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# Iron Ferti-fortification in grain *Amaranthus* (*Amaranthus hypochondriacus* L.)

**Drashti Chaudhari, Punit Mehta, Nisha Chaudhary and Manish Yadav**

## Abstract
The practice of intensive cropping with hybrid varieties for boosting food production in India has caused nutrient depletion in soil, consequently macro and micronutrient deficiencies are reported in soils of India. Further, micronutrient deficient soils result in production of food/feed/fodder low in micronutrient content/density and that in the long-run have been inflicting their deficiency in humans and animals. Attempts are made to enhance micronutrient content in cereal grains and there is a need to explore the possibility of such improvements in other locally available food crops. One such crop that could be considered suitable for this purpose is of the genus *Amaranthus.* It is an excellent source of iron and β-Carotene and thus it can help in removing iron and vitamin A deficiency. Looking to above scenario, an attempt was made to study the effect of Fe fertilization for Fe enhancement in amaranthus grain.
A field experiment was carried out during *Rabi*, 2019-2020 at College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat). There were 12 treatments laid out in randomized block design with a view to study the effect of Iron ferti – fortification in grain Amaranthus (*Amaranthus hypochondriacus* L) grown under *Typic* Ustocrepts. The results revealed that recommended dose of fertilizer, 15 kg $FeSO_4$ $ha^{-1}$ through enriched 200 kg FYM recorded 15% higher grain yield over control. While, maximum grain Fe content and uptake was recorded under soil application of 11.25 kg $FeSO_4$ $ha^{-1}$ through enriched 200 kg FYM. Among the different Fe ferti-fortification treatment recommended dose of fertilizer along with soil application of $FeSO_4$ @ 7.5 kg $ha^{-1}$ through enriched 200 kg FYM showed highest iron use efficiency (15.07%) as well as partial factor productivity (862) over rest of the treatments. However, highest Fe harvest index (13.7%) was noticed in treatment receiving recommended dose of fertilizer coupled with $FeSO_4$ @ 11.25 kg $ha^{-1}$ and bio NPK Consortium is adjudged as the best Fe ferti-fortification strategy for grain amaranthus crop in the middle Gujarat condition.

**Keywords:** Iron, micronutrient, FYM, ferti-fortification, *Amaranthus hypochondriacus* L.

## Introduction
As human population continue to increase, anthropogenic manipulation in the agro-ecosystem to produce food and fiber will place greater demand on soils to supply essential nutrients. The quest for attaining food sufficiency and higher crop production to feed the burgeoning population of the nation has resulted detrimental impact on agro-ecosystem in India.
The practice of intensive cropping with hybrid varieties for boosting food production in India has caused nutrient depletion in soil, consequently macro and micronutrient deficiencies are reported in soils of India. Simultaneously, low soil organic matter level, little return of crop residues and manures to soils exacerbates these deficiencies. Analysis of more than 2.00 lakhs soil samples in 508 districts of India revealed that the problem of Fe deficiency is acute and limiting the crop productivity in the western part of the country, particularly in Rajasthan, Gujarat and Maharashtra (Shukla *et al.*, 2014) [16].
Iron is a needed element to the plants for full fill the chlorophyll formation and photosynthesis process. Almost all plant enzymes are using iron ions to make the proper transpiration cycle in plants. Iron deficiency will discard the high yield and quality of plants Iron deficiency is considered to be the common worldwide nutritional deficiency that affects approximately 20% of the world population. Anemia affects nearly one-third of the world's population, primarily infants and young children from developing countries (Singh and Toteja 2003, Mason *et al.*, 2004) [8, 17]. Iron deficiency anemia majorly affects children under 5 years, women of childbearing age and pregnant women (Dharmalingam *et al.*, 2010, Ahmad *et al.*, 2010, Buchowski *et al.*, 1989) [2, 5, 6].

Biofortification offers a sustainable solution to the escalating micronutrient deficiencies in the population, especially for the poor. Biofortification is a process of enhancing the density of vitamins and minerals in a crop. Among the types of biofortification, agronomic biofortification (use of fertilizers) is a short term approach and the easiest of all to enhance the micronutrient content in the diet (Nissar *et al*., 2019) [11].

