2023). In accordance with food ministry data, between the July 1 and January 18, 2023-24, both private and public agencies importing 27.49 lakh tons of wheat because of a strong demand from the public at large. This is an 84-percentage point rise from the 14.92 lakh tons imported during the identical time frame in the previous year (Daily Star, 2024). This particular grain exhibits nutrition rich in many essential elements. As detailed by Godswill (2019) it has a mean protein content of 10.39% and a moderate fat content of 1.33%. The fibre content in the same study is a commendable 3.14%, promoting digestive health. Carbohydrates are present in 74.22% of the composition (Ahmed, Lydia, & Campbell, 2012) ensuring continuous energy delivery. Additionally, it provides 13.35 mg/100g of calcium, which is essential for bone strength, according to research by Meherunnahar et al. (2018).

The process of feeding plants by saturating their leaves with liquid fertilizer is known as foliar feeding. People widely recognize that plants can absorb vital nutrients through their foliage. Both the epidermis and the stomata of the plant's leaves absorb it. Although the epidermis is still capable of full substance absorption, the stomata facilitate faster elemental movement, and plants can also absorb nutrients through their bark. A higher metabolic rate and more accurate movement of major as well as minor nutrients, such as NPK (nitrogen, phosphorus, potassium), via leaf tissue to the establishing particles are expected to come from the foliar administration of these nutrients, which is more efficient than applying them to the soil as it also prevents the gradual loss of the aforementioned nutrients in leaves (Mandre, Singh, Dubey, Waskle, & Birla, 2020). Because leaves can absorb nutrients better than older roots did as wheat grew, many studies have looked at how nutrients affect wheat grain development when applied to the leaves (Kutman, Yildiz, Ozturk, & Cakmak, 2010; Uscola, Villar-Salvador, Oliet, & Warren, 2014; Visioli et al., 2018). In order to decrease the number of fertilizers administered and nevertheless preserve their benefits, the tendency began to depend on the primary application of the defined fertilizer as soil fertilization and substitute the supplemental fertilizers with fertilization of the foliage (Haytova, 2013). Though soil fertilizer administration achieved only about 10% effectiveness, feeding the foliage resulted in roughly 95% effectiveness in nutrient utilization, according to Tukey, Ticknor, Hinsvark, and Wittwer (1952).

Though foliar application has become commonplace as well as widely used in developed agricultural countries, not much study has been conducted in Bangladesh about the administration of urea along with additional nutrients in the form of liquid fertilizers to retain urea to feed wheat via foliage-sprayed application. Farmers may experience urea shortages during the seeding process. Under such circumstances, applying plant fertilizer topically to crops is advantageous and reasonably priced (Kahn, Samiuilah, & Aziz, 1993). The investigation posits that applying water-soluble fertilizers is liquid from topically can enhance plant effectiveness and increase fertilization efficacy. The purpose of this study was to evaluate the efficacy of foliar fertilizer application on wheat yields, considering the previously mentioned concern.

2. MATERIALS AND METHODS

Through foliar nutrition, this study looked at what happens to the growth and yield of advanced wheat cultivars when fertilizer use is reduced. The research was conducted at the Agronomy Field Laboratory within the Department of Agronomy and Agricultural Extension at the University of Rajshahi, spanning from November 2022 to March 2023.

2.1. Description of the Experimental Site

2.1.1. Location and Climate

The experimental site is located at 24°22'36" north latitude and 88°38'27" east longitude, in Agro-Ecological Zone 11, 20 meters above sea level in the High Ganges River floodplain. It lies on flat land with effective drainage and flood resistance. The soil is sandy at pH 8.5, with 1.44% organic matter, 0.09% total nitrogen, 17.61 ppm available phosphorus, 0.21 ppm potassium, 9.36 ppm sulfur, and 0.33 ppm zinc F. Tropical rainfall, characterized by distinct seasons, characterizes the atmospheric condition. Approximately 90% of the annual rainfall occurs during the monsoon season from May to October, with rainfall occurring during the dry winter months from November to February, accounting for about 2% of the total annual rainfall. The temperature is stable at about 27°C. Monthly temperatures vary, with a minimum of 10°C in January and as high as 30°C in April, July, and August.

2.2. Materials of the Experiment

2.2.1. Planting Material

The current experiment utilized two contemporary wheat varieties, namely BARI Gom 33, where BARI stands for Bangladesh Agricultural Research Institute, and BWMRI Gom 1, sourced from the Bangladesh Wheat and Maize Research Institute (BWMRI) regional office in Shaympur, Rajshahi-6212.

