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Effects of arsenic and moisture regime on nutrient content and their uptake by NERICA rice

S. Bhattacharjee¹, M. A. H. Chowdhury^{1*}, M. H. Rahman² and B. K. Saha¹

¹Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh-2202 and ²Soil Science Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh, *E-mail: akhterbau11@gmail.com

Abstract

A pot experiment was carried out in the net house of Bangladesh Institute of Nuclear Agriculture (BINA) to study nutrient content and their uptake by different rice varieties (NERICA-1, NERICA-10 and BRRI dhan48) in response to different levels of arsenic (As) under varying moisture regimes. Three levels of As were added viz. 0, 30, 60 ppm to the pot soil from sodium arsenate ($\text{Na}_2\text{HAsO}_4 \cdot 7\text{H}_2\text{O}$). After establishment of crops the moisture level of soil was adjusted to maintain flooded, 50% and 100% field capacity condition during crop growing period. The experiment was laid out in a Completely Randomized Design (CRD), with three replications. The amount of N, P, K, S and Zn was calculated as per their rate of application and was applied to the individual pot. Higher levels of As adversely affected the nutrient content and their uptake by rice except N contents. Nitrogen content increased with the increase of As level. Higher amount of nutrient content and uptake was recorded in BRRI dhan48 and flood condition enhanced higher nutrient content as well as uptake by rice. This study suggests the possible management of moisture regime and considering less As susceptible variety, which might reduce the toxic effects of As on nutrient uptake.

Keywords: Arsenic level, Moisture regime, Rice varieties, Nutrient contents, Uptake

Introduction

Rice is the principal cereal crop in Bangladesh that plays the most important role in the national economy. Bangladesh is a delta of high As contamination in groundwater and the water being widely used for irrigation. Irrigation of agricultural land with As-contaminated water or groundwater, particularly in Bangladesh, India and South-east Asia, can easily be accumulated As in both soils and plants, causing risks to soil ecosystems and human health (Martin *et al.*, 1992; Xie & Huang, 1998; Meharg & Rahman, 2003). Rice is more susceptible to arsenic toxicity compared to upland crops, because of an increase in both the bioavailability and toxicity of arsenic under the submerged soil of paddy fields (Horswell and Speir, 2006). Rahman *et al.*, (2008) investigated the severity of straight head in rice (cv. BRRI dhan29) which was increased significantly up to 50 mg of As kg⁻¹ soil treatments. Straight head resulted in sterile florets with distorted lemma and palea, reduced plant height, tillering, panicle length and grain yield. Straight head caused approximately 17-100% sterile florets/spikelet formation and about 16-100% loss of grain yield. No rice plant survived up to maturity stage in soil treated with 60 and 90 mg As kg⁻¹ was reported by Rahman *et al.*, (2007). Wang *et al.*, (2006) reported that As (roxarsone or arsanilic acid) could significantly reduce plant height, number of effective tiller, straw yield and grain yield. Arsenic significantly reduced Phosphorus concentration in rice (Zhu, 2003). Arsenic uptake and accumulation in rice plant from irrigation water may differ depending on cultivars used (Xie and Huang, 1998). Rice is the staple food in this country, any adverse effects on nutrient content of rice due to arsenic contaminated irrigation water would badly cause nutrient deficiency problem. This research attempted to reduce toxic effects of As on nutrient content in rice by using different variety and moisture regime.

Materials and Methods

A pot experiment was carried out during Aus season (May- August) of 2012 at the net house of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh having low arsenic content (2.1 mg/kg) in soil. Before the set up of the experiment soil was tasted and found that silt loam in texture with 6.7 pH, 1.53% organic matter, 0.12% total N, 9.8 mg/kg available P, 10.5 mg/kg available S, 0.11 me/100g exchangeable K and 38.81% field capacity. The size of each pot was 43 cm in diameter and 40 cm in height. There were 27 treatments consisting of three doses of As (0, 30 and 60 ppm), three moisture regime (50% field capacity, 100% field capacity and flood condition) and three rice varieties (NERICA-1, NERICA-10 and BRRI dhan48). The source of added As was sodium arsenate ($\text{Na}_2\text{HAsO}_4 \cdot 7\text{H}_2\text{O}$). The experiment was conducted in a three factorial completely randomized design with three replications. The seeds were sown in the pots on May, 2012. Arsenic at concentrations 0 ppm, 30 ppm and 60 ppm was mixed with the soils one week before sowing of seeds. To maintain flooded condition, 50% and 100% field capacity, required amount of water was added. Plastic pots were weighed daily and the difference in the weight of the pot was ascribed to water lost by evaporation. The lost water was replenished by adding an equal volume of water to the pot. Every pot had received 9g N from urea, 4g P from TSP, 3.5g K from muriate of potash (MoP) and 1.5g S from gypsum. The full amount of all other fertilizers except nitrogen

