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Studying the impact of sulphur and zinc levels on the growth, yield, and quality of Indian mustard [*Brassica juncea* 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 Studying the Impact of Sulphur and Zinc Levels on the Growth, Yield, and Quality of Indian Mustard [*Brassica juncea* L).] The soil was normal in pH of 7.69, electrical conductivity (EC) of 0.26 dSm^{-1}, organic carbon content of 0.44%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 215.70, 19.59, and 148.70 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: Maize, Fe, Zn, QPM

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.

In recent years, the major cereals have experienced further improvements in their nutritional quality 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. Anonymous (2019–2020). Annual Compilation Agriculture Ministry. P-74

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.

Therefore, between 2005 and 2050, food production must rise by 70% in order to ensure global food security (South Asian nations with dense populations and shifting dietary habits will need to double their crop production, according to Bamboriya). 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 over the next ten years is predicted to increase by roughly 15%, or about 200 million tonnes/year, to a total of approximately 1.5 billion tonnes/year when food use for corn and wheat is taken into account. Warwick and others (2006) [2]

A nation like India, which is expected to feed an additional 394 million people by 2050, has a significant risk of unfavorable trade-offs between environmental sustainability and food security. A number of factors, including a growing lack of labor and water, an imbalance in nutrients, weed shift and resistance, and climate change, are contributing to the decline in total factor productivity. Since it has been determined that maize can increase farmers' income while also creating gainful employment, it is a crop with the potential to double farmer income. The "Queen of Cereals" gets its name from its exceptionally high yield potential, which surpasses that of any other cereal crop.

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). [10] As a result, maize is regarded as a multipurpose crop that has the potential to significantly boost the national economy. An estimated 121 million tonnes of maize are expected to be produced in India by 2050.

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. According to Mandal *et al*. (2020) [20], the states that grow Rabi maize the most are Andhra Pradesh (45.5%), Bihar (20.1%), Tamil Nadu (9.3%), Karnataka (8.5%), Maharashtra (7.7%), and West Bengal (5.3%). Since there is a groundwater shortage in the Rabi rice regions of Odisha, West Bengal, Karnataka, Andhra Pradesh, and Tamil Nadu, maize is seen as a possible substitute. 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.

One of the most prevalent micronutrient deficiencies worldwide is zinc deficiency. Because of the negative effects on human health, there is a growing global incidence of zinc deficiency in soils. According to Bromley (2011) [21], 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.

According to Kobayashi and Nishizawa (2015) [22], iron (Fe) is a necessary element for all living things, including humans and microorganisms. It also plays a significant role in cellular proliferation, oxidative metabolism, oxygen metabolism, electron transfer, DNA and RNA synthesis, and enzyme processes. 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. According to Rout and Sahoo (2015) [23], 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 Singh (2010) [24], 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. Reducing malnutrition through direct human consumption is the main objective of QPM research.

Materials and Methods

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 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 7.65, electrical conductivity (EC) of 0.27 dSm^{-1}, organic carbon content of 0.41%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 217.0, 19.5, and 149.50 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, F1 Recommended dose of chemical fertilizer (@ 140:70:70 kg ha^{-1} N: P O:K O), f3 FYM 5 t ha^{-1}, F4 FYM 5 t ha^{-1} + AZ+ PSB, F5 75% RDF +F, T5 50% RDF + F, F6 25% RDF + F, F7 Vermicompost @ 2.5 t ha, F8 Vermicompost @ 2.5 t ha^{-1} Azotobacter @ 7.5 kg ha^{-1} + PSB @ 7.5 kg ha, F9 75% of RDF + F, F10 50% of RDF + F, F11 25% of RDF + F (Recommended dose of N, P and K (140:70:70 kgha^{-1}) were as per the recommendation) data were gathered on five plants chosen from each plot.

Results and Discussion

Growth Parameters

Table 1, which details the various treatments applied to the QPM hybrid plants at different growth stages, shows that, generally speaking, plant height increased as the plants grew older until harvest. The treatment F4 (75% RDF + F3) was found to have significantly higher plant height observations at all observation stages, including 30 DAS, 60 DAS, 90 DAS, and harvest. Treatment F9 (75% RDF + F8) was found to be closely followed by treatment F4. The results closely match those of Mahesh *et al*. (2010) [25], who found that higher growth parameters, such as plant height and total dry matter production, were obtained when the recommended dose of NPK + FYM was applied. The current study's findings regarding the overall improvement in crop growth were very similar to those of Suke *et al*. (2010), [26]. On the other hand, treatment F0 (control plot), which received no fertilizer, showed reduced plant height.

