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Influence of some essential elements (P, K, Ca, Mg, Fe and Mn) on the efficiency of five BGA (blue-green algae) species and two fertilizers in the growth of rice

Abstract

The P-content values obtained at the second harvest were significantly lower than the 1st harvest; P-offtake by plants in pots inoculated with BGA was significantly lower than from pots receiving fertilizer in the 2nd harvest. Like K-content there are no clear differences between Ca-contents or Mg-contents although the values for pots inoculate with BGA were slightly but not significantly lower than for those receiving fertilizer. Fe content significantly higher in plants from pots receiving fertilizer than from those inoculated with BGA at both the 1st and 2nd harvests. In case of Mn there is a little variation at the highest but between harvest there is a significant increase in both % Mn-content and Mn offtake.

Keywords: nutrient elements, interaction, harvest

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Introduction

Competition for space and resources has imposed on us the necessity to further optimize our exploitation of cultivated and wild lands. It has been revealed that agricultural production will have to increase by 60% on the next 20 years to sustain the world's population after 2025. An important problem is not only to increase the yield per unit area, but also per unit input. We cannot rely on the application of chemical and organic fertilizers alone, we need to analyze the ecosystem economy. Elucidation of the essential elements inputs and outputs of the ecosystem, estimation of microbial transformations and internal essential elements turnover and extensive application of low-cost fertilizer are aspects of the major elements economy that still require study. So, water bloom algae mainly composed of microsyst can be utilized as a bio-fertilizer, because elements like carbon, nitrogen, phosphorus and potassium are liberated in forms available to growing plants after decomposition of alga bodies. The quantity of various essential elements released from decomposition of different blue-green algae to the growing crop is likely to vary with different soil conditions. Thus, the blue-green algae may act not only as a substitute for mineral fertilization, but as a supplement.[1] Flooding Paddy soils causes a number of electrochemical changes in that soil that, in general benefit the crop. Many nutrients like N, P, K, Ca, Mg, Fe, Mn etc. become more available to the crop and most nutrients toxicity's and deficiencies associated with extreme soil pH.[2] An effort has been made to estimate to see the influence of various elements on the efficiency and five BGA species and two chemical fertilizers and compare them under green house condition.

Methods and material

The soil for the present experiment is highly productive known as Insch soil obtained from Murrials farm in aberdeenshire of Scotland UK. Chemically, the soil had pH 5.96, organic carbon 7.95 %, total nitrogen 0.28 %, cation exchange capacity 11.5meq 100^{-1} and sandy loam as texture. The rice variety 'MRI' of Malaysian agricultural development Institute were 1R22 collected from school of agriculture, Aberdeen University, UK. 'MR1'was selected as indicator plant because of its high and stable yield that has poor eating quality but excellent plant type. After viability test (98.3 % germination was recorded), the 25 days old seedlings were transplanted to pots. The experiment was laid out in a split plot design. The experimental plots were divided into two blocks representing two replications. Each block was sub-divided into sub-blocks. Each sub-block was again divided into 21 unit plots upon which the treatment was superimposed randomly. The total number of unit plots (pots) was 84. There were three sources of nitrogen, namely urea (U), ammonium sulfate (As) and blue green algae (BGA) each at five rates. For the BGA each species was considered to be a rate (Table 1).

Table 1 Five species of BGA

Rate	Fertilizers (mg N pot-1)	BGA
1	30	*Anabaena variabilies*
2	60	*Anabaena cylindrica*
3	90	*Anabaena doliolum*
4	120	*Nostoc muscorum*
5	150	*Plectonema boryanum*

Two types of control were prepared provided in this design. One control receiving no nitrogen (0) and the second control was inoculated with five species of BGA in each sub block without growing rice plants. Thus there were 21 treatments; the total number of unit plots (pots) was 84. There were three sources of nitrogen, namely urea (U), ammonium sulfate (As) @ 30,60.90,120, & 150 (mg N pot-1) and all five blue green algae (BGA) as the five rates. For the BGA each species was considered to be a rate by the following way (Table 1).

84 plastic 21x17 cm round pots were numbered consecutively. Each pot was about 4-litre capacity and the drainage holes were

closed with thick sticky tape. The pots were washed carefully and dried before use. 1800g air-dry soil was placed into each pot with capillary matting (Fyba mat) at the bottom. The air dry soil was mixed with 20ml of KH_2PO_4 solution in a Kenwood mixer for the basic fertilizer dose of p and K .The moist soil were transferred to the pots with light and even packing and 1500ml of water were added to each pot. This forms a 2cm depth of standing water over the soil surface. The pots were kept at constant temperature covering with polythene sheet. The pots were transformed after 5 days to the glass house and appropriate quantities of N fertilizer added and mixed. In case of BGA pots each inoculate was applied as a liquid suspension. Four days after transplanting, when the seedlings become fully established, the depth of standing water was raised to 4.5cm and maintained throughout the growing period. In the present study the temperature was optimum (25-30^{0}C) up to 56 days and then dropped in month November. In that month and especially on cloudy clays fluorescent lights were used to supply adequate light. The pots were weeded by hand from time to time when necessary the rice plants started tillaring within 2 weeks after transplanting. Six weeks after transplanting, pots numbering 1–21 from block I and 43–63 from block II and twelve weeks after transplanting (harvest) the plant samples were removed, washed, weighed, dried, reweigh and ground. The method of Bremner,[3] was followed for nitrogen analysis.

