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Quality of Amaranthus (*Amaranthus hypochondriacus* L.) and soil properties influenced by irrigation scheduling based on critical growth stages and levels of iron

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Abstract
A field experiment was conducted to study the influence of Irrigation Scheduling based on critical growth stages and Fe levels on the quality of Amaranthus (*Amaranthus hypochondriacus* L.) during *rabi* season of the year 2012-13 at Tribal Research Cum Training Centre Farm, Anand Agricultural University, Devgadhbaria, Dist.-Dahod. Sixteen treatment combinations comprising of four irrigations (I_1:- irrigation at branching stage, I_2:-branching + Flowering stage, I_3:-branching + Flowering + Grain formation stage and I_4:- 0.8 IW: CPE) and four levels of iron (F_0:- 0 kg ha^{-1}, F_1:-10 kg ha^{-1}, F_2:- 0.5 % $FeSO_4$ and F_3:- 5 kg ha^{-1} + 0.5 % $FeSO_4$) were tried under split plot design with four replications. Irrigation scheduling did not significant influence on soil pH, EC, Organic Carbon, available P_2O_5, available K_2O, available Fe and protein content, Fe content in grain. 0.8 IW: CPE recorded significantly higher Fe uptake which was remained at par with irrigation at branching + Flowering + Grain formation stage. Water use efficiency higher by irrigation at branching stage which was remained at par with irrigation at branching + Flowering stage and branching + Flowering + Grain formation stage. Iron levels had not significant differences in soil pH, EC, Organic Carbon, available P_2O_5, available K_2O, available Fe, Fe content in grain, Fe uptake by grain, protein content.

Keywords: *Amaranthus hypochondriacus*, irrigation, Organic Carbon

Introduction
Grain amaranthus (*Amaranthus hypochondriacus* L.) is a potential upcoming subsidiary food crop, considered by many as a crop of future. Certain attributes, like its higher productivity potential added with substantial quantities of minerals, carbohydrates, fast and proteins, compared with any of the improved cereals, have aroused great interest in developing of grain amaranthus as a cultivated crop. Its input requirements are seemingly much lower than that of any cereal. In India, amaranthus is commonly grown in Himachal Pradesh and in the hills of Uttar Pradesh for both grains and greens. However, it is mainly grown for grain, especially in Madhya Pradesh, Maharashtra and some parts of Gujarat. It is estimated that it occupies about 60 percent of Kharif land of higher hills in north-west India. One way of increasing quality production per unit volume of water is to irrigate the crop at critical growth stages, which are more sensitive to water application. The Scheduling of irrigation for grain amaranthus so far has been restricted to climatic approach (IW: CPE ratio) as a close relationship has been established between the rates of consumptive use and evaporation (Pariah *et al*., 1974) [8]. Fertilizers are the most important inputs for plant growth. They play pivotal role in quantitative as well as qualitative improvement in grain and by matter production. Freon (Fe), Zinc (Zn), Copper (Cu) and manganese (Mn) are essential micronutrients for plant. A deficiency of just are of those nutrients can greatly reduce the plant yield. Micronutrient deficiency, especially Fe and Zn are widespread in soils of Gujarat (Patel *et al*., 1999) [6]. Micronutrient concentration and bio availability in cereal grain is generally low. Increasing the micronutrient concentration of cereal grains has been identified as a way of addressing human micronutrient deficiencies.

Material and Methods
An experiment was conducted at the Tribal Research cum Training Center, Anand Agricultural University, Devgadhbaria, Dist. Dahod, Gujarat during the rabi season of year 2012-13. The texture of soil is loamy sand having pH 7.4, EC 0.13 dSm^{-1}, organic carbon 0.45 per cent, available nitrogen 210.25 kg ha^{-1}, available K_2O 352.0 kg ha^{-1}, available Fe 4.20 mg kg^{-1}. Gujarat Amaranthus - 2 was used for experiment.

