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Original Article

Selecting iron and zinc nano-fertilizers for rice traits in drought by statistical analysis

Seleção de nanofertilizantes de ferro e zinco para características do arroz em seca por análise estatística

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Abstract

Optimum use of fertilizer plays an important role in increasing the performance of traits in rice and other agricultural products. The use of nano-fertilizers can be very important in the optimal use of fertilizer and in increasing the quantity and quality of agricultural products. To investigate the effect of iron and zinc nano-fertilizers on the physiological and morphological characteristics of rice plants (Tarom Hashemi variety) under drought stress conditions, a split plot experiment was carried out in the form of a randomized complete block design in three replications in Mazandaran region. The results of the combined analysis indicated that the effect of iron nano-fertilizer and zinc nano-fertilizer has a significant difference at the level of 0.01 and 0.05 in terms of all the evaluated traits. In the means comparison, it was concluded that normal humidity conditions can have a positive effect on the performance of the traits, but in the S1 stress conditions (drought stress at the rate of 50% of normal irrigation), the traits showed a good performance trend. Furthermore, increasing the amount of iron nano-fertilizer at the F2 level (Iron sulphate 100 kg/ha + 1 foliar spraying of iron chelate 2%) can be very effective in the growth of yield and the desirability of traits. In examining the amount of zinc nano-fertilizer consumption on the traits, showed the most positive performance on the traits at the level of Z2 (Use of 5 mg of zinc nano-fertilizer per kg of experiment soil), but with the increase to the level of Z3 (Use 7.5 mg of zinc nano-fertilizer per kg of experiment soil), this favorability was greatly reduced. The result of the correlation coefficients between the traits and the correlation diagram also showed a positive and significant correlation between the traits. In the graphical analysis, treatments tr33, tr8, tr19, tr24, tr7, tr6, and tr2 were selected as desirable treatments from the polygon graph. Treatments tr19, tr9 and tr6 were recognized as favourable treatments in terms of the treatment ranking diagram in terms of all traits. Based on the treatment selection diagram based on ideal treatment, tr19, tr9 and tr6 treatments were identified as desirable treatments. In general, it is possible to use tr19 (S1×F1×Z2), tr6 (N×F1×Z1) and tr9 (N×F2×Z0) treatments as treatments with high efficiency and power to increase the performance of traits and optimal use of nano-fertilizers in rice cultivation.

Keywords: rice, iron nano-fertilizer, zinc nano-fertilizer, drought stress, graphic analysis.

Resumo

O uso ideal de fertilizantes tem um papel importante no aumento do desempenho das características do arroz e de outros produtos agrícolas. O emprego de nanofertilizantes pode ser muito importante na utilização ótima dos fertilizantes e no aumento da quantidade e qualidade dos produtos agrícolas. Para investigar o efeito dos nanofertilizantes de ferro e zinco nas características fisiológicas e morfológicas de plantas de arroz (variedade Tarom Hashemi) sob condições de estresse hídrico, foi realizado um experimento em parcelas subdivididas, na forma de delineamento em blocos completos casualizados em três repetições, em Região de Mazandaran. Os resultados da análise combinada indicaram que o efeito do nanofertilizante de ferro e do nanofertilizante de zinco apresenta diferença significativa nos níveis de 0,01 e 0,05, respectivamente, considerando-se todas as características avaliadas. Na comparação de médias, concluiu-se que condições normais de umidade podem ter efeito positivo no desempenho dos caracteres, mas, nas condições de estresse S1 (estresse hídrico na taxa de 50% da irrigação normal), os caracteres apresentaram bom desempenho tendência. Além disso, aumentar a quantidade de nanofertilizante de ferro no nível F2 (sulfato de ferro 100 kg/ha + 1 pulverização foliar de quelato de ferro 2%) pode ser muito eficaz no crescimento da produção e na desejabilidade das características. Ao examinar a quantidade de consumo de nanofertilizante de zinco nas características, este apresentou o desempenho mais positivo nas características no nível Z2 (utilização de 5 mg de nanofertilizante de zinco por quilo de solo do experimento), mas com o aumento para o nível de Z3 (utilização de 7,5 mg de nanofertilizante de zinco por quilo de solo experimental), esta favorabilidade foi bastante reduzida. O resultado dos coeficientes de correlação entre as características e o diagrama de correlação também mostrou correlação positiva e significativa entre as características. Na análise

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gráfica, os tratamentos tr33, tr8, tr19, tr24, tr7, tr6 e tr2 foram selecionados como tratamentos desejáveis a partir do gráfico poligonal. Os tratamentos tr19, tr9 e tr6 foram reconhecidos como tratamentos favoráveis em termos do diagrama de classificação de tratamento considerando-se todas as características. A partir do diagrama de seleção de tratamento baseado no tratamento ideal, os tratamentos tr19, tr9 e tr6 foram identificados como tratamentos desejáveis. Em geral, é possível utilizar os tratamentos tr19 (S1×F1×Z2), tr6 (N×F1×Z1) e tr9 (N×F2×Z0) como tratamentos com alta eficiência e poder para aumentar o desempenho das características, e otimizar o uso de nanofertilizantes na cultura do arroz.