2.2.2. Chemical Materials

Md. Arif Hossain Khan, Joint Director of the Fertilizer Management Division at the Bangladesh Agricultural Development Corporation (BADC) in Rajshahi, developed Magic Growth (MG) and advanced liquid fertilizer, to develop a broad spectrum of essential nutrients for optimal plant growth and development. In the experiment, Magic Growth was utilized as a foliar spray at a concentration of 4 g/L of water in combination with urea. The fertilizer's nutrient profile includes nitrogen (10.51%), phosphorus (5.58%), potassium (6.33%), sulphur (0.10%), zinc (0.16%), copper (0.04%), iron (0.0006%), manganese (0.006%), boron (0.25%), calcium (0.07%), and magnesium (0.007%), providing a comprehensive solution to enhance plant health and productivity.

2.3. Experimental Details

2.3.1. Treatment

The experiment involved two variables: variety and fertilizer management. These are-

Factor A:

1. BARI Gom 33 (V_1).
2. BWMRI Gom 1 (V_2).

*BARI = Bangladesh Agricultural Research Institute

* BWMRI = Bangladesh Wheat and Maize Research Institute

Factor B:

1. Control (T_1).
2. MG* 1500ml ha^{-1} (T_2).
3. MG 2500ml ha^{-1} (T_3).
4. MG 1500ml+Urea** 2.5kg ha^{-1} (T_4).
5. MG 1500ml+Urea 2.5kg+MoP*** 1.5kg ha^{-1} (T_5).

*MG= Magic Growth (liquid fertilizer).

**urea and ***Mop (muriate of potash) as liquid spray.

2.3.2. Design and Layout of the Experiment

The experiment was conducted using a Randomized Complete Block Design (RCBD) with 3 replications. Each plot had dimensions of 2m×2m, leading to a total of 30 plots.

2.4. Growing of Crops

2.4.1. Land Preparation

On November 24, 2022, a tractor pulled a disc plough to prepare the experimental field. The field layout was done on November 29, 2022 as per experimental design. On November 30, 2022, seeds were sown at a rate of 120 kg per hectare. Continuous seeding was carried out with a manual soil-covered 20 cm × 4 cm spacing. The laboratory germination test of the seed sample was conducted prior to sowing, and it was found that the germination percentage of the seed was 85. The field was kept free from bird damage to the seeds that were just beginning to germinate.

2.4.2. Fertilizer Application

The experimental plots were prepared using the recommended amounts of fertilizer, which were 220 kg ha^{-1} of urea, TSP (Triple Super Phosphate): 180 kg ha^{-1}, MoP (Muriate of Potash): 50 kg ha^{-1}, and gypsum: 120 kg ha^{-1}. During the final stage of land preparation, one-third of the urea and the entire quantities of TSP, MoP, and gypsum were meticulously integrated into the soil. The remaining half of the urea was subsequently applied during the initial irrigation at the CRI (Crown Root Initiation) stage (20 days after sowing) while adhering to treatment specifications, which necessitated omitting at least one-third of the urea. Liquid fertilizer was sprayed three times, e.g., at 20 DAS (CRI), 55 DAS (tillering), and 80 DAS (panicle initiation). When applying urea and MoP for T_4 and T_5 treatments, they were combined with liquid fertilizer containing water. To prevent leaf burning, a spray was applied in the afternoon.

2.5. Harvesting

Next, the crop was harvested according to the plot. BWMRI Gom 1 reached out maturity on March 28,2023 (120 DAS), while BARI Gom 33 reached maturity on March 24, 2023 (116 DAS). Using a sickle to chop the crop at ground level allowed for successful harvesting. Each plot's harvested crops were wrapped individually, labeled, and transported to the Agronomy Farm's spotless threshing floor. For the plants that were sampled, the same process was used.

2.6. Sampling and Data Processing

2.6.1. Sampling

We utilized the SPAD (Soil and Plant Analyzer Development) 502 Plus Chlorophyll Meter to take measurements of the amount of chlorophyll. In the case of yield data, when 90% of the crops turned a golden yellow color and produced a crunching sound when the seeds were squeezed between teeth, the crop was considered mature. Before harvesting, three plants were randomly selected and removed from each plot to gather the necessary data.

2.6.2. Data Analysis

All of the growth, yield, and yield-contributing traits that had been collected were tallied, combined, and statistically analysed. IBM SPSS software was utilized for the analysis of variance (ANOVA). Duncan's Multiple Range Test (DMRT), as outlined by Gomez and Gomez (1984) was employed to analyse the variations in means among the treatments.

3. RESULT & DISCUSSION

3.1. Growth Parameters

3.1.1. Effect of Variety on Plant Height

Plant height was non-significant due to varietal variation at all the intervals of DAS (Days After Sowing). According to that table, plant height in V_2 was generally at its highest 22.74, 52.12, 92.38, and 94.81 cm on days 20, 40, 60, and 80 DAS, respectively, while V_1 produced the lowest value (22.71, 50.68, 92.06 and 94.38 cm) on those same days (Table 1).

