W. J. Horst et al. (Eds), Plant nutrition – Food security and sustainability of agro-ecosystems. 390–391, 2001

Characterizing site specific differences in water availability

R. Duda, R. Gutser and U. Schmidhalter

Department of Plant Science, Chair of Plant Nutrition, Technical University of Munich, Am Hochanger 2, 85350-Freising, Germany, duda@weihenstephan.de

Key words: silicon, site-specific yield, water availability

Abstract

The relationship between cumulative crop transpiration and total silicon uptake in wheat (*Triticum aestivum* L. cv. Thassos) was investigated. Although Si partitioning between leaves and stems was distinctly influenced by transpiration, total Si uptake in total above-ground dry matter [g*m^{-2}] was equally determined by growth and transpiration. Therefore, Si content of old leaves was suggested to represent cumulative crop transpiration until the emergence of the flag leaf.

Introduction

Water availability during growing season predominantly influences site-specific yield within one field. Variations in water availability may result from different soil texture, hence available water capacity (Brunner, 1998) and relief (Auerswald *et al.*, 1997). Cumulative crop transpiration may reflect the amount of water available to the crop during growing season. However, it is difficult to be determined through direct measurements of transpiration (Abdel-Kader, 1996) or with the climatic water balance (Ehlers, 1997). Jones and Handreck (1965) showed that the total silicon uptake was proportional to the amount of transpired water in oat. Our first results with silage maize, however, indicated that growth may have an impact on silicon uptake in above-ground dry matter in addition to transpiration. Therefore, the relationship between cumulative crop transpiration and total silicon uptake was investigated in wheat.

Materials and methods

Wheat (*Triticum aestivum* L., cv. Thassos) was grown in six containers (≈ 0.77 m^2 x 0.6 m) filled with a loamy soil in a growth chamber. Three containers were continuously irrigated throughout the experiment (= control); three were subjected to two drying periods (=stress treatment) by withholding water for nine days. The first drying period started at eight days of the experiment (DE). From 17 DE plants of the stress treatment were irrigated for five further days. At 22 DE the second drying period was started. Crop transpiration was measured by weighing the containers daily. Silicon uptake [g*m^{-2}] was determined before the start of the first drying period (4 DE) and at the end of each drying cycle (14 and 31 DE). The plants were cut above the ground and divided into young leaves, old leaves, and stems. Young leaves were defined as the first two to three leaves directly exposed to the light, while old leaves were shaded within the crop. The youngest, still enrolled leaf was assigned to the stem. Each part was weighed. Then the samples were oven-dried at 60°C to constant weight and dry weight was determined. The samples were first coarsely, then finely ground to powder. Silicon was determined with an ICP (Liberty, Varian) according to the method described by Camp (1996).

Results and discussion

Silicon partitioning within the plant was influenced by crop architecture. Before the start of the first drying period the silicon content in the various plant parts was similar. After the first and the second drying period differences between the various plant parts were found (Table 1).

Table 1. Silicon contents in wheat

Si contents in young (Y) and old (O) leaves as well as in stems (S) of wheat in the control and the stress treatment at the start of the experiment (4 days of experiment (DE)), after the first drying period (14 DE) and after the second drying period (31 DE).

DE	Part	Control	Stress Treatment
4	Y	5.95 ± 0.68a	5.69 ± 1.04a
	O	8.00 ± 1.99a	7.29 ± 0.57a
	S	6.73 ± 0.92a	6.14 ± 0.43a
14	Y	6.53 ± 0.21b	5.13 ± 0.88b
	O	10.26 ± 1.79a	10.01 ± 0.57a
	S	7.03 ± 0.27b	5.26 ± 0.55b
31	Y	10.00 ± 1.50a	7.74 ± 0.72a
	O	15.19 ± 2.05b	11.62 ± 1.81b
	S	6.75 ± 0.73c	5.15 ± 0.53c

Within treatments and measurement times, values with similar letters are not significantly different at P ≤ 0.05 according to Tukey-test.

