Assiut Journal of Agricultural Sciences 56 (3) 2025 (29-37)
ISSN: 1110-0486 / EISSN: 2356-9840
Website: http://ajas.journals.ekb.eg/
E-mail: ajas@aun.edu.eg

(Original Article)

Influence of Foliar Micronutrient Applications on Rice Growth, Yield and Yield Components

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DOI: 10.21608/AJAS.2025.386362.1487

Abstract

To evaluate the effect of nitrogen fertilization levels combined with some micronutrients (Fe, Zn, Mn, Cu, B, N and amino acids) on rice of Sakha 108 cultivar performance, the experiment was conducted in randomized completely block design with 7 treatments. T_1 (Control = without fertilization),T_2 (recommended fertilizer 69kg N /Fed),T_3 (spray with micronutrients Fe, Zn ,Mn, Cu, B, N and amino acids) , T_4 (23kg N/fed), T_5 (23kg N/fed + Fe, Zn ,Mn, Cu, B, N and amino acids) ,T_6 (46kg N/fed) and T_7 (46kg N/fed+ Fe, Zn ,Mn, Cu, B, N and amino acids) with 4 replications. The experiment was conducted at the Sakha Agricultures Res. Station Kafr El-Sheikh Governorate, Egypt, over two consecutive seasons (2021and 2022). The results indicated that growth characteristics such as total chlorophyll content, flag leaf area (cm^2), plant height (cm) and tillers per square meter were significantly increased with application T_2 followed by T_7 without significant differences between them in both seasons of study. Also grain yield t/fed and its attributes (panicles/ m^2, no of filled grains/panicle, panicle length, panicle weight, 1000 grain weight, grain yield t/fed, straw yield t/fed and harvest index were significantly increased with application T_2 followed by T_7 without a significant differences between them in both seasons of study except No. of unfilled grains per panicle which increased with T_1 (control). Also, T_1(control) recorded the lowest values of most studied growth characters and grain yield and its components in both seasons.

Keywords: *Foliar application, Grain yield, Micronutrients, Rice*

Introduction

Rice is one of the staple foods for over half of the world's population. To meet the needs of the world's expanding population, rice production must increase significantly to meet the growing global demand. Reduced arable land area, global climate change, more frequent and severe natural catastrophes, high fertilizer costs, and increased prevalence of diseases and pests are some of the obstacles to boosting rice production (Wu *et al.,* 2016). For plants to develop and produce, nitrogen is one of the most important macronutrients. Accordingly, mineral nitrogen fertilizers are utilized

Received: 1 May 2025/ Accepted: 30 June 2025/ Published online: 2 July 2025

extensively in agriculture worldwide (Kundu and Sarkar, 2009). (Alam *et al.* 2010). The micronutrients examined in this study play crucial biochemical roles in plant development. Manganese (Mn) activate several enzymes in plant cells and needed for acting of some dehydrogenases, kinases, oxidases, and peroxidases and it is involved with other Evolution of photosynthetic O_2 and cation-activated enzymes. According to Taiz and Zeiger (2011), Mn's primary function is in the photosynthetic process, which produces oxygen from water. Zinc (Zn) is a component of carbonic anhydrase, glutamate dehydrogenase, and alcohol dehydrogenase. It is required for the biosynthesis of chlorophyll, stimulates the production of auxin indole acetic acid, and influences cell division in the apical meristem cells of various species. Iron (Fe) is a component of enzymes that facilitate electron conduction and the construction of chlorophyll (redox macronutrients). Even when applied in little amounts, micronutrients are ordered as effective components in the metabolism of plants. As a component of several enzymes, copper (Cu) serves as a respiration catalyst (Haehnel, 1984). When basal soil-applied micronutrients would be too slow to address a deficiency, micronutrients applied to the leaves could save a farm (Zayed *et al.*, 2011).

