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Effect of micronutrients and STCR based macronutrients on growth, yield and nutrient uptake of hybrid maize

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Abstract
A field experiment was conducted at the Agricultural College and Research Institute, Killikulam, to focus on the effect of various micronutrient methods on growth, yield and nutrient uptake of hybrid maize COH (M) 8 during Summer 2021. The experiment was laid out in Randomized Block Design consisting of 10 treatments and replicated thrice. The treatments included the application of micronutrients in the form of soil and foliar applications of zinc sulphate, ferrous sulphate, soil application of maize maxim and also a micronutrient mixture enriched FYM. The observations that were recorded are growth parameters (plant height, days to 50% tasselling and silking, dry matter production), yield parameters (cob length, cob girth, number of rows per cob, number of grains per row, no of grains per cob, grain yield and stover yield) and nutrient uptake in plants. The results revealed that the application of 1% Zinc and Ferrous sulphate (T_7) has proven to be an effective one in terms of growth, yield parameters, and uptake of nutrients in plants. This treatment produced a higher plant height (287.31 cm), dry matter production (17288 kg ha^{-1}), grain yield and stover yield of 7298 kg ha^{-1} and 9844 kg ha^{-1} respectively and also registered higher nutrient uptake (101.61 kg ha^{-1}, 9.87 kg ha^{-1}, 108.53 kg ha^{-1}) N, P, K respectively.

Keywords: Hybrid maize, STCR, Maize maxim, Nutrient uptake

1. Introduction
Maize (*Zea mays*) ranks third place in the world among the cereals as staple food, was next to rice and wheat. It was renowned as the Queen of cereals and a miracle crop, which was due to its greater productive ability. Maize has been used in various forms of food products, such as corn oil, corn syrup, corn sugar, corn starch, and corn flakes. It is also served as fodder for livestock, and it has greater palatability and had a good choice for hydroponic fodder production.
India occupies the seventh position in maize production. In India, maize accounts for 9.5 m ha, 28.7 m tonnes, and 3006 kg ha^{-1} in the terms of area, production and productivity. In Tamil Nadu it was about 0.3 m ha, 2.4 m tonnes, and 7424 kg ha^{-1} (Indiastat, 2020) [8] respectively.
According to the USDA, 100g of maize grains contains 365 calories, 10.37 g of water, 9.4 g of protein, 4.74 g of total lipid, 74.24 g of carbohydrates, 0.64 g of sugars, iron (2.71 g), and 2.21 mg of zinc. Methionine, a sulphur-based amino acid present in maize, help to repair the injured muscle. Corn oil has the capacity to reduce cardiovascular disease due to its antherogenic effect on cholesterol levels. The fibre content helps in the reduction of digestive problems and prevents constipation (Murdia *et al.*, 2016) [14].
Improper application of fertilisers such as excess or insufficient quantities of any one nutrient created a huge impact on the growth and yield of the crop and also affected the fertility status of the soil. To attain maximum productivity of the crop and to maintain the fertility of the soil, proper balanced nutrition has to be given (Singh *et al.*, 2020) [19]. The Soil Test Crop Response is one of the Integrated Plant Nutrition Systems, which is also known as prescription-based fertiliser recommendations. In this approach, the recommendation was given based on the initial nutrient content of the soil. It helps to attain the targeted yield approach for a particular crop in a particular region based on the soil nutrient status. This method is economically beneficial to the farmers as it improves the yield through efficient nutrient uptake.
The growth, yield and quality of the crop can be influenced considerably by the application of macro and micronutrients. Micronutrients are required not only for the improvement of plant growth and yield, but also to enhance crude protein and fibre content in the plants.

Among the micronutrients (Zn, Fe, Co, Mo, Mn, Cu, Ni), zinc and iron are the essential micronutrients which are responsible for various metabolisms in the plant system. Zinc is mainly involved in the formation of chlorophyll. It triggers the enzyme involved in protein synthesis, carbohydrate formation, helps in the starch to sugar conversion, auxin regulation and its prevalence aids in tolerance of environmental stresses (Hafeez *et al.*, 2013) [7]. Similarly, iron is also required by plants to perform metabolic activities such as synthesis of DNA, respiration, photosynthesis, nitrate and sulphate reduction, and is also responsible for maintaining the structure and function of chloroplasts (Rout and Sahoo 2015) [18].