With crop development the Si partitioning was predominantly driven by cumulative transpiration. After the first drying period Si contents of old leaves were significantly higher in the other plant parts regardless of the treatment. After the second drying period Si contents were highest in old leaves, intermediate in young leaves and lowest in stems in both treatments. Si contents were generally higher in the control than in the stress treatment. However, silicon uptake in total above-ground dry matter was equally determined by growth (G) and transpiration (E). The relationship was highly significant at P=0.0001 and could be described by the following multiple regression equation:

$$Si_{uptake} = 0.63 + 0.01\,E + 0.01\,G \qquad R^2=0.83$$

This finding can be explained by the silicon uptake of the various plant parts, which is shown in Figure 1. Although Si content was different between the various plant parts, Si uptake was similar. As further supported by the development of dry matter accumulation in the various plant parts, Si mostly accumulated in stems owing to growth, while Si accumulation in leaves was predominantly driven by cumulative transpiration.

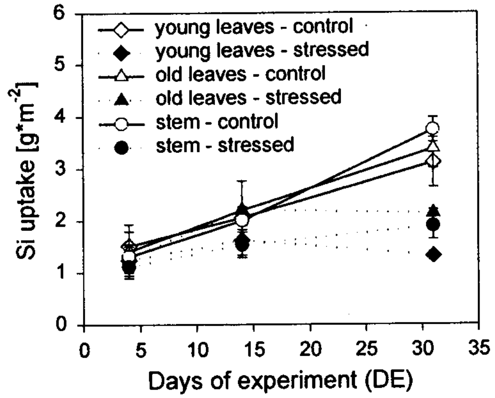

Figure 1. Si uptake in young and old leaves as well as stems of the control (open symbol) and stress treatment (full symbol) before the start of the first drying period (4 DE), after the first drying period (14 DE), and after the second drying period (31 DE). Vertical bars indicate the standard deviation.

Hence, crop transpiration may not always be derived from Si uptake in total above-ground dry matter. Growth effects on Si uptake may be excluded by correlating cumulative crop transpiration with the Si content of old leaves as shown in Figure 2. The relationship was not influenced by the water regime, which is in accordance with the results of Jones and Handreck (1965). They showed that the Si concentration in soil solution was not changed when the water was withdrawn repeatedly from the soil. Still, the value of the relationship between cumulative crop transpiration and silicon content of old leaves may be limited due to retranslocation occurring with leaf senescence. Dry matter loss may necessitate to change the reference for determining Si content. Abdel-Kader (1996) showed that after ear emergence the transpiration of the flag leaf was 20 to 50% higher than the one of the second and third leaf. Accordingly, Si content was shown to be distinctly higher in the flag leaf compared to the other leaves in wheat (Germar, 1934) and in rice (Handreck and Jones, 1967).

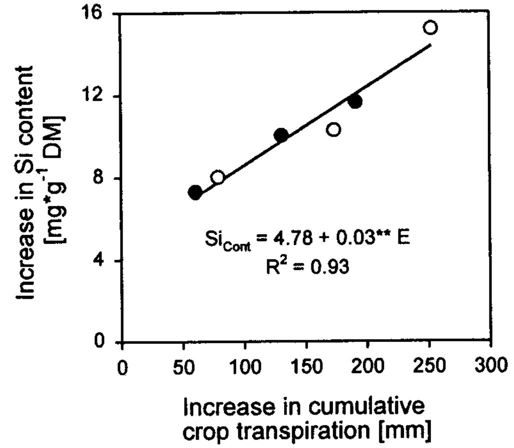

Figure 2. Relationship between the increase in cumulative crop transpiration and the increase in Si content of old leaves. Data is included from both treatments (control = open symbol; stress treatment = full symbol). The regression equation and the coefficient of determination are given. ** indicate significance of the regression coefficient at $P \leq 0.01$.

Site-specific differences in cumulative crop transpiration might be derived from changes in Si content of old leaves until the flag leaf emerges. After its full expansion Si content of the flag leaf might be a suitable reference for quantifying cumulative crop transpiration, which will be verified in future experiments.

References

Abdel-Kader D 1996 FAM-Bericht 12. Shaker Verlag Aachen

Auerswald K Sippel R Kainz M Demmel M Scheinost A Sinowski W and Maidl F-X 1997 Adv. Geoecol. 30, 39-53

Brunner R 1998 FAM-Bericht 21. Shaker Verlag Aachen

Camp K-H 1996 Diss ETH No 11749

Ehlers W 1997 Pflanzenbauwiss 1, 97-108

Germar B 1934 Z Pflanzenernaehr. Dueng. Bodenk. 35, 102-115.

Handreck KA and Jones LHP 1968 Plant Soil 29, 449-459

Jones LHP and Handreck KA 1965 Plant Soil 23, 79-96