**Short Communication**

**Effect of Salinity on the Time Course of Wheat Seedling Growth**

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The salt effect on germination is often thought of as a decrease in the percentage of seeds successfully germinated in a given time. It might be more illuminating, however, to consider the depression in percentage of germination as an extreme of the phenomenon of inhibition of seedling growth (4).

Imbibition by a seed initiates a sequence of interdependent physiological events which becomes, in a favorable environment, the mechanism of germination, growth, and development. Valuable insights into the identification of specific physiological processes affected by salt may be attained by comparing chronologies of development during germination of stressed and unstressed seeds.

As a beginning, we have conducted the following study. Wheat (*Triticum aestivum* var. INIA 66), germinating in 0.5 mM CaCl₂ solutions in the dark, was subjected to 0.1 M NaCl salinity either continuously or for sequential 24-hr periods. Coleoptile growth rate was not suppressed by salt except for a 6- to 12-hr lag, which occurred between 36 and 48 hr after germination started. Roots showed a similar lag, but also a suppression of growth when salt was present in the culture after 48 hr. Removing the salt at any time restored normal growth rates.

**MATERIALS AND METHODS**

Seeds of *Triticum aestivum* var. INIA 66 were obtained from the Department of Agronomy, University of California, Davis, California.

For each replicate of each treatment, 25 seeds, selected for uniformity, were placed in a 400-ml beaker containing 100 ml of test solution. Each beaker was covered and aerated with filtered air through a glass aeration tube. Experiments were conducted at 25 ± 2°C in the dark.

Length measurements were made 45 cm from a 15-w incandescent light, filtered through an amber Kodak "OC" glass. The effect of this light was monitored by maintaining duplicate treatments in continuous darkness. These were measured and discarded, one at a time, at various intervals through the tests. No effect of the amber light was noted. Plantlets were handled by the seed, placed on moist glass over millimeter graph paper or directly against a millimeter rule for individual evaluation. Coleoptiles and roots were considered as extending from the midpoint of the coleorhiza to their respective tips.

The basal solution for these experiments was 0.5 mM CaCl₂. Certain levels of added Ca ion ameliorate NaCl effects on plants (1). However, preliminary trials indicated that the magnitude rather than time of salt damage is affected by Ca. Thus added Ca is useful in timed salt studies to produce plants of predictable vigor relative to controls. A subsequent report will deal with Ca-Na interactions on growth of wheat seedlings.

All experiments were designed with a power of 0.65: \( \alpha = 0.01 \), minimum contrast = \( \sigma \) (i.e. with a 65% probability of showing a difference as significant at the \( \alpha = 0.01 \) level if that difference was as large as the standard deviation [3]).

**Experiments 1, 2, 3. The Time Course of Wheat Coleoptile Growth in Sublethal NaCl Solution.** Salinity was applied to wheat through 0 to 144, 0 to 24, 24 to 48, 48 to 72 and 72 to 96 hr of germination. The salt level, 100 mM NaCl, was chosen to produce measurable differences in growth without a reduction in percentage of germination. The three experiments are essentially repetitions with one or two conditions altered. In experiment 1, coleoptile measurements were made every 6 hr, and original solutions (for continuous treatments) were maintained throughout. It revealed a possibly critical growth period for salt effect. This period was investigated in experiment 2 with shorter measurement intervals and daily changes of all solutions. Experiment 3 began with enough cultures to allow discarding a complete set after each measurement in the light. Data from that experiment are used only as checkpoints to assess the effect of amber light on the results of experiments 1 and 2.

**Experiment 4. The Time Course of Primary Root Growth in NaCl Solutions.** To avoid possible complications from prolonged handling in measurement of each treatment, root studies were carried out in a separate experiment, except that some root lengths were taken during the coleoptile studies to demonstrate the comparability of plant development in all experiments. Treatments and basal conditions were the same as described for experiment 2.

