**Original Research Article**

**Effect of Foliar Application of Moringa Leaf Extract and Potassium Growth, Yield and nutrient uptake in Blackgram**

**Abstract:**

Blackgram (*Vigna mungo* L.) is a valuable pulse crop, and its productivity can be enhanced through integrated nutrient and bio-stimulant management. The present study aimed to assess the effect of foliar application of Moringa Leaf Extract (MLE) at 4% and 8% concentrations, applied alone or in combination with potassium, on the growth and yield of blackgram.

A field experiment was conducted during the Rabi season of 2023–24 at Krishi Vigyan Kendra, Palem, on sandy soils using a Randomized Complete Block Design (RCBD) with ten treatments and three replications. The blackgram variety MBG 1070 was used. Treatments included foliar sprays of MLE alone and in combination with potassium nitrate and muriate of potash (MOP), with 100% Recommended Dose of Fertilizers (RDF) applied to all treatments except the control. Tap water spray served as the control, and foliar applications were made at 30 and 45 days after sowing (DAS). Result revealed that MLE application significantly enhanced vegetative growth, yield attributes, and overall productivity. Among all treatments, T9 (100% RDF + 20 kg MOP as basal + 8% MLE spray at 30 and 45 DAS) was the most effective, recording the highest plant height, number of branches, pods per plant, and grain and straw yields. These finding suggest that integrating MLE with potassium application can significantly improve blackgram performance under sandy soil conditions.

Keywords: Blackgram, Moringa Leaf Extract, Growth, Yield , nutrient uptake

**Introduction**

Blackgram is also known as Urd dal in India. It is highly prized in vegetarian diets in India. It is one of the most important pulse crops grown throughout India. It is a short duration leguminous crop and is self-pollinated. The green pods are also edible. Dried blackgram contains about 23.4% protein, 57.3% carbohydrates, 3.8% fibre and 1.0% fat along with 57.3 calcium. Inspite of being widely adapted crop in India, its productivity is very low.

The origin of Moringa tree is the Himalayan mountains in the Indian Continent (Osman and Abuhassan, 2015). The leaves and the fruits of the tree are rich in its nutritive values for human and animals. It contains many medicinal and chemical substances for other uses to be called the miracle tree (Osman and Abuhassan, 2015). Among the different usages of Moringa is the leaf extract that contains growth hormones (Price, 2007; Amirigbal *et al.,* 2014). Moringa (*Moringa oleifera* L.) extract has been widely recognized as an effective biostimulant with significant positive effects on the growth and productivity of various plant species, including alfalfa, senna, clitoria, and mung bean (Yasmeen et al., 2016; Yuniati et al., 2022). Rich in essential nutrients such as potassium (K), iron (Fe), calcium (Ca), amino acids, ascorbic acid, and the natural cytokinin zeatin, Moringa extract serves as a potent growth enhancer (Gopalakrishnan et al., 2016; Mashamaite et al., 2022).

MLE has demonstrated efficacy in increasing crop yields by 20–35% in species such as cotton, tomato, and wheat (Yasmeen et al., 2013). Foliar application of MLE has also been shown to enhance growth and yield in maize (Biswas et al., 2016). Similarly, Phiri and Mbewe (2010) reported improvements in pod size and sugar content in soybean (*Glycine max* L.) following MLE treatment

Many researchers have indicated that moringa is a highly valued plant with multipurpose effects (Adebayo *et al*., 2011, Moyo *et al.,* 2011, Mishra *et al.,* 2011 and Rana *et al.,* 2019). The leaves of moringa contain significant amount of phytohormones namely zeatin (cytokinin) and gibberellic acid in addition to other growth-enhancing compounds such as ascorbates, phenolics, and minerals. Due to the cumulative effects of hormones, proteins, minerals, vitamins, essential amino acids, glucosinolates, isothiocyanates and phenolics in Moringa leaf Extract (MLE), it has become a novel, natural bio-stimulant whose application to crop can enrich nutritional status, improve plant antioxidant system and boost the growth and yield of crop. Now-a-days, a number of research works have been conducted by many scientists to unravel the role of MLE on the growth and yield enhancement of vegetable and pulse crops under normal as well as stress situations (Abohassan, and Abusuwar, 2018, Hala *et al.,* 2017, Aluko *et al.,* 2017).

