Original Research Article

Enhancing Zn and Fe content in Blackgram seeds by adapting drip fertigation for nutritional security

ABSTRACT

Aims: To study the influence of Zn and Fe content in black gram seeds by adapting drip fertigation.

Study design: Randomized Block design.

Place and Duration of Study: Research block, Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai; March – May 2023.

Methodology: A Field experiment was conducted with black gram var.VBN 8 under drip irrigation on sandy clay textured soil. The treatments comprised of control measures, seed treatment, soil application, foliar spraying of Zn and Fe, a combination of seed and foliar spraying, and fertigation with $ZnSO_4$ and $FeSO_4$. Fertigation with the 100 per cent recommended dose of NPK was given as water-soluble fertilizer for all treatments. A field-based study was executed to explore the impact of zinc sulphate and ferrous sulphate on the growth, yield, and grain quality of micronutrient uptake was recorded. The economics and Water Use Efficiency of different treatments were also calculated.

Results: Among the different treatments, the application of $ZnSO_4$ @ 25 kg $ha^{-1}$and $FeSO_4$ @ 10 kg ha^{-1} through drip fertigation at 15, 30 & 45 DAS recorded the highest plant growth and yield of black gram and it also enhanced the zinc content 17.72 per cent and iron content 23.82 per cent in black gram seeds compared to the control seeds.

Conclusion: Drip fertigation of zinc sulphate and ferrous sulphate improved grain quality, and it was also used to alleviate malnutrition in humans.

Keywords: Zinc; iron; drip fertigation; black gram.

1. INTRODUCTION

India is a major producer of pulses, contributing significantly to global production. Pulses are the cheapest sources of proteins, vitamins, and micronutrients and can be supplied to people through their daily diet. Despite being a prominent protein source in human diets, pulses cultivated in nutrient-depleted soils generally exhibit diminished micronutrient content within their grains, potentially leading to micronutrient deficiencies among human populations. Micronutrient malnutrition is impacting rural communities in developing nations that have limited access to a variety of foods because of their constrained purchasing ability [12]. Iron (Fe) and zinc (Zn) stand out as the most critical micronutrients for human health, and their deficiencies have widespread consequences across the globe. Zinc catalyzes essential enzymes, including ribonucleic acid (RNA) polymerase, superoxide dismutase, and

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cellular signaling proteins. On the other hand, iron plays a vital role in proteins like hemoglobin facilitating oxygen transport throughout the human body and activating numerous enzymes crucial for various biological functions. Among the various agricultural strategies available to combat malnutrition, agronomic bio-fortification stands out as the leading approach for enhancing the iron (Fe) and zinc (Zn) levels in grains. Applying fertilizers either directly to the soil or through foliar spraying is a convenient, efficient, and low-cost method to enhance the levels of Zn and Fe in the edible portions of plants. This approach is commonly referred to as agronomic bio-fortification [4].

In India, black gram holds the third position among the pulse crops, following pigeonpea and chickpea. In Tamil Nadu, black gram is cultivated in an area of 4.07 lakh hectares, with 2.69 lakh tones of production with a productivity of 660 kg per hectare [7]. Black gram is highly susceptible to both water stress and waterlogging throughout its growing period. Effective management of irrigation water is an important issue in crop production since irrigation is a precondition for crop growth, development, and production per mm of water and productivity per unit area. Drip irrigation can be regarded as an efficient irrigation method because it precisely moistens the soil, ensuring that the root zone maintains an optimal moisture level. Drip fertigation is a precise and efficient agricultural practice that combines drip irrigation with the application of fertilizers and nutrients directly to the root zone of plants. In this contrast, black gram is being considered a viable choice for augmenting micronutrient content and providing nourishing food options through drip fertigation.

2. MATERIAL AND METHODS

2.1. Study Area

A field experiment was conducted during the summer, of 2023 at field number C-46 of the research block, Agricultural College and Research Institute, Madurai, which is geographically located at 9˚54' N latitude and 78˚54' E longitude at an elevation of 147 m above the Mean Sea Level. The soil at the experiment site was sandy clay in texture. The main objective of this experiment was to improve the Zn and Fe content and yield of black gram under drip fertigation.

