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Application of Silica Fertilizer on Growth, Production, and SI Absorption of Rice Plants in Regosol Soil

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***Abstract*— *Silica as a beneficial element plays a role for rice plants to increase plant growth, production, and resistance to pest and disease attacks. The purpose of this study was to determine the effect of the best concentration of silica fertilizer on the growth, production, and absorption of Si, N, P, K in rice plants. Fertilization is given at the age of 14 HST and 30 HST. The study used a complete group random design (RAKL) with 3 replications. The level of concentration treatment was without silica (control); 400 ppm; 800 ppm; 1200 ppm; 1600 ppm; and 2000 ppm was performed. The observation data was analyzed using multiple fingerprints (ANOVA) at a level of 5% if there was a significant difference, followed by the Duncan's Multiple Range Test (DMRT). The results showed that the concentration of silica fertilizer of 1200 ppm equivalent to 1.2 grams/L showed a significant improvement in the parameters of dry weight of leaves, total dry weight; weight of 1000 filled grains, weight of filled grains, total grain weight of condensation, and rice harvest. However, not in the parameters of plant height, and number of seedlings. The concentration of silica fertilizer of 1200 ppm is able to increase the level and absorption of silica elements in plant tissues.*

***Keywords*— *Silica, growth, production, absorption Si, rice.*

I. INTRODUCTION

Nutrients plays a crucial role in the growth, development, and productivity of plants, such as silica. Silica (Si) is a category of *beneficial elements,* which are elements that are beneficial to certain types of plants. The type of plant that requires silica in abundance is called silica accumulator, namely the grass family (*Gramineae*) such as rice, sugarcane, and wheat.

The part of rice plants that has a high silica content is found in husks and straw with a composition of 70.8% [1]. The silica element for rice plants plays a role in increasing plant resistance to pest and disease attacks such as blisters, leaf blight, and stem rot. In addition, silica also plays a role in increasing rice grain production, collapse resistance, and enzyme activity [2]. High amounts of Si absorption in rice plants make plants have more upright leaves (not drooping) so that the leaves are more effective at capturing sunlight and efficient in using nitrogen [3].

The phenomenon of rice collapse can occur during the seed filling period until harvest. As a result of collapse, rice can experience a decrease in quality because panicles are waterlogged so that the grain grains become empty even after the panicles are filled with black grain. Thus, rice production can decrease drastically. Some farmers do ways to reduce the losses of collapse by tying several rice clumps so that they become upright again. This method is considered quite effective on a small land. However, not for large land.

According to the Buleleng Agriculture Office [4], rice collapse can occur due to excessive N fertilization factors so that plant overgrowth and stem strength are reduced. Apart from fertilization factors, environmental factors such as wind strength and rainfall also worsen the level of rice fertility. Therefore, to minimize the potential for collapse, nutrients can be provided that can strengthen the plant cell wall.

The land of Regosol is spread quite widely in Klaten Regency, because it is influenced by the geographical conditions of Klaten Regency which cannot be separated from the influence of the volcanic activity of Mount Merapi. The silica content in Regosol soil can also come from the weathering of mineral rich parent rocks such as volcanic rocks (basalt and andesite) and granite. However, silica available to plants is not abundant because silica has strong bonds between minerals. The silica available in the soil will undergo a reduction every periodic time. According to [5], the silica content in the tropics is low because it undergoes intensive weathering. In addition, the absorption of silica by plants without biomass return also affects the availability of silica in the soil.

Silica as a *beneficial element* is expected to be able to create conditions for the availability of other elements, such as macroelements for plants. According to [3], silica application can increase nitrogen metabolism, induce changes in stoichiometry of carbon (C), and phosphorus on shoots to stabilize function and increase photosynthesis and increase nutrient acquisition by roots. Silica also plays a role in increasing the absorption of other elements such as nitrogen and modifying cellular structure to support plant growth against deficiencies of other elements [6]. The effect of applying silica to the element potassium is that it can restore physiological activity that is disrupted by K deficiency, namely by streamlining water use and photosynthesis [3].

II. MATERIALS AND METHODS

The research site is located in the experimental field of the Edu Farmers International Foundation located in Mlese Village, Ceper District, Klaten Regency, Central Java. The Integrated Laboratory, Faculty of Agriculture, UNS, and the Chemistry and Fertility Laboratory of the Soil Science Study Program, Faculty of Agriculture, UPN "Veteran" Yogyakarta, conducted the analysis.

