Boron uptake and distribution in two oilseed rape (*Brassica napus* L.) cultivars with different boron efficiency and their plants grafted each other

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Abstract

To examine the mechanism for boron efficiency in oilseed rape (*Brassica napus* L.), boron uptake and distribution in two oilseed rape cultivars with different boron efficiency and their plants grafted each other were studied under the condition of solution culture experiment. Test results indicated that boron deficiency significantly decreased the boron content in the shoots and roots in grafted or non-grafted oilseed rape plants, but the decrease degree in the boron-efficient oilseed rape cultivar was the least, that of the boron-inefficient one was the most, and their plants grafted each other was in the middle of them. The effects of boron deficiency on boron accumulation in shoots in all oilseed rape plants were similar to their boron content. Furthermore, there was a tendency that the boron distribution rate in the shoots of boron-efficient cultivar and the plant grafted onto the boron-efficient rootstock was higher than that of boron-inefficient one and the plant grafted onto the boron-inefficient rootstock, respectively, whether boron supply was sufficient or deficient. It was suggested that the oilseed rape boron efficiency might be a cooperative consequence of boron absorption and transportation from roots to shoots.

Key words: Oilseed rape (*Brassica napus* L.) cultivars, graft, boron efficiency, absorption, distribution

Introduction

Boron is an essential micronutrient for higher plants, boron deficiency is one of the most widespread micronutrient deficiencies in the world, it's very important to apply boron fertilizer for increasing crop yields and improving crop quality in these areas. Nevertheless, borate minerals which are used for producing boron fertilizer are non renewable resources, and applying boron fertilizer improperly might cause environment problems. Breeding boron efficient utilization cultivars is a good way to save fertilizer application and guarantee the sustainable development of agriculture. 8 boron efficient cultivars and 2 boron inefficient cultivars were screened from 211 oilseed rape (*Brassica napus* L) cultivars in our lab since 1991. Boron efficiency coefficient of the inefficient cultivars was 0.22~0.23, while that of the efficient cultivars was 0.85–0.97(Wang et al., 1995). To improve boron nutrition inheritance character, the physiological mechanism in boron efficiency differences among oilseed rape cultivars is needed to discover firstly. Are the differences because the ability of boron uptake by roots, or transportation from roots to shoots, or utilization in plant, or a combination of them? To answer this question, the experiments were conducted to study boron uptake and distribution in two oilseed rape cultivars with different boron efficiency and their plants grafted each other.

Material and Methods

Plant materials and culture

The boron efficient oilseed rape cultivar 'Qingyou 10' and inefficient one 'Bakow' were selected from 211 cultivars (*Brassica napus* L.) in our lab (Wang et al., 1995). The rape seeds were soaked in water for 4 hours, and then germinated on double-deck gauze which was fixed on the plastic basin. The seeds were cultured in distilled water until their seedling cotyledons were expanded, and then the seedlings were transplanted in darkened plastic boxes with 10 L of one quarter-strength Hoagland solution, containing 1 mL Arnon mixed microelement solution and 1 mL 0.1 mol/L Fe-EDTA in 1 L of the nutrient solution. Five days later, another batch of oilseed rape seedlings was cultured by the same method. The first batch of seedlings was made for rootstock, and the second was for scion. The two oilseed rape cultivars with different boron efficiency were grafted each other when the first batch of seedlings grew two leaves and the second ones grew one leaf. After grafted oilseed rapes survived, there were four kinds of oilseed rapes which were boron efficient cultivar 'Qingyou 10' called 'QY10' in this paper, boron inefficient cultivar 'Bakow' called 'Ba', Ba plant grafted onto QY10 rootstock called 'QY10-Ba', and QY10 plant grafted onto Barootstock called 'Ba-QY10'. Then they were treated with two boron levels: 0.001 (B1) and 0.50 mg B/L (B2). Each treatment had 3 replications. Grown for further 3 weeks, the oilseed rape samples were collected. During the growth of oilseed rape, the container was painted the black paint in order to prevent from the light, the nutrient solution was changed every 7 days and the loss water was supplemented every day.

