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IMPACT OF FOLIAR NUTRIENTS SPRAY AND PLANT GROWTH REGULATORS ON GROWTH, PRODUCTION, AND GRAIN QUALITY OF RICE

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ABSTRACT: A field experiment was conducted at the Experimental Farm of Sakha Agriculture Research Station, Kafr El-Sheikh, Egypt, during the 2022 and 2023 rice growing seasons, to determine the influence of foliar application of different nutrients and plant growth regulators at various growth ages on growth, yield and grain quality of Egyptian rice cultivar Giza179. The experiment was arranged in a Randomized Complete Block Design with four replications. The studied treatments consisted of a foliar spray of: control (distilled water spray), Potassium K_2O 28% (w/v) in the form of potassium phosphite at rates (2 ml/l L water), zinc 22% Zn SO_4 (w/v) in the form zinc sulfate (2 ml/ 1L water), calcium CaO 26% (w/v) in the form calcium oxide (2 ml/ 1 L water), cytokinin with a concentration (30 ppm), and cycocel with a concentration (400 ppm). Foliar application treatments were applied 20, 40, and 60 days after transplanting (DAT). Data showed that foliar applications of nutrients and plant growth regulators could significantly influence rice growth and yield components of Giza 179 cv. Potassium treatment seem to be more effective in improving overall plant performance. The consistent improvement across most treatments from 2022 to 2023 seasons might indicate favorable environmental conditions in the second season of the study.

Keywords: Potassium, zinc, calcium, cytokinin, cycocel

INTRODUCTION

Rice (*Oryza sativa*, L.) is an important grain crop in the world and Egypt. The increased global population demands an urgent increase in rice crop production, which is decreasing due to the adverse effects of environmental stress. Rice scientists in Egypt have developed early-maturing, high-yielding varieties like Giza179, which is adapted for drought and saline soils, but face issues with high broken rice percentages during seed grain quality processes (Okasha *et al.*, 2019).

This might be due to the plant being exposed to some stress conditions or a deficiency of some important elements at different stages. Breakage of cereal grains leads to grain loss in agricultural production, resulting in diminished germination rates and increased vulnerability to insects and fungi, undermining yield and value (Han and Guo, 2016).

Research on cereal grain breakage behavior is crucial for food security and quality, as it can help identify solutions to reduce breakage rates. Numerous studies have indicated that the use of stimulating materials, such as foliar sprays, effectively enhances the quality of rice grains and improves the nutritional value of milled rice. The effective and balanced application of fertilizers significantly enhances crop yield and quality (Kundu *et al.*, 2020). Foliar treatment improves nutrient absorption during essential growth phases, resulting in heightened physiological activity, enhanced yield, and higher grain quality. (Kundu *et al.*, 2020). Jagathjothi *et al.*, (2012) reported that foliar nutrients have been found to enhance photosynthetic rate and carbohydrate translocation, resulting in increased dry matter production.

Foliar spraying with potassium is an agronomic practice that has gained attention for its potential to enhance rice crop productivity and

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health. Potassium, as a vital macronutrient, is crucial to numerous physiological and biochemical processes in plants. It facilitates photosynthesis, enzyme activation, and nutrient delivery, which are essential for healthy growth and development. Mirtaleb *et al.*, (2021) discovered that the foliar application of potassium markedly enhanced the mineral nutritional content and quality of both brown and milled rice. Gharieb (2021) reported that potassium significantly affects rice grain quality, with a continuous supply during the heading stage affecting yield and quality during the rice crop life cycle.

Micronutrients are essential for the production, growth, and yield attributes of rice. (Jha, 2019). Foliar spraying with zinc has emerged as a valuable agronomic strategy for enhancing rice crop performance and grain quality. Zinc is an important micronutrient that is integral to various physiological functions, including enzyme activity, protein synthesis, and plant growth regulation. Given the widespread occurrence of zinc deficiency in many rice-growing regions, applying zinc directly to the leaves can effectively address this nutritional gap.

