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Effect of zinc biofortification on growth, yield and economics of chickpea (*Cicer arietinum* L.)

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Abstract

A field experiment was carried out on medium black calcareous soil at Junagadh Agricultural University, Junagadh, Gujarat during *rabi* season 2017-18 to evaluate biofortification of zinc in chickpea (*Cicer arietinum* L.) varieties through seed, soil and foliar application. The experiment was laid out in factorial randomized block design with three replications which comprised two varieties *viz.*, GG 1 (V₁) and GJG 3 (V₂) and six zinc fortification treatments. The chickpea was grown with standard package of practices. The results revealed that growth parameters *viz.*, plant height, days to 50% flowering, branches per plant, dry matter production at 60 DAS and at harvest, number of root nodules per plant did not influenced significantly with the different chickpea varieties while chickpea variety GJG 3 recorded significantly higher dry matter production at 30 DAS. A significant improvement in 100-seed weight, seed yield, straw yield and biological yield were observed with chickpea variety GJG 3 over GG 1. Significantly higher numbers of pods per plant (45.83) was recorded with variety GG 1. Chickpea variety GJG 3 produced higher net return (₹ 62,508 ha⁻¹) over variety GG 1. Under agronomic strategy, zinc fortification through soil application ZnSO₄ @ 25 kg ha⁻¹ + 0.5% ZnSO₄ foliar spray at flowering and pod filling stages significantly improved all the growth parameters *viz.*, plant height, branches per plant, days to 50% flowering, dry matter production at 30 DAS, 60 DAS and at harvest, yield attributes and yield *viz.*, pods per plant, seed yield and straw yield. While maximum net return (₹ 70,322 ha⁻¹) was obtained with the treatment soil application ZnSO₄ @ 25 kg ha⁻¹ + 0.5% ZnSO₄ foliar spray.

Keywords: Chickpea, varieties, zinc, biofortification, growth, yield

1. Introduction

Pulses are wonderful gift of nature to agriculture. They provide nutrition to human beings and animals. India is one of the major pulses growing country of the world. Pulses occupy a key position in Indian diet and meet about 30% of the daily protein requirement. Among the pulses, chickpea is an important *rabi* season crop with high acceptability and wider use in nutritional food basket. The essential components of balanced nutritional food are protein, fat, fibre, and mineral nutrients. Chickpea is a good source of protein. It contains 17-21% protein, 62% carbohydrates, 4% fat and is rich source of phosphorous, calcium, iron, niacin, vitamin-C (in green stage) and vitamin-B₁. Chickpea contains significant amounts of all the essential amino acids except sulphur-containing amino acids. Its green leaves contains malic and oxalic acid, which has medicinal value for blood purification and also for intestinal effects.

Deficiencies of micronutrients drastically affected the growth, metabolism and reproductive phase in plants, animals and human beings. Micronutrient malnutrition affects more than half of the world population mainly in the developing countries and in particular Fe and Zn deficiency in human nutrition are wide-spread in developing Asian countries including India. Although these nutrients are micro in terms of uptake, their contributions are as important as those of macronutrients. The micronutrients limiting chickpea productivity in the order of importance are Zn>Fe>B (Ahlawat *et al.*, 2007) ^[1].

The agronomic importance of chickpea is linked to its high quality protein content and other essential minerals, especially micronutrients. About 49% of Indian soils are deficient in zinc and response to Zn application has been reported for a number of crops including chickpea. A recent estimate indicates that nearly half of the world population suffers from Zn deficiency. Wuehler *et al.* (2005) ^[24] reported that approximately 20.5% of the world's population is estimated to be at risk of inadequate Zn intake, with the percentage of individuals at risk highest in the South East Asia (33%) followed by Sub Saharan Africa (28%), South Asia

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(27%), Latin America and the Caribbean (25%). Zinc is an essential nutrient for crops as it is a major metal component of many enzymes (dehydrogenase, proteinase, peptidase etc.), boost protein and chlorophyll synthesis, helps in utilization of N and P in plants and promotes seed maturation and production (Malvi, 2011) ^[14]. It is also responsible for resisting pH changes in cytoplasm. Zn is involved in auxin metabolism like, tryptophan synthesis and tryptamine metabolism. Zinc plays an important role in protein synthesis. Biofortification is regarded as one strategy to address the persistent burden of micronutrient malnutrition specifically by improving zinc concentration. The present study was undertaken to study the effect of zinc biofortification on growth yield and quality of chickpea.

