The Pharma Innovation Journal 2023; SP-12(6): 312-316

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(6): 312-316

www.thepharmajournal.com
Received: 11-03-2023
Accepted: 16-04-2023

D Gopal
S.V. Agricultural College, Acharya N. G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

TNVKV Prasad
S.V. Agricultural College, Acharya N. G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

Ch. Bhargava Rami Reddy
Nanotechnology laboratory, Institute of Frontier Technology, Regional Agricultural Research Station, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

AR Nirmal Kumar
S.V. Agricultural College, Acharya N. G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

R Naseeruddin
S.V. Agricultural College, Acharya N. G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

MVS Naidu
S.V. Agricultural College, Acharya N. G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

Corresponding Author:
D Gopal
S.V. Agricultural College, Acharya N. G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India

Enhancing micronutrients content in rice through nanoparticulate delivery of silica

D Gopal, TNVKV Prasad, Ch. Bhargava Rami Reddy, AR Nirmal Kumar, R Naseeruddin and MVS Naidu

Abstract
Recent years have witnessed an increasing acknowledgment of the remarkable impact that nanoscale particles have on plant growth. The unique properties exhibited by these particles offer exciting opportunities for enhancing various aspects of plant development. This study was aimed to investigate the effect of different concentrations of silicon dioxide (SiO_2) nanoparticles (NPs) on content of micronutrient in rice a completely randomized design with three replications. This study explores the effects of foliar spraying, using different concentrations (50, 100, 200, 400, 600, 800, and 1000 ppm) of nanoscale silica (SiNPs) and silicic acid (4 ml/l), on the content of micronutrients such as zinc, copper, iron and manganese in straw and grain of rice at harvest. The highest recorded values for micronutrients content and uptake were observed in the T_6 treatment (RDF + SiNPs @ 200 ppm) during the harvest stage, both in terms of straw and yield. The results of this study provide compelling evidence that the foliar application of particulate nanoscale silica plays a pivotal role in promoting increased growth and yield in rice.

Keywords: Nanoscale, silica, content, micronutrients, rice

1. Introduction

Nanotechnology, an emerging and intriguing field, holds immense promise for revolutionizing the agricultural sector. It enables advanced research and discoveries that can lead to novel applications and transformative solutions in agriculture (Tipu *et al*., 2021) [4]. The integration of nanotechnology in agriculture has the potential to revolutionize crop production, resource management, pest control, and overall sustainability in the field. While, silicon (Si) has traditionally been regarded as a non-essential element for plant growth and development, recent studies have highlighted the significant benefits of Si application in mitigating the detrimental effects of both abiotic and biotic stress on plants. Extensive research has emphasized the positive impact of Si in enhancing the tolerance of plants to abiotic stress, particularly salt and water stresses (Bauer *et al*., 2011) [1]. Si has been shown to contribute to osmotic regulation and reduce oxidative damage in plants experiencing stress. These mechanisms include the activation of key enzymes involved in photosynthesis, enhancement of antioxidative enzymes (Hajizadeh *et al*., 2021) [3], improvement of hydraulic conductivity, increased nutrient uptake (Shen *et al*., 2010) [2], stimulation of root growth, and enhancement of water use efficiency. These combined effects contribute to the overall resilience and productivity of plants subjected to drought stress when Si is applied.

2. Materials and Methods

A pot experiment was conducted during the *kharif* season of 2021 at S.V Agricultural College, Acharya N.G Ranga Agricultural University in Andhra Pradesh, India. The objective of the experiment was to enhancing micronutrients content in rice through nanoparticulate delivery of silica. The experimental design employed a complete randomized block design with three replications. Each pot, measuring 25×25 cm, was filled with ten kilograms of soil, and three seedlings were transplanted into each pot.