was applied as basal to the individual pot. Nitrogen was added in three splits, The first split of urea was applied at 15 days after seed sowing i.e. early vegetative stage, the second split of urea was applied at 40 days after seed sowing i.e. at maximum tillering stage and the third split was applied at 75 days after seed sowing i.e. at panicle initiation stage. Intercultural operations such as weeding and spraying insecticides were done whenever required. The crop was harvested at maturity and the data on yield and yield parameters were recorded. Plants from each pot were measured and averaged to record the yield contributing characters. Grain and straw samples were analyzed for N, P, K and S contents and uptake. All data were statistically analyzed following F-test and the difference between treatment means was adjudged by Duncan's Multiple Range Test.

Results and Discussion

Nitrogen content: Remarkable effect of different doses of added As was observed on the N content in grain and straw of rice (Table 1). The level of N content was higher when high amount of As was added. The highest N content (0.515% in grain and 0.592% in straw) was found with 60 ppm dose of added As. Straw N-content was lowest (0.536%) with 0 ppm As treatment and lowest grain N-content (0.470%) was recorded at 30 ppm As treatment. This finding agrees with Begum *et al.*; 2008 who reported that the N content in grain and straw increased with increasing addition of arsenic. Different rice varieties showed significant effect on N content in grain but in case of straw it had insignificant effect (Table 1). The highest N content (0.727%) was recorded in BRR1 dhan48 and the lowest N content (0.362%) was found in NERICA-10. Nitrogen contents in rice grain and straw was significantly influenced by different moisture regimes (Table 1). N content in grain was increased with the increase of moisture level but the reverse result was observed in case of straw N-content. At 50% field capacity condition no grain was formed. At flood condition N content in grain (1.110%) was recorded highest value and lowest in straw (0.554%). The highest N content (0.576%) in straw was found at 50% field capacity condition. The data presented in Table 2 showed significant variations in N contents of rice grain and straw. The highest N content (1.252%) in grain was found in the treatment combination $As_{60}V_3M_1$ which was statistically identical with the treatment combination of $As_{30}V_1M_2$ and $As_0V_1M_2$. No grain was found at 50% field capacity and 100% field capacity. Only BRR1 dhan48 produced grain at 100% field capacity condition. Straw N-contents ranged from 0.471% in the treatment combination $As_{30}V_3M_2$ to 0.685% in the treatment combination $As_{30}V_3M_0$.

Phosphorus content: Application of different doses of arsenic to soil resulted significant effect on P content in rice grain and straw (Table 1). Phosphorus content was lowest both in grain (0.056%) and straw (0.123%) when As was applied @ 60 ppm. The highest P content in grain (0.072%) was found in the control treatment (no As was applied) which was statistically identical with 30 ppm As treatment. In case of straw the highest P content (0.136%) was recorded at 30 ppm As. Phosphorus content of both grain and straw decreased as the dose of As increased. It has been reported that P content in straw decreased with the increase of As doses whereas the reverse result was found for grain-P content (Islam and Jahiruddin, 2010). Phosphorus content in rice grain and straw was significantly affected by different varieties (Table 1). The highest P content both in grain (0.094%) and straw (0.138%) was recorded in BRR1 dhan48 and the lowest P content both in grain (0.051%) and straw (0.125%) was recorded in NERICA-10. Different moisture regimes had significant effect on P content in rice grain and straw (Table 1). No grain was formed at 50% field capacity condition. The highest P content in grain (0.152%) and in straw (0.153%) were found at flood condition and 50% field capacity condition, respectively. At 100% field capacity condition lowest P content (0.114%) was found in straw. The interaction effect of different rates of As application, varieties and moisture regime was statistically insignificant on P contents in rice grain and straw (Table 2). However, numerically highest P content of grain and straw was found in the treatment combination $As_{30}V_1M_2$ and $As_{60}V_3M_0$, respectively.

