AN ABSTRACT OF THE THESIS OF

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in Farm Crops (Major) presented on August 30, 1971 (Date)

Title: PRESOAKING AND DRYING TREATMENTS TO IMPROVE THE PERFORMANCE OF ORCHARDGRASS AND BLUEGRASS SEED

Abstract approved: Redacted for Privacy
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The objective of this study was to develop a soaking and drying procedure to stimulate the germination and seedling emergence of orchardgrass (Dactylis glomerata L.) and Kentucky bluegrass (Poa pratensis L.) seed. Some of the physiological changes associated with the soaking and drying treatments were also studied.

The seed was soaked on top of blotters moistened with solutions of 200 ppm GA_3, distilled H_2O and 20, 000 ppm NaCl. The most beneficial results were obtained by soaking at 5 C for periods of 3 to 6 days. Following soaking, the seed lots were dried to their original dry weight and stored up to 8 months before testing.

The effect of the treatment on the performance of the seed was evaluated in terms of germination and growth measurements. Presoaked seed germinated up to one day earlier than the unsoaked

control. Radicle growth rate was not affected by any of the treatments. Seedling emergence from soil was more rapid after treatment. Germination tests conducted 8 months after presoaking indicated that the treatments had not caused any loss of viability during storage. Compared to water, there appeared to be little benefit from soaking in GA_3 and NaCl solutions.

Since seedling growth rates were not increased by the treatments, the beneficial results appeared to be related to the effects on germination rate. The small increase in imbibition rate and O_2 uptake by treated seeds may account for part of the accelerated germination. The treatments reduced the level of dormancy as indicated by the reduced requirement for alternating temperatures. Presoaking and drying treatments were most effective on cultivars and seed lots exhibiting higher levels of dormancy.

Presoaking and Drying Treatments to Improve the Performance of Orchardgrass and Bluegrass Seed

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1972

APPROVED:

Redacted for Privacy

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in charge of major

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Date thesis is presented August 30, 1971

Typed by Ilene Anderton for John Colson Haight

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to all those who have aided me during my research and preparation of this manuscript.

The National Science Foundation for providing a Traineeship during the two years of my graduate study.

A special thanks to Dr. Don F. Grabe, my major professor, for his guidance, encouragement and patience throughout my program.

Mr. Ed Hardin, Mr. Rodger Danielson, and all the women in the Oregon State University Seed Laboratory for providing equipment, seed and advice during my research.

Dr. Te May Ching for advice and for making her equipment available for my use.

Dr. Rod Frakes for help with the statistical analysis of the data in this study.

Mr. James Moran for help with making my data fit the computer programs.

Finally a special thanks to my wife Ranee, for her encouragement and assistance throughout my graduate program and who worked as a laboratory technician by day and a typist by night during the preparation of this manuscript.

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INTRODUCTION

Rapid establishment of uniform and vigorous seedlings is a major factor contributing to a successful crop. Faster germination and seedling growth tend to lessen the hazards to stand establishment caused by insects, disease, unfavorable weather, and incorrect management practices. Rapid stand establishment is also important in weed control, moisture utilization and early maturity of the crop.

Accumulating evidence indicates that certain preplanting treatments can increase the growth performance of seed. In recent years magnetic treatment has been found to stimulate some crop seed. Stimulation from irradiation of seed with X-rays and gamma rays has also been claimed. Hard seed of some legumes can be broken by using radio waves. Application of growth regulators and presoaking and drying seed before planting have been reported to increase seed performance.

Soaking and drying of seed was first shown to be beneficial by several German scientists in the 1880's. Later studies indicated that germination speed, emergence rate and yield could be increased by soaking and drying. It has also been reported that beneficial

results of the treatment were greatest under unfavorable conditions for germination and growth (May, Milthorpe and Milthorpe, 1962).

The objectives of this study were threefold: (1) to develop a satisfactory presoaking and drying treatment for seed; (2) to determine the effect of the treatment on seed performance; and (3) to examine the physiological changes associated with the improved performance. Orchardgrass (Dactylis glomerata L.) and Kentucky bluegrass (Poa pratensis L.) were chosen for study because of their inherently long germination and establishment periods.

LITERATURE REVIEW

Early Workers

The earliest evidence of attempts to improve the performance of seeds through preplanting treatments appears to be that of Sir Kenelm Degby, who in 1660 AD, found that by soaking corn (Zea mays L.) seed in saltpeter and other substances, he produced a "plentiful harvest" (Degby, 1660).

In the late 1800's several German scientists were experimenting with presoaking of seed prior to planting. Kraus in 1881 and Wollny in 1885 found that if seed was properly soaked and dried the performance of the seed could be improved (Kidd and West, 1918b). In field trials the treated seed produced plants which yielded more than the control plants. Will in 1883 reported that soaking and drying seed increased drought and frost resistance of the plant (Kidd and West, 1918b). Kinzel in 1899 reported results which confirmed the earlier work by Kraus and Wollny (Chippindale, 1933a).

Methods of Increasing Seed Performance

In the twentieth century many preplanting techniques were explored. Some of these treatments included soaking with different chemical solutions under a variety of conditions. Such techniques as

magnetism, radiation, ultrasonics, glow discharge, weightlessness and increasing the protein content have been employed as preplanting treatments.

Magnetism

Commoner et al. (1957) demonstrated in vitro the presence of unpaired electrons in enzymatic reactions. It followed that magnetism may affect the reaction rate of enzymes since paramagnetic molecules and free radicles are present. Magnetic responses in plants have been studied by Audus (1960), Tarakanova et al. (1965) and Pittman and Ormrod (1971).

Krylov and Tarakanova (1960) reported that magnetism affects the germination of seed. They germinated seed in the field of a permanent magnet and observed that during germination the radicle had a tendency to grow in the direction of the south magnetic pole. They also observed that corn seed sprouted one day earlier when germinated with its embryo pointing toward the earth's south magnetic pole. The tempo of growth of these seedlings was greater than the ones with embryos pointing to the earth's north magnetic pole. However, Puma (1952) found that pointing the embryo of Vicia faba seed toward the south pole of a permanent magnet arrested the growth. He found that if the embryo was orientated in any other direction growth proceeded normally.

Work by Pittman (1963) tends to disagree with the reports of Puma and Krylov. He exposed dry seed of two wheat (Triticum aestivum L.) varieties to a magnetic field, then germinated the seed in the same magnetic field. The evidence from this experiment suggests that seed exposed and germinated with the embryo pointing toward the north pole responded better. In 1964 he confirmed that the roots of most winter wheat seedlings oriented themselves in a general north-south direction when grown in the field (Pittman, 1964). Growth rate of corn and beans (Phaseolus vulgaris L.) was increased by a pregermination exposure and seed orientation during exposure of normal seeds to an introduced magnetic field (Pittman, 1965). He has also shown that the respiration rate of magnetically treated seed of 'Kharkov 22 M. C.' winter wheat was slower during quiescence and germination (Pittman and Ormrod, 1970). Wheat seedlings grown from magnetically treated seed contained more moisture and more reducing sugars than the untreated control. Pittman and Ormrod (1970) summarized some of their work on magnetically treated seed in the following sentence:

> The exciting fact that magnetically treated wheat seed appears to respire more slowly, release heat energy more slowly, and yet grow faster than a similar seed not so treated suggests an increase in the efficiency of metabolism arising from a stimulus applied to the quiescent seed as well as the growing seedling (p. 216).

Irradiation

Accelerated germination of X-rayed seeds was first reported by Maldiney and Thouvenin in 1898 (Breslavets 1946). Evler in 1906 observed some cases of stimulation following irradiation of beans, radish, lettuce and squash seed (Breslavets 1946). A Japanese worker, Komuro reported in 1919 germination stimulation of X-irradiated rice (Oryza sativa L.) seed (Breslavets 1946). Shull and Mitchell (1933) showed that low doses of X-rays given to corn seed resulted in stimulation of early plant growth. These two men were so sure their process had practical significance that they patented it in 1932. Three Russian scientists, Breslavets, Afanas'eva and Medvedeva in 1935, reported remarkable increases in the growth and yield of rye (Secale cereale L.) when the seed was given a dose of 250 r (roentgen units) (Breslavets 1946). After a detailed study of the literature, Sax (1963) concluded that the claim that irradiation of seed results in better yields still lacks critical confirmation.

Nuttall et al. (1968) irradiated seven species of vegetable seed including corn, cucumber (Cucumis sativus L.), eggplant (Solanum melongena L.), lettuce (Lactuca sativa L.), pea (Pisum sativum L.), pumpkin (Cucurbita pepo L.), and tomato (Lycopersicon esculentum L.). They used three rates of gamma irradiation (100, 300 and

1, 000 rad) at a dose rate of 47.99 rad/min. The seed was treated in the dry condition five days before planting in the field. From these tests they concluded that low dose gamma irradiation of seed stimulated earlier maturity and increased yield in several of the species. Whelan (1970) reported different cultivars of cucumber responded differently to high levels of irradiation. He found statistically significant differences between emergence rates of the different cultivars.

There are three excellent reviews compiled on seed irradiation. Breslavets (1946) in her book Plants and X-rays published by the USSR Academy of Science in 1946 gave a very comprehensive review of irradiation of seed. This book was translated by Alena Elb, edited by Arnold H. Sparror and published by the American Institute of Biological Sciences in 1960. The International Atomic Energy Agency (1961) held a Symposium on the effects of ionizing radiations on seed. The proceedings of this meeting have been published in a book, Effects of Ionizing Radiations on Seeds. Sax (1963) wrote a review of the stimulation of plant growth by ionizing radiation in Radiation Botany.

Protein Levels

Ries, Schweizer and Chmiel (1968) found that by applying subherbicidal amounts of simazine (2-chloro-4, 6-bis(ethylamino)-s-

triazine), the protein content of beans, rice, oats (Avena sativa L.), and other crops could be increased. Later Schweizer and Ries (1969) reported that oat seed with high protein content yielded from 21 to 42% more grain than lower protein seed. Vergara, Miller and Avelino (1970) reported that application of simazine would increase protein content of commercial rice grain but at the cost of a reduction in the total grain and protein yields. Ries et al. (1970) reported that the second generation of wheat was most closely associated with seed protein content and not seed weight.

Lopez (1972) found that different levels of seed protein affected seed performance of wheat and barley (Hordeum vulgara L.). He obtained high and low protein seed by field application of nitrogen. The high protein seed exhibited a higher rate of water absorption and oxygen consumption than did the low protein seed. High protein seed germinated faster and developed into larger seedlings. He also found that the effects of high protein were more evident when the seed was grown under stress conditions.

Soaking

Several methods of soaking have been used by different researchers. Sometimes the seed was completely immersed in the solution and other times it was floated on the surface of the liquid. Still another method was to allow the seed to imbibe on top of wet

blotters. Sometimes the soaked seed was sowed while still wet but other times it was dried before sowing.

Soaked and Planted Wet. After the early workers such as Kraus, Wollny, Will, and Kinzel, many reports of seed soaking were published in the literature. Some workers used water as a soaking agent while others used different salt solutions. A good review of the work prior to 1918 is given in Kidd and West (1918b).