The yield and quality of the crop have a direct relationship with the level of micronutrients in the soil. If the micronutrient content in the soil was low, the plant's uptake was affected, and it will create deficiency symptoms and finally affect the yield of the crop. About 48.1% of Zn, 11.2% of Fe, 7% of Cu, and 5.1% of manganese were deficient in the soils of India, which was given under the research project of the Indian Institute of Soil Science (Kumar and Salakinkop 2018) [12]. To ameliorate the micronutrient deficiencies and to improve the micronutrient status of the soil, the same has to be enriched by the application of micronutrients in soil and also through foliage. With this background, the present study was conducted to know the impact of STCR based NPK application and soil and foliar application of micronutrients and crop booster on Maize yield and soil status.

2. Materials and Methods

2.1 Experimental site

The experiment was conducted during Summer, 2021 in the Agricultural College and Research Institute, Tami Nadu Agricultural University, Killikulam which is located at a latitude of $8^0$46'N, longitude of $77^0$42'E and 40 m above MSL and was located in the southern region of Tamil Nadu. The soil samples were tested to work out the STCR recommendations. The pH and Electrical Conductivity of the soil were normal with values of 7.2 and 0.13 dS m^{-1} respectively. Soil was low in available nitrogen (235.2 kg ha^{-1}), medium in available phosphorus (14.83 kg ha^{-1}) and potassium (260 kg ha^{-1}). The experimental field was ploughed using a mouldboard plough followed by a rotavator to obtain fine tilth, and it was carefully prepared and freed from weeds. Then the field was divided into plots to impose the treatments. Lastly, with an interspace of 60 cm, ridges and furrows were established in the plots along with irrigation facilities. Fertilizers are applied in the plots as per the recommendations (155:90:56 kg N, P_2O_5, K_2O ha^{-1}) given under Soil Test Crop Response estimated based on the initial soil available N, P, and K values with a target yield 6-8 t ha^{-1}.

2.2 Experimental design and data collection

The experiment was conducted with three replications and ten treatments in a Randomized Block Design with the maize hybrid COH (M) 8. The spacing adopted was 60cm x 25cm and the treatment consisted of STCR-IPNS (T_1), STCR + 37.5 kg $ZnSO_4$ (T_2), STCR + 50 kg $FeSO_4$ (T_3), STCR + 37.5 kg $ZnSO_4$ + 50 kg $FeSO_4$ (T_4), STCR + 30 kg TNAU Micronutrient mixture as enriched FYM (T_5), STCR + Foliar spray of 0.5% $ZnSO_4$ +Foliar spray of 0.5% $FeSO_4$ (T_6), STCR + Foliar spray of 1% $ZnSO_4$ + Foliar spray of 1% $FeSO_4$ (T_7), STCR + Foliar spray of Maize maxim @ 1.5% two times application (T_8), STCR + Foliar spray of Maize maxim @ 1.5% four times application (T_9) and compared with Absolute control (T_{10}).

The data was collected from the five samples in the plot and it was pooled and the mean data arrived. The growth parameters such as plant height, days to attain 50% tasselling and silking, dry matter production and the yield parameters, namely length and girth of the cob, number of rows cob^{-1}, number of grains row^{-1}, number of grains cob^{-1}, grain yield, stover yield and plant nutrient uptake were observed and estimated. The data collected during the study were statistically analysed in accordance with Gomez and Gomez (1984) [6]. The differences in the treatment were noted as significant if the critical difference worked out at the probability level of 5% and presented in tables.

