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EFFECT OF GIBBERELLIC ACID AND POLYETHYLENE GLYCOL ON UPTAKE AND TRANSPORT OF ^{36}CL IN BEAN PLANTS

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I. INTRODUCTION

Relatively few studies have been made on the effect of gibberellic acid on the transport of sugar and other substances. Such studies sometimes fail to distinguish between direct and indirect effects (HALEVY and MONSELINE, 1964). In the grape, transport of ^{14}C-labelled photosynthate during a 6 hour period was markedly increased in plants treated with gibberellic acid for 3 previous days (SHINDY and WEAVER, 1967).

KANNAN and MATHEW (1970) found that application of gibberellic acid to the trifoliate bean leaf enhanced absorption of Fe^{3+} applied to the primary leaf. Absorption of Fe^{3+} by the roots and transport to other parts of the plant was increased by pretreatment of the roots with gibberellic acid.

Little information is available on the effect of gibberellic acid on uptake and transport of Cl^-. Therefore, experiments were conducted on uptake and transport of $^{36}Cl^-$ into the roots, stem and leaves of bean plants which were pretreated with gibberellic acid at various concentrations. Also the interaction between gibberellic acid application and water stress as induced by polyethylene glycol on uptake and transport of the above ion was studied.

Polyethylene glycol itself decreased Cl^- uptake and transport to the leaves of bean plants significantly in a growth experiment (LAGERWERFF and EAGLE, 1961). For this reason, we repeated this experiment for a short period of application (24 hours).

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II. Material and Methods

Bean seeds (*Phaseolus vulgaris*, variety WIDUSA) were germinated in coarse sand; after 9 days the seedlings were transferred to Hoagland solution, with or without addition of gibberellic acid (GA3). Plants were grown in a climate room at an air temperature of 20°C, a relative humidity of 40% and a light nitensity of 40.000 ergs/sec. cm^2 (400–700 nm) for 12 hr a day.

The plants were grown for 3 days in different nutrient solutions containing GA3 in concentrations of 0.1, 1, and 10 mg/liter). After 72 hours the plants were again transferred, this time to a moderately saline solution (25 mM NaCl), corresponding to about 1 atm osmotic pressure, containing ^{36}Cl (7.3 μC/liter). The plants were harvested after 6 or 24 hours and Cl^- was extracted by boiling the plant tissue in water for 5 min. The water was evaporated and the residue bleached with a few drops of H_2O_2. The residue was then dissolved in 2 ml methanol/water (1/1, v/v) and was added to 10 ml of scintillation liquid, which consisted of a mixture of 800 ml dioxane, 160 ml ethylene glycol monoethyl ether, 48 gram naphthalene, 9.6 gram PPO, and 0.48 gram POPOP. Activity of the samples was measured under refrigeration in a Nuclear Chicago liquid scintillation counter.

In another series of experiments, the effect of different osmotic pressure of the nutrient solution on the uptake and transport of ^{36}Cl was studied. Polyethylene glycol (carbowax, molecular weight 20,000) was used as an osmotic agent as described by Lagerwerff et al. (1961). The osmotic pressure of the polyethylene glycol solutions was 0.5, 1, 1.5 and 2 atmosphere, as determined by freezing point depression.

In addition NaCl (25mM) was added to the above polyethylene glycol solutions enriched in $^{36}Cl^-$ (7.3/μc/1). Plants were exposed to the above solution for 6 hours or 24 hours. After this period the roots were washed with distilled water and the amount of $^{36}Cl^-$ was determined in the different parts of the plants.

III. Results and Discussion

1. *Effect of gibberellic acid on uptake and transport of $^{36}Cl^-$.*

Cl^--accumulation into the leaves of bean plants was greatly stimulated by a pretreatment with gibberellic acid (Fig. 1). A 100% increase in Cl^--content was observed in the leaves of plants grown for 3 days in a 10 mg/l GA_3 solution. Cl^--uptake of the roots was also stimulated by GA_3 application, though the effect was less pronounced. The lowered content of Cl^- in the stem tissue might be explained by the fact that Cl^--accumulation of the leaves is stimulated more by application of GA_3 than Cl^--uptake by the roots. With regard to uptake and transport of $^{36}Cl^-$ in bean plants, the effect of gibberellic acid thus proves to be opposite to that of kinetin: while kinetin application under these conditions reduced Cl^--accumulation in the leaves (El-Saidi and Kuiper, 1972), gibberellic acid stimulated it.

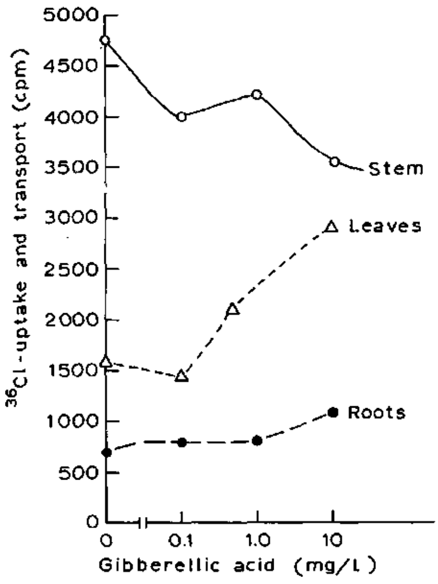

FIG. 1. Effect of gibberellic acid on uptake and transport of ^{36}Cl in bean plants from a moderately saline solution (NaCl, 25 mM for 6 hours).

2. *Effect of polyethylene glycol solution on uptake and transport of* $^{36}CL^-$.

