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Impact of integrated nutrient management on the growth, yield, and quality of quality protein maize (*Zea mays* L.)

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Abstract
A field experiment was conducted during rabi season of 2023-24 on loamy sand of in the rural area of Kanpur district of Mandhana, located 10 km from Kanpur in Uttar Pradesh to Impact of Integrated Nutrient Management on the Growth, Yield, and Quality of Quality Protein Maize (*Zea mays* L.). The soil was normal in pH of 7.63, electrical conductivity (EC) of 0.24 dSm^{-1}, organic carbon content of 0.43%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 215.90, 19.1, and 149.40 kg ha^{-1}, respectively. The experiment was laid out during Rabi season of 2023-24.The experiment consisted of 12 treatment combinations, was laid out in Randomized Block Design (RBD) with three replications.

Keywords: INM, Maize, QPM, yield

Introduction
The world desperately needs to change the global food system so that everyone can eat healthier diets and the environmental impact of agriculture is drastically reduced. To help the world's poorest people, the major cereal grains must be at the center of this new revolution. Recent years have seen a further improvement in the nutritional quality of the major cereals thanks to a crop breeding technique known as "biofortification," which raises the concentration of important vitamins or micronutrients. Children who are deprived of these nutrients suffer from impaired physical and cognitive development as well as increased susceptibility to illness. Often referred to as "hidden hunger," this illness is thought to be the reason behind roughly one-third of the 3.1 million child fatalities linked to malnutrition each year. 820 million people, or 11% of the world's population, consume insufficient amounts of energy, and 1.3 billion people, or 17%, are deficient in certain micronutrients. FAO 2019 [1].

In India, there is an extreme urgency for increased food security and environmental stewardship to coexist. Over the past 50 years, India, the second-most populous country in the world, has remained largely self-sufficient in terms of cereal production, with wheat and rice—grown during the rabi/winter season and the kharif/monsoon season, respectively—serving as the flagship crops that have significantly increased food supply (FAO, 2017) [2].

According to FAO (2017) [7] projections, staple cereals will remain a vital component of food security until 2050, accounting for nearly half of daily calorie intake and protein intake in low- and middle-income nations. This implies that in order to maintain planetary boundaries in the coming decades, there will need to be additional productivity growth in cereals in addition to population growth.

Therefore, between 2005 and 2050, food production needs to rise by 70% in order to achieve global food security (ELD, 2015) [3]. High population density and shifting dietary habits in South Asian nations will require doubling crop production (Ladha *et al*. 2016; Tilman *et al*. 2011) [4, 5]. Grain consumption for the production of biofuel is anticipated to rise concurrently by roughly 60 million tonnes to 145 million tonnes annually. The total demand for corn and wheat is predicted to rise by roughly 15%, or 200 million tonnes/year, to a total of about 1.5 billion tonnes/year over the next ten years when food use for corn and wheat is taken into account (FAPRI, 2008) [6]. A nation like India, which is expected to feed an additional 394 million people by then, faces significant risks associated with sacrificing environmental sustainability for food security.

One of the most promising crops for agricultural diversification in India's highland regions is maize. In India, maize is becoming a very popular cereal due to its rising market price and high production potential under both rainfed and irrigated conditions. It is grown on 8.3 million hectares, yielding productivity and production of 21 million tonnes and 2.5 tonnes ha^{-1}. In India, 28% of the maize crop is used for food, 11% for animal feed, 48% for poultry feed, 12% for the wet milling sector, and 1% as seed (Bezboruah and Dutta, 2021) [8]. As a result, maize is regarded as a multipurpose crop that has the potential to significantly boost the national economy (Narang and Gill, 2004) [9]. An estimated 121 million tonnes of maize are expected to be produced in India by 2050 (Amarasinghe and Singh, 2008) [10]. Rabi maize cropping will be one of the key cereals in the nation's food security and can offer insights on intensive agriculture and other tactics for addressing future challenges in food production (Mandal *et al*., 2020) [12]. In addition to meeting the needs of the states, these states' profitable seed production has the potential to be exported to nearby nations and states. (DMR, 2012) [11].

Compared to boro rice, maize might be less harmful to the environment. Concerns over arsenic contamination in boro rice are growing, but maize presents an alluring substitute cereal crop with demonstrated lower arsenic concentrations. (Yusuf and others, 2009) [14]. One of the most prevalent micronutrient deficiencies worldwide is zinc deficiency (Alloway, 2004) [13]. Because of the negative effects on human health, there is a growing global incidence of zinc deficiency in soils (Singh *et al*., 2005) [15]. There are reportedly over 2 billion people suffering from micronutrient malnutrition worldwide. Insufficient amounts of iron (Fe) impact more than 47% of preschool-aged children globally, frequently leading to compromised physical and mental development, as well as learning disabilities.

