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# Harnessing the productivity and profitability of wheat through foliar feeding of salicylic acid and micronutrient mixture in Indo-Gangetic plains of Uttarakhand

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## Abstract

A field experiment was executed to investigate the effect of foliar application of salicylic acid and micronutrients on the productivity and profitability of wheat under different fertility levels in the Tarai region of Uttarakhand. The Experiment was conducted at the E2 block of Norman E. Borlaug Crop Research Centre (NEBCRC) at GBPUA&T, Pantnagar during the *rabi* season (2020-21). The design chosen for the experiment was Factorial Randomized Block Design (FRBD) with two different factors i.e., A. Fertility factor with 75% and 100% RDF, and B. Foliar spray factor with combination of salicylic acid and micronutrient mixture. The variety employed for the trial was HD-2967, because of its wide range of acceptability of local farmers The Foliar application involved using a micronutrient mixture @ 2.5 ml per liter and salicylic acid at a concentration of 0.4 grams per liter (400 ppm). The study's findings indicate that applying salicylic acid and micronutrient mixture via foliar spray enhances crop performance in terms of both yield and profitability. Notably, the yield from plots treated with 75% RDF along with the application of salicylic acid and micronutrient mixture (5.7 t/ha) was at par with plots treated only with 100% RDF (5.6 t/ha). This implies that using foliar application of salicylic acid and micronutrients can offset the yield reduction associated with lower fertilizer levels while yielding higher returns. Additionally, under 100% RDF conditions along with the application of salicylic acid and micronutrient mixture either individually or in combination, lead to a 15.4% increase in the harvest with a 13.6% higher benefit-to-cost ratio.

**Keywords** productivity, profitability, micronutrient mixture, salicylic acid, wheat

## Introduction

Wheat (*Triticum aestivum*) is prominently known to the world as “KING OF CEREALS” because of its widespread and largest acreage. It occupies 17% of the world’s agricultural land and is responsible for 35% of the food grain production. It is often referred to as the world's primary source of sustenance, providing at least one-fifth of the calories consumed by humans [1]. It has a good potent of providing nutrients and energy that contains about 71% carbohydrates, 13% protein (albumins and globulins are major proteins of gluten complex), 1.5% essential nutrients along with the considerable proportion of vitamins and minerals. It is the dominant cereal crop among global food grains, spanning a cultivated area of 227 million hectares. It annually yields 682 million tonnes, boasting a productivity rate of 30.0 quintals per hectare. In numerous countries, its average yield remains considerably low, primarily attributed to the inadequate supply of nutrients and ineffective management practices. [2]. In India, it holds the position of being the second most crucial staple food crop, following rice. It is cultivated across an expansive area of 30.2 million hectares, resulting in a net production of 93.5 million metric tonnes and a productivity rate of 29.4 quintals per hectare. India's contribution accounts for approximately 12% of the world's production. [3]. India leads in wheat cultivation area, followed by China (24.13 million ha). However, China tops in production (134.34 million tonnes), with India next (98.51 mt). Wheat occupies about 24.8 % of the total food grain area and contributes around 36.25% to total food grain production. The major challenge that agriculture currently facing is to increase production sustainably to tackle the current world demands. However, the decline in soil fertility due to the imbalanced use of plant nutrients and their management has made this task more difficult [4].

Continuous use of chemical fertilizers at higher rates than recommended has resulted in the decline of soil fertility and yield besides causing a threat to the environment. Soils are encountering various challenges due to deteriorating quality, resulting in reduced functionality [5]. The limited utilization of applied plant nutrients by crops raises concerns about the fate of unused fertilizer portions. The main problem evoked from an imbalance in the application of nutrients is that farmers are concentrating only on major nutrients i.e., NPK, while the plant has a mandate for remaining nutrients like secondary and micronutrients. Nowadays, few secondary nutrients are blended with primary nutrients in fertilizers, so the main problem here is micronutrients like iron, copper, zinc, manganese, boron, etc [6]. Due to lack of sufficiency of micronutrients during production leads to lower production and deteriorating the grain quality gradually as these micronutrients have multiple functions in the plant systems.

