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# Evaluation of zinc application methods and integrated nutrient management on variation in growth, yield and yield contributing factors in wheat

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## Abstract

Zinc is an important micro nutrient and plays an important role in improving the crop growth and productivity. Intensive agricultural practices due to rise in population have accelerated the use of chemical fertilizers which resulted in depletion of soil fertility. In this regard, a 2 year field experiment was conducted at Agricultural Research Farm of Lovely Professional University during *rabi* season in 2021-2022 and 2022-23 to examine the effect of different zinc application methods and integrated nutrient management on growth, yield and yield contributing factors on wheat. Three types of zinc application methods along with various levels of integrated nutrient management approaches were used for the study. The results revealed that a significant interaction between zinc application methods and integrated nutrient management practices was observed with dry matter accumulation (g/m$^2$), Leaf area index, spikes/m$^2$, spike length (cm), number of grains per spike and grain yield of wheat crop. Maximum improvement in grain yield (5.5 t/ha) was obtained when soil+foliar application of zinc was combined with 75% recommended dose of fertilizer + 2.5 t/ha farm yard manure + Zinc solubilizing bacteria. Additionally, these studies need to be repeated at many locations with various agro-climatic circumstances.

## Keywords

Zinc; Integrated nutrient management; growth; yield; wheat

## Introduction

Wheat (*Triticum aestivum* L.) is an imperative cereal crop for almost all of the global population. Around 2 billion people (36%) depend on it as their primary source of sustenance. Wheat is cultivated across 215.5 and 29.6 million hectares of land globally and nationally, producing 731.4 and 112.2 million metric tonnes of output with an average productivity of 3390 and 3371 kg/ha respectively. Punjab, the primary wheat-producing state in India, is in a challenging condition, as seen by the continual drop in the compound annual growth rate of wheat production. In Punjab, 35.3 lakh ha of area are cultivated with wheat, yielding 149 lakh tonnes. Numerous causes have been implicated in the fall in wheat productivity and production in Punjab and one among the significant cause is due to deficiency of micro nutrients particularly zinc. About 10.82 per cent of Punjab soil faces zinc deficiency of which 12.2 per cent of Kapurthala district face zinc deficiency. Micro nutrient fertilization helps to delineate the level of zinc deficiency in soil and zinc deficiency has decreased from 43% in the year

1990 to 22 % during 2002-2007. Burgeoning global population pose a significant challenge to human food security. Green revolution helped to increase the food production by the inclusion of high yielding varieties, increased chemical inputs like fertilizers, assured irrigation, insecticides, pesticides and herbicides. Chemical fertilizers assist to boost food production (1, 2) however over-exploitation causes major difficulties and affects productivity. An important factor in this context is the prudent use of chemical fertilizers. With the rapid increase in population, there should be a co-relative increase in food grain production which results in the input of heavy doses of chemical fertilizers and thereby leading to environmental degradation and its cost of cultivation getting unaffordable to farmers.

Soil agricultural production has dropped during the previous 2 decades as a result of the continued use of chemical fertilizers. The above-mentioned impediments led to a rethink of finding out an alternative which led to the think of Integrated Nutrient Management and i.e., the means of compensating by the supply of organic manure and bio fertilizer. Proper blend of organic, inorganic and bio fertilizers plays a dialectical role in sustaining the soil fertility and improving the crop yield by providing major (3) and micro nutrients (4) in a sustained way. Farmers have been using farm yard manure (FYM) in agriculture for years as an essential source of nutrients. Bio fertilizers are microbes that promote plant growth by converting unavailable nutrition into available form, increasing crop yields without harming the environment. Integrated use of chemical fertilizers, organic manures and bio fertilizers act as an appropriate substitute for reducing the dependency on agrochemical without compromising the agricultural productivity.

Effective use of Nitrogen, Phosphorus and Zinc are required for meeting the targeted yield of wheat. But their deficiencies, particularly zinc deficiency adversely affect the yield (5). Wheat has a low Zn concentration, with only about 20–35 mg/kg of whole grain. Over 40% of the world-wide wheat crop is cultivated on soils with low levels of zinc, which contributes to the low Zn concentration in wheat. Zinc is an important micro nutrient which plays a crucial role protein synthesis, carbohydrate metabolism, enzyme activation, auxin production, respiration and metabolism.