According to Bromley (2011) [16], zinc is a mobile plant micronutrient that is needed by plants in comparatively small amounts for normal growth and development. It plays a significant role in photosynthesis, DNA transcription, auxin biosynthesis, and other processes. Globally, there is a problem with soil deficiency in both zinc and iron that is lowering crop yields and compromising food quality (Kanai *et al*., 2009) [18]. A major nutritional problem that affects crops, particularly those grown on calcareous soils, is iron deficiency, which results in reduced vegetative growth and large losses in yield and quality (Abadia *et al*., 2011) [17].

According to Rout and Sahoo (2015) [19], iron is a necessary component of several proteins and enzymes involved in respiration and photosynthesis, as well as a prothesis group that includes numerous enzymes like cytochromes. According to Asad and Rafique (2000) [20], iron is a crucial mineral for plants because it is necessary for biological redox systems and is an essential part of many enzymes that are crucial to the physiological and biochemical functions of plants. According to Singh (2010) [21] and Om *et al*. (2014) [22], quality protein maize is a nitrogen-intensive crop that needs a very high dose of the nutrient. Because N and P alone account for 40–60% of crop yield, wiser and more extensive use of these two major nutrients can result in higher QPM yields (Das *et al*., 2010) [23]. However, because of their low nutrient status, applying organic manures alone does not result in the necessary yields. Only by using the proper blend of chemical fertilizers and green or organic manures could sustainable yield levels be attained. Due to the rising demand for QPM globally, its potential for value addition, and its superior market pricing when compared to traditional varieties of maize, there is a great deal of room to grow QPM cultivation. Reducing malnutrition through direct human consumption is the main objective of QPM research (Sofi *et al*., 2009) [24].

Material and Methods

A field experiment was conducted during rabi season of 2022-23 on loamy sand of in the rural area of Kanpur district of Mandhana, located 10 km from Kanpur in Uttar Pradesh to Impact of Integrated Nutrient Management on the Growth, Yield, and Quality of Quality Protein Maize (*Zea mays* L.)". The soil was normal in pH of 7.63, electrical conductivity (EC) of 0.24 dSm^{-1}, organic carbon content of 0.43%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 215.90, 19.1, and 149.40 kg ha^{-1}, respectively. The experiment was laid out during Rabi season of 2023-24. The experiment consisted of 12 treatment combinations, was laid out in Randomized Block Design (RBD) with three replications. F0 Control (No fertilizers)., F1Recommended dose of chemical fertilizer (@ 140:70:70 kg ha^{-1} N: P :K), F2 FYM 5 t ha^{-1}, F3 FYM 5 t ha^{-1} + AZ + PSB, F4 75% RDF + F3 , F5 50% RDF + F, F6 25% RDF + F3, F7 -1 Vermicompost @ 2.5 t ha, F8 Vermicompost @ 2.5 t ha^{-1} Azotobacter @ 7.5 kg ha^{-1} + PSB @ 7.5 kg ha -1, F9 75% of RDF + F3, F10 50% of RDF + F3, F11 25% of RDF + F3, Recommended dose of N, P and K (140:70:70 $kgha^{-1}$) were as per the recommendation for maize crop for this zone data were gathered on five plants chosen from each plot.

Results and Discussion

Yield and yield attributes

Cob weight with grains plant^{-1}

The cob weight grains plant^{-1} was increased through the application of organic sources in various treatment combinations. The data indicates that, compared to the other treatments, treatment F4 (75% RDF + F3) produced the highest Cob weight (307.7) g with grains plant^{-1} and was comparable to treatments F5 (306.3) (g) and F9 (301.3) (g). On the other hand, F0 (the control plot) had the lowest Cob weight with grains plant^{-1} (262.8) g grains plant^{-1}.

Cob length (cm)

One of the key yield-related traits of a QPM hybrid that affects a crop's vitality and quality is cob length. After a thorough analysis, as shown in Table 1, it was determined that treatment F9 (75% of RDF + F8) had the maximum cob length (cm) (21.2 cm), and that treatment F4 (75% RDF + F3) (20.4 cm) had the same statistical significance as the other treatments. The treatment F0 (control plot) did, however, record the minimum Cob length of 14.10 cm.