2. Materials and Methods

A field experiment was conducted during *rabi* season of 2017-18 at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh to study the "Biofortification of zinc in chickpea (*Cicer arietinum* L.) varieties through seed, soil and foliar application". The experiment was conducted on a clayey textured soil, which was medium in organic carbon (0.42%) and slightly alkaline in reaction with pH 7.60 and EC 0.52 dS m⁻¹. The experimental soil was low in available nitrogen (245.89 kg ha⁻¹), medium in available phosphorus (35.11 kg ha⁻¹), medium in available potash (270.70 kg ha⁻¹) and medium in available zinc (0.73 mg kg⁻¹) during the *rabi* season of 2017-18. The experiment having 12 treatment combinations was laid out in factorial randomized block design with three replications. The main plot comprised two chickpea varieties having contrasting zinc content *viz.*, GG 1 (V₁) and GJG 3 (V₂) and sub plots comprised six zinc biofortification treatments *viz.*, Control (F₁), Seed treatment ZnSO₄ @ 3 g kg⁻¹ seed (F₂), 0.5% ZnSO₄ foliar spray at flowering and pod filling stages (F₃), Seed treatment ZnSO₄ @ 3g kg⁻¹ seed + 0.5% ZnSO₄ foliar spray (F₄), Soil application ZnSO₄ @ 25 kg ha⁻¹ (F₅) and Soil application ZnSO₄ @ 25 kg ha⁻¹ + 0.5% ZnSO₄ foliar spray (F₆) with gross and net plot sizes of 5.0 m × 2.7 m and 4.0 m × 1.8 m, respectively. The chickpea varieties (GG 1 and GJG 3) were grown with standard package of practices.

3. Results and discussion

3.1 Growth parameters

The data pertaining to the effect of different varieties and different zinc fortification on growth parameters are presented in Table 1. In the present study, growth of both chickpea varieties in terms of plant height, number of branches per plant, days to 50% flowering, number of root nodules per plant at 55 DAS, and dry matter production at 30 DAS, 60 DAS and at harvest revealed that growth characteristics of chickpea varieties showed pronounced improvement at all the periodic intervals with the application of zinc fortification treatments. Chickpea varieties had no significant effect on growth parameters. However, between the chickpea varieties, GJG 3 variety registered numerically higher values of plant height and dry matter production over GG 1. The variations in respect of plant height and dry matter production and other growth parameters might be due to differential genetic makeup of the individual variety. Improved growth and higher dry matter portioning at initial stages towards seeds and greater source-sink capacity into numerous metabolites might have needed for better yield.

The effect of different zinc fortification on growth parameters showed significantly pronounced improvement over control. Growth parameters *viz.*, plant height, number of branches per plant, days to 50% flowering and dry matter accumulation at 30 DAS, 60 DAS and at harvest were influenced significantly. The significant changes in these parameters were recorded at 30 days after sowing onwards up to harvest with treatment F₆ (Soil application ZnSO₄ @ 25 Kg ha⁻¹ + 0.5% Zn foliar spray), which statistically remained at par with treatment F₅ (Soil application ZnSO₄ @ 25 Kg ha⁻¹) in most of cases followed by treatment F₄ (Seed treatment @ 3 g kg⁻¹ of seed + 0.5% Zn foliar spray). However, significantly the lowest values of growth parameters were recorded under the treatment F₁ (Control).

A glance of data revealed that different zinc fortification treatments had significant influence on days to 50 per cent flowering. The minimum number of days to attain 50% flowering was recorded with the treatment F₆ (Soil application ZnSO₄ @ 25 kg ha⁻¹ + 0.5% Zn foliar spray) followed by other zinc fortification treatments. The 50% flowering was delayed in control plot (48.83 days). The early flowering in chickpea was noted with soil plus foliar application of ZnSO₄ which might be due to the fact that zinc played a vital role in growth and development of plant because of its stimulatory and catalyst effect in various physiological and metabolic process of the plant. These results are in close conformity with the finding of Sajid *et al.* (2016) ^[17] and Ingle *et al.* (2016) ^[9]. In respect to growth parameters, the superiority of the zinc biofortification applied either through seed, soil or spray treatments over no zinc application may be ascribed to improved physical, chemical and biological conditions of the plant by virtue of better growth and better nutrient uptake. Thus, it accelerated photosynthetic rate and supply of balanced nutrition to the plants which play a pivotal role in cellular growth, differentiation and metabolism which results in vigorous growth of plants. The increment in plant height in relation to the application of zinc is due to the formation of auxin and to ease in availability of zinc to plant leaves in the apical portion of the plant which promotes the height of the plant. The higher dry matter production due to the application of zinc is ascribed to the vigorous and enhanced plant growth and also to higher leaf area development that aided in the effective interception of light leading to higher dry matter production. The foliar application of zinc increased the availability of nutrients to the plants, which is directly absorbed by the plant leaves and translocation of the prepared food by different parts of the plant and hence growth of the plant occurs. Similar results were also reported by Tripathi *et al.* (2012) ^[23], Hadi *et al.* (2013) ^[5], Kayan *et al.* (2015) ^[12], Sajid *et al.* (2016) ^[17] and Hossain *et al.* (2016) ^[8].