Grain amaranth (*Amaranthus hypochondriacus* L.) called a pseudocereal is an under exploited tropical novel crop with a high nutritive value. Amaranth locally known as *Rajagira* and it is grown during *rabi* season. Amaranth is a quick growing, bushy plant with thick stalk. The unique features are lower water and input requirement, tolerance to moisture stress with short growing period In India, the grain is well known as the only food permitted on fast days. The amaranth grain could be easily processed into a variety of products like chikki, malt, popped flour, roti, nippatu, biscuits etc. It is useful in the high quality plastics, cosmetics, natural dyes, pharmaceuticals (laxative) and aqualene (National Research Council, 1984) [10]. It is a $C_4$ dicotyledonous pseudo cereal crop having higher productivity potential added with substantial quantities of minerals, carbohydrates, fats and proteins are comparable with any other improved cereals. It could be used both for grains and green leaves which are rich in vitamin A, calcium and iron (Annapurna *et al*., 2001) [3].

The amaranth grains contain relatively higher iron content than in cereal grains. It is an excellent source of iron and β-Carotene and thus it can help in removing iron and vitamin A deficiency (Narwade *et al*., 2018) [9]. Amaranth has complete protein and is also a good source of minerals such as iron, magnesium, phosphorus, copper and manganese. Its unique composition makes it an attractive food complement and supplement. Looking to the above scenario, the research work on Iron ferti-fortification in grain *Amaranthus* (*Amaranthus hypochondriacus* L.) under middle Gujarat condition.

## Materials and Methods

A field experiment was conducted during *Rabi* season of the year 2019-2020 at College Agronomy farm, BACA, Anand Agricultural University, Anand, Gujarat. This experiment consisting of twelve treatment combinations *viz*.,$T_1$: RDF (Control), $T_2$: RDF + Bio NPK Consortium, $T_3$: RDF + 200 kg FYM $ha^{-1}$, $T_4$: RDF + 7.5 kg $FeSO_4$ $ha^{-1}$, $T_5$: RDF + 7.5 kg $FeSO_4$ $ha^{-1}$ + Bio NPK Consortium, $T_6$: RDF + Enriched 200 kg FYM $ha^{-1}$ with 7.5 kg $FeSO_4$, $T_7$: RDF + 11.25 kg $FeSO_4$ $ha^{-1}$, $T_8$: RDF + 11.25 kg $FeSO_4$ $ha^{-1}$ + Bio NPK Consortium, $T_9$: RDF + Enriched 200 kg FYM $ha^{-1}$ with 11.25 kg $FeSO_4$, $T_{10}$: RDF + 15 kg $FeSO_4$ $ha^{-1}$, $T_{11}$: RDF + 15 kg $FeSO_4$ $ha^{-1}$ + Bio NPK Consortium, $T_{12}$: RDF + 15 kg $FeSO_4$ $ha^{-1}$ + Bio NPK Consortium in randomized block design, which was replicated four times and *Amaranthus* variety GA - 2 was sown.

RDF was applied in common to all the plots where in nitrogen dose was applied at 50% basal and 50% at 30 DAS and 50 DAS respectively, While, total quantity of recommended dose of $P_2O_5$ was applied through diammonium phosphate (DAP) as basal. Application of Bio NPK consortium (*Azotobacter* + PSB + KSB) was made through seed treatment at 10 ml $kg^{-1}$ seed as well as soil drenching at 1 liter $ha^{-1}$ at 30 DAS. $FeSO_4$ was applied as per treatment and for iron enriched FYM, the quantity of 200 kg FYM was taken and thoroughly mixed with the solution of $FeSO_4.7H_2O$ as per treatment. The thoroughly mixed materials was filled in the pits treatment wise and incubated for a period of 50 days. The 50 per cent available soil moisture was maintained in the pits till 50 days. After 50 days, the enriched manure was utilized as soil application as per treatment at the time of sowing of *Amaranthus* crop. The soil of the experimental field was loamy sand in texture, alkaline in reaction. It was low in organic carbon and available nitrogen while medium in available phosphorus and available potash. With respect to DTPA micronutrients, Fe content was low, Zn and Mn was in medium, while Cu was in sufficient range. Standard error of mean (S.Em) and Co-efficient of variation (CV %) were worked out for each observation as per the method suggested by Steel and Torrie (1982) [19].

