



# 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(9): 483-487  
Received: 07-07-2026  
Accepted: 11-08-2026

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## Effect of potassium and zinc fertilization on growth and yield of blackgram in rainfed vertisols

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**DOI:** <https://www.doi.org/10.33545/2618060X.2026.v9.i9g.6546>

### Abstract

A field experiment was conducted during *Rabi* 2025-26 at the Regional Agricultural Research Station (RARS), Nandyal, Andhra Pradesh, to evaluate the effect of potassium (K) and zinc (Zn) fertilization on growth, yield attributes, pod yield and post-harvest soil fertility of blackgram (*Vigna mungo* L.) under rainfed *vertisol* conditions. The experiment was laid out in a randomized block design with nine treatments and three replications. Treatments comprised the recommended dose of N and P (20 kg N and 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>) alone and in combination with K @ 10 and 20 kg ha<sup>-1</sup>, soil application of ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup>, and foliar application of ZnSO<sub>4</sub> @ 0.2% at flowering. The initial soil was slightly alkaline (pH 8.25), non-saline (EC 0.13 dS m<sup>-1</sup>), with 0.39% organic carbon and available N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O contents of 155, 55.25 and 320 kg ha<sup>-1</sup>, respectively. Potassium and zinc fertilization significantly influenced plant height, number of pods plant<sup>-1</sup> and pod yield, whereas the number of primary branches and test weight were not significantly affected. The combined application of K @ 10 kg ha<sup>-1</sup> + ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup> along with recommended N and P (T<sub>5</sub>) recorded the highest plant height (44 cm), pods plant<sup>-1</sup> (25.9) and pod yield (1218 kg ha<sup>-1</sup>), resulting in a 24.0% yield increase over the recommended N and P treatment alone (982 kg ha<sup>-1</sup>). Post-harvest soil properties, including pH, EC, organic carbon, available N, P<sub>2</sub>O<sub>5</sub> and DTPA-extractable Cu, Mn, Fe and Zn, were not significantly influenced by the treatments; however, available K<sub>2</sub>O differed significantly and was highest in T<sub>3</sub> (380 kg ha<sup>-1</sup>). Soil-applied Zn treatments also showed a numerical increase in residual available Zn. The study demonstrates that balanced supplementation of recommended N and P with K @ 10 kg ha<sup>-1</sup> and ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup> is an effective nutrient management strategy for enhancing blackgram productivity under rainfed *vertisol* conditions while maintaining soil fertility.

**Keywords:** *Vigna mungo*, potassium, zinc, balanced fertilization, rainfed Vertisol, nutrient management

### Introduction

Blackgram (*Vigna mungo* L.) is an important short duration grain legume widely cultivated in India and other South Asian countries. It is valued for its high protein content, adaptability and contribution to sustainable agriculture through biological nitrogen fixation. However, its productivity under rainfed conditions is often constrained by erratic rainfall, moisture stress and inadequate or imbalanced nutrient management. Therefore, balanced fertilization is essential for improving productivity and nutrient-use efficiency in rainfed pulse production systems.

Potassium (K) plays a vital role in enzyme activation, photosynthesis, stomatal regulation, osmotic adjustment and assimilate translocation. Its importance is particularly pronounced under rainfed conditions, where adequate K nutrition helps maintain plant water status and tolerance to abiotic stresses. Recent studies have highlighted its role in plant growth and stress adaptation (Wang *et al.*, 2013; Perelman *et al.*, 2022; Johnson *et al.*, 2022) [19, 13, 8]. However, K application in pulse crops is often neglected, assuming sufficient native soil reserves, which may decline with continuous cropping and nutrient removal.

Zinc (Zn) is an essential micronutrient involved in enzyme activation, protein synthesis, membrane integrity and hormonal regulation. Its deficiency is common in alkaline and calcareous soils, including *vertisols*, where high pH may restrict Zn availability. Adequate Zn nutrition promotes root growth, metabolic activity and reproductive development, thereby improving crop productivity and stress tolerance (Babar, 2013; Rahman *et al.*, 2024) [1, 15].

Combined application of K and Zn may provide complementary benefits by improving water relations, nutrient-use efficiency, metabolic activity and assimilate translocation. The

effectiveness of Zn may also vary with its method of application, as soil application provides a sustained nutrient supply, whereas foliar application can correct deficiencies during critical growth stages. Recent studies have emphasized balanced and integrated nutrient management for improving crop productivity and maintaining soil health (Bindraban *et al.*, 2015; Prabhakaran *et al.*, 2025) [3, 14].