Palavras-chave: arroz, nanofertilizante de ferro, nanofertilizante de zinco, estresse hídrico, análise gráfica.

1. Introduction

Rice is a carbohydrate source for more than half of the world's population (Joshi et al., 2018). It is also the most important agricultural product in the world, which plays a very important role in nutrition, so it is the main food for more than half of the world's population (Bernier et al., 2008). Due to the high population growth, the annual production of rice should increase by 1.7% to meet the needs of consumers (Zheng and Sun, 2004). The world's food production is mainly limited by environmental stresses and pathogenic factors, among the types of stresses, drought stress is very important (Lum et al., 2014). Rice is often considered one of the most sensitive crop plants to drought stress, and water shortage stress is always associated with high-temperature stress, which reduces crop production (Xu et al., 2011). Micronutrients play an important role in the growth and development of plants so they have an important contribution in increasing the yield of the product. If these elements are not available to the plant, crops will suffer from the physiological stresses resulting from numerous enzyme systems and other metabolic factors related to these elements (Kandil et al., 2017). Zinc is one of the essential and low-use elements for agricultural plants, which has a very important physiological role, including carbohydrate synthesis, protein synthesis and metabolism of photosynthetic pigments, increasing the photosynthetic power and metabolic actions of the cell, protecting the membrane, creating the cell defence system in It is equal to reactive oxygen species in plants and yield power (Karimi et al., 2016). Iron is also one of the essential nutrients in the production of agricultural products in the world, and plants need its continuous use for optimal and proper growth. Nanotechnology is among the new technologies that are growing and developing today. One of the most important applications of nanotechnology in agriculture is the use of nano-fertilizers to feed plants. Due to the increasing trend of water, soil and environment enrichment due to the excessive use of chemical fertilizers and common methods of food production in the world, has attracted the attention and encouragement of researchers to the sustainable agriculture sector (Karimi et al., 2018). For this reason, the use of nano-fertilizers accurately control the release of nutrients can be very necessary to achieve sustainable and environmentally friendly agriculture (Cui et al., 2006). The interaction effect of treatment and trait is the response of treatment to the changes in the traits, and knowing its nature helps the researcher to evaluate the treatments more accurately and choose the best treatments in terms of stability and high performance (Gauch Junior, 2006). In a research that was conducted to investigate the effect of nano fertilizers on rice yield, it was concluded that the use of nano fertilizers to obtain proper yield in plants is undeniable, and therefore, the use of nano fertilizers can be a suitable solution to optimize the use of fertilizers in rice fields (Sadati et al., 2021). In another study that was conducted on the effect of zinc nano-fertilizer on rice cultivars, it was concluded that the increase in the yield of agricultural, physiological and agrophysiological traits was greater at lower levels of zinc, and with the increase in the amount of zinc in the soil, the yield of the traits decreased (Muthukumararaja et al., 2019). The results of another research conducted to investigate the yield and quality of zinc nanofertilizers on rice plants showed that the controlled and regulated consumption of zinc nanofertilizers can have a positive effect on increasing the yield and quality of rice plants (Zhang et al., 2021). In the study of nano-fertilizers on the performance and quality characteristics of rice cultivars under different conditions, they concluded that the application of zinc nano oxide in conditions of interruption of irrigation has a positive effect on the quantitative and qualitative characteristics of rice (Zarei et al., 2023). In another research, in order to investigate drought tolerance, the correlation analysis between water conditions and drought stress was used, resistant genotypes of rice with high resistance and good performance were selected (Karim and Sabouri, 2018). The aims of this research can be: 1. Investigating the effect of iron and zinc nano-fertilizers in increasing the quantity and quality of yield of rice traits, 2. Investigating the mutual effect of treatment and trait on rice plant growth, 3. Choosing the most suitable treatment for rice cultivation, 4. Investigating the relationships between the evaluated traits in terms of correlation between them and 5. The study of drought stress pointed out the reduction of water use efficiency.