Potassium content: Application of different rates of As to soil had significant effect on K content in rice straw but an insignificant effect was found in case of grain (Table 1). 0.2056%, 0.2064% and 0.1937% K content in grain was recorded at the rate of 0 ppm, 30 ppm, 60 ppm As doses, respectively. K content in straw was highest (1.457%) with 0 ppm As treatment and the lowest (1.303%) straw K-content was recorded at 60 ppm As application. Potassium contents in rice grain and straw was influenced by different rice varieties (Table 1). BRR1 dhan48 resulted the highest K content both in grain (0.318%) and straw (1.443%) and the lowest K content in grain (0.138%) and straw (1.293%) was recorded in NERICA-1. Different moisture condition had significant effect on K content in rice grain and straw (Table 1). The highest K content (0.453%) in grain and (1.423%) in straw were found at flood condition and 50% field capacity condition, respectively. At 100% field capacity condition, the lowest K content (1.317%) was

recorded in straw. Potassium content in rice grain showed insignificance to the interaction effect of different dose of As, rice variety and moisture regime whereas this interaction effect was significant on K content in straw (Table 2). Potassium contents in rice straw ranged from 1.080% in the treatment combination As₆₀V₁M₁ to 1.670% in the treatment combination As₀V₃M₂.

Table 1. Main effects of As, variety and moisture regime on the nutrient contents (%) of rice

Treatments	N		P		K		S	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Arsenic								
As ₀	0.494 b	0.536 c	0.072 a	0.134 a	0.2056	1.457 a	0.047 a	0.091 a
As ₃₀	0.470 c	0.563 b	0.071 a	0.136 a	0.2064	1.339 b	0.041 b	0.087 ab
As ₆₀	0.515 a	0.592 a	0.056 b	0.123 b	0.1937	1.303 c	0.040 b	0.084 b
Level of significance	**	**	**	**	NS	**	**	**
CV (%)	7.05	4.74	14.93	8.84	13.22	4.09	8.02	6.15
Variety								
NERICA-1(V ₁)	0.390 b	0.564	0.054 b	0.131 b	0.138 b	1.293 c	0.030 b	0.084 b
NERICA-10(V ₂)	0.362 c	0.556	0.051 b	0.125 b	0.149 b	1.363 b	0.031 b	0.088 ab
BRRIdhan48(V ₃)	0.727 a	0.570	0.094 a	0.138 a	0.318 a	1.443 a	0.065 a	0.091 a
Level of significance	**	NS	**	**	**	**	**	**
CV (%)	7.05	4.74	14.93	8.84	13.22	4.09	8.02	6.15
Moisture regime								
50% FC(M ₀)	-	0.576 a	-	0.153 a	-	1.423 a	-	0.085 b
100%FC(M ₁)	0.369 b	0.559 ab	0.047 b	0.114 c	0.153 b	1.317 c	0.034 b	0.093 a
Flood (M ₂)	1.110 a	0.554 b	0.152 a	0.126 b	0.453 a	1.360 b	0.092 a	0.083 b
Level of significance	**	**	**	**	**	**	**	**
CV (%)	7.05	4.74	14.93	8.84	13.22	4.09	8.02	6.15

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with different letter(s) differ significantly at 1% level of significance

Table 2. Interaction effects of As, variety and moisture regime on the nutrient contents (%) of rice

