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Potassium effect on tissue hydration and transpiration in cauliflower

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Abstract. Cauliflower (*Brassica oleracea* L. var. Botrytis L. cv. Pusi) grown with 0·2, 0·4, 0·8, 2·0 and 4·0 mM K produced best growth and optimum dry matter at 4 mM K. Suboptimal K supply caused decrease in tissue concentration of K and produced visible symptoms of K-deficiency. Leaves of low K plants showed decrease in stomatal aperture associated with increase in stomatal resistance and decrease in transpiration. At the same time, their specific leaf weight was high and relative water content was low, indicating poor tissue hydration. Low K leaves also showed increased accumulation of proline. The magnitude of the K-deficiency effects was related to the severity of K-deficiency. Observations suggest poor absorption-transport of water under K-deficiency.

Keywords. *Brassica oleracea*; potassium; tissue hydration; transpiration.

1. Introduction

Potassium is essential for plant growth and is involved in diverse aspects of plant metabolism like enzyme activation (Wyn Jones and Pollard 1983), stomatal regulation (Outlaw 1983), membrane transport (Läuchli and Pflüger 1979), anion neutralisation and maintenance of osmotic potential (Clarkson and Hanson 1980). Potassium status of plants has been shown to influence water relations (Brag 1972; Graham and Ulrich 1972; Evans *et al* 1977; Nagarajah and Ratnasuriya 1978; Rao and Rao 1983; Singh and Sharma 1988a) and accumulation of proline (Mukherjee 1974; Udayakumar *et al* 1976; Göring and Bui Huy Thien 1979; Rao *et al* 1981). In this paper we examine effects of K supply on tissue hydration and transpiration.

2. Materials and methods

Plants of cauliflower (*Brassica oleracea* L. var. Botrytis L. cv. Pusi) were grown in refined sand (Agarwala and Sharma 1976) at 0·2, 0·4, 0·8, 2·0 and 4·0 mM K, supplied as KNO_3. Other nutrients were supplied as follows: 4 mM $Ca(NO_3)_2$, 2 mM $MgSO_4$, 1·5 mM NaH_2PO_4, 0·1 mM NaCl, 0·1 mM Fe-EDTA, 10 μM $MnSO_4$, 1 μM $CuSO_4$, 1 μM $ZnSO_4$, 33 μM H_3BO_3, 0·2 μM Na_2MoO_4, 0·1 μM $CoSO_4$ and 0·1 μM $NiSO_4$. Plants grown with 0·2 to 2·0 mM K were supplied $NaNO_3$ to the extent KNO_3 was omitted from the nutrient solution. Plants were raised in white plastic pots of 8 kg capacity. Each pot was supplied 500 ml of nutrient solution daily around 10 AM. There were 6 replicates for each treatment.

At day 67 a set of plants was harvested for determining shoot dry matter. Physiologically comparable (4th or 5th from the top) leaves of another set of plants were harvested and used for determining K concentration, stomatal resistance, transpiration, specific leaf weight, relative water content (RWC) and proline. Micro-relief impressions of lower epidermis of these leaves (Sharma *et al* 1982) were used for measurements of stomatal opening. For all observations samples were drawn in triplicate.

Potassium was determined by flame photometry after drying the thoroughly washed and chopped leaf material at 70°C for 48 h and digesting it with 10:1 mixture of nitric and perchloric acids (Piper 1942).

Stomatal resistance and rate of transpiration were measured using Licor model LI-1600 steady state porometer in intact plants 30 min after applying the nutrient solution. These measurements were made under glasshouse conditions—temperature 21°C, humidity 57% and light intensity (PAR) ranging from 400–600 $\mu Em^{-2} s^{-1}$. For determining RWC, leaves were detached from the plants 30 min after applying the nutrient solution, when the sand in the pots was fully saturated. RWC was measured on 30 discs of 7·5 mm diameter by the method of Barrs and Weatherley (1962). These leaf discs were also used for determining specific leaf weight. Proline was measured colorimetrically as ninhydrin complex in toluene by the method of Bates *et al* (1973).

3. Results

3.1 *Growth and visible symptoms*

Plants grown with 4 mM K showed optimum growth. At lower levels of K, plants developed visible symptoms of K-deficiency. Visible symptoms appeared first at 55 days in plants grown with 0·2 mM K in the form of chlorosis along the margins of the old leaves. A week later, similar effects appeared in old leaves of plants grown with 0·4 mM K. Later, plants grown with 0·8 and 2 mM K also developed mild chlorosis along the margins of the old leaves.

3.2 *Yield and tissue concentration*

Increase in K supply from 0·2 to 0·4 mM caused significant increase in shoot dry weight (table 1). Maximum dry weight of shoot was obtained with 4 mM K.

