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Effects of Nitrogen Levels, Nitrogen Sources and Zinc Rates on the Growth and Mineral Composition of Lowland Rice

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ABSTRACT

Nitrogen use efficiency (NUE) is usually lower in paddy rice (*Oryza sativa* L.) than in upland crops. For this reason, any attempt to improve NUE through the use of different nitrogen (N) carriers, different rice cultivars, properly timed N application, the use of nitrification and urease inhibitorsis of prime interest. Moreover, zinc (Zn) next to N seems to be the most important soil factor affecting rice growth. Although the response of rice N and Zn fertilization has been reported elsewhere, the authors are not aware of any such information for the calcareous paddy rice soils of Iran. Therefore, the present experiment was conducted to study the effects of varying sources and levels of N and Zn rate on the growth and N and Zn concentrations and uptake by rice. Treatments consisted of five N levels (0, 50, 100, 200, and 400 mg N kg^{-1}soil), four N sources [urea (U), sulfur–coated urea (SCU), ammonium sulfate (AS), and ammonium chloride (AC)] and three Zn rates (0, 5, and 10 mg Zn kg^{-1} soil as zinc sulfate). The experiment was factorially arranged in a completely randomized design with three replicates. The results showed that the highest top dry weight was obtained with SCU, and followed by AS, AC and U. Application of N up to 200 mg kg^{-1} as U, AS, and AC increased rice growth significantly. However, there was a consistent significant increase in shoot growth with the addition of SCU. In the present study, Zn fertilization had no significant effect on rice growth. The uptake and concentration of N and Zn were increased by application of N and Zn. However, the highest Zn concentration and uptake were obtained with AC and SCU, respectively. Nitrogen and Zn addition generally increased leaf area and the maximum leaf area was obtained with SCU. Nitrogen yield efficiency (NYE) was reduced with increasing N rates (as U, AS, and AC) and increased up to 200 mg N kg^{-1} as SCU. Apparent N recovery (ANR) increased with increasing N up to 200 mg kg^{-1} as U, AS, and AC and declined thereafter. However, there was an increase in ANR with an increasing N level as SCU. On the other hand, N physiological efficiency (NPE) decreased with increasing N rates regardless of N sources. From the results reported here, it appears that 200 mg N kg^{-1} is the most appropriate N level and SCU appears to be the most efficient N source for lowland rice.

Keywords: Nitrogen, Nitrogen-use efficiency, Rice, Zinc.

INTRODUCTION

Nitrogen is an influential factor in rice production and its immense role in increasing rice productivity is well documented [16]. Nevertheless, nitrogen use efficiency (NUE) is generally low in paddy rice due to various causes of N-loss such as runoff, ammonia volatilization, leaching, and denitrification [29, 31]. Therefore, to ensure a continuous and optimal supply of N and to have higher fertilizer-use efficiency, there is an urgent need to decrease N losses [13]. The main key to both improving NUE and reducing negative N impact on environmental quality is synchronization of the N supply from soil with plant N demand [36]. One possible approach is the use of slow–release N fertilizer such as sulfur–coated urea [36].

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Zinc has a crucial role to play in various aspects of plant physiology, including cell membrane integrity, gene expression, carbohydrates photosynthetic metabolisms, detoxification of reactive oxygen species, phytohormone activity and the proper functioning of a number of enzymes [5, 22, 37]. Therefore, the lack of sufficient Zn may cause severe yield reduction [26]. It has been reported that the deficiency of Zn is aggravated by excess Ca, Mg, Cu, Fe, Mn and P and prolonged submergence would depress Zn availability and uptake (10, 26). Zinc deficiency has also been observed with high bicarbonate content, Mg/Ca ratio>1 in soil, N rates and sources [8, 10, 26, 28, 33].

Although the effect of N and Zn on rice growth has been evaluated elsewhere, there is little if any information available regarding the response of this crop to N and Zn fertilization in the highly calcareous soils of Iran. Therefore, the present study was undertaken to determine the effects of sources and levels of N and Zn rates on rice growth, and Zn and N concentration and uptake by rice.

