



# International Journal of Research in Agronomy

E-ISSN: 2618-0618  
P-ISSN: 2618-060X  
© Agronomy  
NAAS Rating (2026): 5.20  
[www.agronomyjournals.com](http://www.agronomyjournals.com)  
2026; 9(5): 26-30  
Received: 17-02-2026  
Accepted: 21-03-2026

**Suresh Acharya**  
R&D Field, Agrocel Industries Pvt.  
Ltd., Koday, Mandvi, Kachchh,  
Gujarat, India

**Rahul Dharaviya**  
R&D Field, Agrocel Industries Pvt.  
Ltd., Koday, Mandvi, Kachchh,  
Gujarat, India

**Dhaval Dharaviya**  
R&D Field, Agrocel Industries Pvt.  
Ltd., Koday, Mandvi, Kachchh,  
Gujarat, India

**Dipika Ganatra**  
R&D Field, Agrocel Industries Pvt.  
Ltd., Koday, Mandvi, Kachchh,  
Gujarat, India

**Corresponding Author:**  
**Suresh Acharya**  
R&D Field, Agrocel Industries Pvt.  
Ltd., Koday, Mandvi, Kachchh,  
Gujarat, India

## Efficacy of ZoBo, a Specialized Multi-Nutrient Formulation (K, Mg, S, Zn and B) on the Growth and Yield Dynamics of Fiber, Oilseed, Cereal and Vegetable Crops

**Suresh Acharya, Rahul Dharaviya, Dhaval Dharaviya and Dipika Ganatra**

**DOI:** <https://www.doi.org/10.33545/2618060X.2026.v9.i5a.5471>

### Abstract

A field study was conducted at the AGROCEL Industries Pvt. Ltd. R&D Farm, Koday (Kachchh) to evaluate ZoBo, a multi-nutrient formulation (K, Mg, S, Zn and B), on cotton, groundnut, wheat, mustard and onion. The experiment followed a Randomized Block Design with four replications. Treatments included two modes of ZoBo application viz; foliar spray (15 g/L) and fertigation (8 kg/acre) applied at 30–35 and 50–55 DAS along with a commercial standard and crop-specific Recommended Fertilizer Dose (RDF) as control. ZoBo improved yield across all crops, with fertigation outperforming foliar application. Cotton recorded a significant 20.72% yield increase over RDF attributed to improved boll retention, while mustard showed a 22.13% increase driven by enhanced branching and siliquae formation. Positive yield trends were also observed in groundnut (29.55%), wheat (7.85%) and onion (9.41%). The results demonstrate that fertigation of ZoBo at 8 kg/acre effectively makes-up secondary and micronutrient deficiencies, enhancing source–sink relationships, nutrient use efficiency and overall productivity. These responses are attributed to the synergistic roles of K, Mg, S, Zn and B in assimilate translocation, chlorophyll maintenance and reproductive development across diverse crops entailing fibre, oilseed, cereal and vegetable crops.

**Keywords:** ZoBo, fertigation, multi-nutrient formulation, cotton, groundnut, wheat, mustard, onion

### Introduction

Global agricultural systems are under increasing pressure to achieve sustainable intensification while navigating the limitations of soil nutrient depletion. While conventional fertilization strategies have historically prioritized primary macronutrients viz; Nitrogen (N), Phosphorus (P) and Potassium (K), there is a burgeoning realization that the "hidden hunger" caused by secondary and micronutrient deficiencies is a major bottleneck to achieving theoretical yield ceilings. In the arid and semi-arid agro-ecosystems of Kachchh, Gujarat, this challenge is exacerbated by light-textured sandy loam soils characterized by low organic matter and high susceptibility to nutrient leaching. The formulation ZoBo represents a strategic multi-nutrient intervention designed to address these edaphic constraints through a synergistic blend of Potassium (K), Magnesium (Mg), Sulfur (S), Zinc (Zn) and Boron (B). The physiological roles of these elements are foundational yet distinct. Potassium and Magnesium are indispensable for osmotic homeostasis and the structural integrity of chlorophyll molecules, while Sulfur serves as a critical precursor for the synthesis of essential thio-amino acids (methionine and cysteine). Furthermore, Zinc and Boron are vital for auxiliary metabolism, including enzymatic catalysis, pollen tube elongation and the reinforcement of cell wall pectin matrices. Despite extensive documentation on the individual benefits of these nutrients, empirical evidence regarding their collective efficacy when delivered via modern application techniques; specifically, fertigation and foliar supplementation remains sparse across varied botanical families. There is a critical need to understand how these nutrients interact within the "source-to-sink" relationship across diverse metabolic pathways. Therefore, this study was undertaken to evaluate the impact of ZoBo on the growth and yield dynamics of five economically vital crops: cotton (*Gossypium*