The experiment consisted of ten treatments as follows: T_1 - control (distilled water), T_2 - recommended dose of fertilizer (RDF: 120-60-40 kg of N, P_2O_5, and K_2O per hectare), T_3 - RDF + silicic acid at a concentration of 4 ml/l, T4 - RDF + nanoscale silica particles (SiNPs) at a concentration of 50 ppm, T_5 - RDF + SiNPs at a concentration of 100 ppm, T6 - RDF + SiNPs at a concentration of 200 ppm, T_7 - RDF + SiNPs at a concentration of 400 ppm, T8 - RDF + SiNPs at a concentration of 600 ppm, T_9 - RDF + SiNPs at a concentration of 800 ppm, and T10 - RDF + SiNPs at a concentration of 1000 ppm. The foliar application of nanoscale silica and bulk silica was performed twice, at 25 and 50 days after transplanting (DAT). The fertilizers, including N, P, and K, were applied at the rate of 120, 60, and 40 kg/ha, respectively. Phosphorous (single super phosphate) and potassium (muriate of potash) were applied before transplantation, while nitrogen (urea) was applied in three splits. During transplanting, 40% of the urea was applied, followed by another 40% at 30 DAT, and the remaining 20% at 60 DAT.

2.1 Plant analysis

2.1.1 Collection and preparation of plant samples: The plant samples collected at harvest stage (in straw and grain) of rice were shade dried and subsequently dried in a hot air oven at 65 ^{0}C to a constant weight. The plant samples were ground in willey mill and stored in labelled brown paper bags for analysis.

2.1.2 Estimation micronutrients

Zinc, copper, manganese, and iron in the di-acid extract were determined using atomic absorption spectrophotometer as per the specifications mentioned by Lindsay and Norvell (1978).

2.2 Nutrient Uptake

The uptake of nutrients at harvest in both straw and grain was worked out by using the following formula. Micronutrient uptake was expressed in g ha^{-1}.

$$\text{Nutrient Uptake (g ka}^{-1}\text{)} = \frac{\text{Nutrient content (kg ha}^{-1}\text{) X dry matter production (g ha}^{-1}\text{)}}{1000}$$

2.3 Stastical analysis

The data recorded for different parameters were statistically analyzed using the method of analysis of variance technique for completely randomized design as suggested by Panse and Sukhatme (1978).

3. Results and Discussion

3.1. Zinc content

Data on effect of nanoparticulate silica application on zinc content in straw and grain at harvest was presented in Table 1 and Fig. 1a. The results indicated that zinc content was significantly increased by foliar application of SiNPs.

At straw and grain and at harvest stage T_6 (SiNPs @ 200 ppm along with the RDF) treatment significantly recorded highest zinc content (23.54 and 36.75 ppm in straw and grain) over T_5 (SiNPs @ 100 ppm along with the RDF), T_3 (RDF + silicic acid 4 ml l^{-1}) and T4 (SiNPs @ 50 ppm along with the RDF) but that was on par with the SiNPs @ 400 ppm along with the RDF -T_7 (23.11 and 36.31 ppm in straw and grain), SiNPs @ 600 ppm along with the RDF -T_8 (22.97 and 36.11 ppm in straw and grain), SiNPs @ 800 ppm along with the RDF -T_9 (22.97 and 35.87 ppm in straw and grain) and SiNPs @ 1000 ppm along with the RDF -T_{10} (22.91 and 35.56 ppm in straw and grain). The minimum zinc content was (18.37 and 27.44 ppm in straw and grain) recorded with RDF alone (T_2) and control (T_1).

Several strands of evidence indicate interaction between Si and zinc (Zn) in plants under both deficient and excess Zn conditions (Bityutskii *et al*., 2014**)** [5]. For instance, Si application prevented certain symptoms of Zn-deficiency in cucumber plants, most probably due to its indirect effect by enhancing antioxidant defense capacity in plant tissues, rather than to its direct effect on mobility, uptake and tissue distribution of Zn (Bityutskii *et al*., 2014) [5].

