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Influence of Agronomic biofortification on Maize

Augustine Rajendran[1,a,*], Imayavaramban Veeramani[1,b]

[1]Department of Agronomy, Faculty of Agriculture, Annamalai University, Chidambaram – 608002. India
[*]Corresponding author

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ABSTRACT

An experiment was carried out at the ICAR-KVK Research farm, HansRoever Campus, Perambalur, Tamil Nadu, India during the *Kharif* season (July to October), 2020 to study the effect of agronomic biofortification through integrated nutrient management on hybrid maize (biofortified and non-biofortified). The experiment was laid out in Split Plot Design having 36 treatment combinations of hybrids and nutrients and replicated thrice. The treatment sources consisted of two main plots of maize hybrids (M_1: Non-biofortified and M_2: biofortified), and six sub-plots of nutrients (S_1: 100 % Recommended Dose of Fertilizer RDF through Nitrogen, Phosphorus, Potassium, S_2: 100 % RDF through Farm Yard Manure, 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.). The recommended dose of fertilizer was NPK 150:75:75 kg ha^{-1}. Application of 50% RDF through NPK + 50% RDF through FYM with Fe and Zn as foliar application @0.5% conc (S_6) at 45 (active vegetative stage) and 90 (grain filling stage) days after sowing, significantly increased all the growth and yield attributes, grain and stover yield, quality attributes and nutrient uptake by maize. Among the nutrient levels, higher grain yield (8.2 t ha^{-1}) and stover yield (10.16 t ha^{-1}), quality attributes, and nutrient uptake were recorded with the application of 50% RDF through NPK + 50% RDF through FYM with Fe and Zn as foliar application @0.5% conc (S_6). Similarly, significant net return (INR 78,767) and benefit cost ratio (3.07) were noted with the application of 100% RDF through NPK (S_1) followed by 50% RDF through NPK + 50% RDF through FYM with Fe and Zn as foliar application @0.5% conc (S_6). Hence, integrated nutrient management with agronomic biofortification @0.5% conc., at 45th and 90th DAS should be adopted to obtain maximum grain yield, net profit, and nutrient uptake by *Kharif* maize.

[a] *augustinerajendran@gmail.com* *http://orcid.org/0000-0001-9635-5153* | [b] *hdagronomyau@gmail.com* *https://orcid.org/0000-0002-8586-4830*

Introduction

An estimated two billion people are affected by an unbalanced proportion of micronutrients called "micronutrient malnutrition" or "hidden hunger" (Steur et al., 2015). The problem of micronutrient deficiencies is widespread in developing and under-developed countries, where they mainly depend on cereal-based diets as a staple food (Korkmaz et al., 2021). India estimated that 15.2 percent of people are undernourished (Global food policy report, 2016).

There was a need to deliver nutritious, safe, and affordable food to the population, reducing nutritional insecurity. Interventions like an industrial-food fortification, supplementation, and dietary diversification have tried to mitigate micronutrient deficiencies worldwide. None of these were found viable due to ineffective distribution and non-affordability (Tanumihardjo et al., 2007). On the other hand, the development of mineral-enriched staple foods through breeding and agronomic approaches gained significance through the process known as "biofortification," which holds promise for cost-effective and sustainable dietary solutions combat micronutrient deficiencies (Pfeiffer and McClafferty, 2007).

Maize is an important cereal crop of India for a larger section of populations, raw material for industries, and feed for animals and plays a major role in the agro-based economy (Ibrikci et al., 2009). Unfortunately, normal maize has significant flaws in nutritional quality; it lacks a full range of amino acids, namely lysine and tryptophan causing major threats to nutritional security. Biofortified maize produces 70-100% more essential amino acids (lysine and tryptophan) than the most modern varieties of tropical maize (Augustine and Kalyanasundaram, 2020).

In this context growing biofortified maize hybrid with high lysine and tryptophan will play a pivotal role in eliminating protein-calorie malnutrition (Jat et al., 2013). Genotypes with denser grains are developed and need to be adequately fertilized with iron and zinc. Nutrient management plays a key role in sustaining the productivity of this system, as maize crop requires higher level fertilization.