Cob Girth (cm)

Different treatment combinations of organic and inorganic sources had a significant impact on the cob girth (cm) data during the investigation, as shown in Table 1. The maximum cob girth was recorded in treatment F4 (75% RDF + F3) (14.5 cm), and the data provided in Table 1 shows that this was statistically comparable to treatments F9 (75% of RDF + F8) (14.4 cm) and F5 (50% RDF + F3) (14.0 cm).Nonetheless, in treatment F0 (control plot), the minimum cob girth (cm) was recorded at 9.8 cm.

No. of rows cob^{-1}

The application of treatment combinations considerably increased the number of row cob^{-1} over the control years of investigation, according to an analysis of the data in Table 2. Treatment F4 (75% RDF + F3) had the highest number of rows cob^{-1} (15.67) compared to the other treatments, but it was comparable to treatments F9, F5, F1, F10, and F11 (15.17, 15.00, 14.83, 14.67, and 14.67, respectively). In treatment F0 (control plot), the minimum number of rows cob^{-1} registered was 12.67.Because of improved nutrient absorption and increased photosynthetic translocation from source to sink, the number of rows cob^{-1} increased with the increase in organic source levels.

No. of grains cob^{-1}

The information about the number of grains cob^{-1} shown in Table 2. A thorough examination of the data revealed that a significant variance in the number of grains cob^{-1} was seen as a result of various treatment variable doses. The QPM hybrid that was given the treatment combination F4 (75% RDF + F3) (424.0) had the highest number of grains per kilogramme-1 when compared to the other treatments. QPM hybrid, however, registered at the lowest level in F0 (control plot) at 286.0 g.

Test Weight (g)

The examination of the data in Table 1 regarding the (1000-grain weight) of QPM hybrid revealed that treatment variables had a significant impact on the data during the study years. During both study years, treatment F4 (240 g) application (75% RDF + FYM 5 t ha^{-1} + Azotobacter @ 7.5 kg ha^{-1} + PSB @ 7.5 kg ha^{-1}) recorded a significantly higher test weight than the other treatments. It appears from the two-year mean data that the F0 (control plot) registered the lowest (180.0) g.

Grain yield (t ha^{-1})

It is clear from the data in Table 3 that there was a considerable variation in the QPM hybrid grain yields over the course of the two experimentation years. The treatment F4 (75% RDF + F3) showed the highest trends in grain yield (5.27 t ha^{-1}), closely followed by F9 (75% of RDF + F8) (4.72 t ha^{-1}). Of all the treatment variables, treatment F0 (controlplot) had the lowest grain yield (3.07 t ha^{-1}).

Stover yield ha^{-1}

The treatment variables on QPM hybrid during experimentation had a significant impact on the scrutiny of data shown in Table 3v Stover yield. During the first season, treatment F4 (75% RDF + F3) had the significantly highest spoilage yield (7.07 t ha^{-1}), closely followed by F5 (50% RDF + F3) (6.91 t ha^{-1}) and F4 (7.11 t ha^{-1}) (6.84 t ha^{-1}). Nevertheless, other treatment variables showed a significant improvement over the control F0 (control plot), which during the experimentation registered the lowest Stover yield (5.0 t ha^{-1}) and (5.02 t ha^{-1}).

Biological yield ha^{-1}

The biological yield of QPM hybrid is greatly impacted by treatment combinations that include both organic and inorganic sources of nutrients. The data presented in Table 3 demonstrated that during the experiment, treatment F4 (75% RDF + F3) yielded the significantly highest spoilage yields (12.34 t ha^{-1}) and (12.40 t ha^{-1}). Vermicompost, FYM, Azotobacter, and PSB were found to be equally effective in increasing stover yield and yielded significantly higher results than the control F0 (no fertilizer) (8.08 t ha^{-1}) and (8.10 t ha^{-1}) in that order, which recorded the lowest yield.

Harvest Index (%)

The application of different treatment combinations during experimentation resulted in a significant variation in the harvest index (%) result shown in Table 3.The highest Harvest Index, calculated on a mean basis, was 42.66 percent in treatment F4 (75% RDF + F3). Nonetheless, treatment F8 had the lowest HI recorded (379.92%).

Table 1: Yield attributes of Quality protein maize as influenced by nutrient management practices.

