The Influence of Abscisic Acid (ABA) on the Dry Weight, Uptake and Translocation of Ions in Mustard Seedlings.

Ferdowsi Noor*

Abstract: A hydroponic experiment was conducted in growth cabinet(Day and night temperature was 25ºC±1and 20ºC±1, respectively;10 h day and 14 h night) to investigate the effect of abscisic acid (ABA) on the dry weight, uptake and translocation of K^+ Na^+ and $C1^-$ ions in excised and intact mustard seedlings. ABA at different concentrations decreased the root and the shoot dry weight ranging from 13 to 61.5% and 10 to 27% respectively, over a period of 3 to 48h of treatment. ABA stimulated K^+, Na^+ and $C1^-$ ions uptake in excised mustard seedlings. On the other hand, ABA inhibited accumulation of K^+ Na^+ and $C1^-$ ions intact mustard seedlings. It decreased net influx, long distance transport and transport index of K^+, Na^+ and $C1^-$ in mustard seedlings.

Keywords: ABA, mustard seedlings, excised roots, intact seedlings, ΨOC, ΨCX

Introduction

Phytohormone and inorganic nutrients control growth, development, ion absorption and transport in plants like common physiological and biochemical functions. The interaction between plant hormone and inorganic nutrients change ionic balance in plants and as such plants growth may be affected. It is also possible that plant hormone may control growth indirectly by regulating the uptake and distribution of ions in plants.

Inorganic nutrients control growth by maintaining the osmotic potential of cells and tissues. These also act as constituents of inorganic compounds and as cofactor of important biological reactions. It is known that phytohormones affect growth by directly affecting a number of physiological biochemical parameters of plants inducing

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enzymes involved in metabolism (Clarkson, 1974[5]; Fattah and Wort, 1970[8]; Karmoker, 1984[13]; Ruggiero *et al.* 2004[20]).

The effect of ABA on the ion transport in excised tissues are contradictory. For example, Collins and Kerrigan (1974)[6] observed that ABA increased K^+ transport into the isolated xylem of maize roots. On the contradictory, ABA inhibited $K^{+\ 86Rb}$ and Cl^- transport into the excised barley roots[7]. Mansfield and Jones (1971)[16] observed that K^+ transport into the stomatal guard cell of *Commelina communis* was inhibited in presence of ABA and ultimately stomata was closed. Channa and Collins (1990)[3] reported that ABA increased potassium flux leaving the proton flux and differential responses in maize roots segments to create a proton gradient. *Gurmani et al.* (2007)[11] observed that ABA and BA treated plants significantly decreased Na+ content but increased K^+ content in flag leaf of the wheat cultivars. ABAand BA decreased plant height but increased number of grains per spike and grain yield. Chen et al. (2019)[4] showed that ABA plays an important role in the closure of stomata by regulating guard cell ion fluxes. ABA affects stomatal pore size by both Ca^{2+}- dependent and Ca^{2+}-independent pathways.In this paper, the influence of ABA on the absorption and trans location of K^+, Na^+ and $C1^-$ ions in the excised and intact mustard seedlings has been discussed.

Materials and methods

Brassica campestris var. Tori 7 was used as plant materials for this investigation. Seeds were obtained through the courtesy of Bangladesh Agricultural Research Institute (BARI), Gazipur.

The nutrient solution culture technique

Mustard seedlings were grown in half strength Hoagland solution (Hoagland and Arnon, 1950)[12]. The pH of the modified nutrient solutionwas 5.5 to 6. Seeds were surface sterilized by 0.01% $HgCl_2$ solution. Four days old seedlings with uniform growth were transferred to the half strength Hoagland solution filled with beakers. All the beakers with nutrient solution were covered by black papers to avoid exposure of roots in the light.Then all the seedlings with beakers were kept in the growth cabinet (Model EA- 7BH, Environmental Air). Growth conditions were as follows: Day temperature was 25ºC±1, night temperature was 20ºC±1, 10 h day and 14 h night. Nutrient solution of each beaker was replaced every 48 hours.

Preparation of 2X 10^{-5} M stock solution of Abscisic Acid (ABA)

ABA with 2.643 mg was taken in a 150 ml conical flask covered by a black paper to avoid degeneration. 100 ml distilled water was taken in the conical flask and shaken over night. Then the solution was transferred to a 500 ml volumetric flask and the final volume was made up to the mark.

Methods of ion transport experiments

Ion transport experiment with intactseedlings

13-days-old mustard seedlings were selected and transferred to 600 ml experimental solution of 0.5 mM KCl + 0.1 mM $CaSO_4$ solution or 0.5mM NaCl + 0.1 mM $CaSO_4$ solution with or without ABA. The experimental solution was aerated continuously by an air compressor. $CaSO_4$ was used in experimentalsolutionin order to maintain the permeability characteristicsof the membrane.

Ion transport experiment with excised root systems

13-days-old mustard seedlings were decapitated at 1 cm above root stem junction. The excised root systems were then transferred to the experimental solution consisting of 0.5mMKCl+0.1 mM $CaSO_4$ or 0.5mM NaCl0.1 mM $CaSO_4$ solution with or without hormone. The experimental solution was aerated continuously.The shoot and root samples were collected separately at 3, 6, 24 and 30h (hours) after setting up the experiment.

Drying and collecting samples

Plant samples were dried in oven at 60^0C for 48 hours. Then dry weight of the root and shoot samples were recorded separately.

Exraction of K^+, Na^+ and Cl^- in plant tissues

In order to measure total amount of K^+, Na^+ and Cl^-in plant tissues, the root and shoot samples were taken in test tube separately. The test tubes with plant materials were soaked in 10 ml of distilled water for 30 minutes and collected the extracts in another test tubes. Again 5 ml of distilled water was added to the residue and boiled for fifteen minutes and the extract was collected. The procedure was repeated again. The combined extract was made up to a final volume of 20 ml.