In light of the aforementioned considerations, the current study was conducted to examine the effect of zinc application methods through agronomic zinc fortification and integrated nutrient management on growth, yield and yield contributing factors on wheat

## Materials and Methods

### Experimental site description

The field experiment was conducted during rabi season (November–April) in 2021-22 and 2022-23 at the Agricultural Research Farm of Lovely Professional University, Phagwara, Punjab. The site of the experiment was located at 31° 13' 26.4'' N and 75° 46' 14.9'' E. The treatment of the experiment comprised of 3 zinc application methods, including soil (Z1), foliar (Z2) and combined soil and foliar application of zinc (Z3), where soil application was done at 25 kg/ha and foliar application was done at 0.5% and 7 levels of integrated nutrient management with 50 and 75% Recommended dose of fertilizer (RDF), 5 and 2.5t/ha FYM and 3 different bio fertilizers viz., *Azotobacter,* Phosphorus solubilizing bacteria (PSB) and Zinc solubilizing bacteria (ZSB). Thus, there were 21 treatment combinations of zinc application and integrated nutrient management practices. Split plot design with 3 replications was used for the study. Wheat variety PBW-803 was used for the study and was purchased from Punjab Agricultural University and was sown manually in the field. The source of zinc was $ZnSO_4.7H_2O$ which contains 21% of Zinc. The foliar application of $ZnSO_4.7H_2O$ was carried out at 3 growth stages viz., tillering, milking and dough stage of wheat. Nutrients were applied to the plot according to the treatments. Well decomposed farm yard manure (FYM) was applied as per the treatment one week before sowing and was incorporated thoroughly in the respective plots.

Different bio fertilizers like *Azotobacter*, PSB and ZSB were purchased from IFFCO Ltd. and were used for the study as per the treatment requirement. PSB and ZSB were applied at the dose of 500 ml per 3 litres of water for 60 kg seeds, whereas *Azotobacter* was applied at 250 ml per 3 litres of water for 60 kg seeds.

### Sample collection

Various growth and yield-influencing variables, including plant height, dry matter accumulation, Leaf area index (LAI), spikes per square meter, spike length, number of grains per spike, grain yield and straw yield were noted.

### Statistical analysis

The data collected were subjected to analysis of variance in split plot design and graphs were plotted using SPSS and R studio software. The level of significance was compared between the treatments using Duncan's multiple range tests at 5% level of significance.

## Results and discussion

The details of growth yield and yield contributing attributes were noted and are mentioned below:

### Plant height (cm)

Plant height was significantly affected at harvest by different zinc application methods and also due to different integrated nutrient management approaches (Table 1). However, no perceivable difference was obtained with the interaction due to the two factors. A significantly higher value for plant height (105.1 cm) was obtained with soil and foliar application of Zn (Z3). The soil application of Zn (Z1) (100.7 cm) and foliar application of Zn (Z2) (101.8 cm) was found to be statistically at par with each other. This might due to the fact that the combined application of zinc through soil and foliar helped in increasing plant height by proper supply of zinc to the plant and it plays an important role in improving the inter node elongation which directly increased the plant height (6-8). Among the integrated nutrient management approaches, the increase in plant height with application of 75% RDF + 2.5 t/ha FYM + *Azotobacter* (N2) over the lowest treatment i.e., 50% RDF + 5 t/ha FYM + PSB (N3) was 5.47 %. The consistent Zn provision to the plant during its growth phases facilitates an abundant supply of these at ideal concentrations, leading to enhanced cell division and elongation, which in turn improved plant height. These results were quite similar to the earlier findings (9) .The application of *Azotobacter* along with synthetic fertilizer and FYM provided a continuous supply of readily available macro as well as micro nutrients to the plant, improving the physio-chemical properties of soil, increasing soil fertility which in turn improves the growth of plant. (10, 11) reported that *Azotobacter* inoculation improved the growth and development of plants by improving the production of auxin (12, 13).

pH and soil moisture content. ZSB prevent zinc fertilizers from converting into inaccessible forms (14).