Potassium has been described because the “quality element” for crop production. Potassium increases the protein content of plants, the starch content in grains and tubers, Vitamin-C and therefore the solid soluble contents in fruits. The crucial importance of K in quality formation confirms its role in promoting the assembly of photosynthetic and their transport to storage organs like fruits, grains, and tubers and improve their conversion into starch, protein, vitamins, and oil. Potassium (K), as a plant nutrient features a good crop response and is being reported from many parts of the country. By potassium application pulses showed yield benefits. Improved potassium supply also enhances biological organic process and protein content of pulse grains (Srinivasa rao *et al.,* 2003).

The availability of potassium to leguminous crops is major role at the flowering and pod setting stages (Zahan *et al.,* 2009. K also plays an important role as macronutrient in plant growth and sustainable crop production. It maintains turgor pressure of cell which is important for cell expansion. It helps in osmoregulation of plant cell, assists in opening and shutting of stomata. It plays a key role in activation of quite 60 enzymes (Tisdale *et al.,* 1990; Bukhsh *et al.,* 2011).

**2. MATERIALS AND METHODS**

**2.1 Experimental Site**

The field experiment was carried out at Krishi Vigyan Kendra, Palem during Rabi, 2023-24. The field is geographically located at 16o51’N Latitude, 78o25’E Longitude. Throughout the crop growth period, a total rainfall of 2 mm was received in 0 rainy days. The experimental soil was sandy loam with a neutral pH (7.02), EC (0.18dS m-1), low in organic carbon (0.58 g kg-1) and available N (141.6 kg ha-1), medium in available P2O5 (32 kg ha-1) and medium in available K2O (228 kg ha-1).

**2.2 Moringa Leaf Extracts Preparation and Analysis**

Young leaves of moringa were harvested from a fully grown trees located at different places of the KVK, Palem. For preparation of MLE, young leaves of about 100g were taken into a mortar with a pinch of water (10ml/100g fresh material) and ground with a pestle. The juice was extracted by hand pressure and was filtered through the cheese cloth or cotton cloth. The solution was refiltered using Whatman No.2 filter paper. Following the method developed by Fuglie 2000, the extract was diluted with distilled water at ratio of 1:5 and 2:5 and then sprayed directly onto the blackgram plants.

Moringa leaves were shade dried for 1 week followed by oven dry for 4-5 hours at 60oC and then this oven dried sample is grinded into fine powder. Fine powder is for analyses of major and micronutrients and other primary and secondary metabolites, vitamins, enzymes, amnio acids etc., are determined by using fresh leaf sample.

**Table 1. Chemical composition of moringa leaf extract**

|  |  |
| --- | --- |
| **Name of nutrient element/enzymes** | **Values** |
| Total soluble protein (mg g−1) | 1.40 |
| Super oxide dismutase (SOD) | 191.86 |
| Peroxidase (POD) | 21.99 |
| Catalase (CAT) |  |
| Total phenolic contents (mg g-1) | 8.19 |
| Ascorbic acid (m mole g-1) | 0.36 |
| Zeatin (mg g-1) | 0.96 |
| Gibberellins (mg g-1) | 0.74 |
| Nitrogen (%) | 1.933 |
| Phosphorus (%) | 0.180 |
| Potassium (%) | 2.187 |
| Calcium (%) | 2.433 |
| Magnesium (%) | **0.012** |
| Zinc (mg kg-1) | 38.333 |
| Copper (mg kg-1) | 3.50 |
| Iron (mg kg-1) | 544.0 |
| Manganese (mg kg-1) | 49.667 |
| Boron (mg kg-1 ) | 21.333 |

The chemical composition of Moringa leaf extract (MLE) reveals its richness in essential nutrients and bioactive compounds. It contains 1.40 mg g⁻¹ of total soluble protein, along with enzymatic antioxidants such as superoxide dismutase (SOD) at 191.86 units, peroxidase (POD) at 21.99 units, and an unspecified amount of catalase (CAT). The extract also holds 8.19 mg g⁻¹ of total phenolic content and 0.36 mmol g⁻¹ of ascorbic acid. Additionally, it is enriched with plant growth hormones, including 0.96 mg g⁻¹ of zeatin and 0.74 mg g⁻¹ of gibberellins.

