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PHYTOREMEDIATION OF BORON CONTAMINATED SOILS BY NATURALLY GROWN WEEDS

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ABSTRACT

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A pot experiment was conducted at Bangladesh Agricultural University, Mymensingh on the year 2003 to identify naturally grown boron hyperaccumulating weed species in boron contaminated soil. Nine weed species namely, Barnyard grass (*Echinochloa crus-galli*), Joina (*Fimbristylis miliacea*), Chisra (*Scirpus juncoids*), Panikachu (*Monochoria hastata*), Panilong (*Luduwigia hyssopifolia*), Malancha (*Alternanthera philoxeroides*), Topapana (*Pistia stratiotes*) and Water cress (*Enhydra, fluctuans*) accumulate boron in an increasing level of boron treatment except Mutha (*Cyperus rotundus*). The accumulation efficiency of boron was Water cress> Malancha>Panikachu> Joina> Barnyard grass> Chisra>Panilong> Topapana. Although maximum accumulation of boron was found in Water cress but it is not abundant in the rice field; while Joina, Barnyard grass and Chisra are frequently grown. Considering the absorption pattern, biomass and toxicity tolerance Joina and Barnyard grass are the best performer and can be considered as the mitigation of boron contaminated soil due to irrigation water. Water cress and Malancha can be used for remediation of stagnant boron contaminated water as a means of phytoremediation technology.

Key words: Phytoremediation, Boron Contamination, stacking and aromatic rice

INTRODUCTION

Now a day Phytoremediation is an emerging technology. It is a quite novel technique of cleaning polluted sites through the use of plants. Phytoremediation methods are comparatively cheap and ecologically advantageous, compared to common technological approaches. Now, the world is sailing its voyage towards to the green technology. Green plants are being used to remove pollutants from the environment or to render them harmless. There are several species of plants known for their phytoremediative abilities. Two Brassica species *Brassica juncea* and *Brassica carinata* are experimentally screened for the remediation of nickel contaminated soil. Between these two species, Brassica juncea has the potential to be hyper accumulator of Ni (Panwar et al., 2002).

Boron is essential in higher plants primarily for maintaining the integrity of cell walls and might be essential in animals (Takano et al., 2002). Boron is now known to be essential for carbohydrate metabolism and transport of sugars through membranes, nucleic acid (DNA and RNA) and phytohormone synthesis, tissue development etc (Kabata pendias and Pendias, 2001). Excessive boron or boron toxicity induced a decrease of photosynthetic rate of the volume of mesophyll cells, increase volume of intercellular spaces and cell damage (Sotiropoulos et. al., 2002).

Bangladesh is an agro-based country. Irrigation is a vital component of agricultural practice. During dry season the major surface water sources get dry such as small rivers, canals, haor, beels and ponds. Farmers are left with no option but the use of groundwater for irrigating their crops. The groundwater contains different levels of boron. In some cases, boron levels in groundwater exceed the tolerance limit (≤ 0.75 mg BL-1) for irrigating rice. Concentration of B in some of the ground water exceeds the recommended limit (0.75 mg BL-1) for rice production (Zaman and Majid, 1995). In future, boron build-up in soil may develop.

We never consider the water quality assessment before irrigating our soil and it leads our soil contaminated with boron very slowly. Now the scenario is alarming. Boron was detected in ground water sources of 23 thanas of 18 districts of Bangladesh and ground water of rest of the districts would yet to be analyzed. Total of 1090 water sources, 60 sources contained >0.4 mg BL-1, 35 sources >0.5 mg BL-1, 7 water sources contained >0.75 0.75 mg BL-1 and 2 samples had boron levels >1.0 mg BL-1 (Kabir, 2003). Irrigation water containing 0.5 mg BL-1 can be safely used temporarily but long term use may cause yield reduction. If 1 mg BL-1 used for long term would induce B toxicity

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and disease severity. Water containing 4 mg BL-1 if irrigated excessive B would be accumulated in the rice grain and straw and would pose threat to food chain contamination (Kabir, 2003).

Now, we realize boron toxicity may be a Frankenstein to us as we drew less attention to the irrigation water quality. We are deteriorating soil by irrigation though it was considered for better yield production. In this situation soil remediation is required. Considering the socio-economic condition of Bangladesh farmer soil amendment by chemicals and high tech technology is beyond the reach. So, it urges the need of finding out an alternative approach to mitigate the vulnerable boron toxicity problem. Since phytoremediation is a holistic approach, it is potential to serve as a sustained, ecologically sound method to remediate contaminated soil and ground water. Considering the above facts, an experiment was carried out to i) Identify the naturally grown boron hyperaccumulating weed species from boron contaminated soil and ii) assessment of boron accumulation by naturally grown weeds.