MATERIALS AND METHODS

A greenhouse experiment was designed to evaluate the effect of N sources and levels and the rates of Zn on the growth and nutrient status (N and Zn) of rice in a calcareous soil (Fine, carbonatic, hyperthermic, Typic Ustochrepts). The soil sample from the surface horizon (0-30 cm) was collected from a paddy field in Noor Abad in Fars Province, Iran. The soil sample was air-dried, ground, sieved and analyzed for pH (saturated paste), electrical conductivity, organic matter, cation exchange capacity and calcium carbonate equivalent following the procedures outlined by Maftoun *et al.* [20] and clay, silt and sand content according to the method of Bouyuocos [3]. The available P was determined by the $NaHCO_3$ extraction method [27]. Also, the soil was analyzed for DTPA-extractable Zn, Fe, Mn and Cu [19]. The physical and chemical properties of the soil are given in Table 1.

The experiment was carried out in a factorial completely randomized design with three replicates. The treatments consisted of five N levels (0, 50, 100, 200, and 400 mg kg^{-1} soil), four

Table 1. Some physical and chemical properties of the soil.

pH (Saturated paste)	7.30
EC_e (dS m^{-1})	1.05
Clay (g kg^{-1})	340
Silt (g kg^{-1})	410
N (%)	0.145
CCE (g kg^{-1})	530
CEC (c mol c kg^{-1})	27.4
$NaHCO_3$-P (mg kg^{-1})	15.5
DTPA-extractable (mg kg^{-1})	
-Zn	0.67
- Fe	3.22
- Mn	4.3
- Cu	1.7

N sources urea (U), [sulfur–coated urea (SCU), ammonium sulfate (AS), and ammonium chloride (AC)] and three Zn rates (0, 5, and 10 mg kg^{-1} soil as zinc sulfate). All pots received a uniform application of 25 mg P kg^{-1} as KH_2PO_4, 5 mg Fe kg^{-1} as FeEDDHA, 2.5 mg Mn kg^{-1} as $MnO_4.4H_2O$ and 2.5 mg Cu kg $^{-1}$ as $CuSO_4$. The nutrient elements were added as a separate aqueous solution to 2 kg soil in a plastic bag several days before planting. At the time of planting, the soil in each bag was thoroughly mixed and transferred to plastic pots. Ten rice seeds (var. Ghasro-dashti) were planted in each pot. The pots were irrigated with distilled water to bring the soil moisture to near field capacity. The plants were thinned to four uniform stands per pot during the third week. The soil was then kept under constant submergence throughout the growing period of the rice using distilled water.

At the end of the eighth week, leaf area was measured using a ruler [2] and then the aerial part of the plants were cut, rinsed with distilled water, dried at 65°C for 48 hours and weighed. The plant tissues were ground to pass through a 40–mesh screen and dry–ashed at 500°C. The ash was then dissolved in 2 M HCl and Zn was determined by an atomic absorption spectrophotometer. Total N was measured according to Bremner [4]. Nitrogen yield efficiency (NYE), apparent N recovery (NAR) and N physiological efficiency (NPE) were calculated as follows:

$$NYE = \frac{Top\ dry\ matter\ from\ treated\ plot\ (g pot^{-1}) - Top\ dry\ matter\ from\ control\ plot\ (g\ pot^{-1})}{Amount\ of\ N\ applied\ (g\ pot^{-1})}$$

$$ANR\% = \frac{Uptake\ of\ N\ from\ treated\ plot (g\ pot^{-1}) - uptake\ of\ N\ from\ control\ plot (g\ pot^{-1})}{Amount\ of\ N\ applied (g\ pot^{-1})} \times 100$$

$$NPE = \frac{Top\ dry\ matter\ from\ treated\ plot\ (g\ pot^{-1}) - Top\ dry\ matter\ from\ control\ plot (g\ pot^{-1})}{Uptake\ of\ N\ from\ treated\ plot\ (g\ pot^{-1}) - Uptake\ of\ N\ from\ control\ plot\ (g\ pot^{-1})}$$

Data were analyzed statistically using MSTATC and EXCEL software programs.

RESULTS AND DISCUSSION

Analysis of variance indicated that some of plant responses were affected by the main effects of fertilizer treatments and their interactions (Table 2).

The rice top dry matter was affected by N levels and sources, but Zn application did not affect it (Table 2).

