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EFFECTS OF MICRONUTRIENTS ON YIELD AND NUTRIENT UPTAKE OF RICE IN SONATALA SILT LOAM SOIL

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Abstract

A study was undertaken to evaluate the effect of micronutrient application on the growth, yield and nutrient uptake of Transplanted Aman (T. Aman) rice (cv. BINA dhan7) in Sonatala silt loam soil at Bangladesh Agricultural University (BAU) farm, Mymensingh. The experimental field had 7.12 soil pH and 1.93% organic matter with 1.06, 1.04, 2.76, 6.35 and 25.9 mg kg^{-1} available B, Zn, Cu, Mn and Fe contents, respectively. Treatments were set with different combinations of micronutrients such as Zn, B, Cu, Mn, Fe and Mo. Zinc was applied as zinc oxide, B as boric acid, Cu as copper oxide, Mn as manganese chloride, Fe as ferrous sulphate and Mo as sodium molybdate. The field trial was laid out in a randomized block design with three replications. Micronutrient Zn, B, Cu, Mn and Fe were added at the rates of 3, 2, 2, 3, and 5 kg ha^{-1}, respectively. All the plots received 90 kg ha^{-1} N, 15 kg ha^{-1} P, 40 kg K ha^{-1}and 10 kg S ha^{-1} from urea, triple super phosphate, muriate of potash and gypsum, respectively. Among the micronutrients, zinc application demonstrated dominant effect on the crop that was followed by copper and boron application. The grain yield and its components particularly tillers hill^{-1} and grains panicle^{-1} were positively and significantly influenced by micronutrients. Application of Zn markedly increased grain N concentration and Cu increased grain K and S concentrations of rice. The concentration of N in rice grain was almost double the straw concentration while the result was opposite for straw K showing 4 - 5 times higher than in rice grain. The findings suggest retention of straw in the field after crop harvest would save K mining from soils and reduce the rate of K application for the next crop. Overall results indicate that the soil of BAU farm (AEZ 9) is deficient in Zn and to achieve the maximum grain yield of rice the application of Zn at 3 kg ha^{-1} is essential.

Keywords: Micronutrients, Nutrient concentration, Nutrient uptake, Rice yield, Zinc fertilizer.

1. Introduction

Micronutrients, like macronutrients, are absolutely required for supporting normal growth and development of plants. If any element is lacking in the soil or not adequately balanced with other nutrients, growth suppression or even complete inhibition may result (Mengel *et al.,* 2001). Micronutrients are zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), boron (B), molybdenum (Mo), chlorine (Cl) and nickel (Ni).

As the time advances, new nutrient deficiency arises and chronologically N, P, K, S, Zn and B deficiencies have appeared in soils and crops of Bangladesh, and there is sporadic information of Cu, Mn and Mo deficiency of crops. In this country, the Zn deficiency of rice was first identified in late 1970s (Jahiruddin *et al.,* 1981). This element deficiency is pronounced in calcareous and wetland soils and maize and wetland rice are the most responsive to zinc fertilization. Next to Zn, boron deficiency is frequently reported particularly on dry land crops e.g. wheat, mustard, chickpea, etc. (Jahiruddin, 2015). Apart from yield advantage from Zn application, increased concentration of grain Zn is also important in question of importance of Zn in human nutrition. So, Zn fertilization is also important to enhance Zn concentration of food grains. Positive influence of Zn fertilization is reported on Zn concentration of rice and maize grains, mungbean seeds, tuber (potato), curd (cauliflower) grown in alluvial soils of Bangladesh (Hossain *et al.,* 2008; Sarker *et al.,* 2019a,b). Zinc application can help increase N concentration i.e. protein content of rice grain (Siddika, 2019). An increment of 4-8 μg g^{-1} Zn in wheat grain and 2-4 μg g^{-1} Zn in rice grain is possible through Zn fertilization (Jahiruddin and Islam, 2018). Efforts are being paid to develop Zn enriched crop varieties, e.g. BRRI dhan 62, 72, 100; BARI Gom 33. However, integration of agronomic (fertilizer management) with breeding approach is required to achieve the goal of enhancing micronutrient level of food crops (Jahiruddin, 2020). Swaminathan said, "We have to increase our food production and ensure that it gives us all the nutrients we need (Swaminathan, 2014). Cropping intensity (CI) increased from 143% in 1971-72 to 198% in 202-23 (BBS, 2023).