Although the importance of K and Zn nutrition is well recognized, information on their combined effects on blackgram under rainfed *vertisol* conditions remains limited. Most fertilizer recommendations for blackgram mainly emphasize nitrogen and phosphorus, while K and micronutrient management often receive less attention. Therefore, the present investigation was undertaken to evaluate the effect of different levels of potassium and soil and foliar application of zinc on the growth, yield and post-harvest soil properties of blackgram under rainfed *vertisol* conditions.

## Material and Methods

### Experimental site and treatments

A field experiment was conducted during Rabi 2025-26 at the Regional Agricultural Research Station (RARS), Nandyal, Andhra Pradesh, to evaluate the effect of potassium and zinc fertilization on the growth, yield and soil properties of blackgram (*Vigna mungo* L.) under rainfed *vertisol* conditions. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments replicated thrice.

The treatments consisted of T<sub>1</sub>: recommended dose of nitrogen and phosphorus (20 kg N ha<sup>-1</sup> + 50 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>), T<sub>2</sub>: T<sub>1</sub> + potassium @ 10 kg ha<sup>-1</sup>, T<sub>3</sub>: T<sub>1</sub> + potassium @ 20 kg ha<sup>-1</sup>, T<sub>4</sub>: T<sub>1</sub> + ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup>, T<sub>5</sub>: T<sub>1</sub> + potassium @ 10 kg ha<sup>-1</sup> + ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup>, T<sub>6</sub>: T<sub>1</sub> + potassium @ 20 kg ha<sup>-1</sup> + ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup>, T<sub>7</sub>: T<sub>1</sub> + ZnSO<sub>4</sub> @ 0.2% as foliar application at flowering stage, T<sub>8</sub>: T<sub>1</sub> + potassium @ 10 kg ha<sup>-1</sup> + ZnSO<sub>4</sub> @ 0.2% as foliar application at flowering stage, and T<sub>9</sub>: T<sub>1</sub> + potassium @ 20 kg ha<sup>-1</sup> + ZnSO<sub>4</sub> @ 0.2% as foliar application at flowering stage. The respective nutrient sources were applied according to the treatment schedule. All other recommended agronomic and crop management practices, including land preparation, sowing, weed management and plant protection measures were followed uniformly according to the recommended package of practices of ANGRAU.

### Initial soil properties and soil analysis

Before commencement of the experiment, representative composite soil samples were collected from the experimental field and analysed for physicochemical properties and available nutrient status using standard procedures. The initial soil was slightly alkaline in reaction (pH 8.25), non-saline (EC 0.13 dS m<sup>-1</sup>) and contained 0.39% organic carbon. The initial available nutrient status was 155 kg ha<sup>-1</sup> nitrogen, 55.25 kg ha<sup>-1</sup> phosphorus (P<sub>2</sub>O<sub>5</sub>) and 320 kg ha<sup>-1</sup> potassium (K<sub>2</sub>O). The available micronutrient contents were 1.20 ppm Cu, 6.25 ppm Mn, 5.82 ppm Fe and 0.35 ppm Zn.

Soil pH and electrical conductivity were determined in a 1:2.5 soil-water suspension using a digital pH meter and EC meter, respectively. Organic carbon was estimated by the Walkley and Black wet oxidation method (Walkley and Black, 1934) [18]. Available nitrogen was determined by the alkaline potassium permanganate method (Subbiah and Asija, 1956) [17], available phosphorus by the Olsen's method (Olsen *et al.*, 1954) [12] and available potassium by extraction with neutral normal ammonium acetate followed by flame photometry (Jackson, 1973) [6]. Available micronutrients, namely Cu, Mn, Fe and Zn, were

extracted using DTPA extractant (Lindsay and Norvell, 1978) [10] and estimated using an Atomic Absorption Spectrophotometer (AAS).

### Crop observations and statistical analysis

Observations on plant growth and yield attributes, including plant height, number of primary branches, number of pods plant<sup>-1</sup> and test weight was recorded at appropriate crop growth stages. Pod yield was recorded at harvest and expressed as kg ha<sup>-1</sup>. Post-harvest soil samples were collected from each treatment plot and analysed for changes in soil physicochemical properties, available macronutrients and DTPA-extractable micronutrients following the same standard analytical procedures.