Application of 200 mg N kg^{-1} as urea, ammonium sulfate and ammonium chloride increased rice growth significantly; no response was observed with higher N rates as urea and/or ammonium sulfate while it decreased with ammonium chloride. However, the addition of N up to 400 mg kg^{-1} as SCU significantly increased the top dry weight of rice (Table 3). The highest top dry weight was obtained with SCU, being followed by ammonium sulfate, ammonium chloride and urea (Figure 1). This finding is in agreement with those of other researchers [11, 12, 13, 15, 18].

The higher top dry weight obtained with SCU is probably due to slow N release from this fertilizer, that supplies enough N in a pattern to satisfy the rice N requirement based on its physiological stages [13]. Furthermore, the sulfur in SCU and its vital role in rice nutrition can be ignored; the higher top dry weight was obtained from ammonium sulfate, compared to other sources. It has been reported [22] that nitrogen losses from urea are extensive and much greater than ammonium sulfate which might have led to higher yield with ammonium sulfate compared to urea.

Zinc fertilization had no significant effect on rice top dry weight, indicating that indigenous soil Zn was probably sufficient (Tables 2 and 3). Different soil Zn critical levels have been reported for rice, ranging from 0.3 mg kg^{-1} [20], 0.4 mg kg^{-1} [7], 0.6 mg kg^{-1} [35] to 0.78 mg kg^{-1} [30].

Application of 400 mg N kg^{-1} as ammonium chloride in combination with Zn decreased rice growth (Table 3), caused by the effect of high chloride ion concentration [9].

Nitrogen sources had no significant effect on N uptake and concentration, although, they were affected by N and Zn levels (Table 2). Applied Zn significantly increased N uptake and concentration in the aerial part of rice (Table 4; data related to nitrogen concentration not presented) with urea and ammonium sulfate. Salam and Subramanian [32] reported that Zn application increased N concentration and uptake by increasing root development and N use efficiency. Nitrogen uptake and

Table 2. Analysis of variance summary for some plant responses.

Source of variation	df	Top dry matter	N Conc.	N Uptake	Zn Conc.	Zn Uptake	Leaf area
N sources (N_S)	3	**	ns	ns	**	**	**
N levels (N_L)	4	**	**	**	**	**	**
$N_S \times N_L$	12	**	ns	*	**	**	**
Zn levels (Zn_L)	2	ns	**	ns	**	**	**
$Ns \times Zn_L$	6	ns	*	**	ns	ns	**
$N_L \times Zn_L$	8	**	ns	*	**	**	ns
$N_L \times N_S \times Zn_L$	24	*	ns	**	ns	*	**
Error	120						

* and **: Significant at the 0.05 and 0.01 levels, respectively.
ns: non significant.

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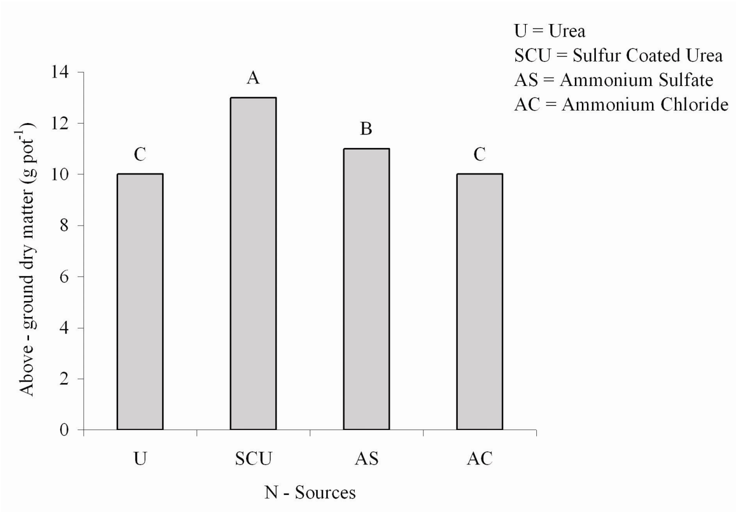

Figure 1. Effect of N-sources on above-ground dry matter weight of rice.

The columns received same letters are not significantly different accoding to Duncans test (P≤0.05)

concentration were not increased by the application of lower N rates (Table 4; data related to nitrogen concentration not presented).