Proper fertilizer management is essential for higher micronutrient uptake by the crops. Loss of micronutrients through erosion & leaching, liming of acid soils, minimum use of organic manure, increasing cropping intensity and use of marginal lands for crop production have increased the incidence of micronutrient deficiencies in worldwide agricultural soils (Fageria *et al.,* 2002). Farmers of this country commonly use N, P & K fertilizers; use of micronutrient fertilizers is limited (Jahiruddin, 2019). It is evidenced that soil fertility is being deleted due to increasing cropping intensity coupled with cultivation of high yield potential in-breed and hybrid crops. Cropping intensity (CI) has increased from 143% in 1971-72 to 198% in 2022-23 (BBS, 2023). With this understanding and perspective, a field experiment was conducted in Sonatala silt loam soil at BAU farm, Mymensingh (AEZ 9) to evaluate the requirement of any mcronutrient for achieving higher yield of rice.

2. Materials and Methods

The experiment was conducted on an Aeric Haplaquept soil at Bangladesh Agricultural University (BAU) farm, Mymensingh (24^0 43.407' N, $90^0$26.22' E) during Transplanted Aman (T. Aman) season. The experimental site is a medium-high land; it belongs to Sonatala soil series and Old Brahmaputra Floodplain agro-ecological zone (AEZ 9) (FAO/UNDP, 1988). The soil texture was silt having 7.12 pH, 1.93% organic matter, 0.09% total N, 4.7 mg kg^{-1} available P, 0.09 cmol (+) kg^{-1} exchangeable K and 9.9 mg kg^{-1} available S; micronutrients such as B, Zn, Cu, Mn and Fe contents being 1.06, 1.04, 2.76, 6.35 and 25.9 mg kg^{-1}, respectively.

There were seven micronutrient treatments (including control) arranged in an additive fashion, as follows: T_1: control, T_2: Zn,T_3: Zn+B, T_4: Zn+B+Cu, T_5: Zn+B+Cu+Mn, T_6: Zn+B+Cu+Mn+Fe and T_7 : Zn+B+Cu+Mn+Fe+Mo. The rates of micronutrients were 3 kg Zn, 2 kg B, 2 kg Cu, 3 kg Mn, 5 kg Fe and 1kg Mo per hectare. Zinc was applied from zinc oxide, B from boric acid, Cu from copper oxide, Mn from manganese chloride, Fe from ferrous sulphate and Mo from sodium molybdate.

Every treatment including control received a recommended and equal amount of N, P, K and S. The experiment was laid out in a randomized block design, with three replications. Every received N @ 90 kg ha^{-1} from urea, P @ 15 kg ha^{-1} from TSP, K @ 40 kg ha^{-1} from MoP and S @ 10 kg ha^{-1} from gypsum. The last Variety was BINA dhan7.

Intercultural operations such as weeding and insecticide spray were done whenever required in order to support normal crop growth. Five hills were randomly selected from each plot at maturity to record the yield contributing characters. The grain and straw yields were recorded plot-wise. The grain and straw samples from every plot were analyzed for N, P, K, S and B concentrations. Data were analyzed following F-Test and comparison of treatment differences was made by Duncan's Multiple Range Test (DMRT) test (Gomez and Gomez, 1984)

3. Results and Discussion

Effects of micronutrients on the yield, yield components, nutrient concentration and nutrient uptake of rice are presented in tables and graphs, and are discussed below.

