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Determination of Critical Limit of Iron for Soil and Wheat Crop in Rajsamand District of Rajasthan

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Abstract

The present investigation was undertaken to establish the critical limit of iron for soil and plant in wheat crop. All the doses of iron applied from 2.5 to 10 kg ha⁻¹ increased the dry matter yield of wheat significantly and it was recorded to be 645.74 to 841.95 g/m² as compared to control where mean dry matter yield was 556.64 g/m². The postulated critical level ranged from 5.30 to 5.59 mg kg⁻¹ and the critical limit was designated as 5.45 mg kg⁻¹ of iron in soils of Rajsamand district. The postulated critical level for wheat plant was obtained as 31.47 to 33.89 mg kg⁻¹ and that critical limit of iron in wheat plant could be referred as 32.68 mg kg⁻¹.

Keywords: Iron, Critical limit, Wheat, Dry matter, Soil, Plant

Introduction

Wheat is the world's leading cereal crop cultivated over an area of about 219.01 m ha with a production of 763.93 mt. In India, the wheat production is about 107.59 million tonnes from an area of around 31.45 m ha. In Rajasthan production of wheat is about 13.89 million tonnes from an area around 3.49 m ha. Although, India is well placed in meeting its needs for food grains the major objective of food and nutritional security for its entire population has not been achieved. Indian soils have become deficient not only in major plant nutrients like nitrogen, phosphorus and in some cases, potash but also in micronutrients such as zinc, boron and to a limited extent iron, manganese, copper and molybdenum have also been reported to be deficient (Singh *et al.* 2013) [19]. Deficiency of micronutrients during the last three decades has grown in both, magnitude and extent because of increased use of high analysis fertilizers, use of high yielding crop varieties and increase in cropping intensity (Yadav, 1999 and Yadav, 2008) [24, 25]. This has become a major constraint for production and productivity of agricultural crops. At present about 47.0, 11.50, 4.8 and 4.0 % of soils are deficient in Zn, Fe, Cu and Mn respectively, (Dhane 2011) [5]. Plants require optimum concentrations of a number of essential nutrients, including micronutrients such as iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), boron (B), and molybdenum (Mo), to operatively complete their life cycle. For normal growth and metabolism of plants, these metal ions are required in trace quantities (Hansch and Mendel, 2009) [9]. Iron is one of the important micronutrients essential for plants, animals and human health. It is needed in very small amount but from the nutritional point of view, it is indispensable like any other essential nutrients.

Critical limit of a nutrient in soils refers to a level below which the crops will readily respond to its application. It can also be considered as the desirable range of values for a selected soil indicator that must be maintained for normal functioning of the soil ecosystem health. Within this range, the soil and plants performs its specific functions in natural ecosystems. The critical limits/levels are quite often employed for a wide variety of soils and crops, even though these critical limits may be different not only for soils, crop species but also for different varieties of a given crop (Singh and Aggarwal, 2007) [21]. The critical concentration of iron in soil and plant is very essential for obtaining economic yield and quality of wheat. The scientific information on iron status and critical limits in swell shrink soil in Rajsamand district of Rajasthan. The critical limit available Fe in soil and plant is a useful index whether a soil needs iron fertilizer for optimum crop productivity in farmers field. Considering the importance and absence of information on these aspects of the soil, the present investigation was proposed.

Materials and Methods

Field experiments were conducted at twenty sites in Rajsamand district of Rajasthan to

establish critical limits for DTPA extractable Fe contents. Varying limits of iron viz., 0.0, 2.5, 5.0, 7.5, 10.0 were applied in addition to recommended dose of N, P and K.