The treatment consist of four levels of irrigation i.e. Irrigation at branching stage, branching + Flowering stage, branching + Flowering + Grain formation stage and 0.8 IW: CPE ratio and four doses of $FeSO_4$ i.e. 0 kg ha^{-1}, 10 kg ha^{-1}, 0.5 % $FeSo_4$ as foliar and 5 kg ha^{-1} + 0.5 % $FeSo_4$ as foliar. Thus sixteen treatment combinations were replicated four times in split plot design. First light irrigation of 50 mm after sowing the seed and after that irrigation was given as per treatments. Application of basal dose of nitrogen @ 20 kg ha^{-1} and phosphorus @ 20 kg ha^{-1} at time of sowing and remaining 20 kg ha^{-1} nitrogen at 30 DAS. Here, soil application of $FeSO_4$ was given at basal and foliar application at flowering stage. The randomly selected plants were tagged and used for recording various observations on chemical and quality parameters.

Result and Discussion

Effect of irrigation

Irrigation scheduling failed to exert their significant differences in soil pH, EC, Organic Carbon, available P_2O_5, available K_2O, available Fe and Fe content in grain. There was significantly higher uptake under irrigation at 0.8 IW: CPE which was at par with irrigation at branching stage, at flowering and at grain formation stage. The increase in Fe uptake under irrigation at and 0.8 IW: CPE and irrigation at branching stage, at flowering and at grain formation stage was to the tune of 37.34 and 32.28 per cent, respectively over treatment irrigation at branching stage. This might be due to increase in mass flow transport of nutrients with sufficient soil moisture availability. The findings are in accordance with those reported by Monjezi *et al.* (2012). Water use efficiency higher at irrigation at branching stage which was at par with irrigation at branching + Flowering stage and irrigation at branching + Flowering + Grain formation stage. Water use efficiency indicated that a decreasing trend as the irrigation level increased which was might be due to the increase in grain yield was not proportional to the quantity of water applied. Similar results were also reported by Chaudhri *et al.* (2009) [3].

Effect of Iron levels

Iron levels failed to exert their significant differences in soil pH, EC, Organic Carbon, available P_2O_5 and available K_2O. While available Fe, Fe content in grain and Fe uptake by grain remained significant. Application of 10 kg $FeSO_4$ ha^{-1} recorded significantly higher available Fe which was remained at par with spraying of 0.5 % $FeSO_4$ and application of 5 kg ha^{-1} + 0.5 % $FeSO_4$. This could be due to increasing the application rates of Fe increased the Fe build up in soil and due to more vegetative growth and root growth which release hydrogen irons, phenolic compounds and organic acids as well as phytosiderophorus helped in increased availability in soils. The present findings are in accordance with those reported by Singh and Gupta (1988) [9] and Abbas *et al.* (2012) [1]. Application of 5.0 kg $FeSO_4$ ha^{-1} + 0.5 % $FeSO_4$ as foliar recorded significantly higher Fe content which was at par with treatment 0.5 % $FeSO_4$ as foliar. The increase in Fe content under application of 0.5 % $FeSO_4$ as foliar and 5.0 kg $FeSO_4$ ha^{-1} + 0.5 % $FeSO_4$ as foliar was at the extent of 10.08 and 11.36 per cent, over treatments control. There was significantly higher uptake under application of 5.0 kg $FeSO_4$ ha^{-1} + 0.5 % $FeSO_4$ as foliar which was at par with treatment 0.5 % $FeSO_4$. The increase in Fe uptake under treatment 5.0 kg $FeSO_4$ ha^{-1} + 0.5 % $FeSO_4$ as foliar and 0.5 % $FeSO_4$ as foliar was at the extent of 32.35 and 26.14 per cent, over treatments 0 kg $FeSO_4$ ha^{-1}. This could be due to increased iron availability in soil and direct uptake of ferrous iron by leaves resulting in higher production of chlorophyll, dry matter and higher total iron content of plant and grain. Similar results were also reported by Babria and Patel (1981) [2], Singh and Gupta (1988) [9], Hellal *et al.* (2008) [4], Patel *et al.* (2009) [7], Zeidan *et al.* (2010) [10] and Abbas *et al.* (2012) [1]. Application of 5.0 kg $FeSO_4$ ha^{-1} + 0.5 % $FeSO_4$ as foliar recorded significantly higher protein content which was remained at par with 0.5 % $FeSO_4$. The increase in Fe content under treatment 0.5 % $FeSO_4$ as foliar and 5.0 kg $FeSO_4$ ha^{-1} + 0.5 % $FeSO_4$ as foliar was at the extent of 5.90 and 6.30 per cent, over treatments 0 kg $FeSO_4$ ha^{-1}. Similar results were also reported by Patel *et al*. (2009) [7]. Application of 5 kg ha^{-1} + 0.5 % $FeSO_4$ recorded higher water use efficiency which was remained at par with application of 0.5 % $FeSO_4$. Water use efficiency indicated the increasing trends as the iron level increased, which might be due to increase in yield and yield attributes with iron application.

