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Yeild Variability Studies and Proximate Analysis of Two Varieties of Maize (*Zea mays* L.) Exposed to Iron Oxide Nanoparticles

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Abstract: A study of yield variability studies and proximate analysis of two maize varieties (Sammaz-S2 and Bida maize) was conducted at the Botanical Garden of the Department of plant Science and Biotechnology, Federal University of Lafia during the 2024 cropping season. Four concentrations of iron oxide nanoparticles (0 RPM, 20 RPM, 40 RPM, and 80 RPM) were prepared and applied as a foliar spray to maize varieties at thrice. The experiment was set in a Randomized Complete Block Design (RCBD) with three replications. Number of cobs per plant fresh and dry weight of 100 seeds were used to determine the yield variability, moisture, ash, carbohydrate, protein and protein were checked for proximate composition. The results showed that Sammaz-S2 performed better, with increased cob numbers and improved seed traits at 20 RPM, while Bida maize showed limited response. At 40 RPM, both varieties experienced reduced productivity, indicating nanoparticle toxicity, though partial recovery at 80 RPM suggests stress adaptation. Fresh seed weight increased at 20 RPM, particularly in Bida maize, reflecting enhanced hydration, while dry weight peaked at 40 RPM, suggesting optimized nutrient storage. Proximate composition analysis showed increased ash and carbohydrate content at moderate doses but reduced moisture and fat levels with higher nanoparticle concentrations. Protein and fibre responses were based on genotype type. These findings demonstrate the potential of iron oxide nanoparticles to improve maize productivity and nutritional quality when used at optimal doses, emphasizing the importance of dose calibration to avoid toxicity.

Keywords: Iron oxide nanoparticles, maize, yield variability, proximate analysis

Introduction

Maize (*Zea mays* L.), belonging to the family Poaceae, is one of the most important staple crops globally, playing a vital role in food security, livestock feed, and bioenergy. Its domestication in North and South America has made it central to agriculture for millennia [1]. However, the increasing global demand for food necessitates innovative agricultural practices to enhance crop productivity and sustainability. Traditional methods face challenges such as nutrient deficiencies, pest infestations, and environmental stressors. Iron oxide nanoparticles have emerged as a potential solution to enhance plant growth, nutrient uptake, and stress resistance.

This study investigates the effects of Iron oxide nanoparticles on maize yield and proximate composition, focusing on two varieties: Sammaz-S2 and Bida maize. The application of nanoparticles in agriculture offers a sustainable approach to improving crop productivity while minimizing environmental impacts. Understanding the interaction between plants and nanoparticles is crucial, as effects vary depending on crop species, environmental conditions, and farming practices [2, 3]. This study aims to evaluate the effects of different Iron oxide nanoparticles concentrations on maize yield variability and proximate composition, providing insights into their potential benefits and risks.

Materials and Methods

Study area

The study was conducted in Lafia, Nasarawa State, Nigeria (latitude 8°28'N, longitude 8°52'E, elevation 158 meters above sea level), located in the southern Guinea Savannah region. Proximate analysis was carried out at the Department of Chemistry Laboratory, Federal University of Lafia.

Experimental design

The experiment was conducted in a screen house at the Botanical Garden of the Department of Plant Science and Biotechnology, Federal University of Lafia, during the 2024 cropping season. Maize seeds (Sammaz-S2 and Bida maize) were obtained from the Nasarawa Agricultural Development Program (NADP). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Four concentrations of Iron oxide nanoparticles (0 RPM, 20 RPM, 40 RPM, and 80 RPM) were applied as foliar sprays.

Preparation of iron oxide nanoparticles

Iron oxide nanoparticles were synthesized using a modified protocol [4]. A 0.01 M Fe(NO33)33·9H22O solution was prepared using ethanol as the solvent and added to avocado leaves soaked in ethanol. The reduction reaction resulted in the formation of black Iron oxide nanoparticle, which were air-dried to obtain solid nanoparticles.

Data collection

Yield data (number of cobs per plant, fresh and dry weight of 100 seeds) were collected at harvest. Proximate analysis was conducted to determine moisture, ash, carbohydrate, protein, fat, and fibre content using standard methods [5].

Statistical analysis

Data were analyzed using a two-way analysis of variance (ANOVA), and means were separated using the Least Significant Difference (LSD) at a 5% probability level using GENSTAT.