2. Materials and Methods

To investigate the effect of iron and zinc nano-fertilizers on the physiological and morphological characteristics of rice plants (Tarom Hashemi cultivar) under drought stress conditions and to choose the most appropriate treatment for the optimal cultivation of this plant, a split-plot experiment was conducted in the form of randomized complete block design with three replications. Drought stress as the main factor and the use of iron and zinc nano-fertilizers as secondary factors were implemented in a research farm located in Mazandaran province. The cultivated research field was carried out with a longitude of 52º30'.102" and a latitude of 36º23'.16.001" and a height of 29.8 meters from the free surface of water. Figure 1 shows the amount of rainfall and climate characteristics of the cultivated area, which indicates that it has a semi-Mediterranean thermal climate with hot and humid summers and annual rainfall of 800 mm and an average temperature of 16 degrees Celsius and moderate winter. To prepare the land before experimenting, the land was plowed. To crush the clods and also to make the condition of the farm soil uniform, a disc and a trowel were used and samples were taken from the farm soil at a depth of 0-30 cm. 21-day-old seedlings of Tarom Hashemi variety are planted on the stacks with a distance of 20 cm. The dimensions of the irrigation cards were 3 x 7 meters and the substrate preparation was done for all the treatments based on the cultivation method. The amount of water consumed was measured by a volumetric meter. After planting, weed control was done with propanil herbicide at the rate of 4 litres per hectare, as well as mechanical control (hand weeding). Pest control (one dose of Sevin poison at a rate of two per thousand to control the rice leaf-eating green worm and one time the use of diazinon poison at the same time as watering the plots to dissolve the poison and to fight the striped stem-eating worm) was carried out with the cooperation and supervision of the relevant experts. The soil characteristics of the cultivated field are also presented in Table 1. The information related to the characteristics of the traits evaluated in the experiment is presented in Table 2. Table 3 shows the code and specifications of the treatments examined in the experiment. To determine traits such as plant height, the number of tillers per plant, and spike length, 10 plants were randomly selected from each experimental plot and these traits were measured. To measure the biological yield, after weeding the plants of each experimental plot, before separating the seeds from the cluster, the weight of all the plants (leaf, stem, cluster and seed) was determined and the biological yield was calculated in kilograms per hectare and after separating Harvesting the seeds from the cluster, the seed yield was determined in terms of kilograms per hectare, and the

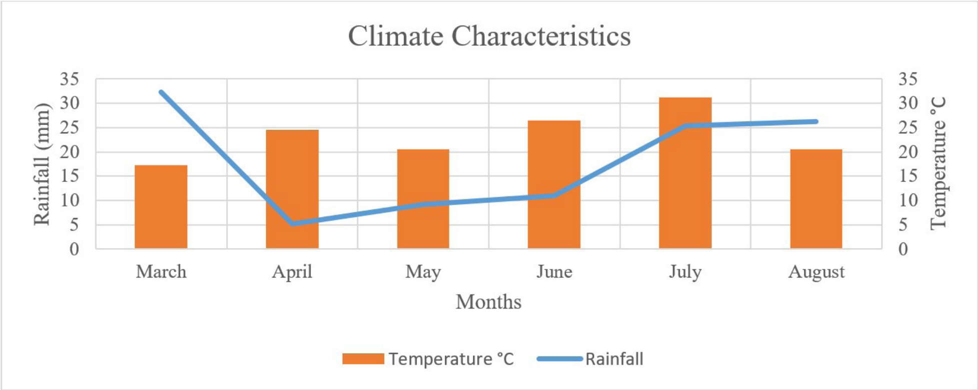

Figure 1. Rainfall and climate characteristics of the experimental area.

Table 1. Some physical and chemical properties of experiment site soil.

Depth (cm)	Soil texture	PH	Electrical conductivity	Organic carbon (%)	Total nitrogen (%)	Absorbable phosphorus ppm	Absorbable Potassium ppm
0-30	Loam- sandy clay	7.5	1.05	1.6	0.06	9.5	289

Table 2. The code and characteristics of the traits evaluated in the experiment.

Trait Code.	Trait	Trait Code.	Trait
PLH	Plant height	YLD	Grain yield
NTP	Number of tiller per plant	GD	Grain diameter
SL	Spike length	GL	Grain length
NSS	Number of seeds per spike	PL	Paddy length
WTS	1000- seeds weight	PD	Paddy diameter
HI	Harvest Index		

Table 3. Code and characteristics of treatments and traits used in the experiment.