In terms of mineral content, MLE comprises 1.933% nitrogen (N), 0.180% phosphorus (P), 2.187% potassium (K), 2.433% calcium (Ca), and 0.012% magnesium (Mg). Among the micronutrients, it contains 38.333 mg kg⁻¹ of zinc (Zn), 3.50 mg kg⁻¹ of copper (Cu), 544.0 mg kg⁻¹ of iron (Fe), 49.667 mg kg⁻¹ of manganese (Mn), and 21.333 mg kg⁻¹ of boron (B).

**2.3 Experimental Details**

The experiment was laid out in a Randomized Block Design (RBD) during Rabi 2023-24, consisting of ten treatments with replicated thrice having net plot size of 4 x 6 m2. The blackgram variety MGB 1070 was sown on sandy loam soil with a spacing of 30 cm×10 cm on 24th October 2023. Nitrogen was applied in the form of urea as per the treatments; Phosphorus was applied as basal dose in the form of SSP. Potassium (50 kg ha-1 ) was applied in the form of muriate of potash (MOP) along with nitrogen and also as foliar spray in the form of KNO3 at 45 DAS (flowering stage), moringa leaf extract was applied at 30DAS (vegetative stage) and 45 DAS (flowering stage) as per treatments, all recommended agronomic practices and plant protection measures were taken as per requirement. The recommended dose of fertilizers: 20 kg N, 50 kg P2O5 and 0 kg K2O per hectare.

The current study comprised of 100% RDF, muriate of potash 20kg (as basal), potassium nitrate @ 0.5% (foliar spray), alone and combined with foliar spray of Moringa Leaf Extract (MLE), keeping tap water spray as a control, Bio stimulant was foliar applied twice was assessed at 30 and 45 DAS. The parameters were compared between treatments with moringa leaf extract application (at 30 and 45 DAS) and those without moringa leaf extract, under potassium source and 100% RDF.

**Treatment details of the experiment**

T1: Control, T2: 100%RDF (20:50:0, kg ha-1 N: P2O5: K2O), T3: 100% RDF+ 20 kg MOP as basal, T4: 100% RDF + 0.5% Potassium Nitrate as foliar spray at 45 DAS, T5 :100%RDF + 4% MLE at 30 and 45 DAS, T6: 100% RDF+ 20 kg MOP as basal+ 4% MLE at 30 and 45 DAS, T7: 100% RDF + 0.5% Potassium Nitrate as foliar spray at 45 DAS+ 4% MLE at 30 and 45 DAS, T8: 100%RDF + 8% MLE at 30 and 45 DAS, T9: 100% RDF+ 20 kg MOP as basal+ 8% MLE at 30 and 45 DAS, T10: 100% RDF + 0.5% Potassium Nitrate as foliar spray at 45 DAS+ 8% MLE at 30 and 45 DAS

**Growth parameters**

Growth and yield parameters recorded in the study included plant height, number of branches per plant, number of active nodules, SPAD meter readings, number of pods per plant, seeds per pod, test weight, seed yield, and stover yield. Plant height was measured at harvest from five randomly selected plants in each plot, from the ground level to the topmost growing point, using a linear meter scale, and expressed in centimetres. The number of branches was counted from the same five plants and averaged to determine the number of branches per plant. For active nodules, five plants per plot were carefully uprooted, and the nodules were counted and averaged to obtain the number of active nodules per plant. SPAD meter readings were taken from the third leaf from the top of five randomly selected plants per plot; three readings per leaf were averaged and recorded as the SPAD value per plant. Yield attributes were recorded post-harvest, where five plants from each plot were assessed for the number of pods per plant, which was averaged accordingly. The number of seeds per pod was determined from five randomly selected pods per plot and expressed as the average seeds per pod. Test weight was calculated by weighing 1,000 processed seeds per treatment and expressed in grams. Seed yield was measured by weighing seeds obtained from each net plot using an electronic balance, with values converted from grams per plot to kilograms per hectare (kg ha⁻¹). Stover yield was recorded by weighing the remaining biomass (excluding seeds) from the same plots and expressed in kg ha⁻¹.

**3. RESULTS AND DISCUSSION**

Exogenous applied MLE and potassium significantly affected blackgram growth, yield and uptake.

**A) Growth parameters**

The data on growth parameters of blackgram are presented in Table 2. Various palnt growth parameter of blackgram crop were affected by varying sources of nutrients.