Chemical analysis of K^+ and Na^+

The uptake of $K^+$and Na^+ was measured using a Flame Analyzer (Gallen Kamp model FGA- 330-C) at the wave lengths of 767 and 589 nm, respectively. The concentration of K^+ and Na^+ were calculated using the standard curves described in Figure 1 and 2, respectively.

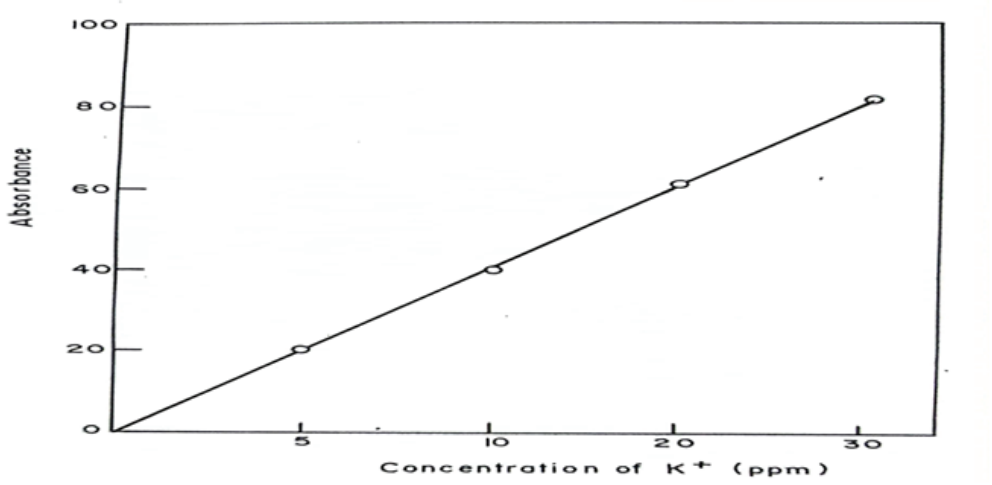

Figure 1: Standard curve for K^+.

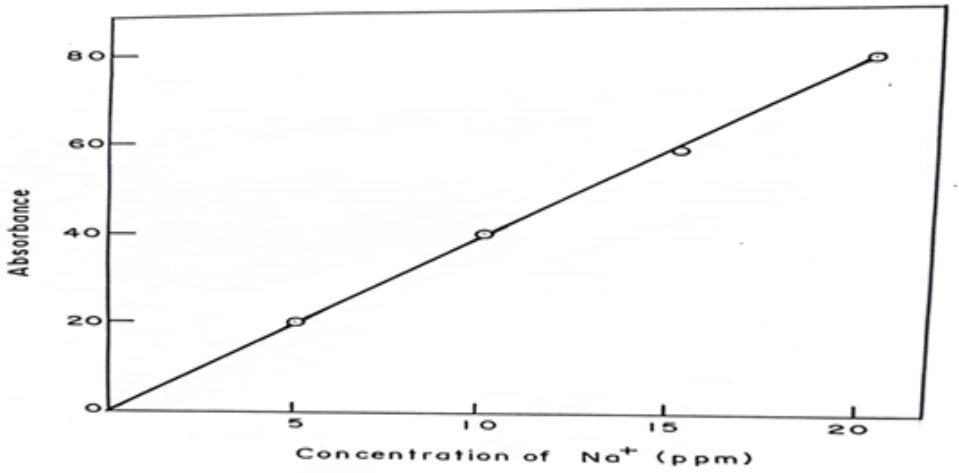

Figure 2: Standard curve for Na^+.

The amount of K^+ and Na^+ were calculated using the following formula:

$$K^+/Na^+ \text{content} = \frac{\text{Concentration of ion in the extract(ppm) X Final volume of the plant in the extract(ml)}}{\text{Dry weight of the tissue X 1000 X Atomic weight of the respective ion}}$$

$$= \text{X m. equivalent } g^{-1} \text{ dry tissue.}$$

Chemical analysis of Cl^-

Cl^- was measured by titrimetric method. 5 ml sample was titrated with 0.1N $AgNO_3$ using potassium chromate (K_2CrO_4) as an indicator. The concentration of Cl^- was calculated using the standard curve presented in Figure 3.

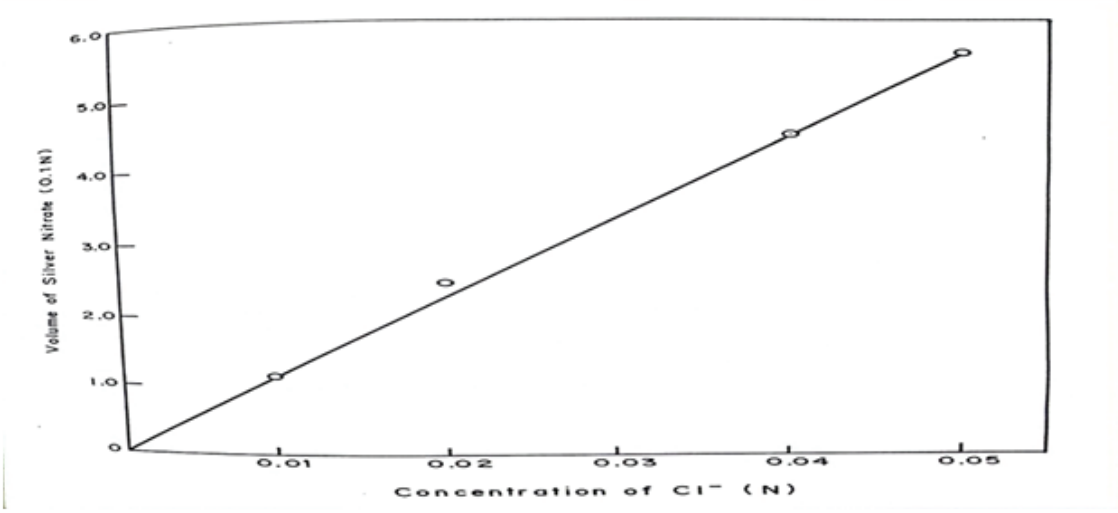

Figure 3: Standard curve for Cl^-.