### Leaf Area Index

Based on the pooled data of two years, the effect of zinc application methods and Integrated Nutrient Management on LAI at 120 DAS and also interaction due to both the aspects was found to be significant (Table 1) (Fig. 1 (b). Maximum LAI (3.62) was observed with combined soil and foliar application of Zn (Z3) and minimum (3.13) with sole soil application of Zn (Z1). The data clearly depicts that application of 75% RDF + 2.5 t/ha FYM + ZSB (N6) recorded significantly higher LAI (3.70) as compared to all the other integrated nutrient management approaches. The % increase in LAI due to 75% RDF + 2.5 t/ha FYM + ZSB (N6) over the lowest treatment of 50% RDF + 5 t/ha FYM + PSB (N3) was 28.5%. A possible reason for an increase in leaf area is the solubilization of essential nutrients in crop leaves by zinc-soluble rhizobacteria, which increases the crop leaf area (15).

**Table 1.** Influence of zinc application methods and integrated nutrient management on growth attributes of wheat (Pooled data)

| Treatments | Plant height (cm) | Dry matter accumulation (g/m$^2$) | LAI |
|---|---|---|---|
| **Zinc application methods** | | | |
| Soil application of Zn (Z1) | 100.7$^b$ | 831.9$^b$ | 3.13$^c$ |
| *Foliar application of Zn (Z2) | 101.8$^b$ | 841.0$^b$ | 3.22$^b$ |
| Soil and foliar application of Zn (Z3) | 105.1$^a$ | 867.2$^a$ | 3.62$^a$ |
| **Integrated Nutrient Management** | | | |
| 50% RDF + 5 t/ha FYM + Azotobacter (N1) | 101.8$^c$ | 836.3$^d$ | 3.21$^c$ |
| 75% RDF + 2.5 t/ha FYM + Azotobacter (N2) | 105.7$^a$ | 854.2$^{bc}$ | 3.40$^b$ |
| 50% RDF + 5 t/ha FYM + PSB(N3) | 98.6$^d$ | 809.2$^e$ | 2.88$^d$ |
| 75% RDF + 2.5 t/ha FYM + PSB (N4) | 102.1$^{bc}$ | 841.5$^{cd}$ | 3.25$^c$ |
| 50% RDF + 5 t/ha FYM + ZSB (N5) | 102.4$^{bc}$ | 858.1$^{ab}$ | 3.41$^b$ |
| 75% RDF + 2.5 t/ha FYM + ZSB (N6) | 104.0$^{ab}$ | 871.7$^a$ | 3.70$^a$ |
| 100% RDF (120:60:40 N-P-K kg/ha) (N7) | 103.3$^{bc}$ | 855.7$^{bc}$ | 3.41$^b$ |
| ***CD ($p \leq 0.05$) Zn X INM** | **NS** | **27.7** | **0.1** |

*CD($p \leq 0.05$) = critical difference , The values with the same superscript letter are statistically similar at the 5% level using Duncan's multiple range test.

### Dry matter accumulation (g/m$^2$)

In view of the pooled data, dry matter accumulation was found to be significantly affected by both the factors of study i.e., zinc application methods, integrated nutrient management and also due to the interaction (Fig. 1 (a). Dry matter accumulation was maximum (867.2 g/m$^2$) with combined soil and foliar application of Zn (Z3) followed by foliar application of Zn (Z2) (841.0 g/m$^2$) and soil application of Zn (Z1) (831.9 g/m$^2$) (Table 1). With respect to the second aspect of study, significantly higher dry matter accumulation (871.7 g/m$^2$) was obtained with 75% RDF + 2.5 t/ha FYM + ZSB (N6) and the minimum (809.2 g/m$^2$) was obtained with 50% RDF + 5 t/ha FYM + PSB (N3). The probable reason for this might be due to the role of ZSB in improving the availability of zinc to the plant. Zinc is immobile in soil and many factors limit the availability of applied zinc to plant. Application of ZSB along with chemical fertilizers and FYM helps to improve the availability of applied zinc by conditioning the soil by improving the soil

### Spikes/m$^2$

It was clearly evident from the findings that number of spikes/m$^2$ varied significantly with agronomic zinc fortification approaches, integrated nutrient management and also due the interaction between the 2 aspects (Table 2) (Fig. 1 (c). Maximum spikes/m$^2$ (386.3**)** was obtained with combined soil and foliar application of Zn (Z3) and was followed by foliar application of Zn (Z2) (357.8). Application of 75% RDF + 2.5 t/ha FYM + ZSB (N6) (392.1) recorded the maximum spikes/m$^2$ whereas the least (318.9) was obtained with 50% RDF + 5 t/ha FYM + PSB (N3) application.

