BRIEF COMMUNICATION

Tolerance of rice to nickel in nutrient solution

S. SAMANTARAY*, G.R. ROUT** and P. DAS*

Plant Physiology and Biochemistry Laboratory and Plant Tissue Culture Laboratory***,
Regional Plant Resource Centre, Bhubaneswar-751 015, Orissa, India

Abstract

For screening tolerance of six cultivars of rice (*Oryza sativa*) to different concentrations of nickel (0, 6, 12, 18, 24 and 30 μg dm^3), growth parameters (root and shoot length, root and shoot dry matter production) and root and shoot tolerance indexes were tested after 7, 10 and 13 d of treatment. In presence of nickel in nutrient solution, root growth of cv. Nilgiri was enhanced, while in cvs. Subhadra, Khandagiri, Rudra, Sankar and Annapurna it decreased. The root tolerance index (RTI) and shoot tolerance index (STI) in cv. Nilgiri were high; cvs. Sankar and Khandagiri, however, showed a low RTI. Based on the standard growth parameters, six cultivars of rice were ranked in respect of their tolerance to nickel: Nilgiri > Annapurna > Subhadra > Khandagiri > Rudra > Sankar.

Additional key words: cultivar differences, growth parameters, *Oryza sativa*.

Nickel is known as an essential component of the enzyme urease and its presence is very important in nitrogen and urea metabolism of higher plants (Dalton *et al.* 1985, Walker *et al.* 1985, Brown *et al.* 1990). It is widely distributed in plant tissues (Brenchley 1936, Gauch 1957, Hewitt 1963). However, excess of nickel in soils causes reduced growth (Hunter 1954, Khalid and Tinsley 1980). Phytotoxicity varies with the concentration of Ni in soil solution as well as with the plant species (Mizuno 1968, Khalid and Tinsley 1980). Therefore, identifying nickel tolerant genotypes for better growth and productivity in Ni-toxic soils could be the best strategy to circumvent nickel toxicity. The present study was intended to find nickel tolerant rice cultivars on the basis of root elongation and biomass production in hydroponic

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* Correspondence to P. Das; fax: (+0674) 418332

cultures with different Ni concentrations. This screening could also be a prerequisite for establishing a breeding programme for nickel tolerance in rice.

Seeds of six rice (*Oryza sativa* L.) cultivars Subhadra, Khandagiri, Rudra, Sankar, Nilgiri and Annapurna were obtained from the Department of Plant Breeding and Genetics, Orissa University of Agriculture and Technology, Orissa, India. Seeds were treated with detergent solution *Teepol* (*Glaxo*, Bombay, India) for 10 min and washed with running tap water for 15 min. Further, the seeds were sterilized with 0.1 % mercuric chloride solution for 20 min and were sown over plastic nets on glass trays (12 × 15 × 7 cm) (*Borosil*, Bombay, India) containing the nutrient solution. The trays were kept in a growth room at temperature of 25 ± 2 °C under cool, white fluorescent lamp (irradiance of 55 μmol m^{-2} s^{-1}; 16-h photoperiod). The nutrient solution consisted of 4.0 mM $CaNO_3$, 2.0 mM $MgSO_4$, 4.0 mM KNO_3, 0.4 mM $(NH_4)_2SO_4$, 2 μM $MnSO_4$, 0.3 μM $CuSO_4$, 0.8 μM $ZnSO_4$, 30 μM NaCl, 0.1 μM Na_2MO_4, 1.43 μM KH_2PO_4, 10 μM H_3BO_3 and 20 μM Fe-Na-EDTA. The pH of the nutrient solution was adjusted to 6.8 by the use of 0.1 M HCl or 0.1 M KOH and the solution was changed in 2-d intervals to facilitate aeration of the roots, maintain the desired level of nutrients and the pH. Nickel was supplied to six cultivars in the form of nickel sulfate at 0, 6, 12, 18, 24 and 30 μg dm^3. The experiment was laid in a Completely Randomized Block Design (CRBD) with three replications. The length of the primary root and the shoot were measured in 3-d-intervals from the start of the experiments up to the 13^{th} day. The rate of relative root elongation in each treatment was determined by subtracting the length of the root recorded on 0 day from that of the 13^{th} day. Tolerance index (TI) for the tested plants was calculated as the ratio of mean root or shoot elongation in solution with Ni and without Ni and was expressed in percentage. Regression analysis were performed to assess the pattern of response of rice cultivars to different levels of nickel. Effects of nickel on growth variables at each level were noted with mean separation using the Waller-Duncan multiple range test of *Harvard Graphics* regression programme.

Table 1. Effect of addition of nickel (18 μg dm^{-3}) into nutrient solution on shoot length, root length and number of roots of six rice cultivars after 13-d of treatment. Means ± S.D.; $n = 20$. Within a column means having a letter in common are not significantly different at 5 % level by Duncan's Multiple Range Test.

