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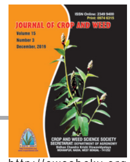

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Yield and nutrient fortification of chickpea by foliar Fe and Zn application

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ABSTRACT

Iron and zinc deficiency among human being is increasing day by day as about one half of the global population is suffering from the micronutrient deficiency. Agronomic biofortification through application of Fe and Zn of pulses receives great attention in recent years to deal with hidden hunger in human population. Research experiments were planned and executed during rabi seasons of 2015-16, 2016-17 and 2017-18 to assess the impact of various methods of application of iron (Fe) and zinc (Zn) on growth, productivity and agronomic biofortification of chickpea. Results of the study revealed that among two chickpea varieties, RSG 931 performed slightly better but failed to record any significant variation in plant height and yield during all the years of experimentation except grain yield during 2015-16. However, significantly higher pods per plant (48.31) was recorded under RSG 931 which was higher by 13.03 percent compared to RSG 807. However, significantly higher pooled seed index (24.85 g) was recorded under variety RSG 807 which was higher by 35.57 per cent compared to variety RSG 931. Nutrition application of 0.5 % $ZnSo_4$ + 0.5 % $FeSo_4$ proved superior as it recorded higher values of pods per plant (52.90) and seed index (22.29 g). The mean increases in seed yield and straw yield due to nutrition application of 0.5 % $ZnSo_4$ + 0.5 % $FeSo_4$ were 22.3 and 17.1 % over control. The maximum net returns (₹ 73355 ha^{-1}) and B:C ratio (2.47) were recorded under RSG-931 and net returns (₹ 78914 ha^{-1}) and B:C ratio (2.40) were recorded under nutrition application of 0.5 % $ZnSo_4$ + 0.5 % FeSo4. The least net returns (₹ 62286 ha^{-1}) and B:C ratio (2.09) were recorded under recommended dose of N and P due to insufficient nutrition application in chickpea.

Keywords: Agronomic biofortification, chickpea, net returns, seed yield

Unlike plants, humans also require essential micronutrients and protein for their normal physiological functions of the body and good health. Due to low concentration of micronutrients and protein in the staple food, billions of people are lacking sufficient daily balanced intake of micronutrient and protein in their diet called as 'hidden hunger'. Globally, the micronutrients which are most commonly associated with human health problems include iodine, iron and zinc. Humans require at least 22 mineral elements for their wellbeing. These can be supplied by a balanced diet. However, it is estimated that about 30 per cent of population is Zn deficient and rest with other micronutrients. In the sequence of micronutrient malnutrition, iron is also playing an important role. Fe deficiency is the most common nutritional deficiency all over the world and zinc deficiency results in poor growth and development and impaired immune response (Whittaker, 1998). Average dietary intake of iron ranges from 1.8 to 25 mg day^{-1} and zinc intake ranges from 1.6 to 40.9 mg day^{-1} (Lim *et al.,* 2015). Pulses are rich source of proteins and other nutrients. Chickpea is an important winter season pulse, has high digestible protein, iron, vitamin B and C. Shakya *et al.* (2008) reported that due to presence of malic acid in green leaves of chickpea, it is very useful for treating stomach related problems and for blood purification.

In Rajasthan, chickpea is cultivated on an acreage of 2.46 million hectares (m ha) producing about 2.66 million tons (mt) with the productivity of 1080 kg ha^{-1} (Anonymous, 2020). Like other legume crops, it has unique property to form root nodules with the help of symbiotic nitrogen fixing bacteria *Rhizobium* and fixes atmospheric nitrogen. Singh *et al*. (2011) reported that about 42 per cent of Indian soils are deficient in Zn. Due to its nitrogen fixing ability, chickpea plays important role in enhancing soil fertility. Micronutrient deficiency (Zn and Fe) is a major problem of now days because of use of high yielding varieties, intensive cropping system, inadequate supply of micronutrient and loss of organic matter content by erosion and pollution. Iron is involved in chlorophyll and thylakoid synthesis and development of chloroplast and important element for plant growth and development (Banjara and Majgahe, 2019). Zn application influences the synthesis of auxin, nodulation and nitrogen fixation which enhances the vigour of crop and ultimately influence the seed yield (Kasthurikrishna and Ahlawat, 2000). Apart from various biochemical processes in plants, zinc is believed to be involved in pollen functionality and fertilization (Pandey *et al.*, 2006). Improvement in micronutrients concentration and yield of various pulses has been reported with varying methods of applications

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of micronutrients (Pathak *et al*., 2012; Brennan *et al*., 2001). Melash *et al*. (2016) concluded that for micronutrient application,foliar/soil/seed treatment is suitable and effective application method. Considering the importance of Zn and Fe in combating under nourishment and improving the quality and quantity of the crop, the present experiment was conducted at instructional farm of Rajasthan Agricultural Research Station, Durgapura, Jaipur.