Critical Limits of Zn by Statistical Method

The steps followed for calculation of critical limit of iron by statistical method of Cate and Nelson (1971) [4] were as follows:

1. The initial soil test iron values were arranged according to their increasing trend (i.e. in ascending order).
2. Bray's per cent yield was calculated by using formula.

$$\text{Brays per cent yield} = \frac{\text{Yield without Fe}}{\text{Yield at optimum Fe}} \times 100$$

3. The percent dry matter yield was written against each soil test zinc values.
4. Firstly the correction factor (C.F.) and total sum of squares (T.S.S.) were calculated from percent dry matter yield by using following formulae.
- 5.

$$CF = \frac{(\sum Y)^2}{n} = \frac{\sum (Y_1+Y_2+Y_3+\dots+Y_n)^2}{n}$$

$$.S.S. = \sum Y^2 - C.F.$$

$$= \sum (Y_1^2 + Y_2^2 + Y_3^2 + \dots + Y_n^2) - C.F.$$

Where,

Y = Percent dry matter yield

n = Total number of observations

5. The data were grouped into two groups i.e. if the total number of observations are "n" then the data is grouped as, (P, n-P), (P+1, n-P+1)

6. Table with following was prepared.

i. Last value of soil

ii. Plant available Fe included in population Ist

$$\text{i.e.} = \frac{P_1 + P_2 + \dots + P_n}{P}$$

iii. Sum of square of deviation from mean of population Ist were combined i.e. CSS I

Here total of all values of population Ist was made

$$CSS I = \sum P_1^2 + P_2^2 + \dots + P_n^2 - \frac{\sum (P_1 + P_2 + \dots + P_n)^2}{n}$$

iv. If, K_n is number of observation in population IInd then, mean relative yield in population IInd

$$\text{i.e.} = \frac{K_1 + K_2 + \dots + K_n}{n}$$

v. Sum of square of deviation from mean of population IInd (CSS II) were combined. Here

total of all values of population IInd was made i.e. (K₁+K₂+.....+K_n)

$$CSS II = \sum K_1^2 + K_2^2 + \dots + K_n^2 - \frac{\sum (K_1 + K_2 + \dots + K_n)^2}{n}$$

vi. Postulated critical limit (split between the two population) i.e. PCL was calculated as

$$PCL = \frac{\text{Last value in I}^{st} \text{ population} + \text{I}^{st} \text{ value in II}^{nd} \text{ population}}{2}$$

$$\text{vii. Coefficient of determination (R}^2\text{)} = \frac{TSS - CSS I - CSS II}{TSS}$$

The concentration having highest R² was the critical concentration limit for respective content in soil and plant.

Results and Discussion

Effect of Iron application on dry matter yield of wheat

The dry matter yield of wheat was significantly affected by the application of iron regardless of initial iron status in the soils (Table 1). The results indicated that the dry matter yield of wheat was greatly influenced by the different levels of iron concentration i.e. 2.5, 5.0, 7.5 and 10 kg ha⁻¹. The dry matter yield in control with no dose of iron varied from 437.93 to 793.77 g m² with a mean yield of 556.64 g m² as compared with 578.13 to 865.50 g m² (mean 645.74 g m²) at the dose 2.5 kg iron ha⁻¹ and 739.61 to 993.65 g m² (mean 841.95 g m²) at the dose of 10 kg iron ha⁻¹. The present findings are in agreement with the findings of Mehra and Shekhawat (1999) [12]; Kumar (2002) [10]; Pervaiz *et al.* (2003); Yadav *et al.* (2005) [23]; Al-Niemi and Dohuki (2009) [1] and Zeidan *et al.* (2010) [27].

Effect of Iron application on Iron content in wheat plants

A perusal of the data presented in Table 2 revealed that the effect of different levels of iron on the iron content in wheat plants differed significantly. Coinciding with the increase in iron doses from 2.5 to 10 kg ha⁻¹, the iron content in wheat plants increased. At zero level, it was recorded to be 25.42 ppm in control which was amplified from 33.03 ppm at 2.5 kg ha⁻¹ to 47.19 ppm at 10 kg ha⁻¹. These results are in agreement with the findings of Singh and Singh (1996) [20], Prasad *et al.* (2010) [15] and Gour *et al.* (2011) [7].

