Agronomic Biofortification through Integrated Nutrient Management on Maize (*Zea mays* L.) Hybrids

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10.18805/ag.D-5457

Abstract

Background: Supplement of balanced nutrition is required for the growth and development of crops and humans, particularly essential amino acids, vitamins and minerals. The application of mineral micronutrient fertilizers to soil or plant leaves to increase micronutrient content in edible parts of crop. Therefore, this study is focused to evaluate the effect of agronomic biofortification with different nutrient levels on maize.

Methods: A field experiment was conducted on sandy clayey loam soil during the *Rabi* season of 2020-21 Perambalur, Tamil Nadu to study the effect of agronomic biofortification through integrated nutrient management for improving maize (*Zea mays* L.) yield and quality under Cauvery delta condition. Two hybrids in main-plots both, QPM and non-QPM were sown by direct method on ridges at a spacing of 60 × 20 cm under split plot design (SPD) with 6 treatments of nutrient management in sub-plot combination under three replications.

Result: The results revealed that the nutrient level treatments containing 50% RDF through NPK + 50% RDF through FYM with Fe and Zn as foliar application @ 0.5% conc led to highest growth and yield attributes, grain yield (8.52 t ha^{-1}) and stover yield (10.35 t ha^{-1}) and also resulted in maximum crude protein content (14.93%), starch content (63.85 mg g^{-1}), Fe (36.25 mg kg^{-1}) and Zn (29.35 mg kg^{-1}) in maize grain. It was observed that agronomic biofortification through integrated nutrient management enhanced the vegetative growth and yield components of non-QPM hybrid, whereas it improved the grain quality content of the QPM hybrid.

Key words: Farmyard manure, Foliar, Grain, Iron, Maize, Yield, Zinc.

Introduction

Maize (*Zea mays* L.) is very popular due to its diverse functionality as a food source for humans and animals. In recent years, intensive cropping, imbalanced fertilization, changes in soil and climatic conditions have exacerbated deficiencies of micronutrients, especially Zn and Fe, in the soil-plant systems in many countries, thereby threatening human nutrition.

Recently escalated calls emerged towards micronutrient deficiency that greatly disturbs plant yield, quality and the health of domestic animals and humans. Iron (Fe) and zinc (Zn) are two heavy metal micronutrients playing vital roles in plants. Although present in soil, their availability to plant roots is limited because of complicated soil processes and conditions. By supplying plants with micronutrients, foliar spray improved yield, quality and macronutrient efficiency by 50%, besides higher absorption rate and cure deficiency symptoms. This can also be an effective method in biofortification in food crops. Micronutrient deficiencies are particularly prevalent in the rural population, where they mainly rely on a cereal-based diet as a staple food. The challenge, therefore, is to deliver nutritious, safe and affordable food to reduce the impact of nutritional insecurity. It is therefore of great interest to improve Fe and Zn nutrition in maize grains through soil-crop system management to improve food security and provide human health benefits.

As an alternative, agronomic biofortification, which consists of increasing the accumulation of target nutrients in edible plant tissues through fertilization, has been increasingly proposed in recent years as a simpler, short term approach to develop functional staple crops and address micronutrient deficiency.

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How to cite this article: Augustine, R., Imayavaramban, V. (2022). Agronomic Biofortification through Integrated Nutrient Management on Maize (*Zea mays* L.) Hybrids. Agricultural Science Digest. 42(2): 187-191. DOI: 10.18805/ag.D-5457.

Submitted: 20-07-2021 **Accepted:** 29-10-2021 **Online:** 01-12-2021

The objective of this research was to evaluate the influence of agronomic biofortification through integrated nutrient management on maize hybrids under cauvery delta condition. The results from these experiments will be useful for providing guidance on agronomic practices aimed at improving the Fe and Zn nutritional qualities in maize grains in the field, thereby providing health benefits to humans.