3.2 Copper content

There was a significant increase in copper content at harvest (in straw and yield) of rice by application of various silicon sources and concentrations (Table 1 and Fig. 1b)

The highest copper content was recorded (13.42 and 23.10 ppm in straw and grain at harvest stage, respectively) in T_6 (SiNPs @ 200 ppm along with the RDF) treatment and lowest potassium content was recorded (9.82 and 17.52 ppm at straw and grain of harvest stages) in RDF treatment (T_2) and (6.54 and 12.13 ppm at straw and grain of harvest stages) control (T_1). Next best treatment were SiNPs @ 400 ppm along with the RDF -T_7 (13.22 and 22.76 ppm at straw and grain of harvest stages), SiNPs @ 600 ppm along with the RDF -T_8 (13.20 and 22.46 ppm at straw and grain of harvest stages), SiNPs @ 800 ppm along with the RDF -T_9 (12.97 and 22.43 at straw and grain of harvest stages) and SiNPs @ 1000 ppm along with the RDF -T_{10} (12.91 and 22.10 at ppm straw and grain of harvest stages). T_6 (SiNPs @ 200 ppm along with the RDF) treatment was statistically significant with T5 (SiNPs @ 100 ppm along with the RDF), T_3 (RDF + silicic acid 4 ml L^{-1}) and T_4 (SiNPs @ 50 ppm along with the RDF).

Si deposits formed in the cell walls increased Cu-binding sites and thus decreased impact of high Cu level in plant cells (Li *et al*., 2008) [6]. Furthermore, the expression of metallothioneins (MTs), the Cu-binding molecules, was maintained at high levels or is even increased in Si-treated plants suggesting that Si may also contribute to regulation of intracellular homeostasis of Cu, besides extending the additional cell wall binding sites for Cu (Khandekar and Leisner, 2011) [7].

3.3 Iron content

Data on effect of nanoparticulate silica application on iron content at harvest (straw and grain) was presented in Table 1and Fig. 2a**.** The results indicated that iron content was significantly increased by foliar application of SiNPs.

In straw and grain at harvest stage T_6 (SiNPs @ 200 ppm along with the RDF) treatment significantly recorded highest iron content (107.23 and 62.12 ppm) over T_3 (RDF + silicic acid 4 ml l^{-1}) but it was on par with the T_7 (106.77 and 61.98 ppm), T_8 (106.46 and 61.23 ppm), T_9 (106.33 and 60.56 ppm) and T_{10} (105.89 and 60.21 ppm). T_6 (SiNPs @ 200 ppm along with the RDF) treatment was statistically significant with T_5 (SiNPs @ 100 ppm along with the RDF), T_3 (RDF + silicic acid 4 ml l^{-1}) and T_4 (SiNPs @ 50 ppm along with the RDF. Minimum iron content (85.23 and 52.06 ppm) was recorded with application of RDF alone (T_2) and (71.25 and 39.56 ppm) Control (T_1).

Hernandez-Apaolaza *et al*. (2020) [8]. reported that Si addition strongly affects Fe availability in the rhizosphere and the root apoplast (directly or indirectly), as well as the expression of genes involved in Fe transport at both root and leaf level, thus influencing Fe uptake, translocation and distribution within different plant organs and tissues.

3.4 Manganese content

The Manganese content in rice of straw and grain of rice followed the similar trend as that of zinc, copper and iron content (Table 1 and Fig. 2b). Application of RDF along with two foliar sprays of SiNPs @ 200 ppm (T_6) was recorded higher content (61.23 and 45.40 ppm) of manganese, which was statistically significant with RDF + SiNPs @ 100 ppm - T_5 (49.17 and 39.22 ppm), RDF + silicic acid @ 4 ml l^{-1} -T_3 (48.56 and 38.56 ppm) and over RDF + SiNPs @ 50 ppm -T_4 (45.10 and 34.89 ppm). The next best treatments were RDF + SiNPs @ 400 ppm (T_7), RDF + SiNPs @ 600 ppm (T_8), RDF + SiNPs @ 800 ppm and RDF + SiNPs @ 1000 ppm (T_{10}). Lowest manganese content was recorded with the treatments RDF alone (T_2) and control (T_1).