Agronomic biofortification is one such unique practice done through fertilization with nutrients and has been extensively used in maize with supplemental foliar spray to increase the grain's high concentrations of nutrients. Even though this practice is common in crops, spraying minerals at the appropriate time during plant growth turns to an efficient nutritional starter/gainer in plant parts which helps in direct nutritional support to the human population and animals, etc. **(**Monika Garg et al., 2018). In this scenario, Agronomic biofortification – using INM is advocated as a viable approach for maintaining and sustaining proper plant growth and productivity and providing crop stability during production **(**Muhammad Sarwar et al., 2012). Biofortification recovery, the term suggests that foliar application was about eight times higher than obtained from soil application (Impa and Johnson-Beebout, 2012). The foliar application implies that nutrients applied will be absorbed by the leaf (point of application) to the growing tissues (point of utilization), and the export of nutrients from leaves transport downwards exclusively to the phloem (Rengel et al., 1999). Furthermore, Guleria et al. (2013) highlighted the potential of kernel Fe and Zn concentrations in grain, which are significantly influenced by soil type, soil fertility, soil moisture, and interactions among nutrients. The characteristics and importance of this Agronomic biofortification (Fe and Zn foliar application) for the maize-production chain justifies the need to evaluate performance in association with INM and biofortified hybrids.

Materials and Methods

A field experiment was conducted at ICAR-KVK farm, Hans Roever campus, Perambalur district, Tamil Nadu state, India during the period from July 2020 to October 2020 (*Kharif* season) to study the productivity, profitability, and uptake of maize hybrids. The experiment was laid out in split-plot design (SPD) with twelve treatment combinations of two hybrids (H) NK6668 (M_1) as non-biofortified maize hybrid from Syngenta and VH 133545 (M_2) as biofortified maize hybrid obtained from CIMMYT, Hyderabad in main plots and six nutrient (N) levels in sub-plots with three replications. Hybrids of non-biofortified (M_1-NK6668) a prolific yielder and biofortified (M_2-CIMMYT hybrid) were tested. The six nutrient levels taken in the experiment were 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.

Hybrids and nutrient levels were randomized in main plots and sub-plots, respectively. The size of the unit plot was 5 m × 4 m. The total number of plots was 36.

Land preparation started in the first week-July and fertilizers were applied as per treatment specification. In hybrid maize, the recommended was 333 kg ha^{-1} urea + 468.75 kg ha^{-1} single super phosphate + 125.25 kg ha^{-1} muriate of potash. The rate of FYM was 10 t ha^{-1}. Foliar application of 0.5 % $FeSo_4$ and $ZnSo_4$ as per treatments was done twice at active vegetative (45 days) and grain filling stage (90 days), respectively with the help of a knapsack sprayer. Seeding was done on 8 July 2020 at a spacing of 60 cm x 20 cm. The grain cobs were harvested on 7 November 2020 (M_1) and 28 October 2020 (M_2). Observations were made in the respect of plant height, leaf area index (LAI), dry matter production (DMP), days to 50% tasseling, days to 50% silking, cob length, cob girth, no. of grains per row, no. of rows per cob, cob weight, shelling%, 1000-grain weight, grain yield ha^{-1}, stover yield ha^{-1}, the net return, benefit-cost ratio (BCR), crude protein%, starch, iron (Fe), zinc (Zn), nutrient uptake and soil available nutrients.

Design of the Experiment and Layout

The experiment was laid out in a split-plot design with three replications. The whole experimental area was first divided into three blocks. Each block was later divided into 12 plots. The size of each unit plot was 5m x 4m. The total numbers of unit plots are 36. The individual plots and the blocks were separated for irrigation drainage by 1.0 m channels.

Detailed procedures of Recording of Data

Growth parameters

Plant height was measured with a graduated ruler, from the base of the plant to the growing tip of the topmost leaf of ten randomly taken from the net plot area. LAI was computed from the selected ten plants by measuring the leaf length and breadth of the third fully opened leaf from the top by LAI= l × b × n × 0.796/plant spacing. Ten plants at random were cut close to the ground level from the sampling row for DMP estimation. Samples were sun-dried for three days followed by oven drying at 70°C for 72 hrs till a constant weight was obtained and the dry weight was recorded.

Crop Phenology

Days to 50% tasseling (the number of days from planting to the start of shredding of pollen by 50% of maize plants in the plots) and days to 50% silking (number of days from planting to silking by 50%) were recorded at their respective stages.

Yield and Yield components

Cob length was measured from the base to the tip of the cob from the sample plants of each treatment and the mean length of the cob was arrived at and expressed in cm. The girth of cob from sample plants was measured at the point of maximum girth using a thread and measured with a scale. The mean girth per cob was computed and expressed in cm. The number of grains in each row of a cob of the sample plants was counted. The mean was worked out and expressed as a number of grains per row. From the cobs collected from sample plants, the number of grain rows per cob was counted and the mean was arrived at and expressed as the number of rows per cob. The cobs of sample plants were dried thoroughly under the sun and their average weight was recorded and expressed in gm as cob weight. The shelling percentage can be determined from ten plants randomly sampled after harvest using the following formula (Undie et al., 2012):

Shelling percentage = (Seed weight/cob weight) × 100%.

