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Residual effect of iron management on chlorophyll and sugar content of sweet corn under rice-sweet corn cropping sequence

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Abstract
A field experiment was conducted at the Navsari Agricultural University farm, Navsari (Gujarat) during *kharif* (Rice) and *rabi* (Sweet corn) season 2020 and 2021 to study the residual effect of iron management on chlorophyll and sugar content of *rabi* sweet corn in rice-sweet corn cropping sequence under South Gujarat condition. Total twelve treatments of different iron fertilizers along with Arbuscular mycorrhiza (AM) and *Pseudomonas fluorescens* biofertilizers replicated three times in Randomized Block Design in preceding *kharif* rice and *rabi* sweet corn crop nourished with recommended dose of fertilizer (120:60:60 NPK kg ha^{-1}) in rice-sweet corn cropping sequence under South Gujarat condition. Among the different treatments, residual effect of $FeSO_4$ @ 50 kg ha^{-1} + AM + *P. fluorescens* Seedling treatment + Field application: 2L ha^{-1} gave significantly higher content of chlorophyll content and sugar content of sweet corn during both the individual years and pooled analysis.

Keywords: Iron management, residual effect, Arbuscular mycorrhiza, pseudomonas fluorescens, chlorophyll content and sugar content

Introduction

Micronutrients are required for proper human growth and development, and their deficiency harms health, contributing to low productivity and a vicious cycle of malnutrition, underdevelopment, and poverty. Micronutrient deficiency is a public health problem affecting more than a quarter of the world's population (Gonmei and Toteja, 2018) [6]. Micronutrients are essential for plant growth and metabolic processes such as photosynthesis, chlorophyll formation, cell wall development, respiration, water absorption, xylem permeability, disease resistance, and enzyme activities involved in the synthesis of primary and secondary metabolites with nitrogen fixation and reduction (Adhikary *et al*. 2010 and Vitti *et al*.2014) [1, 9]. By reducing the availability of micronutrients in the soil, some common farming practises, such as liming acid soils, contribute to the widespread occurrence of micronutrient deficiencies in crops. The difficulty in identifying field crop symptoms, variation in soil micronutrient status, pH, and intensity, seasonal fluctuations in the region's levels and temperature regimes, and insufficient facilities and field tests to validate soil and plant micronutrients are all major issues in alleviating micronutrient deficiencies (Das, 2014) [4].

Sweet corn (*Zea mays* L. Saccharata) is a popular multipurpose cereal crop belonging to the family *Poaceae* and is cultivated as an annual field crop all over the world (Remison, 2005). Sweet corn has grown in popularity due to its superior taste when compared to regular corn. Sweet corn is a type of corn with a high sugar content and nutritional value. The presence of sugar content in sweet corn kernels determines the quality of sweet corn. It is peculiarly an American crop and was introduced in India from the USA. Maize besides being an important staple food for human beings comprises a significant animal and poultry feed and has enormous industrial importance. Karnataka, Madhya Pradesh, Kerala, Telangana, Tamil Nadu, Andhra Pradesh, West Bengal, Bihar, Maharashtra, and Uttar Pradesh are the most important maize-growing states in India (National Horticulture Board, 2020). Gujarat has an area of 3.92 lakh hectares, produces 6.10 lakh tonnes, and has a productivity of 1553 kg ha^{-1}. Dahod, Chhotaudaipur, Panchmahal, Mahisagar, Vadodara, Sabarkantha, Kheda, Banaskantha, Bharuch, Anand, and Dangs are important maize-growing districts in Gujarat. In the South Gujarat region, maize cultivation is almost non-existent (Anonymous, 2017) [2].

Iron absorption from the soil, as well as iron transport and accumulation in sweet corn, have the greatest influence on the iron content of sweet corn.

Iron (Fe) is involved in a wide range of important compounds and physiological processes, despite the fact that it is only required in trace amounts by plants. Iron is required for certain enzyme functions and is used in the production of chlorophyll. Chlorosis (yellowing) caused by Fe deficiency is caused by the role of Fe in chlorophyll synthesis. Iron can be found in plant iron-containing (heme) proteins such as cytochromes. Chloroplasts and mitochondrial electron transfer systems contain cytochromes. Iron is also associated with non-heme proteins like ferredoxin. Due to the low solubility of the oxidised ferric form in aerobic environments, iron ranks third among the most limiting nutrients for plant growth (Zuo and Zhang, 2011) [10].

