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Diagnosis of water transport in a plant by plant excision method.

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Abstract A plant excision method (PEM) was used for diagnosis and understanding of the characteristics of water transport in napiergrass (*Pennisetum purpureum* Schumach.) and maize (*Zea mays* L.). During measurement of the time courses of photosynthetic rate (Pn) and transpiration rate (Tr) in a leaf, a temporary, quick increase was often observed in these parameters directly after excising the basal part of the leaf. The response of the parameters after excision of different parts of a plant was used here as an indicator for diagnosing water transport situations in the plant. In napiergrass a large increase was frequently observed in Pn and Tr when the leaf sheath was excised, but it was not detected by excising the stem below the node having the leaf sheath. This shows that the water flow from stem through node to leaf in this species was greatly regulated by the node, which may be considered to restrict excessive transpiration from the leaf. However, such a regulating role of node in maize was not strong.

Using a pressure flow meter, hydraulic resistances were measured at three parts of a stem segment, i.e., the water flow through stem up to node, and the adaxial (to the stem apex) and abaxial (to the leaf) water flow directions through node. Of these parts, the highest resistance was shown in the abaxial direction through node. A good coincidence was shown between the diagnoses obtained by PEM and with the pressure flow meter.

Introduction The water transport in plants is strongly affected by changes of environmental conditions, and a quick measurement of it is important to know *insitu* water flowing situations in plants grown in fields. We devised a plant excision method (PEM) to use for this purpose. The diagnosis by PEM is based on the responses of photosynthetic rate (Pn) and transpiration rate (Tr) in a leaf shown directly after plant excisions (2). One measurement time by PEM is a few minutes. So far we have recognized using this method that the stem nodes in napiergrass (*Pennisetum purpureum* Schumach.) have a significantly high resistance, by which the water flow from stem to leave is strongly regulated (2).

In this study, the water flow traits in two species, napiergrass and maize (*Zea mays* L.), were identified based on the data monitored by PEM, and then the hydraulic resistances of plant parts were measured using a pressure flow meter to confirm the reliability of measurements obtained by PEM.

Materials and methods Plant materials: napiergrass (cv Merkeron) and maize (cv Golddent KD772) plants grown in pots and a field were used.

Plant Excision Method (PEM): Pn and Tr were simultaneously measured on expanded leaves with a portable CO_2 assimilation and transpiration measure-ment system (ADC; SPB-H4)

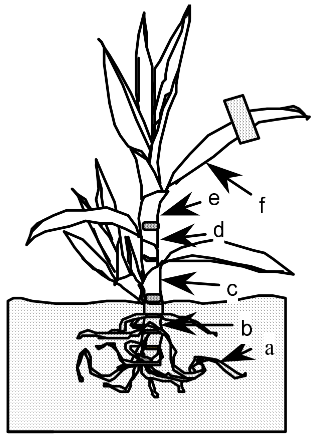

Fig.1 Excision points of a plant. L shows the measuring part of photo - synthetic rate in a plant. Arrows show the exci - sion points of a plant, roots (a), rhizomes (b), stem base (c), the stem part just below the node (d), leaf sheath of a measuring leaf (e) and leaf (f).

intensity of 900-1200 µmol m^{-2} s^{-1}. During the measurement of Pn and Tr in a leaf, the plant was orderly excised along the transpiration stream from roots (Fig. 1a), rhizomes (Fig. 1b), stem base (Fig. 1c), just below the node (Fig. 1d), leaf sheath (Fig. 1e), to leaf (Fig. 1f). The water transport situation in a plant was diagnosed from changes in Pn and Tr by excising plant parts (2).

Measurement of hydraulic resistance: Using a pressure flow meter (3), hydraulic resistances of stem nodes and inter-nodal stems of both species were determined from the rates of water flow produced by applying water pressure to the bottom cut-end of stem segments. Resistances of the inter-nodal water flow, and of the water flows from the node to the stem apex (in the adaxial direction) and to the leaf (in the abaxial direction) were determined by the method of Nagasuga et al. (3). The hydraulic architecture in a stem segment was assumed as an analogue circuit as shown in Fig. 2A. Each resistance was calculated in three cases. In the case 1, the top cut-end of a stem was sealed, accordingly the water flow was limited only to the abaxial direction (Fig. 2B, R_1). In the case 2, the seal was removed, and water was allowed to flow through the node in both abaxial and adaxial directions (Fig. 2C, R_2). In the case 3, the node was excised from the stem segment to measure the inter-nodal water flow (Fig. 2D, R_3).