The tools used in the study consisted of plastic bags, stickers, labels, stationery, meters, scissors, digital scales, brown envelopes, raffias, laboratory tools, laptops, and the SAS On Demand for Academics *website*. The materials used consist of seeds of the Inpari 32 variety aged 14 days after sowing, soil samples, plant samples, chemistry for analysis, basic fertilizers containing N, P, K, Si; insecticides, herbicides, fungicides, and bactericides.

This study used a non-factorial complete group random design (RAKL) with 3 replications. The treatment in the experimental design consisted of 6 levels of treatment for the concentration of silica fertilizer, namely S0 (control); S1 (400 ppm equivalent to 0.4 grams/L); S2 (800 ppm equivalent to 0.8 grams/L); S3 (1200 ppm equivalent to 1.2 grams/L); S4 (1600 ppm equivalent to 1.6 grams/L); and S5 (2000 ppm equivalent to 2 grams/L). Silica fertilizer is applied at the age of 14 HST and 30 HST through leaves in the morning. The factor for the implementation of RAKL is that there is a difference in height of 50 cm – 70 cm between each block which affects the difference in nutrient content and the amount of irrigation.

The study parameters included the assessment of agronomic traits such as plant height, number of seedlings, and dry weight of plants examined at the ages of 75 HST and 110 HST. Rice harvest character parameters such as the weight of 1000 filled grains, the weight of the fill grain, and the total grain weight of the condenser and the rice harvest at 110 HST. Analysis of the level and absorption parameters included the Si, N, P, and K elements of the plant at the age of 110 HST. In addition, supporting analysis was carried out, namely soil analysis at the beginning and after the research. Soil analysis consists of soil H^2O pH (potentiometry); silica available CaCl 0.01 M extract; nitrogen available KCl extract; Phosphorus available by *the Olsen* method of NaHCO3 extract; potassium available as an extract of NH4OAc 1 N pH 7; and soil texture is available by the pipette method. Data obtained from agronomic and nutrient absorption parameters were analyzed using fingerprint analysis (ANOVA) at a level of 5%, if there was a significant difference between treatments, further tests were carried out using the *Duncan's Multiple Range Test* (DMRT). Data processing using *website SAS OnDemand for Academics*.

III. Results and Discussion

Soil conditions are one of the important factors that need to be known before research to determine fertility potential. Preliminary analysis covers soil texture; pH; availability of N, P, K, and Si. The results of soil analysis before treatment are presented in Table 1.

The results in Table 1 of the soil texture at the research location are clay clay with the highest fractional comparative composition, namely dust, clay, and sand. This is influenced by the use of land for agriculture that undergoes further processing. The texture of rice fields is dominated by fine to medium fractions suitable for agriculture [7]. This result is supported by the statement of [8] that the ideal soil conditions for rice growth are sand to clay textured.

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The pH value range of 6.20 to 6.48 has a rather sour dignity. This condition is affected by irrigation which causes reminiscence, creating a sour atmosphere. In a acidic atmosphere, there will be alkaline leaching by water so that it causes an oxidative atmosphere and the pH of the soil will not decrease drastically [9].

TABLE 1. Initial soil conditions used in the study

No	Parameter	Blok I	Blok II	Blok III
1	Tekstur			
	Clay (%)	31,79	29,91	28,43
	Silt (%)	42,80	43,18	46,25
	Sandy (%)	25,41	26,91	25,32
	Texture class	Clay loam	Clay loam	Clay loam
2	pH H_2O	6,25	6,20	6,48
3	N-available (%)	0,008	0,007	0,007
4	P-available (ppm)	7,328	4,995	3,020
5	K-available (me%)	0,251	0,134	0,048
6	Si-available (%)	0,946	0,803	0,668

The results of nitrogen analysis showed that soil had values of 0.007% and 0.008% with very low value. Phosphorus available with values of 3.02 ppm and 4.99 ppm has a very low value, while a value of 7.328 ppm has a low value. The available potassium elements have a low value of 0.251 me% and 0.134 me% and a very low value of 0.048 me%. Silica elements are available with a value range of 0.668 % to 0.946 %.

