Bot. Bull. Academia Sinica 24: 1-9 (1983)

RESPONSE OF SEED GERMINATION AND HYPOCOTYL AND ROOT LENGTH OF TOMATO TO SOME MONOVALENT AND DIVALENT CATIONS

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(Received June 5, 1982; Accepted September 22, 1982)

Abstract

Tomato seeds (*Lycopersicon esculentum* cv. Pearson A-1 improved 11010-17110) were tested for the germination response to the presence of NaCl, KCl, NH_4Cl, $CaCl_2$, $MgCl_2$ and $MnCl_2$ at the concentrations ranging from 10 to 120 meq/l in the incubation media. The hypocotyl and root length of germinated seeds under these conditions were recorded. These elements stimulate both germination and the length at the concentrations as low as 0.05 meq/l for Mg and Mn and 10 meq/l for the other cations, but inhibit germination at higher concentrations above 43, 46, 28, 64, 45 and 35 meq/l for NaCl, KCl, NH_4Cl, $CaCl_2$, $MgCl_2$ and $MnCl_2$ respectively. Length of root is inhibited at concentrations above 22, 30, 12, 65, 5, and 0.9 meq/l while that of the hypocotyl is above 28, 52, <10, 33, 5, and 1.2 meq/l in the same order of cations.

Introduction

Germination of plant seeds can be stimulated, suppressed, or inhibited by a very wide array of substances. Among these substances are those that decrease the osmotic potential of the media such as mannitol and sodium chloride. Uhvits (1946) has shown that mannitol frequently gives results somewhat different from those obtained with sodium chloride which was ascribed to the ionic toxicity of the salt. Later, Hayward and Bernstein (1958) concluded that crop plants differ in their tolerance to salinity (excess of soluble salts in the root media) and the most common response is the suppression of growth. The effect of monovalent cations on the growth response in cucumber hypocotyl segments have been reported (Purves, 1966). The results indicate that a concentration of 0.02 N K^+ ion stimulated the elongation of the segments after 14 hours of treatment. Other monovalent ions did also enhance the elongation but the divalent ions of $CaCl_2$, $CoCl_2$, and $MgCl_2$ did not. Purves conclusion was that nutritional requirement for

K^+ in higher plants results from a specific and non-specific role related to the elongation response. Eaton (1942) did study the effect of addition of either 50 or 150 mg Eq./l as NaCl to the base nutrient media on the growth, leaf size, plant pH, and water requirement of tomato plant grown outdoor in sand culture. Based on his work, he classified tomato plants as medium tolerant to salinity.

Since some arid regions are characterized with high salt content in their soil and one of the problems is germination and establishment of crops under these conditions, it seems more logic in our research program to study, first of all, the effect of ion concentrations either monovalent or divalent on an intact system rather than the use of excised tissue, and use seeds rather than established seedlings. In this study, the most common tomato seeds used by the farmers in this region were selected to evaluate the effect of monovalent chlorides of sodium, potassium, and ammonium and the divalent chlorides of calcium, magnesium, and manganese on the germination and both root and hypocotyl length of the seedlings. The effect of another anion (sulfate) of these salts was alao tested and is under publication elsewhere.

Materials and Methods

Seeds of tomato *Lycopersicon esculentum* cv. pearson A-1 improved 11010–17110) were washed three times with distilled water and dried to remove Arson (Thirom) with which seeds were treated. All treatments were four replicates where each petri dish contained 25 seeds that were put on a whatman #42 filter paper and wetted with 10 ml of either the control (distilled water) or one of the treatment solutions. These were the chlorides "Analar" of the following cations: Na*, K, NH_4, Ca, Mg, and Mn in progressively increasing concentrations from 10, 20, 40, 60, 80, 100 and to 120 meq./l unless stated otherwise. Incubation conditions were constant temperature of 23°C in the dark for 8 days. The humidity were kept close to 90% by maintaining a fan blowing over a large container full of water inside the incubator. Light was avoided whenever possible except when taking the measurements. Seeds were considered germinated whenever the radicle protruded. The length of radicle or hypocotyl were recorded at the end of the 8th day of incubation period.

Results

Salts used in the study are the chlorides of monovalent cations Na, K, NH_4 and divalent cations Ca, Mg, and Mn. The effect of progressively increasing their concentration on germination of tomato seeds is shown in Figs. 1 and 2.

* The sign hereafter is ommitted, assuming the reader should bear it in mind.