The relationships of hydraulic resis-tances between these three cases and various parts in a stem segment were shown as follows:

$R_1 = R_{IN} + R_{Nad}/2 + R_{Nab}$

$R_2 = R_{IN} + R_{Nad}/2 + 1/\{[1/ (R_{Nad}/2)] + (1/R_{Nab})\}$

where R_{IN} was the hydraulic resistance of internodal stem, R_{Nad} and R_{Nab} were the resistances of water flow in the adaxial and abaxial directions through a node, respectively. R_1, R_{Nab}, R_{Nad} and R_{IN} in the unit length were described here as r_1, r_{Nab}, r_{Nad} and r_{IN}, respectively.

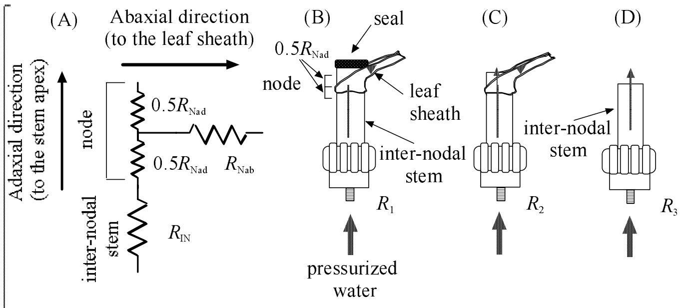

Fig. 2 Analog circuit of the hydraulic architecture in a stem segment (A) and schematic diagram of experimental procedures (B, C and D) for determining the hydraulic resistances of the abaxial (to the leaf sheath, R_{Nab}) and adaxial (to the stem apex, R_{Nad}) direction of node and inter-nodal stem (R_{IN}).

Results and discussion In napiergrass, the bursts of Pn and Tr were observed directly after excising the sheath of a measuring leaf (Fig. 1e), but the phenomena were not detected when the stem below the node (Fig. 1d) was cut. This finding suggests that the node of napiergrass was high resistant to water flow, by which the transpiration stream from stem to leaf was strongly regulated. On the other hand, in maize the burst were measured when the stem base at the soil surface level (Fig.1c) was excised (Fig.3). This suggested that the hydraulic resistance of nodes of maize is lower, and their regulating power of water flow is inferior to that of napiergrass. It may be considered that the water flow from stem to leaves is controlled by each node in napiergrass, but in maize water is readily transported from the stem base to leaves.

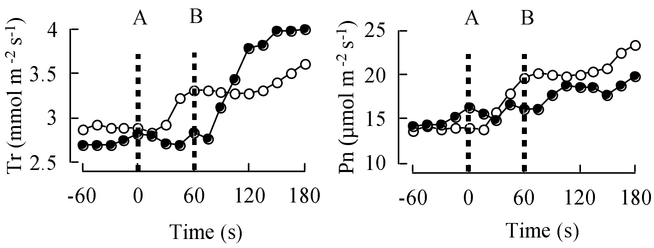

Fig. 3 Changes in photosynthetic rate (Pn) and transpiration rate (Tr) after excision of napiergrass and maize. Plant excision was made at the times marked by dotted lines. A, stem base; B, upper part of a stem.

● napiergrass ○ maize

Main regulators of water transport were demonstrated to be higher resistant to water movement (1). r_1 of napiergrass was about 4 times higher than that of maize (Table1), and this may indicate the superiority of water flow regulation in napiergrass. r_{IN} and r_{Nad}

in napiergrass were lower than those of maize, but r_{Nab}, which showed the highest among the three resistance parameters, was significantly higher in napiergrass stem (Table1). The ratio of r_{Nab}/r_{IN} was 436 in napiergrass and 75 in maize, and this suggests that water flow was strongly restricted at the connecting point of node and leaf sheath in napiergrass. As mentioned, the judgments by PEM and the pressure flow meter method

Table 1 Hydraulic resistance in the unit length of stem segment (r_1), node [abaxial (r_{ab}) and adaxial (r_{ad}) directions] and internode (r_{IN}) in napiergrass and maize. (MPa s mol^{-1} m^{-1})

	r_1	r_{Nab}	r_{Nad}	r_{IN}
A. napiergrass	11.7±0.75	21.8±0.64	0.71±0.07	0.05±0.03
B. maize	2.84±0.30	5.29±0.63	2.91±1.01	0.07±0.02
(A/B)	(4.12)	(4.12)	(0.24)	(0.71)

had a good agreement. This may suggest that PEM is a useful method for the quick and easy diagnosis of the water transport situation in plants. Both plants used here were the C_4 species having a vigorous growth and large biomass production, but there was a large difference in the water transporting system between them. The water regulation system unique to napiergrass may provide fundamental suggestions for improving the water utilization efficiency in production and drought resistance.

References

1. Boyer, J. S. (1969) *Science* 163, 1219-1220
2. Nagasuga, K., Kubota, F., Hirao, K. and Nada, K. (1998) *Japanese Journal of Crop Sci*ence 67, 555-560
3. Nagasuga, K., Yasutake, D., Araki, T. and Kitano, M. (2000) *BIOTRONICS* 29, 71-78