### Spike length (cm)

The length of spike directly influences the number of grains and thereby yields.Spike length was significantly affected by the different agronomic Zn fortification methods, due to different integrated nutrient management practices and also due to interaction between both

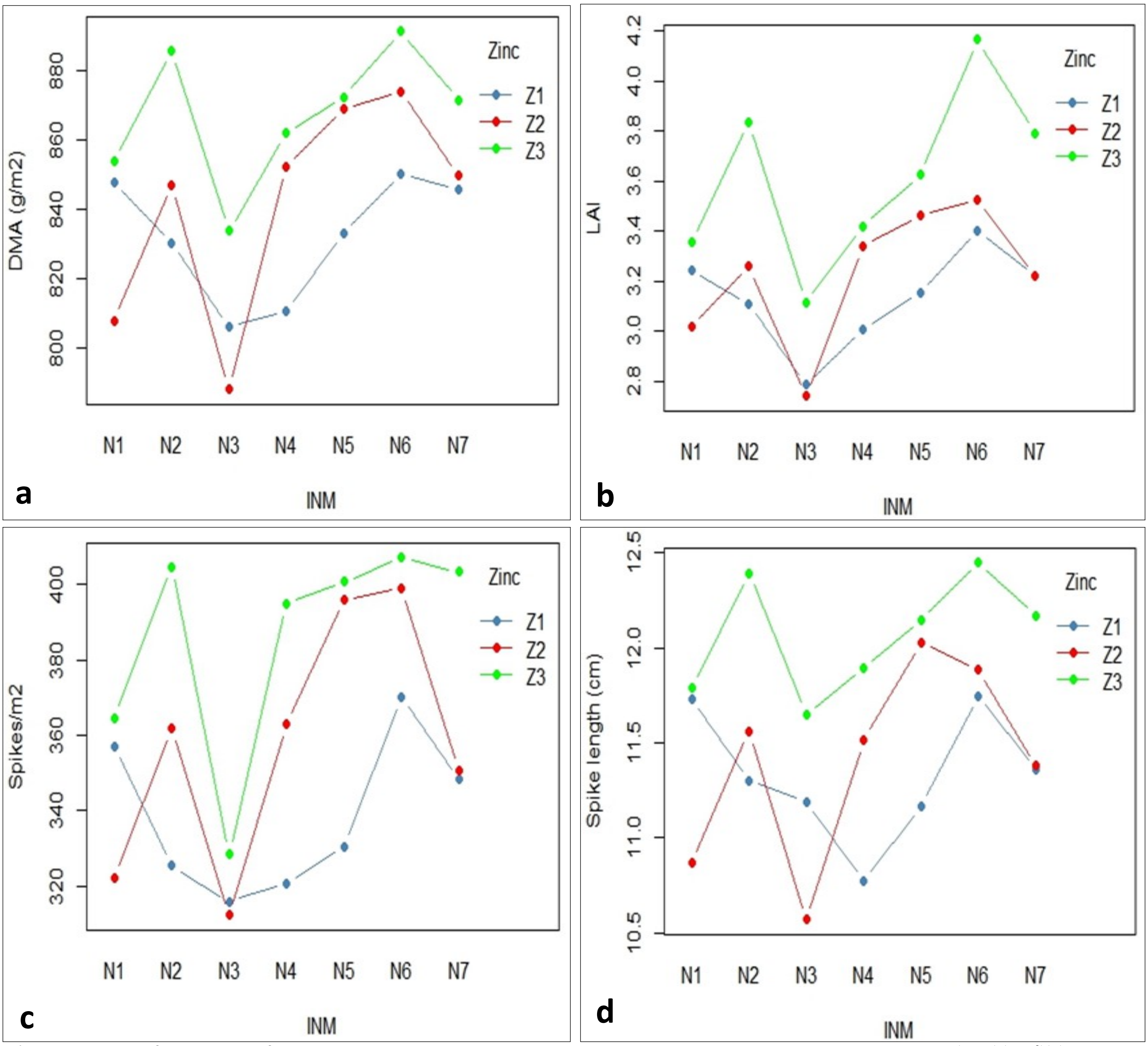


**Fig. 1.** Interaction effect between different zinc application methods and integrated nutrient management on dry matter accumulation (DMA) ($g/m^2$)(**a**), LAI (**b**), spikes/$m^2$ (**c**), spike length (cm) (**d**).

the aspects. Among the first aspect of study, the maximum spike length (12.1cm) was recorded with combined soil and foliar application of Zn (Z3). Sole foliar application of zinc (Z2) (11.4 cm) and soil application of zinc (Z1) (11.3 cm) was found to be statistically at par with each other. With respect to the second aspect of study, maximum spike length (12.0 cm) was obtained with 75% RDF + 2.5 t/ha FYM + ZSB (N6) application which was found to be statistically at par 50% RDF + 5 t/ha FYM + ZSB (N5)(11.8 cm) (Table 2) (Fig. 1 (d). From the pooled data, it was observed that maximum increment in spike length was obtained with Z3N6.

### *Number of grains per spike*

On the basis of the data, the number of grains per spike was significantly affected by zinc application methods, integrated nutrient management and also due to the interaction (Table 2) (Fig. 2 (a). Soil and foliar application of Zn (Z3) recorded maximum (52.7) number of grains per spike and the least number of grains per spike was obtained with soil application of Zn (Z1) (49.0). Superior number of grains per spike than all the different INM approach was registered with 75% RDF + 2.5 t/ha FYM + ZSB (N6) application i.e., 53.7. The interaction due to both the aspects showed a significant effect in improving the number of grains/spike. Significantly higher number of grains per spike was obtained when Z3 combined with N6.