Supporting analysis of soil parameters after treatment was taken after harvest on each block, due to the use of the same amount of basic fertilizer. The results of the soil analysis after treatment are presented in Table 2.

TABLE 2. Final Conditions of Soil used in the Research

No	Parameter	Blok I	Blok II	Blok III
1	pH H_2O	6,45	6,25	6,17
2	N-available (%)	0,005	0,004	0,003
3	P-available (ppm)	12,383	7,441	6,458
4	K-available (me%)	0,271	0,226	0,194
5	Si-available (%)	1,011	0,806	0,702

The pH of the soil after treatment has a value range of 6.17 to 6.45 with a slightly sour value. This value has the same value as the condition of the soil before treatment. According to [10] plants can grow well in mineral soils with a pH range of 5.8 to 6.5. pH condition of the soil where the study was conducted was included in the optimal category for plant growth.

Factors that affect soil pH values at the research site are irrigation, rainfall, and fertilization. Irrigation activities cause reminiscence, which can create a sour atmosphere because there is a reduction and washing of alkaline by water. Application of fertilizers can leave a physiological reaction that affects the pH of the soil. SP-26 fertilizer contains phosphorus, when dissolved it will release H^+ ions and cause a decrease in soil pH [11]. Likewise, ZA, Urea, and NPK fertilizers have an acidic physiological reaction [12], while KCl fertilizer is a fertilizer that has a neutral physiological reaction because it does not produce H^+ or OH ions when dissolved [13].

The source of nitrogen in the soil comes from fertilization, namely ZA (*Zwalvelzure ammonia*), NPK Phonska, and Urea. According to [14], ZA fertilizer contains N in the form of

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ammonium (NH_4^+) and zinc (Zn). Urea fertilizer contains N in the form of urea ($CO(NH_2)_2$) [15].

N is available in soil after treatment has a value range of 0.003% to 0.005% with very low value. The available N value has the same value as the soil condition before treatment. N loss in soil can be affected by immobilization, denitrification, volatilization, leaching, transportation along with crops, and erosion [16].

Based on the results of the analysis, the low availability of N can be increased by fertilizer application. Referring to IAARD Regulation (2021) recommendations for single fertilization for urea with a dose of 350 kg/ha. If adjusted to the area of the experimental plot, an additional urea fertilizer of 0.595 kg/m^2 is needed. In the application of fertilizers, accuracy is also needed according to the 5T procedure, namely the right type, the right dose, the right time, the right way, and the right target.

The available P-value has a range of 6.458 ppm to 7.441 ppm with low value and a value of 12.589 ppm with medium value. When compared to the preliminary analysis, the available P levels experienced an increase that was expected from the application of basic fertilizers. The source of phosphorus in the soil comes from fertilization, namely SP-36 fertilizer. According to [11], SP-36 fertilizer contains P in the form of phosphate. the availability of low to medium P can be increased by applying fertilizer in accordance with the 5T procedure. Referring to IAARD Regulation (2021) recommendations for single fertilization for SP-36 with a dose of 50 kg/ha. If adjusted to the area of the experimental plot, an additional urea fertilizer of 0.085 kg/m^2 is needed.

The results of the final soil analysis found that the available potassium value has a low value range of 0.194 me% to 0.271 me%. When compared to the K value available in the preliminary analysis, there is an increase. However, the difference is not so much. The source of potassium found in the soil comes from fertilization, namely KCl (potassium chloride) fertilizer which is neutral to the soil.

Based on the results of the analysis, the availability of low K can be increased by the application of fertilizer. Referring to IAARD Regulation (2021) recommendations for single fertilization for KCl with a dose of 50 kg/ha. If adjusted to the area of the experimental plot, an additional urea fertilizer of 0.085 kg/m^2 is needed.

The silica value is available in the results of the final analysis of the research soil with a range of 0.702% to 1.011% which has increased from the initial soil analysis. The availability of silica can come from the decomposition of previous plant residues, for example rice plants because rice plants contain high silica elements [1]). The addition of silica value can be affected by the fertilization that takes place, namely when the application of silica fertilizer through the leaves of fertilizer droplets that do not hit the leaves fall to the ground and accumulate.