MATERIALS AND METHODS

Field trial was conducted during three consecutive *rabi* seasons of 2015-16, 2016-17 and 2017-18 at instructional farm of Rajasthan Agricultural Research Institute, Durgapura, Jaipur (26^0 51′ N, 75^0 47′ E and 390 m altitude) to assess the effect of soil, foliar application, seed treatment and or both of Fe and Zinc on growth, yield attributes, yield and quality and economics of chickpea. Durgapura, Jaipur falls in the Semi-Arid Eastern Plain Zone of Rajasthan (III-A) having extreme cold winters and hot summers. Occurrence of frost (below ^{0}C) is quite common during winter season. The zone receives about 529 mm rainfall annually and most of which is received during later half of June to September with erratic distribution over time and space. The soil of the experimental field was sandy loam with sand (86.2%), silt (6.2%), clay (7.6%), pH 7.9, 0.16 % organic carbon and 138.2, 36.8 and 242.0 kg ha^{-1} available N, P_2O_5 and K_2O, respectively. The iron and zinc content was 10.0 ppm and 0.54 ppm respectively. The experiment was laid out in split plot design with three replications. Two popularly grown chickpea varieties of the Rajasthan state RSG 931 (small seeded) and RSG 807 (bold seeded) were selected and six treatments of foliar nutrition (F_1-Recommended dose of N&P (control), F_2- F_1+0.5%ZnSo$_4$, F_3- F_1+0.5% FeSo$_4$, F_4- F_1+0.5%ZnSo$_4$+0.5% FeSo$_4$, F_5.F_1+2g ZnSo$_4$ kg^{-1} seed as a seed treatment and F_6- F_1+25 kgZnSo$_4$ ha^{-1}). One deep ploughing followed by 2 cross harrowing followed by planking was used for field preparation. The chickpea seeds were sown during first fortnight of November during all the years of experimentation using crop geometry of 30 x10 cm. As per recommendations of this zone (Zone IIIa) package of practices, 20 kg N + 40 kg P_2O_5 ha^{-1} was drilled at the time of sowing. Zinc and Iron was applied as per treatments through $ZnSO_4$ and $FeSO_4$. Two foliar sprays of 0.1 % Zn and 0.1 % Fe was done at pre-flowering and pod formation stage either individually or in combined mode as per treatment. To neutralize the acidity 0.25 % lime was mixed with ZnSo$_4$ and or FeSo$_4$. Crop was raised under irrigated condition (chickpea area under irrigation in Rajasthan is 34%) and a total of three including pre-sowing irrigation were applied through sprinkler irrigation and a total of 14 cm water was applied in irrigation. Crop protection measures were followed as and when required. The crop was harvested during first week of April and the seeds were cleaned, dried and weighed. Seed and straw yield were expressed in q ha^{-1}.

To ascertain the economic feasibility, the net returns, B:C ratio was calculated. Economic analysis was carried out to assess the economic feasibility of different treatments on chickpea. The net returns of each treatment were determined by deducting the total cost of cultivation from gross returns of respective treatments and the benefit: cost ratio was calculated by dividing the net returns with total cost of cultivation. The analysis of variance (ANOVA) for each data was determined as per the procedure suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth and yield attributes

Results of the study revealed that among two chickpea varieties, RSG 931 performed slightly better but failed to record any significant variation in plant height and yield during all the three years except seed yield during 2015-16. However, significantly higher pods per plant (48.31) was recorded under RSG 931 which was higher by 13.03 per cent compared to RSG 807. However, significantly higher pooled seed index (24.85 g) was recorded under variety RSG 807 which was higher by 35.57 per cent compared to variety RSG 931 (Table 1). Among the nutrition levels, the maximum plant height (49.21 cm) was recorded under treatment F_6 (recommended dose of N& P along with soil application of 25 kg ZnSO$_4$ ha^{-1}) which was statistically at par with treatment F_4 (recommended dose of N& P along with two foliar sprays of 0.1% each of Zn and Fe) and significantly superior over rest of the treatments. However, maximum no. of pods plant^{-1} (52.90) and seed index (22.29g) was recorded under treatment F_4 closely followed by treatment F_6 (51.55 and 22.18 g) and both were significantly superior over rest of the treatments. The increase in growth and yield attributes under soil or foliar application of Zn might be attributed to higher photosynthetic rate, translocation and assimilation of metabolites in the sink which ultimately led to increased number of pods plants^{-1} and seed index. Similar findings were also reported by Singh *et al*. (2015) and Banjara and Majgahe (2019).