2.2. Experimental Details

The experiment was laid out statistically in a Randomized Block Design with eight treatments and three replications allocated randomly to reduce the experimental error. The treatment comprising of T_1- Control (No Zn and Fe application), T_2- Soil application of RDF of $ZnSO_4$ @ 25kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1} at basal, T_3- Seed treatment with $ZnSO_4$ @ 5 g ha^{-1} + $FeSO_4$ @ 5 g ha^{-1}, T_4- Foliar spray of $ZnSO_4$ @ 0.5% + $FeSO_4$ @ 0.5% at 30 & 45DAS, T_5- Seed treatment with $ZnSO_4$ @ 5g ha^{-1} + $FeSO_4$ @ 5g ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% + $FeSO_4$ @ 0.5 % at 30 & 45DAS, T_6- Fertigation of $ZnSO_4$ @ 12.5 kg ha^{-1} + $FeSO_4$ @ 5 kg ha^{-1} at 15 ,30 & 45 DAS, T_7- Fertigation of $ZnSO_4$ @ 18.75kg ha^{-1} + Fe SO_4 @ 7.5 kg ha^{-1} at 15, 30 & 45 DAS and T_8- Fertigation of $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1} at 15, 30 & 45 DAS. Black gram var.VBN 8 was taken for the experiment. Raised beds were formed with a plot size of 30 x 1.2 m^2. Line sowing of black gram seeds was done by adapting four rows per bed with spacing of 30 x 10 cm. Macronutrients were supplied as water-soluble fertilizer through drip fertigation for all the treatments. Irrigation was done once in 3 days based on 100 per cent potential evapotranspiration (PET).

2.3. Biometric observation

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Five plants were chosen randomly in each plot and tagged. From the tagged plants growth and yield parameters were recorded.

2.3.1. Plant height (cm)

Plant height is the indication of crop growth. With a linear meter scale, the plant height was measured from the ground level to the tip of the last opened leaf at harvest and their average was calculated and expressed in cm.

2.3.2. Leaf Area Index (LAI)

The maximum leaf length and breadth of the third leaf from the top of the plant were measured using a measuring scale and the total number of green leaves was counted from the tagged plants in each treatment. The leaf area index was worked out as suggested by Puttaswamy *et al.*[14] using the formula given below.

$$LAI = \frac{L \times B \times K \times \text{No. of leaves plant}^{-1}}{\text{Unit land area (cm}^2\text{)}}$$

where,

L – Maximum length of the third leaf from the top (cm)
B – Maximum breadth of the third leaf from the top (cm)
K – Constant factor (0.7)

2.3.3. Yield and yield attributes

The number of pods per plant was counted from five tagged plants and the mean number of pods per plant was recorded. To determine grain yield, all pods were harvested separately and threshed manually, cleaned, and dried to a 12 per cent moisture level and the grain yield from the net plot was calculated and expressed in kg ha^{-1}.

2.4. Analysis of Zn and Fe content in black gram seeds

Seed samples were subjected to drying in an oven at a temperature of 60ºC. Subsequently, the oven-dried seed samples were finely ground and then digested using a tri-acid solution. The micronutrient content of Zn and Fe in the seeds was quantified using an Atomic Absorption Spectrophotometer (AAS) at 213 nm and 248.33 nm respectively.

2.5. Water Use Efficiency

Water use efficiency (WUE) is the yield that can be produced from a given quantity of water Viets, [19]. It was worked out by using the following formula and expressed as kg mm^{-1} ha^{-1}.

$$WUE = \frac{\text{Economic yield of crop (kg ha}^{-1}\text{)}}{\text{Total water used (mm)}}$$

2.6. Economics

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To assess the economic returns of each treatment, the following parameters were computed, Cost of cultivation: The expenditure incurred from field preparation to harvest was worked out and expressed as Rs ha^{-1}. Gross return: The crop yield was computed per hectare and the total income was worked out based on the minimum market rate which was prevalent during the time of this study. Net return: Net returns were obtained by subtracting the cost of cultivation from the gross return for each treatment. Net return = Gross return (Rs. ha^{-1}) – Cost of cultivation (Rs. ha^{-1}) and Benefit Cost Ratio was calculated using crop yield and cost of cultivation for each treatment. Finally**,** the collected experimental data were statistically analyzed by the ANOVA method suggested by Gomez and Gomez [5] with R software packages (R v.4.2.1). Graph was drawn using IRRI's Statistical Tool for Agricultural Research (STAR) Version: 2.0.1.