Si availability can be increased by the application of fertilizer. Referring to the statement of Subiksa (2018), the recommendation for silica fertilization is with a dose of 217 kg SiO_2/ha. If adjusted to the area of the experimental plot, an additional urea fertilizer of 0.369 kg/m^2 is needed.

Plant height is an assessment of the growth rate and the response of plants in nutrient absorption. The results of the measurement of plant height are presented in Table 3.

TABLE 3. Average Height of Plants Applied with Silica Fertilizer

Fertilizer Treatment	Average Plant Height (cm)	
	75 HST	110 HST
S0 : control	69,2 a	92,1 a
S1 : silika 400 ppm	76,6 a	93,3 a
S2 : silika 800 ppm	78,8 a	94,9 a
S3 : silika 1200 ppm	79,9 a	97,1 a
S4 : silika 1600 ppm	79,4 a	95,1 a
S5 : silika 2000 ppm	77,5 a	93,7 a

Information: The average followed by the same letter in the same column shows no real difference based on the DMRT test of 5%.

The results of the fingerprint analysis showed that the application of silica fertilizer did not have a significant effect on plant height (Table 3). Silica administration with a concentration of 400 ppm to 2000 ppm showed an increase. However, it is not so far away with silica-free treatment. The best plant height at the age of 75 HST and 110 HST is found in the silica treatment of 1200 ppm. Meanwhile, the lowest plant height is shown in the treatment without silica.

This is in accordance with the statement of [17] silica applications do not have a direct effect on plant growth, but can control abiotic and biotic stressors such as drought and disease pest attacks. Application of silica from several materials with a dose of 961.8 kg/ha has not been able to increase the height parameters of the plant, although it is able to support the development of roots and leaves. Furthermore, the use of silica has little impact on the vegetative phase, as evidenced by the assertion [18].

Table 4 of silica fertilizer application does not show noticeable differences in the number of saplings and the number of productive saplings. However, from each treatment the concentration of silica administration showed an improvement. The response of silica fertilizer to the highest number of saplings at the age of 75 HST and 110 HST was found in the treatment of silica 1200 ppm. Meanwhile, the lowest number of saplings is indicated in the treatment without silica. Likewise, highest number of productive saplings at the age of 75 HST and 110 HST was found in the silica treatment of 1200 ppm and the lowest value of the control treatment.

TABLE 4. Average Number of Saplings

Fertilizer Treatment	Number of Saplings		Number of productive saplings	
	75 HST	110 HST	75 HST	110 HST
S0 : control	26,8 a	18,6 a	8 a	15,2 a
S1 : silika 400 ppm	27,2 a	18,9 a	11,2 a	16,4 a
S2 : silika 800 ppm	27,4 a	21,7 a	11,4 a	18,6 a
S3 : silika 1200 ppm	31,6 a	22,8 a	13,3 a	19,1 a
S4 : silika 1600 ppm	27,7 a	22,3 a	12,7 a	18,7 a
S5 : silika 2000 ppm	27,4 a	21,5 a	12,9 a	18,3 a

Information: Numbers followed by the same letter in the same column show no real difference based on the DMRT test.

The amount of rice seedlings during the reproductive stage is lower than during the peak vegetative stage. The emphasis of plant development is linked to this, with the plant concentrating on producing roots, stems, and leaves during its vegetative phase. Meanwhile, in the generative period, growth focuses on the formation of panicles. Along with the generative phase, unproductive saplings will experience *senescense* (aging and shedding) so that the number of saplings decreases. This condition is in accordance with the results of [19] research, the number of saplings at the age of 60 HST decreases when compared to the age of 30 HST.

Environmental factors also affect the formation of the number of chicks. This is in accordance with the minimum law (Liebig) where plant growth can be affected by limited factors, thus affecting the number of saplings produced. Thus, it is suspected that irrigation and environmental factors affect the increase in the number of rice seedlings.

The sum of the dry weights of the roots, leaves, and stems of the rice plant constitutes its overall dry weight. Calculation of plant dry weight is important to assess plant metabolism because it can represent the results of plant metabolites [20]. The results of the observation of dry weight of leaves and total dry weight are listed in Table 5.