3.1.2. Effect of Variety on Chlorophyll Content

Chlorophyll content in wheat plants differed insignificantly due to varietal variation at all the intervals of DAS. From that table, it was generally found that chlorophyll content was at its maximum (43.71, 45.88, and 46.80 mg m^{-2}) in V_2 at 20, 40, and 60 DAS, while V_1 produced a minimum value (42.90, 44.83 and 45.90 mg m^{-2}) at those days (Table 1).

Table 1. Effect of variety on plant height and chlorophyll content.

Treatment	Plant height (cm)				Chlorophyll content (mg m^{-2})		
	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS
V_1	22.705	50.678	92.056	94.377	42.900	44.833	45.900
V_2	23.744	52.123	92.377	94.811	43.707	45.880	46.800
Level of significance	NS	NS	NS	NS	NS	NS	NS
CV (%)	9.19	11.94	5.05	4.75	2.11	1.85	2.15

Note: "In each column, treatment means followed by the same letter (e.g., a, b) are not significantly different from each other at the 5% level of significance according to Duncan's multiple range test (DMRT). Means with different letters indicate significant differences. NS = Non-significant; CV = Coefficient of variation; DAS = Days after sowing."

3.1.3. Effect of Liquid Fertilizer on Plant Height

The fertilization levels at 60 and 80 DAS caused a substantial variation in plant height, with the exception of 20 and 40 DAS (Table 2). The T_5 treatment showed the maximum plant height (95.970 cm) at 60 DAS, which is statistically equal to that of the T_2 treatment (94.31 cm). Additionally, T_1 treatment, which is statistically equivalent to T_3 treatment, show the lowest plant height, at 88.473 cm. T_4, recorded the second-highest plant height. At 80 DAS, the peaked plant height (97.862 cm) was obtained from T_5, and it was statistically identical with that of T_2 (96.998 cm). While T_3 displayed the shortest plant height at 90.612 cm, it statistically paralleled T_1, which measured 91.61 cm. These results align with research conducted by Yassen, Abou El-Nour, and Shedeed (2010); Woolfolk et al. (2002) and Arif, Chohan, Ali, Gul, and Khan (2006) demonstrating that the application of various nutrients via foliar spraying, either individually or in combination, led to a notable enhancement in the plant height of wheat crops.

Table 2. Effect of liquid fertilizer on plant height at different DAS.

Treatment	Plant height (cm)			
	20DAS	40DAS	60DAS	80DAS
T_1	23.612	49.778	88.473b	91.612b
T_2	22.622	51.807	94.307a	96.998a
T_3	23.612	49.862	88.500b	90.612b
T_4	22.585	52.833	93.833ab	95.887ab
T_5	23.693	52.722	95.970a	97.862a
Level of significance	NS	NS	0.05	0.05
CV (%)	9.19	11.94	5.05	4.75

Note: In each column, treatment means followed by the same letter (e.g., a, b) are not significantly different from each other at the 5% level of significance according to Duncan's Multiple Range Test (DMRT). Means with different letters indicate significant differences. NS = Non-significant; CV = Coefficient of variation; DAS = Days after sowing."

3.1.4. Effect of Liquid Fertilizer Chlorophyll Content

The application of liquid fertilizer at various stages after sowing significantly influenced the chlorophyll levels. At 20 DAS, T_5 exhibited the highest chlorophyll content (44.633 mg m^{-2}), whereas T_3 showed the lowest (42.167 mg m^{-2}). T_2 ranked second with a chlorophyll content of 43.80 mg m^{-2}. By 40 DAS, T_5 recorded the highest chlorophyll content (47.217 mg m^{-2}), while T_3 exhibited the lowest (44.183 mg m^{-2}), statistically equivalent to T_1. At 60 DAS, a similar pattern of variation in chlorophyll content had been observed, i.e., a maximum in T_5 (48.200 mg m^{-2}) and the lowest value of plant height in T_3 (45.167 mg m^{-2}) (Figure 1). The explicit participation of potassium, phosphorus, and nitrogen in the synthesis of chlorophyll is the reason for these variations. The essential component of chlorophyll is nitrogen, whereas other nutrients support general development and growth. Furthermore, micronutrients such as manganese, boron, zinc, etc. Besides these, foliar fertilization helps to direct nutrient absorption without causing stress towards moisture deficits.

