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Effect of Zinc and Iron Fertilization on Yield and Seed Quality of Blackgram Grown in Calcareous Soils

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ABSTRACT

A pot culture experiment was conducted at the Agricultural College, Bapatla, during 2017, to study the effect of zinc and iron fertilization on yield and seed quality of blackgram grown in calcareous soils. The experimental soil was calcareous, moderately alkaline in reaction, low in organic carbon, available nitrogen and available phosphorus, high in available potassium and medium in available sulphur content. The soil was deficient in zinc and iron but sufficient in manganese and copper. The experiment was laid out in CRD with twelve treatments and replicated thrice. The results revealed that application of 44 mg kg^{-1} $ZnSO_4.7H_2O$ + foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid + foliar spray of zinc sulphate (0.2%) (T_{12}) to blackgram crop significantly recorded the highest yield attributes, yield and seed quality parameter *viz.,* number of pods per plant, seed yield, haulm yield, harvest index and protein content when compared to control (T_1). In case of molar ratios, maximum P/Zn and P/Fe ratios were recorded with control (T_1) while minimum was observed with 44 mg kg^{-1} $ZnSO_4.7H_2O$ + foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid + foliar spray of zinc sulphate (0.2%) (T_{12}).

Key words: *Calcareous soils*, *Blackgram*, *Zinc*, *Iron*, *Yield*, *Seed quality*.

Blackgram is one of the highly prized pulse crop, cultivated in all parts of India. It has inevitably marked itself as the most popular pulse and can be most appropriately referred to as the "king of pulses". Seeds are highly nutritious with protein (25-26%), carbohydrate (60%), fats (1.5%) and significant amount of minerals, amino acids and vitamins. Blackgram output accounts for about 10 per cent of India's total pulse production.

The availability of micronutrients is influenced by several factors such as pH, aeration, organic matter, calcium carbonate content of soil *etc*. Calcareous soils usually suffer from a lack of micronutrients, especially zinc and iron. Soil application and foliar spray of zinc sulphate enhanced the yield of crop (Savithri and Chitdeshwari, 2002). Iron deficiency is difficult to manage with the soil application due to the oxidation of soil applied iron in arid conditions. Foliar application of iron is an immediate effective measure to combat deficiency. Zinc and iron deficiency lead to decrease in yield and seed quality of blackgram.

MATERIAL AND METHODS

Three kg of soil was potted in each pot (polthylene- lined) which received FYM @ 5 t ha^{-1} and fertilizers N, P_2O_5, K_2O (25:50:25 kg ha^{-1}) through urea, SSP and MoP. The treatments comprised of T_1 - control, T_2 - 22 mg of $ZnSO_4.7H_2O$ per kg soil, T_3 - 44 mg of $ZnSO_4.7H_2O$ per kg soil, T_4 - Foliar spray of ferrous sulphate at 30 DAS*, T_5 - Foliar spray of zinc sulphate at 40 DAS*, T_6 - T_2 + T_4, T_7 - T_2 + T_5, T_8 - T_4 + T_5, T_9 - T_2 + T_4 + T_5, T_{10} - T_3 + T_4, T_{11} - T_3 + T_5, T_{12} - T_3 + T_4 + T_5. *Ferrous sulphate - $FeSO_4$. $6H_2O$ (0.5%) + 0.1% citric acid foliar spray and **zinc sulphate - $ZnSO_4.7H_2O$ (0.2%) foliar spray. The experiment was laid out in completely randomized design (CRD) with 12 treatments and replicated thrice. Zinc sulphate was applied to soil before sowing.

The experimental soil was clay with moderately alkaline in pH (8.10), normal in EC (0.60 dS m^{-1}), bulk density of 1.36 Mg m^{-3}, water holding capacity of 50.18%, 49% porosity, high in calcium carbonate (17.60%), 46.8 c mol (p^+) kg^{-1} of cation exchange capacity, exchangeable cations Na^+, K^+, Ca^{+2} and Mg^{+2} 2.60, 0.40, 38.30 and 4.80 c mol (p^+) kg^{-1}, 98.5% percent base saturation, low in organic carbon (2.40 g kg^{-1}), nitrogen (148.72 kg ha^{-1}) and P_2O_5 (14.13 kg ha^{-1}), high in potassium K_2O (509 kg ha^{-1}) and medium in sulphur (10.01 mg kg^{-1}). Available zinc (0.50 mg kg^{-1}) and iron (2.32 mg kg^{-1}) were deficient whereas, available manganese (2.63 Mg kg^{-1}) and copper (0.24 mg kg^{-1}) were sufficient. The total number of pods produced was counted from three plants and their average was taken as the number of pods per plant. At harvest stage, haulm and seed were collected separately. Protein content and molar ratios were computed by using formulas given below