TABLE 5. Average Dry Weight of Leaves and Total Dry Weight

Fertilizer Treatment	Bobot Kering Daun (gram)		Bobot Kering Total (gram)	
	75 HST	110 HST	75 HST	110 HST
S0 : control	19,2 b	9,8 b	67,3 c	81,9 b
S1 : silika 400 ppm	19,7 b	10,0 b	82,0 bc	85,5 b
S2 : silika 800 ppm	21,4 b	11,3 ab	82,7 bc	95,7 ab
S3 : silika 1200 ppm	27,3 a	12,6 a	107,6 a	108,2 a
S4 : silika 1600 ppm	20,5 b	11,6 ab	85,8 bc	95,1 ab
S5 : silika 2000 ppm	22,1 ab	10,9 ab	102,0 ab	93,8 ab

Information: The number followed by different letters in the same column shows a real difference based on the DMRT test of 5%.

The application of silica has an effect on increasing the dry weight of the leaves and the total dry weight. The highest dry weight of leaves at the two observation times was found in the 1200 ppm silica treatment and the lowest value in the non-silica treatment. The dry weight of the leaves also affects the total dry weight. With demiikian, the total dry weight was highest in silica treatment at 1200 ppm and lowest value at non-silica treatment(Table 5).

The difference in the dry weight of leaves is influenced by the area of the plant's leaves, the wider the leaf, the greater the plant's ability to capture light to carry out the photosynthesis process so that it will affect the growth and development of the plant. The application of silica that can be absorbed by plants will undergo translocation through evapotranspiration flow and is polymerized and accumulated in stem and leaf tissues in the form of silica gel ($SiO_2.nH_2O$) which acts as a protector of the tissue [21]. In addition to being a plant protector, silica gel will thicken the cell wall and can affect the weight of the leaves themselves.

According to [22] silica accumulated on the cell wall can increase the dry weight of the crown, silica can increase the rate of photosynthesis and prevent chlorophyll damage so as to produce more photosyntheses. Thus, the application of silica can increase the dry weight of the crown and the two parameters have a continuous relationship with each other.

Grain weight is a rice harvest component that affects the quality and production of rice plants and reflects the optimal density and seed filling from the accumulated photosynthate rice harvest. The high weight of the grain reflects the efficiency of the plant in absorbing nutrients, performing photosynthesis, and translocating photosynthates to other parts of the plant. The results of the weight of 100 fill grains, fill grains, and total grains are presented in Table 6.

TABLE 6. Average Filled Weight 1000 Grains, Filled Grains Weight, and Total Grain Weight

Fertilizer Treatment	Filled Weight 1000 Grain (grams)	Filled Grain Weight (grams)	Total Grain Weight (grams)
S0 : control	25.67 d	23.74 d	25.47 e
S1 : silika 400 ppm	26.63 b	26.71 c	28.36 de
S2 : silika 800 ppm	26.73 b	29.58 b	31.12 cd
S3 : silika 1200 ppm	27.57 a	36.02 a	37.82 a
S4 : silika 1600 ppm	26.50 bc	32.32 b	34.20 b
S5 : silika 2000 ppm	26.07 cd	32.20 b	33.33 bc

Information: The number followed by different letters in the same column shows a real difference based on the DMRT test of 5%.

The administration of silica showed significantly different results in the increase in the filled weight 1000 grains, filled grain weight, and total grain weight which was characterized by an increase in value in each treatment. The highest 1000 ppm silica weight is found at 1200 ppm silica treatment and the lowest value is required without silica application. This is in accordance with the statement of [23] that the administration of Si is able to increase the number of seeds per panicel (the number of grains on one rice stalk) and the weight of 1,000 grains (Table 6).

The value of the weight of the filled grain without the application of silica showed the lowest results compared to silica treatment with a value range of 26 grams to 36 grams. The highest value of grain weight is found in the silica treatment of 1200 ppm. The value of the weight of the filled grain will also affect the total grain weight parameters. The total grain weight parameter shows the lowest value in the silica-free treatment. Meanwhile, treatment with silica showed a value range of 28 grams to 37 grams with the highest total grain weight in silica treatment of 1200 ppm.

Silica plays an important role in the formation and quality of rice grains and husks. According to [22]. The application of silica has a beneficial effect on plants, namely it can increase the rice harvest of both basic and dry grain per plant. The weight of the seeds is also affected by the accumulation of photosynthesis results that occur after flowering which will be translocated in the seed filling process. So that during the filling of the seeds of photosynthate that are formed and stored can be used to increase the weight of the seeds [25].