Ten cobs from each treatment were randomly selected and shelled. From this, a representative sample of 1000 maize grains was picked out and weighed using an electronic balance and expressed in g per 1000 grains and reported as 1000 grain weight. The shelled grains from the net plots were dried, cleaned, and again sun-dried and is calculated using the ear fresh weight and the adjusted moisture content (MC) percentage (from 10 to 15%), by using the following formula (ASTM standards 2001):

$$GY = FEW \times 10 \times (100-MC) \times 0.8)/((100-AMC) \times PA$$

Where
GY: Grain yield (t/ha)
FEW: Fresh ear weight (kg/plot)
AMC: adjusted MC
PA: Plot Area

In this case, fresh ear weight is in kg, moisture content (MC) of grains and adjusted MC in percentage (%), 0.8 is the shelling coefficient, and the harvested plot area is in m^2. After cob harvest, the Stover was cut close to ground level and left in the field for three days for sun drying. The dry weight of the stover was recorded plot-wise.

Quality attributes

The Fe and Zn determination by grain is done by using atomic absorption spectrophotometer (AAS; model 210 VGP, Buck scientific).

Nutrient uptake

N, P, and K were calculated by multiplying the content of the nutrients (expressed in percentage) with the respective weights of dry matter of the plant samples at the appropriate stage.

Economic return

Net return and BCR were calculated using the price of inputs and produce that prevailed during the crop season. Net returns = (Gross return – Cost of Cultivation) and BCR = (Gross income / Cost of Cultivation).

Statistical Analysis

The collected data were compiled and tabulated before statistical analysis. Analysis of variance (ANOVA) was done with the help of a computer package (AGRES, 2020). The data recorded during the experiment were subjected to statistical analysis using the F-test as per the procedure given by Gomez and Gomez (1984). Critical difference values at P=0.05 were used to determine the significance of differences between treatment means.

Results and Discussions

Growth attributes

Plant Height

The plant height of nutrient levels significantly varied due to different treatments. The plant height due to different treatments ranged from 219.33 to 184.50 cm. The maximum plant height (219.33 cm) was obtained when S_6 treatment was applied. It was also found that the lowest plant height (184.50 cm) was noted with treatment S_1 (Table 1). The result might be due to the combined source of fertilizers, initially to get decomposed and mineralize before making it available to plants, thus causes nutrients to be slowly released to crop (Okoroafor et al., 2013). On the other hand, the lowest plant height observed in the S_3 is due to a lack of sufficient available nutrients to the crop.

Leaf area index

Leaf area index (LAI) of different nutrient level treatments varied from 3.35 to 4.63. . The highest value (4.63) was experienced in the nutrient level treatment S_6 which was statistically significant with S_3 and S_1 with the value of 4.45 and 4.25 respectively. The lowest leaf area index (3.35) was obtained in treatment S_2 which was statistically on par with S_5 with the value of 3.65 (Table 1). In the present study, better utilization of N resulted in higher leaf surface area and thereby higher LAI. This is in accordance with earlier findings of Agyenium et al. (2006).

Dry matter production

The higher DMP at harvest of different nutrient level treatments varied from 13544.83 to 12475 kg ha^{-1} and the maximum and minimum were found in the treatment S_6 and S_2 respectively. The S_6 was statistically similar to S_3 and S_1 with the value of 13400 and 13217 kg ha^{-1} respectively. Application of S_1 treatment recorded the lowest DMP (12475 kg ha^{-1}) which was statistically similar with S_5 treatment with the value of 12862.50 kg ha^{-1} (Table 1). INM with micronutrient foliar spray 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. Similar results were recorded by Amanullah (1997). Leaf area index and dry matter were significantly correlated demonstrating that a higher amount of radiation associated with higher LAI contributes to enhanced dry matter production, which corroborated the results of Kolawole and Samson, (2009).

Crop Phenology

Tasseling and Silking

Days to 50% tasseling and silking of different nutrient level treatments varied from 57.65 to 54.05 and 66.20 to 60.35 respectively. In treatment, S_6 recorded the reduced (faster) days to 50% tasseling and silking which was statistically similar to S_4 with the value of 54.58. Application of S_2 treatment recorded the higher no. of days to 50% flowering with the value of 57.65 and 66.20 respectively (Table 1). A combined organic and inorganic source with micronutrient applications stimulates vegetative growth and ensuring higher yield. A similar result was found by Ayoola and Makinde, (2009).

Yield and Yield attributes

Cob length

The length of cob was significantly varied by the use of integrated nutrient management with Fe and Zn foliar applications. It was showed that cob length ranged from 18.18 to 15.70 cm. The highest cob length (18.18 cm) was found in the S_6 treatment. The lowest result (15.70 cm) was recorded in S_2 nutrient level treatment which was statistically significant with S_5 treatment with the value of 16.15 cm (Table 1). Our results suggested that an adequate supply of nutrients from both organic and inorganic sources throughout vegetative growth was necessary for proper cob development in maize, as also reported by Samsami (2016). In the case of S_2, the cob may be devoid of recommended demand of nutrients resulted in the lowest cob length. Similar results were recorded by Bukesh et al. (2012).