**1.Plant Height**

A perusal of data in Table (2) clearly indicates that the maximum plant height (30.21 cm) at harvest was recorded under 100% RDF+ 20kg of MOP a basal + 8 % MLE at 30 and 45 DAS which was at par with treatment 100% RDF + 0.5% KNO3spray at 45 DAS + 8 % MLE at 30 and 45 DAS (27.55 cm). Highest plant height was found with 8% concentration of moringa leaf extract in combination with potassium followed by 4% concentration of MLE. The low plant height (17.04 cm) in control treatment could be the result of less nutrient availability. Potassium plays a vital role in meristematic growth by promoting the synthesis of phytohormones such as cytokinins, which contribute to plant growth and yield attributes (Brar et al., 2004). According to Moyo et al. (2011), potassium may also accelerate growth through enhanced cell division, multiplication, and enlargement

.**2. Number of branches per plant**

It is obvious from the data in Table (2) that the result regarding the branches, at harvest the statistically significant the higher number of branches/plant (5.45) was recorded with treatment100% RDF+ 20kg of MOP a basal + 8 % MLE at 30 and 45 DAS was found to be statistically on par with treatment 100% RDF + 0.5% KNO3spray at 45 DAS + 8 % MLE at 30 and 45 DAS (4.33). Adding of MLE singly, at various levels, or associated with potassium significantly elevated the branches number compared with nil treatment. Applying MLE together with potassium by far could augment these two characters i.e., plant height and branches number in comparison with nil treatment and/or applying potassium or MLE alone. The highest values were assigned for applying 8%MLE at 30 and 45 DAS+20 kg MOP as basal. The result of this experiment which grew vigorously by application of Potassium was more relevant to Teggelli *et al.,* (2016). These results are in agreement with those finding reported by Foidl *et al*. (2001)

**3. SPAD Value**

Chlorophyll content Data in Table 2 exhibit chlorophyll content (Spad) in blackgram leaves as affected by spraying MLE. Maximum SPAD value was recorded with (T9):100% RDF + 20 kg MOP as basal + 8% MLE at 30 and 45DAS (56.55), which was on par with (T10):100% RDF + 0.5% KNO3 spray at 45 DAS + 8% MLE at 30 and 45 DAS (54.89) and (T8):100% RDF + 8% MLE at 30 and 45 DAS (54.47). The lowest SPAD value was recorded in (T1) control. This treatment either applied singly or in association with potassium significantly heightened chlorophyll content in comparison with control and/or 100% RDF. The result of Yasmeen *et al*. (2014) and Waqas *et al.* (2017) showed that foliar application of MLE increased chlorophyll content in tomato and maize.

**4. Number of Active Nodules:**

Data in Table (2) revealed that the at harvest the significantly higher number of nodules per plant (15.89) was recorded with treatment 100% RDF+ 20kg of MOP a basal + 8 % MLE at 30 and 45 DAS. The lowest was recorded in control (9.15).

**Table 2. Growth parameters of blackgram influenced by moringa (*Moringa oleifera*) leaf extract and potassium**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Plant height (cm)** | **No. of active nodules** | **No. of branches/plant** | **SPAD Meter value** |
| T1: Control | 17.04 | 9.15 | 2.80 | 48.11 |
| T2: 100% RDF | 21.25 | 12.18 | 3.47 | 50.94 |
| T3: 100% RDF + 20 kg MOP as basal | 21.50 | 13.36 | 3.70 | 51.31 |
| T4: 100% RDF + 0.5% KNO3 spray at 45 DAS | 21.49 | 13.15 | 3.60 | 51.27 |
| T5: T2 + 4% MLE at 30 and 45 DAS | 24.42 | 13.41 | 3.53 | 52.13 |
| T6: T3 + 4% MLE at 30 and 45 DAS | 24.44 | 13.54 | 3.73 | 52.20 |
| T7: T4 + 4% MLE at 30 and 45 DAS | 24.46 | 13.80 | 3.80 | 52.80 |
| T8: T2 + 8% MLE at 30 and 45 DAS | 27.47 | 14.44 | 4.07 | 54.47 |
| T9: T3+ 8% MLE at 30 and 45 DAS | 30.21 | 15.89 | 5.45 | 56.55 |
| T10: T4+ 8% MLE at 30 and 45 DAS | 27.55 | 14.45 | 4.33 | 54.89 |
| SEM+ | 0.92 | 0.47 | 0.38 | 1.13 |
| CD (P=0.05) | 2.72 | 1.40 | 1.14 | 3.36 |

