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Distribution of mineral nutrients between main stem and subtillers in contrasting wheat cultivars under saline conditions

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Abstract

Under saline conditions, the reduced grain yield of wheat is closely related to the tiller number, and grain yield per spike in subtillers is reduced more than that in the main stem spike. We hypothesized that the main stem might exclude salt into subtillers as a strategy for increasing its salt tolerance, resulting in inhibition of tillering and a greater reduction in grain yield per spike in subtillers. Two contrasting cultivars of spring wheat (*Triticum aestivum* L.) were grown in soil with no salt added or with 120 mM NaCl added, in a greenhouse. Inorganic elements (Na^+, Cl^-, Ca^{2+}, Mg^{2+}, K^+ and NO_3^-) were determined in the main stem and subtillers at the end of the tillering stage. Both genotypes showed significantly higher Na^+ and Cl^- contents in the main stem and the subtillers at 120 mM NaCl than in the control treatment, whereas NO_3^- and Mg^{2+} contents in plants were significantly reduced in the salinized treatment. Under saline conditions, the salt-tolerant genotype showed exclusion for Na^+ and Cl^- and a high selectivity for nutrients (Mg^{2+}, K^+ and NO_3^-) in all tillers. The salt-tolerant genotype also excluded both toxic ions into subtillers from the main stem, while the sensitive genotype only excluded Cl^- into the subtillers which may be responsible for a greater reduction in tillers in the sensitive genotypes.

Introduction

Salinity adversely affects the development of wheat such as tillering and the number of spike-bearing tillers when stressed during the vegetative stage (Maas and Poss, 1989). Tillering is generally assumed to be mediated by the competition for mineral nutrients, carbon and water resource, and/or the control of hormones. However, little is known about the possible mechanisms of the reduction in tillering ability under saline conditions. Many plants exhibit apical dominance, and, likewise, the presence of the main stem apex inhibits growth of lateral branches (tillers). The yield of the main stem is less affected by salinity than that of subtillers, and the secondary tillers are more affected than primary tillers umder saline conditions (Maas *et al.*, 1994; Hu *et al.*, 1997). Although the competition among tillers for nutrients could inhibit the growth and development of tillers, the inhibition of subtillers could also be due to more toxic ions (Na^+ and Cl^-) excluded from the main stem tiller or lower nutrient contents (e.g., K^+, Ca^{2+}) in their leaves caused by salt stress. The aim of this study was to investigate the relationship of inorganic elements in the leaves between main stem and subtillers under salt stress.

Materials and methods

Seeds of two contrasting spring wheat cultivars, Sakha 8 (salt tolerant) and Sakha 61 (salt sensitive), were sown in three replications in plastic pots containing 10 kg loamy soil without or with 120 mM NaCl added. Soils were salinized by adding salt solutions layerwise to the soil within the pot having a leaching possibility. The experiment was carried out in a greenhouse at the Research Station of the Chair of Plant Nutrition at the Technical University of Munich, Germany. The plants were grown in a 14-h photoperiod with day/night temperatures of 18/13 ℃ under 550 $\mu mol\ m^{-2}\ s^{-1}$ (PPFD) light intensity. At 55 days after sowing, the first two youngest fully developed leaves were harvested from the main stem and the subtillers (T1 and T2).

Concentrations of Na^+, Mg^{2+}, K^+ and Ca^{2+} were determined with an Inductively Coupled Plasma Emission Spectrometer (ICP model Liberty 200, Varian Australia Pty Ltd, Mulgrave, Vic., Australia). Nitrate and Cl^- were measured using an ion chromatography analyzer (Model LC 20-1, Dionex, Sunnyvale, CA 94086, USA).

Results and discussion

Dry weight of shoots, main stem, T1 and T2 at vegetative growth stages in both genotypes was greatly decreased by 120 mM NaCl (Fig. 1). Compared with Sakha 61, dry weight of shoots, main stem, T1 and T2 in Sakha 8 was less decreased by salinity, confirming that Sakha 8 is more tolerant to salinity. The content of inorganic ions in young leaves of different tillers for both genotypes at 120 mM NaCl is presented in Table 1. Results show significantly higher Na^+ and Cl^- contents in the salt treatment, but significantly lower NO_3^- and Mg^{2+} contents, indicating that the reduced plant growth may be associated with the toxicity of Na^+ and Cl^-, and deficiencies of NO_3^- and Mg^{2+} which is in agreement with reports in literature (e.g., Hu and Schmidhalter 1997).