Critical limit of iron for soil

Data in table 3 showed the critical level of iron as calculated by Cate and Nelson statistical method (1971) [4]. The values of coefficient of determination (R²) increased from 0.363 to 0.516 and then it recorded a decrease. The highest R² (0.516) value was obtained in soils with DTPA- extractable iron level of 5.44 mg kg⁻¹. Hence the critical limit of iron is 5.44 mg kg⁻¹ in soils of Rajsamand district. The results are in agreement with the results reported by Sakal *et al.* (1984) [18] in calcareous soils for rice and lentil. They reported the optimum Fe level 10 mg kg⁻¹ for these soils. Takkar *et al.* (1989) [22] reported the critical limit of DTPA-Fe for maize and wheat in soil of Gujarat and Haryana as 3.9 and 5.8 mg kg⁻¹, respectively. Balali *et al.* (2000) [3] reported the critical limit of iron as 4.03 mg kg⁻¹ for irrigated wheat in North-west provinces of Iran. Rezaei and Malakouti (2001) [17] reported the soil critical limit of iron by graphical method as 4.8 mg kg⁻¹ for cotton and on the basis of analysis of variance method it was 5.5 mg kg⁻¹. Mehra *et al.* (2005) [13] observed the critical limits for DTPA-Fe was 4.69 mg kg⁻¹ in the soil samples from haplustalfs of sub-humid southern plain and aravalli hills of Rajasthan. Feiziassi *et al.* (2009) [6] observed that the critical limit of iron was 4.68 mg kg⁻¹ for dry land wheat in North west Iran. Meena *et al.* (2013) [11] reported the critical limit of iron as 4.67 mg kg⁻¹ for wheat growing soils

of sub-humid southern zone of Rajasthan.

Critical limit of iron for wheat plant

The values of coefficient of determination (R^2) increased from 0.326 to 0.545 and then it recorded a decrease (Table 4). The highest R^2 (0.545) value was obtained in wheat plant iron content up to 32.68 mg kg⁻¹ and therefore critical limit of iron for wheat plant is 32.68 mg kg⁻¹. Similar results were obtained by Sakal *et al.* (1984) [18] in calcareous soils for rice and lentil they reported threshold values Fe as 44 and 74.5 mg

kg⁻¹, respectively, below which appreciable responses to Fe application were observed. Mehra *et al.* (2005) [13] observed that the critical limits for 45 days old maize plant was 44.2 mg Fe kg⁻¹. Gupta *et al.* (2009) [8] evaluated the pearl millet progenies derived from two diverse populations for the micronutrient content. They reported the average Fe content of 37.0 mg kg⁻¹ in pearl millet (IAC-ISC-TCP-1). Meena *et al.* (2013) [11] reported the critical limit of iron in wheat was 43.52 mg kg⁻¹ in sub-humid southern zone (IV-B) of Rajasthan.

Table 1: Effect of iron application on dry matter yield of wheat

S.No.	Village	Tehsil	District	Dry matter yield (g m ²) at Fe rate (kg ha ⁻¹)				
				0.00	2.50	5.00	7.50	10.00
1	Bilakhi	Deogarh	Rajsamand	437.93	578.13	595.81	761.63	818.86
2	Saroth	Bhim	Rajsamand	452.72	515.79	587.07	698.36	750.85
3	Salore	Khamnor	Rajsamand	471.12	518.91	611.07	718.00	771.96
4	Pratap pura	Rajsamand	Rajsamand	493.87	533.60	640.76	735.89	791.19
5	Kanuja	Kumbhalgarh	Rajsamand	504.57	579.01	654.72	785.64	844.68
6	Peetha Ka Khera	Deogarh	Rajsamand	516.27	545.63	669.99	794.36	854.05
7	Nayagaon	Bhim	Rajsamand	557.42	543.40	723.67	785.61	844.66
8	ChhdangaKhera	Railmagra	Rajsamand	522.97	558.54	678.71	771.67	829.66
9	Bhagal	Kumbhalgarh	Rajsamand	464.07	495.54	602.15	687.91	739.61
10	Beeyana	Deogarh	Rajsamand	483.37	611.45	628.15	706.89	760.03
11	Bhilo Ki Talai	Khamnor	Rajsamand	496.46	564.71	644.50	747.24	803.40
12	Guniya	Deogarh	Rajsamand	506.77	607.46	657.96	747.56	803.73
13	Liki	Amet	Rajsamand	542.78	639.42	704.95	719.83	773.93
14	LathiyaKheri	Railmagra	Rajsamand	523.01	710.49	679.32	737.57	793.00
15	Peepali	Deogarh	Rajsamand	592.53	790.25	770.01	835.28	898.04
16	Kuanthal	Deogarh	Rajsamand	610.06	827.86	792.88	872.15	937.68
17	Kalan	Railmagra	Rajsamand	679.29	790.25	883.22	848.19	911.91
18	Sindesar Khurd	Railmagra	Rajsamand	756.45	797.78	983.88	896.75	927.77
19	Bhopji Ka Khera	Amet	Rajsamand	727.35	841.04	945.90	916.30	990.25
20	Bhawa	Rajsamand	Rajsamand	793.77	865.50	1032.53	884.31	993.65
Mean				556.64	645.74	724.36	782.56	841.95
Factor				Soil	Fe levels	Soil x Fe		
SEm±				8.263	4.132	18.477		
CD(P=0.05)				23.044	11.522	51.528		