3. RESULTS AND DISCUSSION

3.1. Plant height (cm)

Among various treatments, a maximum plant height of 65.38 cm was significantly observed by fertigation of $ZnSO_4$@ 25 kg ha^{-1} and $FeSO_4$ @10 kg ha^{-1} at 15, 30, and 45 DAS (T_8) as compared to control (T_1) plots. (Table1.). This might be due to the split application of Zn and Fe throughout the cropping period through fertigation. Greater availability of Zn and Fe promotes the meristematic growth of plants by stimulating auxin production. These results were in accordance with the findings of Kumar *et al.* [11]; Vinoth *et al*. [21] and Rathor *et al.* [15].

3.2. Leaf Area Index (LAI)

LAI was significantly influenced when the application of Zn and fertigation of $ZnSO_4$ (25 kg ha^{-1}) and $FeSO_4$ (10 kg ha^{-1}) at 15, 30, and 45 DAS (T_8) showed higher LAI of 5.55 than the control (T_1) (3.37) as indicated in Table 1. The reason might be due to the continuous supply of water and Zn and Fe produce quality of leaves with optimum size, a greater number of leaves, and greater photosynthetic activity. The findings were confirmed by the result of Anwar *et al.* [2] and Gupta *et al*. [6] who reported greater photosynthetic activity and chlorophyll synthesis due to micronutrient fertilization resulting in higher leaf area index.

3.3. Yield and yield attributes

The maximum number of 64 pods per plant and seed yield of 1267 kg ha^{-1} were recorded in fertigation of $ZnSO_4$ (25 kg ha^{-1}) and $FeSO_4$ (10 kg ha^{-1}) at 15, 30 and 45 DAS (Table1 & Fig.1) which was at par with (T_7). The minimum number of pods per plant (36) and seed yield (910 kg ha^{-1}) were recorded (fig 1). Increased in zinc and iron led to improved capabilities for the effective translocation of photosynthates from source to sink and enhanced the enzymatic activity which helps in catalyzing reaction for growth, finally leading to the development of more yield attributing characters like the number of pods per plant, pod weight, and seed yield. Similar findings were related to yield confirmed by Singh *et al*. [18]; Kakade *et al.* [10] and Saakshi *et al.* [16].

3.4. Zn and Fe content in black gram grains

Among various treatments as indicated in Table 1, drip fertigation of $ZnSO_4$ (25 kg ha^{-1}) and $FeSO_4$ (10 kg ha^{-1}) at 15, 30, and 45 DAS (T_8) released significantly increased Zn content of 76 kg ha^{-1} and Fe content of 184 kg ha^{-1} in seeds of black gram compared to control (T_1). This could be attributed to the balanced nutrient absorption achieved through fertigation,

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which has an impact on pollen production, fertility, and seed quality production. The finding was confirmed with the result of Barla *et al.* [3]; Singh *et al.* [17] and Hanumanthappa *et al*. [7].

Table: 1. Influence of zinc sulphate and ferrous sulphate on the growth, yield and seed quality of black gram under drip irrigation.

Treatments	**Plant height (cm)**	**LAI**	**No. of pods per plant**	**Seed yield (kg ha^{-1})**	**Zn content in seed (kg ha^{-1})**	**Fe content in seed (kg ha^{-1})**	**WUE (kg ha^{-1} mm^{-1})**
T_1-Control (No Zn and Fe application)	45.14	3.37	36	910	54.50	125.03	1.83
T_2- Soil application of RDF of $ZnSO_4$ @ 25kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1} at basal	52.64	4.39	47	1040	63.13	140.28	2.09
T_3 - Seed treatment with $ZnSO_4$ @ 5 g ha^{-1} + $FeSO_4$ @ 5 g ha^{-1}	48.87	3.86	41	975	59.51	132.13	1.96
T_4 - Foliar spray of $ZnSO_4$ @ 0.5% + $FeSO_4$ @ 0.5% at 30 & 45DAS	56.34	4.76	52	1107	66.01	148.83	2.23
T_5 -Seed treatment with $ZnSO_4$ @ 5g ha^{-1} + $FeSO_4$ @ 5g ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% + $FeSO_4$ @ 0.5 % at 30 & 45DAS	57.02	4.81	54	1113	66.77	152.49	2.24
T_6 - - Fertigation of $ZnSO_4$ @ 12.5 kg ha^{-1} + $FeSO_4$ @ 5 kg ha^{-1} at 15 ,30 & 45 DAS	60.82	5.12	58	1178	70.13	167.48	2.37
T_7 - Fertigation of $ZnSO_4$ @ 18.75kg ha^{-1} + Fe SO_4 @ 7.5 kg ha^{-1} at 15, 30 & 45 DAS	64.52	5.48	62	1253	75.15	182.91	2.52
T_8 - Fertigation of $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1} at 15, 30 & 45 DAS	65.38	5.55	64	1267	76.73	184.15	2.55
SEd (±)	1.20	0.14	1.26	30.16	1.20	3.16	1.83
CD (*P*=0.05)	2.57	0.31	2.69	64.68	2.56	6.78	2.09

