LR-4677
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Agronomic Biofortification of Zinc in Chickpea Varieties in Calcareous Soil

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10.18805/LR-4677

ABSTRACT

Background: Pulses are wonderful gift of the nature to agriculture. They provide nutrition to human beings and animals as food and feed respectively. Among the pulses, chickpea is an important *rabi* season crop with high acceptability and wider use in nutritional food basket. A field experiment was carried out on medium black calcareous soil at Junagadh Agricultural University, Junagadh, Gujarat during *rabi* season 2017-18 under saurastra condition to evaluate agronomic biofortification of zinc in chickpea (*Cicer arietinum* L.) varieties through seed, soil and foliar application.

Methods: The experiment was laid out in factorial randomized block design with three replications. The treatment combinations comprised two varieties *viz*., GG 1 (V_1) and GJG 3 (V_2) and six zinc fortification treatments *viz.,* control, seed treatment $ZnSO_4$ @ 3 g kg^{-1} seed, 0.5% $ZnSO_4$ foliar spray, seed treatment $ZnSO_4$ @ 3g kg^{-1} seed + 0.5% $ZnSO_4$ foliar spray, soil application $ZnSO_4$ @ 25 kg ha^{-1} and soil application $ZnSO_4$ @ 25 kg ha^{-1} + 0.5% $ZnSO_4$ foliar spray. The chickpea was grown with standard package of practices.

Result: The results revealed that a significant improvement in 100-seed weight, seed yield, stover 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. Significantly, chickpea variety GJG 3 was found superior in zinc content and uptake in seed and stover. Under agronomic strategy, zinc fortification through soil application $ZnSO_4$ @ 25 kg ha^{-1} + 0.5% $ZnSO_4$ foliar spray at flowering and pod filling stages significantly improved yield attribute and yield *viz*., pods per plant (55.17), seed yield (2288 kg ha^{-1}) and stover yield (3553 kg ha^{-1}) and quality parameters *viz.,* protein content in seed (22.89%) and protein yield (523 kg ha^{-1}), zinc content and uptake in seed and stover (45.98 and 37.51 ppm and 104.87 and 133.35 g ha^{-1}, respectively) over all other zinc biofortification treatments.

Key words: Biofortification, Chickpea, Growth, Quality, Varieties, Yield, Zinc.

INTRODUCTION

Pulses are wonderful gift of the nature to agriculture. They provide nutrition to human beings and animals as food and feed respectively. India is one of the top pulses producing countries of the world. Nearly 30% of daily protein requirement of Indian population is provided by the pulses. 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 in phosphorous, calcium, iron, niacin, vitamin-C (in green stage) and vitamin-B_1. Chickpea contains significant amounts of all the essential amino acids except sulphur-containing amino acids. The green leaves of chickpea contains malic and oxalic acid having medicinal value for blood purification and also for intestinal effects.

Not only plants but humans also require essential micronutrients and protein for normal physiological function of the body (Singh *et al.,* 2015). Growth, metabolism and reproduction in plants, animal and human beings severely affected due to micronutrient deficiency. Half of the world population affected due to micronutrient malnutrition. Animal-based foods contain higher quantity of Zn (Cakmak and Kutman, 2018). In developing countries, the contribution of animal-based foods to the Zn supply is much less as compared to high-income countries (Wessells and Brown, 2012). Zinc deficiency causes problem in different organs of the epidermal, nervous, skeletal, immune, reproductive and gastrointestinal system (Praharaj *et al.,* 2021). 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). Zn deficiency along with other micronutrient deficiencies causes economic loss to countries as the nation faces more health-care problems and does expenditure on the health care (Stein, 2014).

Soils of India are mostly deficient in Zinc. Around 49 percent of Indian soils are zinc deficient. Zinc is an essential nutrient for crops as it is a major metal component of many enzymes (dehydrogenase, proteinase, peptidase *etc*.), boost

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How to cite this article: Parmar, P.M., Poonia, T.C. and Raiyani, V.N. (2021). Agronomic Biofortification of Zinc in Chickpea Varieties in Calcareous Soil. Legume Research. DOI:10.18805/LR-4677.

Submitted: 27-05-2021 **Accepted:** 26-08-2021 **Online:** 28-09-2021

protein and chlorophyll synthesis, helps in utilization of N and P in plants and promotes seed maturation and production (Malvi, 2011). Zn is a part of nearly 3,000 proteins, which constitute 10% of total proteins in the human body (Krezel and Maret, 2016). Plant cultivars differ in their ability to grow in low plant-available Zn with respect to Zn uptake and utilization. Cultivars with higher zinc utilization may contain higher amounts of chelators that bind zinc and increase its availability at the cellular level (Sadeghzadeh, 2013).