### *Test weight (g)*

Test weight reflects the boldness of the grain and the perusal of the data revealed that the test weight was found to be significantly affected due to zinc application methods and integrated nutrient management approaches (Table 2). However, it was observed that there was a non-significant effect on test weight due to interaction between both the aspects. Combined soil and foliar application of zinc (Z3) gave the maximum test weight of 44.8 g as compared to sole application of zinc as either, soil (41.5 g) or foliar (43.2 g). Maximum test weight (44.6 g) was obtained with 75% RDF + 2.5 t/ha FYM + ZSB (N6) and was found to be significantly higher than all the rest of the treatments except, 100% RDF (120:60:40 N-P-K kg/ha) (N7) (44.1 g).

**Table 2.** Influence of zinc application methods and integrated nutrient management on different yield attributes of wheat (Pooled data)

| Treatments | Spikes/m$^2$ | Spike length (cm) | Number of grains/spike | Test weight(g) |
|---|---|---|---|---|
| **Zinc application methods** | | | | |
| Soil application of Zn (Z1) | 338.2$^{c}$ | 11.3$^{b}$ | 49.0$^{c}$ | 41.5$^{c}$ |
| *Foliar application of Zn (Z2) | 357.8$^{b}$ | 11.4$^{b}$ | 50.0$^{b}$ | 43.2$^{b}$ |
| Soil and foliar application of Zn (Z3) | 386.3$^{a}$ | 12.1$^{a}$ | 52.7$^{a}$ | 44.8$^{a}$ |
| **Integrated Nutrient Management** | | | | |
| 50% RDF + 5 t/ha FYM + Azotobacter (N1) | 347.9$^{d}$ | 11.5$^{c}$ | 49.7$^{e}$ | 42.7$^{c}$ |
| 75% RDF + 2.5 t/ha FYM + Azotobacter (N2) | 364.0$^{c}$ | 11.8$^{b}$ | 50.7$^{cd}$ | 43.5$^{bc}$ |
| 50% RDF + 5 t/ha FYM + PSB(N3) | 318.9$^{e}$ | 11.1$^{d}$ | 47.1$^{f}$ | 41.1$^{d}$ |
| 75% RDF + 2.5 t/ha FYM + PSB (N4) | 359.5$^{c}$ | 11.4$^{c}$ | 50.0$^{de}$ | 42.8$^{c}$ |
| 50% RDF + 5 t/ha FYM + ZSB (N5) | 375.7$^{b}$ | 11.8$^{b}$ | 51.7$^{b}$ | 43.3$^{bc}$ |
| 75% RDF + 2.5 t/ha FYM + ZSB (N6) | 392.1$^{a}$ | 12.0$^{a}$ | 53.7$^{a}$ | 44.6$^{a}$ |
| 100% RDF (120:60:40 N-P-K kg/ha) (N7) | 367.4$^{bc}$ | 11.6$^{b}$ | 51.1$^{bc}$ | 44.1$^{ab}$ |
| ***CD ($p \leq 0.05$) Zn X INM** | **15.8** | **0.3** | **1.4** | **NS** |