Statistical analysis

It was necessary to calculate the standard error of differences of means (SED) for correct comparison among all treatments. The Genstat statistical computer package,[4] incorporates a split plot model consists of: N rates, N-rates X N-source interaction, Harvest X rates, harvest X sources, harvest X rate X source at two different harvest. The SED at $p \leq 0.001$, $p \leq 0.01$, $p \leq 0.05$ levels were shown in each table. In comparing those results the superscript letter before the mean indicates weather within the columns are significantly different while those following the means provide information on the significance between columns.

Result and discussion

In (Table 2A) (Table 2B) as content and offtake of P K, Ca, Mg, Fe and Mn are expressed as percentage of dry matter (dm) in duplicate values at 1st and 2nd harvest. The statistical results of above all elements are presented in Table 3–11.

P content and P-offtake

A small difference was observed in %P-content of the plant material at the 1st harvest (Table 3) it being significantly higher with the addition of U which may be due to localized differences in soil/water pH in the early stages of growth as this differences disappeared by the 2nd harvest. The P-content values obtained at the 2nd harvest were significantly lower than for the first harvest because of the increase in dry matter yield. The P-offtake data presented in Table 4 show the same difference for the 1st harvest despite the difference in dry matter yield but by the second harvest offtake of P by plants in pots inoculated with BGA was significantly lower than from pots receiving fertilizer. This difference may be due to the competition between BGA and rice plants for P or it may be due to the lower dry matter yield where BGA was inoculated. Rice yield increased nearly five folds with the application of 150kg P_2O_5 ha^{-1} Compared to control treatments. For upland rice P deficiency is the most limiting factor among all essential plant nutrients. This is due to the low inherent P level of the soil (<2mg kg^{-1}) and high fixation capacities.[5]

Table 2A Nutrient content (P, K, Ca, Mg, Fe and Mn) and offtake (P, Fe and Mn) by rice by following application of different rates of urea, ammonium sulphate and BGA species at 1st harvest

Treat-ments	Dry matter yield(dm) g pot^{-1}		P %		P offtake mg pot^{-1}		K %		Ca %		Mg %		Fe µg g^{-1} dm*		Fe offtake µg pot^{-1}		Mn µg^{-1} dm		Mn offtake mg pot^{-1}	
6	0.87	1.01	0.74	0.51	6.4	5.2	1.95	1.9	0.38	0.37	0.13	0.12	161	164	139.9	165.1	752	713	0.6	0.71
7	1.93	2.08	0.7	0.68	13.5	14.1	1.85	1.92	0.39	0.44	0.13	0.15	224	210	431.4	436.4	1043	977	2	2
8	1.79	1.87	0.72	0.71	12.9	13.3	1.95	1.65	0.4	0.4	0.13	0.13	224	224	400	400.2	1016	977	1.8	1.8
9	1.25	1.37	0.62	0.61	7.8	8.4	1.55	1.65	0.43	0.43	0.14	0.14	346	357	432.6	1779	937	871	1.2	1.8
10	1.56	1.66	0.55	0.53	8.6	8.8	1.85	1.75	0.4	0.42	0.13	0.14	229	237	357.1	686.4	1017	977	1.6	1.6
11	1.63	1.71	0.57	0.62	9.3	10.6	1.65	1.85	0.4	0.4	0.13	0.13	379	357	617.8	687.4	1109	1056	1.8	1.8
12	1.88	1.96	0.58	0.56	10.9	11	1.95	1.85	0.4	0.4	0.14	0.13	360	259	676.2	1127.7	977	951	1.8	1.8
13	1.96	2.01	0.5	0.51	9.8	10.3	1.85	1.75	0.4	0.43	0.15	0.14	253	253	496.7	669.4	898	977	1.8	2
14	1.7	1.76	0.61	0.6	10.4	10.6	1.95	1.98	0.43	0.43	0.14	0.14	270	382	458.6	1424.9	924	898	1.5	1.6
15	1.27	1.41	0.56	0.55	7.1	7.8	1.92	1.85	0.39	0.4	0.13	0.13	371	360	470.7	1155.7	1003	964	1.3	1.4
16	1.12	1.05	0.65	0.64	7.3	6.7	1.65	1.65	0.4	0.38	0.13	0.13	234	278	415.1	613.8	1030	924	1.2	1
17	1.5	1.45	0.66	0.64	9.9	9.3	1.95	1.65	0.4	0.39	0.13	0.13	333	346	351.5	1028.7	898	1096	1.3	1.6
18	1.96	1.83	0.54	0.53	10.6	9.7	1.5	1.85	0.44	0.41	0.15	14	319	335	651.6	1200	950	845	1.9	1.5
19	1.53	1.62	0.58	0.61	8.9	9.9	1.83	1.8	0.39	0.39	0.13	0.13	319	335	487.8	718	1003	964	1.5	1.6
20	1.79	1.93	0.59	0.57	10.6	11	1.95	1.85	0.41	0.4	0.14	0.13	428	436	765.8	1165.7	977	1056	1.7	2
21	2.27	2.33	0.55	0.53	12.5	12.3	1.85	2.05	0.4	0.4	0.13	0.14	199	188	451.5	848	1201	1307	2.7	3