Table 1. Growth and Yield attributes of hybrid maize (*Zea mays* L.) as influenced by Agronomic biofortification through INM

Treatments	Growth attributes			Crop phenology		Yield attributes				
	PH	LAI At harvest	DMP	DT	DS	CL	CG	NGR	NRC	C
Hybrid (H)										
M$_1$ – Non-biofortified	207.83	4.19	13221.67	54.93	62.68	17.48	14.43	32.70	14.21	299.17
M$_2$ – biofortified	203.94	3.93	12960.78	56.42	62.76	16.43	14.13	32.62	14.03	269.22
Nutrient levels (N)										
S$_1$	211.00	4.25	13217.50	55.30	61.90	17.20	14.50	33.50	14.20	286.00
S$_2$	184.50	3.35	12475.00	57.65	66.20	15.70	13.30	30.02	13.45	277.00
S$_3$	214.50	4.45	13400.00	55.80	62.50	16.70	14.15	32.00	13.95	284.00
S$_4$	208.50	4.05	13047.50	54.58	61.22	17.80	14.80	34.25	14.50	287.50
S$_5$	197.50	3.65	12862.50	56.65	64.15	16.15	13.70	31.25	13.60	280.50
S$_6$	219.33	4.63	13544.83	54.05	60.35	18.18	15.25	35.55	15.02	290.17
F test Prob.	P>F									
H	**	N.S	**	**	N.S	**	N.S	N.S	N.S	**
N	**	**	**	**	**	**	**	**	**	**
H×N	**	**	**	**	**	**	**	**	**	**

PH: plant height (cm); LAI: leaf area index; DMP: dry matter production (Kg ha-1); DT: Days to 50% tasselling, DS: Days to 50% silking, CL: Cob length (cm), CG: Cob girth (cm), NGR: No. of grains row-1, NRC: No. of rows cob-1, C: Cob wt. (g), N: nitrogen, P: phosphorus, K: potassium; FYM: farm yard manure; RDF: recommended dose of fertilizer; **significantly different at 0.05 probability levels; N.S: not significant

S$_1$: S$_1$- 100% RDF through NPK, S$_2$: S$_2$ - 100% RDF through FYM, S$_3$: S$_3$ - 50% RDF through NPK + 50% RDF through FYM, S$_4$: S$_4$ - S$_1$ + Iron and Zinc as foliar application @0.5% conc, S$_5$: S$_5$ - S$_2$ + Iron and Zinc as foliar application @0.5% conc, S$_6$: S$_6$ - S$_3$ + Iron and Zinc as foliar application @0.5% conc

Cob girth

The effect of nutrient levels and hybrids on cob diameter was significant. The cob girth varied from 15.25 to 13.30 cm due to different nutrient level treatments. The highest cob girth (15.25 cm) was in the S$_6$ treatment. The least value (13.30 cm) of cob girth was in S$_2$ nutrient level treatment that was statistically similar to S$_5$ treatment with the value of 13.70 cm (Table 1).

The cob can make vigorous growth which causes an increase in diameter and similar findings were reported by Maidul et al. (2018), that sufficient nutrient supply may enhance the individual size of grain finally, which increases the cob diameter.

No. of Grains per Row

A significant variation in the number of grains per row was reflected due to the combined application of INM with Fe and Zn foliar applications. The number of grains per row varied with nutrient level treatments. The maximum (35.55) and the minimum (30.02) number of grains per row were found with the treatment S$_6$ and S$_2$, respectively (Table 1). The increment in the number of grains per row might be due to the presence of micronutrient fertilizers. It was mainly due to the increase in nitrogen content in the soil which was responsible for the all-around enhancement of cell division within the plant. These results were in concurrence with the findings of Ahmad et al. (2017) in harmony with Ali et al. (2012).

No. of Rows per Cob

A significant variation in the number of rows per cob was noted due to different nutrient levels. The number of rows cob^{-1} due to different nutrient level treatments ranged from 15.02 to 13.45. The highest value (15.02) of the number of rows cob^{-1} manifested with the treatment S$_6$ which was statistically significant than all other nutrient levels. S$_2$ nutrient level treatment recorded the lowest value 13.45 in the number of rows cob^{-1}. This treatment was statistically similar to S$_5$ and S$_3$ treatment with the value of 13.60 and 13.95 respectively (Table 1). Different micronutrients and their combination proved beneficial and salubrious in enhancing all physiological and yield parameters of maize crop and yield a good response in terms of the number of grains number of rows per cob. The result of the analysis was in line with the report shown by Kruczek (2005) and Uwah et al. (2011).