Boron (B) forms compounds with polyanionic acid, manna, menthol, and other cell \wall components. Both nucleic acid metabolism and cell elongation depend on boron. According to the data, boron is involved in hormone responses, membrane function, nucleic acid production, and cell elongation. When the micronutrient solution stays on the leaf as a thin layer, the absorption of, the movement of micronutrients into plant tissue appears to entail their uptake by leaf cells and their diffusion via the cuticle. Sometimes, the differences in texture between macronutrients and micronutrients are not as significant as the articles suggest. In many cases, elements are acceptable in concentrations higher than what the plant requires. Extreme cropping, the loss of fertile top soil, and nutrient leaching are the main causes of the majority of known micronutrient deficits (Somani *et al.,* 2008). Micronutrients deficiency is widely extending. When a micronutrient shortage is prevalent, the plant cannot possibly benefit greatly from the application of main and secondary macronutrients

Even when applied in little amounts, micronutrients are ordered as effective components in the metabolism of plants. Without micronutrients, plants cannot finish their life cycle. It is recognized that long-term cropping will alter the approachability of soil micronutrients and that severe cropping (Wei *et al*., 2006). In rice growing territories, the micronutrient leakage is weighed as one of the basic drawbacks of the diminished efficiency, so the single application of particularly NPK cannot be more practical because of continuous elimination of micronutrients after harvesting as well as losses due to leaching or surface floods.

The micronutrients deficiency not only is determinative factor of crop productivity reduction but also is deteriorating quality. According to the reports, most of the soils are micronutrient deficient and incapable of alimenting crops properly. The foliar sprays have been used for multiple crops for providing micronutrients, Considering the importance of micronutrient roles in the plant nutrition and enzyme activation, this investigation has been done on rice (cv. Sakha108) for assessing the effects of integrated foliar application of (Fe, Zn, Mn, Cu, B, N, and amino acids) on yield, yield components, and structural characteristics.

Materials and Methods

1-Location and design of experimental.

The experiment was conducted at the Sakha Agricultural Research Station, Kafr El Sheikh Governorate, Egypt. The study was conducted over the course of two successive growing seasons 2021and 2022. The rice variety used in the study was Sakha108. Through leaf foliar spraying with a dosage of 1 kg micronutrient fertilizer/200 L/fed water (recommended rate) and the fertilizer analysis listed in Table 1, the impact of nitrogen and certain micronutrients on rice, characteristics, yield, and yield components was examined. in randomized complete block design (RCBD) with 4 replications.

Table 1. Micronutrients fertilizer analysis

Fe	Zn	Mn	Cu	B	N	Free amino acids
0.02 %	0.02%	0.02%	0.02%	0.02%	42.2%	2%

2-Treatments and measurements methods

The seven treatments and foliar application respectively, T_1 (Control = without fertilization),T_2 (recommended fertilizer 69kg N /Fed),T_3 (spray with micronutrients Fe, Zn ,Mn, Cu, B, N and amino acids), T_4 (23kg N/fed), T_5 (23kg N/fed + Fe, Zn ,Mn, Cu, B, N and amino acids),T_6 (46kg N/fed) and T_7 (46kg N/fed+ Fe, Zn ,Mn, Cu, B, N and amino acids) with 4 replications. The soil samples were randomly collected from seven various spots in each of the experimental plots from 0-30 cm depth, and after the determination of soil texture, the soil physicochemical features Table 2 evaluated in the lab

Table 2. Analysis of the mechanical and chemical properties of the experimental site soil.

Soil analysis	2021	2022
Mechanical analysis		
Clay %	54.9	54.6
Silt %	30.5	31.8
Sand %	14.6	13.6
Texture class	Clay	Clay
Chemical analysis		
Organic matter %	1.70	1.60
E.C. (dS/m)	2.05	2.37
pH	8.03	8.0
Total N (ppm)	18	19
Available P (ppm)	14	12
Available K (ppm)	340	360
Availability of micro-nutrients (mg kg^{-1})		
Fe	3.60	3.85
Zn	0.27	0.25
Cu	0.14	0.13
Pb	115	116
Cd	8.01	7.10