dm*, dry matter

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Table 2B Nutrient content (P, K, Ca, Mg, Fe and Mn) and offtake (P, Fe and Mn) by rice by following application of different rates of urea, ammonium sulphate and BGA species at 2nd harvest

Treat-ments	Dry matter yield(dm) g pot^{-1}		P %		P offtake mg pot^{-1}		K %			Ca %	Mg %		Fe µg g -1 dm*		Fe offtake µg pot^{-1}		Mn µg^{-1} dm		Mn offtake mg pot^{-1}	
6	3.53	3.74	0.41	0.41	14.5	15.3	1 .35	1.38	0.66	0.62	0.2	0.21	128	134	454.5	499.4	1214	1175	4.3	4.4
7	5.9	5.73	0.43	0.43	25.4	24.6	1.45	1.55	0.68	0.66	0.22	0.2	169	155	996.8	889.9	1584	1478	9.3	8.5
8	5.15	5.42	0.39	0.38	20.1	20.6	1.68	1.65	0.66	0.66	0.21	0.21	174	166	898.2	900.9	1690	1690	8.7	9.2
9	5.74	5.58	0.38	0.39	21.8	21.8	1.65	1.65	0.63	0.66	0.23	0.21	305	319	1751.8	1779	1478	1439	8.5	8
10	4.39	4.58	0.32	0.33	14.5	15.1	1.65	1.75	0.69	0.66	0.21	0.21	134	150	586.2	686.4	1465	1426	6.4	6.05
11	4.57	4.76	0.35	0.35	16	16.7	1.65	1.55	0.66	0.67	0.21	0.22	134	144	610.2	687.4	1610	1571	7.4	7.5
12	4.36	4.45	0.4	0.4	17.4	17 .8	1.75	1 65	0.61	0.57	0.2	0.19	234	253	1021.8	1127.7	1795	1742	7.8	7.8
13	4.19	4.31	0.42	0.41	17.6	17.7	1.67	1.65	0.6	0.51	0.2	0.17	180	155	753.6	669.4	1452	1399	6.1	6
14	6.13	6.3	0.39	0.4	3.9	25.2	1. 70	1.55	0.63	0.57	0.21	0.19	245	226	1503.9	1424.9	1676	1637	10.3	10.3
15	6.24	6.33	0.4	0.4	24.9	25.3	1.52	1.55	0.63	0.61	0.21	0.2	199	183	1241.3	1155.7	1307	1280	8.2	8.1
16	3.99	4.25	0.42	0.36	16.8	15.3	1.55	1.45	0.57	0.56	0.19	0.19	169	144	674.1	613.8	1637	1571	6.5	6.7
17	5.89	5.72	0.41	0.34	24.1	19.4	1.57	1.85	0.66	0.6	0.21	0.2	164	180	963	1028.7	1452	13.73	8.6	7 ·9
18	6.32	5.97	0.4	0.38	25.3	22.7	1. 75	1.5	0.64	0.63	0.23	0.21	183.2	1153.8	1153.8	1200	1439	1386	9	8.3
19	4.06	4.25	0.38	0.38	15.4	16.1	1.35	1.45	0.59	0.6	0.19	0.2	138	169	641.7	718	1402	1412	6.6	6
20	5.97	6.2	0.38	0.38	2.7	23.6	1.55	1.55	0.63	0.62	0.21	0.2	177	188	1057.4	1165.7	1518	1492	9.1	9.2
21	4.89	5.02	0.39	0.39	19.1	9.6	1 .47	1.5	0.62	0.64	0.22	0.23	177	169	866	848	1610	1663	7.9	8.3

dm*, dry matter

Table 3 % P content of rice as obtained by application of different species of BGA and rates of ammonium sulphate and urea at each of two harvests