### Statistical analysis

The data obtained for plant growth and yield attributes, including plant height, number of primary branches, number of pods plant<sup>-1</sup> and test weight and post-harvest soil properties were subjected to Analysis of Variance (ANOVA) appropriate for RBD. Treatment differences were tested using the F-test. The Critical Difference (CD) at the 5% probability level was calculated to compare treatment means when the treatment effect was significant. Non-significant differences were denoted as NS. The Coefficient of Variation (CV) was calculated to assess the variability of the experimental data.

### Results and Discussion

Application of potassium and zinc significantly influenced plant height, number of pods plant<sup>-1</sup> and pod yield of blackgram under rainfed *vertisol* conditions, whereas the effects on primary branches and test weight were non-significant (Table 1).

Plant height ranged from 32 to 44 cm, with the maximum (44 cm) recorded in T<sub>5</sub> (recommended N and P + K @ 10 kg ha<sup>-1</sup> + ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup>), followed by T<sub>3</sub> (41 cm) and T<sub>6</sub> (40 cm), while the minimum (32 cm) was observed in T<sub>1</sub> (recommended N and P alone). The superior growth under T<sub>5</sub> may be attributed to the complementary roles of K and Zn in plant metabolism. Potassium regulates stomatal behaviour, osmotic balance, enzyme activity and photosynthesis, whereas Zn is involved in enzyme activation, protein synthesis and hormonal regulation. These functions are particularly important under rainfed conditions, where intermittent moisture stress can restrict nutrient uptake. The role of K in maintaining physiological activity under stress has been reported by Hasanuzzaman *et al.* (2018) [5] and Wang *et al.* (2013) [19], while Cakmak and Kutman (2018) [4] and Behdani *et al.* (2016) [2] emphasized the importance of Zn in plant growth and metabolic processes. Although primary branches varied from 7.0 to 8.5, the highest being recorded in T<sub>6</sub>, the differences were non-significant, indicating limited response of branching to K and Zn fertilization.

The number of pods plant<sup>-1</sup> showed a significant response to nutrient application, increasing from 19.5 in T<sub>1</sub> to 25.9 in T<sub>5</sub>. T<sub>5</sub> recorded the highest pod number, followed by T<sub>3</sub> (24.5) and T<sub>6</sub> (24.0), whereas T<sub>1</sub> recorded the lowest. The greater pod formation with combined K and Zn application may be associated with improved photosynthetic activity, assimilate translocation and reproductive development. Potassium facilitates the movement of photosynthates towards reproductive sinks and improves plant-water relations, while Zn contributes to enzyme activity, hormonal regulation and reproductive processes. Similar benefits of balanced nutrient management in pulse crops have been reported by Jadhav *et al.* (2019) [7], Shahi *et al.* (2019) [16] and Perelman *et al.* (2022) [13]. Test weight ranged from 4.19 to 4.80 g, with the highest numerical value in T<sub>5</sub> and T<sub>7</sub>; however, the differences were non-significant. Thus, the yield advantage was

mainly associated with increased pod production rather than changes in individual seed weight.

Pod yield was significantly influenced by K and Zn fertilization and ranged from 965 to 1218 kg ha<sup>-1</sup>. The maximum yield (1218 kg ha<sup>-1</sup>) was obtained in T<sub>5</sub>, followed by T<sub>6</sub> (1137 kg ha<sup>-1</sup>) and T<sub>3</sub> (1055 kg ha<sup>-1</sup>), whereas T<sub>4</sub> recorded the minimum (965 kg ha<sup>-1</sup>); T<sub>1</sub> produced 982 kg ha<sup>-1</sup>. T<sub>5</sub> increased pod yield by 236 kg ha<sup>-1</sup> (24.0%) over T<sub>1</sub> and this difference exceeded the CD (146.8 kg ha<sup>-1</sup>) confirming its significant superiority. The higher productivity under T<sub>5</sub> may be attributed to improved nutrient uptake, photosynthetic efficiency, water relations and assimilate partitioning resulting from balanced K and Zn nutrition. Potassium is particularly important in rainfed agriculture because it helps maintain cell turgidity and physiological activity during moisture stress, while Zn supports several metabolic and enzymatic processes. Similar importance of balanced macro- and micronutrient nutrition has been reported by Babar, (2013) [1], Wang *et al.* (2013) [19] and Behdani *et al.* (2016) [2].