Treatments (Arsenic x Variety x Moisture)	N		P		K		S	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
As ₀ V ₁ M ₀	-	0.532 h-l	-	0.124	-	1.237 gh	-	0.087
As ₀ V ₁ M ₁	-	0.564 e-j	-	0.126	-	1.180 h	-	0.090
As ₀ V ₁ M ₂	1.217 ab	0.609 b-f	0.171	0.142	0.412	1.237 gh	0.101 abc	0.092
As ₀ V ₂ M ₀	-	0.475 lm	-	0.144	-	1.193 h	-	0.085
As ₀ V ₂ M ₁	-	0.509 i-m	-	0.113	-	1.330 fg	-	0.104
As ₀ V ₂ M ₂	1.010 f	0.504 j-m	0.178	0.123	0.473	1.430 de	0.097 abc	0.088
As ₀ V ₃ M ₀	-	0.523 h-m	-	0.166	-	1.223 h	-	0.089
As ₀ V ₃ M ₁	1.108 de	0.554 f-j	0.150	0.125	0.465	1.400 d-f	0.096 abc	0.098
As ₀ V ₃ M ₂	1.114 cde	0.557 e-j	0.151	0.145	0.499	1.670 a	0.107 a	0.087
As ₃₀ V ₁ M ₀	-	0.539 h-k	-	0.143	-	1.477 b-e	-	0.087
As ₃₀ V ₁ M ₁	-	0.567 d-i	-	0.110	-	1.490 a-d	-	0.088
As ₃₀ V ₁ M ₂	1.232 a	0.616 b-e	0.185	0.154	0.413	1.240 gh	0.094 abc	0.086
As ₃₀ V ₂ M ₀	-	0.602 b-g	-	0.146	-	1.55 a-c	-	0.075
As ₃₀ V ₂ M ₁	-	0.561 e-j	-	0.115	-	1.440 de	-	0.098
As ₃₀ V ₂ M ₂	1.092 e	0.546 g-j	0.152	0.127	0.458	1.377 ef	0.085 bc	0.077
As ₃₀ V ₃ M ₀	-	0.685 a	-	0.170	-	1.580 ab	-	0.098
As ₃₀ V ₃ M ₁	0.963 fg	0.481 k-m	0.143	0.125	0.494	1.483 b-d	0.102 ab	0.093
As ₃₀ V ₃ M ₂	0.942 g	0.471 m	0.161	0.134	0.492	1.477 c-e	0.088 bc	0.080
As ₆₀ V ₁ M ₀	-	0.579 c-h	-	0.154	-	1.450 c-e	-	0.074
As ₆₀ V ₁ M ₁	-	0.542 g-j	-	0.107	-	1.080 i	-	0.080
As ₆₀ V ₁ M ₂	1.064 e	0.528 h-m	0.135	0.113	0.416	1.250 gh	0.082 c	0.071
As ₆₀ V ₂ M ₀	-	0.602 b-g	-	0.151	-	1.503 a-d	-	0.082
As ₆₀ V ₂ M ₁	-	0.635 a-c	-	0.105	-	1.190 h	-	0.102
As ₆₀ V ₂ M ₂	1.156 cd	0.578 c-h	0.126	0.105	0.416	1.253 gh	0.091 abc	0.083
As ₆₀ V ₃ M ₀	-	0.655 ab	0.000	0.178	-	1.590 a	-	0.093
As ₆₀ V ₃ M ₁	1.252 a	0.626 b-d	0.126	0.105	0.418	1.257 gh	0.099 abc	0.090
As ₆₀ V ₃ M ₂	1.167 bc	0.583 c-h	0.114	0.094	0.491	1.477 b-e	0.094 abc	0.085
Level of significance	**	**	NS	NS	NS	**	**	NS
CV (%)	7.05	4.74	14.93	8.84	13.22	4.09	8.02	6.15

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with different letter(s) differ significantly at 1% level of significance. V₁ = NERICA-1, V₂ = NERICA-10, V₃ = BRRIdhan 48, M₀ = 50% field capacity, M₁ = 100% field capacity, M₂ = Flood condition

Sulphur content: Sulphur concentrations of both grain and straw decreased with increasing concentration of arsenic, the range being 0.040-0.047 % S for grain and 0.084-0.091% S for straw (Table 1). Variety had significant effects on S contents in rice (Table 1). The highest S content was found both in grain (0.065%) and straw (0.091%) of BRRI dhan48 and NERICA-1 recorded lowest S content in grain (0.030%) and straw (0.084%). Moisture regime considerably affected S contents in rice (Table 1). The highest S content 0.092% in grain and 0.093% in straw was found at flood condition and 100% field capacity, respectively. At flood condition the lowest S content (0.083%) was recorded in straw. Table 2 illustrates that the combined interaction effect of different doses of As, rice varieties and moisture regime on S content in rice grain and it was found significant but straw S-content was not influenced by this effect. The highest S content in grain (0.107%) was found in the treatment combination $As_0V_3M_2$.