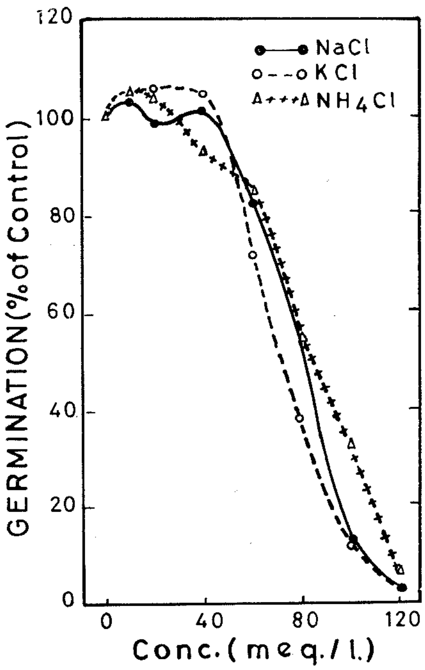

Fig. 1. Effect of concentration of monovalent cations in the incubation media on germination of tomato seeds after 8 days.

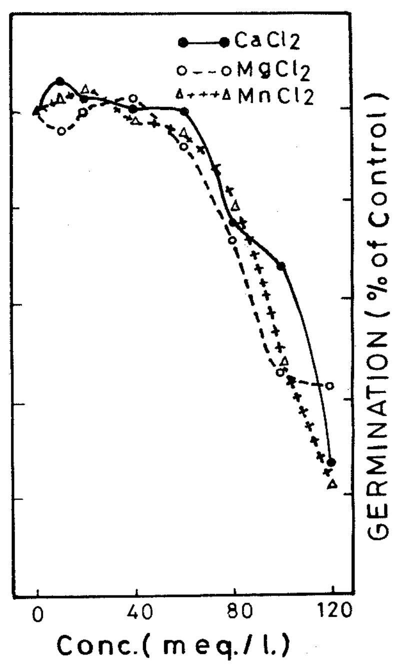

Fig. 2. Effect of concentration of divalent cations in the incubation media on germination of tomato seeds after 8 days.

Figure 1 indicates that all the three monovalent cations slightly stimulated germiantion of tomato seeds at the concentrations as low as 40 meq./l. The threshold tolerance (the highest concentration of the cation that did not reduce the germination below the control) of these cations is 43, 46 and 28 meq./l for Na, K and NH_4, respectively. Progressive inhibition occurred at the concentrations higher than that mentioned and the 50% inhibition of seed germination by these cations is at 82, 72 and 85 meq./l for Na, K and NH_4, respectively. Thus, the effect of these cations were differentiated.

The effect of divalent cations, as presented in Fig. 2 shows more or less similar trend to that of monovalent, but the effective concentration was noticeably higher than that of monovalent as indicated by the following values of the threshold tolerance and inhibition. The threshold tolerance of these cations is 65, 45 and 35 meq./l for Ca, Mg and Mn respectively, while the 50% inhibition is at 110, 95 and 98 meq./l for those cations in the same order. One interesting result in the difference between the effect of divalent and monovalent cations is the degree of inhibition. The lowest germination obtained with all the three divalent cations at 120 meq./l was above 20% whereas the corresponding values for the monovalent cations was 6% or less, i.e. very severe inhibition occurred.

The length of the emerging root and hypocotyl of the germinated seeds as affected by the various concentrations of the cations is presented in Figs. 3, 4, 5 and 6. As shown in Fig. 3, Na and NH_4 stimulated radicle elongation at lowest concentrations whereas both cations showed inhibitory effect at higher concentrations. The K effect was some what inconsistant but was generally inhibitory. The threshold tolerance of these cations was 22, 30 and 12 meq./l in the same order. Figure 4 illustrates the effects of the monovalent cations on hypocotyl length. It could be seen that both Na and K were stimulatory at low concentrations but NH_4 on the other hand was generally inhibitory. The threshold tolerance for Na, K and NH_4 was 28, 52, and less than 10 meq./l respectively while these cations produced 50% inhibition at 64, 67, and 67 meq./l in the same order.