**RESULTS**

Coleoptiles of control plants elongated logarithmically from approximately 24 to 80 hr (Fig. 1). The maximum lengths attained agree with those of Feather et al. (2) for variety INIA. The plants in 100 mM NaCl solutions, either continuously or from 24 to 48 hr, experienced a growth lag for 6 or more hours, between 36 and 48 hr of germination, and then continued growing at the same rate and to the same maximum length as the controls. Salt applied for 24 hr periods other than from 24 to 48 hr had little or no observable effect on coleoptile extension. This surprising result is shown in Figure 1 (0-24 hr salt) and in Figure 1a.

Before 48 hr the roots, like the coleoptiles, showed (Fig. 2) a brief growth lag from 36 to 42 hr. The lag was the same in time and magnitude whether salt was applied from the beginning or from 24 hr. Salt also suppressed root growth after 48 hr, although it no longer affected coleoptile growth rates. Continuous or periodic salt treatments caused equal declinations from the slope of the control growth curve. Salt-affected roots, whenever transferred to nonsaline cultures, recovered relative growth rates equal to those of control roots.

Figure 2a illustrates the salt effects on primary and lateral roots separately. The time of the lag or of subsequent growth suppression was the same, regardless of the length attained before that by each rootlet.

**DISCUSSION**

The inactivity of an ungerminated wheat embryo is not entirely the result of dehydration, for imbibition does not
trigger a simultaneous activation of all metabolic processes. Instead, a chain of interdependent, physiological events is initiated. Such events (processes) may belong to the whole seed embryo and serve to trigger or support growth of the plantlet. Or they may be unique to a specific organ (coleoptile, root, etc.) and contribute to the maintenance of character and of normal response to growth stimuli.

If an organ's ability to respond normally to growth stimuli were impaired by stress, there would be no recovery so long as that stress was maintained. The same would be true if the nutrient supply to the embryo were impaired. But even in continuous salt stress, the lag occurring between 36 and 48 hr is followed by complete recovery in coleoptiles. Thus the lag at 36 hr manifests restraint of a triggering process.

The post-48-hr suppression of root growth contrasts with the lag at 36 hr in two ways. There is no recovery so long as salt remains present, and the effect occurs well after growth has begun. For these reasons, the post-48-hr suppression is interpreted as resulting from interference with a system which enables root response to growth stimuli. Since root growth recovers when salt is removed, the process or system in question is not destroyed, but merely restrained by salt.

The 36-hr lag may be an agronomically important effect, even though normal growth follows in the laboratory. It is understood that these observations are circumscribed by the experimental conditions; 25 C, 0.5 mm CaCl₂, basal solutions,

**Figure 1.** Time course of wheat coleoptile growth as influenced by salt treatments applied continuously and for the periods 0 to 24 and 24 to 48 hr. Salt applied for other 24-hr periods had no effect on coleoptile growth (1a). 1a: Data points from ineffective salt treatments in relation to control and continuous salt lines from Figure 1.

**Figure 2.** Time course of growth of an average seminal root as influenced by salt treatment, either continuously or for various 24-hr periods. Averaging primary and lateral roots (although they differ in time of development) is valid when showing the time of salt effect. The occurrence of the growth lag or the post-48-hr suppression was independent (2a) of the affected organ's length. 2a: Time course of growth of individual roots: I: primary root; II: average lateral root.

darkness, and 100 mm NaCl as salinity. In soil and during periods of temperature below 25 C, a brief delay in outgrowth might be exaggerated. A prolonged lag would allow severe attack of the softened, imbibed seed and embryo by bacteria and fungi. The importance of the post-48-hr suppression is more obvious. A constant restraint of root growth must cause a competitive disability of the plant to acquire water and nutrients. If these became deficient, a secondary reduction in growth of the aerial shoot would certainly follow.

We are continuing to study these effects in order to develop more specific explanations.

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**LITERATURE CITED**