### Fe uptake by grain

The concentrations of micronutrients in plant were expressed in terms of mg $kg^{-1}$. The Fe uptake by grain was calculated using below mentioned formula.

$$\text{Fe uptake (g ha}^{-1}\text{)} = \frac{\text{Fe content (mg kg}^{-1}\text{) X Yield (kg ha}^{-1}\text{)}}{1000}$$

### Fe harvest index

Fe Harvest Index can be interpreted as amount of Fe harvested in cereal grain out of total Fe uptake by the crops; derived using below mentioned formula.

$$\text{Fe HI (\%)} = \frac{\text{Fe uptake in control (g ha}^{-1}\text{)}}{\text{Total uptake (g ha}^{-1}\text{)}} \times 100$$

### Partial factor productivity

The calculation in relation to impact of Fe application on yield of crop was made in terms of partial factor productivity as per formula suggested and adopted by Fageria and Baligar, 2003 [7]. The PFP was calculated as mentioned below.

$$\text{PFP} = \frac{\text{Grain Yield (kg ha}^{-1}\text{)}}{\text{Fe applied (kg ha}^{-1}\text{)}}$$

### Iron use efficiency (%)

Iron use efficiency (FeUE) was calculated in order to assess the utility of Fe in comprehensive applications. It was calculated as per formula by Patel, 1991 [4, 12].

$$\text{FeUE (\%)} = \frac{\text{Fe uptake in fertilized plot (g ha}^{-1}\text{) - Fe uptake in control (g ha}^{-1}\text{)}}{\text{Fe applied (g ha}^{-1}\text{)}} \times 100$$

## Results and Discussion

### Grain yield

The vital effect of experimental variable was reflected in the final yield of *Amaranthus* crop. The consequences obtainable in Table 1 make known that application of suggested quantity of RDF along with soil application of $FeSO_4$ @ 15 kg $ha^{-1}$ through enriched 200 kg FYM was recorded significantly higher (1326 kg $ha^{-1}$) grain yield. The increment in grain yield due to enrichment of farmyard manure with iron regulates its supply to the crop through mineralization and prevents them from leaching and other losses besides mobilizing and supplying the native iron and increase better partitioning of carbohydrates from leaf to reproductive parts resulting in increased yield. The results were accordance with the finding gets support from Rathod (2003) [15], Tolessa Debele *et al.* (2001) [21], Veeranagappa (2009) and Sridevi *et al*. (2010) [18, 22].

### Fe content in grain

The maximum grain Fe content (102.3 mg $kg^{-1}$) recorded under RDF along with soil application of $FeSO_4$ @ 11.25 kg $ha^{-1}$through enriched 200 kg FYM. The highest content of Fe could be due to application of iron enriched with manure. Mineralization of iron from organic matter and the release of iron from iron containing amino acids during decomposition of organic manures and also due to addition of iron containing fertilizers. The results are corroborated with those of reported by Rathod (2003) [15], Ponnamperuma (1972) and Bhadu *et al.* (2017) [4, 14].

### Fe uptake by grain

The maximum removal of 136 g $ha^{-1}$ was recorded with RDF along with soil application of $FeSO_4$ @ 11.25 kg $ha^{-1}$throughenriched 200 kg FYM. Increased iron uptake might be due to increased supply of iron favoured increased accumulation in the plant. Furthermore, the organic manures would have favourably influenced the rhizosphere environment for better iron uptake. The result of the present study reestablishes the opinion of several workers (Veeranagappa (2009), Patil *et al.* (2006) and Abbas *et al.* (2009)) [1, 13, 22].

### Fe harvest index

Fe HI indicates translocation of Fe from stover to grain. High index indicates more movement from stover to grain and low indicates vice versa. The data pertaining to the iron harvest index as affected by different treatments are presented in the Table 2.

### Partial factor productivity and iron use efficiency (%)

The Partial factor productivity could be interpreted by kg grain yield produced per kg nutrient application. Table 2 indicated that among the different treatments highest partial factor productivity (862) and highest iron use efficiency (15.07%) was observed under the RDF along with soil application of $FeSO_4$ @ 7.5 kg $ha^{-1}$through enriched 200 kg FYM ($T_6$).