3.2 Yield and yield attributes

The yield and yield attributes as influenced by different treatments recorded at harvest are presented in Table 2. Among the different yield attributes, significantly the higher number of pods per plant, 100-seed weight and seed and straw yield were recorded under the variety GJG 3 in most of cases over the variety GG 1. Due to the improved yield attributes, variety GJG 3 recorded significantly higher seed index (100-seed weight), seed yield, straw yield and biological yield over variety GG 1. The differences in yield attributes and yield might have been caused due to varietal differences. The variety GJG 3 recorded significantly the higher seed index due to its boldness of seeds. Better growth and higher uptake of nutrients by variety GJG 3 might have produced most

number of pods per plant and 100-seed weight and yields. The results of present investigation strongly corroborates with the findings of Tripathi *et al.* (2012) [23] who reported significant differences among genotypes of chickpea on number of pods per plant and 100-seed weight.

Zinc fortification treatments had significant influence on yield attributes viz., number of pods per plant, seed yield and straw yield. A significant increase in yield attributes and yield of chickpea crop was recorded when crop was biofortified with zinc through soil application ZnSO_4 @ 25 kg ha⁻¹ + 0.5% ZnSO_4 foliar spray (F₆) closely followed by treatment F₅ (Soil application ZnSO_4 @ 25 kg ha⁻¹) in all yield attributes and yield of chickpea. The yield of crop is the cumulative effect of growth and yield attributing characters. Zinc is involved in the starch formation, growth promoting substance like auxin, seed maturation and production. Increased availability has shown marked improvement in growth attributes and indirectly increases grain and straw yields. The favorable influence of sufficient zinc application on yield might be also attributed to its role in various enzymatic reactions, growth processes, hormone production and protein synthesis and also in translocation of photosynthates to seeds. Better plant growth, root growth, increased dry matter production, good source to sink relationship in pods and maximum nutrient uptake by the crop helped the plant to put optimum growth and development, as growth and yield attributes were positively correlated with chickpea seed yield, evidently resulted in higher seed yield under above mentioned zinc fortification treatments. The increase in seed yield with the zinc biofortification treatments applied either through soil @ 25 kg ZnSO_4 ha⁻¹ or foliar spray @ 0.5% ZnSO_4 at flowering and

pod filling stages was to the tune of 30.07 and 21.03 per cent, respectively over no zinc biofortification treatments (control). The results of the investigation are in line with those of Sharma and Abrol (2007) [18], Kaya *et al.* (2009) [11], Pathak *et al.* (2012) [15], Shivay *et al.* (2014) [20] and Kharol *et al.* (2014) in chickpea.

3.3 Economics

The maximum gross return, net return and B: C ratio as given in Table 2. was obtained with the chickpea variety GJG 3 followed by GG 1, which might be due to the higher seed and straw yields. Higher economic returns were generated by virtue of higher crop yields due to genetic makeup of the chickpea varieties. These results are conformity with those reported by Shivay *et al.* (2014) [20]. Application of different zinc biofortification treatments to chickpea fetched the highest gross return, net return and B: C ratio over no zinc fortification (RD of NPK). The higher B: C ratio and net profitability was obtained when the crop biofortified with zinc application through soil application ZnSO_4 @ 25 kg ha⁻¹ + 0.5% ZnSO_4 foliar spray at flowering and pod filling stages (F₆) followed by soil application ZnSO_4 @ 25 kg ha⁻¹ (F₅). The lowest net return (49,135 ₹ ha⁻¹) and B: C ratio (2.46) was obtained in control. The better plant growth, better number of pods per plant and higher seed and straw yield might have been responsible for the higher benefit: cost ratio as well as net profitability of Zn applied treatments over control. These results on relative economics of zinc fortified treatments are in agreement with the findings of Naik and Das, (2008), Gowda *et al.* (2014) [4], Shivay *et al.* (2014) [20], Singh and Shivay (2015) [22] and Jat *et al.* (2015) [10].