3. Results and Discussion

3.1 Growth parameters

3.1.1 Plant height

Treatments produced significant differences with regard to plant height. The higher plant height (138.14 cm) was observed in T_2 (STCR + 37.5 kg $ZnSO_4$) on 30 DAS but at 60 DAS and at harvest, T_7 (STCR + 1% $ZnSO_4$ + 1% $FeSO_4$) recorded highest plant height of 258.94 cm and 287.31 cm respectively. This was observed to be on par with T_5 (STCR + TNAU Micronutrient mixture enriched FYM @ 30 kg), whereas in control (T_{10}) the height obtained by the plant was 221.36 cm. The increase in plant height during 30 DAS at T_2 was due to the effect of soil applied Zinc at the time of land preparation which involved in the synthesis of IAA and tryptophan responsible for cell enlargement. After 30 DAS the foliar application of Zinc and Ferrous sulphate (T_7) would enhance the activity later and improved height over the soil applied treatment. The result of foliar application was similar to the research findings of Borase *et al.*, (2018) [3] with the height of 181.40 cm in maize. The beneficial effect of micronutrients on crop growth could be related to fast cell division and cell elongation. Similar report was given by Choudhary *et al.*, (2015) [4] with the height 277.4 cm. The plant height was improved due to the enhancement of photosynthetic rate and more nutrients obtained by the plants which was because of the combined foliar application of zinc and iron which was obtained by Asif *et al.*, (2020) [1].

3.1.2 Days to attain 50% tasselling and silking

The number of days taken to attain 50% tasselling was much earlier (53.3 days) in the treatment T_7 (STCR + 1% $ZnSO_4$ + 1% $FeSO_4$) and silking was attained in 61.0 days, which was followed by T_5 (STCR + 30 kg TNAU Micronutrient enriched FYM). It took up to 56.5 and 64.3 days to achieve 50% of tasselling and silking in the control plot (T_{10}). The days to attain tasselling and silking could be determined by the photosynthetic build up in the plants due to the effect of micronutrient application. Similar report was given by Jolli *et al.*, (2020) [9].

3.1.3 Dry Matter Production

Significant differences were attained among the treatments with respect to the dry matter production. The maximum dry matter production was obtained in the treatment T_7 (STCR + 1% $ZnSO_4$ + 1% $FeSO_4$) that produced 17288 kg ha^{-1}, which was found to be on par with T_5 (STCR + 30 kg TNAU micronutrient enriched FYM) with 16995 kg ha^{-1}. Lowest dry matter accumulation was accounted in Control (T_{10}) that produced 9866 kg ha^{-1}. The increase in DMP was correlated with the micronutrient application, which would have enhanced the synthesis of auxin in plants by the application of $ZnSO_4$, $FeSO_4$ and Boron @ 0.5%, 1% and 0.2% respectively. The higher leaf area in plants would contribute to the increased availability of nutrients and enhanced the growth of the crop by the activity of photosynthesis, and the supplementation of carbohydrates in the maize crop (Parasuraman 2008) [16].

3.2 Yield parameters

3.2.1 Cob length and girth

In terms of length of the cob, maximum was attained in the treatment T_7 (STCR + 1% $ZnSO_4$ + 1% $FeSO_4$) with the length of 24.53 cm and the lowest length (14.63) was found in the control plot. The cob girth was higher in the treatment T_7 (STCR + 1% $ZnSO_4$ + 1% $FeSO_4$), with a value of 18.15 cm, whereas the lowest cob girth was attained in the control plot with a value of 13.93 cm. The varied length and girth of the cob was correlated with the combined application of zinc and iron which are actively engaged in the source sink relationship by transferring the photosynthates. Similar report was given by Priya *et al.,* (2020) [17].

3.2.2 Number of rows cob^{-1}

The maximum number of rows per cob was found in the plot treated with STCR + 1% $ZnSO_4$ + 1% $FeSO_4$ (T_7) by recording 14.31 rows cob^{-1}, which was on par with T_5 (STCR + 30 kg TNAU Micronutrient mixture enriched FYM) with14.11 rows cob^{-1}. In the control plot (T_{10}) the lowest number of rows was found with a value of 10.86.