**B. Yield attributes and yield**

**1. Number of pods per plant**

Data presented in Table 3 show that the treatment comprising 100% RDF + 20 kg MOP as basal + 8% MLE foliar spray at 30 and 45 DAS (T9) resulted in a significantly higher number of pods per plant compared to all other treatments. Notably, no other treatment was found to be statistically at par with T9, highlighting its superior effectiveness in enhancing this key yield attribute. The increase in the number of pods per plant under T9 can be attributed to the combined effect of adequate potassium nutrition and the bio-stimulatory properties of Moringa Leaf Extract (MLE). Potassium plays a vital role in flower and pod development by improving assimilate translocation, enzyme activity, and water regulation within plant tissues. Meanwhile, MLE contains natural cytokinins and antioxidants that promote flowering, reduce flower drop, and enhance overall plant vigor. These synergistic effects likely contributed to improved reproductive efficiency and pod formation. Similar findings were reported by Hussain et al. (2011), who observed that potassium application significantly influenced the number of pods per plant and other yield components in legumes. The results from the current study further confirm the importance of integrating potassium and bio-stimulants to achieve higher yield potential in blackgram cultivation.

**2.Number of seeds per pod**

The data pertaining to the number of seeds per pod are presented in Table 3. Statistical analysis revealed a significant effect of the treatments on this parameter. The treatment comprising 100% RDF + 20 kg MOP as basal + 8% MLE foliar spray at 30 and 45 DAS (T9) recorded the highest number of seeds per pod (6.03), which was significantly superior to the control (T1). However, T9 was statistically at par with most other treatments, indicating that while MLE and potassium application had a positive impact, the degree of improvement varied across treatments. The increased seed setting in T9 may be attributed to the synergistic effect of potassium and bioactive compounds in MLE, such as zeatin, which is known to enhance flowering, pod development, and seed filling. Potassium plays a key role in translocation of photosynthates and enzyme activation, while MLE improves hormonal balance and physiological efficiency, both of which are crucial for reproductive development. The significantly lower number of seeds per pod in the control treatment further underscores the importance of nutrient and bio-stimulant supplementation in enhancing the reproductive efficiency of blackgram.

**3.Test weight**

Data in Table (3) showed that the statistical analysis on test weight was found to be non-significant. However, highest test weight (42.24 g) was recorded with treatment 100% RDF+ 20kg of MOP a basal + 8 % MLE at 30 and 45 DAS and the lowest (28.96 g) was observed with control. Test weight was not influenced by the application of any nutrient sources, which might be due to characters highly influenced by genetic makeup (Abraham *et al.,* 2021).

**4. Seed yield**

It is apparent from the data in Table (3) the seed yield showed increasing trend with application of MLE and potassium in blackgram. It rose from 752 kg/ha under control to1757 kg/ha with the application of 100% RDF+ 20kg of MOP a basal + 8 % MLE at 30 and 45 DAS. Significant and highest grain yield was observed under 100% RDF+ 20kg of MOP a basal + 8 % MLE at 30 and 45 DAS. However no other treatment was found to be statistically at par with T9 treatment. The effect of potassium increased carbohydrates synthesis and translocation od photosynthesis leads to attributes the better yield reported by Chaudari *et al.,* 2018. Similar results reported by Irshad *et al.* (2022).

**5. Stover yield**

Results presented in Table 3 revealed that the straw yield of blackgram was significantly influenced by the application of Moringa Leaf Extract (MLE) and potassium. Straw yield varied from 1434 kg ha⁻¹ in the control treatment (T1) to 2738 kg ha⁻¹ in the treatment receiving 100% RDF + 20 kg MOP as basal + 8% MLE foliar spray at 30 and 45 DAS (T9). The highest stover yield was recorded in T9, and no other treatment was found to be statistically at par with it, indicating its clear superiority. The enhanced straw yield in T9 can be attributed to the combined effects of balanced nutrient supply and the bioactive compounds present in MLE. Potassium is known to improve water uptake, cell expansion, and structural integrity of plant tissues, which contribute to overall vegetative growth and biomass accumulation. Meanwhile, MLE enhances photosynthetic activity and physiological efficiency due to its content of natural growth hormones like cytokinins and antioxidants. The synergistic interaction between potassium and MLE likely promoted robust vegetative development, resulting in increased biomass production. These findings underline the role of integrated nutrient and bio-stimulant management in improving not only grain yield but also the total biomass, which is critical in cropping systems where straw has fodder or economic value.