Protein content (%)= nitrogen concentration (%) x 6.25

$$\text{No. of moles of P} = \frac{\text{P concentration (\%) x 10}}{\text{Atomic mass of phosphorus (30.97)}}$$

$$\text{No. of moles of Zn} = \frac{\text{Zn concentration (mg kg}^{-1}\text{)}}{\text{Atomic mass of zinc (65.38) x 1000}}$$

$$\text{No. of moles of Fe} = \frac{\text{Fe concentration (mg kg}^{-1}\text{)}}{\text{Atomic mass of iron (55.84) x 1000}}$$

$$\text{P/Zn} = \frac{\text{No. of moles of P}}{\text{No. of moles of Zn}}$$

$$\text{P/ Fe} = \frac{\text{No. of moles of P}}{\text{No. of moles of Fe}}$$

RESULTS AND DISCUSSION

Yield attributes

Number of pods per plant

The results indicated that signicantly highest mean number of pods per plant (9.67) were obtained with T_{12} (44 mg of $ZnSO_4.7H_2O$ per kg soil and foliar spray of iron and zinc) and T_9 (44 mg of $ZnSO_4.7H_2O$ per kg soil and foliar spray of iron and zinc) treatments (Table 1). However, T_6 (22 mg of $ZnSO_4.7H_2O$ per kg soil + foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid), T_8 (foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid + foliar spray of zinc sulphate (0.2%) and T_{10} (foliar spray of 44 mg of $ZnSO_4.7H_2O$ per kg soil + foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid) recorded mean number of pods per plant (9.33). T_7 (22 mg of $ZnSO_4.7H_2O$ per kg soil + foliar spray of zinc sulphate (0.2%) and T_{11} (44 mg of $ZnSO_4.7H_2O$ per kg soil + foliar spray of zinc sulphate (0.2%) recorded equal number of pods per plant (9) while T_3 (44 mg of $ZnSO_4.7H_2O$ per kg soil) and T_5 (foliar spray of zinc sulphate (0.2%) recorded mean number of pods per plant (8.33). Lowest mean number of pods (7.33) were obtained with control (T_1). These results were in consonance with Meena *et al*. (2013) in mungbean, Kavita and Singh (2014) in chickpea. Significant increase in number of pods per plant attributed to the ability of zinc to produce plant growth regulators (auxins, IAA) (Taliee *et al*., 2000) and also contributing to the formation of stamens as well as pollens (Nadergoli *et al*., 2011). Foliar spray of iron resulted higher chlorophyll content which was utilized efficiently by plants to produce more number of pods per plant (Rao, 2016).

Yield

Seed yield

The seed yield was increased significantly due to combined application of zinc and iron (Table 1). The highest seed yield (2.59 g pot^{-1}) was recorded with the treatment T_{12} (44 mg of $ZnSO_4.7H_2O$ per kg soil + foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid + foliar spray of zinc sulphate (0.2%) followed by T_9 (22 mg of $ZnSO_4.7H_2O$ + foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid + foliar spray of zinc sulphate (0.2%) which showed a slight decrease (2.43 g pot^{-1}) in yield. T_3 (1.49 g pot^{-1}) and T_5 (1.55 g pot^{-1}) treatments were on par with each other. The lowest (1.20 g pot^{-1}) seed yield was observed in the treatment T_1 (control). The order of increase in seed yield was $T_{12}>T_9>T_8>T_{10}>T_6>T_{11}>T_7>T_4>T_5=T_3>T_2>T_1$. These results were in accordance with findings of Keram *et al*. (2012) in wheat, Imran *et al*. (2015) in paddy, Rao (2016) in groundnut and Ranpariya *et al.* (2017) in mungbean. Higher seed yield due to zinc fertilization was also attributed to the enhanced synthesis of carbohydrates and their transport to the site of grain production (Peddababu *et al*., 2007). Tiffin (1967) reported that negatively charged Fe-containing compounds were essential for efficient iron movement through the xylem and citrate is the natural carrier of iron. It has an impact on many aspects of physiology of iron deficient plants inciding excretion from roots and to supply the ferric chelate reductase enzymes with enough reducing power. This mechanism could be very important for plants growing in calcareous soils where an absolute iron deficiency does not take place in presence of bicarbonate ion which is common in these soil conditions.