Boron is essential for root growth stimulation and nodule development for nitrogen fixation [7]. It increases the tillering and flowering with increased fertility of spikelets and better seed development and grain yield. Manganese plays a crucial role in the oxygen-evolving system of photosynthesis and is found in various cation-activated enzymes like decarboxylase, kinase, and oxidases [8]. Iron is essential for numerous heme and non-heme iron enzymes and carriers, including cytochromes (respiratory electron carriers) and ferredoxins [9]. Copper plays a vital role in plant enzymatic activities, including oxidation-reduction reactions, and is crucial for chlorophyll and seed production [10]. It enhances plant health by contributing to immune system functioning and is also essential for carbohydrate and protein metabolism, as well as respiration. Zinc (Zn) serves as a significant structural, enzymatic, and regulatory element in various enzymes and proteins [11]. It plays a key role in numerous cellular and physiological processes, helps maintain ion balance, and supports the overall growth, development, and yield of crops. Molybdenum is crucial for the activity of several enzymes, including nitrate reductase, xanthine dehydrogenase, aldehyde oxidase, and sulfite oxidase [12].

Salicylic acid, also known as 2-hydroxy benzoic acid, is a phenolic compound that has been utilized by humans for its therapeutic properties since ancient times. In crop growth, salicylic acid plays a unique role, influencing various aspects such as plant growth, flower induction, ion uptake, and thermogenesis. It also has effects on stomatal movement, inhibits ethylene biosynthesis and transpiration [13], and can reverse the effects of ABA (abscisic acid) on leaf abscission. Additionally, salicylic acid enhances the photosynthetic rate by increasing the levels of photosynthetic pigments and modifies the activity of certain important enzymes [14].

Foliar feeding has become increasingly popular during application at various stages of crop growth and development as it offers a practical, short-term, and complementary approach to enhancing the nutritional value of wheat grains [15]. This method ensures nutrient availability to crops, resulting in higher yields. Moreover, research has shown that foliar spraying of micronutrient mixtures can be more effective than soil application [16]. Some studies even suggest that foliar feeding of micronutrients can be 6 to 20 times more efficient compared to soil application. Foliar feeding is a somewhat debated but relatively new technique that involves applying liquid fertilizer directly over the plant canopy [17].

## Methodology

A field experiment was conducted at the E-2 block at the Norman E. Borlaug Crop Research Centre (NEBCRC) within the campus of Govind Ballabh Pant University of Agriculture and Technology (GBPUA&T) in Pantnagar, Uttarakhand. This research was conducted during the rabi season, spanning from November to April in the year 2020-2021. The center is situated at a latitude of approximately 29.0°N and a longitude of about 79.30°E, with an altitude of approximately 243.84 meters above mean sea level. Pantnagar is situated within the sub-tropical, sub-humid climatic zone. Summers are with high temperatures, humid and hot, whereas winters are very cold and continue from November to March. The mean annual rainfall and temperature are 1420 mm and 33°C, respectively. Throughout the cropping season from November 2020 to April 2021, the weekly weather parameters were monitored and recorded at the meteorological observatory located at the N. E. Borlaug Crop Research Centre in Pantnagar. The respective, highest and lowest temperatures recorded during the crop growing season were 42.2°C in April and 3.4°C in January with rainfall of 18mm. The soil of the Tarai region belongs to the order Mollisols and had originally originated from alluvial sediments of Indo-Gangetic plains. The Textural class of soil is Sandy loam with a bulk density of 1.41 g $cc^{-1}$, pH is 7.2, EC is 0.217 dS $m^{-1}$, soil organic carbon is 0.77%, Available N, $P_2O_5$ and $K_2O$ are 231, 21.2 and 197 kg $ha^{-1}$, respectively.