Materials and Methods

A field experiment was conducted on sandy clayey loam soil during *rabi* season 2020-2021 at ICAR-KVK Farm, Hans Roever campus, Perambalur, Tamil Nadu, India (11.3°N, 78.9°E at an altitude of 124 meters above mean sea level). During the crop growing period, maximum and minimum temperatures were 33.4°C and 16.4°C. The total rainfall received during the crop growing period was 683.3 mm.

The soil of the experimental field was alkaline pH (8.3), medium electrical conductivity (0.37 dSm^{-1}), low available N (235.2 kg ha^{-1}), medium available P (12.7 kg ha^{-1}) and medium available K (148.2 kg ha^{-1}). Maize QPM hybrid obtained from CIMMYT, Hyderabad and non-QPM (NK6668) was sown directly at a spacing of 60 cm × 20 cm under split-plot design (SPD) with 2 hybrids comprising of M_1: Non-QPM, M_2: QPM, as main plot and 6 nutrient level treatments (three replications each) comprising of S_1: 100% RDF through NPK, S_2: 100% RDF through FYM, S_3: 50% RDF through NPK + 50% RDF through FYM, S_4: S_1 + Iron and Zinc as foliar application @0.5% conc, S_5: S_2 + Iron and Zinc as foliar application @0.5% conc, S_6: S_3 + Iron and Zinc as foliar application @0.5% conc., as sub-plots.

The recommended dose of nutrients for maize hybrids (both QPM and non-QPM) was 150 kg nitrogen, 75 kg phosphorus and 75 kg potassium per hectare. The full amount of P_2O_5 and K_2O were applied as basal dose along with 50 per cent N and the remaining 50 per cent was top-dressed after 25 and 45 days after sowing (DAS). The N, P and K concentrations in organic manure used were 0.60, 0.20 and 0.50% in farmyard manure (FYM) and the required quantity as per the treatments was applied in the field before the last tillage operation on a dry weight basis. The net plot size was 5 m × 4 m. Ridges and furrows were formed at 60 cm intervals with bullock-drawn ridge former and rectification were done manually. Foliar application of 0.5 per cent $FeSo_4$ and $ZnSo_4$ as per treatments was done twice at active vegetative (45 days) and reproductive stage or grain filling stage (90 days), respectively with the help of a knapsack sprayer. All other standard agronomic practices were followed as per the schedule.

The growth and yield attribute parameters were collected at harvest from randomly selected 10 plants. Grain and stover yield were recorded in kg ha^{-1}. The crude protein (%), starch (mg g^{-1}), Fe and Zn content in maize grain were recorded in mg kg^{-1}.

The data were subjected to analysis of variance technique as per the statistical procedure and the treatment means were compared at 5% level of significance.

RESULTS AND DISCUSSION

Growth attributes

The data on growth attributes are presented in Table 1. It showed that the maximum plant height at harvest was

Table 1: Effect of agronomic biofortification through integrated nutrient management on growth and yield attributes of maize (*Zea mays* L.).