Kidd and West (1918a) immersed seed of peas, beans, barley, and sunflower (Helianthus annuus L.) in distilled water for varying lengths of time. Subsequent germination and growth rate tests revealed that germination could not be relied upon as a method of evaluation for presoaking. They observed that a decline in growth rate occurred before a decline in the germination rate. They also found that soaking was beneficial to wheat and oats. In 1919, the same two authors reported on the effect of temperature of soaking (Kidd and West, 1919). Their results indicated that soaking for any amount of time in excess water at any temperature was deleterious for Pisum sativum L. and Phaseolus vulgaris L. However, the injurious effect was more marked at low temperatures of soak. They thought that carbon dioxide in the colder water was more able to produce inhibition than at warmer temperatures. Eyster (1940) showed that the deleterious effects of soaking on bean seed was primarily due to the lack of oxygen, although some bacterial action

was present. Orphanos and Heydecker (1968), on the other hand, found that if the bean seed was dried after presoaking, no deleterious effect occurred.

Barton (1954), working with several tree and shrub seed, found that presoaking did not hasten germination or after-ripening. She tried several different temperatures and lengths of soaks.

Bleak and Keller (1969) studied the effect of seed age and the response to presoaking in water. They did not immerse the seed but soaked them on moist blotters. They found that the advantage from treatment of crested wheatgrass (Agropyron desertorum Fish. ex Link) was not altered by the age of the seed. They also found that presoaked crested wheatgrass seed germinated faster and produced larger seedlings when planted in the field.

Much work has been done on soaking with solutions other than water. Most of this work will be reviewed in the section Soaking and Drying; however, some will be covered here.

Popov (1962) reported yield differences by soaking bean seed in such solutions as gibberellin, K-salt of penicillin, heteroauxin, vitamin B_1, and tannin one day prior to planting. Korneev (1962), another Russian worker, found corn seed could be stimulated by soaking it in solutions of succinic and nicotinic acids. He found that the treated seedlings exhibited a faster photosynthetic rate and more enzyme activity than the controls.

Bradford and Ewing (1958) used solutions containing 0, 50, 100 and 200 ppm of gibberellin to soak cotton (Gossypium hirsutum L.) seed prior to planting. They found in all cases a significant reduction in stand and significant increases in seedling height and width of cotyledons. Allan, Vogel and Craddock (1961) soaked wheat seed in several solutions of gibberellin and found that slow emerging varieties could be made to emerge at the same rate as other varieties.

Mikkelsen and Sinah (1961) found that treatment of Oryza sativa L. seed with sodium hypochlorite solution, chlorine water or certain other compounds appeared to destroy or reduce the effectiveness of the inhibitor which was present in the seed. It also tended to increase the rate and uniformity of germination and to stimulate seedling development.

Soaking and Drying. Kraus and Wollny found that seed of certain species could be immersed in water until fully imbibed and then dried with no injurious effects. Their work was summarized by Kidd and West (1918b) and the following is from that summary:

I. Effect of Germination

a. Seeds soaked in the minimum amount of water and afterwards slowly dried at ordinary temperatures imbibe water and develop more quickly when allowed to take up water and germinate than do untreated seeds.

b. Seeds which are rapidly dried after the initial soaking germinate more slowly than untreated seeds.

c. Seeds swollen in water and sown in the still moist condition germinate more quickly than untreated seeds.

II. Effect on subsequent growth and final yield

a. In general, seeds soaked in water previous to germination give rise to slightly fewer plants than untreated seeds. If the seeds are redried too rapidly the number of plants produced may be considerably diminished.

b. Seedlings from treated seeds tend to develop more rapidly at first but this initial growth advantage tends to disappear later on.

c. Plants from treated seed tend to have a longer growth period and flowering period than control plants. The treated plants arrive at maturity later than the checks but yield more per plant.

d. The soaking treatment is especially useful when the seeds are sown in light dry soil.

Chippindale (1933a) presoaked seed of Dactylis glomerata L. in many different solutions including distilled water. Instead of submerging the seed during treatment he floated them on the surface of the solution. Following soaking, the seed was dried for 1 hr and then sowed. He found the speed of germination for the distilled water

treatment was superior to that of any other solutions. In another experiment he dried the seed for much longer periods of time. He concluded that a pronounced acceleration of germination can be produced by soaking the seed of orchardgrass in water and drying them for an indefinite period before sowing. Linehan and Mercer (1936) also worked with orchardgrass. They presoaked the seed in water and then dried it 4 hr before planting. They did not indicate whether or not the seed was submerged during presoaking. No stimulating effects were found when the seed was germinated at an alternating temperature of 18-20 C. In another study by Chippindale (1933b), seed of orchardgrass was floated on distilled water at 20 C for 17 hr. The seed was then dried for 24 hr at 14 C. He found that the effect of presoaking was lost if just the naked caryopses were soaked. His results indicated that pretreated seed imbibed water faster during germination than untreated seed. He thought that the quicker imbibition was the reason treated seed germinated faster. Chippindale (1934) repeated his soaking procedure with several other Gramineae species. He observed that, with most species, an acceleration of germination resulted from presoaking, but this may be negligibly small under optimum conditions in the soil.

Kotowski (1926) used several salt solutions to soak pepper (Capsicum frutescens L.), spinach (Spinacia oleracea L.) and parsnip (Pastinaca sativa L.) seed. He did not find any stimulation or

accelerated germination when the seeds were germinated at optimum temperatures.

Kurbatov and Gluckman (1930), two Russian scientists, did a great deal of work on the absorption of inorganic ions by seed. They found that some ions did not enter the seed during soaking. They observed that swelling of the seed proceeded most rapidly in pure water and less rapidly in solutions with monovalent salts. The rate of swelling decreased still more in solutions of bivalent salts and was slowest in solutions of trivalent salts. They also concluded that the processes started during presoaking were irreversible and the processes are only detained during drying and may be renewed at any time. The data indicated the greatest increase in germination rate occurs with seed previously soaked in pure water or in a weak centi-normal solution. Salt in the water exerted a detaining influence which became greater with increasing concentrations.

Ells (1963) studied the effect of NaCl, K_3PO_4, KNO_3 and distilled water on the performance of tomato seed. He determined that the primary effect of the seed treatment used in his experiments was apparently not due to the salts used in the solution, nor to the amount of water retained by the seed after the treatment. He claimed it was due to certain enzymatic activities which take place within the seed during presoaking. The effects of the treatments were shown to be greater under suboptimal germinating conditions. Oyer and Koehler's (1966)

work with tomato seed tends to agree with the results of Ells'. Bleak and Keller's (1970) work with soaks of crested wheatgrass indicated that the advantage of preplanting treatments was enhanced as conditions favoring emergence deteriorated.

Many other workers have studied the effect of presoaking and drying on the performance of seed. Arny and Leban (1955) found that soaking and drying barley seed was detrimental to field emergence. Geng and Barnett (1969) reported that the economic feasibility of prechilling and drying of Indiangrass (Sorghastrum nutans L.) was questionable. Other workers such as Hull (1969) found more encouraging results. He soaked and dried sugarbeet (Beta vulgaris L.) seed three times and found that emergence was 50% faster than control seed. Watanaba (1955) found increased germination speed with presoaked and sun-dried carrot (Caucus carota L.) seed. Hopkins (1960) reported that seed of Pinus pinaster Ait. could be soaked and dried without harmful effects.

Several times in the previous discussion, reference has been made to using suboptimal or stress conditions to test pretreated seed. Genkel and Kolotiva developed a presoaking technique in 1934 for hardening of seed, and found presoaked seed would perform much better than control seed when sowed under drought or cold conditions (May, Milthorpe and Milthorpe, 1962). May, Milthorpe and

Milthorpe (1962) concluded there was considerable evidence the drought resistance of plants could be increased by subjecting seed to a cycle of wetting and drying prior to sowing. Genkel's method was used on barley seed by Mart'yanova (1960). It was found to exert a beneficial effect on barley growth, development and grain yield. The treatment was most beneficial when there were spring and summer droughts. Salim and Todd (1968) presoaked seed of wheat and barley in several solutions including $CaCl_2$, $ZnSO_4$, $FeSO_4$, adenine, gibberellic acid, vitamin K_3, 2, 4-D, and garlic extract. The seedlings were tested for desiccation, resistance, transpiration, germination and growth in mannitol, and recovery. He concluded that no generalized statement could be made as to the effect of presowing seed treatment since the response seemed to depend upon the treatment and variety used.

Evenari (1964) tried repeated cycles of wetting and drying as a method of hardening sorghum seed to drought. He reported no advantage from hardening of sorghum (Sorghum sp.) by that method. Radish (Raphanus sativus L.) seed were subjected to several cycles of wetting and drying by Hafeez and Hudson (1967). Their results indicated that at least in some circumstances hardening seemed to confer a greater advantage in favorable than in adverse growing conditions. Austin et al. (1969) found an enlargement of the embryo of carrot seed during repeated cycles of wetting and drying. The increase in

size appeared to be due mainly to cell division which occurred during hardening. The hardened seed took up water at a much higher rate than the control seed for the first 3 hr. After 3 hr, however, there were no differences in imbibition rate. He found that differences in germination speed were present during early phases of germination. The optimum hardening procedure for carrot seed was found to be soaking to 70% moisture and drying to original dry weight. This procedure was most beneficial when the wetting and drying cycle was repeated three times. Berrie and Drennan (1971) studied the effect of multiple cycles of wetting and drying on oat and tomato seed. They made the statement that some advancement of the onset of germination was apparently due to slight changes in the seed covering and also to the initiation of metabolic events which could withstand the dehydration. They also said that the effects of wetting and drying are only truly accumulative if the prior imbibitions are of substantial duration.

Miscellaneous Methods

Findley and Campbell (1953) designed an experiment to test the effects of ultrasonic vibrations on the germination, growth and yield of maize. Hybrid corn seed was treated at a frequency of 400 kilocycles up to 16 min, but they found a negative effect upon yield and emergence rate.

Goodenough, Stone and McDow (1970) tested the effect of direct current glow discharge on germination of cottonseed. They used 50 glow discharge treatments with different current levels. Some of the treatments showed decreases in total germination when compared to the check.

Seed exposed to zero gravity by means of a satellite in orbit around the earth have generally shown little effect from the treatments. Jenkins (1968) reported the Russians have found no changes in protein, fat, starch, and amino acid content after such treatment. Lyon (1968) and Conrad (1968) reported similar findings from the American Biosatellite. Johnson (1968) studied the effect of changes in the endosperm of wheat seedlings in the weightless state and found no significant changes had occurred after 45 hr of weightlessness.

MATERIALS AND METHODS

Establishment of Optimum Conditions for Presoaking

A preliminary experiment was conducted to establish the optimum length and temperature of presoaking in distilled water, 200 ppm GA_3[1/] and 20,000 ppm NaCl. For this experiment, 1970 crop seed of 'Potomac' orchardgrass and 'Newport' bluegrass were obtained from the files of the Oregon State University Seed Laboratory. Soaking was accomplished by scattering approximately 500 seeds on top of blue germination blotters in 24 x 16.5 x 3.8 cm clear plastic boxes. The blotters were previously saturated with the appropriate solution and enough additional liquid added to allow for imbibition and evaporation. The covered boxes were placed in seed germinators at temperatures of 5, 10, 15, 20, 25, 30, 15-25, and 5-30 C.

Orchardgrass was soaked for 0, 6, 12, 24, 48, and 72 hr in GA_3 and water and for 0, 24, 48, 72, 96, 120, and 144 hr in NaCl. Bluegrass was soaked for 0, 12, 24, 48, 72, and 96 hr in GA_3 and water and for 0, 24, 48, 72, 96, 120, and 144 hr in NaCl.