Treatment means 1st harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	0.673[b]	0.568[a]	0.555[a]	0.610[a]	0.571[a]	0.0243	P≤0.05
			a=n.s. & b=0.05				
N-sources (S)		**BGA**	**U**	**AS**			
		0.595[b]	0.629[c]	0.563[a]		0.0188	P≤0. 1
			b=0.1	c=0.1			
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	0.625	0.042	P≤0.05
1		[c]0.69[a]	[a]0.72[a]	[a]0.62[a]	a=n.s.		
2		[a]0.54[a]	[a]0.60b[a]	[a]0.57[a]	a=n.s.		
3		[a]0.51[a]	[a]0.61[a]	[a]0.56[a]	a=n.s.		
4		[a]0.65[a]	[a]0.65[b]	[a]0.54[a]	b=0.05		
5		[a]0.60[a]	[a]0.58[a]	[a]0.54[a]	a=n.s.		
		a=n.s	a=n.s	a=n.s			

Treatment means 2nd harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	0.400[a]	0.358[b]	0.403[d]	0.385[c]	0.383[c]	0.00953	P≤0.05
			b=0.05				
N-sources (S)		**BGA**	**U**	**AS**			
		0.388[a]	0.388[a]	0.388[a]		0.00738	P≤0.00 1
			a=n.s				
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			

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Table Continued

Treatment means 2nd harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
0 (Cont)		-	-	-	0.041	0.01651	P≤0.01
1		$^{e}0.430^{b}$	$^{a}0.385a$	$^{a}0.385^{a}$	a=n.s.		
					b=0.05		
2		$^{d}0.325^{b}$	$^{b}0.350^{a}$	$^{b}0.400^{b}$	a=n.s.		
					b=0.01		
3		$^{c}0.415^{a}$	$^{c}0.395^{b}$	$^{c}0.400^{b}$	a=n.s.		
4		$^{b}0.390^{a}$	$^{d}0.375^{c}$	$^{b}0.390^{b}$	a=n.s.		
5		$^{a}0.380^{a}$	$^{c}0.380^{c}$	$^{c}0.390^{b}$	a=n.s.		
		b=0.01	a=n.s.	a=n.s.			

+ abc means bearing the different superscripts differ significantly at P≤0.001, P≤0.01,and P≤0.05

+ All SED!s are against 15 df.

Table 4 P-offtake by rice (mg/pot^{-1}) as obtained by application of different species of BGA and rates of ammonium sulphate and urea at each of two harvests

Treatment means 1st harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	11.67^{d}	9.87^{b}	9.30^{a}	8.92^{a}	10.87^{c}	0.2828	P≤0.01
		b=0.1 , c=0.01 & d=0.05					
N-sources (S)		**BGA**	**U**	**AS**			
		9.79^{a}	10.77^{b}	9.81^{a}		0.2191	P≤0.001
			b=0.001				
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	5.8	0.4899	P≤0.001
1		$^{c}13.80^{b}$	$^{b}13.10^{b}$	$^{a}8.10^{a}$	b=0.001		
2		$^{b}8.70^{a}$	$^{a}9.95^{b}$	$^{b}10.95^{c}$	b=0.05		
					c=0.1		
3		$^{b}10.05^{b}$	$^{a}10.40^{b}$	$^{a}7.45^{a}$	b=0.001		
4		$^{a}7.06^{a}$	$^{a}9.60^{b}$	$^{b}10.15^{b}$	b=0.001		
5		$^{b}9.40^{a}$	$^{a}10.80^{b}$	$^{c}12.40^{c}$	b=0.05		
					c=0.01		
		b=0.01	a=n.s.	a=n.s.			
		c=0.001	b=0.001	b=0.001	c=0.01		

Treatment means 2nd harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	22.38^{d}	16.25^{a}	22.43^{d}	20.61^{c}	19.42^{b}	0.635	P≤0.001
		b=0.001, c=0.01 & d=0.01					
N-sources (S)		**BGA**	**U**	**AS**			
		17.85^{a}	21.23^{b}	21.57^{b}		0.491	P≤0.001
			b=0.001				
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	14.9	1.099	P≤0.001

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Table Continued

Treatment means 2nd harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
1		$^{b}25.00^{b}$	$^{b}20.35^{a}$	$^{b}21.80^{a}$	b=0.01		
2		$^{a}14.80^{a}$	$^{b}16.35^{a}$	$^{a}7.60^{a}$	a=n.s.		
3		$^{ca}7.65^{b}$	$^{b}24.55^{a}$	$^{c}25.10^{a}$	b=0.00		
4		$^{a}16.05^{a}$	$^{b}21.77^{b}$	$^{c}24.00^{c}$	b=0.001		
					c=0.1		
5		$^{a}15.75^{a}$	$^{b}23.15^{c}$	$^{a}9.35^{b}$	b=0.01		
					c=0.01		
		a=n.s.	b=0.01	a=n.s.			
		b=0.001		b=0.01			
				c=0.1			

+ abc means bearing the different superscripts differ significantly at P≤0.001, P≤0.01, and P≤0.05
+All SED's are against 15 df.