Treatment	Level	Characteristic	Interaction treatment	Characteristic	Interaction treatment	Characteristic	Interaction treatment	Characteristic
	N	Normal Irrigation	Tr1	N×F0×Z0	Tr13	S1×F0×Z0	Tr25	S2×F0×Z0
Drought stress	S1	drought stress at the rate of 50% of normal irrigation	Tr2	N×F0×Z1	Tr14	S1×F0×Z1	Tr26	S2×F0×Z1
	S2	drought stress at the rate of 20% of normal irrigation	Tr3	N×F0×Z2	Tr15	S1×F0×Z2	Tr27	S2×F0×Z2
	F0	Non-use of iron nano-fertilizers in the experimental plots	Tr4	N×F0×Z3	Tr16	S1×F0×Z3	Tr28	S2×F0×Z3
Fe nano-fertilizer	F1	Iron sulfate 50 kg/ha + 1 foliar spraying of iron sulfate 2%	Tr5	N×F1×Z0	Tr17	S1×F1×Z0	Tr29	S2×F1×Z0
	F2	Iron sulfate 100 kg/ha + 1 foliar spraying of iron chelate 2%	Tr6	N×F1×Z1	Tr18	S1×F1×Z1	Tr30	S2×F1×Z1
	Z0	Non-use of zinc nano-fertilizers in the experimental plots	Tr7	N×F1×Z2	Tr19	S1×F1×Z2	Tr31	S2×F1×Z2
zinc nano-fertilizer	Z1	Use of 2.5 mg of zinc nano-fertilizer per kg of experiment soil	Tr8	N×F1×Z3	Tr20	S1×F1×Z3	Tr32	S2×F1×Z3
	Z2	Use of 5 mg of zinc nano-fertilizer per kg of experiment soil	Tr9	N×F2×Z0	Tr21	S1×F2×Z0	Tr33	S2×F2×Z0
	Z3	Use 7.5 mg of zinc nano-fertilizer per kg of experiment soil	Tr10	N×F2×Z1	Tr22	S1×F2×Z1	Tr34	S2×F2×Z1
			Tr11	N×F2×Z2	Tr23	S1×F2×Z2	Tr35	S2×F2×Z2
			Tr12	N×F2×Z3	Tr24	S1×F2×Z3	Tr36	S2×F2×Z3

harvest index was calculated by dividing the seed yield by the biological yield. Due to the existence of different units of traits, standardization of traits eliminates the units.

$$Z = \frac{X - \mu}{\sigma} \quad (1)$$

In this equation, Z: the standard score, X: initial data of the trait, μ: the mean of the trait, σ: standard deviation of the trait.

To interpret the experimental data from combined analysis, mean comparison by Duncan's method, comparison chart of interaction effect in terms of grain yield traits, analysis of correlation coefficients and correlation diagram to investigate relationships between traits, graphic analysis including polygon diagram, selection of appropriate treatment from The opinion of all the traits and the selection of the appropriate treatment were used based on the ideal treatment. To analyze the experimental data, Excel, SasV9.1 and Genstat V12 software were used.

3. Results and Discussion

3.1. Combined analysis and Mean comparison

The results of the combined analysis of the obtained data at the probability level of 0.01 and 0.05 indicated that the effect of drought showed a significant difference in all traits except the trait of spike length. The effect of iron nano-fertilizer showed significant differences in all traits, except for the 1000- seed weight trait, and the drought × iron effect in all traits, except for the traits of the number of tiller in the spike and the 1000- seed weight. The effect of Zinc nano-fertilizer and Fe nano-fertilizer ×Zinc nano-fertilizer also showed significant differences in all traits and the effect of Drought × Zinc nano-fertilizer in all traits except plant height. The highest percentage of coefficient of variation was related to paddy diameter (16.8) and paddy length (16.1) and the lowest was related to spike length (5.58). Also, the highest value of the R-square coefficient was related to the grain yield trait (0.96) and the lowest value was related to the grain length trait (0.81) (Table 4). In the comparison of the mean done by Duncan's method on the data obtained from the experiment in terms of drought stress treatment, the normal level had the highest level of favorability in terms of all traits. In terms of plant height trait, level N and S2, in terms of the number of tiller in a spike, level S1, in terms of spike length trait, level N, in terms of Number of seeds per spike trait, level S2, in terms of 1000- seed weight trait, levels N and S1, in terms of harvest index trait levels S1 and S2, in terms of grain yield, level N, in terms of grain diameter in N and S2 treatments, in terms of grain length in S2 level, in terms of paddy length in S1 level and terms of paddy diameter in N level, The highest degree of desirability was observed. The result of comparing the mean of iron nano-fertilizer treatment in terms of all the traits, the F2 level had the highest mean value in terms of the studied traits. In terms of plant height trait of F1 treatment, in terms of Number of tiller per plant trait of F0 level, in terms of spike length trait of F0 level, in terms of Number of seeds per spike trait of F1 level, in terms of 1000- seed weight trait of F1 and F2 levels, in terms of harvest index trait of F1 level, In terms of grain yield traits of F2 level, in terms of grain diameter and grain length traits of F1 and F2 treatments, in terms of paddy length trait of F1 level and in terms of paddy diameter trait, F1 and F2 treatments showed the highest yield in traits. In the comparison of the average amount of zinc nano-fertilizer, the Z2 level was ranked the best compared to other levels. Based on this, in terms of plant height traits, Number of tiller per plant and spike length treatments, Z0 and Z1, in terms of Number of seeds per spike trait, Z3 treatment, in terms of 1000- seed weight, Z2 treatment, in terms of harvest index trait, Z3 level, in terms of grain yield trait, Z1 and Z2 levels And terms of grain length and grain diameter and paddy length and paddy diameter, levels Z0 and Z1 were more favourable than other treatments (Table 5). Considering that the grain yield trait is one of the most widely used and essential