After each presoaking interval, a box from each treatment was removed from each germinator. Seeds were flushed from the

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[1/] Gibberellic Acid manufactured by Merck Chemical Division under the trade name 'Gibrel'.

blotters with distilled water and collected in a fine-mesh wire strainer. The seed was then allowed to air-dry on paper towels in the laboratory (approximately 22 C) for 7 days. The dried seed was placed in paper envelopes for further experimentation.

The effect of the presoaking treatments was evaluated by measuring the speed of germination at 25 C. Twenty seeds were planted on top of moistened blue germination blotters in 12 x 12 x 2.9 cm clear plastic boxes. Light conditions during germination were 8 hr light and 16 hr dark. The three replications were placed in a randomized complete-block design within the germinators, with one box of each treatment appearing on each of the three shelves. Germination counts were made on the 4th and 8th day for orchardgrass and bluegrass, respectively. A seed was considered to have germinated when the radicle was at least 2 mm long. The experiments were analyzed as a factorial arrangement of treatments.

The amount of water present in orchardgrass seed after soaking 72 hrs at 5 C in each of the three solutions was determined. Percent moisture was calculated on a wet weight basis as shown below:

$$\% \text{ Moisture} = \frac{\text{Wet Wt} - \text{Dry Wt}}{\text{Wet Wt}} \times 100$$

Effect of Presoaking on Seed Performance

After establishing the proper temperature and length of soaking,

four additional lots each of orchardgrass and bluegrass were given soaking and drying treatments. These lots were then studied to determine the effects of presoaking on imbibition rate, respiration rate, speed of germination, seedling growth rate, emergence rate from soil, and storability.

Seed Lots

The lots of seed chosen for these experiments were obtained from the Oregon State University Seed Laboratory files. Table 1 summarizes the O. S. U. Seed Laboratory data for each lot of seed prior to presoaking.

Table 1. Description of the individual seed lots prior to presoaking.

Crop	Cultivar	Crop Year	% Germ	% PLS[1/]
Orchardgrass	Potomac	1969	97	98
	Potomac	1970	96	95
	Sterling	1969	95	92
	Sterling	1970	88	83
Bluegrass	Newport	1969	92	91
	Newport	1970	87	86
	Cougar	1969	90	89
	Cougar	1970	89	88

[1/] PLS is Pure Live Seed which is equal to the % germination times the % pure seed.

Each lot of seed was blown in a South Dakota Seed Blower to separate inert matter from pure well-filled seed. Each lot was then divided into four equal samples with a Gamet Divider.

Presoaking and Drying Procedure

A different presoaking treatment was given to each of the four samples within a lot. The presoaking solutions were distilled water, 200 ppm GA_3 and 20, 000 ppm NaCl. All soaks were performed as follows: Orchardgrass: (1) 72 hr at 5 C in H_2O, (2) 72 hr at 5 C in GA_3, (3) 144 hr at 5 C in NaCl and (4) unsoaked control. Bluegrass: (1) 96 hr at 5 C in H_2O, (2) 96 hr at 5 C in GA_3, (3) 144 hr at 5 C in NaCl and (4) unsoaked control. Soaking and drying were performed as before except that approximately 4, 000 seeds were used per treatment. The controls were kept dry and placed in paper envelopes on the laboratory bench (22 C) during soaking and drying of the other samples.

Imbibition Rate

Moisture uptake rate for each of the four treatments of 1970 Sterling orchardgrass was determined. For each of these four treatments, seven groups of 100 seeds were counted and weighed on a Mettler Balance. The seeds were then placed in covered germination dishes on top of blue germination blotters previously moistened

with water. The dishes were placed in a 25 C germinator for periods of 0, 1/2, 1, 2, 3, 4, and 8 hours. After the proper intervals, the dishes were removed from the germinator and the blotters placed seed-side up on paper towels to absorb excess moisture. The seed was scraped off on to another towel and immediately weighed. The moisture content after each soaking interval was calculated as a percentage of the air-dry weight of the seed.

$$\% \text{ Moisture} = \frac{\text{Imbibed Wt} - \text{Air-Dry Wt}}{\text{Air-Dry Wt}} \times 100,$$

where air-dry weight is the weight of the seed at equilibrium with the relative humidity of the air in the laboratory.

Respiration Rate

A Gilson Differential Respirometer was used to measure the oxygen uptake of both 1970 Potomac and 1970 Sterling orchardgrass seed after being subjected to the four treatments. Water bath temperature remained constant at 25 C throughout this experiment. No surface sterilization of the seed was made. Each Warburg Flask contained 100 seeds and 0.5 ml distilled water in the large chamber with 0.2 ml of 4 N KOH and a paper wick in the center well. Each treatment was replicated three times. All readings were for 30 min durations.

After all the plugs had been greased and put into place, the KOH was pipetted into the center well and the paper wick inserted. The dry seed was placed into all the flasks before the distilled water was added. The flasks were placed on the respirometer and 30 min after initial wetting the valves were closed for the first reading. Readings were taken 1/2, 1, 2, 3, 4, 6, 8, 10, and 12 hr after initial wetting.

Speed of Germination

Germination tests were conducted to determine the effect of presoaking on the speed of germination. Seed from all treatments of orchardgrass and bluegrass were germinated at 15-25 C and 25 C. The alternating temperature (15-25 C) is considered optimum for germination of both bluegrass and orchardgrass (AOSA Rules, 1965). The constant temperature (25 C) was considered suboptimal or a stress temperature for both crops. All samples were germinated under 8 hr of light and 16 hr of dark.

Fifty seed of each treatment were planted on water-moistened blotters in closed germination boxes. Each treatment was replicated four times and placed in the germinators in a randomized complete-block design. Orchardgrass germination counts for the 15-25 C experiment were made 4, 6, 14, and 22 days after planting. Counts for the 25 C study were made 4, 6, 14, 28, and 34 days after planting.

Germination counts for all bluegrass treatments were made 6, 8, 14, 21, 28, and 35 days after planting. The germination percentage of Newport bluegrass after 35 days at 25 C was very low, therefore, the tests were transferred to 15-25 C for 29 additional days to obtain a more complete germination.

Growth Rate

Radicle growth measurements were made on the seed of 1970 Sterling orchardgrass. These tests were conducted on blotters in 24.0 x 16.5 x 3.8 cm plastic germination dishes at 25 C. Ten replications with 20 seed each were arranged in a completely randomized design and analyzed as such.

The dishes were placed at an angle so the shoot would grow up and the radicle down. Shortly after radicle emergence, a mark was made on the blotter at the tip of the radicle to serve as the "zero" point for subsequent measurements. Twenty-four hours later the first measurement was made from this "zero" point. Radicle measurements were taken daily on each seedling until six increments of growth had been recorded. Any radicle that displayed signs of injury was pulled off and measurements were discontinued. Seed that had not germinated by the 10th day was discarded.

Soil Emergence Rate

Soil emergence trials were conducted in the greenhouse (approximately 25 C) on all orchardgrass treatments. The seed was planted in rows 7 mm deep in 38 x 58 x 10 cm wooden flats. Fifty seed were planted approximately 1 cm apart in each row. Emergence counts for all Potomac treatments were made each day from the 4th through the 9th day after planting. Counts for the 1969 Sterling treatments were made from the 4th through the 11th day, while 1970 Sterling seedlings were counted 4, 5, 6, 7, 8, 9, 10, and 13 days after planting. Each flat contained one complete replication and there were four flats per treatment. They were arranged in a randomized complete-block design and analyzed as a factorial arrangement of treatments.

Storability

The effect of presoaking and drying upon the storability of the seed was determined by germination tests conducted one month and eight months after treatment. Seed from all treatments of bluegrass and Potomac orchardgrass were used. Due to the lack of seed, Sterling orchardgrass was not included.

Four 50-seed replicates of each treatment were placed on blotters in clear plastic germination dishes at 15-25 C (8 hr light

and 16 hr dark). The final germination count was made after 22 days for orchardgrass and 28 days for bluegrass.

Statistical Analysis

Experimental design and computations were based on Steel and Torrie (1960). The least significant difference (LSD) at 5% and 1% levels of significance was used to test differences between treatment means. A Control Data Corporation 3300 computer was utilized in making the different analyses.

RESULTS

Establishment of Optimum Conditions for Presoaking

The effect of presoaking conditions on the rate of germination of orchardgrass and bluegrass seed is shown in Tables 2 to 7. The seed was soaked at different temperatures in solutions of GA_3, NaCl and water for various periods of time. The analyses of variance for these data are shown in Appendix Tables 1 to 6.

Temperature During Presoaking

The greatest stimulation to germination of orchardgrass seed occurred at the colder and the alternating soaking temperatures. The LSDs indicate that at 72 hr. 5, 10, and 15 C were all equally beneficial presoaking temperatures for orchardgrass (Tables 2, 3, 4). Constant temperatures above 15 C resulted in progressively slower germination. Soaking at both alternating temperatures resulted in a degree of stimulation equal to or greater than that from the colder constant temperature.

The most stimulatory constant temperature for bluegrass seed was 5 C with all warmer temperatures showing progressively less germination (Tables 5, 6, 7). Seed soaked at either 25 or 30 C failed to germinate satisfactorily. However, it was observed that

germination of this seed proceeded normally when it was placed at 15-25 C for several months. The alternating temperature of 5-30 C promoted germination as well as 5 C, but 15-25 C, in contrast to the effect on orchardgrass, had no beneficial effect on bluegrass.

Many orchardgrass seeds germinated during the longer presoaking periods at the warmer temperatures, but no germination was observed at 5 C. Bluegrass did not germinate during any of the presoaking conditions.

Length of Soaking Period

At the lower temperatures, speed of germination was increased progressively with increased duration of soaking periods up to the longest period tested. In orchardgrass, this relationship occurred at 5, 10 and 15 C while this effect occurred only at 5 C for bluegrass.

At the warmer presoaking temperatures, maximum speed of germination occurred at shorter soaking periods (Tables 2-7). Extended soaking had little beneficial effect on orchardgrass at 30 C or on bluegrass at 25 and 30 C.

At alternating temperatures, extended soaking was beneficial to orchardgrass at both 15-25 and 5-30 C, but bluegrass responded only to the 5-30 C soak.

Table 2. Effect of time and temperature of presoaking in GA_3 on the germination percentage of 1970 Potomac orchardgrass seed. Germination recorded after 4 days at 25 C.

Temperature of presoak (C)	Length of presoak (hr)				
	6	12	24	48	72
5	9	18	15	29	44
10	10	20	26	43	48
15	16	22	37	51	43
20	17	18	32	35	28
25	10	05	32	35	30
30	22	11	23	26	17
15-25	12	19	21	39	48
5-30	12	11	24	38	74
Control	14				

$LSD_{.05} = 17.3$

$LSD_{.01} = 22.9$

Table 3. Effect of time and temperature of presoaking in H_2O on the germination percentage of 1970 Potomac orchardgrass seed. Germination recorded after 4 days at 25 C.

Temperature of presoak (C)	Length of presoak (hr)				
	6	12	24	48	72
5	07	08	13	23	36
10	05	08	18	30	39
15	08	12	25	25	32
20	08	20	23	33	27
25	10	10	14	23	17
30	05	08	10	15	07
15-25	07	12	13	42	33
5-30	02	02	15	22	36
Control	05				

$LSD_{.05} = 15.0$

$LSD_{.01} = 19.9$

Table 4. Effect of time and temperature of presoaking in NaCl on the germination percentage of 1970 Potomac orchardgrass seed. Germination recorded after 4 days at 25 C.