Table 5 %K content of rice as obtained by application of different species of BGA and rates of ammonium sulphate and urea at each of two harvests

Treatment means 1st harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	1.795^{a}	1.817^{a}	1.883^{a}	1.767^{a}	1.888^{a}	0.0513	P=n.s.
		a=n.s.					
N-sources (S)		**BGA**	**U**	**AS**			
		1.790^{a}	1.863^{a}	1.837^{a}		0.0397	P=n.s.
			a=n.s.				
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	1.925	0.0888	P≤0.01
1		$^{a}1.89^{b}$	$^{a}1.90^{b}$	$^{a}1.60^{a}$	b=0.01		
2		$^{a}1.80^{a}$	$^{a}1.75^{a}$	$^{b}1.90^{a}$	a=n.s.		
3		$^{a}1.80^{a}$	$^{a}1.97^{a}$	$^{b}1.89^{a}$	a=n.s.		
4		$^{a}1.65^{a}$	$^{a}1.80^{a}$	$^{b}1.85^{a}$	a=n.s.		
5		$^{a}1.82^{a}$	$^{a}1.90^{a}$	$^{b}1.95^{a}$	a=n.s.		
		a=n.s.	a=n.s.	b=0.05			

Treatment means 2nd harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	1.605^{b}	1.667^{b}	1.607^{b}	1.612^{b}	1.478^{a}	0.0502	P≤0.05
		b=0.05					
N-sources (S)		**BGA**	**U**	**AS**			
		1.552^{a}	1.630^{a}	1.599^{a}		0.0389	P=n.s.
			a=n.s.				
N-Sources×Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	1.365	0.087	P≤0.1
1		$^{a}1.50^{a}$	$^{a}1.67^{b}$	$^{a}1.65^{b}$	b=0.1		
2		$^{b}1.70^{a}$	$^{a}1.60^{a}$	$^{a}1.70^{a}$	a=n.s.		
3		$^{b}1.66^{a}$	$^{a}1.63^{a}$	$^{a}1.54^{a}$	a=n.s.		
4		$^{a}1.50^{a}$	$^{a}1.71^{a}$	$^{a}1.63^{a}$	a=n.s.		
5		$^{a}1.40^{a}$	$^{a}1.55^{a}$	$^{a}1.49^{a}$	a=n.s.		
		a=n.s.	a=n.s.	a=n.s.	b=0.1		

+ abc means bearing the different superscripts differ significantly at P≤0.001, P≤0.01,and P≤0.05
+ All SED!s are against 15 df.

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Table 6 % Ca content of rice as obtained by application of different species of BGA and rates of ammonium sulphate and urea at each of two harvests

Treatment means 1st harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	0.415[a]	0.407[a] a=n.s.	0.413[a]	0.403[a]	0.402[a]	0.00833	P=n.s.
N-sources (S)		**BGA**	**U**	**AS**			
		0.404[a]	0.406[a] a=n.s.	10.414[a]		0.00645	P=n.s.
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	0.375	0.01443	P≤0.1
1		[a]0.415[a]	[a]0.400[a]	[a]0.430[a]	a=n.s.		
2		[a]0.410[a]	[a]0.400[a]	[a]0.410[a]	a=n.s.		
3		[a]0.415[a]	[a]0.430[a]	[a]0.395[a]	a=n.s.		
4		[a]0.390[a]	[a]0.395[a]	[a]0.425[a]	a=n.s. b=0.1		
5		[a]0.390[a] a=n.s.	[a]0.405[a] a=n.s. b=0.1	[a]0.410[a] a=n.s.	a=n.s.		

Treatment means 2nd harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	0.658[b]	0.643[b] b=0.1	0.592[a]	0.617[a]	0.617[a]	0.0132	P≤0.1
N-sources (S)		**BGA**	**U**	**AS**			
		0.612[a]	0.636[a] a=n.s.	0.624[a]		0.0102	P=n.s.
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	0.64	0.0228	P≤0.01
1		[b]0.670[a]	[a]0.660[a]	[a]0.645[a]	a=n.s.		
2		[b]0.675[a]	[a]0.665[a]	[a]0.590[a]	b=0.01		
3		[a]0.555[a]	[a]0.600[b]	[a]0.620[b]	b=0.1		
4		[a]0.565[a]	[a]0.630[b]	[a]0.635[b]	b=0.05		
5		[a]0.595[a] a=n.s. b=0.01	[a]0.625[a] a=n.s.	[a]0.630[a] a=n.s.	a=n.s.		

+ abc means bearing the different superscripts differ significantly at P≤0.001, P≤0.01,and P≤0.05

+ All SED!s are against 15 df.

Table 7 % Mg content of rice as obtained by application of different species of BGA and rates of ammonium sulphate and urea at each of two harvests

Treatment means 1st harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	0.137[a]	0.133[a] a=n.s.	0.138[a]	0.135[a]	0.133[a]	0.00349	P=n.s.
N-sources (S)		**BGA**	**U**	**AS**			
		0.136[a]	0.133[a] a=n.s.	0.137[a]		0.0027	P=n.s.