The response to potassium was not proportional to the applied rate. Application of K @ 20 kg ha<sup>-1</sup> alone (T<sub>3</sub>) increased yield to 1055 kg ha<sup>-1</sup> compared with 982 kg ha<sup>-1</sup> in T<sub>1</sub>; however, in the presence of ZnSO<sub>4</sub>, K @ 10 kg ha<sup>-1</sup> (T<sub>5</sub>) produced 1218 kg ha<sup>-1</sup>, compared with 1137 kg ha<sup>-1</sup> in T<sub>6</sub> receiving K @ 20 kg ha<sup>-1</sup>. Although T<sub>6</sub> recorded the highest number of primary branches, this did not result in higher pod yield. The superior performance of T<sub>5</sub> suggests that K @ 10 kg ha<sup>-1</sup> was adequate when combined with ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup> under the prevailing soil and moisture conditions. The absence of further yield response at the higher K rate may be attributed to diminishing returns after satisfying crop K requirements, highlighting the importance of optimum rather than excessive nutrient application (Wang *et al.*, 2013; Perelman *et al.*, 2022) [19, 13].

The method of Zn application also affected crop performance. Soil application of ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup> combined with K (T<sub>5</sub> and T<sub>6</sub>) resulted in higher pod yields than ZnSO<sub>4</sub> alone (T<sub>4</sub>) or foliar application (T<sub>7</sub>-T<sub>9</sub>). While T<sub>4</sub> produced 965 kg ha<sup>-1</sup>, T<sub>5</sub> produced 1218 kg ha<sup>-1</sup>. In contrast, foliar ZnSO<sub>4</sub> @ 0.2% at flowering resulted in 985, 986 and 973 kg ha<sup>-1</sup> in T<sub>7</sub>, T<sub>8</sub> and T<sub>9</sub>, respectively. The limited response to foliar Zn may be related to the single application at flowering and shorter duration of nutrient availability. Soil-applied Zn can provide a more sustained supply, although its availability is influenced by soil pH, carbonate content, moisture and interactions with other nutrients. This is particularly relevant in *vertisols*, where alkaline reaction may restrict Zn availability. Cakmak and Kutman (2018) [4] and Behdani *et al.* (2016) [2] emphasized the importance of soil properties and application method in determining Zn-use efficiency.

The stronger response to combined K and Zn application indicates an interaction between macronutrient and micronutrient nutrition. Potassium improves water relations, photosynthetic performance and assimilate transport, while Zn supports enzyme activity, protein synthesis and hormonal regulation. Under rainfed *vertisol* conditions, adequate K may help maintain physiological activity during moisture stress, while Zn supports metabolic processes associated with reproductive development. Consequently, their combined application may have improved the source-sink relationship and pod setting. The role of K in stress tolerance has been reported by Karthikeyan *et al.* (2020) [9] and Hasanuzzaman *et al.* (2018) [5], while the physiological importance of Zn has been highlighted by Babar (2020) [1] and Behdani *et al.* (2016) [2].

Overall, the results indicate that balanced nutrient supply was more effective than increasing the rate of an individual nutrient. The highest yield was obtained with the moderate K rate of 10 kg

ha<sup>-1</sup> combined with soil-applied ZnSO<sub>4</sub>, while increasing K to 20 kg ha<sup>-1</sup> did not provide additional yield benefit. The significant increase in pods plant<sup>-1</sup>, together with the non-significant response of test weight, indicates that enhanced reproductive sink development was the major contributor to yield improvement. Similar emphasis on integrated nutrient management for improving productivity and nutrient-use efficiency in pulse-based systems has been reported by Yadav *et al.* (2022) [20] and Mahilane *et al.* (2017) [11].

Thus, T<sub>5</sub> (recommended N and P + K @ 10 kg ha<sup>-1</sup> + ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup>) was the most effective treatment, recording the highest plant height (44 cm), pods plant<sup>-1</sup> (25.9) and pod yield (1218 kg ha<sup>-1</sup>), with a 24.0% increase in pod yield over recommended N and P alone. Therefore, supplementation of recommended N and P with K @ 10 kg ha<sup>-1</sup> + ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup> through soil application appears to be a promising nutrient management practice for improving blackgram productivity under rainfed *vertisol* conditions.