Greger *et al*. (2018) [10] showed that Si applied to soil increases manganese (Mn) availability and promotes Mn uptake and translocation to shoots in various plant species grown under conditions of adequate Mn supply. Blamey *et al.* (2018) [9] demonstrated that Si decreases Mn toxicity symptoms in cowpea, soybean and sunflower through increased Mn localization in leaf tissues by directly increasing apoplastic sequestration of Mn, in a nontoxic form, thereby decreasing apoplastic Mn^{2+} and excess Mn accumulation in the cytoplasm or apoplast. Elevated Mn concentrations may have inhibited photosynthesis through several mechanisms, including suppressing chlorophyll and ATP synthesis, decreasing light harvesting processes, impairing (PSI) stability and structure, and slowing activity of phosphoribulokinase.

Table 1: Effect of different concentrations of nanoparticulate silica on Zn, Cu, Fe and Mn (ppm) content of rice in pot culture experiment

Treatments	Zn		Cu		Fe		Mn	
	straw	grain	straw	grain	straw	grain	straw	grain
T_1- Distilled water spray	12.45	18.63	6.54	12.13	71.25	39.56	26.45	18.56
T_2- RDF (120-60-40 of N-P_2O_5-K_2O)	18.37	24.09	9.82	17.52	85.23	52.06	44.56	34.56
T_3- RDF + Foliar application of silicic acid @ 4 ml L^{-1}	20.24	26.14	10.55	19.33	91.52	54.56	48.56	38.56
T_4 - RDF + Foliar application of nanoscale silica @ 50 ppm	19.15	24.56	9.91	17.87	86.10	52.15	45.10	34.89
T_5 - RDF + Foliar application of nanoscale silica @ 100 ppm	20.54	26.17	11.00	20.11	92.11	55.62	49.17	39.22
T_6 - RDF + Foliar application of nanoscale silica @ 200 ppm	23.54	33.09	13.42	23.10	107.23	62.12	61.23	45.40
T_7 - RDF + Foliar application of nanoscale silica @ 400 ppm	23.11	32.84	13.22	22.76	106.77	61.98	60.75	45.10
T_8 - RDF + Foliar application of nanoscale silica @ 600 ppm	22.97	32.76	13.20	22.46	106.46	61.23	60.45	44.77
T_9 - RDF + Foliar application of nanoscale silica @ 800 ppm	22.97	31.52	12.97	22.43	106.33	60.56	60.11	44.15
T_{10} - RDF + Foliar application of nanoscale silica @ 1000 ppm	22.91	30.71	12.91	22.10	105.89	60.21	59.66	43.56
S.Em±	0.30	0.36	0.20	0.33	1.47	0.78	0.83	0.65
CD (0.05)	0.88	1.07	0.60	0.96	4.34	2.30	2.44	1.92