The process of adding vitamins or minerals to the crops in order to improve their overall nutrient content is called as biofortification which is being sustained over a long period, making it cost effective way to overcome micronutrient malnutrition (Bouis and Saltzman, 2017). Enhancement of a particular nutrient by addition of fertilizers to soil or to foliage in appropriate form, time and growth stages of the crop is known as agronomic biofortification. Biofortification promises the better nutritional accessibility to masses overcoming various hindrances and reaching the doorstep (Sharma *et al.,* 2017).

In Saurashtra region, chickpea is grown as a low cost remunerative crop due to its lower water requirement and high market price as compared to other pulses. Zinc deficiency is one of the most frequently encountered micronutrient deficiencies in pulses in most of black cotton soils. Negligence of organic manure application and high emphasis on major nutrients in intensive cropping system, leads to deficiency of some micronutrients, especially Zn and Fe. It results into production of poor nutritional seeds of grain legumes which cause widespread malnutrition in consumers. The present experiment was undertaken to study the effect of zinc biofortification on growth, yield and quality of chickpea varieties.

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 “Biofotification 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 7.6 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 was comprised of two chickpea varieties having contrasting zinc content *viz*., GG 1 (V_1) and GJG 3 (V_2) and sub plots were of six zinc biofortification treatments *viz*., control (F_1), seed treatment $ZnSO_4$ @ 3 g kg^{-1} seed (F_2), 0.5% $ZnSO_4$ foliar spray at flowering and pod filling stages (F_3), seed treatment $ZnSO_4$ @ 3g kg^{-1} seed + 0.5% $ZnSO_4$ foliar spray (F_4), soil application $ZnSO_4$ @ 25 kg ha^{-1} (F_5) and soil application $ZnSO_4$ @ 25 kg ha^{-1} + 0.5% $ZnSO_4$ foliar spray (F_6) with gross and net plot sizes of 5.0 m × 2.7 m and 4.0 m × 1.8 m, respectively. The chickpea varieties were grown by adopting standard package of practices as suggested by the competent authority of Department of Agronomy, Junagadh Agricultural University, Junagadh.

RESULTS AND DISCUSSION

A. Effect of varieties

I. Yield and yield attributes

The yield and yield attributes as influenced by different treatments recorded at harvest are presented in Table 1. Among the different yield attributes, significantly the higher number of pods per plant, 100-seed weight and seed and stover yields were recorded under the variety GJG 3 in most of cases over the variety GG 1. The differences in yield attributes 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 the most number of pods per plant and 100-seed weight. Results of the present investigation strongly corroborate with the findings of Tripathi *et al*. (2012), Sadeghzadeh, (2013) and Hidoto *et al.* (2017).

II. Effect on nutrient content, uptake and quality of chickpea

The quality parameters as influenced by different treatments recorded at harvest are presented in Table 2. A glance of data revealed that protein content in seed of different chickpea varieties were not significantly influenced. However, protein yield, zinc content in seed and stover were significantly influenced by chickpea varieties. Significantly greater protein yield, zinc content in seed and stover were recorded with variety GJG 3 than GG 1. This indicated a significant attainment in respect to zinc biofortification either through seed, soil or foliar spray in chickpea seed adopting agronomic interactions. This was due to that Zn application improved yield and yield components through various mechanisms, for example, it improves chlorophyll content, triggers photosynthetic activity and auxin synthesis which leads to better growth and development of the crop. The differences in zinc content of seed and stover might have been caused due to varietal differences and genetic makeup of individual variety and availability of nutrients in which particular variety leads to more zinc uptake from the soil. These results are in close agreement reported by Siddiqui *et al.* (2015), Hidoto *et al.* (2016), Hidoto *et al.* (2017) and Praharaj *et al.* (2021).

B. Effect of zinc biofortification

I. Yield and yield attributes

The data pertaining to the effect of different zinc fortification treatments on yield attributes and yield are presented in

Table 1. Zinc fortification treatments had significant influence on yield attributes such as number of pods per plant, seed yield and stover yield. A significant increase in yield attributes and yield of chickpea crop were recorded when crop was biofortified with zinc through soil application $ZnSO_4$ @ 25 kg ha^{-1} + 0.5% $ZnSO_4$ foliar spray it was closely followed by the treatment soil application $ZnSO_4$ @ 25 kg ha^{-1} in yield attributes and yields 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 stover yield. 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 (Pal *et al.,* 2021). 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 Pathak *et al*. (2012), Shivay *et al*. (2014), Kharol *et al*. (2014), Kayan *et al.* (2015), Hossain *et al*. (2016), Ingle *et al.* (2016) and Sajid *et al*. (2016) in chickpea.