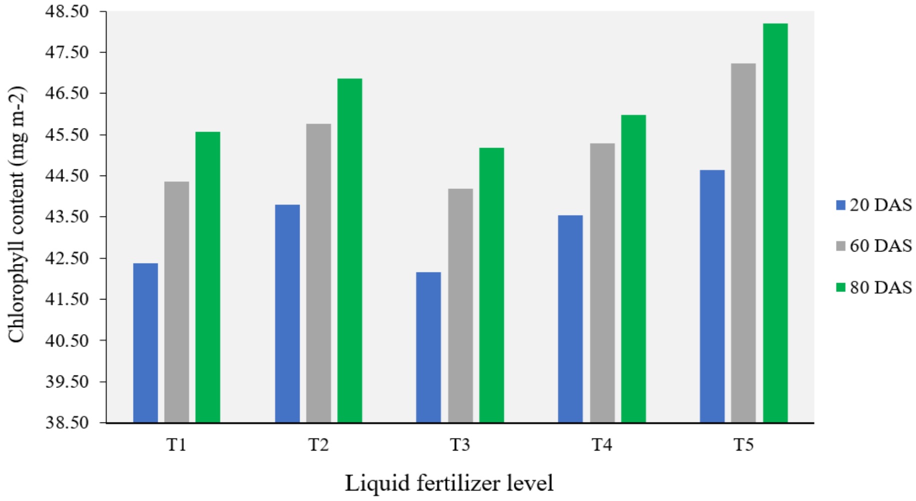

Figure 1. Effect of liquid fertilizer on plant height and chlorophyll content in different DAS.

3.1.5. Interaction Effect of Variety and Liquid Fertilizer on Plant Height

The interaction effect between variety and liquid fertilizer exhibited negligible influence on plant height throughout all DAS observations (Table 3). Prior to application, the V_2T_1 interaction produced the tallest plants at 25.53 cm, while the V_1T_1 interaction produced the shortest plants at 20 DAS, measuring 21.89 cm. After application of LF (Liquid Fertilizer), the highest plant height (56.44, 98.11, and 99.89 cm) was obtained in V_2T_4 at 40, 60, and 80 DAS, respectively, whereas lowest value was obtained in V_2T_1 (47.56 cm), V_2T_1 (84.89 cm), and V_2T_3 (90.00 cm) at 40, 60, and 80 DAS, respectively (Table 3).

3.1.6. Interaction Effect of Variety and Liquid Fertilizer on Chlorophyll Content

If you look at the table, you can see that the interaction between variety and fertilization levels had a big effect on chlorophyll content at 20 DAS, but not at 40 or 60 DAS. Notably, at 20 DAS, the interaction of V_1T_5 yielded the highest chlorophyll content (45.133 mg m^{-2}), while V_1T_3 exhibited the lowest value (40.70 mg m^{-2}), statistically akin to V_1T_1 (42.37 mg m^{-2}). Moving to 40 DAS, V_2T_5 showcased the highest chlorophyll content (47.467 mg m^{-2}), contrasting with the lowest value (43.633 mg m^{-2}) observed in V_1T_3 (Table 3). At 60 DAS, the highest chlorophyll content (48.333 mg m^{-2}) was obtained in V_2T_5, and the lowest value (44.600 mg m^{-2}) was obtained in V_1T_3 (Table 3).

Table 3. Interaction effect of variety and liquid fertilizer on plant height and chlorophyll content.

Treatment	Plant height (cm)				Chlorophyll content (mg m^{-2})		
	20DAS	40DAS	60DAS	80DAS	20DAS	40DAS	60DAS
V_1T_1	21.890	52.000	92.057	94.557	42.367c	43.900	45.300
V_1T_2	22.243	52.723	94.613	96.997	43.100bc	44.400	45.533
V_1T_3	23.613	48.553	88.777	91.223	40.700d	43.633	44.600
V_1T_4	21.947	49.223	89.557	91.887	43.200bc	45.267	46.000
V_1T_5	23.833	50.890	95.277	97.223	45.133a	46.967	48.067
V_2T_1	25.333	47.557	84.890	88.667	42.400c	44.800	45.833
V_2T_2	23.000	50.890	94.000	97.000	44.500ab	47.100	48.167
V_2T_3	23.610	51.170	88.223	90.000	43.633abc	44.733	45.733
V_2T_4	23.223	56.443	98.110	99.887	43.867abc	45.300	45.933
V_2T_5	23.553	54.553	96.663	98.500	44.133ab	47.467	48.333
Level of significance	NS	NS	NS	NS	0.05	NS	NS
CV (%)	9.19	11.94	5.05	4.75	2.11	1.85	2.15

Note: "In each column, treatment means followed by the same letter (e.g., a, b, c, d) are not significantly different from each other at the 5% level of significance according to Duncan's Multiple Range Test (DMRT). Means with different letters indicate significant differences. NS = Non-significant; CV = Coefficient of Variation; DAS = Days After Sowing."