*CD($p \leq 0.05$) = critical difference , The values with the same superscript letter are statistically similar at the 5% level using Duncan's multiple range test.

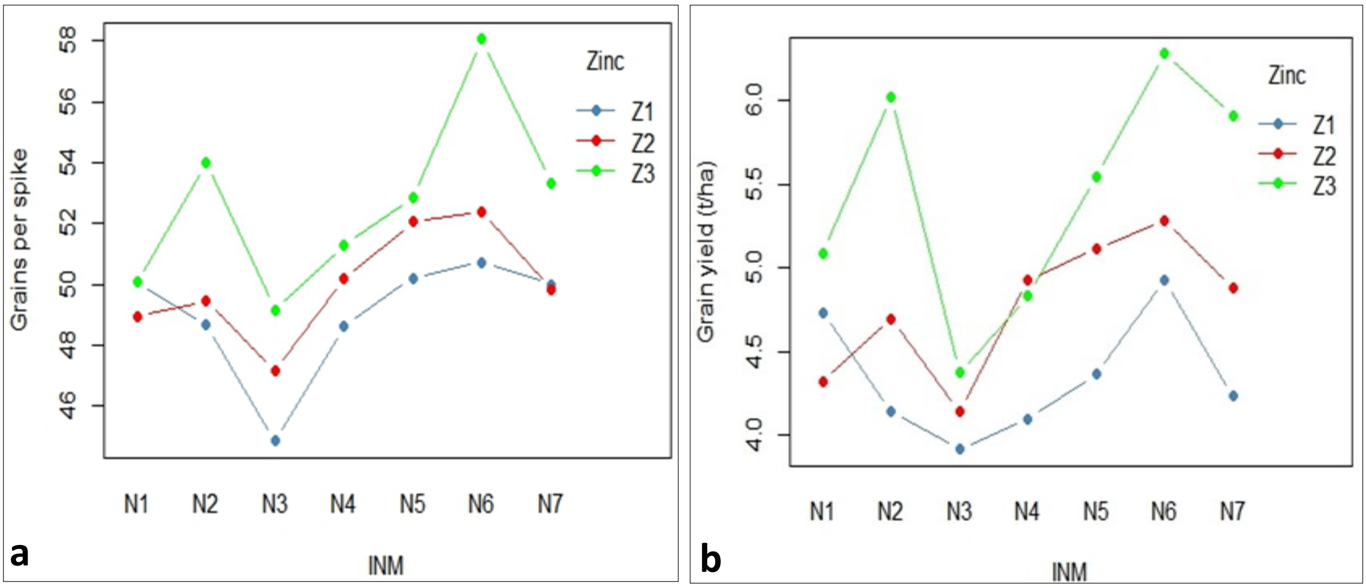


**Fig. 2.** Interaction effect between different zinc application methods and inte-

### *Grain yield (t/ha)*

Grain yield varied significantly with zinc application methods, integrated nutrient management and also due to interaction (Table 3) (Fig. 2 (b). The highest grain yield among the different zinc application methods was observed with combined soil and foliar application of Zn (Z3) (5.4 t/ha). While the lowest (4.3 t/ha) was obtained with soil application of Zn (Z1). Among the integrated nutrient management methods, application of 75% RDF + 2.5 t/ha FYM + ZSB (N6) was found to increase the grain yield by 34.2% as compared to the lowest application method i.e., 50% RDF + 5 t/ha FYM + PSB(N3). In soil + foliar applied plots, Zn was properly supplied up until harvesting time and various enzymatic activities were enhanced, which led to an increase in photosynthetic activity and dry matter accumulation, leading to higher yield characteristics and yield (16-18).The interaction due to both the aspect was found to have significant effect on improving grain yield. Among the 7 different INM approaches, the wheat grain yield recorded from the N6 treatment responded superiorly to the combined soil+foliar zinc application method i.e., Z3.

### *Straw yield (t/ha)*

It was clearly evident from the data that both the aspects of study were found to have a significant effect on straw yield of wheat crop (Table 3). Albeit, the interaction effect due to both the aspects on straw yield was found to be non -significant. Among the pooled data, the maximum straw yields to the tune of 7.6 t/ha was recorded with combined soil and foliar application of Zn (Z3). Application of 75% RDF + 2.5 t/ha FYM + ZSB (N6) resulted in significantly higher straw yield (7.8 t/ha) than all the rest of the treatments.This may be because applying zinc simultaneously from several sources improved the plant's ability to receive nutrients at the right times throughout crop growth, enhancing vegetative growth and ultimately, straw output. Zinc actively participates in the metabolism of hormones that promote plant development, such as auxin, increased tiller density and accumulation of dry matter, all of which improve plant growth and yield (19).