Nitrogen sources and levels and Zn rates affected Zn uptake and concentration (Table 2). Application of 400 mg N kg^{-1} increased Zn uptake and concentration compared to 50 and 100 mg N kg^{-1} and control treatments regardless of N sources (Table 5; data related to zinc concentration has not been presented). This could be explained by the fact that root growth and absorption capacity were increased when 400 mg N kg^{-1} was applied. Mehdi and Dedatta [23] and Salam and Subramanian [32] reported similar results.

Kirk and Bajita [14] also reported the importance of root-induced changes in the plant's Zn uptake. It seems that Zn is solubized by a root-

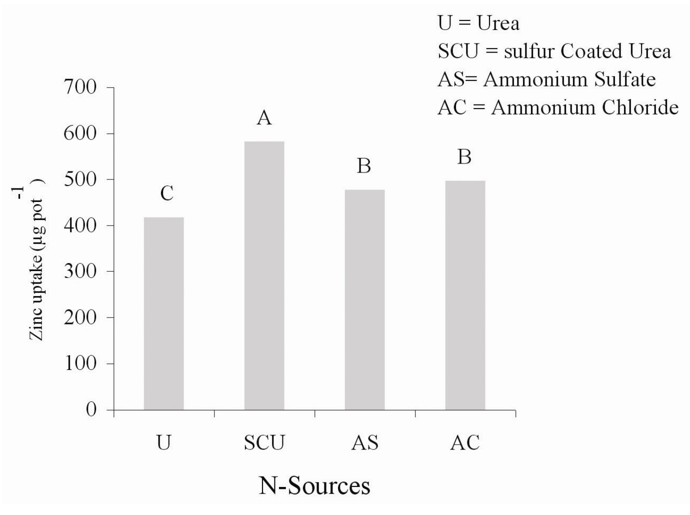

Figure 2. Effect of N-sources on zinc uptake by rice to dry matter.
The columns received same letters are not significantly different accoding to Duncans test (P≤0.05)

Table 3. Effect of N sources and levels and Zn rates on rice top dry weight (g pot^{-1}).

N levels ($mg\ kg^{-1}$)	Zn rates ($mg\ kg^{-1}$)			Mean
	0	5	10	
		U		
0	3.0 d [a]	3.6 d	3.6 d	3.4 d
50	8.7 c	7.9 c	7.5 c	8.0 c
100	11.1 bc	10.9 b	11.8 b	11.2 b
200	12.6 ab	14.9 a	14.2 a	13.9 a
400	14.0 a	13.1ab	12.2 a	13.8 a
Mean	9.9 A [a]	10.1A	10.3 A	
		SCU		
0	4.0 e	3.8 e	4.7 d	4.2 e
50	7.8 d	7.0 d	8.0 c	7.6 d
100	11.3c	12.1 c	11.0 b	11.5 c
200	18.3 b	17.9 b	20.4 a	18.9 b
400	24.8 a	22.3 a	21.3 a	22.8 a
Mean	13.3 A	12.6 A	13.1 A	
		AS		
0	3.7 d	4.0 e	3.8 d	3.8 d
50	7.9 c	6.5 d	8.6 c	7.6 c
100	10.5 b	11.3 c	12.6 b	11.4 b
200	15.5 a	14.8 b	16.7 a	15.7 a
400	16.1 a	18.2 a	13.5 a	15.9 a
Mean	10.7 A	11.0 A	11.0 A	
		AC		
0	3.2 d	3.8 c	4.4 d	3.7 d
50	6.5 c	8.6 b	7.4 c	7.5 c
100	11.6 b	12.4 a	11.5 b	11.8 b
200	15.5 a	14.1 a	15.5 a	15.0 a
400	13.3 b	12.5 a	11.6 b	12.6 b
Mean	10.0 A	10.3 A	10.1 A	

[a] Means followed by the same small letter (in each column) or the same capital letter (in each row) is not significantly different according to Duncan's test ($P \leq 0.05$) for each N source.

induced acidification resulting from an excess of cations (especially NH_4^+) over anions and the concomitant release of H^+ from the roots [26]. On the other hands, Silber *et al.* [33] reported that Zn was the only micronutrient that is significantly correlated with pH of the rhizosphere. They showed a decrease in rhizosphere pH with an increase in NH_4^+/NO_3^-. Zinc uptake was greatest with SCU and followed by AC, AS and U (Figure 2).

Similar results have been reported by Kiran and Patra [13].

by the crop resulting in maximum shoot dry weight and Zn uptake (Figures 1 and 2).