In rice production, applying calcium through foliar spraying can help mitigate the adverse effects of environmental stress such as drought, salinity, and diseases. This practice not only improves plant vigor and growth but also enhances the nutritional quality of the grains. Adequate calcium levels contribute to better grain filling, resulting in larger, more robust grains with improved shelf life and market value. Tripathy et al. (2018) found that foliar Ca treatment throughout 50% of the flowering stages resulted in improved grain filling and yield characteristics.

Foliar application of plant growth regulators (PGRs) has emerged as a transformative practice in rice cultivation, significantly influencing both grain yield and quality. PGRs, such as cytokinin and cycocel, play critical roles in regulating various physiological processes, including cell division, elongation, and differentiation. By manipulating these processes, PGRs can enhance plant growth, improve resilience to environmental stresses, and optimize resource use efficiency. Cycocel, a plant growth regulator, has been shown to influence plant height and tillering, which are critical factors in determining rice yield. By regulating growth patterns, cycocel can help optimize the plant's resource allocation towards grain production rather than excessive vegetative growth. This is particularly beneficial in high-yielding rice cultivars like Giza 179, where maximizing grain yield is essential (Hashem *et al.*, 2016). Abdelmegeed and ElShamey 2022 observed that cycocel application significantly increased panicles, filled grain panicle^{-1}, 1000-grain weight, and grain yield of Giza 179 rice. Plant growth regulators improved protein content in milled grains by transferring synthesized proteins towards the grain, increasing leaf longevity. This enhances plant physiological processes and improves grain nutritional profile, addressing agricultural productivity and food security concerns.

The application of foliar sprays containing potassium, zinc, calcium, cytokinin, and cycocel has been extensively studied for its effects on the growth, yield, and grain quality of rice, particularly Giza 179 cultivar.

MATERIALS AND METHODS

A field experiment was conducted at the Experimental Farm of Sakha Agriculture Research Station, Kafr El-Sheikh, Egypt, during the 2022 and 2023 rice growing seasons, to identify the efficiency of foliar application of nutrients and plant growth regulators at various growth stages on grain quality as well as growth and yield of rice cv. Giza179. The preceding crop was wheat over both seasons. Before field preparation, initial representative soil samples were obtained from several points at a depth of 0-15 cm and prepared for physical and chemical examination. The physical and chemical properties of the experimental soil (Jones, 2001) were specified in Table 1.

Table 1: Physiochemical properties of the experimental soil before planting in the 2022 and 2023 summer seasons.

Soil properties	2022	2023
Mechanical:		
Texture	Clay	Clay
Chemical:		
Organic Matter (%)	1.55	1.60
pH (1:2.5 soil suspension)	8.25	8.14
Ec ($ds.m^{-1}$)	1.02	1.24
Total N (ppm)	478	432
Available P (ppm)	14.10	15.45
Available K (ppm)	346	357
Soluble anions, $meq.L^{-1}$:		
CO^{--}_3	--	--
HCO^-_3	3.60	3.80
Cl^-	14.90	15.40
SO^{--}_4	1.30	1.40
Soluble Cations, $meq.L^{-1}$:		
Ca^{++}	5.20	5.30
Mg^{++}	2.00	2.10
Na^{++}	12.10	12.60
K^+	0.50	0.60
Available micronutrients (ppm)		
Fe^{++}	5.95	6.10
Mn^{++}	3.35	3.20
Zn^{++}	1.00	0.88

The studied treatments consisted of a foliar spray of control (distilled water spray), Potassium (K_2O) 28% (w/v) in the form of potassium phosphite at rates (2 ml/l L water), Zinc (Zn SO_4) 22% (w/v) in form zinc sulfate (2 ml/ 1L water), calcium (CaO) 26% (w/v) in form calcium oxide (2 ml/ 1 L water), cytokinin with a concentration (30 ppm), and cycocel with a concentration (400 ppm). Foliar applications of treatments were applied at 20, 40, and 60 days after transplanting (DAT). The experiment was carried out in a Randomized Complete Block Design, with four replicates.