Nitrogen uptake: Increasing doses of As significantly decreased N uptake by grain and straw (Table 3). The maximum N uptake ($22.14 \text{ mg pot}^{-1}$) by grain and ($45.41 \text{ mg pot}^{-1}$) by straw was recorded at 0 ppm As treatment whereas minimum N uptake ($11.26 \text{ mg pot}^{-1}$ by grain and $31.86 \text{ mg pot}^{-1}$ by straw) was found at 60 ppm As treatment. The highest N uptake by grain ($27.28 \text{ mg pot}^{-1}$) and straw ($38.96 \text{ mg pot}^{-1}$) was found in BRRI dhan48 (Table 3). The lowest N uptake by grain ($12.59 \text{ mg pot}^{-1}$) and straw ($27.44 \text{ mg pot}^{-1}$) was found in NERICA-1. Nitrogen uptake by grain and straw was significantly increased with the increase of moisture regime (Table 3). Maximum N uptake ($50.49 \text{ mg pot}^{-1}$) and ($57.86 \text{ mg pot}^{-1}$) was observed at flood condition in grain and straw, respectively. The lowest N uptake ($31.14 \text{ mg pot}^{-1}$) in straw was recorded at 50% field capacity condition, where no grain was found at this moisture condition. Nitrogen uptake in grain and straw was significantly influenced by the interaction of As, varieties and different moisture regime (Table 4). Maximum N uptake ($161.61 \text{ mg pot}^{-1}$) in grain and ($112.92 \text{ mg pot}^{-1}$) straw was observed in the treatment combination $As_0V_3M_2$. The lowest N uptake in straw ($11.22 \text{ mg pot}^{-1}$) was recorded in the treatment combination $As_{60}V_1M_0$.

Phosphorus uptake: Phosphorus uptake was significantly decreased with the increase of added As doses (Table 3). The highest P uptake by both grain (3.95 mg pot^{-1}) and straw ($10.86 \text{ mg pot}^{-1}$) was found when no As was added. The lowest P uptake by grain (1.69 mg pot^{-1}) and straw (6.69 mg pot^{-1}) was observed in 60 ppm As. The highest P uptake by grain (3.83 mg pot^{-1}) and straw ($10.68 \text{ mg pot}^{-1}$) was found in BRRI dhan48 (Table 3). Again, the lowest P uptake by grain (2.20 mg pot^{-1}) and straw (6.59 mg pot^{-1}) was found in NERICA-10. Phosphorus uptake by grain and straw was significantly increased with the increase of moisture regime (Table 4). Maximum P uptake (6.59 mg pot^{-1} and $13.46 \text{ mg pot}^{-1}$) was observed in the flood condition in grain and straw, respectively. Minimum P uptake (4.85 mg pot^{-1}) in straw was recorded at 50% field capacity condition when no grain was found at this moisture condition. Phosphorus uptake by rice was significantly influenced by the interaction effects of added As, variety and moisture regime (Table 4). Maximum P uptake ($30.57 \text{ mg pot}^{-1}$) by grain and ($30.63 \text{ mg pot}^{-1}$) straw was observed in the treatment combination $As_0V_3M_2$. Minimum P uptake in straw (2.64 mg pot^{-1}) was recorded in the treatment combination $As_{60}V_2M_0$.

Potassium uptake: Increased doses of As remarkably decreased K uptake by rice (Table 3). Maximum K uptake ($17.76 \text{ mg pot}^{-1}$) by grain and ($104.44 \text{ mg pot}^{-1}$) by straw was recorded at 0 ppm As treatment. The minimum K uptake in grain (6.64 mg pot^{-1}) and straw ($50.50 \text{ mg pot}^{-1}$) were observed in 60 ppm As treatment. The highest K uptake by grain ($15.73 \text{ mg pot}^{-1}$) and straw ($114.31 \text{ mg pot}^{-1}$) was found in BRRI dhan48 (Table 3). The Lowest K uptake by grain ($11.39 \text{ mg pot}^{-1}$) and straw ($70.88 \text{ mg pot}^{-1}$) was observed in NERICA-10. Potassium uptake by grain and straw was significantly increased with the increase of moisture level (Table 3). Maximum K uptake by grain ($30.14 \text{ mg pot}^{-1}$) and straw ($121.82 \text{ mg pot}^{-1}$) was observed in the flood condition. The lowest K uptake ($45.69 \text{ mg pot}^{-1}$) in straw was recorded at 50% field capacity condition when no grain was found at this moisture condition. Grain yield was not found at 50% and 100% field capacity condition except BRRI dhan48 which produced grain at 100% field capacity condition and a significant interaction effect was observed on K uptake by rice (Table 4). Maximum K uptake ($74.04 \text{ mg pot}^{-1}$) by grain and ($227.31 \text{ mg pot}^{-1}$) by straw was observed in the treatment combination $As_0V_3M_2$. Minimum K uptake ($29.70 \text{ mg pot}^{-1}$) by straw was recorded in the treatment combination $As_{60}V_2M_0$.