Table 4. Combined analysis in terms of studied traits on drought, iron nano-fertilizer and zinc nano-fertilizer treatments.

	Df	PLH	NTP	SL	NSS	WTS	HI	YLD	GD	GL	PL	PD
Drought	2	13.5*	10.8*	1.9^{ns}	88.7*	0.39*	0.004*	101099*	0.03*	0.5*	0.2*	0.06*
Block	2	273.3**	10.1^{ns}	18.4**	11^{ns}	6.2^{ns}	0.0005^{ns}	152954^{ns}	0.04*	0.61^{ns}	2.69^{ns}	0.04^{ns}
Fe	2	73.6*	17.5*	0.2*	20.03*	0.1^{ns}	0.0009*	954854*	0.11**	3.3**	17.8**	0.34*
Drought × Fe	4	85.4*	8.1^{ns}	2.6*	27.8*	11.3^{ns}	0.001*	283696*	0.04*	2.6*	14.5**	0.23*
Error1	4	114.4	4.41	0.89	31.7	17.5	0.001	351419	0.01	1.09	1.23	0.18
Zinc	3	31.4*	2.17*	0.97*	92.1*	18.5*	0.004*	272860*	0.02*	1.2*	2.2*	0.06*
Drought × Zinc	6	58.4^{ns}	6.59*	1.5*	35.4*	10.1*	0.001*	84693*	0.02*	1.1*	1.8*	0.04*
Fe× Zinc	6	31.5*	3.34*	4.79**	60.5*	2.2*	0.002*	2421543**	0.006*	0.46*	0.98*	0.01*
Error	66	49.7	361.3	2.39	50.2	6.7	0.002	407365	0.02	1.27	2.7	0.06
CV%	--	7.25	9.1	5.58	9.4	10.2	9.48	10.14	15.2	15.09	16.1	16.8
R-square	--	0.82	0.91	0.9	0.82	0.84	0.92	0.96	0.93	0.81	0.92	0.95

*, **, and ^{ns}: significant at 5%, 1% and not-significant. The coefficient of variation (CV).

Table 5. Means comparison by Duncan's method in terms of studied traits on drought, iron nano-fertilizer and zinc nano-fertilizer treatments.

	Levels	Rank	PLH	NTP	SL	NSS	WTS	HI	YLD	GD	GL	PL	PD
Drought stress	N	1	97.1a	25.05ab	27.9a	73.3b	25.41a	0.5ab	6347.7a	1.04a	7.45ab	10.23ab	1.6a
	S1	2	96.6b	26.5a	27.4ab	74.4ab	25.42a	0.51a	6271.4ab	0.99b	7.38ab	10.34a	1.5b
	S2	3	97.8a	26.05ab	27.7ab	76.4a	25.2ab	0.52a	6245.8ab	1.05a	7.62a	10.18ab	1.5b
Fe nano-fertilizer	F0	3	95.8b	26.4a	27.8a	74.7ab	24.8b	0.51ab	6124b	0.96ab	7.1ab	9.4b	1.46b
	F1	2	98.6a	25.3b	27.6ab	75.4a	25.3a	0.52a	6290ab	1.05a	7.6a	10.74a	1.64a
	F2	1	97.2ab	25.2b	27.6ab	73.9b	25.3a	0.51ab	6449a	1.06a	7.6a	10.5ab	1.61a
Zinc nano-fertilizer	Z0	3	98.05a	27.8a	27.8a	75.1ab	25.9ab	0.51ab	6293.7b	1.04a	7.6a	10.4a	1.6a
	Z1	2	98.1a	27.8a	27.8a	72.7c	25.2ab	0.5ab	6324.2a	1.06a	7.7a	10.5a	1.62a
	Z2	1	96.8ab	27.7ab	27.7ab	74b	26.04a	0.51ab	6386.3a	1.01ab	7.3ab	10ab	1.5ab
	Z3	4	95.8b	27.4ab	27.4ab	77.1a	24.2b	0.53a	6149b	0.99b	7.2ab	9.94b	1.4b

a and b: Duncan mean comparison.