*hirsutum*), groundnut (*Arachis hypogaea*), wheat (*Triticum aestivum*), mustard (*Brassica juncea*) and onion (*Allium cepa*). By benchmarking ZoBo against existing commercial formulations and the standard Recommended Fertilizer Dose (RFD), this research seeks to validate a robust, multi-nutrient protocol. The findings aim to provide a scalable solution for enhancing nutrient use efficiency and ensuring long-term agricultural sustainability in nutrient-deficient arid landscapes.

### Materials and Methods

The field investigation was conducted during the *Kharif* and *Rabi* seasons of 2024 at the Research and Development Farm of AGROCEL Industries Pvt. Ltd., located in Koday, Mandvi, Kachchh. The experimental site featured sandy loam soil characterized by a light brown colour, exhibiting excellent drainage and fair moisture retention properties. Chemical analysis of the soil prior to the study indicated a low status of available nitrogen, an optimum level of available phosphorus and a medium status of available potassium. The experiments were laid out in a Randomized Block Design (RBD) with four replications for each of the five target crops. The cultivars selected for the study included Ajeet 1155 BG II for cotton (*Gossypium hirsutum*), GG 7 for groundnut (*Arachis hypogaea*), GW 496 for wheat (*Triticum aestivum*), GDM 4 for mustard (*Brassica juncea*) and Nasik Red for onion (*Allium cepa*).

The experimental framework consisted of six distinct treatments applied to each crop. These treatments evaluated two application methods for ZoBo: a foliar spray at a dose of 15 g/L and fertigation at a rate of 8 kg/acre, both applied twice during the critical growth stages of 30–35 and 50–55 days after sowing (DAS) in conjunction with the Recommended Fertilizer Dose (RFD). These were benchmarked against Mahalaabh powder (15 g/L spray & 8 kg/acre fertigation), Mahalaabh granules (applied as a basal dose at 25 kg/acre), with a sole application of RFD serving as the control (check). All standard agronomic practices, including land preparation, irrigation scheduling and plant protection measures, were strictly followed according to the regional recommendations for each respective crop.

To evaluate the treatment effects, biometric observations were recorded from five plants randomly selected within plot area of each replication. For cotton, parameters included plant height, number of sympodial/plant, number of monopodial/plant, bolls/plant, boll weight and seed cotton yield. Groundnut evaluation focused on pods/plant, seeds/pod, 100-seed weight, pod yield and shelling percentage. In wheat, data were collected on effective tillers/plant, ear length, grains/ear, test weight and grain yield, while observations in mustard included primary and secondary branches/plant, siliqua/plant, seeds/siliqua, test weight and seed yield. For onion, the focus remained on bulb diameter, bulb weight and bulb yield. The resulting data were statistically analyzed using the methodology described by Panse and Sukhatme.

### Results and Discussion

The application of ZoBo; a specialized multi-nutrient formulation (K-23%, Mg-11%, S-15%, Zn-0.6% and B-0.2-0.3) demonstrated a consistent positive trend in growth and yield parameters across all five test crops viz; Cotton, Groundnut, Wheat, Mustard and Onion. The integration of these secondary and micronutrients alongside the Recommended Fertilizer Dose (RFD) enhanced physiological growth and reproductive efficiency by addressing sub-clinical deficiencies common in intensive cropping systems. Across all trials, fertigation of ZoBo

at 8 kg/acre applied at 30–35 and 50–55 DAS emerged as the superior delivery mechanism compared to foliar sprays, likely due to enhanced rhizosphere nutrient saturation and sustained uptake during critical growth stages.