For the nursery preparation, the seedbed was prepared, well-plowed, dry-leveled, and submerged by irrigation water, followed by wet leveling. Calcium mono phosphate at the rate of 36 kg ha^{-1}, and nitrogen in the form of urea at the rate of 80 kg N ha^{-1}, were added.

The permanent field was opened by a tractor, then plowed and cross-plowed twice for optimal tillage and puddle condition, and calcium mono phosphate was used for fertilization. (15.5% P_2O_5) with a dosage of 36.9 kg P_2O_5 per hectare during land preparation. Nitrogen fertilizer was applied at a rate of 165.6 kg N ha^{-1} in the form of urea (46.5% N), with two applications: the first, constituting two-thirds of the prescribed rate, served as a basal application, while the second, one-third, was applied at 30 days after transplanting (DAT). Fertilizers were applied, plots were irrigated, and seedlings were uprooted from the nursery. Seedlings were manually transplanted into 12 m^2 plots on June 10^{th} and 12^{th}, 2022 and 2023, respectively.

At harvest, plant height and the number of panicles per hill were assessed. Ten panicles were randomly taken to assess panicle length, the number of filled grains per panicle, the proportion of unfilled grains, and the weight of 1000 grains. The six inside rows of each plot were harvested, dried, and threshed, and grain yield was assessed to a moisture level of 14%. The grain yield was expressed in tons per hectare (t ha^{-1}).

Grain quality characteristics including milling recovery, gelatinization temperature, and amylose concentration were assessed following the method of Cruz and Khush (2000). One hundred fifty grams of cleaned rough rice with a moisture level of 14% was dehulled utilizing an Experimental Huller Machine (Satake - Japan). The brown rice was segregated and weighed, after which the hulling percentage was computed. Brown rice was processed with MC GILL Rice Miller No. 2 (S.K. Appliances – India). The entire weight of milled rice was recorded, and the percentage of milled rice was estimated. Whole milled grains were separated from the total milled rice using a rice-size apparatus (SKU: 61-220-50 Seedburo – USA).

Protein content in rice grain: samples of grains (50 g of milled rice) were pulverized and digested using the method of Chapman and Pratt (1961) before chemical analysis, as detailed below: The nitrogen content of milled grains was assessed using the Micro-Kjeldahl method (Jackson, 1967) to compute protein content%.

The collected data were analyzed according to Gomez and Gomez (1984). Comparisons between means were conducted using Duncan's Multiple Range Test (Duncan, 1955). All statistical analyses were conducted using the analysis of variance technique by "CoStat" software program.

RESULTS AND DISCUSSION

Data in Table 2 indicated that foliar spray at harvest significantly influenced plant height, number of panicles per hill, panicle length, and the number of filled grains per panicle. The application of foliar spray significantly enhanced the values of these characteristics compared to the control treatment. In both seasons, the tallest plants, the longest panicles, and the filled grains were treated with potassium foliar spray. While plants treated with cycocel gave the shortest plants. On the other hand, the control treatment recorded the lowest values of panicle length and filled grains in both seasons. Potassium foliar application enhanced rice growth, vigor, photosynthesis, production by increasing nutrient availability, absorption, and translocation in plants. These results are corroborated by the findings of Islam et *al.* (2017) and Gharieb (2021). Metwally and Gharib (2011) found that applying potassium twice at mid-tillering and panicle initiation stages significantly increased rice plant height, panicle length, and filled grains per panicle compared to the control. Hashem *et al.* (2016) recorded that applying cycocel or benzyl adenine significantly decreased plant height.

Also, data in Table 2 revealed that the application of cycocel treatment consistently produced the highest number of panicles per $hill^{-1}$ in both seasons. The control plots showed the lowest number of panicles. This might suggest that cycocel might promote tillering at the expense of plant height. These findings concur with those documented by Metwally and Gharib (2011) and Hashem *et al.* (2016). Abdelmegeed and ElShamey (2022) found that cycocel application up to 500 ppm can enhance growth and yield characteristics in various irrigation intervals, up to 12-day irrigation.