Foliar spray application was administered at two time points 30 and 45 days after transplanting. On May 8th of each season, seeds of the Sakha 108 rice variety were sown at a seeding rate of 60 kg/fed. To promote germination, seeds were pre-treated with a 24-hour soaking period followed by a 48-hour incubation period. The nursery received the recommended rates of nitrogen, phosphorus, and zinc. Following a 30-day nursery period, seedlings were meticulously transplanted into their designated experimental plots. The area of each plot was 20 m^2 (4 × 5 m). Each plot was fertilized, according to the rate of each treatment. Nitrogen fertilizer as Urea (46.5%, N) was applied. Seedlings were transplanted manually with a spacing of 20 cm between both hills and rows. 3-4 seedlings per hill were employed. Standard agronomic practices for rice cultivation, as recommended by the Rice Research and Training Center, were implemented throughout the experiment. To assess chlorophyll content by using chlorophyll meter 5 SPAD-502 Minolta Camera Co. Ltd., Japan according to according to Murquard and Timpton (1987).

And flag leaf area was estimated using leaf area meter (Model LI.3000A), three randomly selected hills from each plot were destructively harvested at the booting stage. Plant height, total panicle number and tillers number were determined at harvest by measuring ten randomly chosen hills within each plot. Additionally, For the purpose of evaluating panicle length, the number of filled and unfilled grains per panicle, panicle weight, 1000-grain weight, ten panicles were taken from each plot. From each plot 10m^2 was collected independently at full maturity, dried and threshed. The yields of grain and straw were subsequently determined and translated into t/fed and harvest index % calculated using the following formula. Economic yield or grain yield / biological yield and then X100).

3-Statistical analysis

A statistical analysis of variance (ANOVA) was conducted on the collected data, following the methodologies described by Gomez and Gomez (1984). Duncan's Multiple Range Test (Duncan, 1955) was employed for post-hoc comparisons of treatment means. The entire statistical analysis was performed using the software package "COSTAT.

Results and discussion

1-Characters for growth

Results presented in Table 3 indicate that chlorophyll content, flag leaf area, plant height, and the number of tillers/m² at harvest were significantly enhanced by the application of T_2 (69 kg N/ fed) recommended dose followed by T_7 without a significant difference between them in both seasons compare with other treatments under study. T_1 consistently exhibited the lowest values for all growth parameters across both seasons. This finding remained consistent across both growing seasons. Our results align with those of Mahmudi *et al.* (2015), who also reported improved rice growth characteristics with nitrogen and micronutrient applications. Somani *et al*., (2008) and Lokendra Nath Yogi *et al*., (2024). Zayed *et al*., (2011) noticed that the application of three tested micronutrients (Zn, Mn, Fe) as single or a combination significantly improved rice growth traits like dry matter production, LAI, chlorophyll content as well as plant height for both seasons of study. These results may be attributed to the role of nitrogen in encouraging vegetative growth to produce more laef area, tillers, chlorophyll content and also, the role of nitrogen in cell division and cell elongation consequently increasing plant height.

Table 3. Chlorophyll content, flag leaf area, plant height and tillers/m^2 of Sakha 108 rice cultivar as affected by spray and fertilizer treatments in 2021 and 2022 seasons.

Characters / Treatments	Chlorophyll reading (SPAD unit)		Flag leaf area (cm^2)		Plant height (cm)		Tillers/m^2	
	Seasons		Seasons		Seasons		Seasons	
Fertilizer treatments	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
T_1	33.00 f	33.50 e	20.83 e	21.00 f	90.33 c	89.00 c	395.66 f	400.00f
T_2	40.00 a	40.26 a	27.73 a	28.00 a	95.00 a	94.33 a	501.00 a	504.00a
T_3	35.50 e	35.66 d	21.50 d	21.73 e	91.50 b	90.66 b	420.00 e	422.33 e
T_4	36.50 d	36.10 d	22.50 c	22.60 d	91.83 b	91.00 b	441.66 d	443.33 d
T_5	37.83 c	37.50 c	23.66 b	24.06 c	91.83 b	91.00 b	460.00 c	460.00 c
T_6	38.73 b	39.16 b	23.88 b	25.50 b	92.16 b	91.50 b	490.33 b	487.33 b
T_7	39.66 a	40.00 a	27.50 a	27.53 a	94.66 a	94.00 a	500.00 a	500.00 a
f.test	**	**	**	**	**	**	**	**