Table 1: Effect of different treatments on growth parameters of chickpea.

Treatments	Plant height (cm)	No. of braches plant ⁻¹	Days to 50% flowering	No. of root nodulesplant ⁻¹	Dry matter production (g plant ⁻¹)		
					30 DAS	60 DAS	At harvest
Varieties							
GG 1	39.74	7.69	46.89	17.67	2.36	13.60	26.44
GJG 3	40.95	7.82	46.06	18.39	2.52	13.88	26.73
S.Em	0.76	0.17	0.56	0.32	0.05	0.27	0.49
C.D. at 5%	NS	NS	NS	NS	0.15	NS	NS
Fertilizer							
F ₁	37.20	6.66	48.83	16.83	1.90	10.88	19.36
F ₂	39.30	7.60	47.17	17.83	2.21	12.00	22.01
F ₃	40.12	7.61	47.17	17.83	2.38	13.52	25.01
F ₄	41.17	7.85	46.83	18.00	2.56	14.20	28.39
F ₅	40.47	8.33	44.83	19.17	2.72	15.20	31.67
F ₆	43.83	8.52	44.00	18.50	2.85	16.67	33.12
SEm	1.32	0.29	0.98	0.55	0.09	0.46	0.85
C.D. at 5%	3.87	0.85	2.86	NS	0.26	1.35	2.50
Interaction							
SEm	1.86	0.41	1.38	0.77	0.12	0.65	1.21
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS
C.V.	8.00	9.12	5.14	7.51	8.74	8.23	7.85

Table 2: Effect of different treatments on yield attributes and yield of chickpea.

Treatments	Number of pods plant ⁻¹	100- seed weight	Seed yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Gross return (₹ ha ⁻¹)	Cost of cultivation (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	BCR
GG 1	45.83	17.52	46.89	17.67	89673	34948	54725	2.56
GJG 3	42.00	23.32	46.06	18.39	97456	34948	62508	2.78
S.Em	1.18	0.33	0.56	0.32	-	-	-	-
C.D. at 5%	3.45	0.98	NS	NS	-	-	-	-
F ₁	32.17	20.13	48.83	16.83	82691	33556	49135	2.46
F ₂	37.50	20.71	47.17	17.83	88649	33805	54844	2.62
F ₃	42.67	20.01	47.17	17.83	89079	34147	54932	2.61
F ₄	45.83	20.94	46.83	18.00	93389	34375	59014	2.72
F ₅	50.17	20.16	44.83	19.17	100060	36060	63454	2.73

F ₆	55.17	20.58	44.00	18.50	107521	37199	70322	2.89
SEm	2.04	0.58	0.98	0.55	-	-	-	-
C.D. at 5%	5.98	NS	2.86	NS	-	-	-	-
Interaction								
SEm	2.88	0.82	1.38	0.77	-	-	-	-
C.D. at 5%	NS	NS	NS	NS	-	-	-	-
C.V.	11.38	6.92	5.14	7.51	-	-	-	-

Treatment Details

A: Varieties (V)-V₁ : GG 1 (Having low Zn content in seed), V₂ : GJG 3 (Having high Zn content in seed)

B: Fertilizer levels (F)- F₁ : Control, F₂ : Seed treatment ZnSO₄ @ 3 g kg⁻¹ seed, F₃ : 0.5% ZnSO₄ foliar spray, F₄ : Seed treatment ZnSO₄ @ 3 g kg⁻¹ seed + 0.5% ZnSO₄ foliar spray, F₅ : Soil application ZnSO₄ @ 25 kg ha⁻¹, F₆ : Soil application ZnSO₄ @ 25 kg ha⁻¹ + 0.5% ZnSO₄ foliar spray

4. Conclusion

On the basis of one year field study, it can be concluded that among the two chickpea varieties and six zinc biofortification treatments, chickpea variety GJG 3 was found promising for better production and seed zinc fortification. While zinc fortification through soil application ZnSO₄ 25 kg ha⁻¹ + 0.5% ZnSO₄ foliar spray at flowering and pod formation stages coupled with basal RD of NPK was found the best agronomic practice to improve zinc content in seed and higher seed yield in irrigated chickpea under *Saurashtra* region of Gujarat.

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