Cob weight

The effect of nutrient levels and hybrids on cob weight was significant. The cob weight varied from 290.17 to 277 g due to different nutrient level treatments. The highest cob weight (290.17 g) was in S$_6$ nutrient level treatment. The least value (277 g) of cob weight was recorded in the treatment S$_2$ that was statistically not similar with any treatments (Table 1). The cob may store the highest amount of food from green parts of plants which causes the increased weight of the cob. Similar results were found by Maidul et al. (2018).

Shelling%

A significant variation of shelling % was reflected due to the combined application of agronomic fortification through INM. The shelling % varied from different nutrient level treatments. The maximum (81.31) and the minimum (75.99) shelling% were found in the treatment S$_6$ and S$_2$, respectively (Table 2). The shelling percentage is influenced by many factors such as agro-climatic conditions, years, locations, genotypes, cultural practices, and kernel moisture content and positively correlated with grain yield and has a significant association with plant height, ear height, number of kernels per row, and hundred-grain weight. Similar findings were reported by Masuka et al. (2017); Saleh et al. (2002).

1000-Grain Weight

The result proves the attention to the effect of agronomic fortification through INM on the 1000-grain weight of hybrid maize. The variation was found to be slim due to different treatments. The highest value (236 g) was noted in treatment S_6 (Table 2). The lowest value (211 g) was in treatment S_2. The similar increase of yield attributing characters was the main cause for increased maize yield in the combined application of Fe and Zn through foliage (Nikhil and Salakinkop, 2018).

Grain Yield per Hectare

There is a significant difference in grain yield was noted due to agronomic fortification through INM. The highest grain yield per hectare due to different treatments ranged from 8.27 to 7.90 t ha^{-1}. The highest value (8.27 t ha^{-1}) of grain yield per hectare manifested with the nutrient level treatment S_6. S_2 treatment produced the lowest value (7.90 t ha^{-1}) of grain yield per ha (Table 2). The increase shows the synergetic role of micronutrient spray in improving plant growth and other biochemical and physiological activities. Similar results were confirmed by Zeidan (2010); Hythum and Nasser (2012).

Stover Yield per Hectare

The effect of agronomic biofortification treatment through INM on stover yield per hectare was statistically significant. The stover yield per hectare varied from 10.16 to 9.71 t ha^{-1}. Stover yield per hectare was highest (10.16 t ha^{-1}) with S_6 nutrient level treatments. The least value (9.71 t ha^{-1}) of stover yield per hectare was recorded in the treatment S_2 that was statistically similar with S_5 with the value of 9.99 t ha^{-1} (Table 2). Fertilization of Zn and the addition of organic manures significantly produced high grain and stover yield and thousand-grain weight (Sadiq et al. 2018).

Table 2. Yield, quality and economics of hybrid maize (*Zea mays* L.) as influenced by Agronomic biofortification through INM

Treatments	S	GW	Yield (t ha^{-1})		Economics		Quality attributes			
			GY	SY	NR	BCR	CP	ST	Fe	Zn
Hybrid (H)										
M_1 – Non-biofortified	80.54	241.0	8.53	10.20	79619.17	3.00	10.48	59.77	28.57	24.23
M_2 – biofortified	75.69	203.8	7.68	9.87	69501.03	2.75	14.63	62.12	30.43	24.88
Nutrient levels (N)										
S_1	78.02	223.5	8.15	10.13	78767.07	3.07	11.10	59.45	22.75	18.50
S_2	75.99	211.0	7.90	9.71	72709.00	2.77	10.60	58.40	21.20	16.95
S_3	77.69	221.0	8.20	10.15	75199.50	2.90	11.50	60.50	23.70	19.50
S_4	79.19	228.0	8.10	10.08	74549.33	2.93	14.00	62.10	36.35	30.75
S_5	76.49	215.0	8.00	9.99	70421.70	2.69	13.50	61.37	35.20	29.75
S_6	81.31	236.0	8.27	10.16	75714.00	2.89	14.65	63.85	37.80	31.88
F test Prob.					P>F					
H	**	**	**	**	NS	**	**	NS	**	**
N	**	**	**	**	**	**	**	**	**	**
H×N	**	**	**	**	**	**	**	**	**	**

S: Shelling %, GW: 1000-Grain weight (g), GY: Grain yield, SY: Stover yield, NR: Net return (× 10^3 INR/ha), BCR: Benefit Cost ratio, CP: Crude Protein (%), ST: Starch (mg g^{-1}), Fe: iron(mg kg-1), Zn: zinc (mg kg-1) , NPK: nitrogen, phosphorus, potassium, FYM: farm yard manure, RDF: recommended dose of fertilizer, **significantly different at 0.05 probability levels, N.S: not significant