### Effect of ZoBo on Cotton (*Gossypium hirsutum*)

The impact of nutrient treatments on cotton was most pronounced and statistically significant in the seed cotton weight per plant (Table 1). While other growth traits showed numerical improvements, the ZoBo fertigation (8 kg/acre) treatment emerged as the best treatment, achieving 20.72% higher seed cotton yield than the RFD control (497 kg/acre). Furthermore, this treatment demonstrated a clear competitive advantage over the standard commercial check, Mahalaabh applied through fertigation by 4.89%. This yield enhancement was primarily attributed to superior sympodial branching and enhanced fruit retention. Specifically, ZoBo fertigation resulted in a 2.46% increase in sympodial branches and a 5.56% increase in bolls per plant compared to the Mahalaabh standard commercial check. These results suggested a synergistic effect between the zinc (Zn) and boron (B) components of the ZoBo formulation. Boron is essential for pollen tube elongation and carbohydrate metabolism (Dordas, 2006) <sup>[3]</sup>, while Zinc acts as a precursor to indole-3-acetic acid (IAA), regulating auxin levels that prevent the formation of the abscission layer (Sawan *et al.*, 2008) <sup>[9]</sup>. The delivery of these nutrients via fertigation likely ensured optimal bioavailability during the squaring and flowering stages, effectively reducing boll shedding and maximizing sink capacity. Similar improvements in cotton yield through targeted Zn and B supplementation have been documented, where micronutrient synergy was found to stabilize internal hormone balances during reproductive stress. Sarwar *et al.* (2022) <sup>[8]</sup> reported that foliar application of Zn, K and B mitigated the adverse effects of high temperature stress during the squaring, flowering and boll formation stages, thereby improving seed cotton yield and quality. Similarly, Swetha *et al.* (2022) <sup>[15]</sup>, while evaluating the combined application of Mg (1%), Zn (0.5%) and B (0.1%), observed enhanced growth and yield parameters attributed to this nutrient combination.

### Effect of ZoBo on Groundnut (*Arachis hypogaea*)

In groundnut, although the differences between treatments did not reach statistical significance, a strong numerical trend was observed (Table 2). All nutrient-supplemented treatments exhibited higher pod yield than the RFD sole (1171 kg/acre). The ZoBo fertigation (8 kg/acre) treatment recorded the highest pod yield, surpassing the RFD by 29.55% and the Mahalaabh powder (spray 15 g/L) as standard commercial check by 17.41%. These productivity gains were driven by a holistic improvement in the crop's growth architecture, characterized by increased plant height and a higher pod count per plant. Notably, a concurrent increase in shelling percentage was recorded, which is a critical indicator of efficient dry matter partitioning. This suggested that the inclusion of Sulfur (S) and Magnesium (Mg) in ZoBo played a pivotal role in the reproductive phase. Sulfur is a key constituent of sulfur-containing amino acids (methionine and cysteine), which are essential for oil synthesis and protein configuration in oilseed crops (Singh & Sahu, 2014) <sup>[12]</sup>. Furthermore, Magnesium acts as the central atom of the chlorophyll molecule and serves as a phosphorus carrier, facilitating the translocation of sugars from the leaves to the developing pods (Zhu *et al.*, 2019). The synergy of these elements, delivered effectively via fertigation, likely enhanced

the metabolic efficiency of the "source-to-sink" relationship, resulting in superior pod filling and weight. Kumar *et al.* (2023)<sup>[4]</sup> have also reported that foliar application of Zn (0.5%) and B (0.2%) in conjunction with the variety Kadiri 6 is a promising strategy for enhancing pod yield in groundnut. Saha *et al.* (2015)<sup>[7]</sup> observed that the integrated application of Zn, B and S resulted in a positive interaction, leading to increased yield and nutrient uptake in groundnut. Therefore, the combined application of micronutrients (Zn and B) along with S fertilization can be an effective approach to improve both yield and quality of groundnut.