(RDF- recommended dose of fertilizer, LAI – leaf Area Index, WUE- Water Use Efficiency, Zn – Zinc, Fe – Iron)

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3.5. Water Use Efficiency

The data shown in Table 1, indicated that maximum water use efficiency of 2.55 kg $ha^{-1}mm^{-1}$ was noticed in drip fertigation of $ZnSO_4$ (25 kg ha^{-1})and $FeSO_4$ (10 kg ha^{-1}) at 15, 30 and 45 DAS (T_8) compared to control (T_1). This might be due to application of Zn and Fe through drip fertigation, which provides essential nutrients directly to the root zone, limiting nutrient loss and leading to higher uptake and improved productivity. These findings were in accordance with Vanishree *et al*. [19] and Fanish and Selvam, [1].

Table: 2. Influence of zinc sulphate and ferrous sulphate on the economics of black gram under drip irrigation.

Treatment	COC (Rs. ha^{-1})	GMR (Rs. ha^{-1})	NMR (Rs. ha^{-1})	BCR
T_1 – control	41913	68001	26088	1.62
T_2 - Soil application of micronutrients	43802	77652	33850	1.77
T_3 - Seed treated with micronutrients	41963	72825	30862	1.74
T_4 - Foliar application of micronutrients	42104	82641	40537	1.96
T_5 - Combination of seed and foliar treatment with micronutrients	42153	83184	41031	1.97
T_6 - Fertigation at 50 % RDF of micronutrients	42833	88005	45172	2.05
T_7 - Fertigation at 75 % RDF of micronutrients	43273	93486	50213	2.16
T_8 - Fertigation at 100 % RDF of micronutrients	43943	94551	50608	2.15

(COC – Cost of Cultivation, GMR – Gross Monetary Return, NMR – Net Monetary Return, BCR – Benefit-cost ratio)

3.6. Economics

Application of $ZnSO_4$ (25 kg ha^{-1}) and $FeSO_4$ (10 kg ha^{-1}) by drip fertigation method at 15, 30, and 45 DAS (T_8) registered higher gross return of Rs.94551 ha^{-1}, net return of Rs.50608 ha^{-1} and benefit-cost ratio of 2.15 over control treatment (T_1) (Table 2). Drip fertigation of micronutrients enhanced the black gram productivity and led to an increase in the economics of black gram cultivation. Similar results were supported by Jha *et al*. [9] and Muniyappa *et al*. [13].

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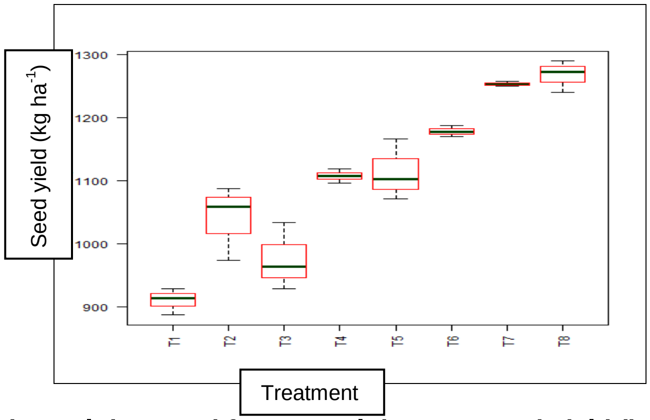

Fig 1. Effect of zinc sulphate and ferrous sulphate on seed yield (kg ha^{-1}) of blackgram under drip irrigation.

4. Conclusion

It is concluded that application of $ZnSo_4$ @ 25 kg ha^{-1} and $FeSo_4$ @10 kg ha^{-1} at 15, 30 and 45 DAS through drip fertigation increased 28.17 percent of blackgram grain yield and enhanced Zn and Fe content in grain of blackgram was 17.72 and 23.82 per cent respectively. Hence, the combined application of Zn and Fe had a positive interaction under drip fertigation and the quality of Zn and Fe content was improved through agronomic approaches.

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