The higher Zn uptake associated with SCU is probably due to the better utilization of N

The interaction between N and Zn rates on the uptake and concentration of N and Zn appears to be synergetic; that is, soil application of N in combination with Zn increased concentration and uptake of these two nutrients. These findings are in agreement with those obtained by Salam and Subramanian [32].

Nitrogen and Zn addition generally increased rice leaf area, while the maximum leaf area was obtained with SCU. Kushwaha *et al.* [17] believe that lower N volatilization and denitrification from SCU is responsible for a higher leaf area in rice treated with this fertilizer. However, the application of 400 mg N kg^{-1} as AC significantly reduced leaf area (Table 6). The relatively high Cl^- ion concentration in soil solution was probably responsible for such leaf area suppression. Some research workers [1, 9, 24, 25, 32] have reported the depressing effect of Cl^- on leaf cell development when N was applied as AC.

The data in Table 9 indicate that nitrogen yield efficiency (NYE) reduced with increasing N rates as U, AS and AC. However, the

Table 4. Effects of N sources and levels and rates of Zn on N uptake by the rice top (mg pot^{-1}).

N levels (mg kg^{-1})	Zn rates (mg kg^{-1})			Mean
	0	5	10	
		U		
0	26.2b [a]	41.0 b	58.9 c	42.0 d
50	82.9 b	79.8 b	92.6 c	85.1 d
100	121.9 b	162.4 b	178.1bc	154.4 c
200	138.5 b	378.2 a	263.6 ab	260.1 b
400	349.0 a	363.7 a	384.4 a	356.7 a
Mean	143.7 B	205.0 A	195.5 A	
		SCU		
0	55.7 c	47.2 c	64.6 c	55.8d
50	85.6 c	72.2 c	78.7 c	78.8 cd
100	121.8 c	138.5 bc	136.4 c	132.2 c
200	250.7 b	234.2 b	260.8 b	248.4 b
400	592.5 a	483.1 a	443.3 a	506.3 a
Mean	221.2 A	195.01 A	196.6 A	
		AS		
0	38.5 b	45.4 b	41.1 c	41.1 c
50	95.4 b	85.4 b	128.1 c	103.0 bc
100	140.1 b	144.5b	213.8 bc	166.1b
200	114.4 ab	194.0 b	581.4 b	319.9a
400	231.0 a	465.1 a	314.2 a	370.4 a
Mean	157.9 B	187.07 B	255.9 A	
		AC		
0	30.4 b	29.3 c	55.4 c	38.4 d
50	46.8b	73.5c	68.1 c	63.8 d
100	134.4 b	148.8 c	141.8 bc	141.6 c
200	273.7 a	293.9 b	209.9 ab	259.2 b
400	323.8 a	432.4 a	333.6 a	360.3 a
Mean	162.4 A	193.8 A	161.7 A	

[a] Means followed by the same small letter (in each column) or the same capital letter (in each row) is not significantly different according to Duncan's test (P≤0.05) for each N source.

addition of N up to 200 mg kg^{-1} as SCU was associated with an increase in nitrogen yield efficiency (NYE); a higher N level declined this growth parameter. Apparent N recovery followed a similar trend as the top dry weight (Table 7).

Apparent N recovery increased with increasing N up to 200 mg kg^{-1} as U, AS and AC and was suppressed with further addition. However, there was an increase in ANR with increasing N levels as SCU. This rising trend of ANR with SCU was attributed to adequate N supply throughout the rice growing resulting in higher N uptake under SCU than under any other N sources [36]. Lower apparent N recovery with SCU compared to other sources especially at lower N levels was probably due to the reduced N release from this N source. These results are in agreement with those reported by Singh and Singh [34] and Yadav and Verma [38]. Nitrogen physiological efficiency decreased with increasing N rates regardless of the sources of N. Chaka *et al.* [6] have reported similar results.

CONCLUSIONS

From the results presented in this study, it can be concluded that under these growing conditions, 200 mg N kg-1 is the most appropriate N level for rice. Furthermore, It appears that SCU is the best N carrier for lowland rice being followed by AS, AC, and U. Sulfur-coated urea can supply N by synchronizing the plant N demand and, thus, could potentially increase NUE and consequently rice growth. Nitrogen enhanced Zn uptake by rice regardless of the N source. The highest ANR and NYE were obtained with AS and SCU, respectively**.** It is strongly recommended that more research needs to be conducted under field conditions with more N sources, levels and diverse rice

Table 5. Effects of N sources and levels and Zn rates on Zn uptake by the rice top (µg pot^{-1}).