Seed and straw yield

Varieties under study failed to record any significant difference in terms of seed and straw yield during all the three years of experimentation (Table 1). Further, on pooled basis, variety RSG 931 performed slightly

Table 1: Effect of Zn and Fe on growth, yield and yield attributes of chickpea

Treatments	Plant height (cm)	Pods plant^{-1}	Seed Index(g)	Seed yield (Q/ha^{-1})				Straw yield (q/ha^{-1})			
	Mean	Mean	Mean	2015-16	2016-17	2017-18	Mean	2015-16	2016-17	2017-18	Mean
Variety											
RSG 807	48.10	42.74	24.85	15.06	23.16	16.20	18.11	30.10	43.08	30.58	34.43
RSG 931	44.25	48.31	18.33	16.07	22.68	17.18	18.64	28.50	39.53	31.30	33.11
SEm(±)	0.98	0.75	0.06	0.22	0.33	0.26	0.33	0.50	2.46	0.43	0.97
LSD (0.05)	NS	4.56	0.36	0.98	NS	NS	NS	NS	NS	NS	NS
Nutrition											
F1	43.49	36.62	20.83	13.50	20.75	15.06	16.44	25.48	38.7	28.77	30.98
F2	46.72	49.31	21.96	16.27	23.64	16.83	18.91	30.45	41.75	31.01	34.40
F3	45.80	45.87	21.42	15.46	22.60	16.03	18.03	29.17	41.50	30.60	33.76
F4	48.21	52.90	22.29	17.31	24.92	18.15	20.11	32.53	43.19	33.09	36.27
F5	43.65	36.88	20.84	13.86	21.31	15.47	16.80	26.53	40.63	29.41	32.19
F6	49.21	51.55	22.18	16.99	24.28	18.59	19.97	31.65	42.07	32.77	35.04
SEm(±)	0.79	0.64	0.05	0.46	0.43	0.40	0.15	0.82	1.03	0.74	0.37
LSD (0.05)	2.33	1.89	0.15	1.34	1.23	1.16	0.45	2.38	NS	2.13	1.09

Note: F_1- Recommended dose of N & P (control), F_2- F_1+0.5% $ZnSo_4$, F_3- F_1+0.5% $FeSo_4$, F_4- F_1+0.5%$ZnSo_4$+0.5% $FeSo_4$, F-$_5F_1$+2g $ZnSo_4$/kg^{-1} seed as a seed treatment and F_6- F_1+25 kg$ZnSo_4$/ha^{-1}.

Table 2: Effect of Zn and Fe on micronutrient content in seed and economics (pooled over 3 year)

Treatments	Zn content in seed (ppm)	Fe content in seed (ppm)	Gross returns (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
Variety						
RSG 807	31.64	52.91	101897	29744	72153	2.43
RSG 931	32.08	55.55	103099	29744	73355	2.47
SEm(±)	0.45	0.88			-	-
LSD(0.05)	NS	NS			-	-
Nutrition						
F1- RDF (N&P)	27.19	47.08	92030	29744	62286	2.09
F2- F1+0.5%$ZnSo_4$	36.71	52.58	105268	32674	72594	2.22
F3- F1+0.5%$FeSo_4$	28.26	62.64	100853	31864	68989	2.17
F4- F1+0.5%$ZnS0_4$+ 0.5% $FeSo_4$	33.88	59.84	111748	32834	78914	2.40
F5- F1+2 g/kg^{-1} $ZnSo_4$ as a seed treatment	27.86	49.58	94817	30000	64817	2.16
F6- F1+25 kg^{-1} $ZnSo_4$/ha^{-1}	37.26	53.66	110348	31744	78604	2.48
SEm(±)	0.31	0.76		29744	-	-
LSD(0.05)	0.92	2.24		29744	-	-

better (18.64 q ha^{-1}) compared to RSG 807 (18.11 q ha^{-1}) compared to control (Recommended dose of N&P) and treatment F_5, rest of the treatments recorded significantly higher seed and straw yield during all the years of study except the straw yield during 2016-17 (Table 1). The maximum pooled seed and straw yield (20.11 and 36.27 q ha^{-1}) was recorded under F_4 involving application of recommended dose of N&P + 0.5% $ZnSo_4$+ 0.5% $FeSo_4$, which was statistically at par with treatment F_6 involving of application of recommended dose of N&P +25 kg $ZnSo_4$/ha and was higher by 22.32 and 17.08 percent over control treatment (Recommended dose of N&P). However, application of recommended dose of N&P +0.5% $ZnSo_4$ and recommended dose of N&P + 0.5%$FeSo_4$ resulted in 18.91 q ha^{-1} and 18.03 q ha^{-1} seed yield respectively. As compared to control, the application of recommended dose of N&P +2 g/kg^{-1} $ZnSo_4$ as a seed treatment did not improve the seed yield much, whereas the application of 20 kg N+40 kg P_2O_5+25 kg $ZnSo_4$ha^{-1} improved the seed yield by 21.4 % over control (Table 2). Ali *et al*., (2017) reported that foliar application of Zn improved seed yield by affecting fertilization. Zn affects pollen production and morphology and its requirement increases at reproductive stage in legume crops. Micro nutrients like Fe and Zn has important roles in plant photosynthesis, fertility and seed production (Pathak *et al*., 2012).