The experimental design used for this study was a Factorial Randomized Block Design (FRBD) comprising two factors, and each factor had three replications. The main factor includes two types of recommended doses of fertilizers (RDF), M1-75% RDF, and M2-100% RDF, and the subfactor include six types of foliar sprays in combination with micronutrient mixture and salicylic acid that includes, S1-No spray(control) S2-Water spray, S3-Micronutrient mixture spray at tillering and jointing stages, S4-Salicylic acid spray at both tillering and jointing stages, S5-Micronutrient mixture and salicylic acid spray, respectively at tillering and jointing stages. S6-Salicylic acid and micronutrient mixture spray, respectively, at tillering and jointing stages. For this experiment, the chosen variety is HD-2967, and the recommended fertilizer dosage was 150:60:40 kg NPK per ha. Plot size for each treatment is 17 $m^2$ (5m x 3.4m).

Both fertility level plots received a basal fertilizer dose, including 50% N, 100% P, and 100% K. This basal dose was applied using an NPK mixture (12:32:16), urea, and MOP. The remaining N was split into two equal portions and applied at the CRI and pre-heading stages. The micronutrient mixture with the trade name of AGROMIN manufactured by Aries-Agro Limited consists of Zn, Mn, Fe, Cu, B, and Mo with proportions of 5.0%, 2.0%, 2.0% 0.5%, 0.5% and 0.05% respectively was used for foliar feeding at two growth stages of the crop i.e., at tillering and jointing stages. Salicylic acid ($C_7H_6O_3$) manufactured by the LABOGENS company was used in the experiment at the same tillering and jointing stages. The dosage of the micronutrient mixture and salicylic acid used in the treatments was 2.5ml per liter and 400ppm (0.4gm per liter of water) respectively. The water spray volume was 500 liters/ha. Except for fertilizer and foliar application, the best practices were chosen for weed management, water management, and insect and pest control.

ANOVA was performed for all the data, including yield and economic parameters, using the R software with the agricolae package, specifically tailored for the Factorial Randomized Block Design (FRBD). If ANOVA results were deemed significant, the differences between treatment means were evaluated using the LSD test at P <0.05 [18]. All the graphs are drawn in the R software using ggplot2, tidyr, and reshape packages.

## Results and Discussion

### *Yield parameters*

### *Grain yield*

The grain yield was notably influenced by both fertility factors and foliar spray treatments, and this effect was statistically significant. Fertility factor with 100 % RDF (5.92 t/ha) recorded a higher grain yield of wheat than the 75% RDF. The yield difference between applying 100% RDF, which yielded 5.92 tons per hectare, and using 75% RDF, which resulted in a yield of 5.43 tons per hectare, amounted to 9.2% (Figure 1). This increase in grain yield with 100% RDF can be attributed to the optimal supply of NPK nutrients. These findings align with the research conducted by Maurya et al., [19]. Among the various foliar spraying treatments, S-6, which involved the application of salicylic acid at the tillering stage and a micronutrient mixture at the jointing stage, achieved the highest grain yield at 6.02 tons per hectare. Interestingly, it was found to be significantly at par with all the three remaining treatments to which foliar spraying was applied i.e., S-5 (5.93 t/ha), S-4 (5.80 t/ha), and S-3 (5.71 t/ha). The lowest grain yield was observed in the control, with a yield of 5.20 t/ha. This yield was statistically similar to the yield achieved in treatment S-2 (5.39 t/ha). The yield difference in comparison between S-6 treatment with S-5, S-4, and S-3 was 1.5, 3.7 and 5.2%, respectively. As compared to water spray, S-2 (5.39 t/ha), and control, S-1 (5.20 t/ha) the difference was 10.5 and 13.7%, respectively against the S-6 treatment.