The concentration was calculated using the following formula:

$$Cl^- \text{ content} = \frac{\text{Concentration of } Cl^- \text{ (N)} \quad \text{Final volume of the extract (ml)} \quad \text{Atomic weight of } Cl^-}{1000 \text{ X Dry weight of the tissue X Atomic weight of the respective ion}} \times 1000$$

$$= \text{X m. equivalent } g^{-1} \text{ dry tissue.}$$

Results and discussion

The effect of ABA on the root dry weight of intact mustard seedlings

Abscisic acid (ABA), at a concentration of 10^{-7} M inhibited the root dry weight by 13 and 18% at 3 and 48h of treatment, respectively but had no effect on the root dry weight from 6 to 24h of treatment (Figure 4a). 10^{-6} M ABA decreased the root dry weightby 17, 18, 61.5 ad 32% at 3, 6, 24 and 24h of treatment, respectively. ABA at 10^{-5} M, inhibited the root dry weight ranging from 35 to 30% up to 48h of treatment (In growth cabinet: Day temperature was 25ºC±1, night temperature was 20ºC±1, 10 h day and 14 h night).

The effect of ABA on the shoot dry weight of intact mustard seedlings

ABA (10^{-6} M) decreased the shoot dry weight by 12 to 10% from 6 to 24h of treatment. Moreover, 10^{-5} M ABA inhibited the shoot dry weight from 27 to 23% over a period of 3 to 48h of treatment (Figure 4b; In growth cabinet: Day temperature was 25ºC±1, night temperature was20ºC±1; 10 h day and 14 h night). Gadallah (1996)[9] reported that the effect of ABA on the growth was more pronounced at optimum temperature (25°C).With stressed plants, ABA application reduced the toxicity of salt treatment, improved K^+ uptake under salinity, effectively increased K^+/Na^+ ratio and helped the plants to avoid Na^+ toxicity and sometimes enhanced growth. Biddington and Dearman (1982)[2] observed that application of abscisic acid (ABA) to the nutrient solution increased the root to shoot ratio of hydroponically-grown cauliflower plants by reducing the dry weight of the shoot and increasing that of the root.

The effect of ABA on K^+ uptake in excised root system of mustard seedlings

In excised root system, 10^{-6} M ABAincreased K^+ uptake by 75.5%at 24h of treatment and decreased by 56 and 32% at 3 and 6h of treatment (Figure 5). ABA at 10^{-7} M, increased K^+ uptake by 77.8% at 24h after an initial inhibition at 3 and 6h of treatment (Figure 5).

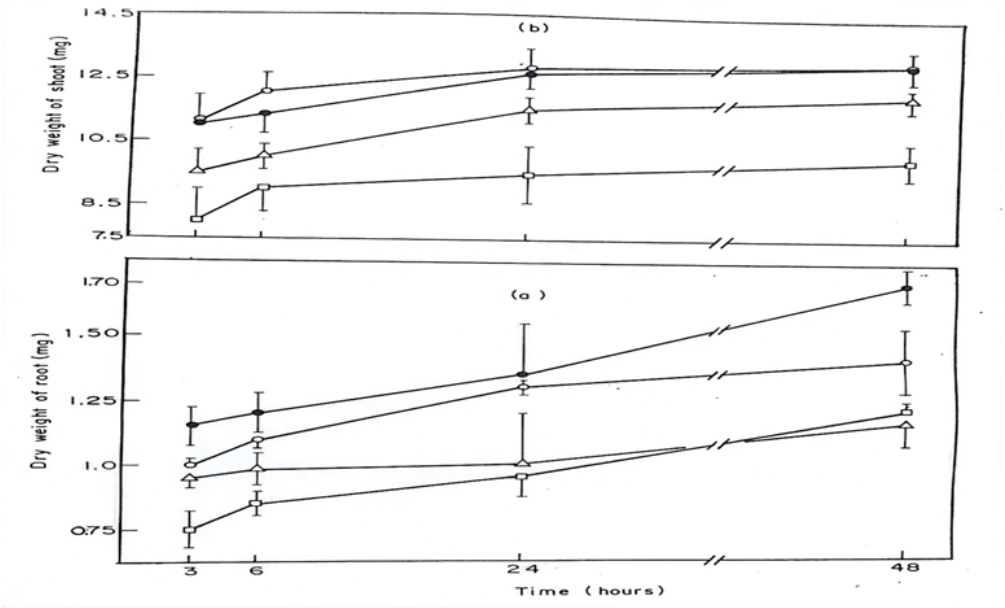

Figure 4: The effect of ABA on the (a) root and (b) shoot dry weight of intact mustard seedlings placed in 0.5 mM KCl + 0.1 mMCaSO4. Black circle represents control, white circle 10^{-7} M ABA, white triangle 10^{-6} M ABA and white square 10^{-5} M ABA. Each point represents the mean of three replications; the bars represent ± standard error.

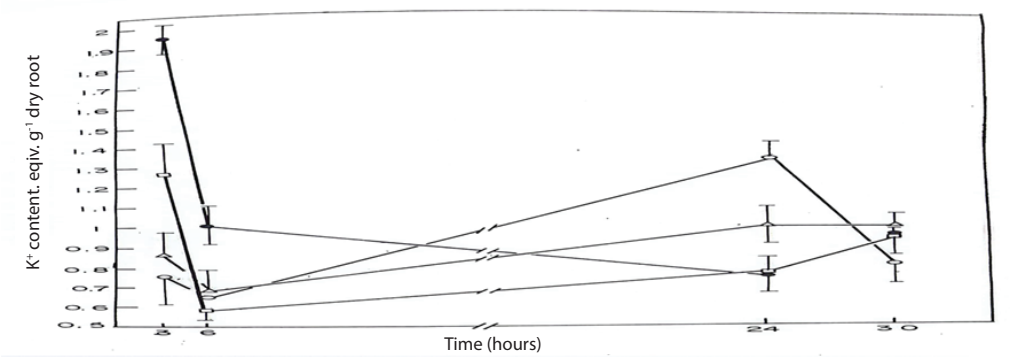

Figure 5: The effect of ABA on K+ uptake in the excised root systems of mustard seedlings placed in 0.5 mM KCl + 0.1 mMCaSO4 with or without ABA, otherwise as figure 4.