Haulm yield

The haulm yield was significantly influenced by application of zinc and iron (Table 1). The haulm yield increased when zinc was applied either through soil or foliar spray and foliar spray of iron. The treatment T_{12} (44 mg of $ZnSO_4.7H_2O$ per kg soil + foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid + foliar spray of zinc sulphate (0.2%) showed a significant increase (5.12 g pot^{-1}) followed by T_9 (22 mg of $ZnSO_4.7H_2O$ per kg soil + foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid + foliar spray of zinc sulphate (0.2%) which recorded a haulm yield (4.64 g pot^{-1}). However, treatments T_3 (44 mg of $ZnSO_4.7H_2O$), T_4 (foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid) and T_5 (foliar spray of zinc sulphate (0.2%) were on a par with each other and recorded 15.90, 17.67 and 22.96 % increase over control. The minimum haulm yield (2.83 g pot^{-1}) was observed with T_1 (control). These results were also in consonance with those reported by Kassab *et al*. (2004) in wheat. The significant effect might be due to combined application of zinc and iron which increased the yields mainly due to recovery from chlorosis caused by the deficiencies of micronutrients, and increased chlorophyll contents resulting in more photosynthesis and productivity (Singh *et al*., 1993).

Table1. Effect of zinc and iron fertilization on yield and yield attributes of blackgram grown in calcareous soils

Treatments	NO. of pods per plant	Seed (g pot^{-1})	Haulm (g pot^{-1})	Harvest index (%)
T_1 - Control	7.33	1.20	2.83	29.78
T_2 - 22 mg of $ZnSO_4.7H_2O$ per kg soil	7.67	1.32	3.06	30.17
T_3 - 44 mg of $ZnSO_4.7H_2O$ per kg soil	8.33	1.49	3.28	31.25
T_4 - Foliar spray of ferrous sulphate at 30 DAS*	8.67	1.63	3.33	32.87
T_5 - Foliar spray of zinc sulphate at 40 DAS**	8.33	1.55	3.48	30.82
T_6 - T_2 + T_4	9.33	1.89	4.01	32.00
T_7 - T_2 + T_5	9.00	1.73	3.70	31.82
T_8 - T_4 + T_5	9.33	2.06	4.39	31.94
T_9 - T_2 + T_4 + T_5	9.67	2.43	4.64	34.42
T_{10} - T_3 + T_4	9.33	1.97	4.23	31.78
T_{11} - T_3 + T_5	9.00	1.81	3.92	31.50
T_{12} - T_3 + T_4 + T_5	9.67	2.59	5.12	33.59
SEm $\pm$	0.09	0.02	0.07	0.43
CD at 5%	0.27	0.07	0.21	1.30
CV %	1.81	2.37	2.13	2.35

*Ferrous sulphate- 0.5% $FeSO_4$. $6H_2O$ + 0.1% citric acid, **zinc sulphate-0.2% $ZnSO_4.7H_2O$ limitations to plants will lead to the improvement of harvest index.

Table2. Effect of zinc and iron fertilization on quality parameter of seed

Treatments	Seed		
	Protein content (%)	Molar ratios P/Zn	Molar ratios P/Fe
T_1 - Control	16.87	257.81	32.12
T_2 - 22 mg of $ZnSO_4.7H_2O$ per kg soil	18.43	205.24	31.73
T_3 - 44 mg of $ZnSO_4.7H_2O$ per kg soil	18.68	198.89	31.04
T_4 - Foliar spray of ferrous sulphate at 30 DAS*	17.81	242.48	29.62
T_5 - Foliar spray of zinc sulphate at 40 DAS**	18.69	201.33	31.00
T_6 - T_2 + T_4	19.12	196.34	29.66
T_7 - T_2 + T_5	20.12	173.63	30.70
T_8 - T_4 + T_5	19.94	181.37	29.51
T_9 - T_2 + T_4 + T_5	20.69	174.37	29.13
T_{10} - T_3 + T_4	19.50	186.29	29.40
T_{11} - T_3 + T_5	20.56	165.30	30.32
T_{12} - T_3 + T_4 + T_5	20.81	161.90	28.59
SEm $\pm$	0.27	3.43	0.57
CD at 5%	0.81	9.97	1.67
CV %	2.50	3.02	3.29

*Ferrous sulphate- 0.5% $FeSO_4$. $6H_2O$ + 0.1% citric acid; **zinc sulphate- 0.2% $ZnSO_4.7H_2O$