Table 2: Plant height, number of panicles per hill panicle length, and number of filled grains per panicle of rice cv. Giza 179 as affected by foliar applications of nutrients and plant growth regulators in the 2022 and 2023 seasons.

Treatment	Plant height (cm)		panicles /hill^{-1}		Panicle length (cm)		filled grains / panicle^{-1}	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	95 bc	101 bc	19.9 c	20.2 c	19.97 c	20.37 d	141 c	142 c
Potassium	104 a	108 a	24.2 ab	25.3 ab	21.60 a	22.27 a	151 a	150 a
Zinc	101 a	107 a	23.8 ab	24 ab	20.80 b	21.20 c	152 a	153 a
Calcium	98 ab	104 ab	22.2 b	23.6 b	21.63 a	21.70 b	149 ab	149 b
Cytokinin	97 abc	103 b	24.5 a	24.3 ab	21.30 ab	21.80 b	147 b	146 b
Cycocel	93 c	99 c	25.8 a	27.3 a	21.03 b	21.30 c	145 b	146 b
F-test	**	*	*	**	**	**	*	*

Table 3 showed the impact of foliar treatments of nutrients and plant growth regulators on the proportion of unfilled grains during the two seasons. Foliar spray of nutrients and plant growth regulators markedly decreased the percentage of unfilled grains compared to control in both seasons. The highest values of the unfilled grain percentage were obtained with the control treatments. Cycocel treatments produced the lowest values of unfilled grains percentage in the two seasons. This reduction in unfilled grains suggests improved grain-filling efficiency and reduced spikelet sterility under such treatments. Hashem et al. (2016) revealed that the utilization of any growth regulators reduced the percentage of unfilled spikelets. The impact of nutrient use and growth regulators on thousand-grain weights is illustrated in Table 3. Foliar application of nutrients and plant growth regulators increased 1000-grain weight in both seasons. Maximum values of 1000-grain weight were observed with potassium application in both seasons. Meanwhile, control treatments showed the lowest values, indicating that nutrient foliar applications enhanced grain filling and development. Metwally and Gharib (2011) stated that applying K_2O topically raised Egyptian hybrid rice's 1000-grain weight. These findings were additionally supported by Naeem (2016); Rekani (2020) and Mirtaleb *et al.* (2021).

Table 3 indicated that the foliar application of nutrients and growth regulators considerably enhanced rice grain yield per hectare compared to control. The highest grain yield per hectare was achieved when plants received potassium foliar spray in both seasons. Moreover, no substantial variations were observed in grain yield among plants treated with potassium, zinc, calcium, cytokinin, and cycocel during both seasons. The improvement of yield components was the main cause of the rise in grain yield ha^{-1} following the application of potassium fertilizer. K is commonly recognized as critical for photosynthesis since it immediately raises the growth and leaf area index, which improves CO_2 assimilation and encourages the outward translocation of more ATP, which is necessary for plants to develop vigorously. Numerous studies have documented the beneficial effects of foliar K_2SO_4 treatment on rice (Islam *et al.*, 2017, Rekani, 2020, and Mirtaleb *et al.*, 2021). Metwally and Gharib (2011) discovered that applying K_2O topically enhanced the grain yield of Egyptian hybrid rice. Gahrieb (2021) found that the application of potassium three times at different growth stages, substantially increased the yield quantity compared to other treatments.

Table 3: Unfilled grains %, 1000-grain weight, and grain yield per hectare of rice cv. Giza 179 as affected by foliar applications of nutrients and plant growth regulators in the 2022 and 2023 seasons.