Treatments	Plant height at harvest (cm)	LAI	DMP (kg ha^{-1})	Days to 50% tasseling	Days to 50% silking	Cob length (cm)	Cob girth (cm)	No. of grains row^{-1}	No. of rows cob^{-1}	Cob wt. (g)
Hybrid										
M_1- Non-QPM	220.25	5.03	14251.67	56.45	62.67	18.87	15.33	35.00	14.88	306.83
M_2- QPM	214.85	5.02	13893.83	57.53	64.72	18.43	14.65	34.15	14.27	270.06
SEd	0.65	1.47	33.00	0.07	0.07	0.52	0.10	0.20	0.10	0.33
CD (P=0.05)	2.81	NS	141.99	0.29	0.29	NS	0.43	NS	0.43	1.43
Nutrient levels										
S_1- 100% RDF through NPK	219.10	5.35	14202.50	56.50	63.00	18.95	15.30	35.25	14.85	290.50
S_2- 100% RDF through FYM	208.50	3.52	13462.50	59.15	66.25	17.10	13.20	31.10	12.85	278.50
S_3- 50% RDF through NPK + 50% RDF through FYM	222.55	5.55	14310.00	56.90	63.60	18.35	14.75	34.60	14.30	286.50
S_4- S_1 + Iron and Zinc as foliar application @0.5% conc	215.25	5.15	14030.00	55.93	62.42	19.55	15.70	35.80	15.45	293.50
S_5- S_2 + Iron and Zinc as foliar application @0.5% conc	212.75	4.85	13902.50	58.00	65.10	17.95	14.55	33.75	13.65	283.00
S_6- S_3 + Iron and Zinc as foliar application @0.5% conc	227.15	5.75	14529.00	55.45	61.80	20.00	16.45	36.95	16.35	298.67
SEd	0.59	0.85	19.05	0.04	0.04	0.30	0.10	0.12	0.06	0.19
CD (P=0.05)	1.24	1.77	39.74	0.08	0.08	0.63	0.22	0.24	0.12	0.40
Interaction										
M × S										
SEd	0.39	0.57	12.90	0.03	0.03	0.20	0.07	0.08	0.04	0.13
CD (P=0.05)	0.88	1.41	31.67	0.06	0.06	0.50	0.15	0.19	0.10	0.32
S × M										
SEd	0.42	0.60	13.47	0.03	0.03	0.21	0.07	0.08	0.04	0.14
CD (P=0.05)	0.87	1.25	28.10	0.06	0.06	0.44	0.15	0.17	0.09	0.28

LAI-leaf area index; DMP- Dry matter production; QPM- Quality protein maize; NPK- Nitrogen, phosphorus, potassium; FYM- Farm yard manure.

observed with the nutrient level treatment S_6 in which 50 percent RDF through NPK + 50 percent RDF through FYM with Fe and Zn foliar application @0.5% Conc., helps to increase by 3.67% and 8.94% of plant height from S_1 and S_2 but statistically it was unaffected with all nutrient levels. Among all treatments, maximum LAI was observed with S_6 was significantly higher than all other nutrient levels as 7.47% from S_1, 63.35% from S_2, 3.60% from S_3, 11.65% from S_4 and 18.55% from S_5.

The data revealed that among all nutrient levels higher DMP was observed under S_6 was significantly higher from all nutrient levels as 2.30% from S_1, 7.92% from S_2, 1.53% from S_3, 3.55% from S_4 and 4.50% from S_5. Better utilization of N with Fe and Zn spraying enabled the leaf area duration to extend and provided an opportunity for the plants to increase the photosynthetic rate leading to the higher accumulation of dry matter. Results were agreed with the study of Prasad and Naik (2013).

The data revealed that among all nutrient levels early days were evident under S_6 with lower days taken to tasselling from all other nutrient levels as 1.85% from S_1, 6.25% from S_2, 2.50% from S_3, 0.85% from S_4 and 4.39% from S_5. The data showed that earlier days of silking were observed under S_6 with lower days taken to silking from all other nutrient levels as 1.90% from S_1, 6.71% from S_2, 2.83% from S_3, 0.99% from S_4 and 5.06% from S_5.

Yield attributes

The data on yield attributes was presented in Table 1. It showed that among all the nutrient level treatments, the maximum cob length was recorded with S_6 which was statistically higher than all other nutrient level treatments as 5.54% from S_1, 16.95% from S_2, 8.99% from S_3, 2.30% from S_4 and 11.42% from S_5.

The maximum cob girth was recorded from S_6 which was significantly higher among all nutrient level treatments as 7.51% from S_1, 24.60% from S_2, 11.52% from S_3, 4.77% from S_4 and 13.05% from S_5.

The data showed that among all nutrient level treatment, maximum grains row^{-1} was observed with S_6 which was significantly higher than all other nutrient level treatments as 4.82% from S_1, 18.80% from S_2, 6.79% from S_3, 3.21% from S_4 and 9.48% from S_5. An increase in the number of grains row^{-1} is attributed to the genetic potential of hybrids takes most advantage to withstand higher densities, availability of nitrogen and other nutrients from organic source with the presence of micronutrient fertilizers required for plant development up to cob formation. This corroborated the findings of Ahmad *et al.* (2017).