#### Effect of ZoBo on Wheat (*Triticum aestivum*)

The response in wheat followed a similar trend of nonsignificant differences among the treatments, yet underscoring the clear efficacy of supplemental nutrition in optimizing cereal productivity (Table 3). Both ZoBo application methods demonstrated a yield advantage over the RFD control, with ZoBo fertigation (8 kg/acre) and ZoBo foliar spray (15 g/L) achieving grain yield increases of 7.85% and 5.09%, respectively. While the basal application of Mahalaabh Granules as standard commercial check recorded the highest grain yield, the performance of ZoBo highlights the strategic benefit of split-applications during peak demand periods. The application of ZoBo during the 30–35 and 50–55 DAS intervals corresponded with the critical tillering and jointing stages in wheat. During these phases, the availability of Magnesium (Mg) and Zinc (Zn) is paramount; Magnesium supports the high photosynthetic rates required for tiller survival, while Zinc is essential for the synthesis of tryptophan, a precursor to the growth hormone auxin, which drives spikelet differentiation (Cakmak, 2008)<sup>[2]</sup>. The results suggested that providing these nutrients via fertigation or foliar spray serves as a viable alternative to purely basal-oriented programmes. This approach ensures steady nutrient flux, preventing "hidden hunger" during the transition from vegetative to reproductive growth. Such supplemental strategies have been reported to improve test weight by maintaining green leaf area (stay-green habit) during the grain-filling period (Rawashdeh & Sala, 2014)<sup>[6]</sup> that is so important for realising higher productivity in wheat. Neha *et al.* (2015)<sup>[5]</sup> evaluated the effects of potassium, zinc and boron on wheat productivity and reported that application of Zn increased grain yields by 11%, over the control. Similarly, application of B resulted in increases of 5.6% in grain yield. Abido *et al.* (2020) also reported that foliar application of zinc in addition to soil application of potassium, enhanced productivity and grain quality of wheat under similar environmental conditions. Singh *et al.* (2024)<sup>[13]</sup> observed improved grain quality in wheat with zinc and boron application, concluding that combined soil and foliar application of Zn and B improved the content and uptake of Zn and B, as well as protein content, thereby enhancing the nutritional quality of wheat.

#### Effect of ZoBo on Mustard (*Brassica juncea*)

Mustard exhibited a substantial numerical response to fertigation treatments (Table 4). ZoBo applied via fertigation (8 kg/acre) recorded a remarkable 22.13% increase in seed yield compared to the RFD as control. Furthermore, this treatment demonstrated superior efficiency over the Mahalaabh fertigation as

commercial standard check by 12.58%. The foliar application of ZoBo also showed a positive trend, with a 5.85% increase over the control. As a member of the Brassicaceae family, mustard is a sulfur-demanding crop. The sulfur (S) and magnesium (Mg) components in ZoBo likely promoted the development of primary and secondary branches, which are key determinants of siliquae density and overall sink capacity. Sulfur plays a vital role in the synthesis of glucosinolates and oil, while magnesium enhances chlorophyll content, thereby supporting the high energy requirements during seed filling (Ahmad *et al.*, 2007)<sup>[1]</sup>. The observed increase in yield underscores the importance of multi-nutrient supplementation in maximizing the reproductive potential of oilseed crops.

Sharma *et al.* (2026)<sup>[10]</sup> reported that foliar treatment of S (2%) + Zn (0.5%) + B (0.2%) in addition to RFD applied at 30–35 and 45–50 DAS resulted in the highest plant height, number of branches, siliquae per plant and 1000-seed weight. Similarly, Shoja *et al.* (2018)<sup>[11]</sup> concluded that the combined application of B, S and Zn along with RFD significantly improved yield and yield attributes in rapeseed. Furthermore, the quality of edible oils depends largely on the proportion of unsaturated fatty acids; particularly linoleic and linolenic acids, adequate nutrient supply is essential, as these are essential fatty acids that must be obtained through the diet.