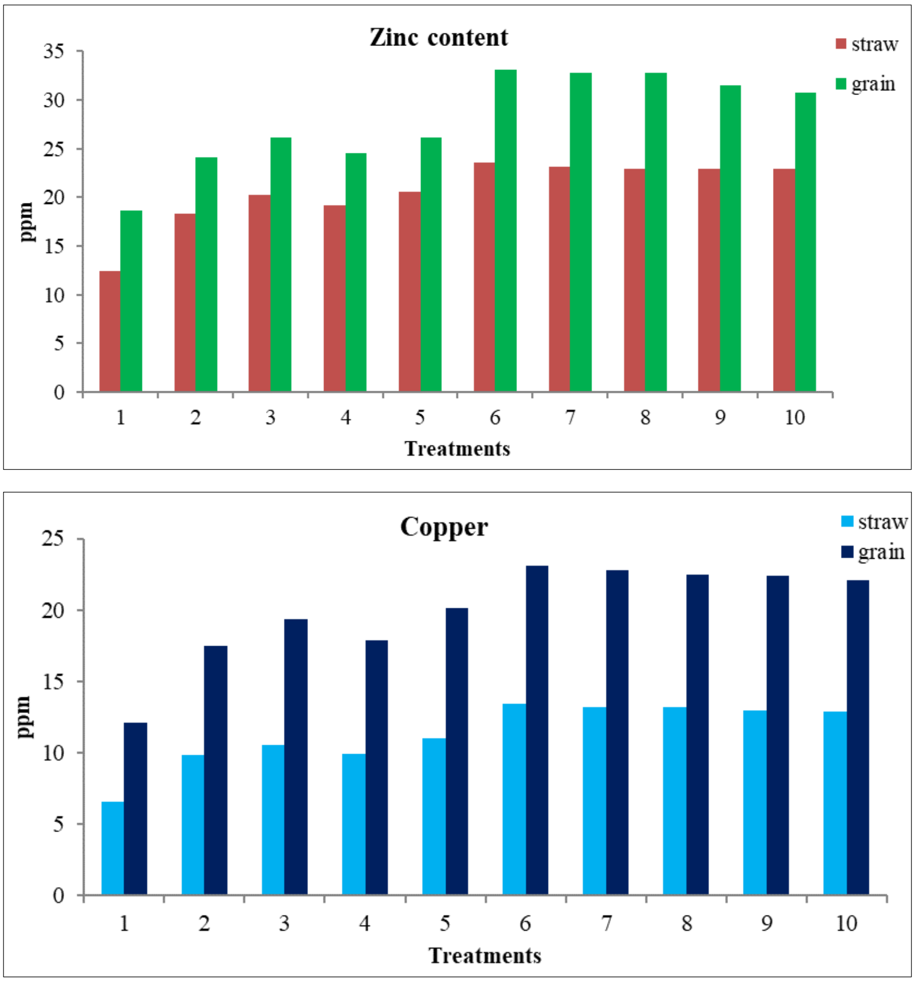

Fig 1: Effect of nanoscale silica on, a) zinc content (ppm) in rice; b) copper content (ppm)