The data presented revealed that among all nutrient level treatments the maximum number of rows cob^{-1} was observed under S_6 which was significantly higher than all other treatments as 10.10% from S_1, 27.23% from S_2, 14.33% from S_3, 5.82% from S_4 and 19.78% from S_5.

The maximum cob weight was found from S_6 which was significantly higher among all nutrient level treatments as 2.81% from S_1, 7.24% from S_2, 4.24% from S_3, 1.76% from S_4 and 5.50% from S_5. It is prevalent, that cob may store the highest amount of food from green parts of plants which causes the increased weight of cob. The results were also in agreement with the findings of Maidul Hasan *et al.* (2018).

The interactions of non-QPM hybrid with S_6 nutrient level had a significant (P= 0.05) effect on plant height, leaf area index, dry matter production, days taken to 50% tasselling and days to 50% silking, cob length, cob girth, no. of grains row^{-1}, no. of rows cob^{-1} and cob weight.

Yield

The data on yield components are given in Table 2. The highest shelling % were recorded under S_6 was significantly higher than all nutrient level treatments as 4.88% from S_1, 8.86% from S_2, 7.21% from S_3, 2.89% from S_4 and 8.11% from S_5.

The data proved that the maximum test weight was observed with the nutrient level treatment S_6 in which 50 percent RDF through NPK + 50 per cent RDF through FYM with Fe and Zn foliar application @ 0.5% Conc., contributes to an increase by 7.86% from S_1, 16.68% from S_2, 11.72% from S_3, 4.69% from S_4 and 14.06% from S_5. An increase in seed weight might also be due to the synergistic effects of combined fertilizers for better growth and grain filling of maize. This was in agreement with the finding of Admas *et al.* (2015).

The data represented that among all the treatments, the maximum grain yield was recorded with S_6 which was statistically higher than all other nutrient level treatments as 2.89% from S_1, 7.30% from S_2, 2.28% from S_3, 4.28% from S_4 and 5.57% from S_5. The mineral (Fe and Zn) foliar nutrition enhanced plant growth, total dry matter production and chlorophyll content as a result of better uptake of Zn and Fe and their translocation to reproductive parts. Such favorable crop growth enhanced the yield attributes and increased the yield ultimately (Kumar and Salakinkop, 2018).

The maximum stover yield was recorded from S_6 which was statistically higher among all other nutrient level treatments as 0.87% from S_1, 5.07% from S_2, 0.68% from S_3, 1.27% from S_4 and 2.67% from S_5. The increase in stover yield is due to adequate biomass production and better nutrient uptake. These results corroborated with the findings of Naveed *et al.* (2018).

Grain quality

The data on quality components are given in Table 2. It showed that among all nutrient level treatments, maximum crude protein content was obtained from S_6. Results showed that S_6 was statistically higher at 33.30% from S_1, 40.18% from S_2, 28.15% from S_3, 5.14% from S_4 and 7.79% from S_5. The maximum crude protein percent was significant with combined treatments is due to the congenial and favorable environment with the extended benefit of biochemical relations (*i.e.*, respiration, photosynthesis and chlorophyll content) in the plants.

The analysis of data revealed that among all nutrient level treatments, maximum starch content in maize grain was obtained from S_6. Results noted that S_6 was statistically

Table 2: Effect of agronomic biofortification through integrated nutrient management on grain yield and quality of maize (*Zea mays* L.).