#### Effect of ZoBo on Onion (*Allium cepa*)

In the onion trial, both ZoBo delivery protocols proved numerically superior to the RFD control (Table 5). ZoBo fertigation (8 kg/acre) and foliar spray (15 g/L) enhanced bulb yields by 9.41% and 6.31%, respectively. While the basal application of Mahalaabh Granules yielded the highest bulb weight, the ZoBo treatments demonstrated that targeted applications during the bulb enlargement phase (30–55 DAS) effectively supported the translocation of dry matter from the leaves to the bulbs. The inclusion of Boron (B) in the ZoBo formulation is particularly significant for bulb crops as it facilitates the transport of sugars across cell membranes and is vital for cell wall structural integrity; its presence likely contributed to improved bulb diameter and skin quality, which are essential for post-harvest shelf life. Sundarajan *et al.* (2024)<sup>[14]</sup> while studying the integrated application of FYM along with NPK reported that S application in soil and foliar sprays of B (0.2%) and Zn (0.05%) was superior in enhancing bulb yield, soil fertility and bulb quality in onion. In this treatment, boron contributed to improved bulb size and weight, while zinc and sulfur played a significant role in enhancing pungency and overall quality. Similarly, Yadav *et al.* (2025)<sup>[17]</sup> also emphasized that balanced and integrated nutrient management, particularly the inclusion of sulfur, zinc and boron along with the RFD, significantly enhances growth, yield potential and bulb quality. That apart, Tsewang *et al.* (2023)<sup>[16]</sup> concluded that application of ZnSO<sub>4</sub> and borax can be a potent tool to achieve higher yields and improved shelf life of onion under the high-altitude trans-Himalayan cold desert conditions of Ladakh. This approach can, therefore, be effectively adopted to improve productivity, bulb quality and economic returns in onion cultivation across agro-climatic regions.

**Table 1:** Comparative impact of ZoBo application on seed cotton yield and its attributes in cotton

| Treatment Specification (T <sub>1</sub> to T <sub>4</sub> each applied twice 30-35 & 50-55 DAS) |                                            | Plant height (cm) | Sympodial/ plant | Monopodial/ plant | Bolls/ plant | Boll weight (g) | Seed cotton weight/ plant (g) | Seed cotton yield (kg/acre) |
|-------------------------------------------------------------------------------------------------|--------------------------------------------|-------------------|------------------|-------------------|--------------|-----------------|-------------------------------|-----------------------------|
| T <sub>1</sub>                                                                                  | RFD+ZoBo spray at 15 g/L                   | 69.40             | 9.75             | 1.00              | 17.25        | 4.25            | 74.72                         | 507                         |
| T <sub>2</sub>                                                                                  | RFD+ZoBo fertigation at 8 kg/acre          | 70.21             | 10.40            | 2.00              | 19.00        | 4.55            | 84.91                         | 600                         |
| T <sub>3</sub>                                                                                  | RFD+Mahalaabh (P) spray at 15 g/L          | 68.99             | 9.20             | 2.33              | 17.00        | 4.40            | 72.31                         | 502                         |
| T <sub>4</sub>                                                                                  | RFD+Mahalaabh (P) fertigation at 8 kg/acre | 70.39             | 10.15            | 2.00              | 18.00        | 4.65            | 79.19                         | 572                         |
| T <sub>5</sub>                                                                                  | RFD+Mahalaabh Granules 25 kg/acre as basal | 69.78             | 9.90             | 1.33              | 17.75        | 5.00            | 73.62                         | 556                         |
| T <sub>6</sub>                                                                                  | RFD (80:16:40:26 kg NPKS/acre)             | 68.04             | 8.85             | 1.33              | 15.75        | 4.20            | 69.30                         | 497                         |
| S.Em. ±                                                                                         |                                            | 2.78              | 0.53             | 0.45              | 0.90         | 0.29            | 3.21                          | 36.38                       |
| CD                                                                                              |                                            | NS                | NS               | NS                | NS           | NS              | 9.68                          | NS                          |
| CV%                                                                                             |                                            | 8.00              | 10.85            | 46.48             | 10.26        | 13.05           | 8.49                          | 13.50                       |

