RHYTHMICITY IN THE ABSORPTION AND RELEASE OF IONS BY BROAD AND KIDNEY BEANS

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SUMMARY

The exposure of the root system of broad and kidney bean seedlings to cadmium chloride clearly shows that strongly stimulated plant roots release K and absorb Ca in amounts exceeding the absorption and release of these ions in normally functioning roots.

The reciprocity of K and Ca absorption and elimination by roots under normal conditions of nutrition, the increased excretory function of the roots with regard to K, K release and Ca absorption by the roots caused by high concentration of $CdCl_2$, all this evidence suggests that rythmicity of the roots is due to periodic changes in their functional state (excitation — inhibition), and that the « ion pump » plays a role similar to that in animal tissue.

INTRODUCTION

In a previous study, Nosseir and Spiridinov (1965), found that corn and pea roots behave differently towards the absorption and elimination of nutrients under various levels of temperature, pH and light regime. Rhythmicity in the ion absorption and elimination by these plants was also observed. Thermal, pH or light regime stimuli generally enhanced Ca absorption and K release. The experimental period of this study was 72 hours where only three determinations of ions, absorbed or released, were done. The importance of Ca as a preservative for the fine structure of cytoplasm (Marschner et. al., 1966), and the diverse response of Ca and K uptake and elimination to physical stimuli after relatively long periods (12, 24 or 72 hours) have led me to use a chemical stimulus ($CdCl_2$) where successive one hour-interval determinations were carried out during a total experimental period of 12 hours. According to Smirnova (1955), $CdCl_2$ ($10^{-3}M$) concentration stops streaming of the plant protoplasm. The rate of cytoplasmic streaming is a reliable indicator of the functional status of the cells so that the changes caused by $CdCl_2$ show that this compound is a potent stimulus of plant tissues.

The aim of the present investigation is to study the effect of $CdCl_2$ upon the rythmic absorption and elimination of Ca and K by broad and kidney bean seedlings where approach was made towards the elucidation of the causes underlying rythmic activity of the roots.

MATERIAL AND METHODS

Phaseolus vulgaris and Vicia faba seeds were germinated in the same way as previously shown by Nosseir and Spiridinov (1965) and seedlings were transplanted to nutrient solution after 10 days. Screened deep glass vessels, 1 L. capacity each, were used to contain nutrient solution. One plant is supported in each vessel so that the plants could be transferred to other cultures and the roots could be examined periodically. Plants were grown on a Knop's nutrient solution containing 1.41 mM KNO^3, 3.5 mM Ca $(NO^3)_2$, 1.19 mM $MgSO_4.7H_20$, 1.05 mM KH^2PO^4 and 0.95 mM KCl for a period of 20 days. The minor element solution of Shive and Robbins (1942) was used. The plants were grown in an aqueous culture at 1/5 concentration of this mixture, aerated daily and renewed 1 — 2 times a week. The plants were cultivated and experimented on under the laboratory conditions where the vessels were kept at 23°C in a water bath and light intensity was artificially adjusted at about 5000 Lux. After cultivating the plants in this nutrient solution for 20 days, they were transferred to solutions of K and Ca chloride both combined or single. The solution contained 40 mgm./L K and 20 mgm./L Ca. Cadmium chloride was added to these solutions in concentrations of $10^{-3}M$ and $o.5 \times 10^{-3}M$ (Vicia) and $10^{-3}M$, $10^{-4}M$ and $10^{-5}M$ (Phaseolus). Samples of the nutrient solutions were taken during 12 hours with one hour-interval. For each treatment, 5 replicates for each plant were used. Ca was estimated by titration against trilon solution (Nosseir, 1967) and K by flame photometer. The data obtained (means of 5 replicates) were represented graphically by figures 1, 2 and 3.

RESULTS AND DISCUSSION

It is noted that 2 — 3 hours after transfer to $CdCl_2$ solutions, the Vicia plant lost its turgor while phaseolus plants proved somewhat more resistant where part of turgor has been lost by the leaves after 4 — 5 hours.

