EFFECTS OF OSMOTIC CONCENTRATION AND PH ON PLANT GROWTH[1]

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Abstract: Osmotic concentration and pH may inhibit the seed germination and radicle growth of lettuce. At 25 milliosmols, an aqueous solution of Hoagland, sodium chloride, and sucrose exhibits over 50% inhibition on the radicle growth of lettuce. However, mannitol solution reveals 50% inhibition only at concentrations above 125 milliosmols. The pH range of from 4 to 8 has only slight significant effect on the radicle growth of lettuce. Interaction between pH and osmotic effects is not evident. Compared with aqueous plant extracts, the nutrient solutions give less inhibition. The results of this study can be used as an indication of a solution of which the cause of inhibition is due to one or both of the aforementioned effects, or due to a phytotoxic effect.

INTRODUCTION

The inhibition of seed germination and radicle growth is not always due to toxic substances, but sometimes is due to osmotic concentration and pH. In some cases, osmotic pressure is one of the most important inhibiting agents. Evan (1949) reported that grape juice at the osmotic pressure of 35–37 atm inhibited seed germination and that the glucose content at this pressure was 19.4%. When the solution was diluted to 2.1 atm, however the germination of seeds increased to 47 percent. Therefore, he concluded that the high osmotic pressure of glucose content (over 19.4%) could significantly inhibit seed germination of many plants. Additionally, many investigators (Koeckemann, 1934; Kaufmann, 1943; Chou, 1971) obtained similar results from a variety of plant extracts. On the other hand, plant growth can be suppressed by a solution with high acidity. For instance, lemon juice at pH 2.5 significantly inhibited seed germination (Evan, 1949). In addition, soil pH often plays a role in regulating plant growth, resulting in a change of the vegetation (Daubenmire, 1967).

Since 1950 only a few investigations dealing with the effects of osmotic concentration and pH on seed germination and radicle growth have been reported (Ehling, 1964; Strogonov, 1964). However, the sophisticated instruments developed in recent years have made it possible for us to precisely determine the osmotic concentration and the pH of a solution. Thus, the authors of this report were able to demonstrate in more detail the possible effects of osmotic concentration and acidity on the seed germination and radicle growth of lettuce. The results of this study could eventually be used as an indication of a solution of which the cause

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of inhibition is due to one or both of the aforementioned effects, or due to an unknown toxic substance.

MATERIALS AND METHODS

Preparation of solutions:

Aqueous solutions were prepared from the following chemicals: sodium chloride, mannitol, sucrose, mannitol plus sodium chloride (1:1, g/g), mannitol plus sucrose (1:1, g/g), and the Hoagland's solution. Each solution was prepared in an osmotic series of 0, 25, 50, 75, 100, and 125 milliosmols, using a Fiske osmometer G-66. Solutions were then adjusted to five different pH values (4, 5, 6, 7, and 8) with a Chemtrix type-40 pH meter. Aqueous extracts were prepared from such grasses as: *Chloris gayana*, *Cortaderia selloana*, *Cynodon dactylon*, and *Digitaria decumbens* collected from TSC Farm Animals Breeding Station at Chunan. Leaves of the grasses were chopped into small pieces about 2.5 cm in length. To 10 grams of chopped leaves, 100 ml of distilled water was added, and shaken for 2 hr. Aqueous extracts were then obtained, using the same techniques as described by Chou and Chung (1974). Each extract was finally adjusted to pH 6, and osmotic concentration of 25 milliosmols before bioassaying.

Bioassay of solutions:

The inhibitory effect revealed by each solution mentioned was determined by means of the sponge bioassay (Chou and Chung, 1974). Seeds of lettuce (*Lactuca sativa* var. Great Lake 366) were used as the test material. The distilled water was treated with the same processes so as to serve as a control. Seeds were incubated for 72 hr in a growth chamber at 25°C, and the germination percentage and length of radicle were recorded. The length of radicle growth of the control was treated as 100%; thus, the growth for each treatment was obtained in percentage.

Statistical analyses:

The biossay data was analyzed by means of analysis of variance; the F values of least significant difference (L. S. D.) at 1% and 5% levels were obtained.

RESULTS

Inhibition of inorganic substances on plant growth:

A series of the Hoagland's solution, 5%, 10%, 25%, and 50% was bioassayed against lettuce seeds. The distilled water was also bioassayed as control. As shown in Table 1, the Hoagland's solution without dilution completely inhibited seed germination; the inhibition decreased with increasing the level of dilution. When the non-germinated seeds were washed with distilled water and re-incubated for another 72 hr, they all germinated. This indicated that the non-germinated seeds were not killed but inhibited by the solution. The inhibition was probably due to the osmotic effect rather than toxins.

On the other hand, Fig. 1 shows the effects of different osmotic concentrations and pH values on the radicle growth. The inhibition increased with the increase of osmotic concentration; and at 25 milliosmols each of the solutions which were

Table 1. Effect of Hoagland's solution on radicle growth of lettuce. Length of radicle was measured in millimeters.