Cl^--uptake and -transport was strongly affected by the presence of polyethylene glycol in the root medium (Fig. 2). Especially Cl^--accumulation in the leaves and the stem dropped in a logarithmic fashion with increasing amounts of polyethylene glycol in the solution. Cl^--uptake of the roots was less affected. Electric mobility of the Cl^--ion in the root medium was not affected by polyethylene glycol, as shown in Table 1. Electrical conductivity due to polyethylene

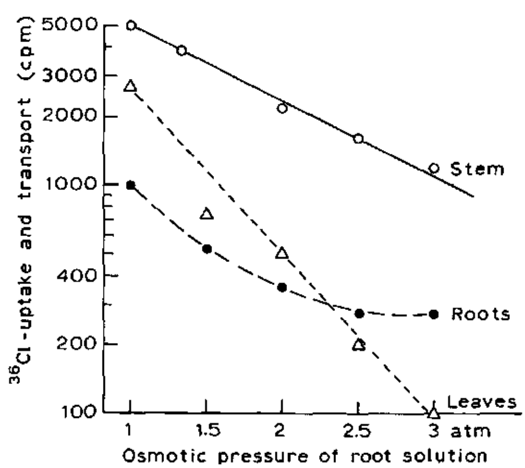

FIG. 2. Effect of osmotic pressure of the root medium, consisting of 1 atm of NaC (25 mM) + varying amounts of polyethylene glycol on ^{36}Cl-uptake and -transport in bean plants in an experiment of 24 hours.

TABLE 1. Electrical conductivity of solutions of NaCl, polyethylene glycol, and of both.

Solute	Concentration	Resistance (Ω)	Conductivity ($1/\Omega$)
NaCl	25 mM	290	0.00345
Polyethylene glycol	10% (w/v)	1000	0.00100
NaCl + Polyethylene glycol	25 mM+10%(w/v)	230	0.00435

glycol and to NaCl (25 mM) contributed additively to the electrical conductivity of the solution, demonstrating that the electrical mobility of the ions was not affected up to 10% polyethylene glycol, which corresponds to 2 atm osmotic pressure. Evidently, the presence of this compound in the root solution greatly reduced the Cl^- permeability and transport system of the bean plant. Such compounds thus may possibly reduce damage to the plant caused by excessive Cl^--accumulation in the leaves.

3. *Effect of gibberellic acid on $^{36}Cl^-$-uptake and transport in a root solution of 3 atm osmotic pressure.*

This experiment was carried out only for a period of 6 hours to avoid long term effects of the relatively high osmotic pressure (2 atm due to polyethylene glycol +1 atm due to NaCl). Surprisingly, gibberellic acid did not significantly affect Cl^--uptake and transport in the bean plants (Fig. 3) contrary to what was observed in plants exposed to 1 atm osmotic pressure by NaCl (Fig. 1). Clearly, the reduced permeability and transport of Cl^- owing to the presence of polyethylene glycol in the root medium cannot be alleviated by application of gibberellic acid, indicating that the stimulatory effect of gibberellic acid on Cl^--transport observed in root media without polyethylene glycol is annihilated by the presence of this compound. Thus, polyethylene glycol reduces Cl^--uptake and transport itself as well as the stimulatory effect of gibberellic acid on Cl^--transport.

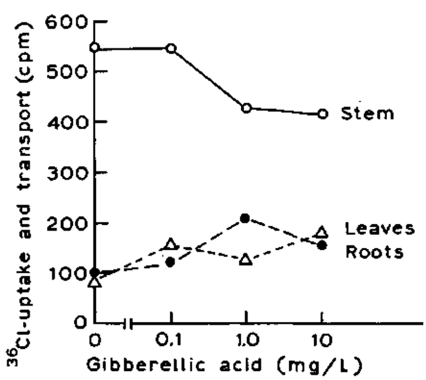

FIG. 3. Effect of a pretreatment of gibberellic acid on ^{36}Cl-uptake and -transport in bean plants under strong salinity stress (1 atm NaCl + 2 atm polyethylene glycol) for 6 hours.

4. *Discussion.*

Polyethylene glycol profoundly decreases Cl^--uptake and -transport in the bean plant in our short-term experiments. This was also noted by LAGERWERFF and EAGLE in their growth experiments with the same plant. This compound has much less effect on uptake and transport of Na^+ and Ca^{2+} (LAGERWERFF and EAGLE, 1961; MESCHGI, 1969), while the K^+-content of the leaves was even strongly increased in polyethylene glycol exposed plants (LAGERWERFF and EAGLE, 1961). In a preliminary experiment on the effect of polyethylene glycol on Na^+-uptake and transport in cotton, we also noted only a limited decrease in Na^+-transport by this compound.

Polyethylene glycol is generally used as a non-specific osmotic agent, because it is not absorbed by the roots in short-term experiments. The experiment thus indicated that under drought conditions a reduced transport of Cl^- takes place in bean plants. Possibly, this plant possesses an adaptive mechanism to prevent Cl^--damage of the leaves under conditions of water stress, though we realize that more experimentation is required to prove this point. It is also evident that under conditions of water stress gibberellic acid is not capable to stimulate Cl^--transport to the leaves, which also points to an adaptive mechanism to prevent excessive Cl^- accumulation in the leaves.

SUMMARY

When bean plants were exposed to a moderate salinity stress, 25 mM NaCl, gibberellic acid application stimulated Cl^--transport to the leaves. Under conditions of a stronger salinity stress, induced by 1 atm. of NaCl (25 mM) + 2 atm. of polyethylene glycol, this effect of gibberellic acid practically disappeared. Application of polyethylene glycol to the root medium as a nonspecific osmotic stress greatly reduced Cl^--uptake and further transport into the plant, suggesting that, under conditions of water stress, the bean plant possesses an adaptive mechanism to prevent damage to the leaves owing to excessive Cl^--accumulation.

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