Temperature of presoak (C)	Length of presoak (hr)					
	24	48	72	96	120	144
5	05	19	15	22	25	48
10	08	13	30	32	33	44
15	09	23	27	39	35	48
20	08	14	35	43	47	44
25	18	17	17	28	32	20
30	07	12	12	18	18	08
15-25	15	27	32	32	38	51
5-30	08	22	37	43	55	63
Control	09					

$LSD_{.05} = 16.8$

$LSD_{.01} = 22.2$

Table 5. Effect of time and temperature of presoaking in GA_3 on the germination percentage of 1970 Newport bluegrass seed. Germination recorded after 8 days at 25 C.

Temperature of presoak (C)	Length of presoak (hr)				
	12	24	48	72	96
5	17	17	37	52	57
10	08	12	40	37	42
15	12	30	18	15	25
20	15	15	02	05	10
25	02	02	03	02	02
30	03	02	02	05	00
15-25	10	22	13	08	15
5-30	03	07	37	53	57
Control	03				

$LSD_{.05} = 12.6$

$LSD_{.01} = 16.7$

Table 6. Effect of time and temperature of presoaking in H_2O on the germination percentage of 1970 Newport bluegrass seed. Germination recorded after 8 days at 25 C.

Temperature of presoak (C)	Length of presoak (hr)				
	12	24	48	72	96
5	02	07	15	48	44
10	04	10	35	34	32
15	02	07	16	24	15
20	02	14	06	02	02
25	02	02	00	00	00
30	00	00	00	00	00
15-25	02	05	00	04	03
5-30	02	03	07	27	44
Control	04				

$LSD_{.05} = 8.7$

$LSD_{.01} = 11.6$

Table 7. Effect of time and temperature of presoaking in NaCl on the germination percentage of 1970 Newport bluegrass seed. Germination recorded after 8 days at 25 C.

Temperature of presoak (C)	Length of presoak (hr)				
	48	72	96	120	144
5	02	18	42	39	50
10	28	26	30	30	46
15	18	32	12	25	19
20	12	12	10	19	19
25	00	00	00	00	02
30	00	02	00	00	00
15-25	00	19	03	03	04
5-30	12	05	13	30	34
Control	04				

$LSD_{.05} = 13.7$

$LSD_{.01} = 18.2$

Chemical Presoaking Solutions

Since the tests with the different chemical presoaking solutions were not performed or evaluated concurrently, no statistical comparisons of chemicals could be made. However, some definite trends were apparent.

After comparable soaking periods, the NaCl solution often caused slower germination than GA_3 and water, but at the maximum length of soak for each of the three solutions, resultant germination was essentially equal (Tables 2-7).

Germination did not occur in the salt solutions at any temperature or length of soaking, while a small percentage of seeds germinated in water and GA_3. To determine if seeds imbibed sufficient water from NaCl solutions to allow germination to occur, moisture tests were conducted on orchardgrass seed soaked at 5 C for 72 hr in water and GA_3 and 144 hr in NaCl solutions. At the end of the soaking periods, the seed contained 45.4, 45.4 and 45.6% moisture respectively.

Summary of Optimum Presoaking Conditions

The soaking conditions judged to be most practical for each solution on the basis of consistency of beneficial results and convenience of treatment are summarized in Table 8.

Table 8. Optimum presoaking treatments for orchardgrass and bluegrass.

Solution	Temperature (C)	Length (hr)
Orchardgrass		
GA_3 (200 ppm)	5	72
H_2O (distilled)	5	72
NaCl (20, 000 ppm)	5	144
Bluegrass		
GA_3 (200 ppm)	5	96
H_2O (distilled)	5	96
NaCl (20, 000 ppm)	5	144

Effect of Presoaking and Drying on Seed Performance

Performance tests were conducted on seed soaked under the conditions listed in Table 8. These tests were designed to obtain detailed information on germination, growth characteristics and physiological changes associated with the soaking and drying treatments.

Imbibition Rate

As shown in Figure 1, soaking seeds of 1970 Sterling orchardgrass in NaCl solution resulted in a considerably faster rate of water imbibition than any of the other three treatments. During the first hour, GA_3 and H_2O treatments also exhibited a greater imbibition rate than the non-soaked check. Imbibition by NaCl soaked seed was essentially complete after 3 hr, while the other seed continued to imbibe for 4 to 8 hours. The initial percent moisture of the pre-soaked and dried seed prior to re-wetting was 7.0 % for GA_3, 8.2 % for H_2O, 6.7 % for NaCl, and 7.7% for the control.

Respiration Rate

The rates of oxygen uptake for 1970 Sterling and 1970 Potomac orchardgrass seed are shown in Figures 2 and 3, respectively. NaCl treated seed generally showed a higher respiration rate than the other three treatments. The untreated control showed the lowest O_2 uptake rate in both trials.

Speed of Germination

Treated orchardgrass seed consistently germinated faster than the nontreated control seed (Figures 4, 5, 6, 7). Treated seed had up to 45% more germination than the control on the 4th day of

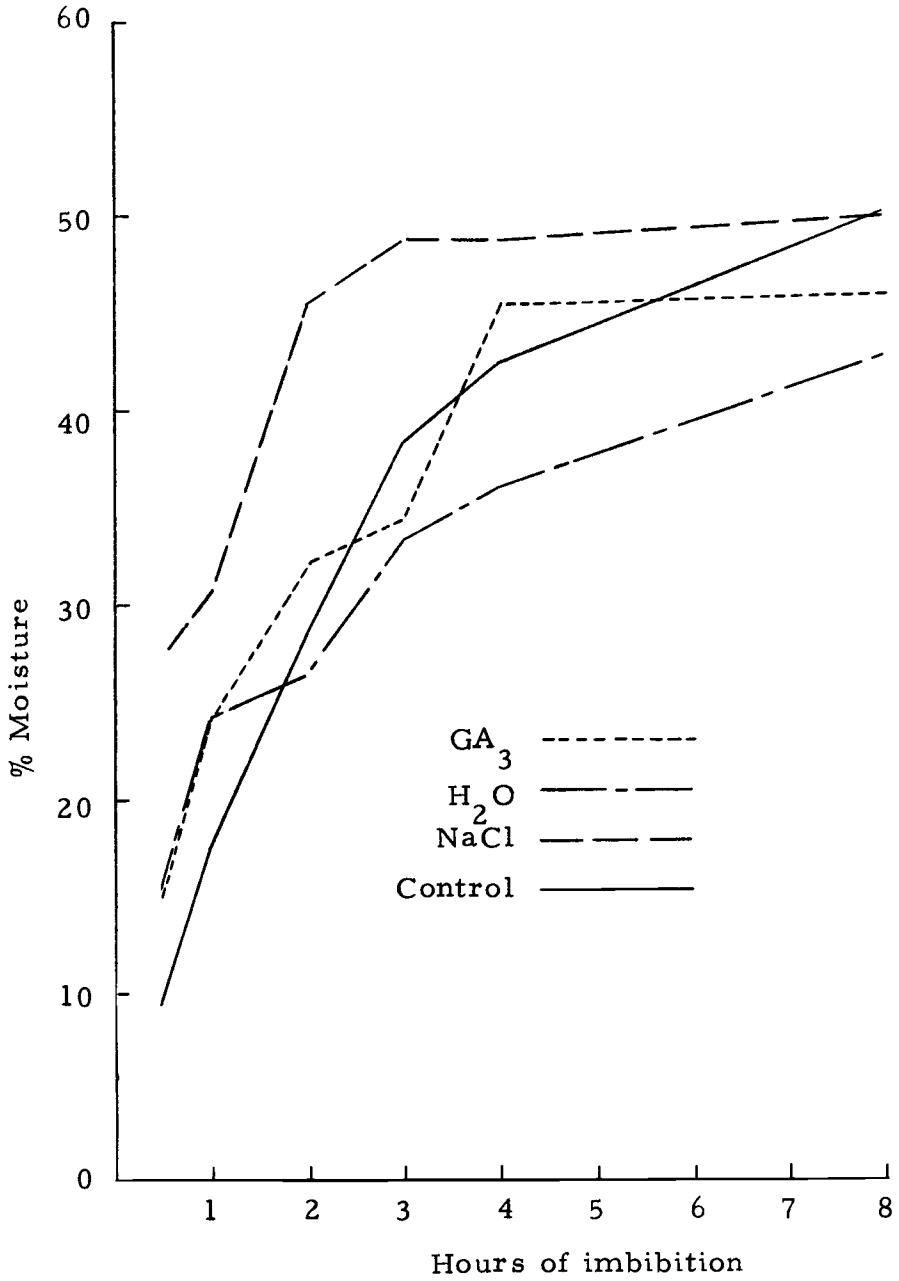

Figure 1. Rate of water imbibition by 1970 Sterling orchardgrass seed after soaking and drying treatments.

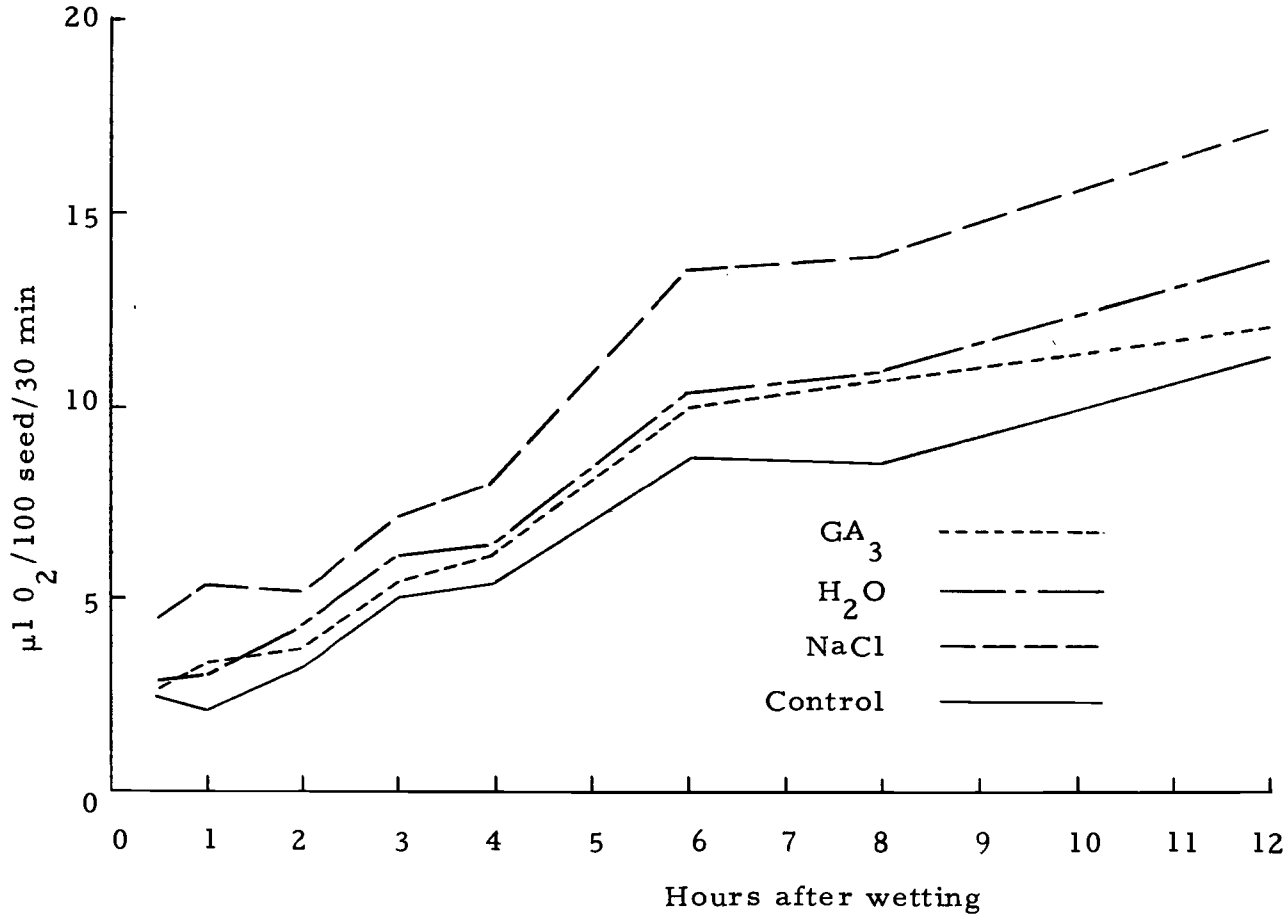

Figure 2. Rate of oxygen uptake by 1970 Sterling orchardgrass seed after wetting and drying treatments.