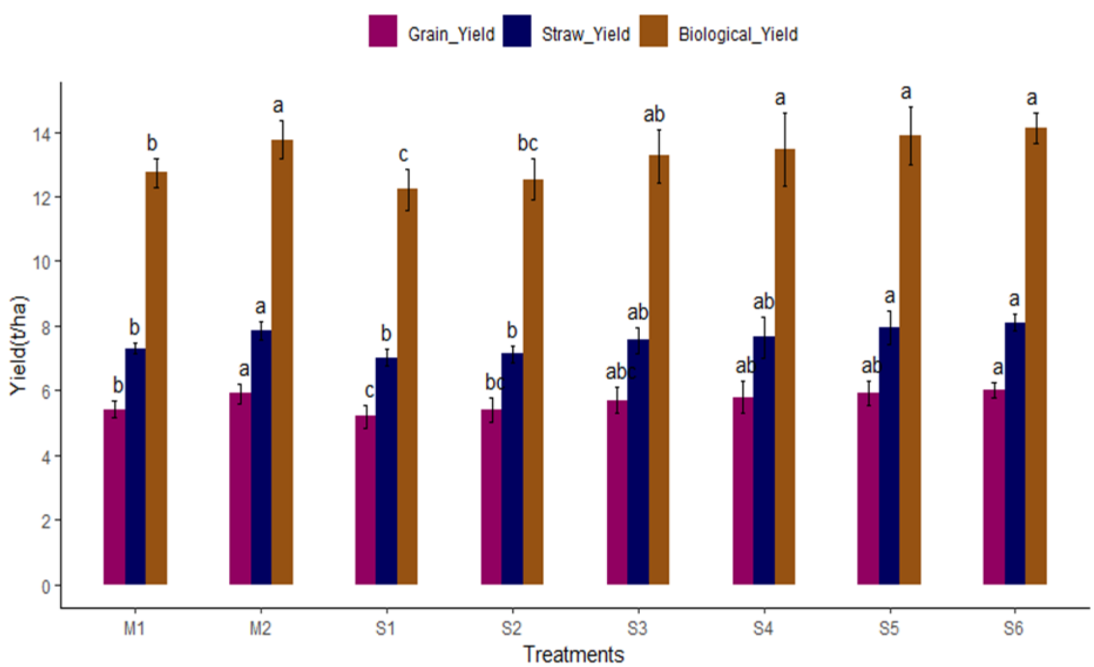


**Figure 1. Effect of different fertilizer doses and foliar spray treatments on yield parameters of wheat**

The increase in yield observed in the treatments that received foliar feeding is likely attributed to the optimal availability of micronutrients (Zn, Cu, Mn, Fe, B, and Mo) in addition to the presence of Salicylic acid, which has a significant influence on plant physiology. Higher grain yield as obtained under micronutrient-treated plots confirms to earlier findings of Singh et al., [20] and Sobolewska et al., [21] and can be credited to improved values of yield parameters.

Safar-Noori et al., [22] found a higher grain yield of wheat in SA treated plots compared to untreated plots. The Non-significant effect on fertility factors and foliar feeding treatments interaction was recorded on the grain yield of wheat during experimentation.

***Straw yield***

Fertility factors and foliar spraying treatments significantly impacted on the straw yield of the wheat. The 100% RDF (7.84 t/ha) resulted in more straw yield in comparison with 75% RDF (7.31 t/ha) which might have resulted due to the optimum availability of NPK. The difference in the yield between fertility factors was 9.3 %. Similar results of increment in straw yield were noticed by Mohanta et al., [23]. The higher straw yield under higher fertility can be credited to improved tillering and plant height due to the application of the additional amount of NPK. Treatment S-6, with a straw yield of 8.11 t/ha, achieved the highest straw yield. Interestingly, this result was not significantly different from the straw yield of treatments S-5 (7.95 t/ha), S-4 (7.66 t/ha), and S-3 (7.55 t/ha). The yield advantage over the control (7.03 t/ha) with S-6, S-5, S-4, and S-3 was 13.4, 11.6, 8.3 and 6.9%, respectively. The higher straw yield observed in these treatments can likely be attributed to factors such as increased plant height, greater dry matter content, and a higher number of tillers in the treated plots. Similar results of increment in straw yield by application of micronutrients and SA have been noticed by Shalaby et al., [24]. The non-significant effect of fertility factors and foliar feeding treatment interaction was recorded on the straw yield of wheat during experimentation.