	Distilled water (control)	Concentration				
		5%	10%	25%	50%	100%
Replication	12.26	4.9	4.4	4.0	2.58	0
	10.62	5.1	5.9	4.1	3.0	0
	8.8	6.5	5.5	4.2	2.45	0
Means	10.53	5.5	5.3	4.12	2.73	0
% of control		52*	50*	39*	26*	0*

* Significant differences from the control at the 1% level of confidence, using analysis of variance.

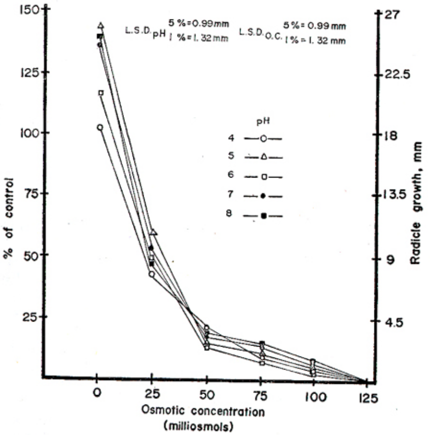

Fig. 1. Effects of Hoagland's solution with a series of osmotic concentrations and pH on radicle growth of lettuce.

prepared, showed that their cation concentrations ranged from 200 to 500 ppm when analyzed with an atomic absorption spectrophotometer (Perkin-Elmer, model 300); and when the osmotic concentration was increased to 125 milliosmols, the seed germination was completely inhibited.

Results of a sodium chloride series are presented in Fig. 2. At 25 milliosmols the inhibition reached from 60–70%, while the inhibition was raised to 80 to 90% at 125 milliosmols. By means of statistical analysis, both osmotic and pH effects differed significantly from each other.

Inhibition of carbohydrates on plant growth:

The results of mannitol bioassay are given in Fig. 3. It is evident that the inhibition revealed from the mannitol solution was much lower than that of Hoagland's and NaCl solutions. Compared with the control, for example, the inhibition at 25 milliosmols ranged from 11 to 35%, while at 125 milliosmols the inhibition was around 50%. The effect of pH was less significant than that of osmotic concentration.

The bioassay results of sucrose solution are given in Fig. 4. The inhibition caused by sucrose solution was higher than that by mannitol solution. The suppression of radicle growth varied from 55 to 75% of the control. In addition, the solutions at pH 5 and 6 gave singificant inhibition. The difference of inhibition between mannitol and sucrose is probably due to their molecular structure since the former is a monosaccharide and the latter a disaccharide.

Inhibition of a mixed solution on plant growth:

Since a plant extract is a mixture of organic and inorganic substances, the additive or antagonistic effect of the mixture on lettuce growth is not fully understood. Thus, a solution mixed with mannitol and sodium chloride, or sucrose was bioassayed by using the aforementioned techniques, and the results are shown in Fig. 5. As compared with that shown in Fig. 2 and 3, the pattern of radicle growth from the different treatments is almost identical, but the inhibition caused by the mannitol-NaCl solution is intermediate between the two solutions. This is similar to the result of antagonistic effect caused by a pure solution. The effect of osmotic concentration differed significantly from one treatment to the other, but the effect of pH was not significant.

Similarly, when a solution mixed from two carbonhydrates, such as mannitol and sucrose, was bioassayed, the results of fluctuation were dependent upon the use of osmotic concentration (Fig. 6). The level of inhibition revealed by this mixed solution was between those caused by the two solutions which were prepared from a single carbonhydrate. This phenomenon is likely due to the antagonistic effect of the two pure solutions. However, no additive effect was found.

Comparison of inhibition on radicle growth with different plant extracts and nutrient solutions.

The results of the inhibition caused by different plant extracts and nutrient solutions are shown in Fig. 7. The growth of lettuce was generally poor as affected by these plant extracts. Among them, the extracts from *Digitaria decumbens* exhibited the highest inhibition, and the extracts of *Cortaderia selloana* the least. However, mannitol solution under the same conditions revealed no significant inhibition.

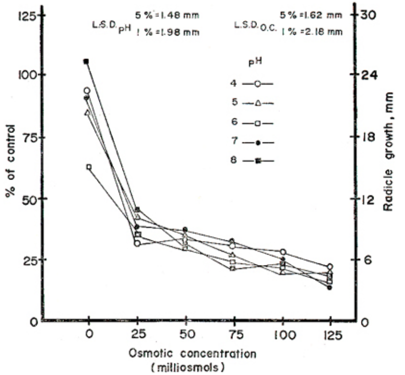

Fig. 2. Effects of aqueous solution of sodium chloride with a series of osmotic concentrations and pH on radicle growth of lettuce.