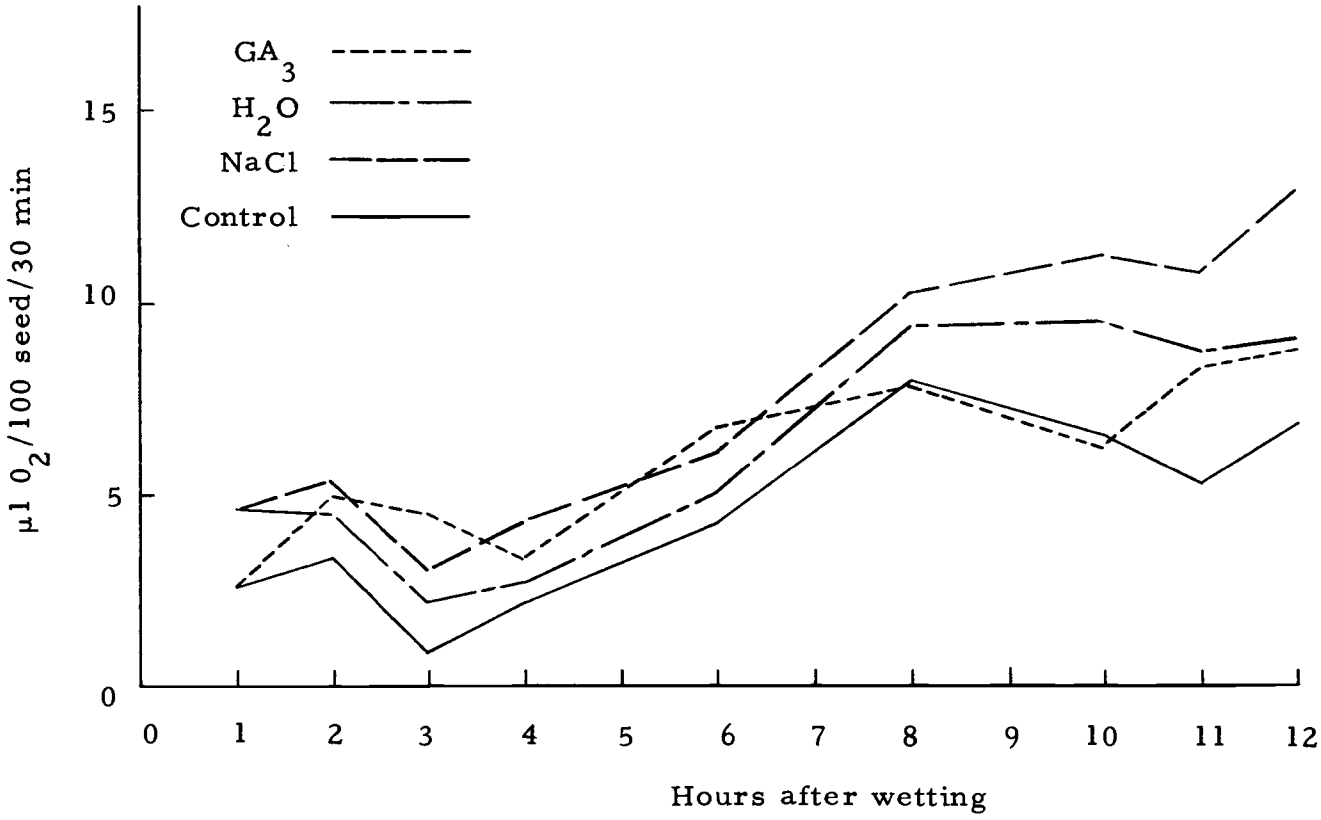

Figure 3. Rate of oxygen uptake by 1970 Potomac orchardgrass seed after wetting and drying treatments.

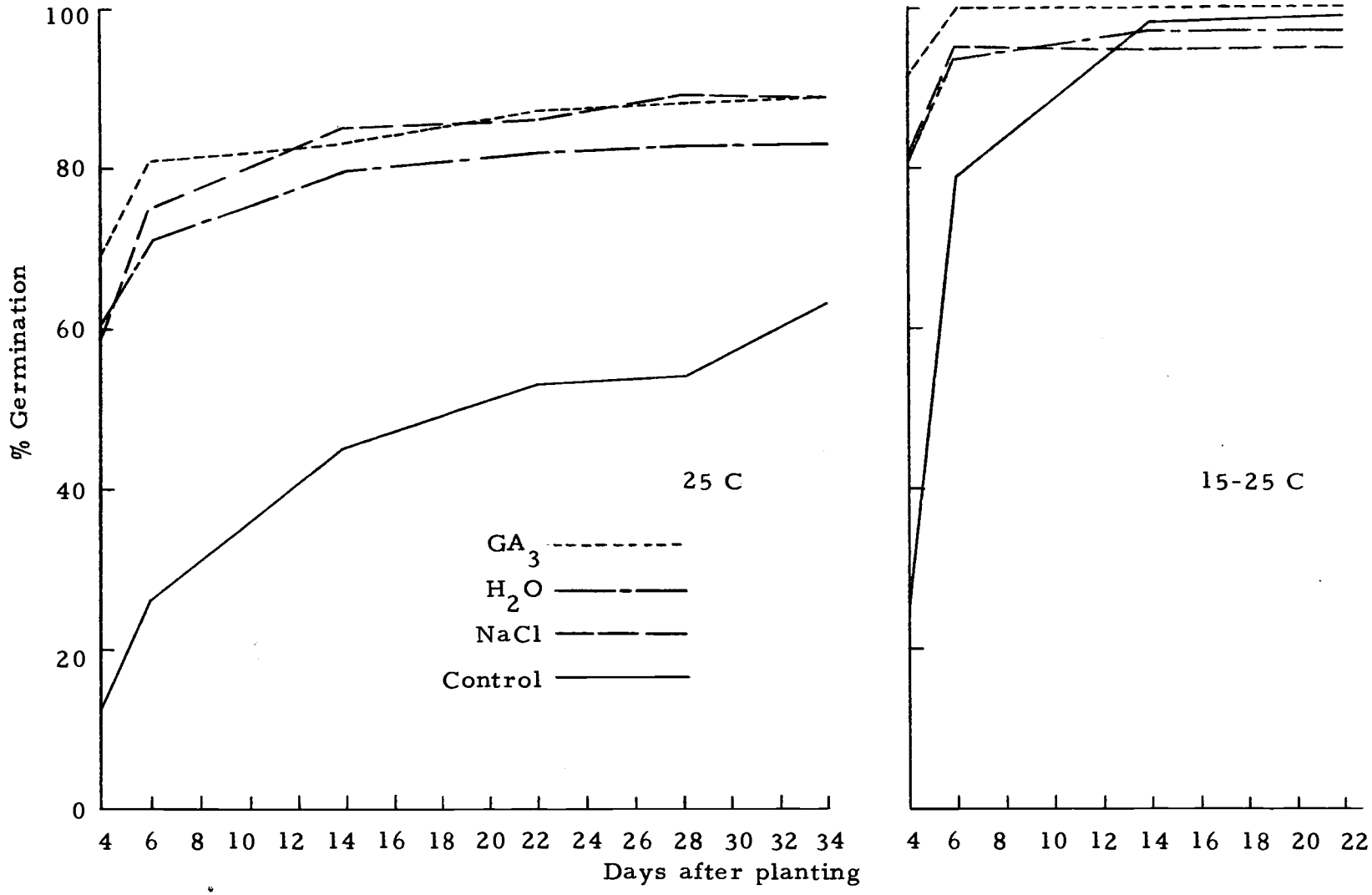

Figure 4. Rate of germination of 1970 Sterling orchardgrass seed after wetting and drying treatments. Seed germinated at stress (25 C) and optimum (15-25 C) temperatures.

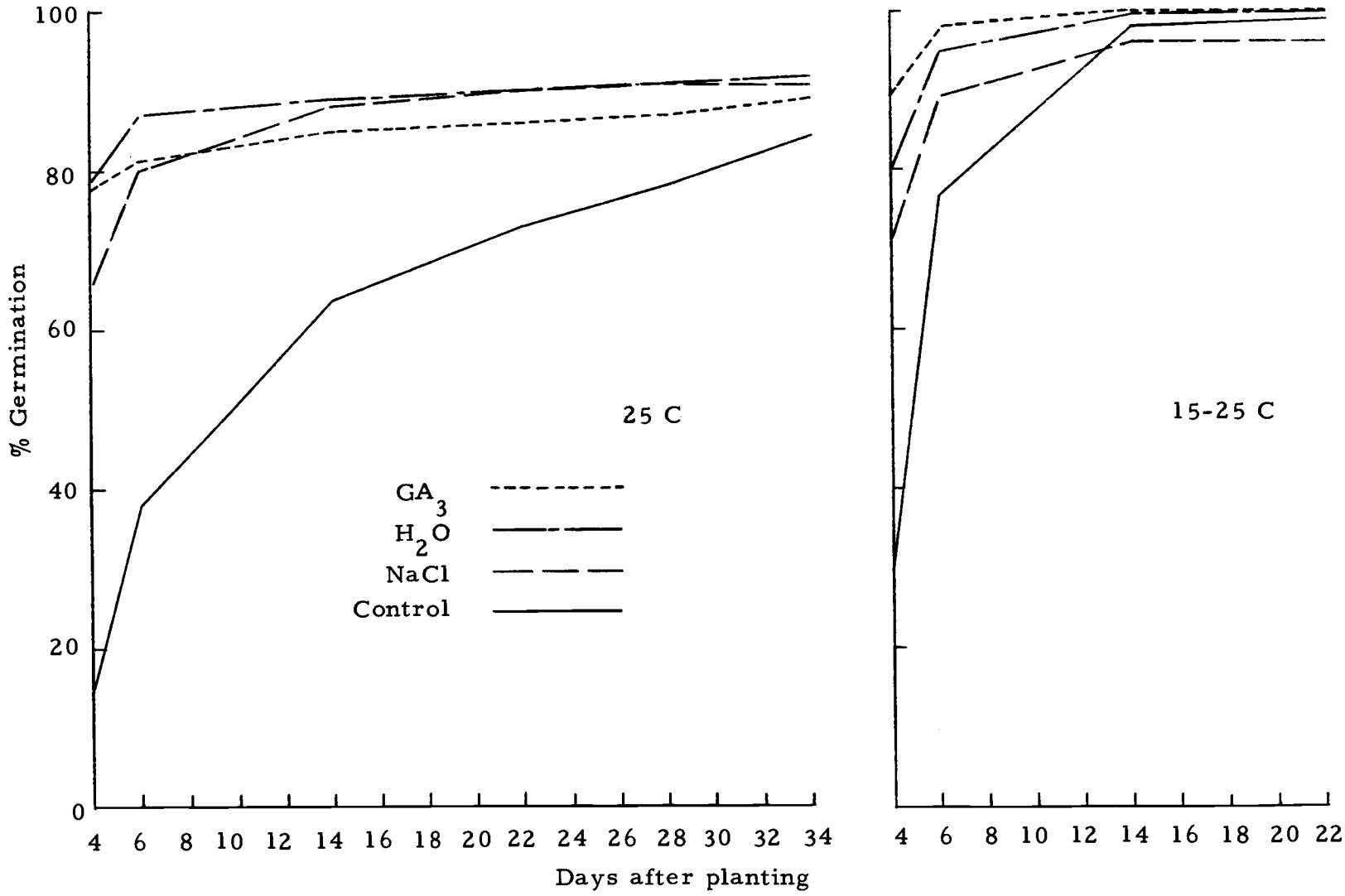

Figure 5. Rate of germination of 1969 Sterling orchardgrass seed after wetting and drying treatments. Seed germinated at stress (25 C) and optimum (15-25 C) temperatures.