traits in agricultural research, especially in the rice crop, the average effect of drought × iron nano-fertilizer × zinc nano-fertilizer was compared in terms of the grain yield trait and the treatments were compared accordingly. The result of this analysis showed that treatments tr10, tr8, tr7 and tr22 had the best rank compared to other treatments in terms of this trait and treatments tr32 and tr13 had low desirability (Figure 2). In general, based on the comparison of the mean, it can be concluded that considering that normal humidity conditions can have a positive effect on the performance of traits, but under S1 stress conditions, the traits showed a good performance trend. Also, increasing the amount of iron nano-fertilizer at the F2 level can be very effective in the growth of yield and the desirability of traits.

In the examination of the amount of nano-fertilizer consumption on the traits, a different result can be expressed and that is, considering that the zinc nano-fertilizer at the level of Z2 showed the most positive performance on the traits, but with the increase to the level of Z3, this benefit is greatly reduced. It can be concluded that the amount of zinc nano-fertilizer consumed should be controlled and regulated.

3.2. Relationships between traits

To investigate the relationship between the evaluated traits in the experiment, the analysis of correlation coefficients was used (Table 6). In this analysis, the highest numerical amount of correlation between the traits was determined with red color (+1) and the lowest numerical amount with blue colour (-1). Based on this analysis, the plant height trait had a positive and significant correlation with the grain yield trait and a negative and significant correlation with the Number of seeds per spike trait. The Number of tiller per plant trait also showed a positive and significant correlation with the grain yield trait. The number of seeds per spike trait also had a positive and significant correlation with traits of 1000- seed weight, harvest index and grain yield. The 1000-seed weight trait had a positive and significant correlation with the grain yield trait. Also, a positive and

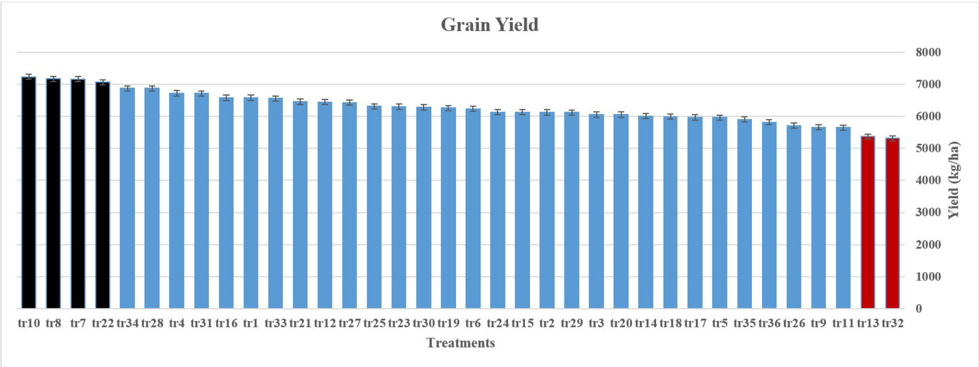

Figure 2. Means comparison effect of drought × iron nano-fertilizer × zinc nano-fertilizer in terms of grain yield trait.

Table 6. The correlation coefficients between evaluated traits in the experiment.

	PLH	NTP	SL	NSS	WTS	HI	YLD	GD	GL	PL	PD
PLH	1										
NTP	0.03	1									
SL	0.05	0.15	1								
NSS	-0.16*	0.09	-0.02	1							
WTS	0.15	0.04	0.01	0.2*	1						
HI	-0.16	0.09	-0.02	0.9**	0.2*	1					
YLD	0.09*	0.02*	0.01	0.2*	0.11**	0.2*	1				
GD	0.1	-0.08	-0.03	0.09	-0.05	0.09	0.03	1			
GL	0.06	-0.11	-0.02	0.1	-0.02	0.1*	0.05	0.9*	1		
PL	0.04	-0.12	-0.07	0.12	-0.005	0.12*	-0.006	0.8*	0.8*	1	
PD	0.09	-0.14	0.02	-0.02	-0.06	-0.02	-0.01	0.7*	0.7*	0.65*	1

*, **significant at 5% and 1%. PLH: Plant height; NTP: Number of tiller per plant; SL: Spike length; NSS: Number of seed per spike; WTS: 1000-seeds weight; HI: Harvest index; YLD: Grain yield; GD: Grain diameter; GL: Grain length; PL: Paddy length; PD: Paddy diameter.

significant correlation was observed between the traits of harvest index and traits of grain yield, paddy length and grain length. The grain diameter trait showed a positive and significant correlation with the traits of grain length, paddy length and paddy diameter, grain length trait with paddy length and paddy diameter traits, and paddy length trait with paddy diameter trait.