Treatment	Unfilled grains (%)		1000-grain weight (g)		Grain yield (t ha^{-1})	
	2022	2023	2022	2023	2022	2023
Control	11.2 a	12.7 a	24.7 c	25.1 c	10.11 c	9.96 b
Potassium	9.2 cd	10.2 bc	27.1 a	26.8 a	11.76 a	11.72 a
Zinc	9.8 bc	10.4 bc	26.9 a	26.3 ab	11.48 ab	11.49 a
Calcium	10.1 b	10.6 b	26.5 ab	26.2 ab	10.83 b	10.96 a
Cytokinin	8.8 d	9.5 cd	26.2 ab	26.0 b	11.14 ab	11.28 a
Cycocel	8.6 d	9.1 d	25.9 b	25.9 b	11.39 ab	11.64 a
F-test	**	*	**	**	**	**

The effects of foliar application of nutrients and growth regulators on hulling, milling, and head rice percentages are displayed in Table 4. Foliar application of nutrients and growth regulators generally enhanced the milling recovery characteristics. Foliar applications treatment recorded the highest value in hulling percentage without significant difference among them as compared to control treatments in the first season. The highest hulling percentage was observed cycocel and potassium treatments with no significant difference between them in the second seasons. The control treatment exhibited the lowest hulling percentage in both seasons. The milling percentage was dramatically affected by treatments in both seasons. All treatments, except the control, showed similar and high milling percentages. The maximum milling percentage was achieved when plants received calcium foliar spray during the start of seasons. On the other hand, in the second season, the highest milling percentage was obtained when plants were treated with cycocel foliar spray. Moreover, the head rice percentage was significantly affected by treatments. Potassium treatment produced the highest head rice percentage in the two seasons. Control treatment had the lowest value of head rice percentage in both seasons. Potassium application positively changes characteristics by facilitating the transfer of assimilates from vegetative parts to grains during the reproductive stage. (White and Karley, 2010 and Timsina *et al.*, 2013). Garieb 2021 found that the application of potassium three times outperformed other treatments in terms of grain quality.

Table 4: Hulling, milling, and head rice percentages of rice cv. Giza 179 as affected by foliar applications of nutrients and plant growth regulators in the 2022 and 2023 seasons.

Treatment	Hulling (%)		Milling (%)		Head rice (%)	
	2022	2023	2022	2023	2022	2023
Control	80.2 b	80.5 c	68.6 c	69.3 b	56.2 c	55.8 d
Potassium	83.0 a	82.7 ab	71.2 ab	71.8 a	62.3 a	61.0 a
Zinc	82.3 a	81.8 b	70.2 b	71.5 a	60.1 b	59.8 c
Calcium	83.3 a	82.5 b	71.7 a	71.7 a	61.2 ab	60.2 abc
Cytokinin	82.5 a	82.1 b	70.7 ab	71.5 a	60.6 b	59.9 bc
Cycocel	82.6 a	83.9 a	70.8 ab	72.4 a	60.8 b	60.8 ab
F-test	**	**	*	**	**	*

Figure (1) shows rice products of husk rice (t ha^{-1}), rice bran (t ha^{-1}), broken rice (t ha^{-1}), and head rice yields (t ha^{-1}) of rice Giza 179 cv. was affected by foliar applications of nutrients and plant growth regulators in the 2022 and 2023 seasons. Head rice yield, a crucial quality parameter, improved significantly with foliar treatments. Potassium application consistently produced the highest head rice yields in 2022, while Cycocel gave that similarity in 2023. Interestingly, the effect of treatments on broken rice yield varied between seasons. In 2022, calcium treatment significantly reduced broken rice yield, while in 2023, zinc, cytokinin, and cycocel treatments increased it. This variation suggests that the impact of these treatments on grain strength might depend on environmental factors. Husk rice yield showed no significant differences among treatments in either season. Rice bran yield, however, was affected significantly by treatments, with potassium, zinc, and cycocel generally producing higher bran yields.