Zn levels (mg kg^{-1})	N rates (mg kg^{-1} l)					Mean
	0	50	100	200	400	
			U			
0	107 a [a]	265.5 b	159 b	333 b	457 b	304 b
5	121a	315 ab	438 a	641 a	531 a	409 b
10	139 a	369 a	504 a	687 a	997 a	539 a
Mean	122 E	316.5 D	434 C	554A	662 A	
			SCU			
0	102 a	217 a	217 a	678 b	663 b	395 c
5	200 a	297 a	515 a	852 b	1222 a	599 b
10	168 a	306 a	504 a	1312 a	1468 a	752 a
Mean	127 D	273 D	445.5 C	974 B	1117.5 A	
			AS			
0	138 a	241 b	318 b	502 b	458 b	331 c
5	173 a	269 ab	440 b	754 a	951 a	517.5 b
10	179 a	394 a	593 a	851 a	897 a	583 a
Mean	163 D	301 C	450 B	702 A	769 A	
			AC			
0	86 a	178 a	354 a	532 b	639.5 b	358 b
5	140 a	318 a	468 a	694 b	951 a	514 a
10	191 a	345 a	603 a	998 a	949 a	617 a
Mean	139 D	280 C	475 B	741 A	847 A	

a Means followed by the same small letter (in each column) or the same capital letter (in each row) is not significantly different according to Duncan's test (P≤0.05) for each N source.

Table 6. Effects of N sources and levels and Zn rates on rice leaf area (cm^2 pot^{-1}).

Zn levels (mg kg^{-1})	N rates (mg kg^{-1})					Mean
	0	50	100	200	400	
			U			
0	92 a [a]	229 b	364 a	544.5 b	611.5 c	368 c
5	114.5 a	241 ab	371 a	607 a	661.5 b	399 b
10	123 a	365 a	365 a	692 a	730 a	436 a
Mean	200 E	247 D	367 C	614 B	668 A	
			SCU			
0	97 b	164 b	346 a	625 a	921.5 b	436 a
5	128 b	238 a	326 a	599 b	956.5 a	449 a
10	193 a	158 b	346 a	569 b	800 c	413 b
Mean	139.5 E	187 D	340 C	607 B	893 A	
			AS			
0	171 a	182 b	218 b	425 b	510 c	310 c
5	172 a	131 b	297 a	479 ab	578 b	331 b
10	141 a	255 a	293 a	513 a	755 a	391 a
Mean	161 D	189.5 D	269 C	472 B	614 A	
			AC			
0	45 c	203.5b	335 c	481 c	344.5 a	282 c
5	129 b	266 a	409 a	565 b	349 a	344 a
10	183 a	259 a	368 b	584 a	267 b	322 b
Mean	191 E	243 D	370.5 C	543.5 A	320 B	

a Means followed by the same small letter (in each column) or the same capital letter (in each row) is not significantly different according to Duncan's test (P ≤ 0.05) for each N source.

Table 7. Effects of N sources and levels on N use efficiency**.**

N levels (mg kg^{-1} soil)	Zn rates (mg kg^{-1} soil)		
	ANR (%)	NYE	NPE
		U	
50	43.0	46.0	107.5
100	56.0	39.0	70.0
200	54.5	35.0	48.0
400	40.5	17.0	32.0
		SCU	
50	23.0	35.0	150.0
100	37.0	38.0	96.0
200	48.0	37.0	76.0
400	56.0	23.0	41.0
		AS	
50	61.0	38.0	62.0
100	62.0	38.0	61.0
200	69.5	30.0	43.0
400	41.0	15.0	37.0
		AC	
50	25.0	38.0	49.5
100	52.0	40.5	78.0
200	55.0	28.0	51.0
400	40.0	11.0	27.5

varieties in order to make an appropriate N recommendation for this crop.