S_1: S_1- 100% RDF through NPK, S_2: S_2 - 100% RDF through FYM, S_3: S_3 - 50% RDF through NPK + 50% RDF through FYM, S_4: S_4 - S_1 + Iron and Zinc as foliar application @0.5% conc, S_5: S_5 - S_2 + Iron and Zinc as foliar application @0.5% conc, S_6: S_6 - S_3 + Iron and Zinc as foliar application @0.5% conc

Economic Returns

Net Return

The effect of treatment with agronomic biofortification through INM on net return was statistically significant. The highest net return (INR 78767.07 ha^{-1}) was recorded in the S_1 nutrient level treatment followed by S_6 (INR 75714 ha^{-1}). This was statistically similar to S_3 (INR 75199.50 ha^{-1}) treatment. On the other hand, the lowest net return (INR 70421.70 ha^{-1}) was recorded in the S_5 nutrient level treatment (Table 2). The result might be because of the minimum cost of cultivation and favorable minimum support price during *the Kharif* season. This confirms the findings of Kumar et al. (2007).

Benefit-Cost Ratio

A significant variation of BCR was noted due to different nutrient level treatments. The BCR varied from 3.07 to 2.77 due to different treatments. The highest BCR (3.07) was in the S_1 nutrient level treatment. The least value (2.77) of BCR was recorded in the S_2 treatment (Table 2). This confirms the findings of Kumar et al. (2007) and Kumari et al. (2010).

Quality attributes

Crude Protein

The effect of agronomic biofortification through INM on the crude protein was statistically significant. The crude protein varied from 14.65 to 10.60 %. Crude protein was highest (14.65%) with S_6 treatment. The least value (10.60 %) of crude protein was recorded in the treatment S_2 that was statistically similar with S_1 and S_3 nutrient level treatments with the value of 11.10 and 11.50 % respectively (Table 2). Similar results were reported that improvement in grain yield, protein content as a result of Fe and Zn spraying by Yuan et al. (2012).

Starch

A significant variation of starch content was recorded due to different nutrient level treatments. The starch due to different nutrient level treatments ranged from 63.85 to 58.40 mg g^{-1}. The highest value (63.85 mg g^{-1}) of starch manifested with treatment S_6. S_2 produced the lowest value (58.40 mg g^{-1}) of starch content that was statistically similar with S_1 nutrient level treatment with the value of 59.45 mg g^{-1} (Table 2).

Iron

Iron content in maize hybrid grain was significantly varied by the use of agronomic biofortification through INM. It was shown that the Fe content ranged from 37.80 to 21.20 mg kg^{-1}. The highest Fe content in grain (37.80 mg kg^{-1}) was found in the S$_6$ treatment. The lowest result (21.20 mg kg^{-1}) was recorded in S$_2$ treatment which was statistically significant with S1 treatment with the value of 22.75 mg kg^{-1} (Table 2). The increased result was due to increase soil N application significantly enhanced shoot and grain Fe concentrations both under field and greenhouse conditions (Cakmak et al., 2010; Kutman et al., 2010). Also, it was found that foliar application of Fe and Zn proved a better way to increase the nutrient contents in maize grain in comparison with soil application (Saleem et al., 2016).

Zinc

The Zn content in grain was significantly varied due to agronomic biofortification through INM. It was showed that the Zn content ranged from 31.88 to 16.95 mg kg^{-1}. The highest Zn content (31.88 mg kg^{-1}) was found in the S$_6$ treatment. The lowest result (16.95 mg kg^{-1}) was obtained in the S$_2$ treatment (Table 2). Agronomic biofortification through Zn fertilization results in increased grain production as well as higher Zn concentration in grains at the same time thus reported by Prasad (2009) and also Chakraborti et al., (2009) reported a higher concentration of Zn in QPM inbreds compared to normal inbreds.

Nutrient Uptake

Nitrogen

The nitrogen uptake at harvest was significantly higher (243.54 kg ha^{-1}) with S$_6$ nutrient level treatment and significantly superior to the rest of the treatments. In S$_6$ nutrient level treatment was highest in N uptake which was statistically similar with S$_3$ with the value of 243.54 kg ha^{-1}. Significant lower nitrogen uptake (224.55 kg ha^{-1}) was recorded with S$_2$ treatment (Table 3). The increase in grain yield and stover yield could be related to an increase in uptake of N, P, and K by the crop. All these nutrients are important in many physiological processes controlling growth and development in plants. The combined application of nitrogen and organics increased the concentration of nutrient ions in the soil solution and their uptake by plants. Similar findings were recorded by Reddy and Reddy (1998).