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Table Continued

Treatment means 1st harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	0.125	0.00604	P≤0.05
1		^{a}0.140^{b}	^{a}0.130^{a}	^{a}0.140^{a}	b=0.1.		
2		^{a}0.135^{a}	^{a}0.130^{a}	^{a}0.135^{a}	a=n.s.		
3		^{a}0.145^{b}	^{a}0.140^{b}	^{a}0.130^{a}	a=n.s.		
4		^{a}0.130^{a}	^{a}0.130^{a}	^{a}0.145^{b}	a=n.s.		
					b=0.05		
5		^{a}0.130^{a}	^{a}0.135^{a}	^{a}0.135^{a}	a=n.s.		
		a=n.s	a=n.s	a=n.s			

Treatment means 2nd harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	0.212^{a}	0.207^{a}	0.197^{a}	0.206^{a}	0.208^{a}	0.00527	P=n.s.
		a=n.s.					
N-sources (S)		**BGA**	**U**	**AS**			
		0.198^{a}	0.206^{b}	0.213^{b}		0.00408	P≤0.1
			b=0.1				
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	0.205	0.00913	P≤0.05
1		^{a}0.210^{a}	^{a}0.205^{a}	^{a}0.220^{a}	a=n.s.		
2		^{a}0.210^{a}	^{a}0.215^{a}	^{a}0.195^{a}	a=n.s.		
3		^{a}0.185^{a}	^{a}0.200^{b}	^{a}0.205^{b}	b=0.1.		
4		^{a}0.190^{a}	^{a}0.205^{b}	^{a}0.220^{c}	b=0.1		
					c=0.1		
5		^{a}0.195^{a}	^{a}0.205^{a}	^{b}0.225^{b}	b=0.05		
		a=n.s	a=n.s.	a=n.s.			
				b=0.1			

+ abc means bearing the different superscripts differ significantly at P≤0.001, P≤0.01, and P≤0.05

+ All SED's are against 15 df.

Table 8 Fe content of rice (μg g^{-1} dry matter) as obtained by application of different species of BGA and rates of ammonium sulphate and urea at each of two harvests

Treatment means 1st harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	263.9^{a}	317.9^{c}	292.9^{b}	320.2^{c}	317.5^{c}	6.96	P≤0.001
		b=0.001 & c=n.s.-0.01					
N-sources (S)		**BGA**	**U**	**AS**			
		279.6^{a}	308.2^{b}	319.6^{c}		5.39	P≤0.001
			b=0.001& c=0.1				

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Table Continued

Treatment means 1st harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
N-Sources × Rates (R×S)		BGA	U	AS			
0 (Cont)		-	-	-	162.3	12.06	P≤0.001
1		^{a}216.4^{a}	^{a}223.4^{a}	^{b}351.5^{b}	a=n.s. b=0.001		
2		^{a}233.0^{a}	^{c}367.9^{b}	^{b}352.9^{b}	b=0.001		
3		^{b}256.1^{a}	^{b}261.6^{a}	^{b}361.0^{b}	a=n.s. b=0.001		
4		^{d}365.1^{c}	^{b}256.1^{a}	^{b}339.3^{b}	b=0.01 c=0.05		
5		^{c}327.0^{b}	^{d}431.9^{c}	^{a}193.5^{a}	b=0.001 c=0.001		
		a=n.s b=0.1 c=0.001 d=0.01	b=0.05 c=0.001 d=0.001	b=0.001			

Treatment means 2nd harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	274.9^{b}	174.8^{a}	204.7^{b}	173.9^{a}	173.0^{a}	6.67	P≤0.001
		a=n.s. & b=0.001					
N-sources (S)		**BGA**	**U**	**AS**			
		158.3^{a}	183.9^{b}	222.6^{c}		5.17	P≤0.001
			b=0.001 & c=0.001				
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	130.8	11.56	P≤0.001
1		^{a}162.1^{a}	^{b}170.5^{a}	^{c}312.0^{b}	a=n.s. b=0.001		
2		^{a}141.1^{a}	^{a}139.0^{a}	^{b}243.8^{b}	a=n.s. b=0.05		
3		^{a}167.6^{a}	^{c}255.7^{c}	^{a}190.7^{b}	b=0.01 c=0.00		
4		^{a}156.7^{a}	^{b}171.7^{a}	^{a}193.5^{b}	a=n.s. b=0.001		
5		^{a}163.5^{a}	^{b}182.6^{a}	^{a}173.0^{a}	a=n.s.		
		a=n.s	b=0.05 c=0.001	a=n.s. b=0.001 c=0.001			

+ abc means bearing the different superscripts differ significantly at P≤0.001, P≤0.01,and P≤0.05

+ All SED!s are against 15 df.