MATERIALS AND METHOD

A field experiment was carried out at the experimental field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during the rainy season of 2002. The experimental site is located at the center of Madhupur tract ($24^o09^/$ N latitude and $90^o26^/$ E longitude) having an elevation of 8.2 meter from the sea level. The climate of the experimental site is sub-tropical in nature characterized by heavy rainfall during the months from June to September and scanty rainfall during winter with gradual fall of temperature. Average air temperature ranged from 30.18^oC (Maximum) to 19.86^oC (minimum) and total rainfall recorded 744.6 mm during the study period (August to December 2002). The soil type of the experimental field belongs to the shallow red-brown terrace type of Salna series. The soil is characterized by poor fertility and impeded internal drainage.

Rice cultivars, namely Chinigura, Kalijira, Shakkorkhora and Kataribhog were grown with three levels of nitrogen fertilizer (0, 60 and 120 Kg N ha^{-1}).The experiment was laid out in a randomized complete block design.

Triple Super Phosphate, Muriate of Potash, Gypsum and Zinc Sulphate were applied as the sources of P_2O_5, K_2O, S and Zn, respectively. P_2O_5, K_2O, S and Zn were applied at the rate of 90, 50, 40, and 5 kg ha^{-1}, respectively. All fertilizers except urea were applied and thoroughly mixed with the soil at the time of final land preparation. Urea was applied as top dressing in three equal installments, first at active tillering stage (18 Days after transplanting), 2nd at maximum tillering stage (35 days after transplanting) and 3rd before panicle initiation stage (50 Days after transplanting). The seedlings were transplanted at 30 days after seeding. One seedling per hill was used maintaining 25 cm row to row and 10 cm plant to plant distance in well prepared land. Weeding, irrigation and application of pesticide were done as and when necessary. Standing water of 2 to 4 cm. was maintained in the field until the crop attained hard dough stage.

At the time of heading the experimental plots were equally divided into two parts. Thus every part of the plot occupied 3.75 m^2 land area. The crop in the half of the plot was left on the fate of the nature (treated as 'non-stacking') and that in the other half of the plot was mechanically supported by stacking (treated as 'stacking') to prevent lodging. Bamboo sticks and plastic ropes were used for stacking. Mechanical supports were provided in such a fashion that the canopy architecture and light interception remained almost unaffected.

The total number of emerged panicle per hill was counted at maturity stage. The length of all the panicles of a hill was measured in centimeter from the collar (base mark) of the culm to the tip of the panicle. Both fertile and sterile spikelets per panicle were separately counted manually from all of the panicles of sample hill. From the filled grains of a hill, 1000 grains were randomly counted by Multi-auto counter and the weight of these grains was recorded.

From the middle portion of the plots the stacked and non-stacked hills were harvested separately and grain yield was recorded and adjusted with 14% moisture content. Harvest index (HI) was calculated by dividing the economic yield (grain) by the biological yield (grain + straw) from the same area

The data were analyzed by partitioning the total variance by using MSTATC program. The treatment means were computed using Least Significant Difference test and interrelationship was worked out employing regression analysis.

RESULTS AND DISCUSSION

Rice grain yield is a function of the number of filled grains per unit area multiplied by the grain size. The number of grains or spikelets per unit area depends on the number of grains per panicle and the panicle density. On the other hand, lodging plays a great role for reducing the grain yield.

The number of panicle per hill

Irrespective of cultivars, increasing levels of nitrogen up to 120 kg N ha^{-1} significantly increased the number of panicle per hill (Table 1). Application of 60 kg N ha^{-1} increased panicle number by 1.4, 1.3, 1.3, 4 and 120 kg N ha^{-1} by 2, 3.2, 2.9, 4.9 in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively. The highest panicle number per hill was observed in Kataribhog with 120 kg N ha^{-1} (12.39) and the lowest in Shakkorkhora without N fertilization (6.45). Lodging did not show any substantial effect on panicle number. This might be due to that the lodging started after heading when the panicle number became stable.

Number of spikelet per panicle

Number of spikelet per panicle also increased with increasing levels of N (Table 1).

Table 1. Number of panicles per hill in four aromatic rice cultivars at three nitrogen levels under stacking and non-stacking conditions

Cultivar	N dose (kg ha^{-1})	Number of panicles hill^{-1}		Total Spikelet panicle^{-1}	1000-grain weight (g)	
		Stacking	Non-stacking		Stacking	Non-stacking
Shakkorkhora	0	6.08	5.94	129.00	11.70	11.84
	60	7.44	7.42	138.67	11.80	11.85
	120	8.16	8.72	143.00	10.74	11.89
Chinigura	0	6.74	6.63	123.67	13.17	13.36
	60	8.03	8.13	142.67	13.34	13.45
	120	9.93	9.69	153.00	12.56	12.91
Kalijira	0	6.77	6.63	175.00	11.31	11.35
	60	8.05	7.91	193.00	11.43	11.58
	120	9.62	10.17	207.33	11.12	11.20
Kataribhog	0	6.24	5.92	107.67	17.87	18.21
	60	10.21	10.39	122.33	17.53	17.92
	120	11.12	11.84	135.00	16.21	17.72
LSD (.05)		0.99	1.079	6.46	NS	NS
CV (%)		7.15	7.72	2.59	3.37	3.37