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تأثیر منبع و سطوح نیتروژن و میزان روی بر رشد و ترکیب معدنی برنج

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چکیده

راندمان استفاده نیتروژن معمولاً در برنج از سایر گیاهان کمتر است. اخیراً کوششهایی به عمل آمده است تا بتوان با استفاده از منابع مختلف نیتروژن، ارقام برنج، تقسیم صحیح کودهای نیتروژن‌دار و بازدارنده‌های نیترات‌زایی و اوره آز، راندمان استفاده نیتروژن را افزایش داد. بعلاوه، روی پس از نیتروژن بیش از هر عنصر غذایی ضروری، رشد برنج را محدود می‌کند. اگر چه تأثیر نیتروژن بر رشد برنج در جهان ارزیابی شده است، اما اطلاعات قابل دسترس کمی در رابطه با پاسخ این گیاه به کاربرد نیتروژن و روی در خاکهای آهکی ایران وجود دارد. بنابراین یک آزمایش گلدانی برای مطالعه آثار منبع و سطوح نیتروژن و میزان روی بر رشد، غلظت و جذب نیتروژن و روی در برنج انجام گرفت. تیمارها شامل پنج سطح نیتروژن (۰، ۵۰، ۱۰۰، ۲۰۰ و ۴۰۰ میلی‌گرم در کیلوگرم خاک)، چهار منبع نیتروژن (اوره، اوره با پوشش گوگردی، سولفات آمونیوم و کلرید آمونیوم) و سه میزان روی (۰، ۵ و ۱۰ میلی‌گرم روی در کیلوگرم خاک به صورت سولفات روی) بودند. آزمایش به صورت فاکتوریل و در قالب طرح کاملاً تصادفی با سه تکرار انجام شد. نتایج نشان داد که بیشترین وزن خشک اندام هوایی با اوره و با پوشش گوگردی به‌دست آمد که پس از آن بترتیب سولفات آمونیوم، کلرید آمونیوم و اوره قرار داشتند. کاربرد نیتروژن تا ۲۰۰ میلی‌گرم در کیلوگرم خاک به صورت اوره، سولفات آمونیوم و کلرید آمونیوم سبب افزایش معنی‌دار رشد برنج شد، اما کاربرد نیتروژن تا ۴۰۰ میلی‌گرم در کیلوگرم به صورت اوره با پوشش گوگردی به طور معنی‌داری با افزایش وزن خشک اندام هوایی همراه بود. روی تأثیر معنی‌داری بر وزن خشک اندام هوایی برنج نداشت. جذب کل و غلظت نیتروژن و روی با کاربرد روی و نیتروژن افزایش پیدا کرد، با این حال بیشترین غلظت و جذب کل روی بترتیب با کلرید آمونیوم و اوره با پوشش گوگردی به‌دست آمد. برهمکنش نیتروژن و روی بر جذب و غلظت نیتروژن و روی مثبت بود. به‌طور کلی اضافه‌کردن نیتروژن و روی به خاک با افزایش سطح برگ همراه بود و ماکزیمم سطح برگ همراه اوره با پوشش گوگردی به‌دست آمد.راندمان عملکرد نیتروژن با افزایش نیتروژن به صورت اوره، سولفات آمونیوم و کلرید آمونیوم کاهش پیدا کرد، در این صورت اضافه‌کردن این عنصر غذایی تا ۲۰۰ میلی‌گرم در کیلوگرم به صورت اوره با پوشش گوگردی با افزایش این پارامتر همراه بود. با کاربرد بیشتر نیتروژن در خاک، روند معکوس مشاهده شد. بازیابی ظاهری نیتروژن تا ۲۰۰ میلی‌گرم نیتروژن در کیلوگرم خاک به صورت اوره، سولفات آمونیوم و کلرید آمونیوم افزایش پیدا کرد ولی اضافه‌کردن بیشتر نیتروژن باعث کاهش بازیابی ظاهری شد. بازیابی ظاهری نیتروژن با افزایش نیتروژن به صورت اوره با پوشش گوگردی زیاد شد. از طرف دیگر، راندمان فیزیولوژیکی نیتروژن با افزایش سطوح نیتروژن و بدون توجه به منبع نیتروژن کاهش پیدا کرد. کاربرد ۲۰۰ میلی‌گرم نیتروژن در کیلوگرم خاک و اوره با پوشش گوگردی، نسبت به سایر منابع نیتروژن، بهترین بودند.