In the bi-plot correlation diagram between the traits, the cosine of the angle between the vectors of the traits indicates the intensity of the correlation between the traits. If the angle between the vectors is less than 90 degrees, the correlation between the vectors is +1, if the angle between the trait vectors is 90 degrees, the correlation between the trait vectors is zero, and if the angle between the vectors is 180 degrees, it indicates correlation will be -1 (Yan et al., 2007). To determine the correlation of traits, treatment-trait bi-plot diagrams are used, which are obtained from the GGE biplot method (Akcura and Kokten, 2017). In examining the correlation diagram between traits, the first component accounted for 24.34% and the second component accounted for 19.01% and in total accounted for more than 43% of the total variance of the data. In this diagram, grain yield, number of seeds per spike and number of tillers per plant traits together, number of tiller per plant, spike length, paddy diameter and harvest index traits together, paddy diameter, harvest index, plant height and 1000- seed weight traits together, and grain length and grain diameter traits have a positive correlation. The spike length and paddy diameter traits with grain diameter trait and the number of tillers per plant trait with grain length trait also had a negative correlation due to the angle of 180 degrees between their vectors. Also, according to the angle of 90 degrees between the vectors of the number of tiller per plant traits with 1000- seed weight and spike length trait with grain yield, the correlation between these traits was estimated to be zero (Figure 3).

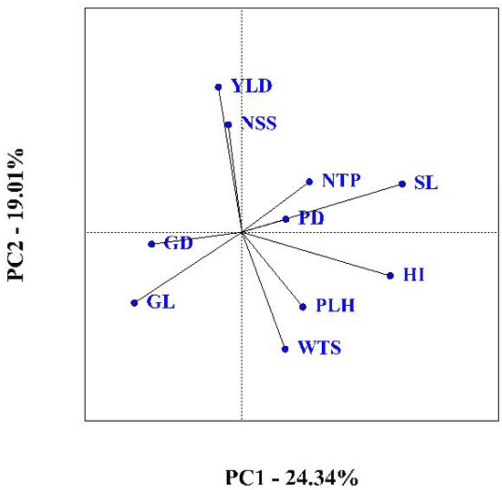

Figure 3. Correlation diagram of evaluated traits in the experiment. PLH: Plant height; NTP: Number of tiller per plant; SL: Spike length; NSS: Number of seed per spike; WTS: 1000-seeds weight; HI: Harvest index; YLD: Grain yield; GD: Grain diameter; GL: Grain length; PL: Paddy length; PD: Paddy diameter.

3.3. Polygon view

The polygon diagram is used to identify the best treatments among the studied traits. This graph is drawn by connecting the treatments that have the greatest distance from the origin, so that the other treatments are placed inside this polyhedron. In each section, the treatments that have more performance and desirability with specific characteristics are separated by lines. Many researchers used this type of diagram on different plants intending to identify appropriate treatments, including maize (Mousavi et al., 2023; Khatibi et al., 2023), rice (Semeskandi et al., 2023), canola (Shojaei et al., 2023), sunflower (Isa ansarifard et al., 2020). The polygon diagram drawn to compare the treatments in terms of traits indicated that the treatments tr33, tr8, tr19, tr24, tr7, tr6 and tr2 were identified and selected as the desired treatments due to the large distance from the origin of the diagram. In each section, treatment tr10 in terms of grain yield, treatment tr19 in terms of spike length, treatment tr24 in terms of 1000- -seed weight and plant height traits, treatment tr6 in terms of grain length, treatment tr14 in terms of number of seeds per spike and treatment tr15 According to the paddy diameter trait were more desirable (Figure 4a). The polygon diagram is one of the

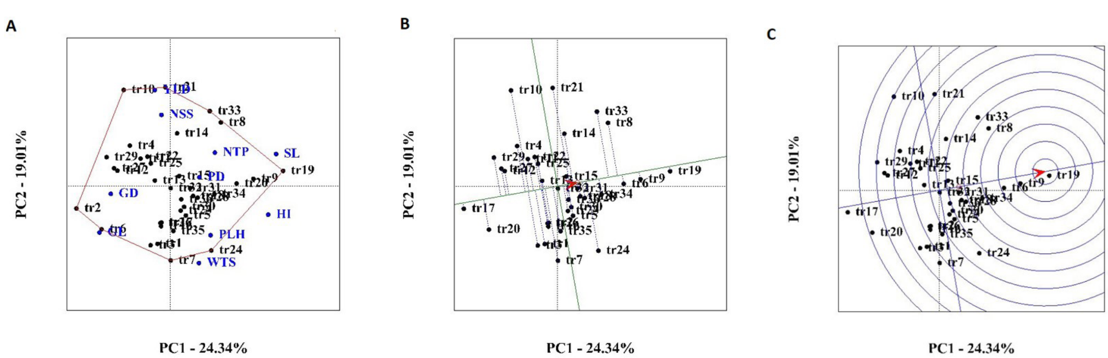

Figure 4. Selection of suitable treatments in the experiment in terms of evaluated traits based on graphic analysis. (a) Polygon diagram to select appropriate treatments based on traits; (b) Treatment ranking diagram based on the traits evaluated in the experiment; (c) Diagram for choosing the suitable treatment based on the ideal treatment.