***Biological yield***

Biological yield varied significantly both by fertility factors and foliar feeding levels. Fertility level, 100% RDF (13.75 t/ha) resulted in higher biological yield than 75% RDF (12.74 t/ha) and the increase is a result of higher grain and straw yields under this fertility level. The difference in the yield between fertility factors was 10.1 %. Aziz et al., [25] also found biological yield increment with increasing fertility levels. Treatment S-6, involving foliar spray, achieved the highest biological yield at 14.12 t/ha. Remarkably, this result was not significantly different from the biological yields of treatments S-5 (13.88 t/ha), S-4 (13.45 t/ha), and S-3 (13.26 t/ha). The yield advantage over the control (water spray, 12.22 t/ha) with S-6, S-5, S-4, and S-3 was 13.4, 11.6, 8.3 and 6.9%, respectively. The higher biological yield observed in these treatments can likely be attributed to the balanced and optimal availability of micronutrients and salicylic acid (SA), which support crop growth and result in higher grain and straw yields, increased plant height, greater dry matter content, and a larger number of tillers in the treated plots. Yassen et al., [26] also found similar results with foliar feeding of SA and micronutrients.

***Harvest index***

The difference in the harvest index due to foliar spraying treatments was found significant, whereas nonsignificant results are found in fertility factors. Treatments 100% RDF (0.44) and 75% RDF (0.43) recorded almost similar figures and are at par with each other. Among the foliar feeding treatments, the highest value was observed in treatment S-1, followed by S-2, and both of these treatments were statistically similar (at par) in terms of their effects. Similarly, no significant difference was found between the S-4, S-5, and S-6 treatments (Figure 2). Non-significant of different treatments on HI reveals that production of grains to total biomass did not differ appreciably due to variable fertility as well as foliar feeding treatments Karim and Khursheed [27]. Non-significant effect of fertility factors and foliar feeding treatments interaction was recorded for the harvest index.

***Grain: straw ratio***

Variation in grain: straw ratio as attributed to fertility factors was found significant, whereas significant results are found for foliar spray treatments. Fertility levels, 100% RDF (0.761) and 75% RDF (0.754) recorded almost similar figures with only a 0.9% difference. In the case of foliar spray