### Effect of potassium and zinc fertilization on post-harvest soil properties

The application of potassium and zinc had limited short-term effects on most post-harvest soil properties of blackgram under rainfed *vertisol* conditions, as the differences in pH, EC, organic carbon, available N, P<sub>2</sub>O<sub>5</sub> and micronutrients were statistically non-significant (Table 2). Soil pH ranged from 8.04 to 8.31, compared with the initial value of 8.25, while EC varied from 0.13 to 0.18 dS m<sup>-1</sup>, indicating that the nutrient treatments did not appreciably alter soil reaction or cause salt accumulation during a single cropping season. Similarly, organic carbon ranged from 0.39 to 0.42% against the initial value of 0.39%, showing no significant changes among treatments. Such short-term stability in basic soil properties following mineral nutrient application has also been reported in nutrient management studies, as changes in soil chemical properties generally require repeated fertilizer application and longer durations (Karthikeyan *et al.* 2020; Hasanuzzaman *et al.*, 2018; Wang *et al.*, 2013) [9, 5, 19].

Available nitrogen ranged from 158 to 197 kg ha<sup>-1</sup>, compared with the initial value of 155 kg ha<sup>-1</sup>, while available P<sub>2</sub>O<sub>5</sub> varied from 48.67 to 64.80 kg ha<sup>-1</sup> against the initial value of 55.25 kg ha<sup>-1</sup>. However, the differences were non-significant. The numerical variation in available N may be associated with differences in crop uptake and biological nitrogen fixation by blackgram, whereas variations in available P could be related to fertilizer reactions, crop removal and soil fixation processes. The application of K and Zn alone was therefore insufficient to cause substantial short-term changes in soil N and P availability. Similar observations on the importance of balanced nutrient interactions and soil nutrient dynamics have been emphasized in recent studies on sustainable nutrient management (Mahilane *et al.*, 2017; Wang *et al.*, 2013) [11, 19].

Among the available nutrients, K<sub>2</sub>O was the only parameter significantly influenced by the treatments. Available K<sub>2</sub>O ranged from 285 to 380 kg ha<sup>-1</sup>, compared with the initial value of 320 kg ha<sup>-1</sup>. The highest value was recorded in T<sub>3</sub> (380 kg ha<sup>-1</sup>), followed by T<sub>2</sub> (375 kg ha<sup>-1</sup>), T<sub>6</sub> (364 kg ha<sup>-1</sup>) and T<sub>5</sub> (358 kg ha<sup>-1</sup>), whereas the lowest value was observed in T<sub>1</sub> (285 kg ha<sup>-1</sup>). The significant increase in available K<sub>2</sub>O under K-fertilized treatments reflects the contribution of applied K to the available soil K pool. The higher residual K under T<sub>3</sub>, receiving K @ 20 kg ha<sup>-1</sup>, indicates that a portion of the applied K remained available in the soil after crop uptake. This finding supports earlier and recent reports highlighting the importance of K fertilization in replenishing soil K reserves and sustaining crop productivity

(Karthikeyan *et al.* 2020; Hasanuzzaman *et al.*, 2018; Wang *et al.*, 2013) [9, 5, 19].

The available micronutrient status also showed only minor variations among treatments. Available Cu ranged from 1.08 to 1.32 ppm, Mn from 6.23 to 6.52 ppm and Fe from 5.83 to 6.25 ppm, with no significant treatment effects. The relatively stable availability of these micronutrients may be attributed to the buffering capacity of the *vertisol* and the short duration of the experiment. Soil pH, organic matter and clay minerals largely regulate the availability of these micronutrients, and a single season of K and Zn application may not be sufficient to cause measurable changes.

Available Zn increased numerically from the initial value of 0.35 ppm to 0.36 - 0.44 ppm after harvest, although the differences among treatments were non-significant. The highest Zn content was recorded in T<sub>6</sub> (0.44 ppm), followed by T<sub>5</sub> (0.43 ppm) and T<sub>4</sub> (0.42 ppm), all receiving ZnSO<sub>4</sub> through soil application. In comparison, foliar Zn treatments recorded relatively lower values of 0.39 - 0.41 ppm. This numerical increase indicates a residual contribution of soil-applied ZnSO<sub>4</sub> to the available soil Zn pool.