Results and Discussion

Yield variability

Sammaz-S2 exhibited superior performance at 20 RPM, with increased cob numbers and improved seed traits, while Bida maize showed limited response. At 40 RPM, both varieties experienced reduced productivity, indicating nanoparticle toxicity. Partial recovery at 80 RPM suggested stress adaptation (Table 1). Fresh seed weight increased at 20 RPM, particularly in Bida maize, reflecting enhanced hydration, while dry weight peaked at 40 RPM, indicating optimized nutrient storage (Table 2). These findings align with existing literature that suggests nanoparticles can enhance plant growth and productivity, but their effects are highly dependent on the concentration and application method [6, 7].

Table 1: Effects of number of cobs per plant of two varieties of maize treated with iron oxide nanoparticles

Varieties Treatments	Bida maize	Sammaz-S2	Total	LSD 0.05
Control	3.50 ± 0.71	3.00 ± 1.41	**3.17 ± 0.94**	2.75
20 RPM	3.00 ± 1.41	4.50 ± 0.71	**4.33 ± 2.61**	
40 RPM	2.00 ± 0.00	1.00 ± 0.00	**3.00 ± 1.54**	
80 RPM	2.50 ± 2.12	3.00 ± 1.41	**2.58 ± 1.56**	
Total	2.75 ± 1.16	2.88 ± 1.55		
LSD 0.05	2.75			

The values represent the mean ± standard deviation (n = 2). Values marked with an asterisk (*) are statistically significant (p > 0.05) as their differences exceed the Least Significant Difference (LSD)

Table 2: Effects of fresh and dry weight of 100 seeds in the treated with iron oxide nanoparticles

Varieties	Bida Maize		Sammaz-52 maize		Total	LSD0.05
Treatments	Wet	Dry	Wet	Dry		
control	23.75 ± 3.46	22.70 ± 1.70	42.47 ± 2.64	26.88 ± 2.38	**29.87 ± 7.94**	
20 RPM	37.05± 15.77	28.55 ± 3.75	36.59± 19.85	23.18 ± 0.90	**34.61 ± 9.29**	
40 RPM	29.25 ± 2.62	25.95 ± 4.03	40.42 ± 0.69	32.40 ± 6.38	**30.54± 10.23**	
80 RPM	37.15 ± 1.77	31.55 ± 0.92	41.97 ± 23.55	35.79 ± 7.84	**33.26 ± 8.96**	10.23
LSD 0.05			10.23			

The values represent the mean ± standard deviation (n = 2). Values marked with an asterisk (*) are statistically significant (p > 0.05) as their differences exceed the Least Significant Difference (LSD).

Table 3: Proximate composition in Bida maize treated with iron oxide nanoparticle

Variety	Bida maize					
Treatment/Site	Ash content %	Moisture content %	Crude fat content %	Crude protein content %	Crude fibre content %	Carbohydrate
Control	2	60	1.3	7.7	6	23.0
20 RPM	4	20	3.1	8.2	4	60.7
40 RPM	8	65	2.1	6.2	4	14.7
80 RPM	2	40	1.4	8.5	6	52.1

Table 4: Proximate composition in Sammaz-52 maize treated with iron oxide nanoparticle

Variety	Sammaz-52 maize					
Treatment/Site	Ash content %	Moisture content %	Crude fat content %	Crude protein content %	Crude fibre content %	Carbohydrate
Control	3.3	60	3.2	8.5	6	19
20 RPM	6	60	2.1	8.1	12	11.8
40 RPM	2	60	1	7.9	6	76.9
80 RPM	4	40	3.2	7.3	8	37.5

Proximate composition

Proximate analysis revealed increased ash and carbohydrate content at moderate nanoparticle doses but reduced moisture and fat levels at higher concentrations. Protein and fibre responses were based on genotype (Tables 3 and 4). These findings align with previous studies [8, 9, 10] highlighting the potential of Iron oxide nanoparticles to enhance maize productivity and nutritional quality when applied at optimal doses.

Conclusion

This study highlights the significant effects of iron oxide nanoparticles on maize productivity and seed traits, including cob production, seed weights, and proximate composition. Sammaz-S2 performed better, with increased cob numbers and improved seed traits at 20 RPM, while Bida maize showed limited response. At 40 RPM, both varieties experienced reduced productivity, indicating nanoparticle toxicity, though partial recovery at 80 RPM suggests stress adaptation.

Fresh seed weight increased at 20 RPM, particularly in Bida maize, reflecting enhanced hydration, while dry weight peaked at 40 RPM, suggesting optimized nutrient storage. Proximate composition analysis showed increased ash and carbohydrate content at moderate doses but reduced moisture and fat levels with higher nanoparticle concentrations. Protein and fibre responses were based on genotype type.

These findings demonstrate the potential of iron oxide nanoparticles to improve maize productivity and nutritional quality when used at optimal doses, emphasizing the importance of dose calibration to avoid toxicity.

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