Arbuscular mycorrhiza and *Pseudomonas fluorescens* are P solvents, organic matter decomposers, and plant growth regulator producers in the combination of microorganisms used. Iron (Fe) is beneficial to plant growth, particularly during the vegetative phase, and it aids in the formation of chlorophyll. Low chlorophyll content was reported under control conditions as a result of lower chlorophyll synthesis, a low rate of the PSII reaction centre, decreased activity of carbonic anhydrase and nitrate reductase, an imbalance in ion flux within plants, and an effect on the membrane stability index. Oxidative stress caused by low iron (Fe) content may result in deterioration of chloroplast structure and, as a result, a decrease in chlorophyll content.

Materials and Methods

Location and chemical Properties of soil: During the *kharif* and *rabi* seasons 2020 and 2021, the field experiment was carried out at the Navsari Agricultural University farm in Navsari (Gujarat). The Navsari Agricultural University campus is located at 200 57' North Latitude, 720 54’ East Longitudes, and is 10 metres above mean sea level. The experimental field's soil was fairly level and uniform. The soil of the experimental field was clayey in texture, low in organic carbon (0.36%, 0.42%) and available nitrogen (204.4, 214.1 kg ha^{-1}), medium in available phosphorus (36.2, 34.7 kg ha^{-1}) and high in available potassium (300.3, 312.4 kg ha^{-1}). In response, the soil became slightly alkaline (pH- 8.01, 7.98).

Climate and weather condition: Weather prevailed during the course of investigation was quite congenial for the satisfactory growth and development of *kharif* rice crop and *rabi* sweet corn crop. Moreover, there was no serious incidence of disease and pests. The maximum temperature ranged between 28.1 to 38.1 ºC and 26.4 to 39.5 ºC, while minimum temperature ranged between 10.7 to 27.9 ºC and 11.1 to 25.8 ºC during 2020-21 and 2021-22, respectively. In *kharif* season, total rainfall of 2310 mm and 1565 mm during 2020-21 and 2021-22 was recorded, respectively. The crop has got optimum duration of sunlight and humidity during the growth period.

Treatment: The treatment consisted of iron management *viz*., M_0 - Control (RDF), M_1 - Fe-EDTA @ 1.5 kg ha^{-1}, M_2 - $FeSO_4$ @ 50 kg ha^{-1}, M_3 - Arbuscular mycorrhiza (AM) Seedling treatment + Field application: 2L ha^{-1}, M_4 - *Pseudomonas fluorescens* (P) Seedling treatment + Field application: 2L ha^{-1}, M_5 - AM Seedling treatment + Field application: 2L ha^{-1} + *P. fluorescens* Seedling treatment + Field application: 2L ha^{-1}, M_6 - $FeSO_4$ @ 25 kg ha^{-1} + AM Seedling treatment + Field application: 2L ha^{-1}, M_7 - $FeSO_4$ @ 25 kg ha^{-1} + *P. fluorescens* Seedling treatment + Field application: 2L ha^{-1}, M_8 - $FeSO_4$ @ 25 kg ha^{-1} + AM + *P. fluorescens* Seedling treatment + Field application: 2L ha^{-1}, M_9 - $FeSO_4$ @ 50 kg ha^{-1} + AM Seedling treatment + Field application: 2L ha^{-1}, M_{10} - $FeSO_4$ @ 50 kg ha^{-1} + *P. fluorescens* Seedling treatment + Field application: 2L ha^{-1}, M_{11} - $FeSO_4$ @ 50 kg ha^{-1} + AM + *P. fluorescens* Seedling treatment + Field application: 2L ha^{-1} to rice in *kharif* season replicated three times in randomized block design. During *rabi* season, only RDF (recommended dose of fertilizers) of sweet corn (100:60:60 NPK kg ha^{-1}) was applied.

Note

1. **Seedling treatment:** Slurry was prepared by mixing AM (250 g ha^{-1}: 3000 IP/g of biofertilizer, 1000 spores $gram^{-1}$) and *P. fluorescens* (cfu: 108 per ml) at 1L ha^{-1} in 40 L of water and rice seedlings were dipped in the suspension for 15-30 minutes before transplanting.
2. **Field application:** Application of AM (250 g ha^{-1}) and 1L ha^{-1} of *P. fluorescens* by mixing it with FYM.

Chlorophyll content analysis

The chlorophyll content of previously selected 10 plants was measured at harvest by SPAD chlorophyll meter. The average chlorophyll content was worked out and recorded for each plot. The SPAD reading were converted to chlorophyll content in Nano mol mg^{-1} FW of plant (Ling *et al*., 2011) [7].