3.1 Grain and straw yields

The grain yield of rice (BINA dhan7) responded significantly to the applied micronutrients showing a yield variation from 3786 to 4950 kg ha^{-1} (Table 1). Treatment T_2 comprising only Zn (+ recommended rate of N, P, K & S) demonstrated the highest yield and treatment T_1 (control) containing N, P, K, & S only and no micronutrient produced the lowest. The lone Zn treatment (T_2) producing the maximum yield was not significantly different from the Zn+B (T_3) and Zn+B+Cu (T_4) treatments which indicates that added Zn had substantial positive influence on grain yield. The exclusive Zn treatment gave 30% yield benefit over micronutrient control. Available Zn content in soil of the experimental field was 1.04 ppm showing a low level of Zn for growing rice which is supported by yield response. It is noted that addition of Mn and Fe showed rather negative effect on rice yield indicating that slight excess application of Mn or Fe can suppress the yield. The results are in agreement with the findings of a number of authors. Islam *et al.* (1997) observed that application of Zn at 5 kg ha^{-1} increased the grain yield of rice by 15% and the application of B at 3 kg ha^{-1} increased the yield by only 4.0%.

There was a significant effect of micronutrient application on the straw yield of rice (Table 1); the yield varied from 4953 to 6329 kg ha^{-1} with the highest straw yield recorded with Zn+B+Cu+Mn treatment (T_5) which however was not significantly different from other micronutrient treatments, except Control (T_1). Significantly the lowest straw yield was noted for the micronutrient control treatment (T_1). There was a 22-27% yield increase due to added micronutrients over no application of any micronutrient (T_1). Grain yield was significantly correlated with tillers $hill^{-1}$ ($r = 0.925$, $p<0.01$), grains $panicle^{-1}$ ($r = 0.919$, $p<0.01$), 1000-grain weight ($r = 0.941$, $p<0.01$) and straw yield ($r= 0.848$, $p<0.05$).

3.2 Yield contributing characters

Application of lone zinc produced 15.2 tillers $hill^{-1}$and addition of other micronutrients (B, Cu, Mn, Fe, Mo) did not add any benefit showing the effect of exclusive Zn and that of Zn + other micronutrients was similar (Table 1). Supplementation of N, P, K & S, no any micronutrient displayed the lowest number of tillers $hill^{-1}$ (9.2). This result also supports low Zn availability of soil.

The number of grains $panicle^{-1}$ increased significantly due to added Zn, not any other micronutrients (Table 1) showing similar effects of Zn and Zn + others. The number of grains $panicle^{-1}$ ranged from 83.0 in T_1 treatment (control) to 93.2 in T_2 treatment (Zn). Although not significant, grain set went down when Mn or Fe was added. Thus, superiority of Zn supplement over other micronutrients was clearly visible. This result otherwise indicates that the experimental field was deficient in Zn. Islam *et al.* (1996) also reported a significant increase in the number of grains $panicle^{-1}$ of BR 11 rice at farmer's field in Melandha for application of 20 kg S combined with 5 kg Zn ha^{-1}.

Thousand grain weight of rice did not increase significantly due to various micronutrient treatments. This showed a narrow range of 25.2 – 24.3 g (Table 1), the highest value being observed in T_2 treatment (Zn) and the lowest value in T_1 treatment (micronutrient control). The results indicate that the micronutrients were not limiting for the translocation of carbohydrate from the photosynthetic organs (leaf and stem) to the grains. Hossain *et al.* (1997) also reported that micronutrient deficiency might limit the grain yield by reducing tillers and number of grains $panicle^{-1}$ in rice, but not affecting the weight of individual grain weight.

Table 1. Effects of micronutrients on the yield and yield components of rice

Treatments	Tillers hill^{-1}	Grains panicle^{-1}	1000-grain wt. (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1: Control	9.2b	83.0c	22.5	3787c	4953b
T_2: Zn	15.2a	93.2a	24.3	4950a	6296a
T_3: Zn+B	15.1a	88.1a	24.0	4600ab	6066a
T_4: Zn+B+Cu	15.2a	90.0a	23.7	4707ab	6295a
T_5: Zn+B+Cu+Mn	13.9a	84.4ab	23.6	4325b	6329a
T_6: Zn+B+Cu+Mn+Fe	14.3a	86.5ab	23.8	4420b	5917a
T_7: Zn+B+Cu+Mn+Fe+Mo	14.9a	91.0a	24.0	4613ab	6053a
CV (%)	*6.95*	*2.82*	*2.90*	*4.76*	*3.97*
SE (±)	*0.560*	*0.921*	*0.397*	*123*	*137*

SE = Standard error of means; CV= Co-efficient of variation

In a column, the figure (s) having same letter do not differ significantly at 5% level of significance by DMRT.