Leaves of plants grown with 0·2 mM K contained 7·3 mg K g^{-1}. Increase in K supply caused significant increase in leaf tissue concentration of K reaching a maximum (33·2 mg K g^{-1}) in plants supplied 4 mM K (table 1).

Table 1. Effect of K supply on shoot dry weight, K concentration, stomatal resistance and transpiration in cauliflower.

K supply (mM)	Shoot dry weight[a] (g $plant^{-1}$)	Leaf tissue K[a] (mg g^{-1} dry wt.)	Stomatal resistance[b] (s cm^{-1})	Transpiration[b] ($\mu g\ cm^{-2} s^{-1}$)
0·2	1·51 ± 0·44	7·3 ± 0·54	4·54 ± 2·98	2·71 ± 1·41
0·4	2·26 ± 0·26	8·8 ± 0·0	2·08 ± 0·09	4·98 ± 0·23
0·8	2·76 ± 0·57	14·6 ± 1·11	2·22 ± 0·33	5·04 ± 0·73
2·0	4·03 ± 0·60	21·3 ± 1·65	2·23 ± 0·24	5·12 ± 0·55
4·0	4·26 ± 0·48	33·2 ± 1·37	1·94 ± 0·84	5·83 ± 0·43

[a]Data are mean ± SE [a](n = 3) and [b](n = 5).

Table 2. Effect of K supply on specific leaf weight, RWC, stomatal opening and proline concentration in cauliflower.

K Supply (mM)	Specific leaf weight ($g\,cm^{-2}$)	RWC (%)	Stomatal aperture (μM)	Proline [μ mol(100 g fresh wt)$^{-1}$]
0·2	0·866 ± 0·041	87·9 ± 1·24	2·16 ± 0·22	81·8 ± 1·18
0·4	0·829 ± 0·057	89·4 ± 0·56	2·30 ± 0·13	55·0 ± 4·58
0·8	0·771 ± 0·057	91·5 ± 1·65	3·40 ± 0·13	45·0 ± 4·58
2·0	0·750 ± 0·025	93·3 ± 0·83	4·23 ± 0·53	39·9 ± 2·29
4·0	0·707 ± 0·041	94·5 ± 1·54	5·56 ± 0·18	36·2 ± 0·0

Data are mean ± SE (n = 3).

3.3 *Stomatal opening and water balance*

Microscopic examination of microrelief impressions of leaves showed that in plants that were supplied 0·2 and 0·4 mM K and which developed visible symptoms of K-deficiency, a large proportion of the stomata remained close throughout the day and the few stomata that opened, had a smaller aperture than in plants grown with 4 mM K (table 1). Stomatal aperture was also reduced in plants grown with 0·8 and 2 mM K, in which visible symptoms of K-deficiency were very mild.

Compared to plants grown at 4 mM K supply plants grown at suboptimal levels showed significant increase in specific leaf weight and significant decrease in RWC (table 2). Potassium effect on specific leaf weight and RWC was most marked and significant in plants that were supplied 0·2 mM K and which exhibited visible symptoms. These leaves also showed significant increase in proline concentration (table 1). Low K plants also showed increase in stomatal resistance associated with decrease in rate of transpiration (table 2). The difference between stomatal resistance and transpiration rate of normal plants grown with 4 mM K supply and that of low K plants grown with 0·2 mM supply was very marked (> 50%), but the later showed large within sample variations.

4. Discussion

Observations in respect of K effect on leaf tissue K and shoot dry matter are in agreement with our earlier observations (Singh and Sharma 1988b) and support the contention of Pitman (1972) that growth rate of shoot is a function of the rate at which K is supplied to shoots from roots.

Investigations using epidermal strips have shown that K plays a role in the opening of stomata (Zelitch 1969; Raschke 1975; Outlaw 1983) and explains the decrease in stomatal aperture under K-deficiency as observed here and by several other workers (Graham and Ulrich 1972; Nagarajah and Ratnasuriya 1978; Rao and Rao 1983). It also explains the observed increase in stomatal resistance (Peaslee and Moss 1968; Terry and Ulrich 1973a, b; Nagarajah 1979) and decrease in rate of transpiration under potassium deficiency (Peaslee and Moss 1968; Evans *et al* 1977; Nagarajah and Ratnasuriya 1978; Rao and Rao 1983) but is not in consonance with greater deficit of water as evidenced by increase in specific leaf weight, decrease in relative water content and increased accumulation of proline (Singh *et al* 1973). Poor tissue hydration in leaves of K-deficient plants are attributed to a role of K in driving the water from the surrounding cells into the xylem vessels (Baker and Weatherley 1969) and its impact on the root pressure (Mengel and Pflüger 1969).

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