Sugar content analysis

The sugar content of sweet corn grain was estimated by Phenol Sulphuric acid method given by Dubois *et al*. (1956) [5] and it was expressed in percentage.

Result and Discussion

The data on chlorophyll content and sugar content of *rabi* sweet corn as influenced by residual effect of different iron management practices are presented in Table 1 and Fig 1.

1. Chlorophyll content in *rabi* sweet corn

The data on chlorophyll content in *rabi* sweet corn as influenced by different iron management practices applied to preceding *kharif* rice crop are presented in Table 1. Chlorophyll content in *rabi* sweet corn was significantly higher (1.719, 1.730 and 1.724 Nano mol mg^{-1} FW) with treatment M_{11} (FeSO4 @ 50 kg ha^{-1} + AM + *P. fluorescens* (P) as seedling treatment (S) and field application (F): 2 L ha^{-1}) was remain at par during both individual years and pooled analysis with treatments M_8, M_9 and M_{10}. The lowest chlorophyll content (1.360, 1.333 and 1.347 Nano mol mg^{-1} FW) in *rabi* sweet corn was found with control (M_0: RDF) during individual years and in pooled.

Iron is essential for the formation of chlorophyll in plants. It also helps to maintain the structural integrity of chloroplasts, which contain chlorophyll. Leaf greenness is a measure of chlorophyll content that is used as an important growth indicator because it determines the plant's photosynthetic activity. Arbuscular mycorrhiza fungi and *P. fluorescens* boost chlorophyll synthesis, resulting in higher concentrations of various metabolites in plants. Mycorrhizal symbiosis increases anthocyanin and chlorophyll accumulation and significantly improves photosynthetic rate and other gas exchange traits (Birhane *et al*., 2012) [3].

2. Sugar content in *rabi* sweet corn

Perusal of data in Table 1 revealed that the iron management treatments applied to earlier *kharif* rice crop had marked influence on sugar content of *rabi* sweet corn. Significantly higher sugar content (19.3, 20.3 and 19.8%) was recorded by application of $FeSO_4$ @ 50 kg ha^{-1} + AM + *P. fluorescens* (P) as seedling treatment (S) and field application (F): 2L ha^{-1} (M_{11}) and it was remained at par with treatments M_2, M_5, M_6, M_7, M_8, M_9 and M_{10} during both the years and treatments M_8, M_9 and M_{10} in pooled study. Treatment (M_0: RDF) resulted in lowest sugar content (17.2, 18.2 and 17.7%) during both the years of study and in pooled analysis, respectively.

Table 1: Residual effect of different iron management treatments on Chlorophyll content and sugar content of *rabi* sweet corn

Treatment	Chlorophyll content (Nano mol mg^{-1} FW)			Sugar content (%)		
	2020	2021	Pooled	2020	2021	Pooled
M_0	1.360	1.333	1.347	17.2	18.2	17.7
M_1	1.548	1.517	1.532	17.5	18.6	18.0
M_2	1.570	1.553	1.561	18.9	19.8	19.3
M_3	1.498	1.480	1.489	17.4	18.4	17.9
M_4	1.549	1.517	1.533	17.4	18.5	17.9
M_5	1.552	1.547	1.549	18.0	19.0	18.5
M_6	1.577	1.560	1.568	18.9	19.9	19.4
M_7	1.613	1.623	1.618	19.0	19.9	19.4
M_8	1.707	1.697	1.702	19.1	20.1	19.6
M_9	1.650	1.670	1.660	19.0	19.9	19.5
M_{10}	1.676	1.677	1.676	19.0	20.0	19.5
M_{11}	1.719	1.730	1.724	19.3	20.3	19.8
S.Em ±	0.03	0.03	0.02	0.19	0.16	0.13
CD (P=0.05)	0.10	0.10	0.07	0.56	0.48	0.36
Y x T						
S.Em ±			0.03			0.179
CD (P=0.05)			NS			NS
CV (%)	3.64	3.81	3.73	1.79	1.47	1.63

Conclusion

On the basis of two years experimental results, it can be concluded that for getting higher chlorophyll content and sugar content in *rabi* sweet corn, the preceding *kharif rice* crop should be nourished with $FeSO_4$ @ 50 kg ha^{-1} + AM Seedling treatment + Field application: 2L ha^{-1} + *P. fluorescens* Seedling treatment + Field application: 2L ha^{-1} and *rabi* sweet corn crop nourished with recommended dose of fertilizer (120:60:60 NPK kg ha^{-1}) in rice-sweet corn cropping sequence under South Gujarat condition.

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