**Table 1:** Effect of iron on yield and uptake by grain *Amaranthus*

| No. | Treatment details | Grain yield (kg $ha^{-1}$) | Grain Fe content (mg $kg^{-1}$) | Grain Fe uptake (g $ha^{-1}$) |
|---|---|---|---|---|
| $T_1$ | RDF (Control) | 1154 | 82.4 | 96 |
| $T_2$ | RDF + Bio NPK Consortium | 1216 | 85.7 | 104 |
| $T_3$ | RDF + 200 kg FYM $ha^{-1}$ | 1201 | 87.5 | 105 |
| $T_4$ | RDF + 7.5 kg $FeSO_4$ $ha^{-1}$ | 1256 | 92.3 | 116 |
| $T_5$ | RDF + 7.5 kg $FeSO_4ha^{-1}$ + Bio NPK Consortium | 1283 | 94.8 | 122 |
| $T_6$ | RDF + Enriched 200 kg FYM $ha^{-1}$ with 7.5 kg $FeSO_4$ | 1293 | 100.1 | 129 |
| $T_7$ | RDF + 11.25 kg $FeSO_4ha^{-1}$ | 1268 | 96.1 | 122 |
| $T_8$ | RDF + 11.25 kg FeSO4 $ha^{-1}$ + Bio NPK Consortium | 1293 | 98.0 | 127 |
| $T_9$ | RDF + Enriched 200 kg FYM $ha^{-1}$with 11.25 kg $FeSO_4$ | 1326 | 102.3 | 136 |
| $T_{10}$ | RDF + 15 kg $FeSO_4ha^{-1}$ | 1274 | 99.3 | 127 |
| $T_{11}$ | RDF + 15 kg $FeSO_4ha^{-1}$ + Bio NPK Consortium | 1288 | 98.5 | 127 |
| $T_{12}$ | RDF + Enriched 200 kg FYM $ha^{-1}$with 15 kg $FeSO_4$ | 1326 | 100.9 | 134 |
| | S.Em.+ | 2.28 | 3.34 | 5.60 |
| | C.D. (P = 0.05) | 6.56 | 9.60 | 16.11 |
| | C.V.% | 8.33 | 7.04 | 9.31 |

**Table 2:** Effect of iron ferti-fortification on Fe harvest index, partial factor productivity and Fe use efficiency

| Trt. | Treatment details | Fe harvest index (%) | Partial factor productivity | Fe use efficiency (%) |
|---|---|---|---|---|
| $T_1$ | RDF (Control) | 13.8 | - | - |
| $T_2$ | RDF + Bio NPK Consortium | 12.8 | - | - |
| $T_3$ | RDF + 200 kg FYM $ha^{-1}$ | 13.2 | - | - |
| $T_4$ | RDF + 7.5 kg $FeSO_4ha^{-1}$ | 13.3 | 837 | 10.13 |
| $T_5$ | RDF + 7.5 kg $FeSO_4ha^{-1}$ + Bio NPK Consortium | 13.7 | 855 | 11.73 |
| $T_6$ | RDF + Enriched 200 kg FYM $ha^{-1}$ with 7.5 kg $FeSO_4$ | 13.7 | 862 | 15.07 |
| $T_7$ | RDF + 11.25 kg $FeSO_4$ $ha^{-1}$ | 13.4 | 564 | 8.53 |
| $T_8$ | RDF + 11.25 kg $FeSO_4$ $ha^{-1}$ + Bio NPK Consortium | 14.2 | 575 | 7.56 |
| $T_9$ | RDF + Enriched 200 kg FYM $ha^{-1}$with 11.25 kg $FeSO_4$ | 14.1 | 589 | 10.80 |
| $T_{10}$ | RDF + 15 kg $FeSO_4$ $ha^{-1}$ | 13.4 | 425 | 7.37 |
| $T_{11}$ | RDF + 15 kg $FeSO_4$ $ha^{-1}$ + Bio NPK Consortium | 13.7 | 429 | 6.77 |
| $T_{12}$ | RDF + Enriched 200 kg FYM $ha^{-1}$ with 15 kg $FeSO_4$ | 13.5 | 442 | 8.83 |

## Conclusion

On the basis of Fe harvest index, soil application of 11.25 kg $FeSO_4$ along with Bio NPK consortium application through seed treatment at 10 mL $kg^{-1}$ seed as well as soil drenching (1 L $ha^{-1}$) at 30 DAS is adjudged as the best Fe ferti-fortification strategy for grain *Amaranthus* crop grown in middle Gujarat condition.

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