Similar results were found by Karmoker and Baten (1992)[14] in excised root system of jute. Higher concentration, 10^{-5} M, ABA decreased K^+ accumulation in excised root

systems of mustard seedlings. It was reported that ABA inhibited K^+ accumulation in excised maize roots (Shaner *et al.* 1975)[21]. The inhibitory effect of ABA on ion transport may be due to its effect on the activity of guard cell mechanisms, decrease in enzymic activity, inhibition of protein synthesis which are related in regulation of ion transport (Van Steveninck, 1976)[22].

In the excisedroot systems,10^{-6} M ABA decreased Na^+ accumulationby 43% at 3h of treatment, whereas it increased by 3.2, 2.3 and 2.6 fold at 6, 24 and 30h of treatment (Figure 6). 10^{-7} M ABA gradually increased Na^+ accumulation in excised root system from 5 to 6 fold over a period of 6 to 30h of treatment while it had no effect at 3h of treatment. Similarly, 10^{-5} M ABA increased Na^+ accumulation by 2.6 to 3.6 fold over a period of 6 to 30h of treatment. The results are supported by Karmoker and Van Steveninck (1978)[15] who found that ABA stimulated Na^+ transport into the excised xylem of bean root systems. On the other hand, Behl and Raschke (1986)[1] found that ABA caused 93 to 98% inhibition of K^+ and Na^+ uptake in the excised barley roots within 2 to hours treatment.

ABA at 10^{-6} M, gradually increased Cl^- accumulation in the excised root from19.4 to 23% over a period of 3 to 30h of treatment (Figure 7).

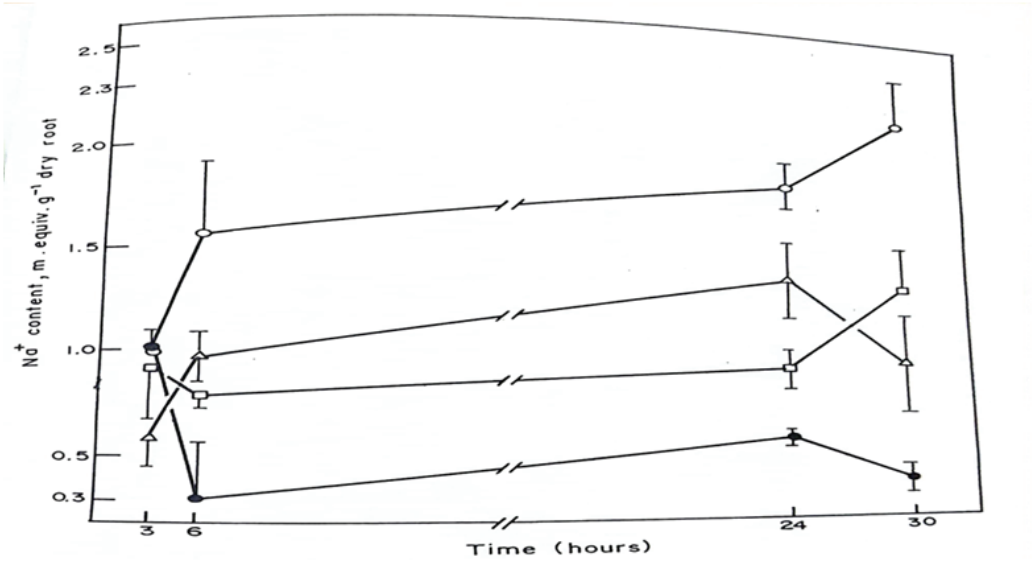

Figure 6: The effect of ABA on Na+ uptake in the excised root systems of mustard seedlings placed in 0.5 mM NaCl + 0.1 mMCaSO4 with or without ABA, otherwise as figure 4.

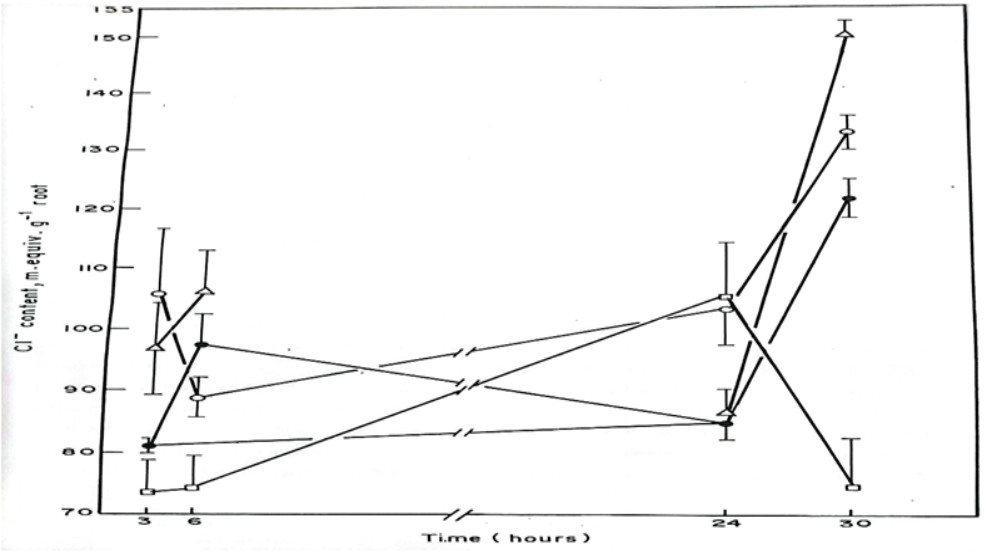

Figure 7: The effect of ABA on Cl- uptake in the excised root systems of mustard seedlings placed in 0.5 mM KCl + 0.1 mMCaSO4 with or without ABA, otherwise as figure 4.

