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Effects of Applied Selenium on Rice Root Parameters

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ABSTRACT

Selenium (Se) plays a major role in human and animal's diet. Because of the low concentration of Se reported in staple foods such as rice, developing a Se fertilizer strategy would play a key role in increasing Se levels in the human body. Se uptake in relation to morphological root parameters among 6 lowland rice varieties was studied by conducting a solution culture experiment using modified Yoshida solution in Agriculture Faculty of University Putra Malaysia. Three Se levels were developed by the addition of 0, 20 and 200 mgL^{-1} Na_2SeO_3 and rice seedlings were harvested in week 4. Se uptake in roots of rice showed significant differences among all varieties and Se uptake significantly increased with increased in Se levels. Other root parameters (length, average diameter, surface area, volume and number of root tips) did not show any significant differences at different Se treatments.

Key words: Selenium, rice, morphological root traits

INTRODUCTION

Selenium (Se) is a trace element required in small amounts by humans and animals for their normal physiological and biological functions (Rayman, 2000; Fordyce, 2013). Se has been involved in the protection of body tissues against oxidative stress, maintenance of defenses against infection and modulation of growth and development (Broadley *et al*., 2006). The majority of Se requirements by humans and animals is taken up through food, most of which is derived directly from plants, including staple foods such as rice, wheat, maize and sorghum (Lyons *et al*., 2004). The main source of Se for the majority of people living in Asian countries is rice, which is consumed in large proportion in Asia. But Se concentrations may be insufficient to maintain good human health (Cao *et al*., 2001; Chen *et al*., 2002). A previous study reported that most of the rice in the market do not provide the daily minimum requirement of Se for an average adult. A lot of efforts have been made to raise the low Se concentration in cereal crops through fertilizer application of Se into soil crop systems, called agronomic biofortification (Eurola *et al*., 1991; Lyons *et al*., 2004).

There is also evidence that SeO_3^{2-} is not as readily absorbed and transported as SeO_4^{2-} (Arvy, 1993; De Souza *et al*., 2000). Many studies have been performed on the importance of Se uptake as an essential element for both human and animal health, while there have been little critical consideration its effects on plant root traits. This study was carried out to assess the effects of different levels of Se applied as sodium selenite on root morphological traits of different anaerobic rice genotypes in Malaysia.

MATERIALS AND METHODS

Six anaerobic rice varieties (MR211, MR219, MR220, MR232, MR253 and MR263) were collected from Penang, Malaysia. This Study was conducted at Faculty of Agriculture, University Putra Malaysia from June 2012 to July 2012.

Three treatments of different Se concentrations (0, 20 and 200 μg L^{-1}) as sodium selenite (Na_2SeO_3) were applied to all rice varieties. Rice plants were grown in Yoshida solution culture (Yoshida and Yasumoto, 1987) in pots. The nutrient solutions were changed at 4 days interval and pH was adjusted to 5.5 with NaOH and HCl every day. The experiment was laid out in a Randomized Complete Block Design (RCBD) in 3 replications.

Seedlings were harvested weekly. Root length, surface area, average diameter, root volume and number of root tips were determined by WinRHIZO root scanning software. The dry-matter weights of roots were determined separately. Sample analysis was prepared by wet digestion and then stored for Se content measurement by ICP-EOS (De Blas *et al.*, 1996).

RESULTS AND DISCUSSION

Se uptake in rice seedling's roots and shoots, increased significantly each week for all Se levels. As shown in Table 1 and 2, significant differences were found between rice varieties when 20 and 200 µg L^{-1} Na_2SeO_3 were supplied for 28 days ($p<0.05$) (Table 1). Total Se in MR232 was 3.64 times higher than MR253. And when the Se level was increased to 200 µg L^{-1}, the total Se in the MR232 was 2.09 times higher than in MR253.

When 20 µg L^{-1} of Na_2SeO_3 was supplied for 28 days, total Se in shoots of MR232 was 1.5 times higher than MR253. And by increasing the Se supply to 200 µg L^{-1} total Se of the former was 3.52 times higher than that of the latter.

All root parameters presented in Table 3 for six different varieties of rice namely MR211, MR219, MR220, MR232, MR253 and MR263, were significantly different at $p\leq 0.01$ and $p\leq 0.05$, except for root surface area and root volume. On the number of tips, MR232 recorded the highest value of 248.11 followed by MR219 with 237.03. The lowest value was recorded on MR253 of 138.11 (Fig. 1). MR253 with a root diameter of 0.619 mm was the longest, followed by MR263 (0.568 mm) whereas MR220 had the lowest root diameter of 0.517 mm (Fig. 2). MR219 with the value of 89.44 cm for root length and MR211 with a value of 84.16 cm had longest root length after MR232 with 98.77 cm. The shortest root length value was recorded for MR253 at 74.56 cm (Fig. 3). During seedling establishment, the root system attributes such as root average diameter, root volume, root surface area, root length and number of tips were not significantly different at $p\leq 0.01$ and $p\leq 0.05$ (Table 3). The effect of time on all root parameters