The corresponding effect of the divalent cations on growth of radicle and hypocotyl is shown in Figs. 5 and 6. In this respect, the divalent cations fell into 2 distinct groups, Ca on one hand and both Mg and Mn on the other hand. Calcium markedly increased radicle growth at concentration up to 60 meq./l i.e. its effect on radicle growth paralleled with its effect on seed germination (see Fig. 2). Moreover, Ca exhibited moderate stimulation on hypocotyl growth (Fig. 6). On the other hand, both Mg and Mn severly inhibited radicle growth even at their lowest concentration used. The highest inhibition caused by the highest Ca concentration was even slightly lower than the lowest inhibition caused by the lowest concentration of either Mg and Mn. The inhibition of hypocotyl growth exhibited by both Mg and Mn was much less severe than it was on radicle growth. The threshold tolerance of the radicle growth for Ca, Mg, and Mn was 65, <10, and <10 meq./l and the 50% inhibition was at 88, <10, and <10 meq./l respectively. The values of threshold tolerance of hypocotyl growth for Ca, Mg, and Mn were 33, <10, and <10 meq./l while the 50% inhibition was at 86, 12, and 10 meq./l in the same order.

These findings clearly indicate the differentiated response of both root and hypocotyl of tomato to these divalent cations. The following experiments were carried out to clarify the exact effect of Mg and Mn cations. Seeds were germinated as mentioned before but the concentrations of 0.05, 0.1, 0.5, 1.0 and 5.0 meq./l of either Mg or Mn were employed. The response of germination to the increasing concentrations of both cations is illustrated in Fig. 7. which indicates similar trend to that of other cations, i.e. low concentrations stimulated the germination process. The effect of these two cations on radicle and hypocotyl growth is graphically illustrated in Figs. 8 and 9. These figures clearly reveal the masked effect because of high concentrations

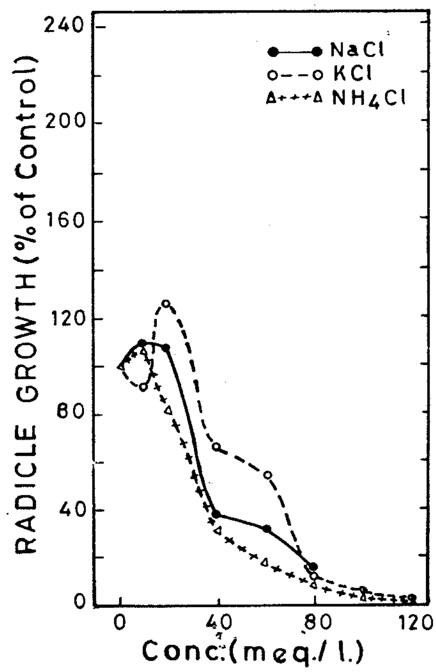

Fig. 3. Effect of concentrations of monovalent cations in the incubation media on the radicle growth of germinating tomato seeds after 8 days.

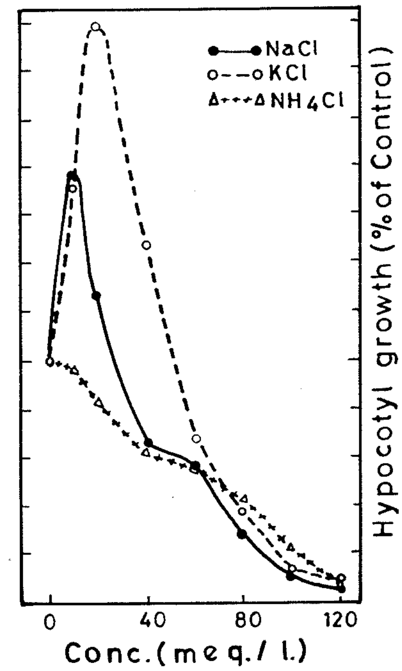

Fig. 4. Effect of concentration of monovalent cations in the incubation media on hypocotyl length of germinating tomato seeds after 8 days.

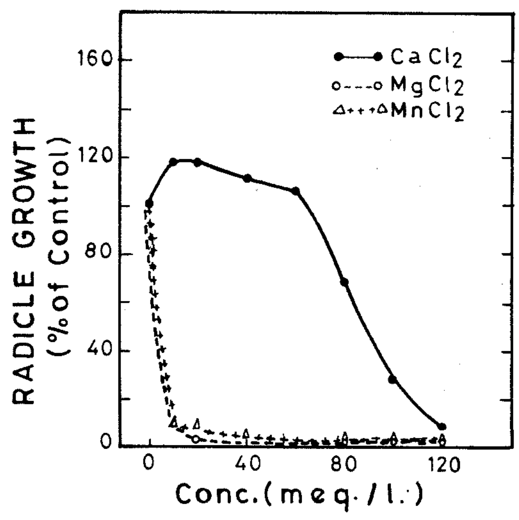

Fig. 5. Effect of concentration of divalent cations in the incubation media on the radicle growth of germinating tomato seeds after 8 days.