**Table 2:** Comparative impact of ZoBo application on pod yield and its attributes in groundnut

| Treatment Specification (T <sub>1</sub> to T <sub>4</sub> each applied twice 30-35 & 50-55 DAS) |                                              | Plant height (cm) | Pods/ plant | Seeds/ pod | 100 seed weight (g) | Pod yield (kg/acre) | Shelling% |
|-------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|-------------|------------|---------------------|---------------------|-----------|
| T <sub>1</sub>                                                                                  | RFD+ZoBo spray at 15 g/L                     | 38.47             | 22.10       | 1.70       | 40.90               | 1419                | 70.38     |
| T <sub>2</sub>                                                                                  | RFD+ZoBo fertigation at 8 kg/acre            | 39.80             | 24.45       | 1.75       | 41.96               | 1517                | 69.73     |
| T <sub>3</sub>                                                                                  | RFD+Mahalaabh (P) spray at 15 g/L            | 38.47             | 23.05       | 1.75       | 41.42               | 1292                | 69.54     |
| T <sub>4</sub>                                                                                  | RFD+Mahalaabh (P) fertigation at 8 kg/acre   | 39.75             | 24.70       | 1.60       | 41.64               | 1483                | 70.58     |
| T <sub>5</sub>                                                                                  | RFD + Mahalaabh Granules 25 kg/acre as basal | 39.11             | 23.45       | 1.60       | 42.01               | 1355                | 68.42     |
| T <sub>6</sub>                                                                                  | RFD (05:10:12:00 kg NPKS/acre)               | 38.35             | 21.90       | 1.70       | 41.24               | 1171                | 67.91     |
| S.Em. ±                                                                                         |                                              | 1.15              | 0.84        | 0.09       | 0.95                | 112.11              | 1.53      |
| CD                                                                                              |                                              | NS                | NS          | NS         | NS                  | NS                  | NS        |
| CV%                                                                                             |                                              | 5.89              | 7.19        | 11.20      | 4.57                | 16.33               | 4.41      |

**Table 3:** Comparative impact of ZoBo application on grain yield and its attributes in wheat

| Treatment Specification (T <sub>1</sub> to T <sub>4</sub> each applied twice 30-35 & 50-55 DAS) |                                            | Plant height (cm) | Effective tillers/plant | Spike length (cm) | Grains/ spike | Test weight (g) | Grain yield (kg/acre) |
|-------------------------------------------------------------------------------------------------|--------------------------------------------|-------------------|-------------------------|-------------------|---------------|-----------------|-----------------------|
| T <sub>1</sub>                                                                                  | RFD+ZoBo spray at 15 g/L                   | 81.47             | 6.55                    | 10.30             | 38.80         | 40.75           | 1446                  |
| T <sub>2</sub>                                                                                  | RFD+ZoBo fertigation at 8 kg/acre          | 86.64             | 7.05                    | 10.31             | 40.10         | 41.88           | 1484                  |
| T <sub>3</sub>                                                                                  | RFD+Mahalaabh (P) spray at 15 g/L          | 83.44             | 6.40                    | 9.69              | 37.90         | 40.14           | 1414                  |
| T <sub>4</sub>                                                                                  | RFD+Mahalaabh (P) fertigation at 8 kg/acre | 85.41             | 6.80                    | 10.43             | 39.15         | 41.57           | 1452                  |
| T <sub>5</sub>                                                                                  | RFD+Mahalaabh Granules 25 kg/acre as basal | 85.30             | 6.85                    | 11.40             | 42.10         | 40.63           | 1583                  |
| T <sub>6</sub>                                                                                  | RFD (48:24:16:00 kg NPKS/Acre)             | 78.96             | 5.85                    | 9.64              | 36.90         | 39.64           | 1376                  |
| S.Em. ±                                                                                         |                                            | 3.04              | 0.31                    | 0.63              | 1.32          | 0.86            | 100.86                |
| CD                                                                                              |                                            | NS                | NS                      | NS                | NS            | NS              | NS                    |
| CV%                                                                                             |                                            | 7.28              | 9.42                    | 12.16             | 6.76          | 4.23            | 13.82                 |