Table 3. Main effects of As, variety and moisture regime on the nutrient uptake (mg pot⁻¹) by rice

Treatments	N		P		K		S	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Arsenic								
As ₀	22.14a	45.41a	3.95a	10.86a	17.76a	104.44a	4.98a	7.23a
As ₃₀	16.44b	41.30b	2.85b	8.21b	10.56b	62.92b	2.66b	5.26b
As ₆₀	11.26c	31.86c	1.69c	6.69c	6.64c	50.50c	1.68c	3.66c
CV(%)	9.334	6.668	9.934	7.209	10.420	7.454	9.577	6.726
Level of sig.	**	**	**	**	**	**	**	**
Variety								
NERICA-1(V ₁)	12.59b	27.44b	2.23b	6.65b	12.40b	72.36b	1.73b	4.41b
NERICA-10(V ₂)	13.96b	30.36b	2.20b	6.59b	11.39b	70.88b	1.77b	4.70b
BRRIdhan48(V ₃)	27.28a	38.96a	3.83a	10.68a	15.73a	114.31a	2.98a	7.11a
CV(%)	9.334	6.668	9.934	7.209	10.420	7.454	9.577	6.726
Level of sig.	**	*	**	**	**	**	**	**
Moisture regime								
50% FC(M ₀)	-	31.14b	-	4.85b	-	45.69c	-	3.48c
100%FC(M ₁)	7.60b	34.68b	1.36b	7.08b	5.19b	63.36b	1.79b	4.65b
Flood(M ₂)	50.49a	57.86a	5.76a	13.46a	30.14a	121.82a	6.90a	9.32a
CV(%)	9.334	6.668	9.934	7.209	10.420	7.454	9.577	6.726
Level of sig.	**	**	**	**	**	**	**	**

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with different letter(s) differ significantly at 1% level of significance

Table 4. Interaction effects of As, variety and moisture regime on the nutrient uptake (mg pot⁻¹) by rice