**: Highly significant at 0.01 level. Means of each factor designated by the same letter are not significantly differed at 5% level of probability. T_1 (Control = without fertilization),T_2 (recommended fertilizer 69kg N /Fed),T_3 (spray with micronutrients Fe, Zn ,Mn, Cu, B, N and amino acids) , T_4 (23kg N/fed), T_5 (23kg N/fed + Fe, Zn ,Mn, Cu, B, N and amino acids) ,T_6 (46kg N/fed) and T_7 (46kg N/fed+ Fe, Zn ,Mn, Cu, B, N and amino acids)

1-Grain yield and its component

Data in Table 4 revealed that the application of T_2 (69 kg N/fed) recommended dose and T_7 (46kg N/fed+ Fe, Zn, Mn, Cu, B, N and amino acids) give the highest values of No. of panicles/m^2 and No. of filled grains/panicle without a significant difference between them for both seasons. Additionally, T_2 and T_7 recorded the lowest values of No. of unfilled grains per panicles in the two seasons of study without significant between them, while control treatment (T_1) noted the lowest values of No. of panicles/m^2 and No. of filled grains/ panicle. Also, (T_1) recorded the highest values of unfilled grains percentage in both seasons of study.

Table 4. Panicle /m^2, No. of filled grains/panicle and unfilled grains% of Sakha 108 rice cultivar as affected by spray and fertilizer treatments in 2021 and 2022 seasons.

Characters / Treatments	Panicles/m^2		Filled grains/panicles		un filled grains/panicles %	
	Seasons		Seasons		Seasons	
Fertilizer treatments	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
T_1	382.0 f	381.0 f	123.0 f	122.0 f	10.86 a	10.72 a
T_2	491.66 a	492.33 a	144.0 a	141.66 a	5.39 e	5.33 e
T_3	402.66 e	400.6 e	126.33 e	126.0 e	9.97 b	9.41 b
T_4	420.66 d	424.0 d	129.66 d	129.0 d	8.47 c	8.35 c
T_5	441.0 c	440.0 c	133.33 c	132.66 c	7.61 d	7.49 d
T_6	479.66 b	480.33 b	139.33 b	138.0 b	7.60 d	7.45 d
T_7	490.0 a	490.66 a	142.33 a	141.33 a	5.49 e	5.43 e
f. test	**	**	**	**	**	**

** =Highly significant at 0.01 level . Means of each factor designated by the same letter are not significantly differed at 5% level of probability. T_1 (Control = without fertilization),T_2 (recommended fertilizer 69kg N /Fed),T_3 (spray with micronutrients Fe, Zn ,Mn, Cu, B, N and amino acids) , T_4 (23kg N/fed), T_5 (23kg N/fed + Fe, Zn ,Mn, Cu, B, N and amino acids) ,T_6 (46kg N/fed) and T_7 (46kg N/fed+ Fe, Zn ,Mn, Cu, B, N and amino acids)

These findings corroborate earlier studies by Zayed *et al.,* (2011), Ghasemi *et al.* (2014), Daneshtalab Lahijani *et al., (*020), demonstrating the effectiveness of nitrogen and micronutrients combinations in optimizing rice growth and Lokendra Nath Yogi *et al*., (2024). The increased number of panicles/m^2 with T_2 and T_7 may be due to the essential role of nitrogen for producing new tillers which led to the increase in number of tillers bearing panicles.