Table 1: 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})	Stover yield (kg ha^{-1})
Varieties				
GG 1	45.83	17.52	1908	3094
GJG 3	42.00	23.32	2074	3369
S.Em	1.18	0.33	55	69.09
C.D. at 5 %	3.45	0.98	161.89	202.65
Fertilizer				
F_1	32.17	20.13	1759	2906
F_2	37.50	20.71	1886	3115
F_3	42.67	20.01	1895	3233
F_4	45.83	20.94	1987	3181
F_5	50.17	20.16	2129	3360
F_6	55.17	20.58	2288	3553
SEm	2.04	0.58	95	119.68
C.D. at 5 %	5.98	NS	280.41	351.00
Interaction				
SEm	2.88	0.82	135	169.25
C.D. at 5 %	NS	NS	NS	NS
C.V.	11.38	6.92	11.76	9.07

II. Effect on nutrient content, uptake and quality of chickpea

The data pertaining to the effect of different zinc fortification treatments quality parameters are presented in Table 2. Quality of chickpea in terms of protein content revealed that

Table 2: Effect of different treatments on quality of chickpea.

Treatments	Protein content (%)	Protein yield (kg ha^{-1})	Zinc content in seed (ppm)	Zinc content in stover (ppm)	Zinc uptake in seed (g ha^{-1})	Zinc uptake in stover (g ha^{-1})
Varieties						
GG 1	21.52	412	31.40	27.77	61.55	86.61
GJG 3	21.91	455	32.76	32.59	69.40	111.29
S.Em	0.18	11	0.23	0.40	1.93	2.47
C.D. at 5 %	NS	33.58	0.68	1.17	5.66	7.25
Fertilizer						
F_1	20.50	361	17.25	21.17	30.44	61.60
F_2	21.01	397	23.36	25.29	44.48	79.93
F_3	21.84	414	31.98	28.88	60.64	93.71
F_4	21.77	431	34.25	31.86	68.17	102.21
F_5	22.27	474	39.56	36.40	84.28	122.91
F_6	22.89	523	45.98	37.51	104.87	133.35
SEm	0.31	20	0.40	0.69	3.35	4.28
C.D. at 5 %	0.90	58.17	1.18	2.03	9.81	12.56
Interaction						
SEm	0.44	28	0.57	0.98	4.73	6.05
C.D. at 5 %	NS	NS	NS	NS	NS	NS
C.V.	3.48	11.21	3.07	5.62	12.51	10.60

significantly the superior values of protein content in seed and protein yield was analyzed when crop was biofortified with zinc through soil application $ZnSO_4$ @ 25 kg ha^{-1} + 0.5% $ZnSO_4$ foliar spray (F_6) over the control. The lowest protein content and protein yield was analyzed in control (no zinc biofortification). This might be due to the increase in carbohydrates and fat synthesis on accent of stimulating effect of sprayed zinc on several dehydrogenase, proteinase, peptidase enzymes activity as Zn is a constituent of these enzymes, better N uptake and enhancement of the expression of Zn transporter proteins resulted in maximum nutrient translocate from source to sink and improved protease enzyme leads to higher protein content in seed. These results are in close conformity with the finding of Malvi (2011), Kharol *et al.* (2014) and Dadkhah *et al*. (2015).

Biofortification of zinc in chickpea crop through agronomic manipulations revealed that significantly the higher values of zinc content in seed and stover were analyzed when Zn was applied through soil application $ZnSO_4$ @ 25 kg ha^{-1} + 0.5% $ZnSO_4$ foliar spray (F_6). The other zinc fortification treatments in which zinc was applied either through soil or seed treatment or foliar spray significantly increased the zinc content and uptake in seed and stover over control. The study clearly indicates that fortification of Zn treatments either through soil or foliar or both had positive bearing on seed and stover content of chickpea. This might be due to that Zn has moderate phloem mobility so its application as a foliar alone or as a combination of soil plus foliar application markedly increases zinc content in seed and stover of chickpea. This might be due to the fact that increasing levels of zinc increased its concentration in the soil solution which leads to increased absorption of zinc by plants in calcareous soils, which resulted in greater uptake of nutrients by the crop and this caused higher metabolic and photosynthetic activity in the plant leading to higher yield and nutrients uptake. As the content in seed and stover increased, the total uptake also increased with the application of zinc. These findings are in agreement with the earlier results as obtained by Cakmak (2008) and Shirani *et al.* (2015) and Hidoto *et al.* (2016).

CONCLUSION

On the basis of field study, it can be stated that among the two chickpea varieties GJG 3 was found better while, seed fortification with zinc showed its superiority to other biofortification treatments. However zinc fortification through soil application $ZnSO_4$ 25 kg ha^{-1} + 0.5% $ZnSO_4$ 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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