**Uptake of nutrients**

It is evident from the data in Table (4&5) that the average uptake of nutrients by blackgram grain ranged from 8.62 kgha-1 to 23.19 kgha-1 for nitrogen, 1.90 to 4.80 kgha-1 for phosphorus, 8.12 to 24.89 kgha-1 for potassium, 138.68 to 288.51(g ha-1) for iron,81.89 to 169 (g ha-1) for manganese, to for copper and 42.39 to 107.85(g ha-1) for zinc. The ranges of uptake of nutrients by stover were 41.68 to 91.62 kgha-1 for nitrogen, 4.40 to 9.03 kgha-1 for phosphorus, 15.30 to 35.32 kgha-1 for potassium 57.02 to143.74 (g ha-1) for iron, 29.86 to 73.01(g ha-1) for manganese, 12.51 to 25.62 (g ha-1) for copper and 15.55 to 51.23 (g ha-1) for zinc. These results showed that the treatment T9 maintained higher uptake values of all the nutrients most probably owing to the higher yield and T1 recorded the lowest uptake values, which is again the reflection of the lowest yield recorded under this treatment. Application of moringa leaf extract and potassium alone, and combined form along with 100% RDF improved their uptake by blackgram. Similar results reported by Ismail and Ganzour. 2021.

**Table 3. Yield attributes, Seed yield (kg ha-1) and Stover yield (kg ha-1) of blackgram influenced by moringa (*Moringa oleifera*) leaf extract and potassium**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatments** | **No. of Pods plant-1** | **Seeds pod-1** | **Test weight (g)** | **Seed yield**  **(kg ha-1)** | **Stover yield**  **(kg ha-1)** |
| T1: Control | 11.13 | 2.67 | 28.96 | 752 | 1434 |
| T2: 100% RDF | 14.77 | 4.53 | 34.92 | 1347 | 2345 |
| T3: 100% RDF + 20 kg MOP as basal | 17.07 | 5.53 | 38.27 | 1454 | 2410 |
| T4: 100% RDF + 0.5% KNO3 foliar spray at 45 DAS | 17.47 | 5.37 | 38.93 | 1395 | 2365 |
| T5: T2 + 4% MLE at 30 and 45 DAS | 19.67 | 5.13 | 39.48 | 1362 | 2361 |
| T6: T3 + 4% MLE at 30 and 45 DAS | 19.73 | 5.77 | 39.74 | 1496 | 2414 |
| T7: T4 + 4% MLE at 30 and 45 DAS | 19.80 | 5.37 | 39.89 | 1397 | 2380 |
| T8: T2 + 8% MLE at 30 and 45 DAS | 22.15 | 5.77 | 41.07 | 1461 | 2441 |
| T9: T3+ 8% MLE at 30 and 45 DAS | 25.23 | 6.03 | 42.24 | 1757 | 2738 |
| T10: T4 + 8% MLE at 30 and 45 DAS | 23.07 | 5.80 | 41.07 | 1527 | 2510 |
| SEm + | 0.72 | 0.41 | 0.90 | 67.48 | 70.64 |
| CD (P=0.05) | 2.13 | 1.22 | 3.36 | 200.49 | 209.89 |