Treatment	Number of cobs plant^{-1}	Cob weight with grains plant^{-1} (g)	Length of cob (cm)	Cob Girth (cm)	No. of rows cob^{-1}	No. of grains cob^{-1}	Test Wt.(g)
F0	1.00	262.67	14.10	9.77	13.00	285.00	179.13
F1	1.33	289.67	18.57	13.40	15.00	379.00	211.93
F2	1.00	258.33	15.73	12.23	14.00	324.67	207.60
F3	1.33	267.33	16.67	12.70	14.33	341.33	212.23
F4	1.67	307.33	20.13	14.47	15.67	422.67	239.20
F5	1.33	304.00	19.90	13.90	15.00	388.67	221.97
F6	1.33	282.33	17.73	13.20	14.33	364.67	210.37
F7	1.00	271.67	15.67	12.30	14.33	306.00	206.80
F8	1.33	265.33	16.47	12.97	14.33	333.33	208.07
F9	1.33	300.00	21.10	14.33	15.33	400.67	224.87
F10	1.33	288.00	19.40	13.27	14.67	382.00	214.00
F11	1.33	270.33	17.83	13.04	14.67	362.67	209.73
S.Em +	0.29	9.20	0.85	0.45	0.47	8.13	4.91
CD (0.05)	0.86	26.97	2.51	1.31	1.38	23.85	14.41

F0: Control (No fertilizers), F1: RDF (@ 140:70:70 kg/ha N:P_2O_5:K_2O), F2: FYM 5 t/ha, F3: FYM 5 t/ha + AZ + PSB, F4: 75% RDF + F3, F5: 50% RDF + F3, F6: 25% RDF + F3, F7: Vermicompost @ 2.5 t/ha, F8: Vermicompost (@ 2.5 t/ha) + Azotobacter (@ 7.5 kg/ha) + PSB (@ 7.5 kg/ha, F9: 75% of RDF + F8, F10: 50% of RDF + F8, F11: 25% of RDF + F8

Table 2: Yield attributes of Quality protein maize as influenced by nutrient management practices.

Treatments	Number of cobs/plant	Cob weight with grains plant^{-1} (g)	Length of cob (cm)	Cob Girth (cm)	No. of rows/cob	No. of grains/cob	Test Wt.(g)
F0	1.00	262.8	14.1	9.8	12.67	286	180
F1	1.17	291.7	18.7	13.5	14.83	381	212
F2	1.00	260.5	15.9	12.3	14.00	326	208
F3	1.33	267.7	16.8	12.8	14.33	326	213
F4	1.50	307.7	20.4	14.5	15.67	424	240
F5	1.50	306.3	20.0	14.0	15.00	390	223
F6	1.33	285.5	17.9	13.2	14.50	366	211
F7	1.00	274.3	15.7	12.3	13.67	308	207
F8	1.33	266.8	16.5	13.1	14.17	335	209
F9	1.50	301.3	21.2	14.4	15.17	402	225
F10	1.17	289.5	19.5	13.4	14.67	384	214
F11	1.33	272.3	17.9	13.1	14.67	365	210
S.Em ±	0.28	9.29	0.85	0.44	0.51	10.06	4.97
CD (0.05)	NS	NS	NS	NS	NS	NS	NS

Table 3: Yield of quality protein maize as influenced by nutrient management practices

Treatments	Yield of quality protein			
	Grain yield ha^{-1} (t)	Stover yield ha^{-1}	Biological yield ha^{-1}	Harvest Index (%)
F0	3.07	5.01	8.08	37.99
F1	4.32	6.70	11.64	33.62
F2	4.02	6.05	10.07	40.05
F3	4.10	5.80	9.90	41.54
F4	5.27	7.07	12.34	42.70
F5	4.44	6.91	11.58	37.61
F6	4.19	6.68	10.87	38.54
F7	3.78	5.92	10.25	39.01
F8	4.02	6.07	10.66	37.92
F9	4.72	6.71	11.57	39.24
F10	4.40	6.78	11.45	38.60
F11	4.14	6.90	11.04	37.55
S.Em ±	0.08	0.27	0.47	1.90
CD (0.05)	0.23	0.80	1.38	5.57

Conclusion

The experimental results suggest that, in order to achieve the highest possible yield and economics during the Rabi season, QPM hybrid VMH-53 should be fertilized with 75% RDF ($N:P_2O_5:K_2O$) @ 140:70:70 kg ha^{-1} + FYM 5 tha^{-1} + AZ @ 7.5 kg ha^{-1} + PSB @ 7.5 kg ha^{-1} as a basal dose application. Additionally, foliar application of zinc & iron sources of concentration: zinc @ 0.1% + foliar spray of iron @ 0.1% (twice spray).

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