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Agronomic bio fortification of cowpea (*Vigna unguiculata* (L.) Walp.) with iron

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Abstract
The field experiment was conducted in summer 2017 at the VRS, RHRS, ASPEE College of Horticulture and Forestry, Navsari, Gujarat, to study the effect of soil and foliar applied Fe on the iron content of cowpea pods and leaves. The results revealed that both soil and foliar application of $FeSO_4$ significantly increased the iron content in both leaves and pods of cowpea. The treatment T_8 (Soil application of $FeSO_4$ @ 50 kg ha^{-1}) resulted in maximum increase in Fe content (232 mg kg^{-1}) in pods while treatment T_4 (Foliar spray of $FeSO_4$ @ 1% at 45 and 60 DAS) gave maximum Fe content (264.33 mg kg^{-1}) in cowpea leaves.

Keywords: Cowpea, iron, $FeSO_4$, bio fortification, foliar

Introduction
Cowpea (*Vigna unguiculata* (L.) Walp.) is one of the most important legume vegetable grown in India. The choice of cowpea as a vegetable is due to its palatibility, nutritional factors and absence of metabolites or other toxins. The use of cowpea as a vegetable acts as a cheap source of protein (22-24%) in vegetarian dominated diets. Being rich in protein and containing many other nutrients, it is also known as vegetable meat. Agronomic bio fortification or ferti fortification is the process of increasing the concentration of essential elements in the edible portion of plants through soil application, foliar application or fertigation. This strategy has been developed as a food based method to address widespread deficiencies in Fe and Zn that remain prevalent to a great extent in various countries. Micronutrient malnutrition, which is also known as "hidden hunger" is a major health issue in most parts of the world and affects more than 2 billion people. More than 60% of the world's population is Fe deficient (Amarakoon *et al*., 2012) [1]. Anaemia is the most common Fe deficiency disorder. Nearly 50% of women of reproductive age and 26% of men in the age group of 15-59 years are anaemic. This area has not been widely explored in vegetables yet, hence, this concept on proper research and study might help reduce the problem of malnutrition.

Material and Methods
The field experiment was laid out during summer season of the year of 2017 at the Vegetable Research Scheme, Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat. The soil of the experimental plot was deep black, well drained with good water holding capacity, neutral in reaction (pH 7.84), soil organic carbon 0.47%, available nitrogen 258 kg ha^{-1}, available P_2O_5 59 kg ha^{-1}, available K_2O 361 kg ha^{-1} and DTPA extractable Fe 2.86 mg kg^{-1}. The seeds of cowpea cv. GDVC 2 (Gujarat Dantiwada Vegetable Cowpea 2) were sown in the third week of February, 2017 in plots of 3.0m x 3.0m at a spacing of 60cm x 30cm. As per the recommended dose, well decomposed farm yard manure (15 t ha^{-1}) and inorganic fertilizers *i.e.* 20 kg N, 40 kg P_2O_5 and 0 kg K_2O per hectare were applied in the form of DAP and urea. The entire quantity of well decomposed FYM was mixed well in each plot prior to a week before sowing of cowpea followed by irrigation. All the recommended quantity of nitrogen (20 kg ha^{-1}) and phosphorus (40 kg ha^{-1}) were applied in the form of urea and DAP as basal dose. For the soil and foliar application of iron, $FeSO_4.7H_2O$ (19% Fe) was used. In soil application, it was applied along with other fertilizers as basal dose while foliar application was done at 45 DAS and 60 DAS. The experiment was laid out in a Randomized Block Design with three replications and 9 treatments *viz*., T_0:- Control; T_1:- Foliar spray of $FeSO_4$ @ 0.5% at 45 DAS; T_2:- Foliar spray of $FeSO_4$ @ 0.5% at 45 DAS and 60 DAS; T_3:- Foliar spray of $FeSO_4$@

1.0% at 45 DAS; T_4:- Foliar spray of $FeSO_4$ @ 1.0% at 45 DAS and 60 DAS; T_5:-Soil application of $FeSO_4$ @ 12.5 kg ha^{-1}; T_6:- Soil application of $FeSO_4$ @ 25 kg ha^{-1}; T_7:- Soil application of $FeSO_4$ @ 37.5 kg ha^{-1}; T_8:- Soil application of $FeSO_4$ @ 50 kg ha^{-1}.