The results in Table 5 revealed that the fertilization with T_2 (69 kg N/fed) and T_7 (46kg N/fed+ Fe, Zn, Mn, Cu, B, N and amino acids) gave the highest values of panicle length and panicle weight with no significant difference between them in both seasons. Also, T_2 and T_7 registered the maximum values of 1000 grain weight (g) without a significant difference between them in the two growing seasons compared with other treatments, while (T_1) control gave the minimum values of panicle length (cm), panicle weight and 1000 grain weight (g) in both seasons of study. Similar results were reported by Zayed *et al.,* (2011), Daneshtalab Lahijani *et al*., (2020) and Lokendra Nath Yogi *et al*., (2024). Increasing panicle weight and 1000 grain weight with T_2 and T_7 may be due to the role of nitrogen in keeping rice plant healthy through vegetative growth, maturity and accumulation of carbohydrates such as sugar and starch. Carbohydrates are accumulated in rice vegetative parts then translocated and stored in grains. Similar results were reported by Ghazy (2015).

Table 5. Panicle length, panicle weight and 1000 grains weight of Sakha 108 rice cultivar as affected by spray and fertilizer treatments in 2021 and 2022seasons.

Characters / Treatments	Panicle length (cm)		Panicle weight (g)		1000 grain weight (g)	
	Seasons		Seasons		Seasons	
Fertilizer treatments	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
T_1	20.66 e	21.00 e	2.71 e	2.76 f	21.73 e	21.93 e
T_2	26.16 a	25.66 a	3.86 a	3.92 a	26.70 a	26.40 a
T_3	22.33 d	22.50 d	3.06 d	3.11 e	22.50 d	22.83 d
T_4	23.50 c	23.50 c	3.35 c	3.40 d	23.00 d	23.30 d
T_5	23.75 c	23.78 c	3.45 c	3.52 c	24.00 c	24.23 c
T_6	24.83 b	24.43 b	3.64 b	3.70 b	25.50 b	25.16 b
T_7	26.06 a	25.33 a	3.82 a	3.90 a	25.40 a	25.96 a
f.test	**	**	**	**	**	**

** =Highly significant at 0.01 level. Means of each factor designated by the same letter are not significantly differed at 5% level of probability T_1 (Control = without fertilization),T_2 (recommended fertilizer 69kg N /Fed),T_3 (spray with micronutrients Fe, Zn ,Mn, Cu, B, N and amino acids) , T_4 (23kg N/fed), T_5 (23kg N/fed + Fe, Zn ,Mn, Cu, B, N and amino acids) ,T_6 (46kg N/fed) and T_7 (46kg N/fed+ Fe, Zn ,Mn, Cu, B, N and amino acids)

Findings in Table 6 showed that the grain yield, straw yield and harvest index. The various fertilizer treatments that were examined had a considerable impact. During both seasons, fertilizer application of T_2 followed by T_7 gave the best significant values of all the above merited traits in the two grown seasons, but the control treatment (T_1) provided the lowest values of these characters for both seasons. The superiority in grain yield with T_2 and T_7 treatments, could be ascribed to the increase in grain yield attributes. These findings could also be explained by the fact that the availability of nutrients promotes the development and movement of the dry matter content to panicles, which increases grain weight and filling and yields more grain. A similar discovery was made by Zayed *et al.,* (2011) Patel *et al*., (2019), Daneshtalab Lahijani *et al*., (2020) and Lokendra Nath Yogi *et al*., (2024). Zayed *et al.,* (2011) reported that the application of micronutrients as single or a combination significantly improved rice grain yield and straw yield and harvest index. Also, Patel *et al.,* (2019) reviled that significantly highest grain yield and straw yield was measured with two foliar sprays at 1.5% boron during the tillering and grain filling stages. The same treatment also showed that plants and grains absorbed the most nutrients (N, P, K, and B). When compared to control or other treatments.

Table 6. Grain yield, straw yield t/fed and harvest index of Sakha 108 rice cultivar as affected by spray and fertilizer treatments in 2021 and 2022seasons.