most important features of the bi-plot method to determine the best treatments (Qasemi et al., 2022). Overall, the polygon diagram is a key component of the bi-plot method used to determine the best treatments in agricultural research. By utilizing this visual tool, researchers can make informed decisions on which treatments to pursue for further study and potential implementation in crop management practices. The use of a polygon diagram in agricultural research is a valuable tool for identifying the most effective treatments for specific traits. By connecting treatments with the greatest distance from the origin, researchers are able to visually see which treatments perform best in relation to the studied characteristics.

3.4. Ranking of treatments in terms of all investigated traits

In the ranking diagram of the treatments in terms of all the traits, the axis marked with a red arrow (horizontal axis or AEC-abscissa) and past the mean of the traits (circle) determines the performance of cultivars, so that any digit on the right side If this axis is located, it has more features. The average of traits is obtained by calculating the average value of PC1 and PC2 for all traits. The vertical axis in the diagram (AEC-Ordinate) shows the stability or instability of treatments. Treatments that have a greater distance from the origin of this axis are less stable. Furthermore, treatments that have a greater vertical distance from the AEC-abscissa axis are less stable (Qasemi et al., 2022). In the ranking of treatments in terms of all traits, treatments tr19, tr9 and tr6 had the highest degree of desirability in terms of the examined traits and treatments tr17, tr20 and tr29 had the lowest degree of desirability in terms of traits (Figure 4b). Based on this, the ranking of treatments from the most favourable treatment to the least favourable treatment is as follows:

Tr19> tr9> tr6> tr8> tr33> tr34> tr28> tr31> tr36> tr23> tr5> tr30> tr24> tr20> tr14> tr21> tr13> tr35> tr7> tr15> tr11> tr3> tr18> tr2> tr16> tr32> tr1> tr25> tr22> tr10> tr4> tr12> tr27> tr29> tr26> tr17.

The most stable treatments, due to their proximity to the mean axis, include the treatments tr19, tr9, tr6, tr15, tr13 and tr17, which considering that the treatments tr19 and tr9 have more favorable traits performance than other treatments were identified as favourable and stable treatments (Figure 4b).

3.5. Selection of the most suitable treatment based on the ideal treatment

In this diagram, the most suitable treatment is selected based on the ideal treatment, from the origin of the linear coordinates to the mean point and continues to the sides. The best treatment is the one that is close to the positive end of this axis. In this diagram, the best point is the center of the concentric circles marked by the arrow, and the other treatments are ranked based on this point. The treatment that has the smallest distance from this point is identified as the superior treatment. The appropriate treatment selection diagram is drawn based on determining the distance from the hypothetical ideal treatment. This hypothetical ideal treatment is defined based on the most stable and productive treatment (Yan and kang., 2003). Based on this diagram, treatments tr19, tr9 and tr6 were identified as desirable treatments and treatments tr17, tr20 and tr29 were identified as undesirable treatments. The ranking of treatments based on this diagram from favorable to unfavorable is as follows: (Figure 4c)

Tr19> tr9> tr6> tr18> tr34> tr28> tr31> tr8> tr33> tr3> tr23> tr16> tr11> tr14> tr15> tr32> tr5> tr1> tr7> tr12> tr24> tr30> tr36> tr22> tr25> tr13> tr35> tr26> tr21> tr4> tr27> tr2> tr10> tr29> tr20> tr17.

4. Conclusion

Many efforts have been made by researchers to improve the formulation of conventional chemical fertilizers, which has resulted in little success. The use of nano-fertilizers can be important in the optimal use of fertilizer in agricultural systems. The results of this research showed that tr19 (S1×F1×Z2), tr6 (N×F1×Z1) and tr9 (N×F2×Z0) treatments are suggested as practical treatments in rice cultivation and the use of nano-fertilizers can increase the stability and yield of rice plants under drought stress conditions. Also, the results of this research indicated that the use of iron nano-fertilizer and controlled consumption of zinc nano-fertilizer can have a positive effect on improving the quantity and quality of traits in the cultivation of this plant.

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