Table 2 shows that during the experiment, the application of treatment greatly increased DMA plant-1 at every stage of crop growth from 30 days to harvest. The data was scanned, and it became evident that there was a large variation in the dry matter accumulation by plant as a result of applying varying amounts of inorganic and organic fertilizer at every growth stage. The results show that treatment F4 (75% RDF + F3) recorded significantly higher dry matter-1 at harvest and at 30 DAS, 60 DAS, and 90 DAS. Treatment F9 (75% of RDF + F8) and F5 (50% RDF + F3) were closely behind. These results are consistent with those of Thavaprakash *et al*. (2005) [27]. On the other hand, treatment F0 (control plot) showed reduced dry matter accumulation even though no treatment doses were applied.

The information in Table 3 and the analysis of variances it provides show that after the first legs phrase, or 30 DAS to 60 DAS, LAI increased quickly and that the subsequent increase in LAI in QPM maize was not significant. Additionally, data show that the application of treatments had a significant impact on the LAI at every stage of crop growth, from 30 DAS to harvest, relative to control. According to Singh *et al*. (2017) [28], the results are consistent. During the experiment, LAI was found to be highest with treatment F4 and to be closely followed by treatment F9 and treatment F10 over control F0.

Table 1: Plant height (cm) of quality protein maize as influenced by INM management practices

Treatment	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
F0	49.67	89.67	139.00	151.00
F1	68.00	117.67	163.00	178.00
F2	60.67	108.33	155.33	168.00
F3	63.67	112.00	159.67	174.00
F4	75.33	126.67	176.67	190.00
F5	71.00	121.67	167.00	182.67
F6	67.00	114.67	162.33	177.67
F7	59.67	106.67	153.33	166.67
F8	62.00	110.67	158.67	173.67
F9	73.33	122.00	174.67	185.67
F10	70.67	119.67	165.33	181.33
F11	65.67	113.00	163.33	176.67
S.Em±	2.40	3.32	2.14	2.36
CD (0.05)	7.05	9.73	6.26	6.91

Table 2: Dry matter accumulation (g plant^{-1}) in cob of quality protein maize as influenced by nutrient management practices

Treatments	Dry matter accumulation (g plant^{-1})			
	30 DAS	60 DAS	90 DAS	at harvest
F0	11.34	129.72	162.61	257.44
F1	16.24	139.50	184.45	274.94
F2	12.73	134.35	171.10	267.60
F3	15.15	136.55	178.76	270.26
F4	21.34	142.71	198.28	288.10
F5	18.18	141.29	192.57	281.06
F6	15.39	138.59	181.62	273.45
F7	12.67	133.52	166.54	264.37
F8	13.31	135.13	174.49	268.65
F9	20.64	144.19	190.72	283.54
F10	17.52	140.67	187.42	277.58
F11	14.56	137.74	176.38	271.88
S.Em±	1.58	2.21	4.21	3.35
CD (0.05)	4.62	6.47	12.34	9.83

Table 3: Leaf area index (LAI) of quality protein maize as influenced by nutrient management practices

Treatment	Leaf area index (LAI)			
	30 DAS	60 DAS	90 DAS	at harvest
F0	0.35	2.41	3.28	3.23
F1	0.51	2.68	3.59	3.57
F2	0.40	2.49	3.43	3.40
F3	0.44	2.58	3.50	3.48
F4	0.63	2.81	3.66	3.64
F5	0.55	2.74	3.61	3.58
F6	0.47	2.64	3.57	3.54
F7	0.38	2.47	3.40	3.40
F8	0.42	2.55	3.48	3.46
F9	0.62	2.83	3.64	3.62
F10	0.53	2.70	3.60	3.59
F11	0.47	2.61	3.54	3.52
S.Em±	0.03	0.02	0.03	0.03
CD (0.05)	0.09	0.07	0.08	0.08

Conclusion

The following conclusion may be made based on the findings of the current investigation, which was carried out over the course of two consecutive Rabi seasons:

75% RDF ($N:P_2O_5:K_2O$) at 140:70:70 kg ha^{-1} + FYM 5 tha^{-1} + AZ @ 7.5 kg ha^{-1} + PSB @ 7.5 kg ha^{-1} application provided the significantly highest growth parameters in QPM and was discovered to be the most lucrative treatment in comparison to other QPM treatments in terms of economic returns (net return and B:C ratio).

Significant results were obtained with the application of RDF plus foliar sprays of zinc at 0.1% and iron at 0.1% (twice sprayed). highest growth parameters and was discovered to be the most lucrative among the other QPM treatments in terms of economic returns (net return and B:C ratio).

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