Grain yield was positively correlated with grains panicle^{-1} ($r= 0.919$; $P<0.01$), 1000-grain weight ($r=0.941$; $p<0.01$), tillers hill^{-1} ($r=0.925$; $p<0.01$) and also with straw yield ($r=0.848$, $p<0.05$). As an effect of one or more micronutrients, the grain yield of rice increased by 14.2-30.7%, number of grains per panicle by 1.7-12.3% and straw yield by 19.5-27.8% (Fig. 1).

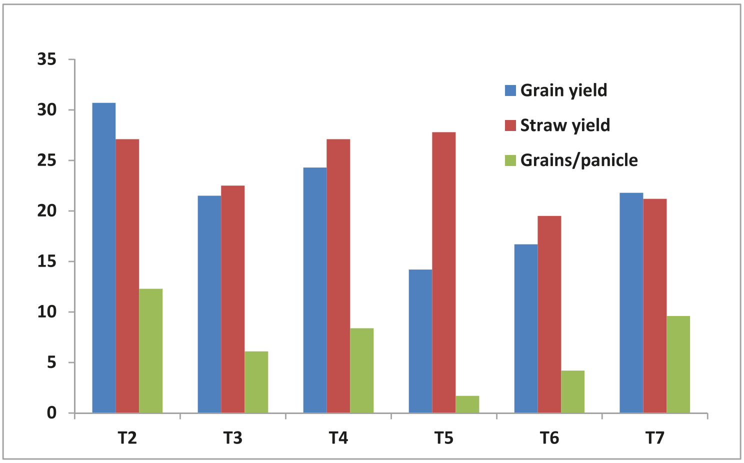

Fig. 1 Results of % increase over control for grain yield, grains/panicle and straw yield due to added micronutrients. Treatment details are shown in Table 1.

3.3 Nutrient concentrations of rice grain and straw

There was a significant effect of the different treatments on N concentration of both rice grain and straw (Table 2). The N concentration in grain varied from 1.01% in T_1 treatment to 1.11 % in T_2 treatment and that in straw varied from 0.594% in T_1 treatment to 0.626% in T_7 treatment. The result showed that T_2 (Zn) produced the highest concentration of N in grain which was statistically similar to $T_{3,}$ T_4, T_5 & T_7 treatments. Treatment T_7 (Zn+B+Cu+Mn+Fe+Mo) showed the highest concentration of N in straw which was statistically at par with all other treatments except control. The lowest N concentration was found in T_1 (control) treatment in both grain and straw. The result endorses that application of Zn helped protein synthesis.

Table 2 shows that the P concentration of rice grain and straw was significantly influenced by the added micronutrients. The P concentration of rice grain ranged from 0.227% in T_1 treatment to 0.241% in T_7 and that in straw varied from 0.124% in T_4 treatment to 0.161% in T_7 treatment. It appears that the grain-P concentration due to T_7 treatment was statistically alike with that due to all other treatments except T_6 (All-Mo). In case of straw P-concentration, all the treatments except T_4 (Zn+B+Cu) had similar effect. Uddin (2000) reported that application of S, Zn and B had positive effect on the P concentration of rice grain and straw.

Table 2. Effects of micronutrients on N, P, K and S concentrations of rice

Treatments	N (%)		P (%)		K%		S%	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Control	1.01c	0.594b	0.227ab	0.144ab	0.202b	1.168 c	0.105d	0.110
T_2: Zn	1.11a	0.621a	0.234ab	0.161a	0.202b	1.245a	0.160ab	0.125
T_3: Zn+B	1.04ab	0.607ab	0.224ab	0.155a	0.212b	1.240a	0.160ab	0.115
T_4: Zn+B+Cu	1.10ab	0.621a	0.226ab	0.124b	0.242a	1.216b	0.174a	0.121
T_5: Zn+B+Cu +Mn	1.06 abc	0.607ab	0.225ab	0.142ab	0.202b	1.216b	0.157abc	0.120
T_6: Zn+B+Cu +Mn+Fe	1.02bc	0.612ab	0.214b	0.144ab	0.202b	1.226ab	0.144bc	0.125
T_7:Zn+B+Cu+Mn+Fe+Mo	1.04abc	0.626a	0.241a	0.161a	0.212b	1.215b	0.133c	0.115
CV (%)	*2.28*	*0.50*	*0.39*	*1.32*	*3.88*	*1.03*	*1.80*	*8.67*
SE (±)	*0.0107*	*0.0022*	*0.001*	*0.002*	*0.006*	*0.009*	*0.002*	*0.007*

SE = Standard error of means; CV= Co-efficient of variation
In a column, the figure (s) having same letter do not differ significantly at 5% level of significance by DMRT.