Table 1: Se uptake in roots of rice varieties at different rates of Se applied

	Na_2SeO_3 (µg L^{-1})		
Variety	0	20	200
MR211	0.014^a	14.88^a	25.96^b
MR219	0.015^a	15.35^a	27.69^{ab}
MR220	0.012^a	6.63^b	16.61^c
MR232	0.015^a	16.03^a	29.86^a
MR253	0.020^a	4.40^c	14.24^c
MR263	0.013^a	3.90^c	17.70^c

Means in the same column followed by different letters differ significantly ($p\leq 0.05$) by Duncan

Table 2: Se uptake in shoots of rice varieties at different rates of Se applied

	Na_2SeO_3 (µg L^{-1})		
Variety	0	20	200
MR211	0.014^a	14.88^a	25.96^b
MR219	0.015^a	15.35^a	27.69^{ab}
MR220	0.012^a	6.63^b	16.61^c
MR232	0.015^a	16.03^a	29.86^a
MR253	0.020^a	4.40^c	14.24^c
MR263	0.013^a	3.90^c	17.70^c

Means in the same column followed by different letters differ significantly ($p\leq 0.05$) by Duncan

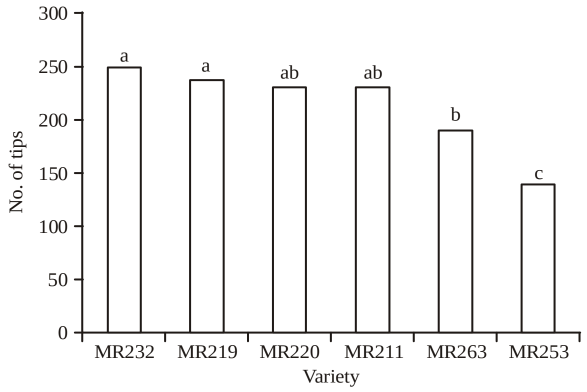

Fig. 1: Means comparison of number of tips of six rice varieties; MR211, MR219, MR220, MR232, MR253, MR263

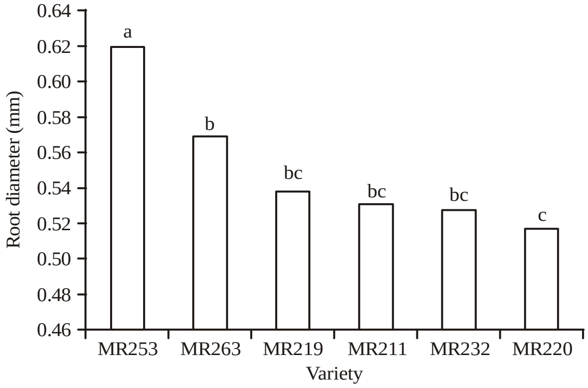

Fig. 2: Means comparison of root diameter of six rice varieties; MR211, MR219, MR220, MR232, MR253, MR263

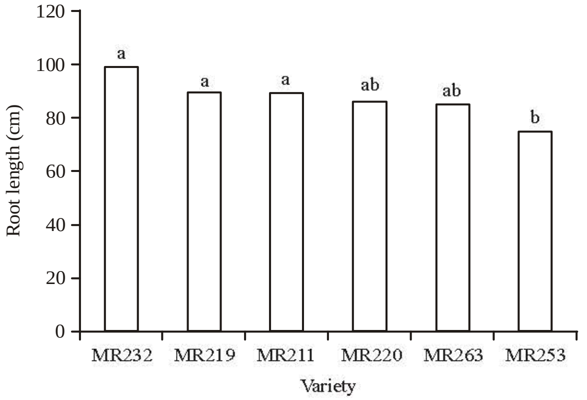

Fig. 3: Means comparison of root lengths of six rice varieties; MR211, MR219, MR220, MR232, MR253, MR263

Table 3: ANOVA for root parameters of six rice varieties treated with different Se rate