However, the alkaline nature of the *vertisol* may have limited the availability of applied Zn through adsorption and precipitation reactions. The importance of soil pH and fertilizer application method in determining Zn availability and use efficiency has been well documented by Cakmak and Kutman (2018) [4] and Behdani (2016) [2]. Recent studies have also emphasized that Zn management in alkaline soils requires appropriate application strategies to improve its availability and crop uptake (Babar, 2013; Prabhakaran *et al.*, 2025) [1, 14].

Overall, the results showed that potassium and zinc fertilization did not adversely affect the basic soil properties and had limited short-term effects on available N, P and other micronutrients. However, the significant improvement in available K<sub>2</sub>O and the numerical increase in residual Zn under soil-applied Zn treatments demonstrate the beneficial contribution of these fertilizers towards maintaining soil nutrient status. Thus, balanced application of K and Zn along with recommended N and P can improve crop productivity while maintaining soil fertility under rainfed *vertisol* conditions.

**Table 1:** Effect of potassium and zinc fertilization on the growth and yield of blackgram under rainfed conditions in *vertisol*

| Treatments                                                                                                        | Plant height (cm) | No. of primary branches | No. of pods/plant | Test weight (gm) | Pod yield (kg ha <sup>-1</sup> ) |
|-------------------------------------------------------------------------------------------------------------------|-------------------|-------------------------|-------------------|------------------|----------------------------------|
| T <sub>1</sub> : Recommended dose of N & P (N: 20 and P <sub>2</sub> O <sub>5</sub> : 50 kg ha <sup>-1</sup> )    | 32                | 7.3                     | 19.5              | 4.30             | 982                              |
| T <sub>2</sub> : T <sub>1</sub> + Potassium @ 10 kg ha <sup>-1</sup>                                              | 37                | 7.5                     | 22.0              | 4.20             | 994                              |
| T <sub>3</sub> : T <sub>1</sub> + Potassium @ 20 kg ha <sup>-1</sup>                                              | 41                | 8.0                     | 24.5              | 4.70             | 1055                             |
| T <sub>4</sub> : T <sub>1</sub> + ZnSO <sub>4</sub> @ 50 kg ha <sup>-1</sup>                                      | 35                | 7.0                     | 21.0              | 4.50             | 965                              |
| T <sub>5</sub> : T <sub>1</sub> + Potassium @ 10 kg ha <sup>-1</sup> + ZnSO <sub>4</sub> @ 50 kg ha <sup>-1</sup> | 44                | 8.0                     | 25.9              | 4.80             | 1218                             |
| T <sub>6</sub> : T <sub>1</sub> + Potassium @ 20 kg ha <sup>-1</sup> + ZnSO <sub>4</sub> @ 50 kg ha <sup>-1</sup> | 40                | 8.5                     | 24.0              | 4.60             | 1137                             |
| T <sub>7</sub> : T <sub>1</sub> + ZnSO <sub>4</sub> @ 0.2% as foliar application at flowering stage               | 34                | 7.6                     | 20.5              | 4.80             | 985                              |
| T <sub>8</sub> : T <sub>1</sub> + Potassium @ 10 kg ha <sup>-1</sup> + ZnSO <sub>4</sub> @ 0.2% as foliar         | 35                | 8.0                     | 21.5              | 4.19             | 986                              |
| T <sub>9</sub> : T <sub>1</sub> + Potassium @ 20 kg ha <sup>-1</sup> + ZnSO <sub>4</sub> @ 0.2% as foliar         | 37                | 7.0                     | 22.0              | 4.30             | 973                              |
| SEm                                                                                                               | 2.30              | 0.17                    | 1.24              | 0.09             | 49.0                             |
| CD (p=0.05)                                                                                                       | 6.91              | NS                      | 3.71              | NS               | 146.8                            |
| CV %                                                                                                              | 10.73             | 4.00                    | 8.73              | 3.28             | 8.2                              |