Characters / Treatments	Grain yield t/fed		Straw yield t/fed		Harvest index %	
	Seasons		Seasons		Seasons	
Fertilizer treatments	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
T_1	2.50 f	2.52 f	3.68 f	3.71 f	40.42 e	40.52 e
T_2	4.68 a	4.75 a	5.68 a	5.75 a	45.12 a	45.08 a
T_3	2.85 e	2.80 e	4.10 e	4.03 e	40.94 d	40.97 d
T_4	3.55 d	3.60 d	4.75 d	4.82 d	42.77 c	42.75 c
T_5	3.90 c	3.85 c	5.16 c	5.10 c	43.01 c	43.01 c
T_6	4.25 b	4.24 b	5.48 b	5.43 b	43.77 b	43.86 b
T_7	4.62 a	4.72 a	5.65 a	5.75 a	45.17 a	45.23 a
f. test	**	**	**	**	**	**

** =Highly significant at 0.01 level. Means of each factor designated by the same letter are not significantly differed at 5% level of probability T_1 (Control = without fertilization),T_2 (recommended fertilizer 69kg N /Fed),T_3 (spray with micronutrients Fe, Zn ,Mn, Cu, B, N and amino acids) , T_4 (23kg N/fed), T_5 (23kg N/fed + Fe, Zn ,Mn, Cu, B, N and amino acids) ,T_6 (46kg N/fed) and T_7 (46kg N/fed+ Fe, Zn ,Mn, Cu, B, N and amino acids)

Conclusion

Ultimately, it can be said that applying 46 kg N/fed+ Fe, Zn, Mn, Cu, B, N, and amino acids can save almost 30% of the nitrogen from mineral fertilizers while only slightly lowering the grain productivity of the Sakha 108 rice cultivar.

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تأثير الرش بالعناصر الصغرى على نمو الأرز والمحصول ومكوناته

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الملخص

أقيمت تجربة لدراسة تأثير التسميد النيتروجيني مع الرش ببعض العناصر الصغرى على انتاجية وسلوك صنف الارز سخا 108 نفذت التجربة في نظام القطاعات كاملة العشوائية باستخدام 7 معاملات مختلفة هي الكنترول (المعاملة الاولى)، المعاملة الثانية هي استخدام 69 وحدة نيتروجين للفدان المعدل الموصي به والمعاملة الثالثة هي الرش بالعناصر الصغرى فقط والمعاملة الرابعة هي استخدام 23 وحدة نيتروجين للفدان فقط , المعاملة الخامسة هي استخدام 23 وحدة نيتروجين للفدان بالإضافة للرش بالعناصر الصغرى والمعاملة السادسة هي استخدام 46 وحدة نيتروجين فقط للفدان والمعاملة السابعة هي استخدام 46 وحدة نيتروجين للفدان بالإضافة الى الرش بالعناصر الصغرى مع استخدام اربعة مكررات , ونفذت التجربة في المحطة البحثية لمحطة بحوث سخا كفر الشيخ ، مصر خلال موسمي الزراعة 2021 ، 2022 .

تشير النتائج المتحصل عليها الى ان معظم صفات النمو الخضري مثل (محتوى الكلوروفيل في الاوراق ، مساحة ورقة العلم ، ارتفاع النبات ، عدد الاشطاء في المتر المربع) ايضا المحصول ومكوناته (عدد الداليات في المتر المربع ،عدد الحبوب الممتلئة في السنبلة ، طول ووزن السنبلة بالإضافة الى وزن 1000 حبة ومحصول الحبوب والقش بالطن للفدان ودليل الحصاد للمحصول) الى ان هناك استجابة وزيادة معنوية لهم بتطبيق المعاملة الثانية يليها المعاملة السابعة مع عدم وجود أي فروق معنوية بينهم في كلا الموسمين فيما عدا عدد الحبوب الفارغة للسنبلة والتي زادت بتطبيق المعاملة الاولى (الكنترول) والتي اعطت اقل القيم في معظم صفات النمو الخضري والمحصول ومكوناته في كلا الموسمين .

الكلمات المفتاحية: *الرش الورقي، العناصر الصغرى، الارز، محصول الحبوب*