Sampling and plant analysis

The oilseed rape plants were rinsed for a few seconds with double distilled water and then blotted up. They were divided into shoots and roots, dried at 70°C. Boron was extracted from milled plant samples by shaking for 2 hours with 1 mol/L HCl, analyzed by ICP-AES.

Results

Boron content in shoots and roots of two oilseed rape cultivars and their plants grafted each other

When boron supply (B2) was normal, boron content in shoots and roots was higher in boron-inefficient cultivar 'Ba' than that of boron-efficient one 'QY10' (Table 1), which was consistent with the earlier experiments of our lab(Yu et al.,1999; Yang et al., 2005). Furthermore, boron content in shoots of QY10-Ba which scion was from Ba and in roots of Ba-QY10 which rootstock was from Ba was higher than that in the corresponding part of the plant which scion and rootstock was from QY10. These suggested that boron content in their scion or rootstock was consistent with their maternal plant when boron-efficient and boron-inefficient cultivar was grafted each other.

When boron supply (B1) was deficient, boron content in shoots and roots of two oilseed rape cultivars with different boron efficiency and their plants grafted each other was decreased markedly, but their decrease degree was different. The range that boron-inefficient cultivar 'Ba' decreased was the largest, which boron content in shoots and roots was respectively reduced 78.47% and 44.99%, while boron-efficient one 'QY10' was the smallest which were 71.02% and 26.29%, respectively. This was consistent with the earlier results in our lab (Yang et al., 2005). It was worth notice that the decrease degree in the grafted plants was between boron-inefficient cultivar and boron-efficient one, boron content in shoots and roots was respectively reduced 75.53% and 35.28% in QY10-Ba, 73.16% and 41.46% in Ba-QY10. It could be primarily concluded that boron content in oilseed rape were not only controlled by roots or shoots but both of them.

Table 1 Boron concentration in shoots and roots of two oilseed rape cultivars with different boron efficiency and their plants grafted each other

Cultivars	Boron content in shoots			Boron content in roots		
	B1(mg/kg)	B2(mg/kg)	$\frac{B1}{B2}\times 100$ (%)	B1(mg/kg)	B2(mg/kg)	$\frac{B1}{B2}\times 100$ (%)
QY10	22.86	78.87	28.98	29.25	39.68	73.71
Ba	19.05	88.49	21.53	24.61	44.74	55.01
QY10-Ba	19.79	80.88	24.47	27.46	42.43	64.72
Ba-QY10	20.69	77.09	26.84	28.42	48.55	58.54

Boron accumulation in shoots and roots of two oilseed rape cultivars and their plants grafted each other

Whether boron supply was deficient(B1) or sufficient(B2), the boron accumulation in shoots of QY10 was significantly higher than that of Ba, but there was no obvious difference in roots between both cultivars(Table 2). The boron accumulation of shoots in QY10-Ba was significantly higher than that of in Ba-QY10, but there was no difference in roots between both cultivars as well.

Boron deficiency significantly decreased the boron accumulation in shoots in all of the four kinds of oilseed rapes(Table 2). For examples, boron accumulation was reduced by 69.82% in QY10, 79.81% in Ba, 77.27% in QY10-Ba and 75.87% in Ba-QY10, the decrease degree of two grafted plants was also between their maternal plants, which arrangement tendency was consistent with their boron content (Table 1). The boron accumulation in these oilseed rapes roots was also decreased by boron deficiency, the decrease degree of boron-efficient cultivar 'QY10' was also less than boron-inefficient one 'Ba', but those of the grafted plants were greater than their maternal plants, which the tendency was different from their shoots.

It could also be seen from Table 2 that boron accumulation in shoots was much higher than in roots in all of oilseed rape plants whether boron supply was sufficient or deficient, so the total boron accumulation in plant was mainly controlled by the shoots, and the law of variation with boron supply or grafting was consistent with its shoots.