Similarly, lower concentration (10^{-7} M) ABA increased Cl^- uptake by 30.4, 21.4. and 9.3% at 3, 24 and 30h of treatment, respectively. On the other hand, higher concentration, 10^{-5} M ABA decreased Cl^- accumulation in the excised root system by 9, 23.5 and 38% at 3, 6 and 30h of treatment. On the contrary, Migliaccio and Rossi (1977)[17] found that 10^{-5} M ABA increased Cl^- and $SO4^{-2}$ transport into the excised root xylem at 22^0C over a period of 24 hour of treatment. The energized chloride pump may be affected by ABA which operates in the plasma membrane is activated by ion concentration of ABA. The high concentration of ABA inhibits Cl^- pump thereby decreasing Cl^- uptake.

The effect of ABA on K^+ uptake in intact mustard seedlings

In the root of intact mustard seedlings,10^{-7} M ABA increased K^+ uptake ranging from 15.6 to 12% over a period of 3 to 6h of treatment, whereas it had no effect on K^+ uptake from 24 to 48h of treatment (Figure 8). 10^{-6} M ABA decreased K^+ uptake in the root from 18 to 36.3% at 24 to 48h of treatment.10^{-5} M ABA had no effect on K^+ uptake in the root from 3 to 6h of treatment. It decreased K^+ uptake by 24.6 and 39.5% at 24 and 48h of treatment, respectively.

In the shoot of intact seedlings,10^{-7} M ABA showed a decreasing tendency of K^+ transport from 6 to 48h of treatment (Figure 9). 10^{-6} M and 10^{-5} M ABA decreased K^+ accumulation ranging from 26.2 to 13% and 24 to 17.7% over a period of 3 to 48h of treatment, respectively.

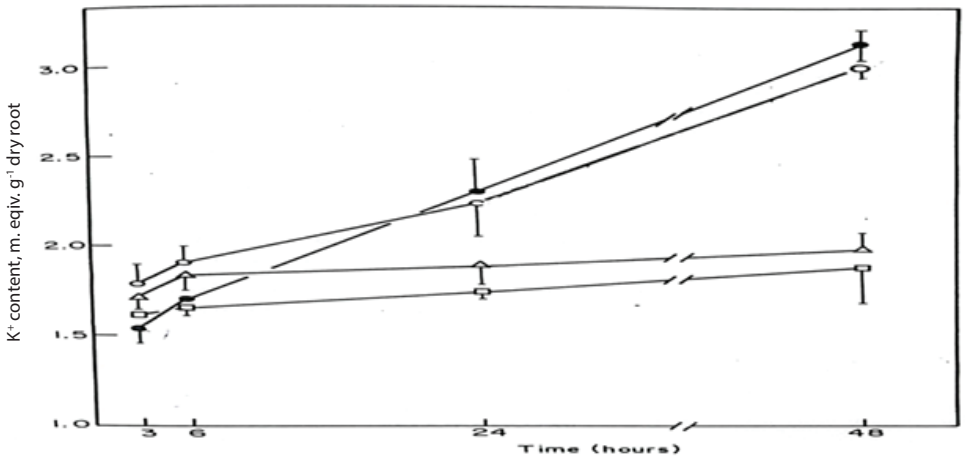

Figure 8: The effect of ABA on K+ uptake in the root of intact mustard seedlings placed in 0.5 mM KCl + 0.1 mMCaSO4 with or without ABA, otherwise as figure 4.

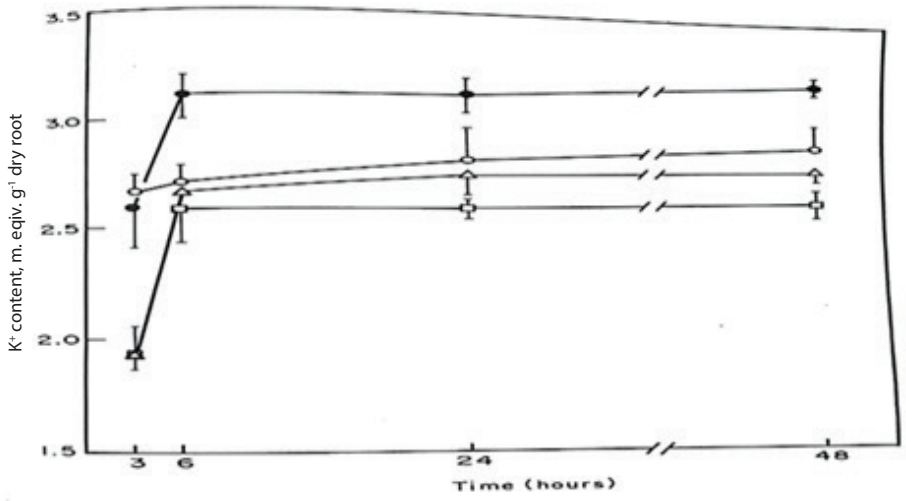

Figure 9: The effect of ABA on K+ uptake in the shoot of intact mustard seedlings placed in 0.5 mM KCl + 0.1 mMCaSO4 with or without ABA, otherwise as figure 4.

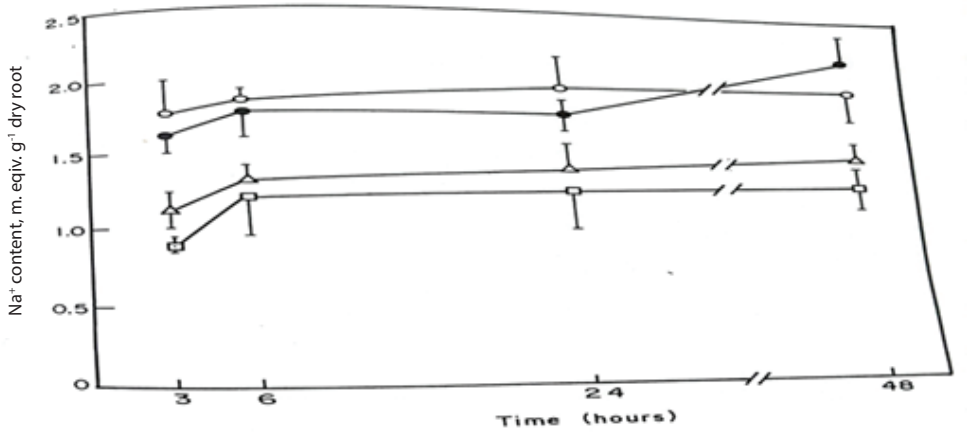

Figure10: The effect of ABA on Na+ uptake in the root of intact mustard seedlings placed in 0.5 mM NaCl + 0.1 mMCaSO4 with or without ABA, otherwise as figure 4.