3.2.3 Number of grains row^{-1}

The highest number of grains row^{-1} (29.15) was achieved in the treatment T_7 (STCR + 1% $ZnSO_4$ + 1% $FeSO_4$) and it was on par with (T_5). Meanwhile, the lowest number of grains per row^{-1} was found in the control plot (T_{10}) with a value of (21.16).

3.2.4 Number of grains cob^{-1}

The application of STCR + 1% $ZnSO_4$ + 1% $FeSO_4$ (T_7) has greatly influenced and recorded the highest number of grains cob^{-1} (417) and it found was on par with T_5 (STCR + 30 kg TNAU Micronutrient mixture enriched FYM) with (409). At the same time, the control plot T_{10} achieved the least number with a value of 230 grains per cob. A similar report was given by Krishnaraj *et al.,* (2020) [11] by reporting a maximum number of grains cob^{-1} in hybrid maize. The yield attributes viz., number of rows cob^{-1}, number of grains row^{-1} and number of grains cob^{-1} were increased by the photosynthate translocation which was due to the foliar application of Zinc and Iron. Similar report was given by Naveenaa *et al.,* (2018) [15].

3.2.5 Grain yield

Maximum grain yield was achieved in the treatment T_7 (STCR + 1% $ZnSO_4$ + 1% $FeSO_4$) with a quantity of 7298 kg ha^{-1}, which was significantly on par with T_5 (STCR + 30 kg Micronutrient mixture enriched FYM) with 7149 kg ha^{-1}. The control plot (T_{10}) has produced the lowest grain yield of 3513 kg ha^{-1}. The increase in no of row cob^{-1}, no of grains row^{-1}, no of grains cob^{-1} have significantly improved the yield of the crop. The significance of zinc and iron in numerous physiological processes, as well as improvements in growth components, may explain the rise in yield owing to their application, improved glucose partitioning from leaf to reproductive regions, resulting in enhanced yield. Similar results were reported by Manasa and Devaranavadagi (2015) [13].

3.2.6 Stover yield

The highest stover yield (9844 kg ha^{-1}) was obtained in the treatment T_7 (STCR + 1% $ZnSO_4$ + 1% $FeSO_4$) and the treatment T_5 (STCR + 30 kg Micronutrient mixture enriched FYM) was found on par by attaining the yield of 9690 kg ha^{-1}. With regard to the lowest yield, the control plot (T_{10}) achieved it by producing 6295 kg ha^{-1}. The increased stover yield was positively correlated with the parameters of plant height, leaf area, and dry matter production. The foliar application of zinc and iron improved the stover yield, according to the findings of (Karrimi *et al.,* 2017) [10].

3.3 Nutrient uptake in plants

The differential performance of the treatments was well reflected in the N, P, K uptake by plants. Higher N, P, K uptake was attained by the treatment T_7 (STCR + 1% $ZnSO_4$ + 1% $FeSO_4$). The N, P, and K uptake in this treatment was 224.74 kg, 51.86 kg, and 231.66 kg, respectively, while the control plot had the lowest range of N, P, and K uptake with values of 101.61 kg, 9.87 kg, and 108.53 kg ha^{-1}. Similar report was also documented by Augustine and Kalyanasundaram (2021) [2] in maize. The application of $ZnSO_4$ and $FeSO_4$ would enhance the nutrient uptake in plants by the mobilization of native nutrients present in the soil. Same report was revealed by Daphade *et al.,* (2018) [5].