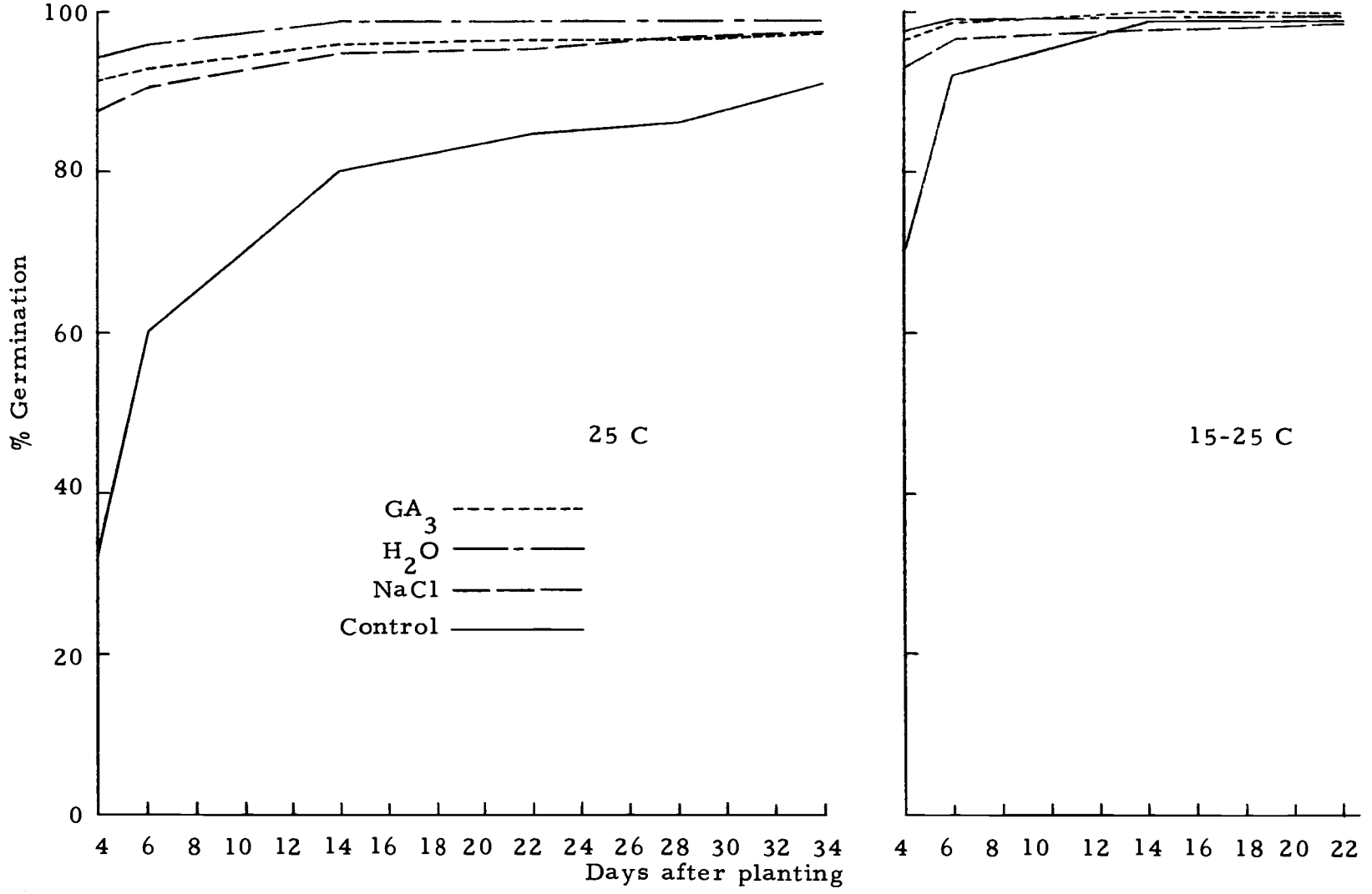

Figure 6. Rate of germination of 1970 Potomac orchardgrass seed after wetting and drying treatments. Seed germinated at stress (25 C) and optimum (15-25 C) temperatures.

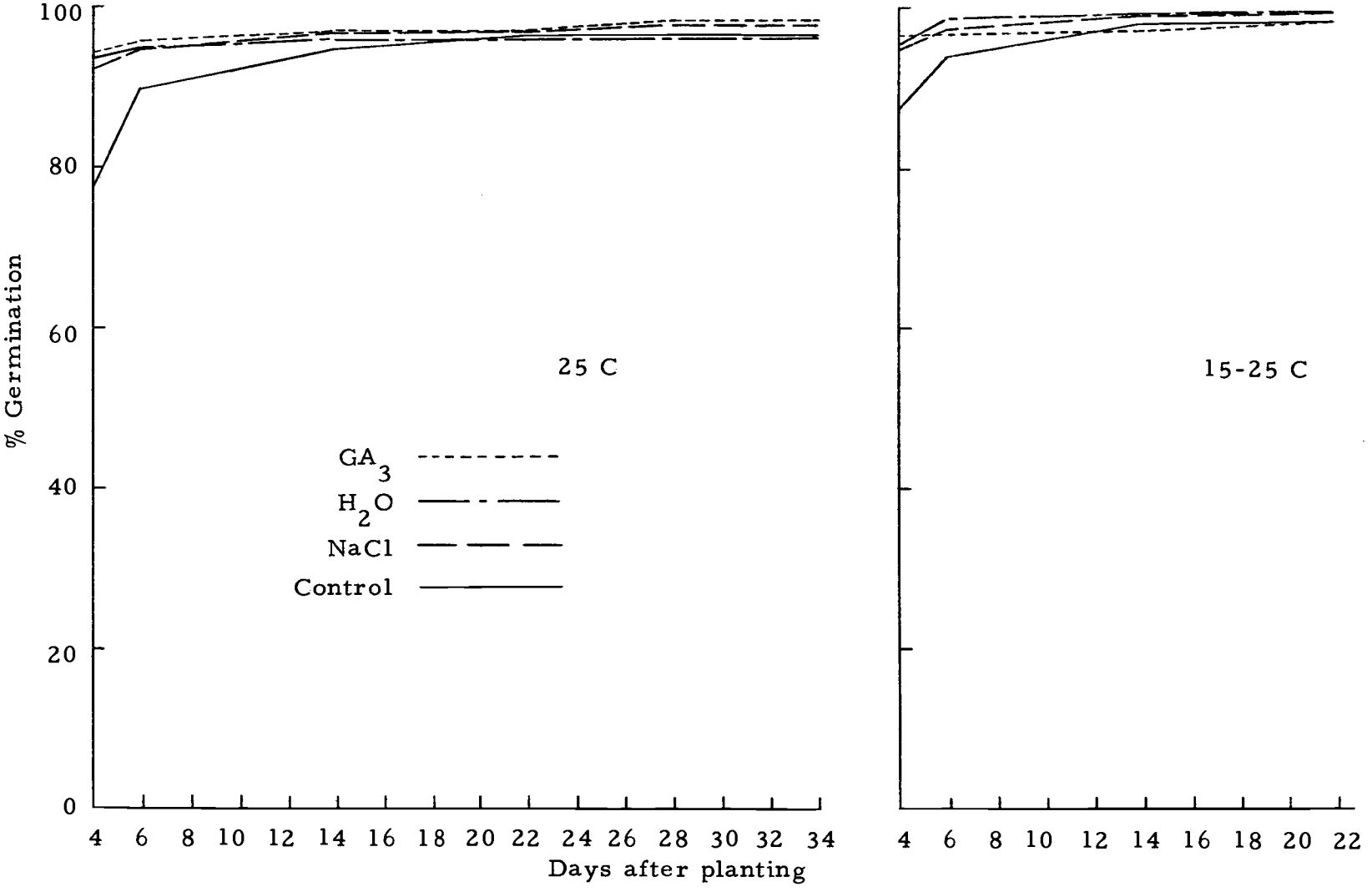

Figure 7. Rate of germination of 1969 Potomac orchardgrass seed after wetting and drying treatments. Seed germinated at stress (25 C) and optimum (15-25 C) temperatures.

germination. By the last count, however, the total germination of the control seed was nearly equal to that of the other treatments. Neither of the chemical solutions showed a clear advantage over distilled water as a soaking medium.

Different cultivars and age classes responded differently to the presoaking treatments. Newer lots of orchardgrass seed showed a greater response to soaking than older seed of the same cultivar. Sterling exhibited greater differences in this regard than Potomac.

The response to presoaking was more evident at 25 C than at 15-25 C. The soaking and drying treatments appeared to substitute for the alternating temperature requirement and allowed germination to proceed at a faster rate at the warmer temperature. A small percentage of Sterling seed, however, were not able to germinate at the constant temperature of 25 C. The analyses of variance for the orchardgrass germination data are shown in Appendix Tables 7 and 8.

Early counts of Newport bluegrass showed up to 50% more germination after the soaking and drying treatments (Figures 8, 10). GA_3 and H_2O soaks appeared to be superior to the NaCl soaks. Newport bluegrass germinated poorly under the stress (25 C) temperature, consequently, it was transferred to 15-25 C after the 35th day and germination proceeded normally after several weeks. (Figures 9, 11).