3.2. Effect of Variety on Yield and Yield Contributing Characters

3.2.1. Plant Height

Variety at harvest had a considerable impact on wheat plant height. However, the data revealed that V_2 yielded the tallest plant, measuring 98.111 cm. On the other hand, V_1 produced the smallest plant structure (96.655 cm) (Table 4).

3.2.2. Total Tillers Plant^{-1}

Variety did not exert a significant influence on the total number of tillers per plant. However, V_2 exhibited the highest reported total number of tillers per plant at 6.199, whereas V_1 showed the fewest at 6.067 tillers per plant (Table 4).

3.2.3. Number of Effective Tillers Plant^{-1}

The varietal effect on the number of effective tillers per plant was found to be non-significant. Based on the findings, variety V_2 had the most effective tillers per plant (4.089), while variety V_1 had the fewest (3.801) (Table 4).

3.2.4. Number of Spikelet's Spike^{-1}

The results indicate that the influence of variety on the number of spikelet's per spike was not statistically significant. Based on the results, it was determined that variety V_2 had the greatest number of spikelet's (18.644). In terms of the quantity of spikelet's spike^{-1} produced, variety V_1 ranked second (18.355) (Table 4).

3.2.5. Number of Effective Spikelet's Spike^{-1}

The results of the analysis of variance showed that variation had no discernible impact on the spike in the number of infertile spikelet's. However, despite the lack of statistical significance, variety V_1 yielded the highest number of productive spikelet's per spike (16.421), while variety V_2 exhibited the fewest effective spikelet's per spike (16.133), as shown in Table 4.

3.2.6. Spike Length

Variety did not significantly impact spike length. According to Table 4, variation V_2 produced the biggest spike length (14.445 cm), while variety V_1 produced the smallest (14.089 cm).

3.2.7. 1000-Grain Weight

Varietal differences did not significantly affect the 1000-grain weight, according to the results. Overall, it was found that variety V_2 had a maximum 1000-grain weight (40.527g). However, variety V_1 had the least 1000 grain weight (40.267g) (Table 4). This could be due to its underdeveloped grain and reduced grain weight.

3.2.8. Grain Yield

The primary goal of wheat farming is to achieve a high grain yield. This yield is influenced by various factors, including the number of efficient tillers per square meter, the number of spikes per plant, the number of productive spikelets' per spike, the number of grains per spike, and the weight of 1000 grains. Variety did not continue to have a major impact on grain output. It was noted from the results that variety V_2 had the highest grain yield (2.779 t ha^{-1}). Conversely, V_1 yielded the second-highest grain (2.616 t ha^{-1}) according to Table 4.

3.2.9. Straw Yield

Varietal differences had negligible impact on straw yield. The variety V_2 yielded the maximum amount of straw (7.496 t ha^{-1}). Whereas V_1 had the smallest straw yield (7.264 t ha^{-1}) (Table 4).

3.2.10. Biological Yield

Varietal variation has a significant impact on wheat's biological yield. Nevertheless, the variety V_2 had the greatest biological output (10.275 t ha^{-1}) according to the results. V_1 had the least biological yield (9.880 t ha^{-1}) according to Table 4.

3.2.11. Harvest Index

Variations in variety did not significantly affect the harvest index. Variety V_2 had the greatest harvest index (27.048%). On the other hand, V_1 had the shortest harvest index (26.475%) (Table 4).

Table 4. Effect of variety on yield attributes of wheat.

Treatment	Plant height (cm)	Total tiller (No.)	No. of effective tiller	No. of spikelets' spike^{-1}	No. of effective spikelets' spike^{-1}	No. of non-effective spikelets' spike^{-1}	Length of spike (cm)	1000 grain weight	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	96.655^{b}	6.067	3.801	18.355	16.421	1.934	14.089	40.267	2.616	7.265	9.881b	26.476
V_2	98.111^{a}	6.199	4.089	18.644	16.133	2.511	14.445	40.527	2.779	7.496	10.275^{a}	27.049
Level of significance	0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.05	NS
CV (%)	1.21	10.42	15.39	4.27	2.74	31.79	5.84	1.49	17.35	7.01	4.74	14.68

Note: "In each column, treatment means followed by the same letter (e.g., a, b) are not significantly different from each other at the 5% level of significance according to Duncan's multiple range test (DMRT). Means with different letters indicate significant differences. NS = Non-significant; CV = Coefficient of variation; DAS = Days after sowing."

3.3. Effect of Liquid Fertilizer on Yield and Yield Contributing Characters

3.3.1. Plant Height

Liquid fertilizer had a considerable effect on plant height (Table 5). The control dose yielded the smallest plant structure (95.277 cm), while T_5 yielded the tallest plant (99.361 cm), which was statistically identical to T_4 (99.11 cm). Conversely, the second and third highest plant heights were obtained with T_3 (97.00 cm) and T_2 (96.17 cm) doses. The outcomes of Soylu et al. (2005) who saw improved wheat vegetative growth with foliar N treatment, are consistent with our observations. Likewise, foliar spraying of several nutrients separately or in combinations resulted in a substantial rise in the plant height of the wheat crop, as documented by Kenbaev and Sade (2002) and Arif et al. (2006).