**Table 3.** Influence of zinc application methods and integrated nutrient management on yield of wheat (Pooled data)

| Treatments | Grain yield (t/ha) | Straw yield (t/ha) |
|---|---|---|
| **Zinc application methods** | | |
| Soil application of Zn (Z1) | 4.3[c] | 6.8[b] |
| *Foliar application of Zn (Z2) | 4.8[b] | 7.0[b] |
| Soil and foliar application of Zn (Z3) | 5.4[a] | 7.6[a] |
| **Integrated Nutrient Management** | | |
| 50% RDF + 5 t/ha FYM + Azotobacter (N1) | 4.7[c] | 7.0[b] |
| 75% RDF + 2.5 t/ha FYM + Azotobacter (N2) | 5.0[b] | 7.3[b] |
| 50% RDF + 5 t/ha FYM + PSB(N3) | 4.1[d] | 6.4[c] |
| 75% RDF + 2.5 t/ha FYM + PSB (N4) | 4.6[c] | 7.0[b] |
| 50% RDF + 5 t/ha FYM + ZSB (N5) | 5.0[b] | 7.3[b] |
| 75% RDF + 2.5 t/ha FYM + ZSB (N6) | 5.5[a] | 7.8[a] |
| 100% RDF (120:60:40 N-P-K kg/ha) (N7) | 5.0[b] | 7.3[b] |
| ***CD (p≤0.05) Zn X INM** | **0.2** | **NS** |

*CD(p≤0.05) = critical difference , The values with the same superscript letter are statistically similar at the 5% level using Duncan's multiple range test.

## Conclusion

The results obtained from the current study showed the impact of different zinc application methods and integrated nutrient management approaches on growth, yield and yield contributing factors in wheat. Combined soil and foliar application of zinc along with application 75% RDF + 2.5 t/ha FYM + ZSB increased growth, yield attributes and over other treatments. The results indicated that proper blend of organic and inorganic sources along with zinc solubilizing bacteria helped in effectively solubilizing the applied zinc (soil + foliar) and make them effectively utilized by plants thereby improving the growth and yield of wheat. Thus, it can be concluded that combined application of 25 kg/ha zinc as basal + 3 foliar sprays of zinc at 0.5% at tillering, milking and anthesis stage along with the application of 75% RDF through chemical fertilizers + 2.5 t/ha FYM as organic source +ZSB as bio fertilizer is more promising for obtaining higher productivity in wheat crop.

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## Authors contributions

SS and VC prepared the research plan, carried out the research work and analysis. GK helped with writing and proofreading of the manuscript. All authors approved the final manuscript.

## Compliance with ethical standards

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

**Ethical issues**: None.

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