The two lots of Cougar seed showed less stimulation from the

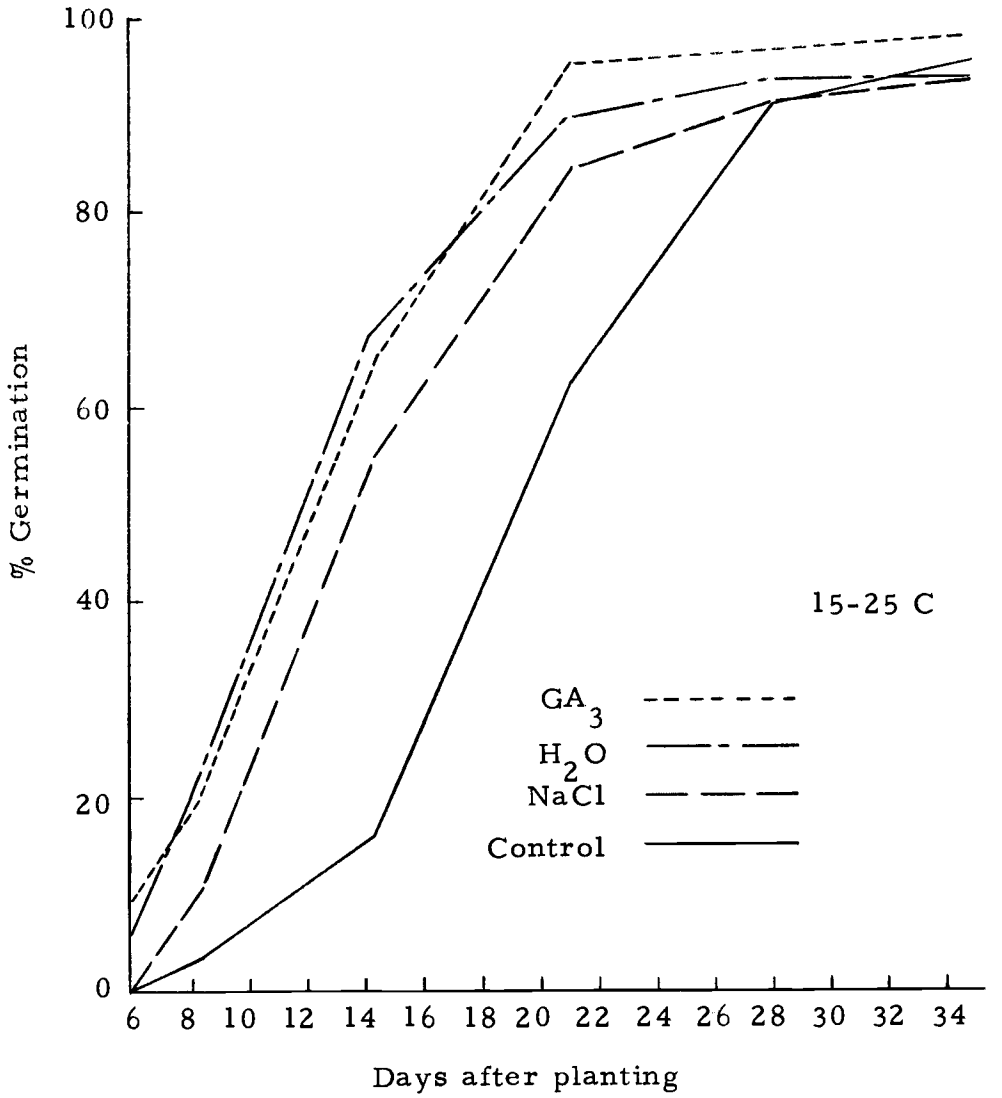

Figure 8. Rate of germination of 1970 Newport bluegrass seed after wetting and drying treatments. Seed germinated at optimum (15-25 C) temperature.

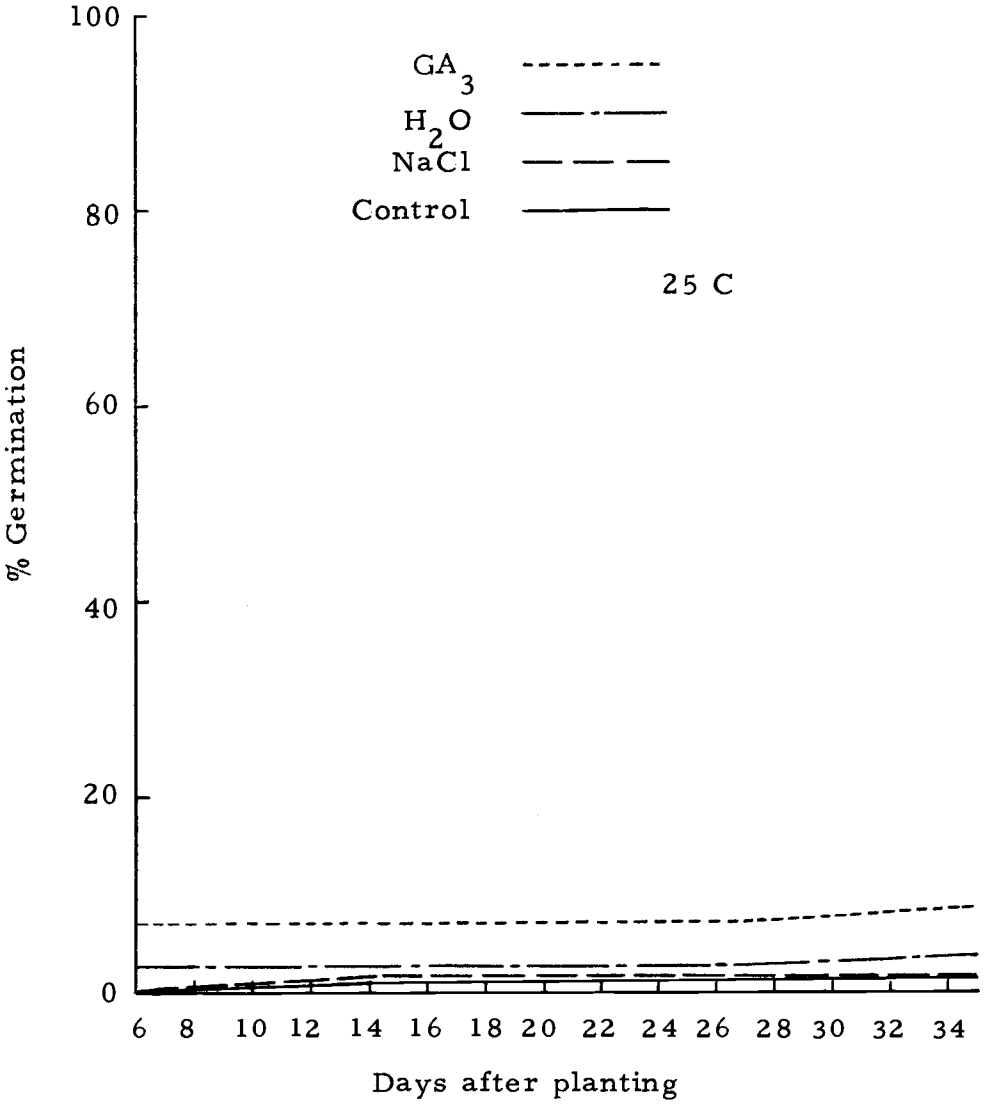

Figure 9. Rate of germination of 1970 Newport bluegrass seed after wetting and drying treatments. Seed germinated at stress (25 C) temperature.

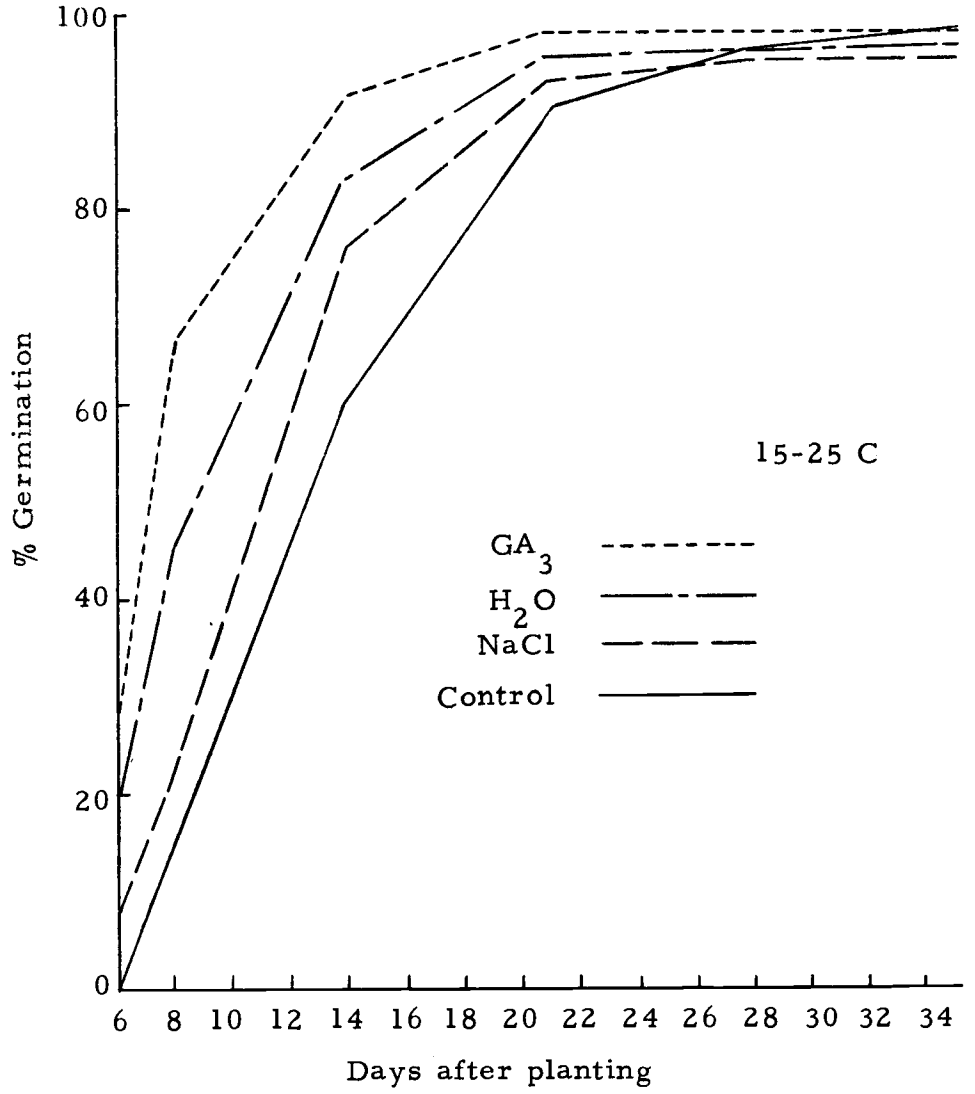

Figure 10. Rate of germination of 1969 Newport bluegrass seed after wetting and drying treatments. Seed germinated at optimum (15-25 C) temperature.