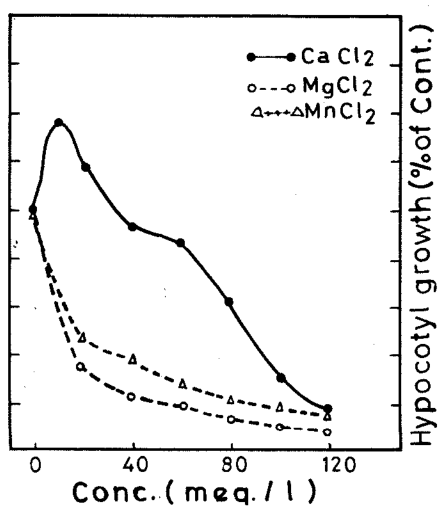

Fig. 6. Effect of concentrations of divalent cations in the incubation media on hypocotyl length of germinating tomato seeds after 8 days.

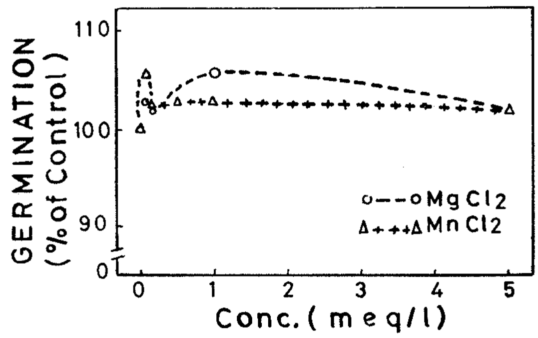

Fig. 7. Effect of concentrations of Mg and Mn cations in the incubation media on germination of tomato seeds after 8 days.

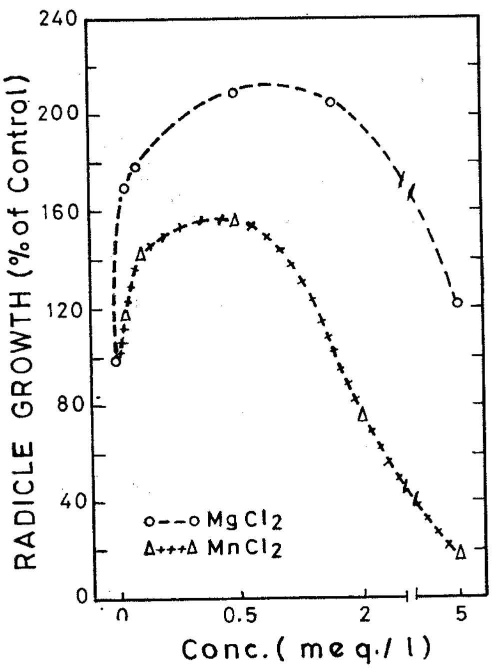

Fig. 8. Effect of concentrations of Mg and Mn cations in the incubation media on radicle growth of germinating tomato seeds after 8 days.

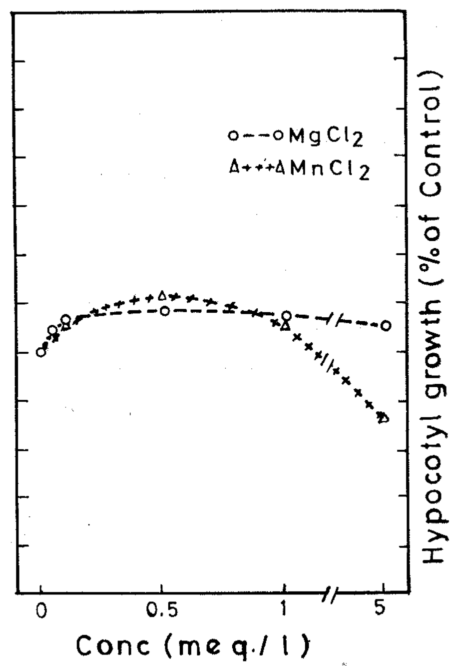

Fig. 9. Effect of concentrations of Mg and Mn cations in the incubation media on hypocotyl length of germinating tomato seeds after 8 days.

used in the previous experiment (Figs. 5 and 6). Both cations (Mg and Mn) did stimulate lengthening of roots (Fig. 8) at the lower concentration, where the threshold tolerance of radicle growth was >5 <10 and 0.9 meq./l while 50% inhibition was at >5 <10 and 3 meq./l respectively. As for the effect of these cations on hypocotyl growth the threshold tolerence was >5 <10 and 1.2 meq./l and the 50% inhibition was at 12 and 15 meq./l in the same order. In general, as these parameters indicate, Mg exerted higher stimulatory effect on radicle growth at 0.5 meq./l than Mn.