Table 2 Boron accumulation in shoots and roots of two oilseed rape cultivars with different boron efficiency and their plants grafted each other

Cultivars	B accumulation in shoots			B accumulation in roots			B accumulation in plant		
	B_1 (mg/plant)	B_2 (mg/plant)	$\frac{B_1}{B_2}\times 100$ (%)	B_1 (mg/plant)	B_2 (mg/plant)	$\frac{B_1}{B_2}\times 100$ (%)	B_1 (mg/plant)	B_2 (mg/plant)	$\frac{B_1}{B_2}\times 100$ (%)
QY10	38.02	125.97	30.18	6.72	7.78	86.38	44.74	133.75	33.45
Ba	21.94	108.68	20.19	4.38	8.10	54.07	26.32	116.78	22.54
QY10-Ba	8.33	36.65	22.73	1.44	2.97	48.48	9.77	39.62	24.66
Ba-QY10	6.53	27.06	24.13	1.42	3.00	47.33	7.95	30.06	26.45

Table 3 Boron distribution rate in shoots and roots of two oilseed rape cultivars with different boron efficiency and their plants grafted each other

Cultivars	B1		B2	
	Shoots (%)	Roots (%)	Shoots (%)	Roots (%)
QY10	84.98	15.02	94.18	5.82
Ba	83.36	16.64	93.06	6.94
QY10-Ba	85.26	14.74	92.50	7.50
Ba-QY10	82.14	17.86	90.02	9.98

Boron distribution in shoots and roots of two oilseed rape cultivars and their plants grafted each other

Boron distribution ratio in roots in 4 types of oilseed rapes was enhanced markedly by boron deficiency and decreased markedly in shoots (Table 3), this result was consistent with the experiments of Shen et al(1991). Whether boron supply was sufficient or deficient, there was a trend that boron distribution ratio in shoots in boron-efficient cultivar 'QY10' was higher than in boron-inefficient one 'Ba', but the contrary trend was found in their roots. The similar law was also seen in the oilseed rape plants grafted each other, boron distribution in shoots of QY10-Ba grafted onto boron-efficient cultivar rootstock was higher than Ba-QY10 grafted onto boron-inefficient cultivar rootstock, there was also a contrary trend in their roots. These results suggested that there was a stronger ability transporting boron to shoots in the roots of boron-efficient cultivar than boron-inefficient cultivar.

Discussion

Plant response to boron deficiency varied widely among cultivars or mutants, but the reason remained unclear. Considerable experiments had reported the ability in boron uptake or transport from roots to shoots was the base of plant boron efficiency. The markedly different response to low boron in the soil was found among 44 grape cultivars, after boron-sensitive cultivar was grafted onto boron-insensitive cultivar rootstock, its boron deficiency symptom disappeared, by contraries, boron-insensitive cultivar was displayed the symptom after it was grafted onto boron-sensitive rootstock(Scott et al., 1941). Similar grafting experiment results were reported by Takano et al(2002) in boron-sensitive Arabidopsis thaliana mutant *bor1-1* and boron-insensitive wild-type. These experiments indicated that the differences in boron efficiency among cultivars were mainly controlled by roots. Grafting experiments in different boron-efficient tomato plants by Brown and Jones (1971) showed that there was an obvious genotypic difference in boron transferring into xylem from roots. Boron content in roots of boron-efficient cultivar was similar to that of boron-inefficient one, but that in xylem sap was 5 times higher than in boron-inefficient one. Bellaloui and Brown(1998) reported that the major mechanism for boron efficiency in celery cultivar was the transportation of boron from roots to shoots rather than the uptake of boron by roots. In tomato, however, two mechanism of boron efficiency contribute, that was boron distribution within the plant as well as the uptake of boron. These results above suggested that mechanism for boron efficiency was not the same in different cultivars or species.

Our test results indicated that the decrease of boron content and accumulation in the shoots in the boron-efficient cultivar by boron deficiency was less than the boron-inefficient one, and that of their plants grafted each other was in the middle of them(Table 1 and Table 2). Moreover, the boron distribution rate in the shoots of boron-efficient cultivar and the plant grafted onto the boron-efficient rootstock was a little higher than that of boron-inefficient one and the plant grafted onto the boron-inefficient rootstock, respectively, whether boron supply was sufficient or deficient. Those suggested that the differences in boron efficiency between the oilseed rape cultivars might be a common consequence of boron absorption by roots and transportation from roots to shoots. It was necessary to further study which boron efficiency mechanism was more important in oilseed rape.

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