Phosphorus

Phosphorus uptake was significantly varied by the agronomic biofortification through INM. It was shown that the P uptake ranged from 44.65 to 41.17 kg ha^{-1}. The highest value (44.65 kg ha^{-1}) was found in the S$_6$ nutrient level treatment. The lowest result (41.17 kg ha^{-1}) was recorded in S$_2$ nutrient level which was statistically significant with S$_5$ treatment with the value of 42.45 kg ha^{-1} (Table 3). Integrated nutrient supply is one of the most important factors that determine the growth of the crop. The growth and yield are determined by the presence of sufficient quantities of the available form of nutrients in the soil for plant uptake. A similar result was found by Babannavar et al. (1990).

Potassium

A significant variation in the parameter was noted due to differences in treatments. The potassium uptake due to different treatments ranged from 175.89 to 162.18 kg ha^{-1}. The highest value (175.89 kg ha^{-1}) of potassium uptake manifested with the nutrient level treatment S$_6$ which was statistically similar with S$_3$ nutrient level treatment with the value of 174.26 kg ha^{-1} (Table 3). S$_2$ treatment produced the lowest value (162.18 kg ha^{-1}). Higher nutrient content in the produce and higher biomass production of maize might be the pertinent reason for the higher uptake of nutrients. These findings are in close agreement with the results reported by Singh et al. (2011).

Table 3. Nutrient uptake and soil properties of hybrid maize (*Zea mays* L.) as influenced by Agronomic biofortification through INM

Treatments	Nutrient uptake (kg ha^{-1})			Soil properties			
	At harvest stage			Post-harvest			
	N	P	K	OC	MIN	AVAP	AVAK
Hybrid (H)							
M$_1$ – Non-biofortified	237.99	43.63	171.90	0.410	229.00	12.30	539.43
M$_2$ – biofortified	233.22	42.76	168.43	0.409	226.23	12.06	537.33
Nutrient levels (N)							
S$_1$	237.92	43.62	171.83	0.410	228.25	12.25	541.35
S$_2$	224.55	41.17	162.18	0.408	219.10	11.50	518.75
S$_3$	241.25	44.24	174.26	0.415	239.25	13.14	558.90
S$_4$	234.86	43.06	169.62	0.406	225.25	12.00	539.25
S$_5$	231.53	42.45	167.21	0.406	218.25	11.35	516.85
S$_6$	243.54	44.65	175.89	0.412	235.60	12.85	555.20
F test Prob.	P>F						
H	**	**	**	N.S	**	**	**
N	**	**	**	**	**	**	**
H×N	**	**	**	**	**	**	**

OC: Organic Carbon (%), MIN: Mineralizable N (kg ha^{-1}), AVAP: Available P (kg ha^{-1}), AVAK: Available K (kg ha^{-1}), N: nitrogen, P: phosphorus, K: potassium, FYM: farm yard manure, RDF: recommended dose of fertilizer, **significantly different at 0.05 probability levels, N.S: not significant

S$_1$: S$_1$- 100% RDF through NPK, S$_2$: S$_2$ - 100% RDF through FYM, S$_3$: S$_3$ - 50% RDF through NPK + 50% RDF through FYM, S$_4$: S$_4$ - S$_1$ + Iron and Zinc as foliar application @0.5% conc, S$_5$: S$_5$ - S$_2$ + Iron and Zinc as foliar application @0.5% conc, S$_6$: S$_6$ - S$_3$ + Iron and Zinc as foliar application @0.5% conc

Table 4. Interaction effect of Hybrids and Nutrient levels on yield, net returns and benefit: cost ratio

Hybrid	Nutrient level	Grain yield (t ha^{-1})	Net returns (×10^3 INR/ha)	Benefit:cost ratio
M$_1$ – Non-biofortified	S$_1$	8.55	81696.00	3.14
	S$_2$	8.38	76303.60	2.86
	S$_3$	8.61	80990.80	3.04
	S$_4$	8.50	80407.20	3.08
	S$_5$	8.44	76612.40	2.84
	S$_6$	8.70	81705.00	3.04
M$_2$ – Biofortified	S$_1$	7.75	75838.13	2.99
	S$_2$	7.41	69114.40	2.68
	S$_3$	7.78	69408.20	2.75
	S$_4$	7.70	68691.47	2.78
	S$_5$	7.56	64231.00	2.54
	S$_6$	7.85	69723.00	2.74
SEm±		17.76	1587.40	0.04
CD (P=0.05)		37.35	4345.77	0.11

RDF: recommended dose of fertilizer, N: nitrogen, P: phosphorus, K: potassium, FYM: farm yard manure, **significantly different at 0.05 probability levels, S$_1$: S$_1$- 100% RDF through NPK, S$_2$: S$_2$ - 100% RDF through FYM, S$_3$: S$_3$ - 50% RDF through NPK + 50% RDF through FYM, S$_4$: S$_4$ - S$_1$ + Iron and Zinc as foliar application @0.5% conc, S$_5$: S$_5$ - S$_2$ + Iron and Zinc as foliar application @0.5% conc, S$_6$: S$_6$ - S$_3$ + Iron and Zinc as foliar application @0.5% conc