Rice harvest as an indicator assesses the success of rice cultivation from the treatment carried out. Rice harvest reflects the accumulation of the parameters of the number of tillers, the weight of 1000 grains, and the weight of the grain. The following rice harvest data is presented in Table 7.

The response of rice harvest to the application of silica fertilizer to the productivity variable showed significantly different results in Table 7, where the highest value was found in

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the 1200 ppm silica treatment [6.7 tons/ha] and the lowest value in the non-silica treatment [5.6 tons/ha]. The rice harvest obtained from 1200 ppm silica fertilization showed a 19.6% increase compared to without silica application. Silica plays an important role in the formation and quality of rice grains and husks so that it can affect rice harvest. However, if you look at rice productivity, it is 7 tons/ha, while the average rice harvest is 6.3 tons/ha. So that in the S3 treatment there was an increase of 6.35% from the average GKG result.

TABLE 7. Average Rice harvest

Fertilizer Treatment	Rice harvest (ton/ha)
S0 : tanpa silika	5,6 c
S1 : silika 400 ppm	5,7 c
S2 : silika 800 ppm	6,0 bc
S3 : silika 1200 ppm	6,7 a
S4 : silika 1600 ppm	6,4 ab
S5 : silika 2000 ppm	5,8 c

Remarks: The average followed by different letters in the column shows a real difference based on the DMRT test of 5%.

The application of silica and boron can increase the content of grain and reduce empty grain. The results of the study of [26] showed that the application of Silica fertilizer increased the rice harvest of harvested dry grain (GKP) by 50.8%. In addition, rice harvest are also influenced by grain weight as presented in Table 7 which shows the response of silica fertilizer application with the highest value, namely in silica treatment of 1200 ppm. A decrease in rice harvest value and agronomic parameter values at the highest silica fertilizer concentration indicates that excessive application will cause toxicity and cause poisoning to plants. So that the value produced does not get higher but decreases from a lower concentration.

Silica as *a beneficial element* is needed for certain types of plants, such as rice. Silica in plant tissue is immobile, because the element will accumulate in certain parts of the plant. The results of silica content and absorption analysis are presented Table 8.

TABLE 8. Average Silica Levels and Absorption in Plant Tissues

Fertilizer Treatment	Si Plant Tissue (%)	Si Absorption (mg/tanaman)
S0 : control	3,27 d	268,02 d
S1 : silika 400 ppm	3,85 c	329,21 cd
S2 : silika 800 ppm	4,27 b	407,45 bc
S3 : silika 1200 ppm	4,98 a	541,69 a
S4 : silika 1600 ppm	4,95 a	470,52 ab
S5 : silika 2000 ppm	4,91 a	459,62 ab

Information: Numbers followed by different letters in the same column show a real difference based on the DMRT test of 5%.

The application of silica fertilizer showed significantly different results on the level and absorption of plant tissue. The highest silica content was found at 1200 ppm treatment and lowest at non-silica treatment. Likewise, the highest silica absorption value in silica treatment is 1200 ppm and the lowest value is in the non-silica treatment (Table 9).

The calculation of the optimum point, an equation is obtained $y = -0.0001x^2 + 0.3222x + 247.43$ The optimum point value was obtained at a concentration of 1611 ppm with an absorption of 506.64 mg/plant. When viewed from the determination value (R2 = 0.87), it shows that the application of silica plays a role in increasing the absorption value of plants.

This shows that the higher the concentration given, the total silica value and silica absorption decrease. This condition is supported by the opinion of [19] that plant growth and production can reach optimal if the supporting factors for growth are in optimal conditions, balanced elements, the right dose, and nutrients available to plants. Thus, the application of fertilizer according to the dosage and needs of the plant can increase rice harvest, on the contrary, excessive application causes the fertilizer to be not absorbed properly by the plant.

IV. CONCLUSION

The results of the study showed that:

Application of silica fertilizer at a concentration of 1200 ppm, equivalent to 1.2 grams/L, increased leaf dry weight, total dry weight, weight of 1000 filled grains, weight of filled grains, total weight of filled grains, rice yield, and increased silica content and absorption in plant tissues. However, it did not increase plant height, seedling number, or the number of productive seedlings.

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