3.3.2. Total Tillers Plant^{-1}

Liquid fertilizer had a substantial impact on the total number of tillers plant^{-1}. In the T_5 treatment, the greatest number of total tillers plant^{-1} (8.057) was recorded. T_2 dose produced the fewest (Table 5) total tillers plant^{-1} (4.333), while T_4 (6.94), T_3 (6.44), and T_1 (4.89) produced the second, third, and fourth-highest numbers of tillers plant^{-1}, respectively. Our results were in line with those of Khan, Memon, Imtiaz, and Aslam (2009) who found that foliar feeding increases crop absorption of nutrients and produces greater functional tillers.

3.3.3. Number of Effective Tillers Plant^{-1}

The number of effective tillers per plant is a crucial characteristic of wheat, directly impacting its yield. The findings of this study revealed that liquid fertilizer significantly influenced this trait. It was observed that treatment T_5 yielded the highest number of effective tillers per plant (5.000), while the lowest number (3.112) was recorded in T_1, statistically equivalent to T_2. Whereas, T_4 produced the second highest (4.168) effective tiller plant^{-1}, which is statistically identical to T_3 (Table 5). These findings support the findings published by Ahmed, Ahmed, Mohamed, and Tawfik (2011); Zaki, Gomaa, Radwan, Hassanein, and Wali (2012) and Zaki, Ahmed, and Hassanein (2015) who found that foliar fertilizing of NPK increased the number of productive tillers and the production of grain and straw.

3.3.4. Number of Spikelets' Spike^{-1}

The number of spikelets' per spike is considered the most influential factor affecting grain yield. Liquid fertilizer induced significant variability in the number of spikelets' per spike. According to the findings, treatment T_5 exhibited the highest number of spikelets' per spike (20.333), statistically similar to T_4, while treatment T_1 showed the lowest number (17.333), statistically akin to T_2 and T_3 (Table 5). Additionally, T_4 was noted to produce the second-highest number of spikelets' per spike, as observed in the same table. The reason for this might be because there is more nitrogen available, which influences higher levels of photosynthesis and lessens grain abortion and fierce competition among grains. Rahman, Rahman, Hasan, Begum, and Sarker (2014) and these findings are in agreement.

3.3.5. Number of Effective Spikelets' Spike^{-1}

The count of effective spikelets' per spike is considered the foremost yield determinant, influencing a substantial portion of the yield reduction per unit area. The application of liquid fertilizer significantly influenced the number of productive spikelets' per spike. As per the results, treatment T_5 yielded the highest number of viable spikelets' per spike (18.610), whereas treatment T_1 recorded the lowest (Table 5) count of functional spikelets' per spike (15.053).

3.3.6. Spike Length

Liquid fertilizer had a significant variation in terms of spike length. From the result, it was noted that the longest spike length (15.777cm) was produced by T_5 and the shortest spike length (12.862 cm) was produced by T_1 (Table 5). On the contrary, T_4 produced the second longest spike length (14.585 cm) which is statistically identical to T_3. The phenomenon arises from the deeper absorption of both water and nutrients, leading to a greater accumulation of dry matter. The findings align with those of Wagan et al. (2017).

3.3.7. 1000-Grain Weight

Liquid fertilizer had a considerable impact on the 1000-grain weight. In the T_5 treatment, the maximum 1000-grain weight (41.183g) was observed. It could be the result of a balanced buildup of various elements in the grain, leading to a larger grain weight. Yet, the control dose yielded the least 1000-grain weight (39.367g). However, T_4 yielded the second-highest 1000-grain weight (40.933 g), which is comparable to T_3 statistically (Table 5). According to Hamouda, El-Dahshouri, Manal, and Thalooth (2015) this could also be because potassium functions to increase cell division and growth, as well as speed up photosynthesis and transfer photosynthesis material to grains. It thus fills grains, increases particle size, and ultimately increases grain weight. The purpose of this compound is to enhance nutrient transport from source to sink, boost the functioning of enzymes, and improve the uptake of nutrients in vegetative tissues (Taiz & Zeiger, 2006). This outcome agrees with Bahmanyar and Ranjbar (2008) and Hamouda et al. (2015).