Application of 60 kg N ha^{-1} increased spikelet number by 10, 19, 18, 14 and 120 kg N ha^{-1} by 14, 29, 32 and 27 in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively. Among the cultivars, Kataribhog produced comparatively lower number of spikelets per panicle (107,122 and 135 at 0, 60, 120 kg N ha^{-1}, respectively). On the other hand, Kalijira produced the higher spikelet number per panicle (175,193 and 207 at 0, 60, 120 kg N ha^{-1} respectively).

1000-grain weight

1000-grain weight did not show any significant variation among the cultivars with different N levels (Table 1). But in general the 1000-grain weight reduced with the higher (120 kg N ha^{-1}) N levels compared to control. Under non-stacking condition the 1000-grain weight slightly reduced, might be due to the poor grain filling rate. The 1000-grain weight is a stable varietal character because the grain size is rigidly controlled by the size of the hull (Yoshida, 1981). However, under stacking condition the 1000-grain weight increased by 0.4, 0.8, 1.3, 2.2 % at 60 kg N ha^{-1} and by 10.7, 2.8, 0.7, 9.3 % at 120 kg N ha^{-1} in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively. Momin (2003) reported that the grain size increased by less than 3% in mechanically lodging prevented cultivars Kono (1995) reported the similar findings.

Number of filled grains per panicle

The cultivars also varied significantly in number of filled spikelets per panicle with different N levels (Table 2). Irrespective of cultivars, number of filled grain per panicle increased up to 60 kg N ha^{-1}, further increase in nitrogen levels filled grains per panicle decreased due to lodging. A similar result was found by Yoshida (1981) who reported that the decrease in the number of filled grains at high N levels due to lodging or culm bending. Number of filled spikelets per panicle ranged from 161.7 (Kalijira at 120 kg N ha^{-1}) to 91.93 (Kataribhog without N fertilization) under artificially stacking condition. But, under non-stacking condition the number of filled grains per panicle ranged from 142.2 (Kalijira at 60 kg N ha^{-1}) to 80.54 (Kataribhog at 120 kg N ha^{-1}).

Under stacking condition application of 60 kg N ha^{-1} increased filled spikelet number by 15, 18, 15, 12 % and 120 kg N ha^{-1} by 4.6, 16, 11, 9 % in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively. Under non-stacking condition application of 60 kg N ha^{-1} increased filled spikelet number by 13, 12, 2, 8 % and 120 kg N ha^{-1} by 7, 6, 5, and 11 % in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively.

Stacking increased the number of filled grain per panicle by 0.6, 5.8, 12, 5% at 60 kg N ha^{-1} and by 10, 9.4, 14, 19.4 % at 120 kg N ha^{-1} in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively.

Sterility

Sterility percentage varied significantly among the cultivars with different N levels (Table 2). Sterility percentage was lower at control treatment compared to 60 and 120 kg N ha^{-1} in all the cultivars. Under non-stacking condition plants fertilized with 120 kg N ha^{-1} had the higher sterility percentage.

Table 2. Spikelet number, filled grain per panicle and sterility in four aromatic rice cultivars at three nitrogen levels under stacking and non-stacking conditions

Cultivar	N dose (kg ha^{-1})	Filled grain panicle^{-1}		Sterility (%)	
		Stacking	Non-stacking	Stacking	Non-stacking
Shakkorkhora	0	100.50	100.41	22.87	22.17
	60	114.60	113.85	17.37	17.90
	120	104.14	93.59	27.17	34.53
Chinigura	0	100.38	99.55	18.83	19.50
	60	118.69	111.76	16.80	21.67
	120	116.53	105.61	23.83	31.00
Kalijira	0	139.61	138.83	20.22	20.67
	60	161.68	142.26	16.20	26.33
	120	155.13	132.27	25.17	36.17
Kataribhog	0	91.93	90.63	16.17	17.33
	60	103.40	98.25	15.45	19.67
	120	100.20	80.54	25.78	40.33
LSD $_{(0.05)}$		5.69	6.424	2.62	1.705
CV (%)		2.87	3.48	2.29	4.92

The sterility was greatly influenced by lodging. Increasing N rates increased the sterility percent; this might be due to lodging or culm binding at higher N levels as reported by Yoshida and Parao (1976). The environmental condition, particularly the availability of solar radiation and the supply of nutrient during the post- heading phase largely determine the ripening percentage (Akita, 1989). From the previous discussion it was found that , under non-stacking condition the light interception was highly disturbed and the translocation of assimilates towards grain was very much restricted, these might be a cause of higher sterility under non-stacking condition. Stacking reduced the sterility by 3, 22, 38, 21% at 60 kg N ha^{-1} and by 21, 23, 30, 36 % at 120 kg N ha^{-1} in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively.