Harvest Index

The harvest index increased significantly due to combined application of zinc and iron (Table 1). Maximum harvest index (34.37%) was obtained with 22 mg kg^{-1} zinc sulphate per kg soil+ foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid and foliar spray of zinc sulphate (0.2%) (T_9) which was on par with 44 mg kg^{-1} zinc sulphate per kg soil+ foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid + foliar spray of zinc sulphate (0.2%) (T_{12}). While lowest harvest index was obtained with treatment control (T_1) (29.77%) which was on par with soil application of zinc sulphate @ 22 mg kg^{-1} (T_2) (30.14%) and foliar spray of zinc sulphate (T_5) (30.82%). Similar results of significant increase in harvest index were reported by Yaseen *et al*. (2013) in cotton. Zinc and iron acts as the factors that alleviates the existing limitations to plants will lead to the improvement of harvest index.cx

Seed Quality

Protein content

The results (Table 2) revealed that among all treatments T_{12} (44 mg kg^{-1} of $ZnSO_4.7H_2O$ per kg soil and foliar spray of ferrous sulphate and zinc sulphate) recorded maximum seed protein content (20.81%) which was on par with T_9 (22 mg kg^{-1} of $ZnSO_4.7H_2O$ per kg soil and foliar spray of ferrous sulphate and zinc sulphate) (20.69%), T_{11} (44 mg kg^{-1} of $ZnSO_4.7H_2O$ per kg soil and foliar spray of zinc sulphate (20.56%) and T_7 (44 mg kg^{-1} of zinc sulphate per kg soil and foliar spray of zinc) (20.12%). Similar results were reported by khattak *et al*. (2015) and Zeidan *et al*. (2010) in wheat. Improvement in seed protein content might be attributed to the role of micronutrients in enhancing accumulation of assimilate in the seed (during grain filling stage) and thus the resultant seeds had greater individual mass (Fenner, 1982; Roach and wulf, 1987; Zeidan, 2001) Minimum protein content (16.87%) was observed with control (T_1). Treatments T_7, T_8, T_9 and T_{11} were on par with each other while T_6, T_7, T_8 and T_{11} and T_5, T_3 and T_2 treatments were on par with each other.

P/Zn

Maximum P/Zn ratio (257.81) was observed with control (T_1) when compared to all treatments while minimum P/Zn ratio (161.93) was observed with T_{12} (soil application of zinc sulphate @ 44 mg kg^{-1} and foliar spray of iron and zinc) which as on par with T_{11} (165.30) (Table 2). These results of significant increase in P/Zn ratio was reported by Welch *et al*. (2005) and Kutman *et al*. (2011) in wheat.

Treatments T_2, T_3, T_5 and T_6 were on par with each other and also T_8 and T_{10} treatments were on par with each other while T_7, T_8 and T_9 treatments were on par with each other. Higher the molar ratio (P/Zn), the bioavilability of zinc was less and vice versa (Zhang *et al*., 2010)

P/Fe

Significant effect was observed in molar ratio (P/Fe) of blackgram seed due to zinc and iron fertilization.

Maximum P/ Fe ratio (32.12) was observed with control (T_1) and minimum (28.59) with T_{12} (soil application of zinc sulphate @ 44 mg kg^{-1} + foliar spray of iron and zinc). Similar results of increase in P/Fe ratio were reported by Zhang *et al.* (2010) in wheat. P/Fe ratios of the treatments T_1, T_2, T_3, T_5 and T_7 were on par with each other. Treatments T_2, T_3, T_5, T_7 and T_{11} were on par with each other while T_3, T_4, T_5, T_6, T_7, T_8, T_{10} and T_{11} on par with each other. Treatments T_4, T_6, T_7, T_8, T_9 were on par with each other whereas, T_6, T_4, T_8, T_{10}, T_9 and T_{12} treatments were on par with each other. Lower the value of P/Fe ratio, higher the iron bioavailability.

Among these two molar ratios (P/Zn and P/Fe), P/Zn ratio was higher than P/Fe. This might be due to relatively higher mobility of zinc when compared to iron (Zhang *et al*., 2010).

CONCLUSION

Besides, major and secondary nutrients pulses also require micronutrients for completing its life cycle. Due to increase intensity of the pulse based cropping systems and use of high analysis fertilizers pulse growing areas of the country become multinutrient deficient particularly zinc and iron in calcareous soil. Application zinc and iron fertilizers are the effective method to overcome the zinc and iron deficiency in calcareous soils. Among different treatments, soil application of zinc sulphate @ 44 mg kg -1 + foliar spray of ferrous sulphate (0.5%) + 0.1% citric acid + foliar spray of zinc sulphate (0.2%) (T 12) highly increased the yield (number of pods per plant, seed. yield, haulm yield) and seed quality (protein content, P/Zn and P/Fe) of blackgram grown in calcareous soils.

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