Cultivar	Root length [cm]		Shoot length [cm]		Number of lateral roots [$plant^{-1}$]	
	control	Ni	control	Ni	control	Ni
Subhadra	5.86 ± 0.2 d	2.57 ± 0.3 d	5.94 ± 0.7 a	4.06 ± 0.6 a	3.21 ± 0.8 d	1.61 ± 0.3 d
Khandagiri	6.25 ± 0.4 e	1.42 ± 0.1 c	6.96 ± 0.4 d	4.53 ± 0.5 b	4.10 ± 0.9 d	1.30 ± 0.2 c
Nilgiri	3.26 ± 0.5 a	3.30 ± 0.3 e	6.59 ± 0.6 b	5.48 ± 0.3 d	2.82 ± 0.2 c	1.83 ± 0.7 e
Annapurna	3.68 ± 0.4 b	2.26 ± 0.5 d	6.82 ± 0.2 c	5.67 ± 0.7 e	1.81 ± 0.8 a	0.65 ± 0.1 b
Rudra	4.25 ± 0.5 c	0.97 ± 0.2 b	7.30 ± 0.6 e	4.85 ± 0.3 c	2.41 ± 0.3 b	0.32 ± 0.1 a
Sankar	3.81 ± 0.3 b	0.81 ± 0.2 a	6.81 ± 0.3 c	4.95 ± 0.4 c	2.62 ± 0.3 c	0.42 ± 0.1 a

Six cultivars of rice subjected to five levels of nickel responded differently in terms of seed germination, elongation of shoot and root and the total biomass production. The percentage of germination 72 h after sowing was the maximum in the nutrient solution without nickel (control) and with low concentration of nickel (6 μg dm^{-3}). The concentration 18 μg dm^{-3} was chosen to compare the performance of different cultivars. The root and shoot growth were affected by this nickel concentration in all the six cultivars of rice tested (Table 1). Root length in cv. Nilgiri, increased by 1.22 % in presence of Ni compared to control, while in cvs. Annapurna, Subhadra, Khandagiri, Rudra and Sankar it was reduced by 38.58, 56.14, 77.17, 77.28, and 78.74 %, respectively. Symptoms of nickel toxicity were observed a few days after germination and became more severe with the age of the seedlings. Some of the leaves showed signs of chlorosis. Severe chlorosis and necrosis appeared at higher concentrations of 24 and 30 μg(Ni) dm^{-3}. Taylor and Foy (1985) reported root tolerance index (RTI) as one of the most important markers for screening genotypes for metal toxicity. Our results showed cv. Nilgiri to be tolerant to

Table 2. Effect of addition of nickel (18 μg dm^{-3}) into nutrient solution on shoot tolerance index (STI), root tolerance index (RTI), root and shoot biomass [mg $plant^{-1}$] and shoots/root ratio of six rice cultivars after 13-d of treatment. Values are mean of 20 samples. Within a column means having a letter in common are not signifcantly different at 5 % level by Duncan's Multiple Range Test.

Cultivar	STI	RTI	Root biomass		Shoot biomass		Shoot/root	
			control	Ni	control	Ni	control	Ni
Subhadra	68.35	43.85	28.40 d	8.32 c	26.31 a	12.18 b	0.92	1.46
Khandagiri	65.08	22.72	32.15 e	6.67 b	31.23 b	10.11 a	0.97	1.58
Nilgiri	83.15	101.22	22.31 c	17.48 e	32.42 c	18.24 e	1.45	1.04
Annapurna	83.13	61.41	18.52 a	9.20 d	30.64 b	14.46 d	1.65	1.57
Rudra	66.43	22.58	20.34 b	4.21 a	35.82 d	14.80 d	1.76	3.52
Sankar	72.68	21.25	18.65 a	3.42 a	30.22 b	13.61 c	1.61	4.00

18 μg(Ni) dm^{-3} having RTI value 101.22 (Table 2). The solution containing 6 and 12 μg(Ni) dm^{-3} did not affect shoot growth significantly. There were several reports to show even enhanced germination and further growth of plants at low concentrations of nickel either in solution or in soil (Gupta *et al.* 1987, Tsui 1955, Brown *et al.* 1987 a,b).

Root and shoot biomass production were in accordance with root length. The minimum (21.64 %) reduction of root biomass was observed in cv. Nilgiri and the maximum (80. 18 %) in cv. Khandagiri (Table 2). Cultivar Rudra showed an increase in the shoot/root biomass ratio in presence of nickel compared to their respective controls. Nickel accumulated principally more in shoots than in roots (Palacios *et al.* 1995, Vergnano 1953, Khalid and Tinsley 1980). Ni-induced reduction in growth of seedlings in nutrient solutions have been also showed by Khalid and Tinsley (1980), Wang (1987) and Palacios *et al.* (1995).

The linear regressions of root length versus concentration after exposure to nickel for 7, 10 and 13 d also confirmed different response to nickel in six cultivars of rice tested. Therefore, it was possible to categorise these rice cultivars based on their relative tolerance to Ni: Nilgiri > Arnapurna > Subhadra > Khandagiri > Rudra > Sankar. The hydroponics was efficient in the determination of nickel tolerance among the tested cultivars of rice and cv. Nilgiri was found to be the most suitable for growing on soils with enhanced Ni content.

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