There was a significant positive effect of the added micronutrients on K concentration of rice grain and straw (Table 2). The highest K concentration in grain was obtained as the T_4 treatment (Zn+B+Cu) was significantly higher than that of all other treatments including control. The straw-K concentration was the highest (1.245%) in T_2 treatment and statistically at par result was recorded with T_3 and T_6 treatments. The lowest K concentration of grain and straw was obtained with K control treatment. Jahiruddin *et al.* (1994) reported that S, Zn and B fertilization had inconsistent effect on K concentration of rice grain and straw.

It appears from Table 2 that treatments T_4, T_3 and T_2 had significant influence on S concentration of rice grain and they themselves were statistically alike. The grain S concentration varied from 0.105% in T_7 treatment to 0.174% in T_4 treatment. On the other hand, the various treatments had no significant effect on straw. Sulphur concentration indicating that all the treatments were statistically similar. Thus, micronutrients had significant effect on S concentration in rice grain but not in straw. In both grain and straw, the control treatment (T_1) had inferior result.

3.4 Nutrient uptake by rice

Results in Table 3 indicate significant increase in N uptake by grain as well as by straw due to various treatments. The N uptake by grain varied from 39.17 to 53.63 kg ha^{-1}. The highest N uptake by grain was due to T_2 treatment (Zn) which was statistically alike to the N uptake observed in T_3, T_4 and T_7 treatments. Concerning straw N uptake, all the micronutrient treatments (T_2-T_7) resulted in higher N uptake compared to control (T_1). The straw N uptake ranged between 39.52 and 28.23 kg ha^{-1}, the highest value recorded in exclusive Zn (T_2) treatment. Total N uptake by rice ranged from 67.4 kg ha^{-1} in T_1 (control) treatment to 93.15 kg ha^{-1} in T_2 (Zn) treatment. The lowest N uptake by grain and straw was observed in T_1 treatment (control). This means that micronutrients had significant effect on N uptake and it was particularly for Zn treatment.

Like N uptake there was a significant positive effect on P uptake by both grain and straw as well as total uptake by rice due to addition of micronutrients especially Zn (T_2) to soil (Table 3). This result was related to crop yield influenced by Zn condition. Phosphorus uptake by rice grain ranged from 8.83 kg ha^{-1} in T_1 (control) treatment to 11.32 kg ha^{-1} in T_2 (Zn) treatment. The amount of P uptake by rice grain obtained in T_5 (Zn+B+Cu+Mn) and T_6 (Zn+B +Cu +Mn +Fe) treatments was very close and significantly low compared to T_2, T_3, T_4 and T_7 treatments. The P uptake by rice straw varied from 6.82 kg ha^{-1} in T_1 treatment of 10.26 kg ha^{-1} in T_2 treatment. The total P uptake by rice straw obtained in T_1 and T_4 treatments were very close. Total amount of P uptake by rice 15.65 kg ha^{-1} due to T_1 (control) treatment and 21.58 kg ha^{-1} due to T_2 treatment. Total P uptake by the treatments T_2 and T_7 were very close. Similarly total P uptake by the treatments T_3, T_4, T_5 and T_6 were very close. Treatment T_1 (control) recorded the lowest P uptake.