Under saline conditions, concentrations of toxic ions (Na^+ and Cl^-) in the young leaves of Sakha 8 were lower than those in Sakha 61, while those of nutrients (K^+, Mg^{2+} and NO_3^-) in Sakha 8 were higher that those in Sahka 61 (Tab. 1). This indicates that the salt tolerant genotype, Sahka 8, may have a higher selectivity for nutrients, and may better exclude for toxic ions under saline conditions.

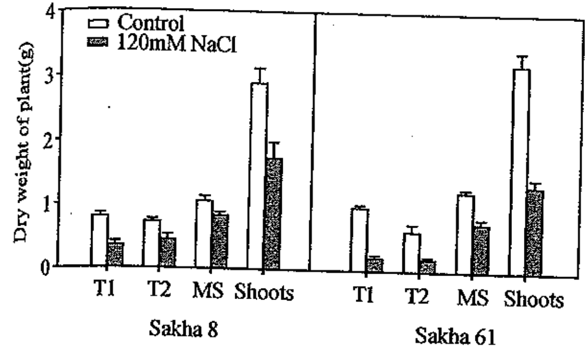

Figure 1. Effects of salinity on dry weight of main stem (MS), subtillers (T1 and T2) and shoots for Sakha 8 and Sahka 61.

Table 1. Inorganic ion concentrations in the first two youngest fully developed leaves of different tillers of Sakha 8 and Sahka 61 grown in soils with no or with 120 mM NaCl added.

NaCl	Sakha 61 (mmol/kg DW)			Sakha 8 (mmol/kg DW)		
(mM)	MS	T1	T2	MS	T1	T2
			.... Na^+..................			
0	14^{aA}	20^{aA}	19^{aA}	29^{aA}	32^{aA}	21^{aA}
120	62^{aB}	78^{aB}	68^{aB}	44^{aB}	60^{bB}	59^{bB}
			.... K^+..................			
0	938^{aA}	1058^{abA}	1129^{bA}	927^{aA}	1014^{aA}	1029^{aA}
120	836^{aA}	837^{aB}	903^{aB}	900^{aA}	1054^{bA}	1017^{abA}
			.... Ca^{2+}..................			
0	184^{aA}	171^{aA}	136^{aA}	159^{aA}	179^{aA}	183^{aA}
120	174^{aA}	180^{aA}	158^{aA}	129^{aA}	168^{aA}	146^{aA}
			.... Mg^{2+}..................			
0	106^{aA}	99^{aA}	91^{aA}	116^{aA}	122^{aA}	123^{aA}
120	71^{aB}	78^{aB}	75^{aA}	77^{aB}	83^{aB}	84^{aB}
			.... Cl^-			
0	24^{aA}	34^{aA}	44^{aA}	29^{aA}	29^{aA}	33^{aA}
120	520^{aB}	647^{bB}	622^{bB}	419^{aB}	565^{bB}	492^{cB}
			.... NO_3^-..................			
0	74^{aA}	84^{aA}	93^{aA}	118^{aA}	161^{abA}	184^{bA}
120	4^{aB}	7^{aB}	7^{aB}	12^{aB}	27^{aB}	22^{aB}

Means followed by the same lower case letters in rows or upper case letters in columns for each tiller are not statistically different at $P < 0.05$. MS: main stem.

Table 2. Correlation coefficients between inorganic ion concentrations of the youngest fully developed leaves in the main stem and in T1 and T2 at 120 mM NaCl.

	Sakha 61		Sakha 8	
	T1	T2	T1	T2
Na^+	0.605^{ns}	0.249^{ns}	0.992***	0.866*
K^+	0.405^{ns}	0.768^{ns}	0.874*	0.809*
Ca^{2+}	0.505^{ns}	-0.170^{ns}	0.657^{ns}	0.456^{ns}
Mg^{2+}	0.573^{ns}	0.485^{ns}	0.499^{ns}	0.435^{ns}
Cl^-	0.974**	0.695^{ns}	0.868*	0.639^{ns}
NO_3^-	0.785^{ns}	0.558^{ns}	0.896*	0.825*

ns: not significant; $*P < 0.05$; $**P < 0.01$; $***P < 0.001$.

Furthermore, the relationships of inorganic ions among the main stem, T1 and T2 in Tab. 2 show that the main stem of Sakha 8 tended to exclude Na^+ and Cl^- into subtillers, but Sahka 61 only excluded Cl^- into subtillers (Tab. 1 and 2).

Conclusions

Our study shows that the salt-tolerant genotype is characterized by a high selectivity for nutrients and the exclusion for toxic ions under saline conditions. The ion distribution among the main stem and the subtillers in the salt-tolerant genotype differ from that of the sensitive genotype. The results confirm our hypothesis that the main stem excludes salt into subtillers as a strategy for increasing its salt tolerance.

Acknowledgments

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