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Table 9 Fe offtake by rice (µg pot^{-1}) as obtained by application of different species of BGA and rates of ammonium sulphate and urea at each of two harvests

Treatment means 1st harvest

N-rates(R)	1	2	3	4	5		SED	Significance of difference
	434.4^{a}	555.5^{c}	487.5^{b}	468.7^{b}	587.9^{d}		13.57	P≤0.001
		b=0.05, c=0.001 & d=0.05						
N-sources (S)		**BGA**	**U**	**AS**				
		445.9^{a}	530.7^{b}	543.8^{b}			10.51	P≤0.001
			b=0.001					
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**				
0 (Cont)		-	-	-	152.5		23.5	P≤0.001
1		^{a}433.8^{a}	^{a}408.9^{a}	^{a}460.4^{a}	a=n.s.			
2		^{a}375.3^{a}	^{b}613.9^{b}	^{d}677.3^{c}	b=0.001			
					c=0.05			
3		^{b}508.5^{b}	^{a}449.8^{a}	^{b}504.3^{b}	b=0.05			
4		^{a}396.4^{a}	^{a}377.3^{a}	^{c}632.4^{b}	a=n.s			
					b=0.001			
5		^{b}515.4^{b}	^{c}803.6^{c}	^{a}444.8^{a}	b=0.01			
					c=0.001			
		a=n.s	a=n.s	a=n.s				
		b=0.001	b=0.001	b=0.1				
			c=0.001	c=0.001				
				d=0.1				

Treatment means 2nd harvest

N-rates(R)	1	2	3	4	5		SED	Significance of difference
	1202.8^{e}	786.7^{a}	1124.7^{d}	938.9^{c}	882.8^{b}		31.09	P≤0.001
		b=0.001, d=0.001 & c=0.1 e=0.05						
N-sources (S)		**BGA**	**U**	**AS**				
		723.0^{a}	1024^{b}	1214.5^{c}			24.08	P≤0.001
			b=0.001 &c=0.001					
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**				
0 (Cont)		-	-	-	477		53.85	P≤0.001
1		^{b}943.4^{a}	^{b}899.5^{a}	^{d}1765.4^{b}	a=n.s.			
					b=0.001			
2		^{a}636.3^{a}	^{a}649.0^{a}	^{b}1074.7^{b}	a=n.s.			
					b=0.001			
3		^{a}711.4^{a}	^{e}1464.1^{c}	^{c}1198.5^{b}	b=0.001			
					c=0.00			
4		^{a}643.9^{a}	^{c}995.9^{b}	^{c}1177.0^{c}	b=0.001			
					c=0.001			
5		^{a}679.9^{a}	^{d}1111.6^{c}	^{a}857.1^{b}	b=0.01			
					c=0.001			
		a=n.s	b=0.001	b=0.01				
		b=0.001	c=0.1	c=0.1				
			d=0.05	d=0.001				
			e=0.001					

+ abc means bearing the different superscripts differ significantly at P≤0.001, P≤0.01,and P≤0.05

+ All SED!s are against 15 df.

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Table 10 Mn content of rice (µg g^{-1}) as obtained by application of different species of BGA and rates of ammonium sulphate and urea at each of two harvests

Treatment means 1st harvest								
N-rates(R)	**1**	**2**	**3**	**4**	**5**		**SED**	**Significance of difference**
	970[a]	1014[a]	944[a]	957[b]	1085[b]		34	P≤0.05
		a=n.s., & b=0.05						
N-sources (S)		**BGA**	**U**		**AS**			
		981[a]	1001[a]		1001[a]		26.3	P=n.s.
			b=0.001					
N-Sources × Rates (R×S)		**BGA**	**U**		**AS**			
0 (Cont)		-	-		-	733	58.8	P≤0.001
1		[a]1010[a]	[a]997[a]		[a]904[a]	a=n.s.		
2		[a]997[a]	[a]1082[a]		[a]964[a]	a=n.s.		
3		[a]937[a]	[a]911[a]		[a]983[a]	a=n.s.		
4		[a]977[a]	[a]997[a]		[a]898[a]	a=n.s		
5		[a]983[a]	[a]1016[a]		[b]1254[b]	a=n.s.		
						b=0.01		
		a=n.s	a=n.s		a=n.s			
					b=0.001			

Treatment means 2nd harvest								
N-rates(R)	**1**	**2**	**3**	**4**	**5**		**SED**	**Significance of difference**
	1560[b]	1602[b]	1459[a]	1543[b]	1531[b]		39.4	P≤0.1
		b= n.s.–0.1						
N-sources (S)		**BGA**	**U**		**AS**			
		1492[a]	1611[b]		1514[a]		30.5	P≤0.1
			a=n.s.& b=0.01					
N-Sources × Rates (R×S)		**BGA**	**U**		**AS**			
0 (Cont)		-	-		-	1195	68.3	P≤0.01
1		[a]1531[a]	[a]1690[b]		[a]1459[a]	a=n.s.		
						b=0.05		
2		[a]1445[a]	[a]1591[b]		[c]1769[c]	b=0.05		
						c=0.05		
3		[a]1426[b]	[a]1657[e]		[a]1294[a]	b=0.1		
						c=0.01		
4		[a]1604[b]	[a]1612[b]		[a]1412[a]	b=0.05		
5		[a]1452[a]	[a]1505[a]		[b]1637[b]	a=n.s.		
		a=n.s	a=n.s		a=n.s	b=0.1		
					b=0.05			
					c=0.1			

+ abc means bearing the different superscripts differ significantly at P≤0.001, P≤0.01,and P≤0.05

+ All SED!s are against 15 df.