Soil Available Nutrients

Soil Organic Carbon (SOC %)

SOC is a major constituent of organic matter, and 58% of estimated organic matter is evaluated through organic carbon. A highly significant increase in SOC was noticed due to treatment effects on the soil after harvest. The maximum increased SOC (0.415%) at harvest was observed in treatment containing S$_3$ (50% RDF through NPK + 50% RDF through FYM) which was statistically similar with S$_6$ and S$_1$, that resulted in superior growth during the crop growing period, whereas the lowest (0.406 %) among the nutrient level treatments was observed in S$_4$ and S$_5$ (Table 3). The SOC and total nitrogen are interrelated. It has been reported that the organic matter in soil increases with an increase in the level of applied N, which in turn causes an increase in total nitrogen content. The results corroborated with the findings of Kannan et al. (2013).

Soil Available Nitrogen (SAN, kg ha^{-1})

Organic manures integrated with inorganic fertilizers in maize have increased soil health as compared to the lone application of fertilizers. The highest significant difference was recorded (239.25 kg ha^{-1}) with the nutrient level treatment S$_3$, which contains a combination of organic and inorganic sources of nutrients which was found to be statistically similar with S$_6$ nutrient level treatment with the value of 235.60 kg ha^{-1} (Table 3). The above result is similar to Sharma et al. (2012) and Maidul et al. (2018) who reported that integration of organics and inorganics improves soil fertility status.

Soil Available Phosphorus (SAP, kg ha^{-1})

The available soil P performed vital functions including root development to fruit formation. The highly significant difference was recorded due to the effect of organic and inorganic fertilizers on SAP after harvest. Compared with the rest of the nutrient level treatments used in this trial S$_3$ (50% RDF through NPK + 50% RDF through FYM) was found to be the highest SAP (13.14 kg ha^{-1}) whereas, S$_5$ (S$_2$ +Fe and Zn foliar @0.5% conc.,) was recorded with lowest SAP (11.35 kg ha^{-1}) which was found to be statistically similar with S$_2$ (100% RDF through NPK) (Table 3). The results are in similarity with the findings of Sharma et al. (2012) and Maidul et al. (2018) that application of FYM along with RDF increases soil fertility status.

Soil Available Potassium (kg ha^{-1})

The effect of organic and inorganic fertilizers has shown a significant difference in soil available potassium after harvest. Compared with the rest of the nutrient level treatments used in this trial S$_5$ (S$_2$+Fe and Zn foliar @0.5% conc.,) was found to have the lowest soil available potassium (516.85 kg ha^{-1}) whereas, S$_3$ (50% RDF through NPK + 50% RDF through FYM) was recorded with the highest soil available potassium (558.90 kg ha^{-1}) than any other treatments used which was found to be statistically the same with S$_6$ (50% RDF through NPK + 50% RDF through FYM with Fe and Zn foliar @0.5% conc.,) in their action towards the improvement of soil available potassium (Table 3). Similar results were recorded by Pawar (1996) in maize that increases in available K$_2$O content in soil due to combined application of urban compost or FYM and inorganic fertilizers.

Interaction Effect of Hybrids and Nutrient Levels

The interaction effect of hybrids and nutrient levels was observed on yield, net returns, and benefit: cost ratio (Table 4) indicated that maximum grain yield (8.70 t ha^{-1}), net returns (INR 81705 ha^{-1}) recorded with non-biofortified hybrid (M$_1$) with S$_6$ nutrient level treatment and significantly superior over rest interactions. Similarly benefit: cost ratio was maximum (3.14) in non-biofortified hybrid (M$_1$) with S$_1$ nutrient level treatment, which was closely followed by S$_3$ and S$_6$ with the value of 3.04. The lowest value of yield, net returns, and benefit: Cost ratios were recorded under the biofortified (M$_2$) hybrid with S$_2$ nutrient level treatment. It indicates that every hybrid needs a different nutrient management strategy for the realization of the highest yield and profit.

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, crop phenology, yield and yield attributes, quality attributes, nutrient uptake, whereas higher net returns were observed in 100 % RDF through NPK (S_1). Likewise organic carbon and soil available nutrients were higher in 50% RDF through NPK + 50% RDF through FYM (S_3). Similarly interaction effect of non-biofortified maize hybrid (M_1) was superior to biofortified maize hybrid with 50 % RDF through NPK + 50 % RDF through FYM with Fe and Zn foliar application @0.5% Conc., (S_6) treatment in all the parameters except quality attributes.

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