Table 2: Effect of iron application on iron content in wheat

S.No.	Village	Tehsil	District	Fe content (ppm) at Fe rate (kg ha ⁻¹)				
				0.00	2.50	5.00	7.50	10.00
1	Bilakhi	Deogarh	Rajsamand	12.76	16.33	22.23	28.13	30.88
2	Saroth	Bhim	Rajsamand	14.26	18.30	28.58	27.64	30.34
3	Salore	Khamnor	Rajsamand	15.15	19.48	29.99	32.72	35.95
4	Pratap pura	Rajsamand	Rajsamand	17.24	22.24	25.42	29.96	32.90
5	Kanuja	Kumbhalgarh	Rajsamand	17.46	22.53	33.93	39.61	43.57
6	Peetha Ka Khera	Deogarh	Rajsamand	14.76	18.96	31.18	37.64	41.39
7	Nayagaon	Bhim	Rajsamand	20.97	27.16	33.14	35.97	39.54
8	ChhdangaKhera	Railmagra	Rajsamand	22.98	29.81	29.84	38.63	42.48
9	Bhagal	Kumbhalgarh	Rajsamand	22.87	29.66	26.84	34.69	38.13
10	Beeyana	Deogarh	Rajsamand	21.63	28.03	28.02	33.35	36.65
11	Bhilo Ki Talai	Khamnor	Rajsamand	23.96	31.10	32.28	39.61	43.57
12	Guniya	Deogarh	Rajsamand	27.43	35.68	37.87	42.81	47.11
13	Liki	Amet	Rajsamand	28.92	37.65	39.35	40.6	44.66
14	LathiyaKheri	Railmagra	Rajsamand	27.68	36.01	41.81	50.67	55.80
15	Peepali	Deogarh	Rajsamand	28.44	37.01	59.05	50.79	55.94
16	Kuanthal	Deogarh	Rajsamand	36.88	48.14	60.82	53.06	58.44
17	Kalan	Railmagra	Rajsamand	35.01	45.68	51.66	56.25	61.97
18	Sindesar Khurd	Railmagra	Rajsamand	38.52	50.31	52	57.22	63.05
19	Bhopji KaKhera	Amet	Rajsamand	41.88	54.74	59.6	64.24	70.80
20	Bhawa	Rajsamand	Rajsamand	39.62	51.77	60.13	64.12	70.67
Mean				25.42	33.03	39.19	42.89	47.19
Factor				Soil	Fe levels	Soil x Fe		
SEm±				0.442	0.221	0.988		
CD(P=0.05)				1.232	0.616	2.756		

Table 3: Calculation of coefficient of determination (R^2) for best two population split using two mean discontinuous model for wheat in soils of Rajsamand district