Treatments (Arsenic x Variety x Moisture)	N		P		K		S	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
As ₀ V ₁ M ₀	-	20.28g	-	5.28fg	-	42.7h	-	3.38f
As ₀ V ₁ M ₁	-	27.56f	-	7.80f	-	57.21f	-	4.94de
As ₀ V ₁ M ₂	63.09c	71.92c	13.33c	17.55c	22.17d	161.80bc	8.84cd	11.13b
As ₀ V ₂ M ₀	-	19.72gh	-	5.52f	-	41.44h	-	3.29f
As ₀ V ₂ M ₁	-	26.68f	-	7.64f	-	58.10f	-	4.49e
As ₀ V ₂ M ₂	57.12c	61.20c	13.43c	15.23d	25.29d	141.40c	8.83cd	9.38c
As ₀ V ₃ M ₀	-	20.80g	-	6.36f	-	43.56gh	-	3.47f
As ₀ V ₃ M ₁	45.01d	34.45e	6.11d	9.51e	10.65fg	73.16e	3.67d	6.27d
As ₀ V ₃ M ₂	161.61a	112.92a	30.57a	30.63a	74.04a	227.31a	17.61a	17.29a
As ₃₀ V ₁ M ₀	-	16.20h	-	3.96h	-	34.72i	-	2.81fg
As ₃₀ V ₁ M ₁	-	26.18f	-	5.67f	-	52.65fg	-	4.08e
As ₃₀ V ₁ M ₂	43.13d	51.17d	6.09d	11.08e	16.16e	93.68d	3.06de	7.48c
As ₃₀ V ₂ M ₀	-	16.80h	-	4.18g	-	35.84i	-	2.63fg
As ₃₀ V ₂ M ₁	-	24.06fg	-	5.52f	-	52.64fg	-	4.03e
As ₃₀ V ₂ M ₂	40.16d	50.84d	5.61de	9.83e	16.20e	91.23d	2.96e	7.30c
As ₃₀ V ₃ M ₀	-	15.83h	-	4.43g	-	36.64i	-	2.72fg
As ₃₀ V ₃ M ₁	25.66f	30.25e	4.04e	7.36f	7.86g	64.69ef	2.50e	5.45d
As ₃₀ V ₃ M ₂	130.66b	93.35b	27.88b	21.88b	52.02b	186.74b	10.18b	13.68b
As ₆₀ V ₁ M ₀	-	11.22i	-	3.05h	-	30.80ij	-	2.06h
As ₆₀ V ₁ M ₁	-	18.80g	-	3.96h	-	48.16g	-	3.44f
As ₆₀ V ₁ M ₂	35.10e	50.09d	6.14d	7.04f	12.60f	71.50e	2.29e	5.53d
As ₆₀ V ₂ M ₀	-	14.12hi	-	2.64i	-	29.70j	-	2.02h
As ₆₀ V ₂ M ₁	-	21.16g	-	3.61h	-	47.74g	-	3.53f
As ₆₀ V ₂ M ₂	30.30e	48.96de	6.07d	6.83f	12.15f	68.20e	2.07ef	5.35d
As ₆₀ V ₃ M ₀	-	15.43h	-	3.57h	-	31.90i	-	2.63g
As ₆₀ V ₃ M ₁	22.16f	28.02f	3.05f	5.94f	7.09g	61.60f	1.67f	5.19d
As ₆₀ V ₃ M ₂	109.08b	86.95b	12.55c	13.97d	40.18c	156.73c	9.12c	8.33c
CV(%)	9.34	6.668	9.934	7.209	10.420	7.454	9.577	6.726
Level of sig.	**	**	**	**	**	**	**	**

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with different letter(s) differ significantly at 1% level of significance. V₁ = NERICA-1, V₂ = NERICA-10, V₃ = BRRIdhan 48, M₀ = 50% field capacity, M₁ = 100% field capacity, M₂ = Flood condition

Sulphur uptake: Sulphur uptake by grain and straw decreased with the increase dose of arsenic, the range being (1.68-4.98 mg pot⁻¹) by grain and (3.66-7.23 mg pot⁻¹) by straw (Table 3). Variety had significant effects on S uptake by rice (Table 3). Maximum S uptake by grain (2.98 mg pot⁻¹) and straw (7.11 mg pot⁻¹) was found in BRR1 dhan48 and NERICA-1 recorded minimum S uptake by grain (1.73 mg pot⁻¹) and straw (4.41 mg pot⁻¹). Moisture regime considerably affected S uptake by rice (Table 3). There was no grain formation at 50% field capacity. The maximum S uptake (6.90 mg pot⁻¹) by grain and (9.32 mg pot⁻¹) by straw was found at flood condition. At 50 % field capacity, minimum S uptake (3.48 mg pot⁻¹) was recorded in straw. Table 2 illustrates that the combined interaction effect of different doses of As, rice varieties and moisture regime on S uptake by rice grain and was found significant. The maximum S uptake by grain (17.21 mg pot⁻¹) and straw (17.29 mg pot⁻¹) were found in the treatment combination As₀V₃M₂.

Conclusion

It appears that higher level of As in soil adversely affected the nutrient content as well as uptake by rice. With the increase of moisture regime nutrient uptake was increased. At flood condition all the rice varieties recorded higher nutrient content and uptake by both grain and straw compared to other two level of moisture irrespective of As dose. Although, P, K, S contents both in grain and straw decreased with the increasing As level but N content in rice showed opposite trend. Grain was not obtained from plants grown under 50% and 100% field capacity condition apart from variety BRR1 dhan48 which produced grain at 100% field capacity condition. The treatment combination As₀V₃M₂ recorded highest amount of nutrient uptake by rice. Further it is to be mentioned that 0ppm As and flood condition had better influence on the nutrient content and uptake by rice. For further confirmation field trial is needed.

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