As per treatments, foliar application of $FeSO_4$ solution was done at 45 DAS and 60 DAS. For the preparation of 0.5% $FeSO_4$ solution, 91.44 g of $FeSO_4.7H_2O$ crystals were dissolved in 1 litre of distilled water. The highly acidic pH (3.1) of the solution was increased to slightly acidic (5.8) with saturated $CaCO_3$ solution and then the solution was diluted to 10 litres for the spray. Similarly, for 1% solution 183 g of $FeSO_4.7H_2O$ crystals were used (Table 1).

Table 1: Quantity of water and $FeSO_4.7H_2O$ required

Treatments	Water required (lit. ha^{-1})	$FeSO_4.7H_2O$ required (kg ha^{-1})
T_0 - Control	0	0
T_1 - Foliar spray of $FeSO_4$ @ 0.5% at 45 DAS	300	2.74
T_2 - Foliar spray of $FeSO_4$ @ 0.5% at 45 & 60 DAS	300 (45 DAS) 400 (60 DAS)	2.74 3.65
T_3 - Foliar spray of $FeSO_4$ @ 1.0% at 45 DAS	300	5.49
T_4 - Foliar spray of $FeSO_4$ @ 1.0% at 45 & 60 DAS	300 (45 DAS) 400 (60 DAS)	5.49 7.32
T_5 - Soil application of $FeSO_4$ @ 12.5 kg ha^{-1}	0	22.86
T_6 - Soil application of $FeSO_4$ @ 25 kg ha^{-1}	0	45.72
T_7 - Soil application of $FeSO_4$ @ 37.5 kg ha^{-1}	0	68.58
T_8 - Soil application of $FeSO_4$ @ 50 kg ha^{-1}	0	91.44

Table 2: Effect of different treatments on Fe content (mg kg^{-1}) periodically in pod of cowpea

Treatments	2nd picking	4th picking	6th picking	Average
T_0 - Control	163.33	156.00	143.67	154.33
T_1 - Foliar spray of $FeSO_4$ @ 0.5% at 45 DAS	188.00	168.67	150.00	168.67
T_2 - Foliar spray of $FeSO_4$ @ 0.5% at 45 & 60 DAS	216.33	210.67	200.00	209.00
T_3 - Foliar spray of $FeSO_4$ @ 1.0% at 45 DAS	196.00	182.00	169.00	182.33
T_4 - Foliar spray of $FeSO_4$ @ 1.0% at 45 & 60 DAS	233.67	217.00	187.67	212.67
T_5 - Soil application of $FeSO_4$ @ 12.5 kg ha^{-1}	187.00	183.33	173.33	181.00
T_6 - Soil application of $FeSO_4$ @ 25 kg ha^{-1}	241.67	208.00	192.33	205.00
T_7 - Soil application of $FeSO_4$ @ 37.5 kg ha^{-1}	237.00	223.00	219.33	226.00
T_8 - Soil application of $FeSO_4$ @ 50 kg ha^{-1}	243.33	224.67	227.33	232.00
S.Em. ±	9.69	7.87	7.12	4.76
C.D. at 5%	29.06	23.59	21.36	14.29
C.V. %	8.04	6.92	6.68	4.19

Table 3: Effect of different treatments on Fe content (mg kg^{-1}) periodically in leaves of cowpea

Treatments	2nd picking	4th picking	6th picking	Average
T_0 - Control	204.00	202.00	168.67	191.67
T_1 - Foliar spray of $FeSO_4$ @ 0.5% at 45 DAS	241.67	228.00	185.00	218.33
T_2 - Foliar spray of $FeSO_4$ @ 0.5% at 45 & 60 DAS	268.33	243.00	197.67	236.33
T_3 - Foliar spray of $FeSO_4$ @ 1.0% at 45 DAS	290.33	265.67	184.00	246.67
T_4 - Foliar spray of $FeSO_4$ @ 1.0% at 45 & 60 DAS	318.67	279.67	194.67	264.33
T_5 - Soil application of $FeSO_4$ @ 12.5 kg ha^{-1}	240.00	231.67	190.33	220.67
T_6 - Soil application of $FeSO_4$ @ 25 kg ha^{-1}	259.33	245.67	207.00	237.67
T_7 - Soil application of $FeSO_4$ @ 37.5 kg ha^{-1}	268.67	260.00	212.00	246.67
T_8 - Soil application of $FeSO_4$ @ 50 kg ha^{-1}	269.67	266.33	214.33	250.00
S.Em. ±	9.23	6.74	8.44	4.52
C.D. at 5%	27.66	20.21	25.32	13.55
C.V. %	6.09	4.73	7.51	3.34