A comparison of ion absorption by Vicia and Phaseolus likewise revealed the great susceptibility of the former to $CdCl_2$. This compound greatly stimulated K release and Ca absorption by Vicia roots. In a solution with an initial content of 40 mgm./L K and 20 mgm./L Ca, K concentration was higher throughout the experiment while Ca concentration dropped almost to zero (Figure 1). Such effect was increased with the increase of $CdCl_2$ dose used. The normal rythm of K and Ca absorption did not recover in the Vicia up to the end of the experiment.

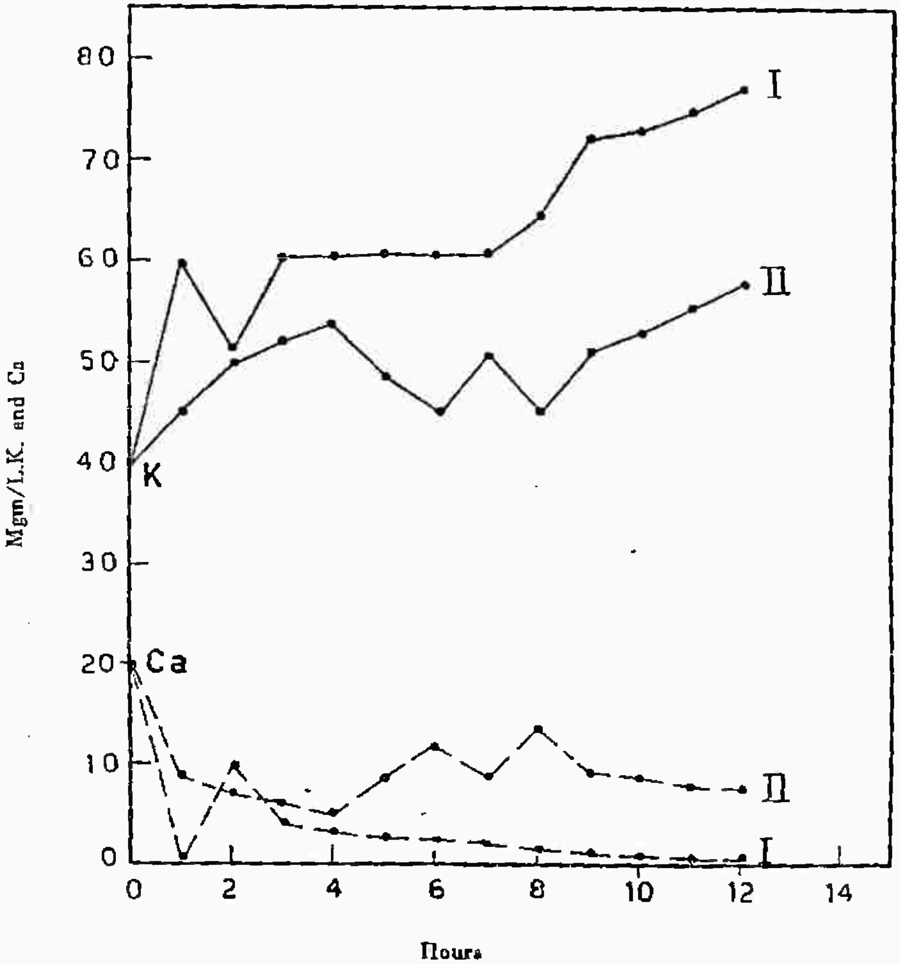

Fig. (1)

The effect of $CdCl_2$ on absorption and elimination of K and Ca by Vicia roots (from a mixture of K and Ca chloride).
I : $CdCl_2$ 10^{-3}M and II : 0.5 × 10^{-3}M.

In Phaseolus, the effect of 10-^{3}M $CdCl_2$ (Figure 2) was much less pronounced than in the Vicia where no appreciable K release by the roots has been recorded. In this variant of the experiment, Phaseolus absorbed K at some hours while at others it eliminated this ion. Both absorption and release of K proceeded at a similar rate so that the initial and final concentration of K proved similar. Ca was absorbed but to a much lesser degree than that by Vicia, (Figure 2).