**Table 4. Effect of moringa leaf extract and potassium on uptake of NPK (kgha-1) by blackgram**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | Nitrogen | | Phosphorus | | Potassium | |
| Grain | Stover | Grain | Stover | Grain | Stover |
| T1: Control | 8.62 | 41.68 | 1.90 | 4.40 | 8.12 | 15.30 |
| T2: 100% RDF | 17.83 | 75.74 | 3.59 | 7.50 | 16.25 | 26.03 |
| T3: 100% RDF + 20 kg MOP as basal | 19.93 | 81.19 | 4.51 | 8.55 | 18.81 | 29.89 |
| T4: 100% RDF + 0.5% KNO3 foliar spray at 45 DAS | 18.46 | 79.96 | 4.37 | 8.33 | 18.64 | 28.79 |
| T5: T2 + 4% MLE at 30 and 45 DAS | 18.21 | 77.45 | 3.31 | 7.32 | 17.75 | 27.23 |
| T6: T3 + 4% MLE at 30 and 45 DAS | 19.63 | 80.13 | 4.08 | 8.53 | 21.05 | 30.25 |
| T7: T4 + 4% MLE at 30 and 45 DAS | 18.17 | 79.69 | 4.24 | 7.80 | 18.72 | 29.32 |
| T8: T2 + 8% MLE at 30 and 45 DAS | 19.43 | 82.60 | 4.14 | 8.64 | 19.96 | 30.25 |
| T9: T3+ 8% MLE at 30 and 45 DAS | 23.19 | 91.62 | 4.80 | 9.03 | 24.89 | 35.32 |
| T10: T4 + 8% MLE at 30 and 45 DAS | 20.61 | 84.25 | 4.33 | 8.62 | 21.07 | 31.21 |
| SEm + | 1.64 | 2.93 | 0.40 | 0.56 | 0.92 | 1.27 |
| CD (P=0.05) | 4.87 | 8.72 | 1.20 | 1.67 | 2.74 | 3.78 |

**Table 5. Effect of moringa leaf extract and potassium on uptake of Fe, Cu, Mn and Zn (g ha-1) by blackgram**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | Iron | | Manganese | | Copper | | Zinc | |
| Grain | Stover | Grain | Stover | Grain | Stover | Grain | Stover |
| T1 | 138.68 | 57.20 | 81.89 | 29.86 | 12.51 | 3.99 | 42.39 | 15.55 |
| T2 | 240.07 | 108.53 | 144.38 | 57.86 | 22.29 | 9.47 | 85.62 | 32.20 |
| T3 | 256.25 | 124.13 | 168.01 | 56.44 | 24.63 | 10.06 | 83.16 | 39.15 |
| T4 | 230.86 | 109.25 | 164.41 | 52.70 | 22.21 | 9.43 | 84.19 | 33.45 |
| T5 | 241.79 | 114.76 | 142.74 | 57.08 | 22.88 | 9.18 | 89.33 | 37.06 |
| T6 | 240.91 | 130.07 | 157.58 | 63.43 | 21.84 | 11.10 | 93.29 | 42.93 |
| T7 | 250.72 | 113.58 | 141.97 | 72.07 | 24.10 | 8.94 | 94.41 | 41.65 |
| T8 | 241.78 | 115.01 | 165.62 | 61.01 | 22.82 | 10.57 | 100.15 | 43.94 |
| T9 | 288.51 | 143.74 | 169.00 | 73.01 | 25.62 | 12.05 | 107.85 | 51.23 |
| T10 | 258.46 | 132.16 | 166.89 | 70.77 | 25.21 | 10.35 | 103.00 | 39.72 |
| SEm + | 20.17 | 11.65 | 15.34 | 6.27 | 2.09 | 0.93 | 8.41 | 5.91 |
| CD(P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS |

**Conclusion**

It can be concluded that the combined application of 100% recommended dose of fertilizer (RDF) with 20 kg of muriate of potash (MOP) as a basal dose, along with foliar spraying of 8% Moringa leaf extract (MLE) at 30 and 45 days after sowing (DAS), resulted in significantly higher growth and yield parameters. This treatment also led to greater gross and net returns, making it an economically viable option for farmers. A significant increase in key growth and yield attributes—such as plant height, number of nodules per plant, branches per plant, and pods per plant—was observed with the combined application of potassium (K) and MLE. The nutrient-rich composition of Moringa leaves may effectively meet the nutritional requirements of crops at a lower cost, thereby contributing to sustainable and cost-effective farming practices.

Although both Moringa leaf extract (MLE) and NPK fertilizer promoted crop growth and enhanced the activities of key enzymatic antioxidants—superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD)—MLE proved to be more effective overall. Based on these findings, it can be concluded that MLE may serve as a viable substitute for conventional NPK fertilizers. In addition to its efficacy, MLE is cost-effective and more accessible to the farming community, making it a practical option for sustainable agriculture.

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Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

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