3.3.8. Grain Yield

Wheat grain yield greatly increased as a result of liquid fertilizer (Figure 2). The range of the grain yield was 2.165-3.246 t ha^{-1}. Treatment T_5 demonstrated the highest grain yield, harvesting 3.247 t ha^{-1}, while the control treatment, T_1, yielded the lowest amount of grain at 2.165 t ha^{-1}. Conversely, treatment T_4 recorded the second-highest grain yield, garnering 2.957 tons per hectare. The application of liquid fertilizer enhanced grain yield, according to study results. This could be due to the key yield-contributing characteristics that are beneficial to increased grain production. Control T_1 had the lowest wheat grain yield because of the unbalanced uptake of critical components, which hindered plant growth and development and eventually led to poor yield attribute performance. Several experts say that foliar spraying increased crop yield by making nutrients easier to reach during the plant's critical growth stage (Aali, Noori, & Asl, 2013) and by making starches and moving them around (Gholami, Akhlaghi, Shahsavani, & Farrokhi, 2011; Rahman et al., 2014).

3.3.9. Straw Yield

The application of liquid fertilizer did not exhibit a significant impact on the production of straw. As per the results, treatment T_5 yielded the highest straw yield at 7.738 t ha^{-1}, a figure statistically akin to treatment T_3. Conversely, treatment T_1 generated the lowest straw yield at 6.983 t ha^{-1}, a value statistically similar to treatment T_2. Less effective tillers per plant and reduced plant height could potentially account for this discrepancy. It is plausible that the highest straw yield observed in treatment T_5 could be attributed to its maximum plant height and the greatest number of productive tillers per plant (Figure 2).

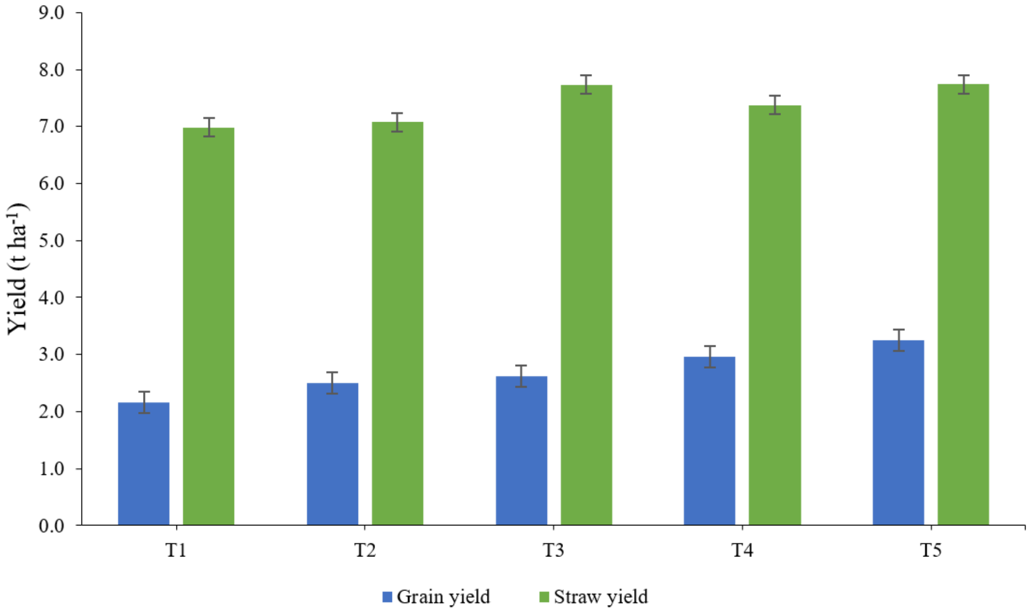

Figure 2. Effect of liquid fertilizer on grain and straw yield.

3.3.10. Biological Yield

Using liquid fertilizer resulted in a significant differences in biological yield. According to the findings, the control dose had the lowest biological yield (9.148 t ha^{-1}) while treatment T_5 had the highest biological yield (10.985 t ha^{-1}). This occurred as a result of T_5 producing more grain and straw and having the highest biological yield, while T_1 produced less grain and straw and had the lowest biological yield (Table 5). However, the second-highest biological production (10.353 t ha^{-1}) was obtained with the T_3 treatment.

3.3.11. Harvest Index

Applying liquid fertilizer significantly varied the harvest index. Based on the results, T_5, which is statistically equivalent to T_4, had the highest harvest index (29.555%), whereas T_1 had the lowest harvest index (23.665%).

Table 5. Effect of liquid fertilizer levels on yield and yield attributes of wheat.