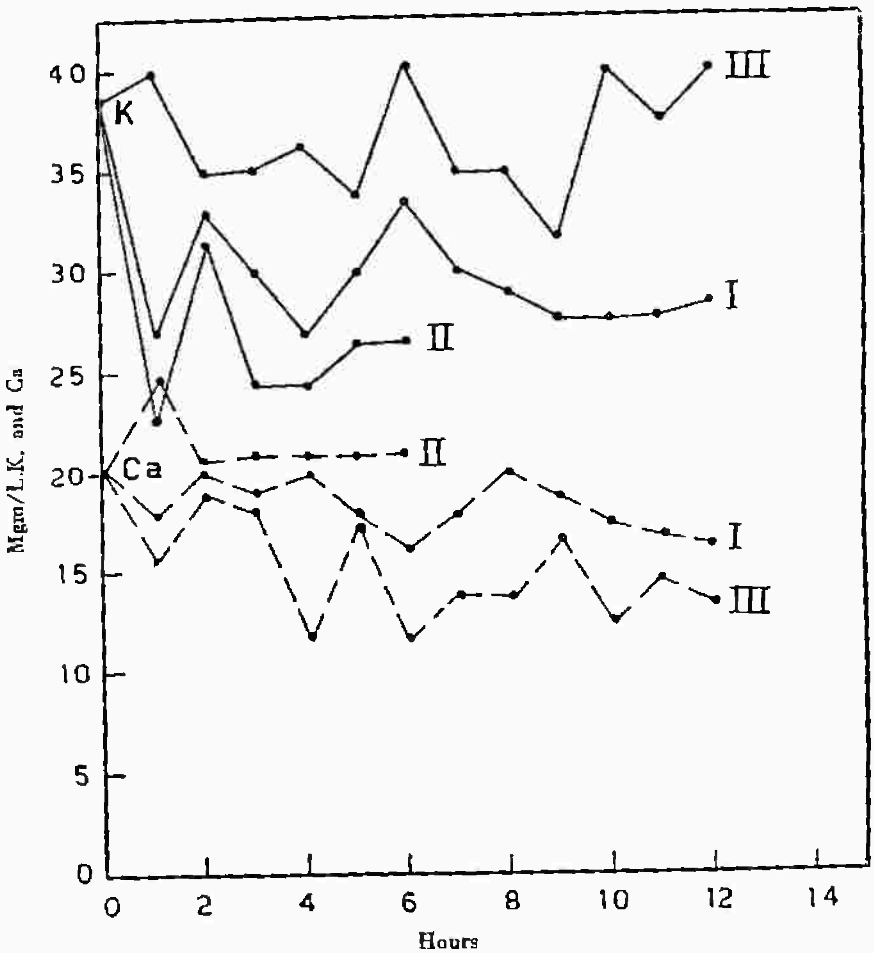

Fig. (2)

The effect of $CdCl_2$ on absorption and release of K and Ca by Phaseolus roots (from a mixture of K and Ca chloride).

I : without $CdCl_2$ II : 10-^{5}M $CdCl_2$ III : 10-^{3}M $CdCl_2$.

A decrease in $CdCl_2$ concentration concentration by 100 times (10^{-5}M) causes a change in the reaction of Phaseolus to this stimulus where K absorption increases while that of Ca decreases as compared with the control, whereas a higher dose (10^{-3}M) produces an opposite effect (Fig. 2).

An intermediate $CdCl_2$ dose (10^{-4}M) was almost ineffective with regard to K and Ca absorption by Phaseolus and hence these data are not presented in figure (2). Such an effect of different $CdCl_2$ concentration upon ion absorption by Phaseolus was observed not only with a mixture of K and Ca salts, but also with KCl alone. With 10^{-3}M $CdCl_2$, K absorption by Phaseolus from a KCl solution was reduced, but increased with 10^{-5}M $CdCl_2$ as compared with the control (KCl without $CdCl_2$), Figure 3.