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Table 11 Mn oftake by rice (mg pot^{-1}) as obtained by application of different species of BGA and rates of ammonium sulphate and urea at each of two harvests

Treatment means 1st harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	1.773^{b}	1.773^{b}	1.617^{b}	1.417^{a}	2.083^{c}	0.092	P≤0.001
		b=0.05 & c=0.001					
N-sources (S)		**BGA**	**U**	**AS**			
		1.634^{a}	1.70^{a}	1.84^{b}		0.071	P≤0.1
			b=0.1				
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	0.68	0.16	P≤0.001
1		^{c}2.02^{b}	^{a}1.80^{b}	^{a}1.50^{a}	b=0.1		
2		^{b}1.60^{a}	^{a}1.80^{a}	^{a}180^{a}	a=n.s.		
3		^{c}1.90^{b}	^{a}1.60^{a}	^{a}1.35^{a}	b=0.1		
4		^{a}1.10^{a}	^{a}1.45^{b}	^{a}1.70^{b}	b=0.1		
5		^{b}1.55^{a}	^{a}1.85	^{b}2.85^{c}	a=n.s.		
					c=0.001		
		b=0.05	a=n.s	b=0.001			
		c=0.1					

Treatment means 2nd harvest							
N-rates(R)	**1**	**2**	**3**	**4**	**5**	**SED**	**Significance of difference**
	8.70^{d}	7.23^{a}	8.17^{c}	7.83^{b}	7.85^{b}	0.0502	P≤0.01
		b=0.01 , c=0.1 & d=0.01					
N-sources (S)		**BGA**	**U**	**AS**			
		6.86^{a}	8.82^{a}	8.19^{b}		0.129	P≤0.001
			b=0.001 & c=0.001				
N-Sources × Rates (R×S)		**BGA**	**U**	**AS**			
0 (Cont)		-	-	-	4.35	0.288	P≤00.1
1		^{b}8.90^{b}	^{c}8.95^{b}	^{a}8.25^{a}	b=0.05		
2		^{a}6.45^{a}	^{a}7.45^{b}	^{a}7.80^{b}	b=0.001		
3		^{a}6.05^{a}	^{d}10.30^{c}	^{a}8.15^{b}	b=0.001		
					c=0.001		
4		^{a}6.60^{a}	^{b}8.25^{b}	^{a}8.65^{b}	b=0.001		
5		^{a}6.30^{a}	^{c}9.15^{c}	^{a}8.10^{b}	b=0.001		
					c=0.01		
		b=0.001	b=0.05	a=n.s.			
			c=0.05				
			d=0.01				

+ abc means bearing the different superscripts differ significantly at P≤0.001, P≤0.01,and P≤0.05

+ All SED!s are against 15 df.

% K content

There are no obvious differences in % K content except that at both 1st and 2nd harvests (Table 5) values for plants from pots inoculated with BGA were marginally but not significantly lower. There was a significant reduction in values at the 2nd harvest because of increased dry matter yields.

% Ca and Mg content

Like K-content there is no clear difference between Ca-content (Table 6) and Mg-contents (Table 7) although the values for pots inoculated with BGA were slightly but not significantly lower than for those receiving fertilizer. However, for both elements values for % content at the 2nd harvest were significantly higher than at the first,

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which indicates increased demand or uptake for those elements in the later period of growth.

% Fe content and Fe-offtake

Values for % Fe content are presented in Table 8 and showed significantly higher Fe content in plants from pots receiving fertilizer than those from inoculated with BGA at both the 1st and 2nd harvests, this difference which is more obvious in the Fe-offtake (Table 9) may be due to competitive uptake by the BGA. Fe- content and Fe up-take was highest in plants receiving AS fertilizer at both harvests. This may be due to localized higher acidity in the pots receiving AS compared to those receiving U. Off-take values increase with increasing amounts of N-applied which may due to increased dry matter yields.

% Mn content and Mn-offtake

These values are presented in Tables 10 & 11 respectively. There is little variation in 1st harvest but between harvests there is a significant increase in both % Mn-content and Mn-offtake. As in the case of Ca and Mg this must represent increased demand and or uptake of the element in the later period of growth. Plant material obtained at the 2nd harvest showed significant differences in Mn-content. Values were highest in material from pots receiving U and lowest in material from pots inoculated with BGA. There was no obvious relationship with the rate of N-application. Mn-offtake at the 2nd harvest is significantly higher than for the 1st harvest and the values are highest for the fertilizer treated pots.

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Conflict of interest

The authors have no conflict of interests.

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