S.No.	Village	DTPA-Fe in soil (mg kg ⁻¹)	Mean	Dry matter yield of wheat			Population I		Population II		Postulated critical levels		R ² from postulated critical levels
				Threshold yield (g)	Plateau yield (g)	Relative yield (%)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS I)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS II)			
S ₁	Bilakhi	3.600		9.03	15.41	58.60							
S ₂	Saroth	3.700		10.34	16.19	63.87							
S ₃	Salore	4.000	3.77	11.24	17.27	65.08	62.52	23.77	67.66	257.65	3.77	4.89	0.363
S ₄	Pratap pura	4.660		11.95	18.24	65.52							
S ₅	Kanuja	5.000		12.25	19.03	64.37							
S ₆	Peetha Ka Khera	5.020	4.89	12.45	18.93	65.77	63.87	35.83	68.57	140.39	4.89	5.30	0.479
S ₇	Nayagaon	5.100		12.65	18.93	66.83							
S ₈	ChhdangaKhera	5.300		12.95	19.81	65.37							
S ₉	Bhagal	5.500	5.30	13.25	19.51	67.91	64.81	55.17	69.29	98.34	5.30	5.59	0.516
S ₁₀	Beeyana	5.500		13.55	20.39	66.45							
S ₁₁	Bhilo Ki Talai	5.580		14.60	20.10	72.64							
S ₁₂	Guniya	5.700	5.59	14.06	20.88	67.34	65.81	113.47	70.00	69.55	5.59	5.71	0.399
S ₁₃	Liki	5.700		14.46	20.49	70.57							
S ₁₄	LathiyaKheri	5.720		14.06	21.56	65.21							
S ₁₅	Peepali	5.720	5.71	14.76	20.98	70.35	66.39	152.05	70.44	41.38	5.71	7.14	0.376
S ₁₆	Kuanthal	6.560		15.66	21.37	73.28							
S ₁₇	Kalan	6.990		14.86	21.27	69.86							
S ₁₈	Sindesar Khurd	7.880	7.14	15.56	21.57	72.14	67.29	230.15	71.48	8.68	7.14	8.40	0.099
S ₁₉	Bhopji Ka Khera	8.100		15.96	22.15	72.05							
S ₂₀	Bhawa	8.700	8.40	15.76	22.50	70.04	67.66	257.65	71.05	2.02	8.40		

Critical limit 5.45 0.76

Table 4: Calculation of coefficient of determination (R^2) for best two population split using two mean discontinuous model for wheat plant

S.No.	Village	DTPA-Fe in plant (mg kg ⁻¹)	Mean	Dry matter yield of wheat			Population I		Population II		Postulated critical levels		R ² from postulated critical levels
				Threshold yield (g)	Plateau yield (g)	Relative yield (%)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS I)	Mean relative yield	Corrected sum of squares of deviations from mean (CSS II)			
S ₁	Bilakhi	22.02		9.20	15.41	59.70							
S ₂	Saroth	23.78		10.34	16.19	63.87							
S ₃	Salore	26.61	24.13	11.24	17.27	65.08	62.88	15.93	67.65	246.27	24.13	28.54	0.326
S ₄	Pratap pura	25.50		11.71	18.24	64.20							
S ₅	Kanuja	31.37		12.25	19.03	64.37							
S ₆	Peetha Ka Khera	28.74	28.54	12.45	18.93	65.77	63.83	22.80	68.49	150.09	28.54	31.47	0.508
S ₇	Nayagaon	31.31		12.65	18.93	66.83							
S ₈	ChhdangaKhera	32.70		12.95	19.81	65.37							
S ₉	Bhagal	30.39	31.47	13.25	19.51	67.91	64.79	42.55	69.29	98.34	31.47	33.89	0.545
S ₁₀	Beeyana	29.49		13.55	20.39	66.45							
S ₁₁	Bhilo Ki Talai	34.06		14.60	20.10	72.64							
S ₁₂	Guniya	38.13	33.89	14.06	20.88	67.34	65.79	101.29	70.00	69.55	33.89	42.24	0.421
S ₁₃	Liki	38.19		14.46	20.49	70.57							
S ₁₄	LathiyaKheri	42.35		14.06	21.56	65.21							
S ₁₅	Peepali	46.20	42.24	14.76	20.98	70.35	66.38	140.12	70.44	41.38	42.24	51.22	0.396
S ₁₆	Kuanthal	51.42		15.66	21.37	73.28							
S ₁₇	Kalan	50.07		14.86	21.27	69.86							
S ₁₈	Sindesar Khurd	52.17	51.22	15.56	21.57	72.14	67.27	218.60	71.48	8.68	51.22	57.71	0.104
S ₁₉	Bhopji Ka Khera	58.21		15.96	22.15	72.05							
S ₂₀	Bhawa	57.22	57.71	15.76	22.50	70.04	67.65	246.27	71.05	2.02	57.71		

Critical limit 32.68 0.783

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