Interaction effect

Treatment combination of irrigation at branching and at flowering stage with 5 kg $FeSO_4$ ha^{-1} + 0.5 % $FeSO_4$ recorded significantly higher WUE which was remained at par with treatment combination irrigation at branching stage with application of $FeSO_4$ @ 10 kg ha^{-1}, irrigation at branching stage with application of 0.5 % $FeSO_4$ and irrigation at branching + Flowering + Grain formation stage with application of $FeSO_4$ @ 5 kg ha^{-1} + 0.5 % $FeSO_4$.

Table 1: Chemical and quality attribute of Amaranthus as influenced by irrigation and levels of iron

Treatment	pH	EC (dsm^{-1})	O.C (%)	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Available Fe (mg kg^{-1})	Fe Content (mg kg^{-1})	Fe uptake (g ha^{-1})	Protein Content In grain (%)	Water Use Efficiency (kg ha^{-1} mm)
Irrigation										
I_1:- irrigation at branching stage	9.41	0.129	0.334	24.36	342.54	4.61	104.6	151	15.68	9.65
I_2:-branching + Flowering stage	7.48	0.128	0.331	24.12	341.54	4.73	103.19	189	15.69	9.04
I_3:-branching + Flowering + Grain formation stage	7.45	0.126	0.321	24.12	339.96	4.82	104.75	223	15.71	8.49
I_4:- 0.8 IW: CPE)	7.45	0.123	0.322	24.12	339.43	4.82	105.81	241	15.82	6.48
S.E.(m)±	0.03	0.001	0.003	0.12	1.74	0.07	1.23	7	0.04	0.43
CD (P=0.05)	NS	NS	NS	NS	NS	Ns	NS	23	NS	1.36
C.V. %	1.4	4.70	4.03	2.02	2.05	5.85	4.71	14.5	1.08	20.24
Fe Levals (F_eSO_4)										

F_0:- 0 kg ha^{-1}	7.47	0.126	0.330	24.18	339.38	4.18	97.00	161	15.13	7.33
F_1:-10 kg ha^{-1}	7.48	0.128	0.324	24.19	341.06	5.27	103.50	187	15.54	8.01
F_2:- 0.5 % $FeSO_4$	7.42	0.125	0.325	24.18	341.36	4.58	107.88	218	16.08	8.95
F_3:- 5 kg ha^{-1} + 0.5 % $FeSO_4$	7.405	0.126	0.330	24.18	341.68	4.96	109.44	238	16.15	9.37
S.E.(m) ±	0.02	0.001	0.003	0.005	1.43	0.07	1.31	8	0.04	0.31
CD (P=0.05)	NS	NS	NS	NS	NS	0.19	3.25	22	0.118	0.887
Interaction (I X F)	NS	NS	NS	NS	NS	NS	NS	NS	NS	SIG
C.V. %	1.32	5.002	***4.47***	0.09	1.67	5.48	4.34	15.5	1.04	14.68

Table 2: Interaction effect between levels of irrigation and iron on WUE

Interaction effect WUE (kg ha^{-1}mm)	**$FeSO_4$ (F)**			
Irrigation schedules (I)	**F_0 : 0 kg ha^{-1}**	**F_1 : 10 kg ha^{-1}**	**F_2 : 0.5%**	**F_3 : 5 kg ha^{-1} + 0.5%**
I_1:- Irrigation at branching stage	9.31	9.76	11.0	8.55
I_2:- I_1+ Flowering stage	7.04	8.40	9.42	11.32
I_3:- I_1+I_2+ Grain formation stage	7.24	7.83	8.68	10.23
I_4:-0.8 IW: CPE ratio	5.76	6.06	6.71	7.40
S.Em.±	0.69			
C.D. (P=0.05)	1.77			
C.V. %	14.68			

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