Biofortification of chickpea seed with Zinc

Application of Zn to chickpea either through soil or through foliar application recorded significantly higher Zn and Fe content in seed than control except the Zn content in seed under treatment T_5 (Table 2). Slightly higher zinc concentration (32.08 ppm) was recorded in the chickpea variety RSG 931 as compared to RSG 807 (31.64 ppm). Among the nutrition treatments, the application of treatment F_6 (recommended dose of N&P + 25 kg $ZnSo_4$ ha^{-1}) recorded maximum Zn content in seed (37.26 ppm) which was statistically at par with treatment F_2 (recommended dose of N&P + 0.5% $ZnSo_4$) and both the treatments were significantly superior over rest treatments. Further, treatment F_4 also recorded significantly higher Zn concentration (33.88 ppm) compared to control. The least zinc content in seed (27.19 ppm) was observed in control. The increase in Zn content in seed due to application of treatments F_6 and F_2 were by 37.03 and 35.01 per cent, respectively over control. This is because of the positive effect of zinc in plants. Waters *et al*. (2009) and Curie *et al*. (2009) in their study found that a number of Zn and Fe regulated transporters proteins help in xylem and phloem loading and unloading, xylem-to-phloem exchange and grain deposition of Zn and Fe. Hidoto *et al*. (2017) also observed 22% increase in Zn content in grain due to foliar application of Zn over seed priming with Zn.

Biofortification of chickpea seed with iron

The chickpea variety RSG 931 resulted in higher Fe concentration (55.55 ppm) as compared to RSG-807 (52.91 ppm) from existing average iron content of 45 to 50 ppm. However they were statistically at par with each other. Among the nutrition treatments, the treatment F_3 (recommended dose of N&P + 0.5% $FeSo_4$) recorded significantly maximum (62.64 ppm) iron content in seed followed by treatment F_4 (recommended dose of N&P + 0.5% $ZnSo_4$+ 0.5% FeSo4) and both the treatments were significantly superior over rest treatments (Table 2). The application of recommended dose of N&P + 0.5%$ZnSo_4$ resulted in 52.58 ppm Fe content in seed. The application of recommended dose of N&P +2 g kg^{-1} ZnSo4 as seed treatment recorded 49.58 ppm Fe content in seed. The least Fe content in seed (47.08 ppm) was observed in control. The application of treatment F_3 and F_4 improved Fe content in grain by 33.1 and 27.1 % over control treatment. Iron and zinc application had a positive effect on Zn and Fe content of chickpea seed. Significant improvement in Fe content in chickpea seeds due to application of Zn was also noticed by Pal *et al.* (2019).

Effect of agronomic biofortification on economics

Among the various treatments of agronomic biofortification in chickpea, the mean maximum cost of cultivation (₹ 32834), gross returns (₹ 111748) and net returns (₹ 78914) were recorded with application of recommended dose of N&P+0.5%$ZnSo_4$+0.5% FeSo4 (Table 2). Whereas minimum values for cost of cultivation (₹ 29744), gross returns (₹ 92030) and net returns (₹ 62286) were observed under control treatment (recommended dose of N&P). The soil and foliar application each of $FeSo_4$ and $ZnSo_4$ @0.5% increased gross return and net returns with magnitude of 21.4 and 26.7% over control, Similarly, application of Zn as foliar, seed treatment and soil application reported 14.4%, 3.1% and 19.9% increase in gross return and 16.5%, 4.0% and 26.2% increase in net returns, respectively. The higher crop productivity of crop might be the principal reasons for higher net returns with application of recommended dose of N&P+0.5% $ZnSo_4$+0.5% FeSo4 compared to other treatments. Similar findings of higher farm profitability was also reported by Majeed *et al.* (2020) with iron application in mungbean.

CONCLUSION

The results of the present study revealed that the soil and foliar application of Zn and Fe resulted in higher concentrations of Zn and Fe in chickpea seeds as compared to their sole applications and thus play an important role in biofortification. The application of recommended dose of N&P+0.5%$ZnSo_4$+0.5% FeSo4 resulted in higher Fe and Zn fortification in the two varieties of chickpea under study and can help in eliminating the micronutrient malnutrition from Zn and Fe in human beings.

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