Discussion

The germination of tomato seeds in response to varying concentrations of monovalent cations suggests a general trend of all the cations studied, i.e. low concentrations stimulate germination where each cation has an optimum, then inhibition proceeds with progressively increasing the concentration (Fig. 1). The degree of stimulation is in the following order $K > Na > NH_4$ as would be expected because it is well known that plants do not accumulate NH_4 and high concentration of this cation inhibit the production of ATP (cited in most textbooks of plant physiology, for example Salisbury and Ross 1979). Concentrations of these cations above the threshold tolerance are suspected to be toxic especially NH_4, besides their effect on increasing the osmotic potential of the media and the decrease in osmotic potential of cells as monovalent cations increases the hydration of cell colloids while divalent cations decrease it (Gauch, 1972). This point is indirectly implied from the results of the divalent cations effect on germination (Fig. 2), where germination is still insignificantly affected even at higher concentrations as indicated by the threshold tolerance (above 40 meq./l) and the 50% inhibition mentioned in the results. The results also revealed that monovalent cations suppressed germination at 120 meq./l while the divalent cations did not. This could be due to a combination of an osmotic effect and a level of toxicity depending on the cation and the range of concentration.

Hypcotyl and radicle growth of germinating seeds responded differentially according to concentration of the salt in use as illustrated in the results (Figs. 3, 4, 5 and 6). Except for K effect, these results do not agree with those obtained by Purves (1966). This disagreement might be due to the use of an intact system in our study while Purves used excised cucumber hypocotyl. This indicates that the use of an intact system is more sensitive in the response to cations, since it was noted that excised tissue do not respond to treatment until a lag of time (14 hours in Purves experiments). The enhancement of hypocotyl length by K treatment (Fig. 4) support the conclusion of Purves (1966) that nutritional requirement for K is essential. The same findings were reported by Cooil (1951) on the enhancement effect of various K and Na salts on growth of young Avena seedlings.

An interesting result is the effect of the divalent cations (Figs. 5 and 6) on the radicle and hypocotyl growth of tomato where Ca treatment exhibited the general trend of stimulation and inhibition similar to the effect of monovalent cations, while Mg and Mn showed inhibitory effect at all equivilant concentrations studied. However, at the concentrations as low as 10 meq./l, Mg and Mn cations show the same trend. Again these results are in contrast with other results mentioned earlier with excised systems. It is clear that at the concentrations of both monovalent and divalent cations studied, their osmotic potential in the incubation media is different. Calculation of their osmotic potential would not add much because it has been shown by Younis and Hatata (1971) that the osmotic activity of mannitol solution was higher than that of NaCl, Na_2SO_4, KCl, K_2SO_4, $MgCl_2$ and $MgSO_4$ solutions which was proved to be suppressive on the germination of wheat.

Finally, results of this paper suggest that addition of any cation to the incubation media causes inhibition of germination and suppression of both hypocotyl and radicle growth whenever the concentration of added cation is above what is considered to be adequet for normal growth of the plant. It is still premature for the program to reach a convincing conclusion related to the problems of germination and establishment of seedlings of crops in highly saline soils based only on these results except all other basic information such as interaction of these cations as well as other anions, which we intend to investigate, are available.

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單價及二價氯化物對番茄種子的發芽及其胚莖和根生長的影響

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本篇論文探討鈉、鉀、氨、鈣、鎂及錳等氯化物（濃度在 10～120 毫當量/公升）對番茄種子發芽的影響。在上述條件下記錄胚莖及根的長度。實驗結果顯示鎂及錳的濃度在 0.05 毫當量/公升，其他離子濃度在10毫當量/公升時對發芽以及胚莖及根的生長有促進作用。但是鈉、鉀、氨、鈣、鎂及錳的濃度分別在 43、46、28、64、45及35 毫當量/公升以上時，對發芽有抑制作用。這些離子濃度分別爲 22、30、12、65、5 及0.9 毫當量/公升以上時對根的生長有抑制作用。其濃度分別爲 28、52、<10、33、5 及1.2 毫當量/公升或以上時對胚莖的生長有抑制作用。