UPTAKE OF MONOSILICIC ACID BY *TRIFOLIUM INCARNATUM* (L.)*

By K. A. HANDRECK† and L. H. P. JONES†

Silica is present in soil and culture solutions as undissociated monosilicic acid (H_4SiO_4) and this suggests that its uptake by plants would be a passive, non-selective process. We have earlier reported (Jones and Handreck 1965) that the overall uptake by oats (*Avena sterilis* cv. Algerian) can be accounted for simply in terms of the concentration of monosilicic acid in the soil solution and the amount of water transpired. Thus, when grown in two potted soils containing 7 and 67 p.p.m. SiO_2 in solution, oat plants at maturity contained 28 and 274 mg SiO_2 per plant respectively, having transpired 3·9 litres of water and produced 7·0 g of dry matter. The concentration of silica in xylem sap from oats is similar to that in the external solution. When *Trifolium incarnatum* (L.) (crimson clover) was grown in these two soils the plants had transpiration ratios of 510–530 but contained silica in concentrations which were only 5–10% of those in oats. This suggests that *T. incarnatum* has some means of excluding silica from the tops; we have examined this further by measuring the concentration of silica in the xylem sap.

The plants were grown in polyethylene jars containing solutions at one-fourth the strength used by Johnson *et al.* (1957) and monosilicic acid was added at the following levels: 0, 30, 60, 100, and 120 p.p.m. SiO_2. There were four replicates at each level and the cultures were housed in a glasshouse. At 10 weeks after germination some plants were decapitated just below the cotyledons. Samples of xylem sap were collected with a micropipette within 20 min and analysed for silica by the reduced silicomolybdate method (Jones and Handreck 1965). The silica was present entirely as monosilicic acid. The results may be conveniently expressed in terms of the transpiration stream concentration factor (TSCF) which is defined as the ratio of the concentration of silica in the transpiration stream (xylem sap) to that in the external solution (Russell and Shorrocks 1959). No silica was detected in the xylem sap from plants growing in solutions without added silica. The concentrations of monosilicic acid in xylem sap from plants growing in solutions with added silica were such that the TSCF ranged from 0·052 to 0·073 (Table 1). Plants decapitated at 18 and 20 weeks after germination had similar concentrations of monosilicic acid in the xylem sap and in no case did the TSCF exceed 0·08. The time of the day at which the plant was decapitated had little or no effect on the TSCF.

It is surprising that in the bean (*Phaseolus vulgaris*) the concentration of silica in the xylem sap should be several times greater than that of the external solution (Shone 1964). Such a relationship would imply an accumulation of silica in the tops in amounts exceeding those expected from a passive uptake in the transpiration stream. Taken further it would mean that the bean is similar to rice, which can apparently take up silica actively and in which the TSCF for silica greatly exceeds unity (Okuda and Takahashi 1964). This is contrary to the long recognized difference

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†Division of Plant Industry, CSIRO, School of Agriculture, University of Melbourne.

between the concentrations of silica in gramineous and leguminous species, including beans (Russell 1961). It is also contrary to our own observations with *T. incarnatum* where the concentration of silica in the tops (Table 1) was only 5–10% of those in oats of a similar age grown in similar solutions.

Samples of xylem sap were taken from *T. incarnatum* plants at intervals over a period of 48 hr after decapitating. Within 20 min after decapitation the concentration of monosilicic acid was only 5% of that in the external solution. However, during the next 20 hr the concentration rose continuously to about 60% of that in the external solution and it subsequently showed a diurnal fluctuation. The pattern of the diurnal fluctuation, which was similar at each level of monosilicic acid in the external solution, is illustrated in Figure 1. This fluctuation was inversely related to the diurnal fluctuation in the rate of exudation of xylem sap, which showed a maxi-

TABLE 1

SILICA IN *T. INCARNATUM* IN RELATION TO THE CONCENTRATION OF MONOSILICIC ACID IN THE EXTERNAL SOLUTION

Monosilicic Acid in External Solution (p.p.m. SiO_2)	Monosilicic Acid in Xylem Sap* (p.p.m. SiO_2)	Transpiration Stream Concentration Factor†	Total SiO_2 in Tops (% dry wt.)	Total SiO_2 in Roots (% dry wt.)
30	2·2	0·073	0·06	0·46
60	3·1	0·052	0·09	0·87
100	5·9	0·059	0·15	0·96
120	6·7	0·056	0·17	0·92

*Collected within 20 min after decapitation.

†Concentration of SiO_2 in xylem sap/concentration of SiO_2 in external solution.

mum at about midday (cf. Grossenbacher 1939; Pate and Greig 1964). It appears that the variation in the concentration of monosilicic acid in xylem sap is also inversely related to the concentration of total solids and amino compounds because in legumes these reach maximum concentrations at about the same time as the rate of exudation of xylem sap reaches a maximum (Pate and Greig 1964; Skrogg, Broyer, and Grossenbacher 1938).

The initial steep increase in the concentration of silica indicates that decapitation has reduced to a large degree the capacity of the roots to exclude monosilicic acid from the transpiration stream. The subsequent fluctuation is difficult to explain but since it appears that the metabolic activity of decapitated roots increases during the day (Pate and Greig 1964) it is possible that the ability of the root to exclude silica is to some degree restored.

In the course of these experiments it was noted that the concentration of monosilicic acid in the culture solutions invariably increased as the intact plants of *T. incarnatum* withdrew water by transpiration. The concentration of silica in the

dry matter of the roots was about eight times that in the corresponding tops. We conclude therefore that *T. incarnatum* has a low concentration of silica in its tops because it is able to exclude monosilicic acid from its transpiration stream either within the root or at its external surface. The mechanism by which monosilicic acid is excluded is obscure but is under further investigation.

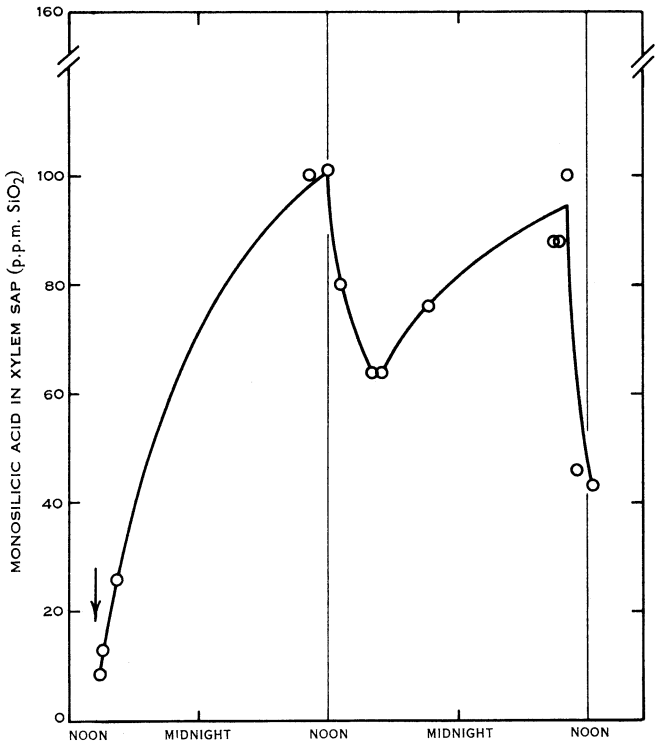

Fig. 1.—Concentration of monosilicic acid in xylem sap from stems of *T. incarnatum* as a function of time after decapitation. At the time of decapitation, which is shown by the arrow, the concentration of monosilicic acid in the external solution was 160 p.p.m. SiO_2.

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