Grain yield

The effect of nitrogen fertilizer on grain yield was significant. Under non-stacking condition irrespective of cultivars, grain yield increased up to 60 kg N ha^{-1} and slightly increased also at 120 kg N ha^{-1} in Shakkorkhora, Chinigura and Kalijira but reduced in Kataribhog (Table 3). At 60 Kg N ha^{-1} grain yield of aromatic rice was recorded 2787, 2807, 2750 and 2975 Kg ha^{-1} in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively, which were by 11.4, 14.4, 14 and 15.5% higher than those of control. While at 120 kg N ha^{-1} the grain yields were 2565 kg ha^{-1} in Shakkorkhora, 2608 kg ha^{-1} in Chinigura , 2441 kg ha^{-1} in Kalijira and 2063 kg ha^{-1} in Kataribhog, which were by 2.6, 6.3 and 1.2% higher in Shakkorkhora, Chinigura and Kalijira , respectively and 19.8% lower in Kataribhog than the control. The yield reduction in Kataribhog at high level of nitrogen might be due to lodging just 3 days after heading.

Under stacking condition with the application of 60 Kg N ha^{-1} the grain yields obtained were 2802, 3511, 3262 and 3316 Kg ha^{-1} in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively which were by 11.6, 22.7, 29.2 and 18% higher than those of control.

Under stacking condition with the application of 60 Kg N ha^{-1} the grain yields increased by 11.6, 22.7, 29.2 and 18% in Shakkorkhora, Chinigura, Kalijira and Kataribhog, respectively. By stacking yield increased by 0.6% in Shakkorkhora , 25% in Chinigura, 18% in Kalijira and 11% in Kataribhog at 60 kg N ha^{-1} and by 18% in Shakkorkhora , 27% in Chinigura, 35% in Kalijira and 80% in Kataribhog at 120 kg N ha^{-1}. The grain yield increase under stacking condition was supported by the increase in the number of filled spikelets per panicle, 1000-grain weight and decrease in sterility.

Table 3. Yield in four aromatic rice cultivars at three nitrogen levels under stacking and non-stacking conditions

Cultivar	N dose (kg ha^{-1})	Grain yield (kg ha^{-1})		Grain yield increase under stacking		Harvest Index	
		Stacking	Non-stacking	kg ha^{-1}	(%)	Stacking	Non-stacking
Shakkorkhora	0	2509	2500	9	0.36	0.44	0.45
	60	2802	2787	15	0.55	0.38	0.38
	120	3035	2565	470	18.34	0.35	0.31
Chinigura	0	2860	2453	407	16.58	0.44	0.40
	60	3511	2807	704	25.08	0.39	0.38
	120	3328	2608	720	27.59	0.32	0.26
Kalijira	0	2523	2410	113	4.70	0.40	0.39
	60	3262	2750	512	18.63	0.39	0.36
	120	3306	2441	866	35.48	0.34	0.27
Kataribhog	0	2808	2575	234	9.09	0.45	0.44
	60	3316	2975	342	11.50	0.40	0.37
	120	3713	2063	1651	80.01	0.38	0.23
LSD $_{(0.05)}$		269.8	209.1	147.8	6.33	0.016	0.053
CV (%)		5.17	4.79	20.93	21.0	3.27	6.44

Harvest index

Harvest index (HI), also termed as co-efficient of effectiveness, is a good indicator to identify the potentiality of a crop to produce economic yield compared to biological yield. Irrespective of cultivars, under both stacking and non-stacking conditions the HI decreased with the increase in N levels, however the decrease was more distinct under non-stacking condition (Table 3).

The findings of the experiment can finally be summarized as follows:

i) Under natural growing condition the aromatic rice cultivars showed their highest yielding ability at 60 kg N ha^{-1}, and this yielding ability can be further increased by 0.6% in Shakkorkhora, 25% in Chinigura, 19% in Kalijira and 11% in Kataribhog by preventing lodging.

ii) Under lodging preventing condition, except Chinigura the other three cultivars Shakkorkhora, Kalijira and Kataribhog showed their highest yielding ability even upto 120 kg N ha^{-1}.

iii) As the indigenous aromatic rice cultivars Shakkorkhora, Kalijira and Kataribhog showed their highest yielding ability even at highest level of nitrogen (120 kg N ha^{-1}) application, these cultivars may be used as parent materials for the development of high yielding aromatic rice varieties.

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