Table 1: Effect of micronutrients and STCR based macronutrients on maize plant height (cm)

Treatments	30 DAS	60 DAS	90 DAS
T_1- STCR – IPNS	102.5	205.19	235.69
T_2- STCR + 37.5 kg $ZnSO_4$	138.14	220.6	254.1
T_3- STCR + 50 kg $FeSO_4$	125.39	216.83	243.38
T_4- STCR + 37.5 kg $ZnSO_4$ + 50 kg $FeSO_4$	128.64	227.2	258.72
T_5- STCR + 30 kg TNAU Micronutrient mixture as enriched FYM	131.29	249.38	280.19
T_6- STCR + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$	117.63	237.15	269.53
T_7 – STCR + 1% $ZnSO_4$ + 1% $FeSO_4$	122.61	258.94	287.31
T_8- STCR + Maize maxim @ 1.5% two times application	120.15	240.61	276.81
T_9- STCR + Maize maxim @ 1.5% four times application	110.81	231.91	263.60
T_{10}- Absolute control	91.31	187.46	221.36
SEd	4.10	6.86	11.25
CD (p= 0.05)	8.61	14.41	23.64

Table 2: Effect of micronutrients and STCR base macronutrients on 50% tasseling and silking, dry matter production

Treatments	50% tasseling (days)	50% silking (days)	Dry Matter Production (kg ha^{-1})		
			30 DAS	60 DAS	90 DAS
T_1- STCR – IPNS	55.9	63.9	1964	8838	13921
T_2- STCR + 37.5 kg $ZnSO_4$	55.2	63.1	2652	9812	15136
T_3- STCR + 50 kg $FeSO_4$	55.4	63.6	2497	9336	14638
T_4- STCR + 37.5 kg $ZnSO_4$ + 50 kg $FeSO_4$	54.9	63.0	2744	10148	15491
T_5- STCR + 30 kg TNAU Micronutrient mixture as enriched FYM	54.0	61.6	3045	10900	16995
T_6- STCR + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$	54.3	62.4	2952	10493	16383
T_7 – STCR + 1% $ZnSO_4$ + 1% $FeSO_4$	53.3	61.0	3136	11124	17288
T_8- STCR + Maize maxim @ 1.5% two times application	54.2	62.2	2964	10673	16656
T_9- STCR + Maize maxim @ 1.5% four times application	54.6	62.7	2907	10374	16020
T_{10}- Absolute control	56.5	64.3	1402	6447	9866
S.Ed	1.21	1.14	124.05	238.66	510.17
CD (p= 0.05)	NS	NS	260.62	837.38	1071.84

Table 3: Effect of micronutrients and STCR based macronutrients on maize yield attributes

Treatments	Cob length (cm)	Cob girth (cm)	No of rows cob^{-1}	No of grains row^{-1}	No of grains cob^{-1}
T_1- STCR – IPNS	20.79	15.73	12.43	27.18	338
T_2- STCR + 37.5 kg $ZnSO_4$	21.41	16.21	13.24	27.45	363
T_3- STCR + 50 kg $FeSO_4$	21.05	16.14	12.9	27.36	353
T_4- STCR + 37.5 kg $ZnSO_4$ + 50 kg $FeSO_4$	21.81	16.51	13.3	27.76	369
T_5- STCR + 30 kg TNAU Micronutrient mixture as enriched FYM	24.09	17.83	14.11	29.00	409
T_6- STCR + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$	23.02	17.15	13.69	28.63	392
T_7 – STCR + 1% $ZnSO_4$ + 1% $FeSO_4$	24.53	18.15	14.31	29.15	417
T_8- STCR + Maize maxim @ 1.5% two times application	23.72	17.36	13.98	28.84	403
T_9- STCR + Maize maxim @ 1.5% four times application	22.65	16.53	13.45	27.98	376
T_{10}- Absolute control	14.63	13.93	10.86	21.16	230
S.Ed	0.92	0.91	0.77	0.84	10.51
CD (p= 0.05)	1.92	1.92	1.61	1.76	22.08

Table 4: Effect of micronutrients and STCR based macronutrients on maize yield

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1- STCR – IPNS	5786	8099
T_2- STCR + 37.5 kg $ZnSO_4$	6317	8759
T_3- STCR + 50 kg $FeSO_4$	6106	8489
T_4- STCR + 37.5 kg $ZnSO_4$ + 50 kg $FeSO_4$	6450	8893
T_5- STCR + 30 kg TNAU Micronutrient mixture as enriched FYM	7149	9690
T_6- STCR + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$	6838	9361
T_7 – STCR + 1% $ZnSO_4$ + 1% $FeSO_4$	7298	9844
T_8- STCR + Maize maxim @ 1.5% two times application	6998	9524
T_9- STCR + Maize maxim @ 1.5% four times application	6720	9224
T_{10}- Absolute control	3513	6295
S.Ed	279.03	362.73
CD (p= 0.05)	586.22	762.08