**Table 4:** Comparative impact of ZoBo application on seed yield and its attributes in mustard

| Treatment Specification (T <sub>1</sub> to T <sub>4</sub> each applied twice 30-35 & 50-55 DAS) |                                              | Plant height (cm) | Primary branches/ plant | Secondary branches/ plant | Siliqua/ plant | Seeds/ siliqua | Test weight (g) | Seed yield (kg/acre) |
|-------------------------------------------------------------------------------------------------|----------------------------------------------|-------------------|-------------------------|---------------------------|----------------|----------------|-----------------|----------------------|
| T <sub>1</sub>                                                                                  | RFD+ZoBo spray at 15 g/L                     | 188.70            | 6.65                    | 18.10                     | 504.25         | 13.60          | 4.97            | 923                  |
| T <sub>2</sub>                                                                                  | RFD+ZoBo fertigation at 8 kg/acre            | 205.05            | 7.20                    | 20.65                     | 539.70         | 14.85          | 5.18            | 1065                 |
| T <sub>3</sub>                                                                                  | RFD+Mahalaabh (P) spray at 15 g/L            | 186.60            | 6.60                    | 18.10                     | 502.00         | 13.05          | 4.91            | 876                  |
| T <sub>4</sub>                                                                                  | RFD+Mahalaabh (P) fertigation at 8 kg/acre   | 201.30            | 6.90                    | 19.35                     | 525.75         | 14.10          | 5.07            | 946                  |
| T <sub>5</sub>                                                                                  | RFD + Mahalaabh Granules 25 kg/acre as basal | 197.85            | 6.75                    | 18.45                     | 514.65         | 13.85          | 5.02            | 940                  |
| T <sub>6</sub>                                                                                  | RFD (20:20:16:16 kg NPKS/Acre)               | 185.35            | 6.45                    | 17.45                     | 486.20         | 12.80          | 4.83            | 872                  |
| S.Em. ±                                                                                         |                                              | 9.02              | 0.39                    | 1.05                      | 19.63          | 0.56           | 0.15            | 59.14                |
| CD                                                                                              |                                              | NS                | NS                      | NS                        | NS             | NS             | NS              | NS                   |
| CV%                                                                                             |                                              | 9.30              | 11.66                   | 11.26                     | 7.67           | 8.13           | 5.89            | 12.63                |

**Table 5:** Comparative impact of ZoBo application on bulb yield and its attributes in onion

| Treatment Specification (T <sub>1</sub> to T <sub>4</sub> each applied twice 30-35 & 50-55 DAS) |                                              | Bulb diameter (mm) | Bulb weight (g) | Bulb yield (t/acre) |
|-------------------------------------------------------------------------------------------------|----------------------------------------------|--------------------|-----------------|---------------------|
| T <sub>1</sub>                                                                                  | RFD+ZoBo spray at 15 g/L                     | 50.06              | 70.40           | 8.25                |
| T <sub>2</sub>                                                                                  | RFD+ZoBo fertigation at 8 kg/acre            | 52.44              | 71.10           | 8.49                |
| T <sub>3</sub>                                                                                  | RFD+Mahalaabh (P) spray at 15 g/L            | 50.53              | 69.50           | 7.99                |
| T <sub>4</sub>                                                                                  | RFD+Mahalaabh (P) fertigation at 8 kg/acre   | 50.61              | 72.90           | 8.42                |
| T <sub>5</sub>                                                                                  | RFD + Mahalaabh Granules 25 kg/acre as basal | 55.25              | 77.00           | 8.75                |
| T <sub>6</sub>                                                                                  | RFD (20:10:08:08 kg NPKS/Acre)               | 46.30              | 68.85           | 7.76                |
| S.Em. ±                                                                                         |                                              | 2.33               | 3.61            | 0.37                |
| CD                                                                                              |                                              | NS                 | NS              | NS                  |
| CV%                                                                                             |                                              | 9.16               | 10.08           | 8.92                |

## Conclusion

The study demonstrates that integrating ZoBo; a multi-nutrient formulation containing K, Mg, S, Zn and B through fertigation provides a more efficient and holistic nutrient management strategy than conventional RDF-based NPK protocols. Its consistent performance across crops highlights its role in strengthening source–sink relationships, improving nutrient use efficiency and enhancing yield potential. Fertigation proved superior to foliar application, with ZoBo applied at 8 kg/acre at 30–35 and 50–55 DAS emerging as the most effective schedule. Improved source–sink dynamics were particularly evident in cotton, where reduced boll abscission led to a 20.72% yield increase over RDF, while mustard recorded a 22.13% yield improvement due to enhanced branching and siliquae formation. These responses can be attributed to the synergistic roles of K (translocation), Mg (chlorophyll), S (metabolic functions) and Zn and B (reproductive development), resulting in better assimilate partitioning and overall crop productivity.