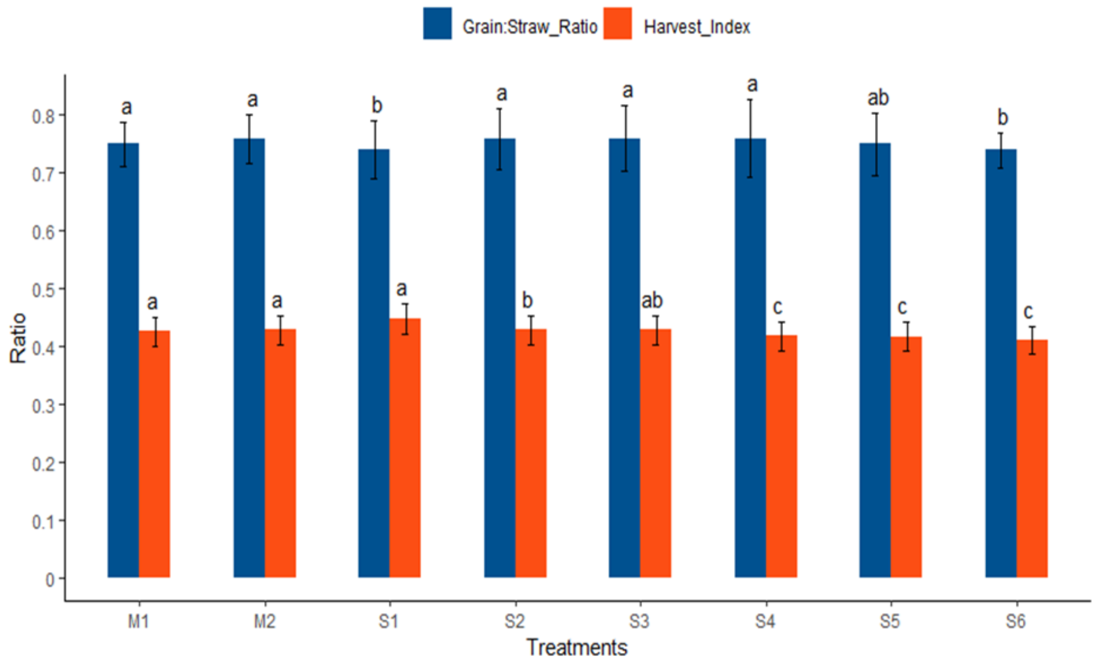


**Figure 2. Effect of different fertilizer doses and foliar spray treatments on grain: straw ratio and harvest index of wheat**

treatments, S-2, S-3, and S-4 are at par with each other. Similarly, S-1, S-5, and S-6 are at par among with each other [28]. And for the interaction effect also the results were non-significant.

***Economics***

***Cost of cultivation***

Between two fertility levels, 100% RDF ($ 473/ha) incurred a higher cost of cultivation by a margin of $ 22/ha over 75% RDF ($ 451/ha). This cost difference was due to the application of an additional 25% NPK in 100% RDF. The rise in cultivation costs with increasing fertility levels aligns with the conclusions drawn in the research conducted by Rathwa et al., [29]. Coming to foliar spraying treatments highest cost of cultivation ($ 472/ha) was registered by the S-3 treatment, and the same cost was incurred for S-5 and S-6 treatments ($ 470/ha), the cost difference among these treatments was attributed to variability in material and operational cost. The lower cost of cultivation was incurred for treatments S-2 ($ 451/ha) and S-1 ($ 443/ha) as neither salicylic acid nor micronutrient mixture was sprayed. In S-2 higher cost incurred in comparison with S-1 was attributed due to labor cost for water spray.

***Gross returns***

Fertility factors and foliar spraying treatments influenced the gross return significantly. Fertility factor 100% RDF attained a higher gross income of $ 1858/ha with a 10.4% higher value than 75% RDF ($ 1710/ha). Devi et al., [30] got similar gross returns with 100% RDF over lower levels. In the case of foliar feeding treatments, S-6 recorded the highest gross return of $ 1895/ha (Table 1.). It was significantly at par with the remaining three foliar feeding treatments i.e., S-5 ($ 1866/ha), S-4 ($ 1819/ha), and S-3 ($ 1791/ha) with reduction of 1.0, 4.2, and 5.4%, respectively to about S-6

**Table 1. Economics of wheat as affected by different fertilizer doses and foliar spray treatments**

| Treatments | Cost of cultivation (US $) | Gross return (US $) | Net return (US $) | B:C ratio |
|---|---|---|---|---|
| | | **Fertility levels** | | |
| M1 | 451 | 1710b | 1147b | 2.54b |
| M2 | 473 | 1858a | 1273a | 2.69a |
| SEm± | – | 29 | 18 | 0.03 |
| LSD (p=0.05) | – | 86 | 54 | 0.10 |
| | | **Foliar sprays** | | |
| S1 | 443 | 1638c | 1084d | 2.44d |
| S2 | 451 | 1692bc | 1130cd | 2.50d |
| S3 | 472 | 1791ab | 1208bc | 2.55c |
| S4 | 465 | 1819ab | 1240ab | 2.66b |
| S5 | 470 | 1866a | 1284ab | 2.73a |
| S6 | 470 | 1895a | 1313a | 2.79a |
| SEm± | – | 51 | 32 | 0.06 |
| LSD (p=0.05) | – | 149 | 94 | 0.17 |
| | | **Interaction** | | |
| LSD (p=0.05) | – | NS | NS | NS |