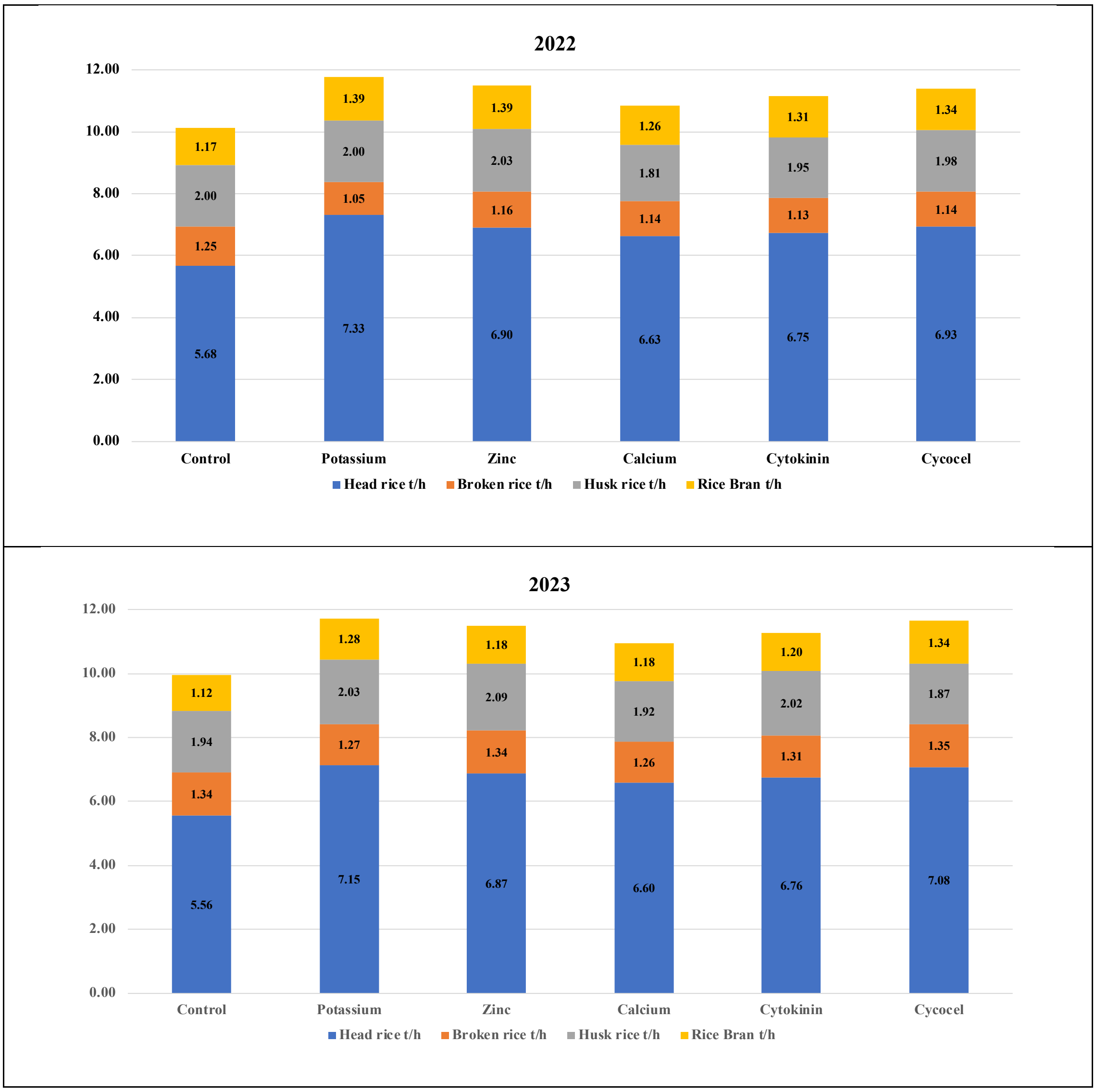

Fig. 1. Rice products (husk rice t ha^{-1}, rice bran t ha^{-1}, broken rice ha^{-1} and head rice yields t ha^{-1}) of rice cv. Giza 179 as affected by foliar applications of nutrients and plant growth regulators in the 2022 and 2023 seasons.