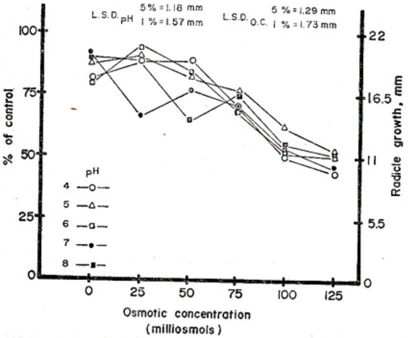

Fig. 3. Effects of mannitol solution with a series of osmotic concentrations and pH on radicle growth of lettuce.

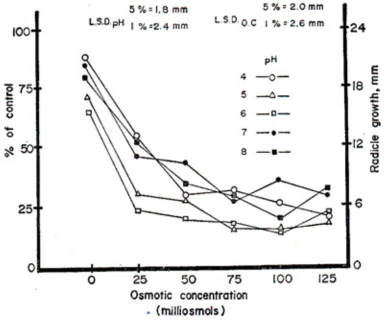

Fig. 4. Effects of sucrose solution with a series of osmotic concentrations and pH on radicle growth of lettuce.

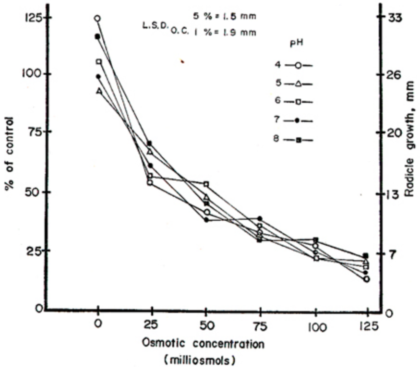

Fig. 5. Antagonistic effect of a solution mixed with mannitol and sodium chloride in a series of osmotic concentrations and pH on radicle growth of lettuce.

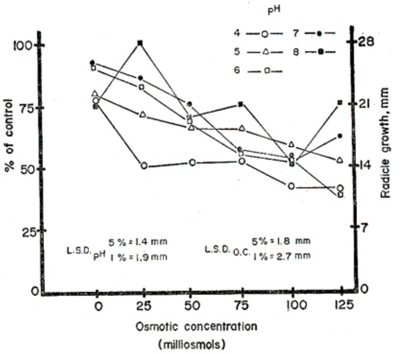

Fig. 6. Antagonistic effect of a solution mixed with mannitol and sucrose in a series of osmotic concentrations and pH on radicle growth of lettuce.

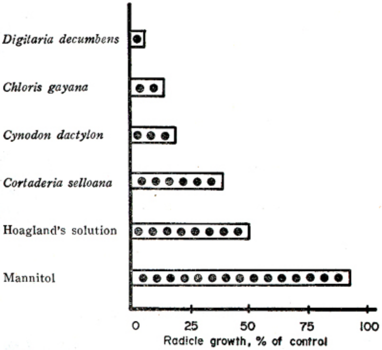

Fig. 7. Effects of aqueous plant extracts and nutrient solutions on radicle growth of lettuce. The pH of these solutions was at 6, and osmotic concentration at 25 milliosmols. Results of treatments were significantly different from each other at the 1% level, using the analysis of variance.

DISCUSSION

Evidently, results from these experiments indicate that any kind of aqueous solution, e. g., mannitol, sucrose, NaCl, and Hoagland's solution may able to inhibit the seed germination and to suppress the radicle growth of lettuce when the osmotic concentration of a solution is over 25 milliosmols. Thus, when the concentration of a plant extract is high, the suppression of growth may be due to the osmotic effect. Chou (1971) reported that the aqueous extract of *Arctostaphylos* pericarp could suppress the growth of herbs. However, comparing the osmotic concentration of the 5% extracts of bark with pericarp, the former was 10 milliosmols and the latter 150. The suppression of growth caused by the pericarp extract was primarily due to the osmotic effect, although a small amount of phytotoxic substances was found. In our recent findings, extracts borne many herbaceous leaves may suppress the growth of lettuce, when the osmotic concentration is below 25 milliosmols. This inhibition may then be mainly due to a toxic substance rather than the osmotic effect.

Strogonov (1964) reported that at the equal osmotic concentration, NaCl depressed the germination of alfalfa seed much more than did mannitol. We obtained the similar results as above (Fig. 2 and 3). However, Levitt (1972) concluded that the inhibition caused by NaCl was not due to the osmotic concentration but by the anion of Cl^-. It is very possible that plant extracts may contain a certain amount of Cl^-; nevertheless, the evidence we now have is not able to support this idea.

The results shown in Fig. 5 and 6 show the antagonistic effects appearing from a mixed solution. As far as natural extracts of plant are concerned, the extracts always consist of a variety of substances, such as amino acids, carbohydrates, phenolics, alkaloids, and inorganic nutrients (Tukey, 1971). Thus, the effect of antagonism and chemical interaction in these extracts may be highly complicated. To an allelopathic worker, it seems impossible to eliminate such kinds of interactions. However, when the effects of osmotic concentration and acidity are eliminated, the inhibitory effect which is due to a toxic substance can therefore be considered.

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