treatment. The lowest return was recorded in control, S-1 ($ 1638/ha) with 13.5% lower returns than S-6. Argal et al., [31] also found similar results regarding gross returns with foliar application of micronutrients. The higher gross returns observed in treatment S-6 and with the fertility factor using a 100% recommended dose of fertilizer (RDF) can be attributed to greater grain and straw productivity compared to their respective counterparts. Notably, the interaction effect between fertility factors and foliar spraying treatments was found to be non-significant.

***Net returns***

The value of net return obtained from 100% RDF ($ 1273/ha) was found significantly superior to 75% RDF ($ 1147/ha) with a 9.0% difference. and Dhiman et al., [32] observed higher net returns under higher fertility levels. Foliar spraying treatment S-6 recorded the maximum net return of $ 1313/ha. It was significantly at par with the S-5 treatment ($ 1284/ha) and followed by S-4 ($ 1240/ha) and S-3 ($ 1208/ha) with 2.0, 6.2, and 7.4% lower net returns to about S-6 treatment, respectively. The lowest net return was recorded in control, S-1 ($ 1084/ha) with 18.4% lower than S-6. Similarly, Louhar [33] found an increase in economic returns due to foliar feeding treatments. Higher net returns under treatment S-6 and fertility factor, 100% RDF might be attributed to higher gross returns in comparison to the cost increase in these treatments. It was determined that the interaction effect between fertility factors and foliar feeding treatments did not yield significant results.

***Benefit***
***Cost ratio***

Variation in B: C ratio was found to be significant owing to both fertility factors and foliar spraying levels. B: C ratio in fertility factor with 100% RDF was 2.69 in comparison to 2.54 in 75% RDF. Narimani et al., [34] also found a similar trend in the BC ratio. Regarding the foliar spray treatments, the highest Benefit-Cost (B:C) ratio was achieved in S-6, reaching a ratio of 2.79. It was significantly at par with the S-5 (2.73) and followed by S-4 (2.66) and S-3 (2.55) with 0.06, 0.13, and 0.24 lower magnitude against S-6 treatment (2.79). A higher B:C ratio under S-6 and S-5 treatments reveals that the net profit per rupee invested was comparatively more than their respective counterpart treatments. The control (S-1) had the lowest Benefit-Cost (B:C) ratio at 2.44, and this ratio was statistically similar (at par) to that of S-2 (water spray), which had a B:C ratio of 2.50. The higher B: C ratio under 100% RDF and S-6 was attributed to higher gross and net returns with almost similar costs of cultivation in comparison with the remaining. Solanki et al., [35] found similar figures of B: C ratio with foliar supplementation of micronutrients.

## Conclusion

Based on a one-year study, we can conclude that wheat requires 100% recommended fertilizer dose (RDF) to attain its maximum growth and productivity, and this level of fertility also leads to a higher benefit-to-cost ratio. To maximize both yield and economic returns, it is crucial to provide the crop with foliar feeding, whether using a micronutrient mixture or salicylic acid alone or in combination. Among these treatments, S-6 proved to be the most economically advantageous, boasting the highest net return and benefit-to-cost ratio. Notably, plots treated with 75% RDF along with micronutrient mixture and salicylic acid (5.7 t/ha) achieved a yield comparable to plots treated with 100% RDF alone (5.6 t/ha). Nevertheless, the greatest yield and economic advantages, including a 13.6% higher benefit-to-cost ratio, were evident in plots, where a combination of 100% RDF was used alongside foliar application of micronutrient mixture and salicylic acid. This highlights the significance of this approach compared to the excessive use of macronutrients.

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