SOV	df	Root surface area	Root volume	No. of tips	Root average diameter	Root length
Block	2	228.78ns	0.011ns	5705.01ns	0.012ns	401.68ns
Variety	5	85.39ns	0.010ns	61604.17*	0.052*	2230.68*
Se rate	2	106.65ns	0.014ns	11351.62ns	0.018ns	267.72ns
week	3	1874.35*	0.202*	675556.54*	0.049*	70461.33*
Variety*rate	10	44.07ns	0.006ns	9127.78ns	0.004ns	608.17ns
variety*week	15	43.33ns	0.007ns	5942.90ns	0.009ns	236.16ns
Rate*week	6	193.05*	0.019ns	33615.39*	0.024*	3501.63*
Variety*Rate*week	30	73.43ns	0.010ns	8123.52ns	0.005ns	854.17ns
Error	142	79.59	0.011	7648.97	0.007	822.60

ns: Non-significance, *Significant at the 0.01 probability level

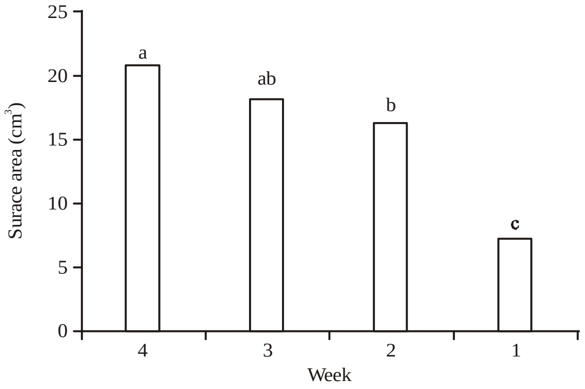

Fig. 4: Means comparison of surface area of six rice varieties after four weeks

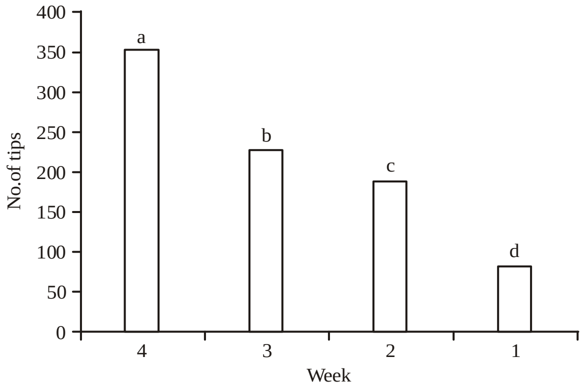

Fig. 6: Means comparison of number of tips of six rice varieties after four weeks

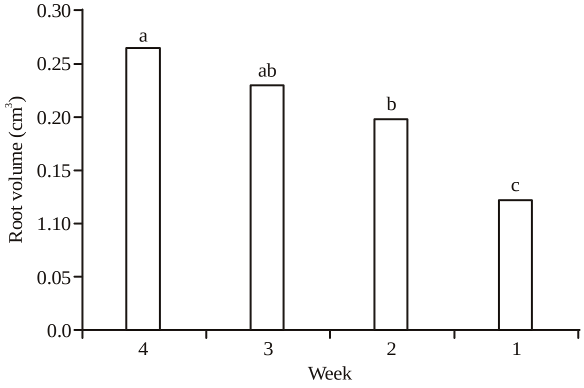

Fig. 5: Means comparison of root volume of six rice varieties after four weeks

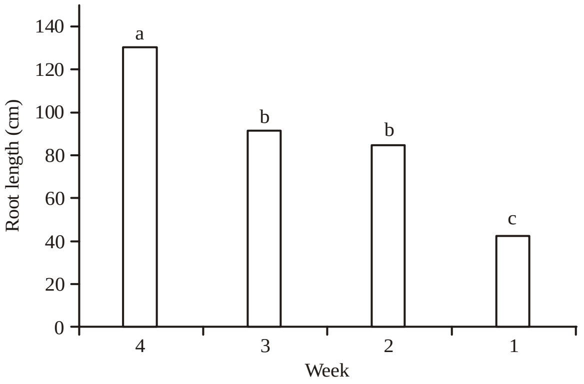

Fig. 7: Means comparison of root lengths of six rice varieties after four weeks

provided significant differences at $p \leq 0.01$ and $p \leq 0.05$ (Table 3). It was found that the root surface area had the highest value of 20.776 cm^3 at fourth week of growth, followed by 18.18 cm^3 at the third week, while it had the lowest value of 7.219 cm^3 after the first week (Fig. 4, 5). The highest root volume of 0.264 cm^3 was observed at the fourth week, while ta value of 0.121 cm^3 was observed after the first week.

The highest number of tips and root length were recorded at the fourth week with values of 352.19 and 130.23 cm, respectively followed by 226.93 and 91.471 cm after the third week. The lowest values of 81.28 and 42.05 cm were observed after the first week, respectively for the number of tips and the root length (Fig. 6, 7). The longer root diameter of 0.58 mm was recorded after the first week while the shortest was observed at fourth week of growth (Fig. 8). From the analysis of variance for the traits measured on interaction between six different rice varieties and three different Se levels and the interaction between different levels and weeks, the root system attributes like root average diameter, root volume, root surface area, root length and number of tips were not significantly different at $p \leq 0.01$ and $p \leq 0.05$ (Table 3). Interaction effects of variety, rates and time showed significant differences for all root parameters except root volume.