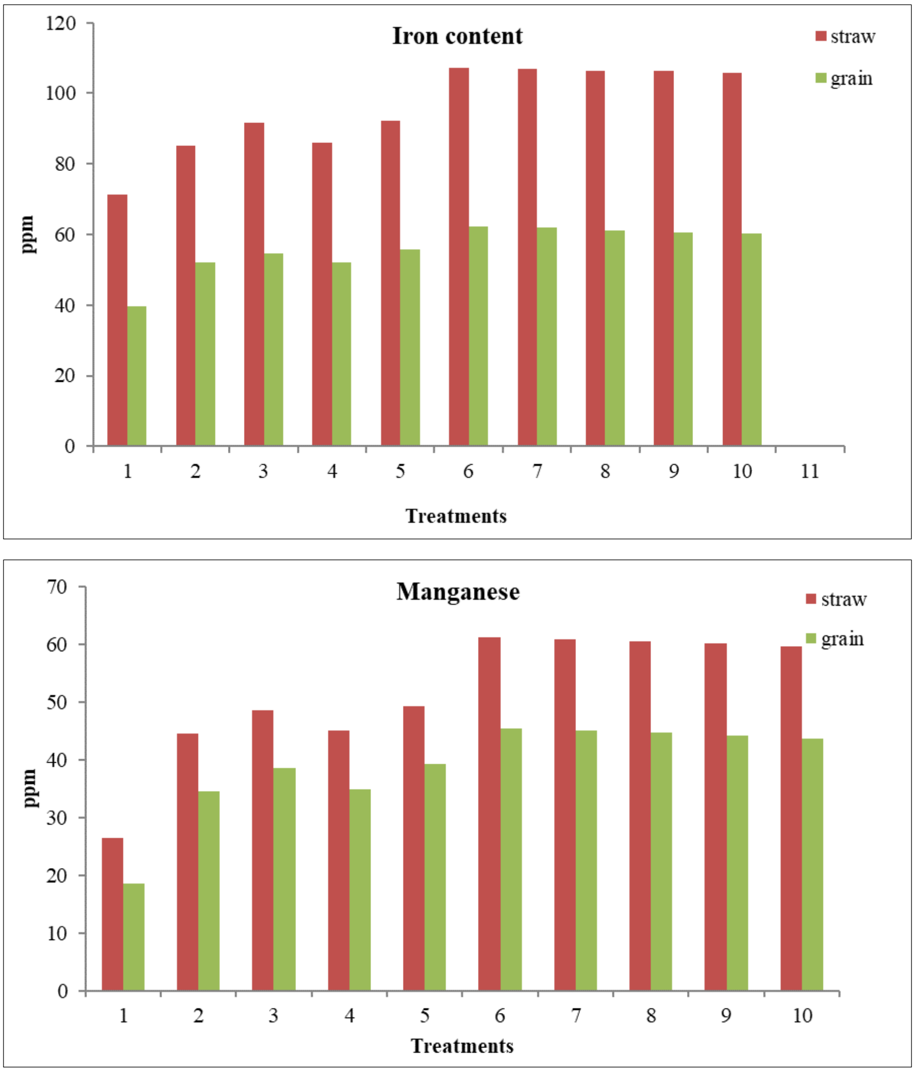

Fig 2: Effect of nanoscale silica on, a) iron content (ppm) in rice; b) manganese content (ppm)

5. Conclusion

the study demonstrated that foliar spraying with different concentrations of nanoscale silica nanoparticles and silicic acid had a significant impact on the micronutrient content in rice straw and grain at harvest. The treatment with 200 ppm of nanoscale silica nanoparticles (T_6) resulted in the highest values for micronutrient content and uptake, surpassing other concentrations. These results provide strong evidence supporting the pivotal role of nanoscale silica nanoparticles in enhancing the growth and yield of rice. Future research can expand upon these findings to further optimize the application of nanoscale silica for maximizing crop productivity. The potential benefits of incorporating nanotechnology in agriculture hold promise for sustainable food production and nutrient management.

6. References

1. Bauer P, Elbaum R, Weiss IM. Calcium and silicon mineralization in land plants: transport, structure and function. Plant Science. 2011;180(6):746-756.
2. Shen X, Zhou Y, Duan L, Li Z, Eneji AE, Li J. Silicon effects on photosynthesis and antioxidant parameters of soybean seedlings under drought and ultraviolet-B radiation. Journal of plant physiology. 2010;167(15):1248-1252.
3. Hajizadeh HS, Asadi M, Zahedi SM, Hamzehpour N, Rasouli F, Helvacı M, *et al*. Silicon dioxide-nanoparticle nutrition mitigates salinity in gerbera by modulating ion accumulation and antioxidants. Folia Horticulturae. 2021;33(1):91-105.
4. Tipu MMH, Baroi A, Rana J, Islam S, Jahan R, Miah MS, *et al*. Potential applications of nanotechnology in agriculture: a smart tool for sustainable agriculture. In Agricultural Development in Asia-Potential Use of Nano-Materials and Nano-Technology. Intech Open; c2021.
5. Bityutskii N, Pavlovic J, Yakkonen K, Maksimović V, Nikolic M. Contrasting effect of silicon on iron, zinc and manganese status and accumulation of metal-mobilizing compounds in micronutrient-deficient cucumber. Plant physiology and Biochemistry. 2014;74:205-211.
6. Li J, Leisner SM, Frantz J. Alleviation of copper toxicity in Arabidopsis thaliana by silicon addition to hydroponic solutions. Journal of the American Society for Horticultural Science. 2008;133(5):670-677.
7. Khandekar S, Leisner S. Soluble silicon modulates expression of Arabidopsis thaliana genes involved in copper stress. Journal of Plant Physiology. 2011;168(7): 699-705.
8. Hernández-Apaolaza L, Escribano L, Zamarreño ÁM, García-Mina JM, Cano C, Carrasco-Gil S. Root silicon addition induces Fe deficiency in cucumber plants, but facilitates their recovery after Fe resupply. A comparison with si foliar sprays. Frontiers in Plant Science.

2020;11:580552.
9. Blamey FPC, McKenna BA, Li C, Cheng M, Tang C, Jiang H, *et al*. Manganese distribution and speciation help to explain the effects of silicate and phosphate on manganese toxicity in four crop species. New Phytologist. 2018;217(3):1146-1160.
10. Greger M, Landberg T, Vaculík M. Silicon influences soil availability and accumulation of mineral nutrients in various plant species. Plants. 2018;7(2):41.