The effect of ABA on Na^+ uptake in intact mustard seedlings

ABA at 10^{-7} M concentration, showed no effect on Na^+ uptake in the root of intact mustard seedlings (Figure 10). 10^{-6} M ABAdecreased Na^+ accumulation in the root from 30.6 to 31.8% over a period of 3 to 48h of treatment. Furthermore, 10^{-5} M ABA inhibited Na^+ uptake in the root by 40.7 to 41% over a period of 3 to 48h of treatment (Figure 10).

In the shoot of intact mustard seedlings, 10^{-7} M ABA had no effect on Na^+ uptake in the shoot at 3, 6 and 48h of treatment. On the other hand, it decreased Na^+ accumulation in the shoot by 10.5% at 24h of treatment (Figure 11). 10^{-6} M ABA increased Na^+ accumulation in the shoot by 37.8, 21.2, 26 and 21.4% at 3, 6, 24 and 48h of treatment, respectively. Similarly, 10^{-5} M ABA increased Na^+ accumulation in the shoot from 44 to 34% over a period of 3 to 48h of treatment.

The effect of ABA on Cl^- uptake in intact mustard seedlings

In the intact mustard seedlings,10^{-7} M ABA had no effect on Cl^- uptake in the root (Figure 12). 10^{-6} M ABAdecreased Cl^- accumulation in the root from 19 to 31% over a period 3 to 24h of treatment. In the same way, 10^{-5} M ABAinhibited Cl^- accumulation in the root ranging from 20 to 21.2% over a period of 3 to 48h of treatment.

In the shoot of intact mustard seedlings,10^{-7} M ABA decreased Cl^- transport from 7 to 12.7% from 3 to 24h of treatment (Figure 13). 10^{-6} M ABAalso decreased Cl^- accumulation in the shoot by 17.8, 26, 22.5 and 18% at 3, 6, 24 and 48h of treatment,

respectively. Similarly, 10^{-5} M ABAdecreased Cl^- transport in the shoot 22.7 to 43.4% over a period of 3 to 48h of treatment.

ABA inhibited K^+, Na^+ and Cl^- in the root and the shoot of intact mustard seedlings (Figure 8 to 13).Since ABA is a growth retardant hormone and therefore exogenous supply of ABA causes a dramatic increase in endogenous ABA level. This may lead to inhibition of ion uptake and translocation in intact mustard seedlings. It was reported that ABA decreased K^+ transport in the guttation fluid from passive hydathodes (Dieffenbachet al. 1980)[7] and in the shoots (Riedellet al. 1984)[18] of barley seedlings.

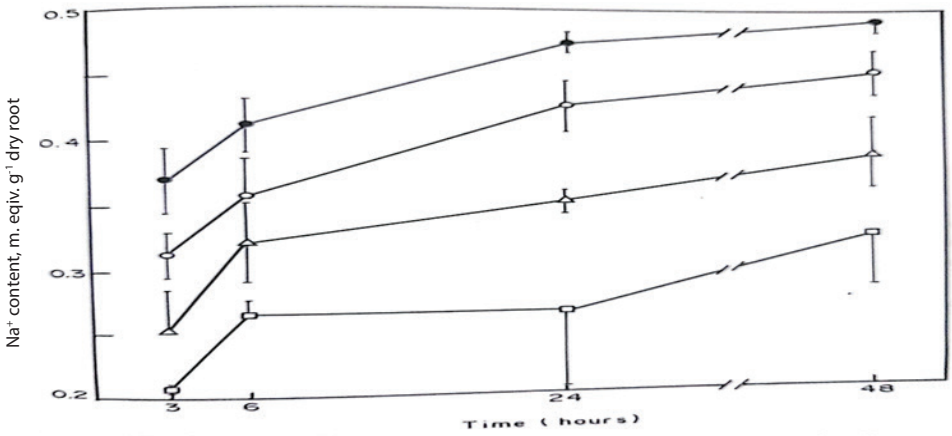

Figure11: The effect of ABA on Na+ uptake in the shoot of intact mustard seedlings placed in 0.5 mM NaCl + 0.1 mMCaSO4 with or without ABA, otherwise as figure 4.

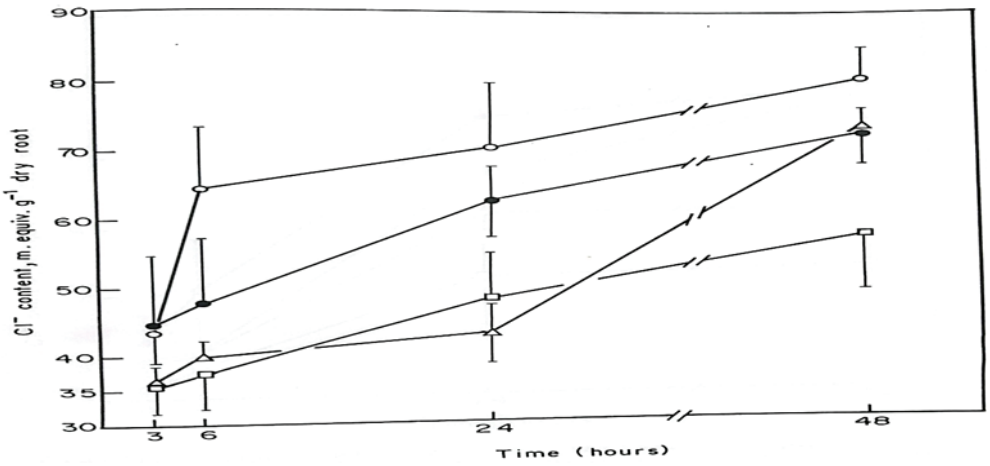

Figure12: The effect of ABA on Cl- uptake in the root of intact mustard seedlings placed in 0.5 mM KCl + 0.1 mMCaSO4 with or without ABA, otherwise as figure 4.