Treatments	Shelling (%)	Test weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Crude protein (%)	Starch (mg g^{-1})	Fe (mg kg^{-1})	Zn (mg kg^{-1})
Hybrid								
M_1- Non-QPM	80.63	24.75	8.75	10.41	10.53	60.95	28.57	23.13
M_2- QPM	78.14	21.12	7.70	9.99	14.96	63.29	29.79	23.95
SEd	0.05	0.33	9.51	0.88	0.17	0.33	0.07	0.10
CD (P=0.05)	0.21	1.43	4.09	0.37	0.72	1.43	0.29	0.43
Nutrient levels								
S_1- 100% RDF through NPK	79.65	23.15	8.28	10.26	11.20	60.25	23.55	19.25
S_2- 100% RDF through FYM	76.74	21.40	7.94	9.85	10.65	59.30	21.10	17.25
S_3- 50% RDF through NPK + 50% RDF through FYM	77.92	22.35	8.33	10.28	11.65	61.20	24.75	19.95
S_4- S_1 + Iron and Zinc as foliar application @0.5% conc	81.19	23.85	8.17	10.22	14.20	63.70	35.20	28.15
S_5- S_2 + Iron and Zinc as foliar application @0.5% conc	77.27	21.90	8.07	10.08	13.85	62.85	34.22	27.30
S_6- S_3 + Iron and Zinc as foliar application @0.5% conc	83.54	24.97	8.52	10.35	14.93	65.42	36.25	29.35
SEd	0.02	0.19	5.49	0.73	0.10	0.19	0.04	0.06
CD (P=0.05)	0.04	0.40	1.14	0.15	0.20	0.40	0.08	0.12
Interaction								
M × S								
SEd	0.01	0.13	3.72	0.48	0.07	0.13	0.03	0.04
CD (P=0.05)	0.04	0.32	0.91	0.11	0.16	0.32	0.06	0.10
S × M								
SEd	0.01	0.14	3.88	0.51	0.07	0.14	0.03	0.04
CD (P=0.05)	0.03	0.28	0.81	0.10	0.14	0.28	0.06	0.09

Fe - Iron; Zn - Zinc; QPM - Quality protein maize; NPK - Nitrogen, phosphorus, potassium; FYM- Farm yard manure.

higher as 8.58% from S_1, 10.32% from S_2, 6.89% from S_3, 2.70% from S_4 and 4.08% from S_5. The production factors which improved the grain yield also improved the starch content of the grain.

The data revealed that among all the nutrient level treatments, maximum iron content was obtained from S_6. Results showed that S_6 was statistically higher as 53.92% from S_1, 71.80% from S_2, 46.46% from S_3, 2.98% from S_4 and 5.93% from S_5. Foliar Zn spraying facilitated the transport of endogenous Fe, simultaneously improved the concentrations and bioavailability of Zn and Fe in maize grains. Lower kernel Fe and Zn concentration in non-biofortified hybrids was reported as compared to biofortified hybrids. Similar findings were reported by Chakraborti *et al.* (2009).

The data regarding zinc content in (mg kg^{-1}) maize grain showed that the maximum zinc content was obtained from S_6. Results showed that S_6 was statistically higher as 52.46% from S_1, 70.14% from S_2, 47.11% from S_3, 4.26% from S_4 and 7.50% from S_5. An increase in Zn concentration in maize grain is positively correlated with grain yield, test weight, cob diameter and cob length. These results corroborated with the findings of Sadiq Naveed *et al.* (2018).

The interactions of QPM hybrid with S_6 nutrient level had a significant (P= 0.05) effect on shelling %, test weight, grain yield, stover yield, crude protein, starch, Fe and Zn content in maize grain.

CONCLUSION

The findings of the present investigation revealed that among different nutrient level treatments, 50% RDF through NPK + 50% RDF through FYM with Fe and Zn foliar application @0.5% Conc., (S_6) registered the maximum highest growth attributes and yield components with non-QPM hybrid and highest in grain quality parameters with QPM hybrid. It can be recommended to farmers that agronomic biofortification with INM, achieves more benefit from maize hybrids during *rabi* season under cauvery delta condition.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the advice and guidance provided by Dean (Agriculture) and Research Advisory Council members, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India.

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