Results and Discussion

The results from Table 2 reveal that the Fe content in pod increased significantly over control during 2nd, 4th as well as 6th picking. The treatment T_8 (soil application of $FeSO_4$ @ 50 kg ha^{-1}) recorded maximum Fe content in 2nd (243.33 mg kg^{-1}), 4th (224.67 mg kg^{-1}) as well as 6th picking (227.33 mg kg^{-1}). The lowest Fe content was noted with control (T_0) in all the three pickings. The average Fe content for 2nd, 4th and 6th picking ranged from 154.33 mg kg^{-1} to 232 mg kg^{-1}. The treatment T_8 (soil application of $FeSO_4$ @ 50 kg ha^{-1}) recorded maximum Fe content (232 mg kg^{-1}) in pod which was at par with the treatment T_7. The lowest Fe content (154.33 mg kg^{-1}) was noted with control (T_0). The per cent increase in Fe content of pod treated with soil application of $FeSO_4$ @ 50 kg ha^{-1} (T_8) was 50.32% over control.

The results from Table 3 revealed that the Fe content in leaves also increased significantly over control during 2nd, 4th as well as 6th picking. The treatment T_4 (foliar spray of $FeSO_4$ @ 0.5% at 45 and 60 DAS) recorded maximum Fe content in 2nd (318.67 mg kg^{-1}) and 4th (279.67 mg kg^{-1}) while treatment T_8 (soil application of $FeSO_4$ @ 50 kg ha^{-1}) recorded maximum Fe content of 214.33 mg kg^{-1} during 6th picking. The lowest Fe content was noted with control (T_0) in all the three pickings. The average Fe content for 2nd, 4th and 6th picking of leaves ranged from 192 mg kg^{-1} to 264 mg kg^{-1}. The treatment T_4 (foliar spray of $FeSO_4$ @ 0.5% at 45 and 60 DAS) recorded maximum Fe content (264 mg kg^{-1}) in leaves. The lowest Fe content (192 mg kg^{-1}) was noted with control (T_0). The per cent increase in Fe content of pod treated with foliar spray of $FeSO_4$ @ 0.5% at 45 and 60 DAS (T_4) was 37.5% over control.

The increase in Fe content in pod and leaves could have been because of the reason that the direct addition of iron in soil or by foliar spray might have increased the availability of these nutrients, which in turn increased iron content. The deficiency of iron in the experimental soil could also have been a reason for the response of cowpea to iron and abundant availability of nitrogen in the soil and the nitrogen fixing ability of cowpea further increased iron availability due due to synergistic effect of nitrogen on Fe. Similar results were obtained by Shukla and Shukla (1994) [2], Singh (1999) [3], in chickpea; Fawzi *et al*. (1993) [4], Mahriya and Meena (1999) [5], Márquez-Quiroz *et al*. (2015) [6], in cowpea; Kumawat *et al*. (2006) [7], Ali *et al*. (2014) [8] in mung bean; Singh *et al*. (2013) [9] in rice; Togay *et al*. (2015) [10] in lentil and Saleem *et al*. (2016) [11] in maize.

Conclusion

Based on the obtained results, it can be concluded that either soil or foliar application of Fe was found to be a promising option for the Ferti-fortification of vegetable cowpea. The soil application of $FeSO_4$ @ 50 kg ha^{-1} significantly increased the iron content in cowpea pod while foliar spray of $FeSO_4$ @ 1.0% at 45 and 60 DAS increased iron content in leaves of cowpea.

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