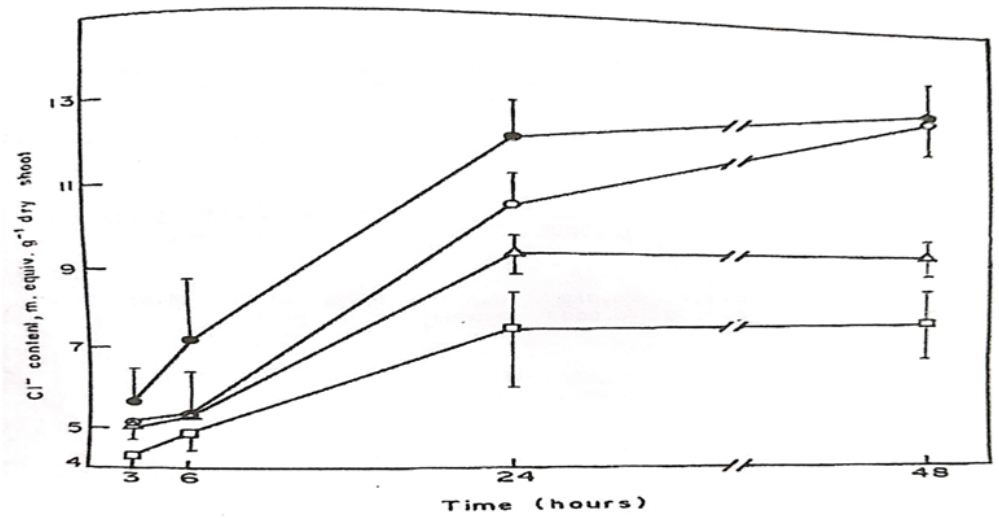

Figure13: The effect of ABA on Cl- uptake in the shoot of intact mustard seedlings placed in 0.5 mM KCl + 0.1 mMCaSO4 with or without ABA, otherwise as figure 4.

The effect of ABA on long distance transport and net influx of K^+ in intact mustard seedlings

In intact mustard seedlings, 10^{-7} M ABA increased net influx (ΨOC) of K^+ by 16.3% at 3h of treatment whereas it inhibitedfrom 14 to 20.7% over a period of 6 to 48h of treatment (Table I). 10^{-6} M ABA decreased net influx (ΨOC) of K^+ from 56.8 to 30.4% over a period of 3 to 48h of treatment. 10^{-5} M ABA also decreased net influx of K^+ by 58.6, 26.4 and 37.2% at 3, 6, 24 and 48h of treatment, respectively.

In the intact mustard seedlings, 10^{-7} M ABA had no effect on long distance transport (ΨCX) of K^+ at 3h of treatment whereas it was inhibited by 25.4 and 24.5% at 6 and 24h of treatment, respectively. Similarly, 10^{-6} M ABA caused a decrease in long distance transport of K^+ from the root to the shoot from 70 to 27.2% over a period of 3 to 48h of treatment. 10^{-5} M ABA decreased long distance transport of K^+ ranging from 37.2 to 29.6% over a period of 3 to 48h of treatment(Table I). In the mustard seedlings, 10^{-7} M and 10^{-6} M ABA decreased transport index of K^+ at 3 and 6h of treatment. On the other hand, 10^{-5} M ABA increased transport index of K^+ at 24 and

48h of treatment (Table I). Similarly, Gunvor *et al.* (1990)[10] showed that ABA (40-80 μM) inhibited K^+ (^{86}Rb) influx in 7 days old wheat seedlings while K^+ (^{86}Rb) was temporarily stimulated by pretreatment of the plants with ABA.

Table I. The effect of ABA on net influx and long distance transport of K+ in intact mustard seedlings placed in 0.5 mM KCl + 0.1 mMCaSO4 with or without ABA.Each value is the mean of three replicates, ±standard error.

Time (h)	Transport of K^+ from root to shoot (Ψcx), mg/shoot				Net influx of K^+ (Ψoc) mg/plant				Transport index=($\frac{\Psi cx}{\Psi oc}$ X 100)			
	Control	10^{-7}M	10^{-6}M	10^{-5}M	Control	10^{-7}M	10^{-6}M	10^{-5}M	Control	10^{-7}M	10^{-6}M	10^{-5}M
0-3	0.702 ±0.0004	0.72 ±0.0002	0.21 ±0.0010	0.23 ±0.0007	0.822 ±0.0007	0.956 ±0.0004	0.355 ±0.0011	0.357 ±0.0013	85.40	75.31	59.15	64.42
0-6	0.97 ±0.0003	0.724 ±0.0006	0.720 ±0.0001	0.695 ±0.0004	1.12 ±0.0072	0.962 ±0.00075	0.953 ±0.0010	0.828 ±0.0011	86.61	75.25	75.55	83.94
0-24	0.98 ±0.0001	0.740 ±0.0003	0.73 ±0.0004	0.704 ±0.005	1.38 ±0.00092	0.991 ±0.0009	0.96 ±0.0011	0.857 ±0.0010	71.01	74.67	76.04	82.15
0-48	1.02 ±0.0001	0.762 ±0.0002	0.742 ±0.0005	0.718 ±0.0007	1.44 ±0.00052	1.142 ±0.0008	0.970 ±0.0012	0.904 ±0.0010	70.83	66.73	76.49	79.42

The effect of ABA on net influx and long transport Na+ in intact mustard seedlings

In the intact mustard seedlings, 10^{-7} M ABA inhibited net in flux (ΨOC) of Na^+ from 28 to 35%over a period of 3 to 48h of treatment (Table II). 10^{-6} M ABA inhibited net influx of Na^+ by 60, 63.3, 71.5and 77.3% at 3, 6, 24 and 48h of treatment.10^{-5} M ABA caused a decrease of net influx of Na^+ ranging from 77.5 to 79.8% over a period of 3 to 48h of treatment (Table II).