Table 5: Effect of micronutrients and STCR based macronutrients on nutrient uptake in plants

Treatments	Plant nutrient uptake (kg ha^{-1})		
	N	P	K
T_1- STCR – IPNS	146.17	29.03	161.48
T_2- STCR + 37.5 kg $ZnSO_4$	160.44	30.27	180.12
T_3- STCR + 50 kg $FeSO_4$	155.16	29.33	169.80
T_4- STCR + 37.5 kg $ZnSO_4$ + 50 kg $FeSO_4$	165.75	32.53	190.53
T_5- STCR + 30 kg TNAU Micronutrient mixture as enriched FYM	220.93	47.58	222.63
T_6- STCR + 0.5% $ZnSO_4$ + 0.5% $FeSO_4$	190.04	39.32	212.98
T_7 – STCR + 1% $ZnSO_4$ + 1% $FeSO_4$	224.74	51.86	231.66
T_8- STCR + Maize maxim @ 1.5% two times application	199.87	43.31	216.53
T_9- STCR + Maize maxim @ 1.5% four times application	176.22	36.85	205.06
T_{10}- Absolute control	101.61	9.87	108.53
S.Ed	5.56	1.63	5.74
CD (p= 0.05)	11.69	3.43	12.06

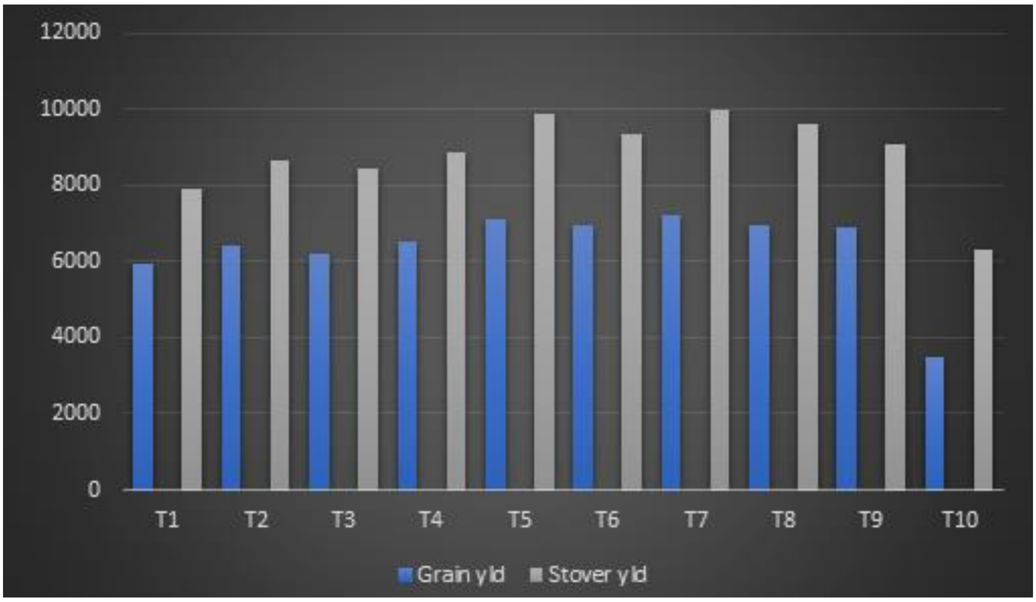

Fig 1: Effect of various treatments on yield of hybrid maize

4. Conclusion

It is revealed that the application of foliar spray of $ZnSO_4$ and $FeSO_4$ @ 1% together with balanced STCR based fertilisation has shown a better response in hybrid maize in terms of growth parameters, yield and yield attributes, and also the efficient uptake of nutrients in plants.

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