**Table 2:** Effect of potassium and zinc fertilization on soil properties of black gram under rainfed conditions in *vertisol*

| Treatments                                                                                                        | pH   | EC (d S m <sup>-1</sup> ) | OC (%) | N                   | P <sub>2</sub> O <sub>5</sub> | K <sub>2</sub> O | Cu   | Mn   | Fe   | Zn   |
|-------------------------------------------------------------------------------------------------------------------|------|---------------------------|--------|---------------------|-------------------------------|------------------|------|------|------|------|
|                                                                                                                   |      |                           |        | Kg ha <sup>-1</sup> |                               |                  | ppm  |      |      |      |
| T <sub>1</sub> : Recommended dose of N & P (N: 20 and P <sub>2</sub> O <sub>5</sub> : 50 kg ha <sup>-1</sup> )    | 8.15 | 0.14                      | 0.40   | 161                 | 52.33                         | 285              | 1.10 | 6.35 | 5.83 | 0.35 |
| T <sub>2</sub> : T <sub>1</sub> + Potassium @ 10 kg ha <sup>-1</sup>                                              | 8.22 | 0.17                      | 0.41   | 197                 | 64.80                         | 375              | 1.32 | 6.31 | 5.90 | 0.36 |
| T <sub>3</sub> : T <sub>1</sub> + Potassium @ 20 kg ha <sup>-1</sup>                                              | 8.08 | 0.15                      | 0.42   | 191                 | 60.70                         | 380              | 1.25 | 6.45 | 6.20 | 0.37 |
| T <sub>4</sub> : T <sub>1</sub> + ZnSO <sub>4</sub> @ 50 kg ha <sup>-1</sup>                                      | 8.16 | 0.16                      | 0.41   | 182                 | 54.50                         | 289              | 1.10 | 6.48 | 6.12 | 0.42 |
| T <sub>5</sub> : T <sub>1</sub> + Potassium @ 10 kg ha <sup>-1</sup> + ZnSO <sub>4</sub> @ 50 kg ha <sup>-1</sup> | 8.22 | 0.18                      | 0.42   | 168                 | 56.67                         | 358              | 1.20 | 6.28 | 6.25 | 0.43 |
| T <sub>6</sub> : T <sub>1</sub> + Potassium @ 20 kg ha <sup>-1</sup> + ZnSO <sub>4</sub> @ 50 kg ha <sup>-1</sup> | 8.08 | 0.17                      | 0.40   | 158                 | 48.67                         | 364              | 1.09 | 6.23 | 6.10 | 0.44 |
| T <sub>7</sub> : T <sub>1</sub> + ZnSO <sub>4</sub> @ 0.2% as foliar application at flowering stage               | 8.04 | 0.15                      | 0.42   | 164                 | 54.20                         | 292              | 1.12 | 6.52 | 6.20 | 0.39 |
| T <sub>8</sub> : T <sub>1</sub> + Potassium @ 10 kg ha <sup>-1</sup> + ZnSO <sub>4</sub> @ 0.2% as foliar         | 8.31 | 0.13                      | 0.40   | 166                 | 50.83                         | 340              | 1.13 | 6.45 | 6.15 | 0.40 |
| T <sub>9</sub> : T <sub>1</sub> + Potassium @ 20 kg ha <sup>-1</sup> + ZnSO <sub>4</sub> @ 0.2% as foliar         | 8.16 | 0.14                      | 0.39   | 179                 | 53.00                         | 334              | 1.08 | 6.36 | 5.95 | 0.41 |
| SEm                                                                                                               | 0.35 | 0.009                     | 0.0196 | 10.23               | 3.21                          | 22.49            | 0.07 | 0.33 | 0.31 | 0.02 |
| CD (p=0.05)                                                                                                       | NS   | NS                        | NS     | NS                  | NS                            | 67.44            | NS   | NS   | NS   | NS   |
| CV %                                                                                                              | 7.43 | 11.28                     | 8.3    | 10.18               | 10.10                         | 11.62            | 10.5 | 8.9  | 9.5  | 7.60 |

## Conclusion

The study revealed that combined application of K @ 10 kg ha<sup>-1</sup> + ZnSO<sub>4</sub> @ 50 kg ha<sup>-1</sup> along with recommended N and P (T<sub>5</sub>) was most effective for blackgram under rainfed *vertisol* conditions. It recorded the highest pod yield (1218 kg ha<sup>-1</sup>), representing a 24% increase over recommended N and P alone. Higher K application and foliar Zn were comparatively less effective. The treatment also maintained favourable soil fertility, indicating that balanced

application of K and Zn is a promising nutrient management strategy for improving blackgram productivity.

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