Table 3. Effects of micronutrients on N and P uptake of rice

Treatments	N (kg ha^{-1})			P (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total
T_1: Control	39.17d	28.23b	67.40d	8.83c	6.82c	15.65c
T_2: Zn	53.63a	39.52a	93.15a	11.32a	10.26a	21.58a
T_3: Zn+B	47.84ab	36.86a	84.70ab	10.30abc	9.38abc	19.68b
T_4: Zn+B+Cu	52.43ab	39.24a	91.67ab	10.78ab	7.87d	18.65b
T_5: Zn+B+Cu +Mn	45.60c	38.42a	84.02c	9.71bc	8.99bc	18.70b
T_6: Zn+B+Cu +Mn+Fe	46.34bc	36.66a	83.00c	9.69bc	8.59cd	18.28b
T_7:Zn+B+Cu+Mn+Fe+Mo	47.95abc	37.72a	85.67bc	11.14a	9.70ab	20.84a
CV (%)	*5.15*	*4.61*	*3.03*	*4.96*	*4.17*	*2.43*
SE (±)	*1.721*	*1.194*	*1.804*	*0.359*	*0.260*	*0.281*

Table 4. Effects of micronutrients on K and S uptake of rice

Treatments	K (kg ha^{-1})			S (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total
T_1: Control	7.84d	7.84d	63.34c	4.08e	5.23c	9.31d
T_2: Zn	9.74bc	9.74bc	88.64a	7.75ab	7.93a	15.68a
T_3: Zn+B	9.75bc	9.75bc	84.95ab	7.36abc	6.96b	14.32abc
T_4: Zn+B+Cu	11.52a	11.52a	88.42a	8.28a	6.64b	14.92ab
T_5: Zn+B+Cu +Mn	8.74cd	8.74cd	85.74ab	6.77bcd	7.29ab	14.06bc
T_6: Zn+B+Cu +Mn+Fe	9.15bc	9.15bc	82.45ab	6.53cd	6.59b	13.12c
T_7:Zn+B+Cu+Mn+Fe+Mo	9.78b	9.78b	79.98b	6.14d	6.93b	13.07c
CV (%)	4.20	4.20	3.74	5.89	5.27	3.21
SE (±)	0.281	0.281	2.167	0.278	0.253	0.306

The K uptake by both grain and straw and total uptake by rice varied significantly due to application of micronutrients (Table 4). The K uptake by rice straw was 7-8 times higher than that of K uptake by rice grain which can be attributed to higher K concentration of straw. The K uptake by rice grain ranged from 7.84 kg ha^{-1} in T_1 (control) treatment to 11.52 kg ha^{-1} in T_4 (Zn+B +Cu) treatment while by rice straw ranged from 55.5 kg ha^{-1} in T_1 (control) treatment to78.9 kg ha^{-1} in T_2 (Zn) treatment. Total K uptake by rice was 63.34 kg ha^{-1} in T_1 (control) treatment to 88.64 kg ha^{-1} in T_2 (Zn) treatment. This result has special implication that soil K is markedly removed by rice straw and so straw retention could be a good means for arresting K mining from soils.

The S uptake by both rice grain and straw was significantly affected due to addition of different micronutrients (Table 4). The S uptake by rice grain varied from 4.08 kg ha^{-1} in T_1 (control) treatment to 8.28 kg ha^{-1} in T_4 (Zn+B+Cu) treatment. The highest uptake of S by rice grain recorded in T_4 treatment was comparable to the S uptake recorded in T_2 and T_3 treatments. The S uptake by rice straw ranged from 5.23 kg ha^{-1} in T_1 (control) treatment to 7.93 kg ha^{-1} in T_2 treatment. Treatments T_2 and T_5 were statistically similar in terms of S uptake by rice straw. When grain and straw S uptake was combined, it appears that the S uptake the crop varied between 15.68 and 9.31 kg ha^{-1}. The highest S uptake was recorded with T_2 (Zn) treatment and the lowest S uptake with T_1 treatment. Treatments T_2, T_3 & T_4 were statistically similar in consideration of S uptake by the crop (BINA dhan7).

4. Conclusions

Six micronutrients were tested to quantify their effects on rice yield and nutrient contents. The effect of zinc was prominent, next to it the effect of copper and boon was considerable, but other micronutrients viz. iron, manganese and molybdenum had no effect. Importantly, application of Zn had significant positive effect on grain N (or protein) and the Cu application increased grain K and S concentrations of rice. The K concentration of rice straw was found about five times higher than that of rice grain which renders a scope to save K mining from soils through retention of rice straw in the land as much as possible.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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