## References

- Ahmad A, Abraham G, Abdin MZ. Physiological investigation of the impact of nitrogen and sulphur on the yield and oil content of rapeseed-mustard. *J Plant Nutr.* 2007;22(12):1933-1942.
- Cakmak I. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification. *Plant Soil.* 2008;302(1-2):1-17.
- Dordas C. Foliar boron application affects lint yield and elemental concentration of cotton as a function of boron supply. *J Plant Nutr.* 2006;29(1):157-169.
- Kumar TS, Mehera B, Kumar P, Kumar B. Effect of micronutrients on growth and yield of groundnut (*Arachis hypogaea* L.) varieties. *Int J Environ Clim Change.* 2023;13(5):269-275.
- Neha RP, Sepehya S, Kumar P, Sharma GD. Influence of potassium, zinc and boron on productivity of wheat in an acid alfisol. *Himachal J Agric Res.* 2017;43(1):16-22.
- Rawashdeh HM, Sala F. The importance of foliar fertilization of iron and zinc on growth and yield of wheat. *J Agric Food Chem.* 2014;2(2):11-20.
- Saha B, Saha S, Saha R, Hazra G, Mandal B. Influence of Zn, B and S on the yield and quality of groundnut (*Arachis hypogaea* L.). *Legume Res.* 2015;38(6):832-836.
- Sarwar M, Saleem MF, Ali B, Saleem MH, Rizwan M, Usman K, *et al.* Application of potassium, zinc and boron as potential plant growth modulators in *Gossypium hirsutum* L. under heat stress. *Turk J Agric For.* 2022;46(4):1-13.
- Sawan ZM, Mahmoud MH, El-Guibali AH. Influence of potassium fertilization and foliar application of zinc and phosphorus on growth, yield components, yield and fiber properties of Egyptian cotton (*Gossypium barbadense* L.). *J Plant Ecol.* 2008;1(4):259-270.
- Sharma R, Singh R, Kumar H, Kumar R, Kumar K, Chaubey P, *et al.* Effect of foliar application of sulphur, zinc and boron on growth and development of mustard (*Brassica juncea* L.) cultivars. *Int J Adv Biochem Res.* 2026;10(3):330-333.
- Shoja T, Majidian M, Rabiee M. Effects of zinc, boron and sulfur on grain yield, activity of some antioxidant enzymes and fatty acid composition of rapeseed (*Brassica napus* L.). *Acta Agric Slov.* 2018;111(1):73-84.
- Singh AL, Sahu MS. Mineral nutrition of groundnut. Directorate of Groundnut Research (ICAR). 2014.
- Singh S, Singh V, Kumar M. Effect of zinc and boron on grain quality of wheat (*Triticum aestivum*) in north-western plain zone of India. *Indian J Agron.* 2024;69(1):44-47.
- Sundarrajan RV, Jeevitha S, Karthick R, Karthik Raj BG, Loganathan R, Manivannan M, *et al.* Influence of macronutrients and micronutrients on biochemical and yield contributing traits in onion (*Allium cepa* L.). *Plant Arch.* 2024;24(2):1823-1828.
- Swetha D, Laxminarayana P, Vidyasagar GECH, Reddy SN, Sharma HK. Influence of potassium, secondary (Mg) and micronutrients (Zn and B) on growth, yield attributes and yield of Bt cotton. *Int J Environ Clim Change.* 2022;12(10):157-164.
- Tsewang T, Kapila S, Kumar K, Verma V, Norbu T, Chaurasia OP, *et al.* Foliar application of zinc and boron improved physiological traits, productivity and shelf life of onion. *J Plant Nutr.* 2024;47(3):351-362.
- Yadav H, Mandal J, Sahu B. The effect of NPK, zinc and boron on growth and yield of onion (*Allium cepa* L.). *J Sci Res Rep.* 2025;31(11):1087-1093.