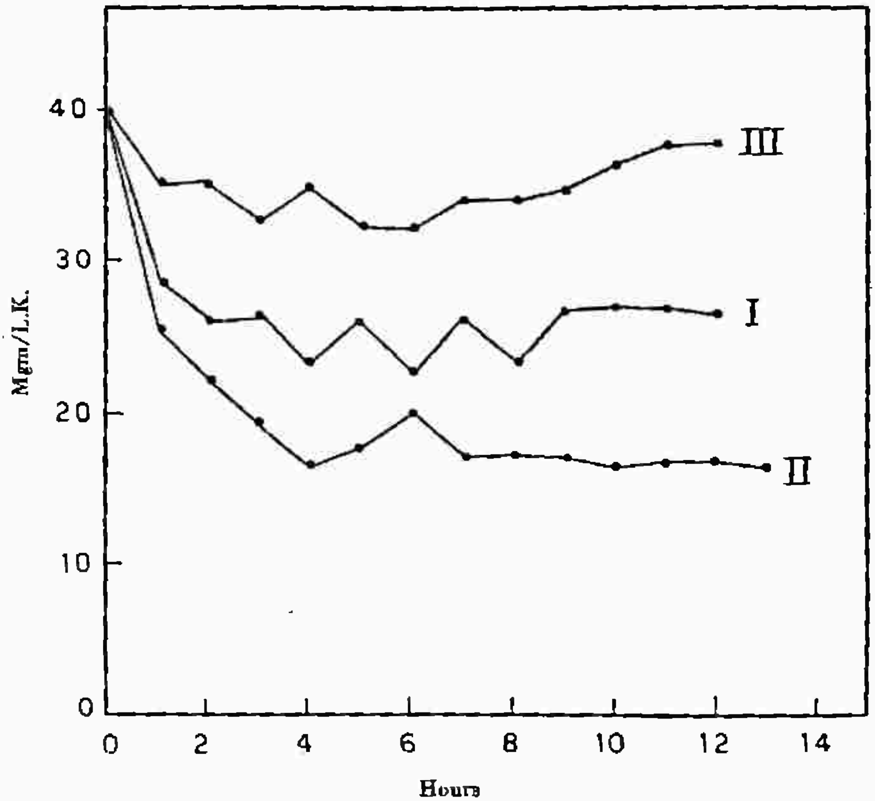

Fig. (3)

The effect of $CdCl_2$ on K absorption by Phaseolus from a KCl solution.
I : without $CdCl_2$ II : $CdCl_2$ 10^{-5}M   III : 10^{-3}M $CdCl_2$

From the foregoing results, it is clear that K and Ca absorbed and released by plants show a definite rythmicity independent of the outward factors and with a several hour period. Such a rythmicity has been stated by some workers for other physiological processes such as photosynthesis (Waugh, 1939), transpiration (Curtis, 1902 and Lloyd, 1908) and respiration (Brown et al., 1955). A several hour rythmicity period cannot be accounted for by ontogenetic or phylogenetic adaptations of the plants to the environment since none of the environmental factors already operated around pea & corn roots (Nosseir & Spiridinov, 1965) or operated around broad and kidney bean roots used in present investigation where $CdCl_2$ was used, show such a periodicity as the other physiological processes (photosynthesis, transpiration or respiration).

It, thus, can be proposed that the cause of this rythmicity is the biphasic character (excitation — inhibition) of the responses of the roots to $CdCl_2$. The rythmic changes are probably due, like in animal organs to periodic variations of the functional state of the roots. Owing to the refractory period during which the roots of the plants are unable to respond to stimulation, the excitation periods are regularly followed by inhibition periods. This is why even under constant conditions of the environment and with a continuously acting stimulus ($CdCl_2$), the physiological process is composed of a series of subsequent impulses. Hence alternation of ion absorption and release by roots, the opposite course of absorption and elimination of K and Ca and the greater K release and Ca fixation are due to overexcitation caused by $CdCl_2$.

As yet as early as in 1902 — 1904, Osterhout has succeeded in demonstrating that stimulated animal tissues release into the surrounding media K and PO_4 ions while absorbing Na and Cl ions. Since then this observa-tion has been reproduced on most diverse animal objects. This process was shown to be reversible, i.e. in resting tissues K and PO_4 ions are absorbed while Na and Cl ions are released. This phenomenon has been called «ion pump» (Troshin, 1956).

Some kind of «ion pump» has been revealed from this investigation. Following up simultaneous K and Ca absorption by Vicia & Phaseolus roots, it is clear that K and Ca absorption curves proved reciprocal, that is to say while K is absorbed, Ca is released by the roots, and vice versa. The reciprocal course of these curves does not depend on the stimulus added since the reciprocity of the K and Ca absorption curves persists under normal nutritional conditions as well as in presence of the stimulus.

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