Protein percentage, amylose percentage, and gelatinous temperature of milled grain of rice were significantly affected by foliar application of different stimulating compounds (Table 5). Application of nutrients and plant growth regulators significantly increased protein and gelatinous temperature. The highest protein and gelatinous temperature values were observed when rice plants were treated with cycocel in both seasons. Moreover, the control treatment consistently showed the lowest values of protein and gelatinous temperature in the two seasons. Moreover, no substantial variations in amylose content were seen across the evaluated treatments over the two seasons. These results are in line with those obtained by Hashem *et al*. (2016), Abdelmegeed *et al. (*2022), and Abdelmegeed and ElShamey (2022).

Table 5: Protein % and amylose % in grains and gelatinous temperature of rice cv. Giza 179 as affected by foliar applications of nutrients and plant growth regulators in the 2022 and 2023 seasons.

Treatment	Protein %		Amylose (%)		Gelatinization temperature	
	2022	2023	2022	2023	2022	2023
Control	7.26 d	7.14 c	19.10	18.60	4.05 c	4.00 b
Potassium	8.33 c	8.18 b	18.60	18.10	4.35 ab	4.27 a
Zinc	8.45 bc	8.46 ab	19.00	18.50	4.20 b	4.25 a
Calcium	8.81 ab	8.66 a	18.30	18.00	4.22 ab	4.41 a
Cytokinin	9.11 a	8.79 a	18.90	18.50	4.21 ab	4.23 a
Cycocel	9.23 a	8.81 a	18.70	18.40	4.41 a	4.34 a
F-test	**	**	NS	NS	**	**

CONCLUSION

Recent data suggested that foliar applications of nutrients and plant growth regulators can significantly affect the growth and yield components of rice (Giza 179 cv.). Potassium treatments appear to be particularly effective in improving overall plant performance. The consistent improvement across most treatments from 2022 to 2023 may also indicate favorable environmental conditions in the second season of the study.

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تأثير الرش الورقي بالعناصر الغذائية ومنظمات النمو النباتية على نمو وانتاجية وجودة حبوب الأرز

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الملخص العربى

أجريت تجربتان حقليتان في المزرعة التجريبية لمحطة بحوث سخا الزراعية كفر الشيخ مصر خلال موسمي زراعة الأرز ٢٠٢٢و ٢٠٢٣ لتحديد تأثير التسميد الورقي لبعض العناصر الغذائية ومنظمات النمو في مراحل نمو مختلفة وتأثيرها على النمو وانتاجية وجودة حبوب الأرز للصنف جيزة ١٧٩. تم تنفيذ التجربة في قطاعات كاملة العشوائية في أربع مكررات. تضمنت المعاملات المدروسة الرش الورقي بكل من : معاملة المقارنة (رش بالماء)، البوتاسيوم ٢٨٪ (وزن/حجم) في صورة بوتاسيوم فوسفيت (٢مل/١لتر ماء)، الزنك ٢٢٪ (وزن/ حجم) في صورة كبريتات الزنك (٢مل/١ لتر ماء) ، الكالسيوم ٢٦٪ (وزن/حجم) في صورة أكسيد الكالسيوم (٢مل/١لتر ماء) ، سيتوكينين بتركيز (٣٠ جزء في المليون) ، السيكوسيل بتركيز (٤٠٠ جزء في المليون). تم تطبيق معاملات الرش الورقي بعد ٢٠و ٤٠و ٦٠ يوم من الزراعة. أظهرت النتائج ان تطبيق الرش الورقي للمغذيات ومنظمات النمو اثرت بشكل كبير على صفات النمو وانتاجية وجودة حبوب الأرز للصنف جيزة ١٧٩. كما أظهرت النتائج أن الرش الورقي بالبوتاسيوم له تأثر فعال جدا في تحسين الأداء العام للنبات. ويشير التحسن المستمر في معظم المعاملات من موسم ٢٠٢٢ الي موسم ٢٠٢٣ إلي ظروف بيئية مواتية في الموسم الثاني من الدراسة.

الكلمات المفتاحية: البوتاسيوم، الزنك، الكالسيوم، السيتوكينين، السيكوسيل.