With increasing Se supply, the accumulation of Se in both shoots and roots rose remarkably. It was also found that the Se accumulation in shoots was higher than the accumulation in roots. These results for growth parameters is in accordance

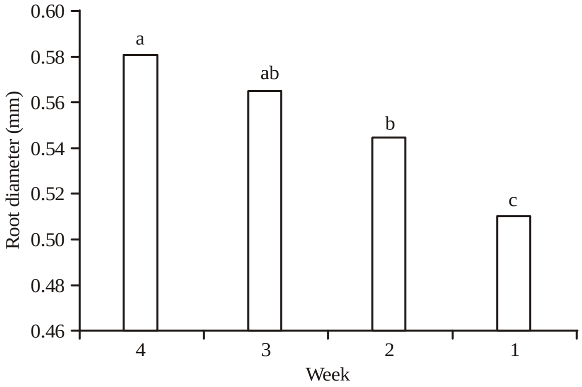

Fig. 8: Means comparison of root diameters of six rice varieties after four weeks

with Zhang *et al.* (2006c), who found that the Se content of brown rice was affected greatly by the total Se in the whole plant and shoot. He found that the Se content of brown rice was not affected to a great extent by the Se content of roots. Zhang *et al.* (2006a) reported that the rice genotypes, Xiushui 48 and S. Andrea, exhibited differences in Se accumulation in their shoots. As Se content in brown rice grains was positively correlated with the total Se in shoots (Zhang *et al.*, 2006b), a high Se accumulation in shoots may result in high Se levels in brown rice. Result in this study also showed that the Se accumulation in shoots in all different varieties was greater than Se accumulation in roots.

The higher capacity of Se uptake and the greater Se translocation from roots to shoots for all varieties resulted in higher Se accumulation in the shoots of rice. Among all varieties, MR232 showed the highest Se accumulation and MR 253 the lowest. Previous publications indicated that selenite could be quickly transformed to organic Se, such as Se-Met or other forms, once it entered the root cells Gissel-Nielsen, 1979; De Souza *et al.*, 1998; Zayed *et al.*, 1998). Roots may translocate organic Se molecules more readily than selenite even though selenite is the only form supplied to the plants. Thus, the difference of Se accumulation in shoots may be a function of the fundamental difference between the different varieties in transporting metabolites.

Previous study by Mikkelsen *et al.* (1989) reported that the uptake of Se^{4+} and Se^{6+} by the roots follow different mechanisms. Shrift and Ulrich (1969) and Ulrich and Shrift (1968) reported that Se^{6+} uptake requires energy, whereas Se^{4+} uptake is energy-independent. The roots provided with Se^{4+} never accumulated Se to concentrations greater than the external bathing solution whereas Se^{6+} was actively accumulated to concentrations far exceeding the external solution concentration. The uptake of Se^{6+} into the root appears to follow the same transport path as SO_4^{2-}Epstein (1955) showed that for SO_4^{2-}, the uptake was inhibited by Se^{6+}. Leggett and Epstein (1956) concluded that Se^{6+} and SO_4^{2-} compete for the same binding sites within the cell.

Once Se^{4+} and Se^{6+} are present in the root, a differential preference is exhibited for translocation to the plant shoot. Asher *et al.* (1977) traced the movement of $^{75}Se^{4+}$ and $^{75}Se^{6+}$ in the xylem of tomato plants. When the roots were supplied with Se^{6+}, the xylem exudate Se concentration was 6 to 18 times higher than that in the external solution. In the Se^{4+} supplied plants, xylem Se concentrations were lower than the Se concentration in the external solution. In addition to differences in uptake and translocation, Asher *et al.* (1977) found significant differences in the chemical form of Se in the Se^{4+} and Se^{6+} treated plants. After entering the plant, the Se^{6+} movement remains through the plant to the leaves, similar to SO_4^{2-} (Peterson *et al.*, 1981). However, Se^{4+} was rapidly converted to inorganic Se^{6+} and unidentified organic Se compounds prior to translocation in the xylem (Asher *et al.*, 1977). The results of different Se rates on root parameters revealed that different Se concentration have no effect on the root traits. It seems that Se does not have any influence on rice root parameters such as length, average diameter, surface area, volume and number of root tips.

CONCLUSION

Results of this study confirmed that six varieties of rice (MR211, MR219, MR220, MR232, MR253 and MR263), have different Se accumulation patterns in shoots and roots. These six varieties showed significant effects on Se uptake in shoots and roots but different Se concentrations had no significant effect on root parameters including root length, root volume, root diameter, number of tips and root surface area. The results showed that Se accumulation in shoots in all varieties was greater than Se accumulation in roots. The MR232 had the higher value of shoot's Se and MR253 showed the lowest uptake.

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