Treatment	Plant height (cm)	Total tiller	No. of effective tiller	No. of spikelet's spike^{-1}	No. of effective spikelet's spike^{-1}	Length of spike (cm)	1000 grain weight	Biological yield (t ha^{-1})	Harvest index (%)
T_1	95.277^{c}	4.888^{c}	3.112^{c}	17.333^{b}	15.053^{c}	12.862^{c}	39.367^{c}	9.148^{c}	23.665
T_2	96.166^{bc}	4.333^{c}	3.278^{bc}	17.833^{b}	15.500^{c}	13.528^{bc}	40.017^{bc}	9.572^{bc}	26.083
T_3	97.000^{b}	6.443^{b}	4.167^{ab}	17.777^{b}	15.500^{c}	14.583^{ab}	40.483^{ab}	10.353^{a}	25.338
T_4	99.111^{a}	6.943^{b}	4.168^{ab}	19.222^{a}	16.722^{b}	14.585^{ab}	40.933^{ab}	10.332^{ab}	28.617
T_5	99.361^{a}	8.057^{a}	5.000^{a}	20.333^{a}	18.610^{a}	15.777^{a}	41.183^{a}	10.985^{a}	29.555
Level of significance	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	NS
CV (%)	1.21	10.42	15.39	4.27	2.74	5.84	1.49	4.74	14.68

Note: "In each column, treatment means followed by the same letter (e.g., a, b, c) are not significantly different from each other at the 5% level of significance according to Duncan's multiple range test (DMRT). Means with different letters indicate significant differences. NS = Non-significant; CV = Coefficient of variation; DAS = Days after sowing."

4. CONCLUSION

A vital component of enhanced crop yield technology is fertilizer (Saifullah, Ranjha, Yaseen, & Akhtar, 2002). A bountiful crop's output is thought to be mostly dependent on applying the right level of fertilizer. In comparison to soil fertilization, fertilization of foliage offers numerous benefits and can make up for a deficiency in soil fertilization. Foliage application by spraying, which is frequently advised in production, can increase crop intake of nutrients and effectiveness in transforming as an adjunct to basic fertilization.

In order to increase crop productivity, foliar fertilization can supplement and ensure that nutrients are available to crops (Arif et al., 2006).

Ali (2012) observed that the plant's foliage absorbed nutrients more effectively than its roots through the soil itself. When nutrients are given to crop foliage, their intake rate and effectiveness in use are significantly greater than when fertilizers are administered to the soil (Zhang et al., 2010). Due to the complex soil conditions and soil fertilization, the crop's efficiency in absorbing nutrients was poor; therefore, Neuhaus, Geilfus, and Mühling (2014) recommend applying foliar magnesium and iron fertilizer. The application through the foliage of potassium fertilizer has several advantages over soil K fertilization, including lower costs and no restrictions on irrigation settings.

Additionally, potassium fertilizer can be used with spray administration for synchronized insect prevention, which combines three preventive measures into a single spraying session. Nitrogen applied foliarly has a significant impact on seed quality as well as yield (Wilhelm, McMaster, & Harrell, 2002). Increased seed output was seen when N was applied foliarly during the milky and blooming stages (Zečević, Đokić, Knežević, & Mićanović, 2004). N is essential for seed protein production as well as plant growth; the crop's ability to get it from the soil or from fertilizer has a significant impact on grain protein concentrations (Grant, Gauer, Bailey, & Gehl, 1991). Researchers have demonstrated that foliar fertilization primarily integrates nitrogen into storage proteins, thereby influencing bread quality.

One of the most important quality characteristics that can affect how wheat marketing categories are used in different parts of the globe is the protein level of the wheat grain.

The current study shows that complete and halfway prescribed NPK (nitrogen, phosphorus, and potash) together with varying levels of foliar application intensities had a substantial impact on every aspect of wheat development and yield parameters. The application of MG (Magic Growth) at a concentration of 1500 ml, along with urea at 2.5 kg and MoP at 1.5 kg per hectare (T_5) as a foliar spray, resulted in notable enhancements being observed across various parameters compared to the control treatments. These enhancements encompassed the tallest plant stature (cm), highest tiller density (per square meter), longest spike length (cm), maximal grains per spike, highest grain yield (kg per hectare), grain protein content (%), grain starch content (%), and seed moisture content (%).

These findings are in alignment with the research findings documented by Arif et al. (2006) who stated that all characteristics of the wheat crop were shown to be highly significant when using foliar treatment (Orloff, Wright, & Ottman, 2012). The treatment known as T_1 (control) yielded an inferior result nonetheless. Comparing nitrogen administered as foliage application alongside soil implementation, as opposed to a single mode of soil treatment, produced higher yield and other yield components, according to similar results as published by Abdi, Nour-Mohamadi, and Golchin (2002) and Njuguna, Macharia, Akuja, Waweru, and Kamwaga (2011). Overall, the findings showed that foliar nitrogen spray was more effective than soil application at raising wheat production and profitability.

In the long run, it's necessary to evaluate the formulation of liquid fertilizer with different modern varieties with a view to justifying the climate resilience of modern wheat varieties against the global warming era. Additionally, assessing its economic feasibility and integrating with other sustainable practices should be crucial.

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