10^{-7} M ABA decreased long distance transport (ΨCX) of Na^+ in the root to shoot from 28.4 to 41.4%over a period of 3 to 48h of treatment. Similarly, 10^{-6} M and 10^{-5} M ABA caused an inhibition of Na^+ from 75.8 to 79.5% and 78.7 to 82.8% over a period of 3 to 48h of treatment, respectively. ABA had no effect on transport index of Na^+ in the intact mustard seedlings (Table II).

Table II. The effect of ABA on net influx and long distance transport of Na+ in intact mustard seedlings placed in 0.5 mM NaCl + 0.1 mMCaSO4 with or without ABA. Each value is the mean of three replicates, ± standard error.

Time (h)	Transport of Na^+ from root to shoot (Ψcx), mg/shoot				Net influx of Na^+ (Ψoc), mg/plant				Transport index=($\frac{\Psi cx}{\Psi oc}$ X 100)			
	Control	10^{-7}M	10^{-6}M	10^{-5}M	Control	10^{-7}M	10^{-6}M	10^{-5}M	Control	10^{-7}M	10^{-6}M	10^{-5}M
0-3	0.0704 ±0.0005	0.0504 ±0.0002	0.017 ±0.0006	0.015 ±0.0007	0.125 ±0.0009	0.090 ±0.0009	0.050 ±0.0007	0.0282 ±0.0009	56.31	56.00	54.00	53.19
0-6	0.087 ±0.0004	0.062 ±0.0010	0.032 ±0.0001	0.028 ±0.0010	0.157 ±0.0012	0.120 ±0.0013	0.057 ±0.0005	0.051 ±0.0012	55.41	51.67	56.14	54.90
0-24	0.138 ±0.0003	0.095 ±0.0003	0.036 ±0.0001	0.028 ±0.0010	0.218 ±0.0005	0.157 ±0.0006	0.062 ±0.0003	0.051 ±0.0011	66.34	60.51	58.06	54.90
0-48	0.186 ±0.0007	0.109 ±0.0009	0.038 ±0.0002	0.032 ±0.0001	0.282 ±0.0010	0.183 ±0.0011	0.064 ±0.0003	0.057 ±0.0003	66.67	59.56	59.38	54.14

The effect of ABA on net influx and long transport Cl^- in intact mustard seedlings

In the intact mustard seedlings, 10^{-7} M ABA inhibited net in flux (ΨOC) of Cl^- by 14 and 43% at 3 and 6h of treatment, respectively (Table III). 10^{-6} M ABA decreased net in flux (ΨOC) of Cl^- by 16.3 and 14.5% at 3 and 48h of treatment, respectively. 10^{-5} M ABA also caused an inhibition of net influx of Cl^- from the root to the shoot from 40.1 to 45.2% over a period of 3 to 48h of treatment.

In the intact mustard seedlings, 10^{-7} M ABA decreasedlong distance transport (ΨCX) of Cl^- from the root to the shoot by 18, 37.8 and 13.6% at 3, 6 and 48h of treatment (Table III). In the same way, 10^{-6} M ABA inhibited long distance transport of Cl^- from the root to the shoot by 12.4, 28.4 and 21.8% at 3, 6 and 48h of treatment, respectively. 10^{-5} M ABA also decreased long distance transport of Cl^- from 57.1 to 59% over a period of 3 to 48h of treatment.

10^{-7} M and 10^{-6} M ABA had no effect on transport index of Cl^- whereas 10^{-5} M ABA decreased transport index of Cl^- over a period of 3 to 48h of treatment (Table III) .

These results support the view that plant hormones exert differential effect on ion transport in various species (Van Steveninck, 1976)[22].

ABA, at different concentrations, inhibited net influx (ΨOC), long distance transport (ΨCX) and transport index of K^+, Cl^- and Na^+ from the root to the shoot of intact mustard seedlings (Table I, II and III). Roberts and Snowman (2000)[19] used radiotracers and reported that ABA applied to excised barley roots decreased the net efflux of K^+ and Cl^- from the stelar cells to the xylem vessels, but was without effect on the net uptake of these ions in the root cortex.

Table III. The effect of ABA on net influx and long distance transport of Ci- in intact mustard seedlings placed in 0.5 mM KCl + 0.1 mMCaSO4 with or without ABA. Each value is the mean of three replicates, ± standard error.

Time (h)	Transport of Cl^- from root to shoot (Ψcx), mg/shoot				Net influx of Cl^- (Ψoc), mg/plant				Transport index=($\frac{\Psi cx}{\Psi oc}$ X 100)			
	Control	10^{-7}M	10^{-6}M	10^{-5}M	Control	10^{-7}M	10^{-6}M	10^{-5}M	Control	10^{-7}M	10^{-6}M	10^{-5}M
0-3	0.105 ±0.002	0.070 ±0.004	0.092 ±0.0003	0.045 ±0.0001	0.147 ±0.0004	0.126 ±0.0006	0.142 ±0.0005	0.088 ±0.0006	71.43	71.43	64.79	51.14
0-6	0.148 ±0.004	0.092 ±0.003	0.106 ±0.0002	0.059 ±0.0005	0.203 ±0.0006	0.136 ±0.0005	0.17 ±0.0004	0.108 ±0.0008	72.91	67.65	62.35	54.63
0-24	0.190 ±0.0003	0.188 ±0.0005	0.188 ±0.0002	0.091 ±0.0004	0.271 ±0.0005	0.27 ±0.0007	0.29 ±0.0003	0.158 ±0.0006	70.01	69.63	64.83	57.59
0-48	0.243 ±0.0002	0.210 ±0.001	0.190 ±0.0003	0.100 ±0.0003	0.33 ±0.0004	0.295 ±0.0004	0.282 ±0.0009	0.181 ±0.0006	73.64	71.19	67.38	55.25

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