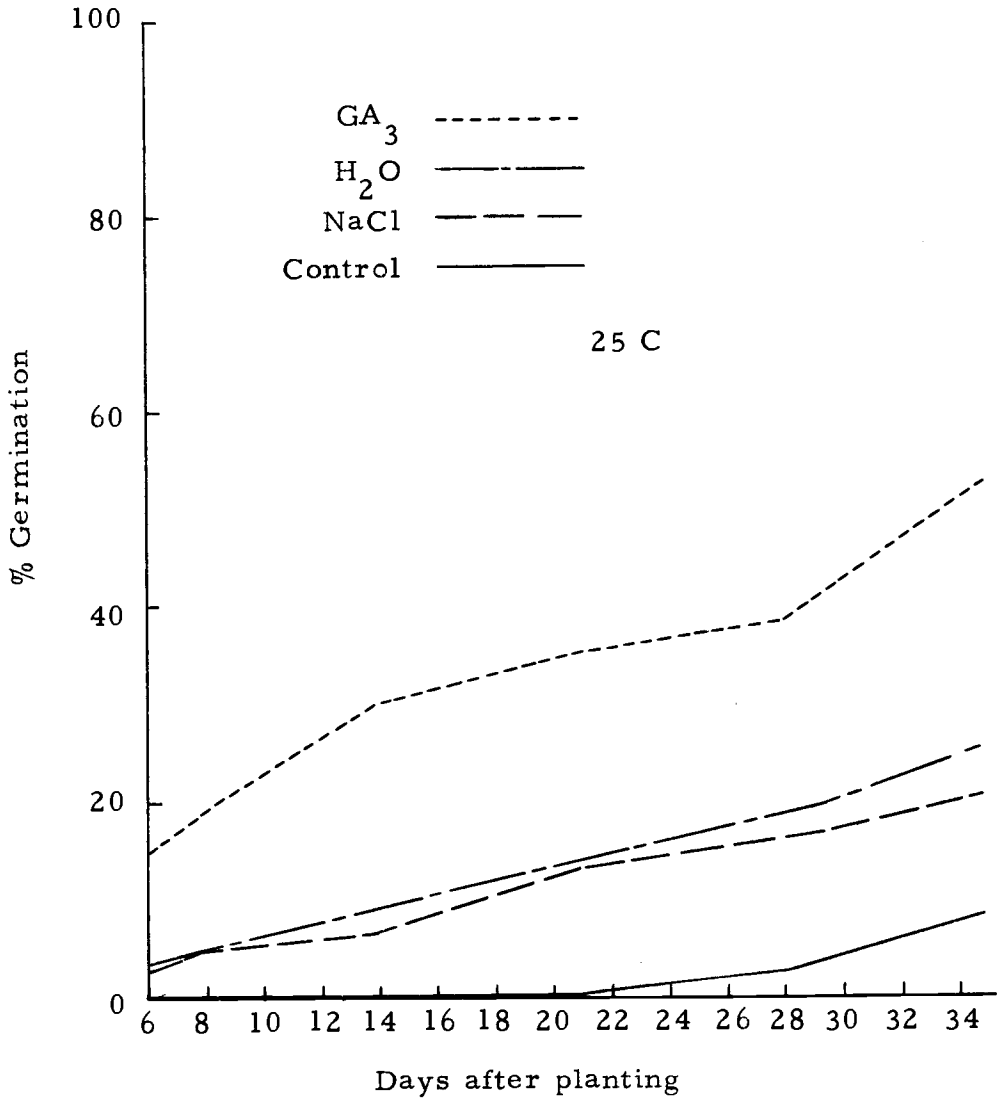

Figure 11. Rate of germination of 1969 Newport bluegrass seed after wetting and drying treatments. Seed germinated at stress (25 C) temperature.

soaking treatments (Figures 12, 13) than did Newport, and the chemical treatments showed little or no differential effect. Germination proceeded rapidly at 25 C. Analyses of variance for the bluegrass data are shown in Appendix Tables 9, 10, 11, and 12.

Growth Rate

In sharp contrast to the effects of soaking on the speed of germination, the treatments had no significant affect on the rate of radicle growth (Figure 14). The analyses of variance of the growth rate data are shown in Appendix Tables 13 and 14.

Soil Emergence

The emergence rate of orchardgrass seedlings from soil during the first few days after planting was increased by the presoaking and drying treatments (Figures 15, 16, 17, 18). The 1970 seed of Potomac showed more response to soaking than did the 1969 seed, but there were no differences due to age of the Sterling seed lots. There were greater differences in emergence rate between presoaked seed and the untreated control than among treatments. Appendix Tables 15, 16, 17, and 18 present the analyses of variance for these experiments.

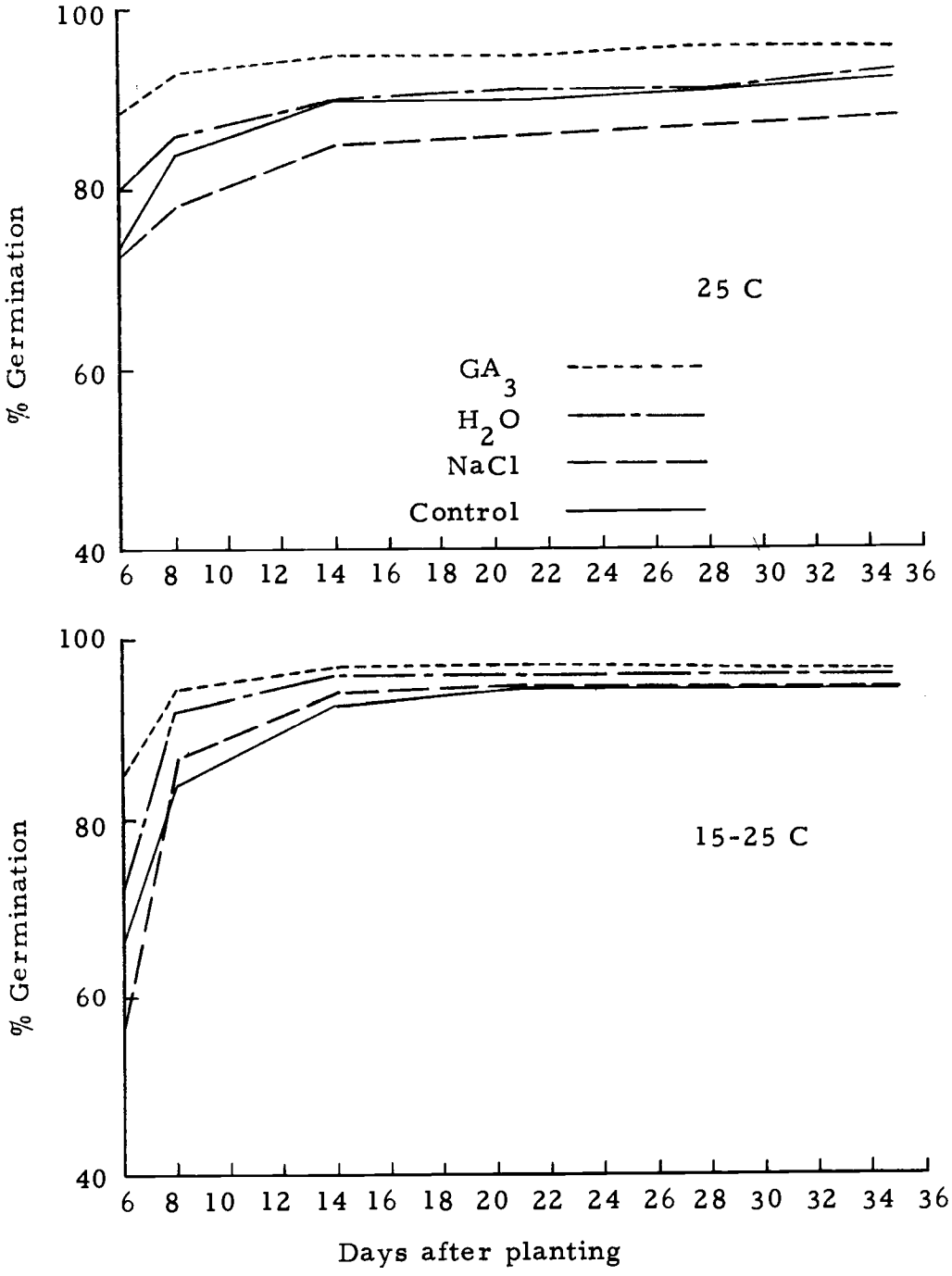

Figure 12. Rate of germination of 1970 Cougar bluegrass seed after wetting and drying treatments. Seed germinated at stress (25 C) and optimum (15-25 C) temperatures.

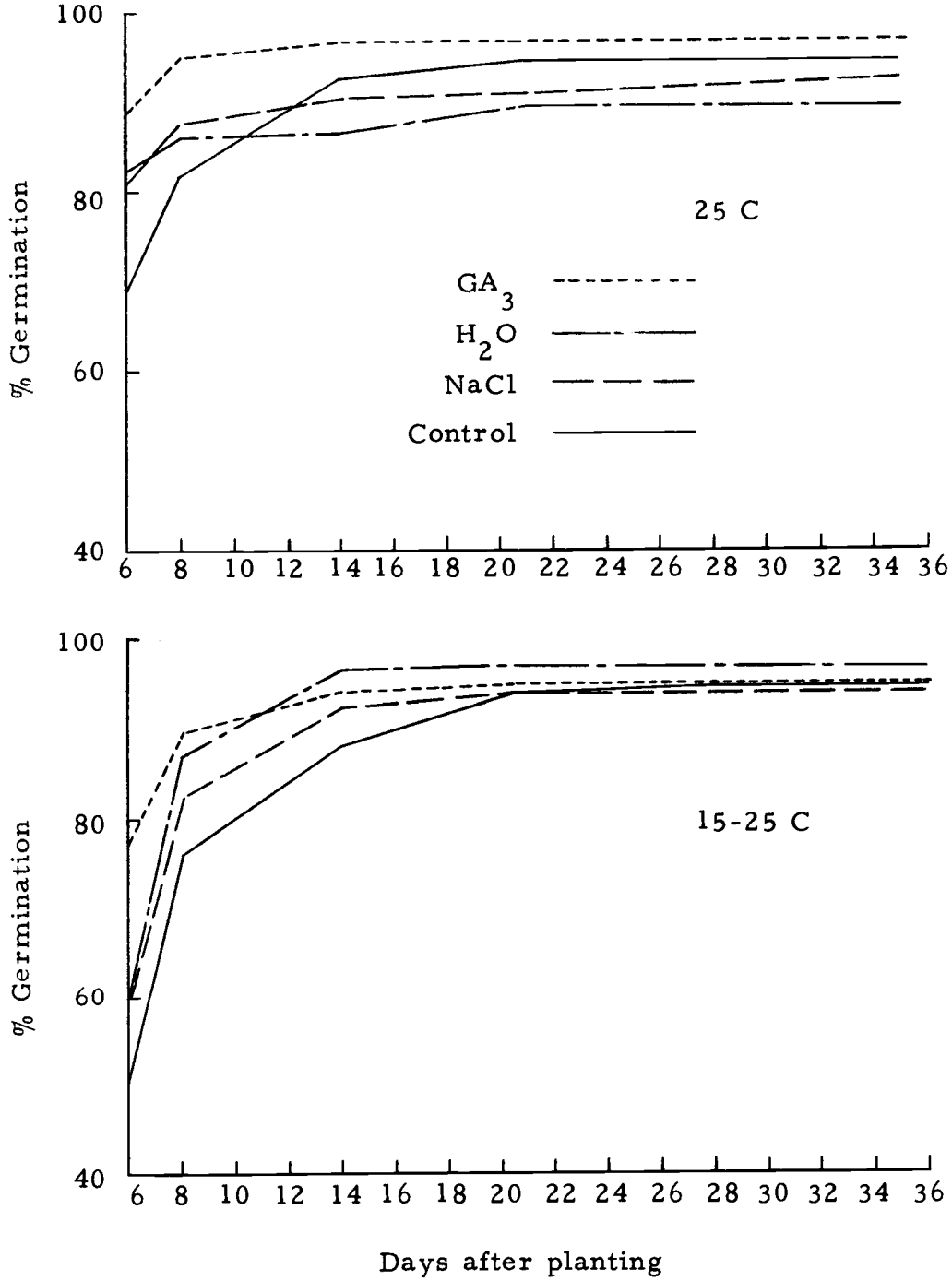

Figure 13. Rate of germination of 1969 Cougar bluegrass seed after wetting and drying treatments. Seed germinated at stress (25 C) and optimum (15-25 C) temperatures.

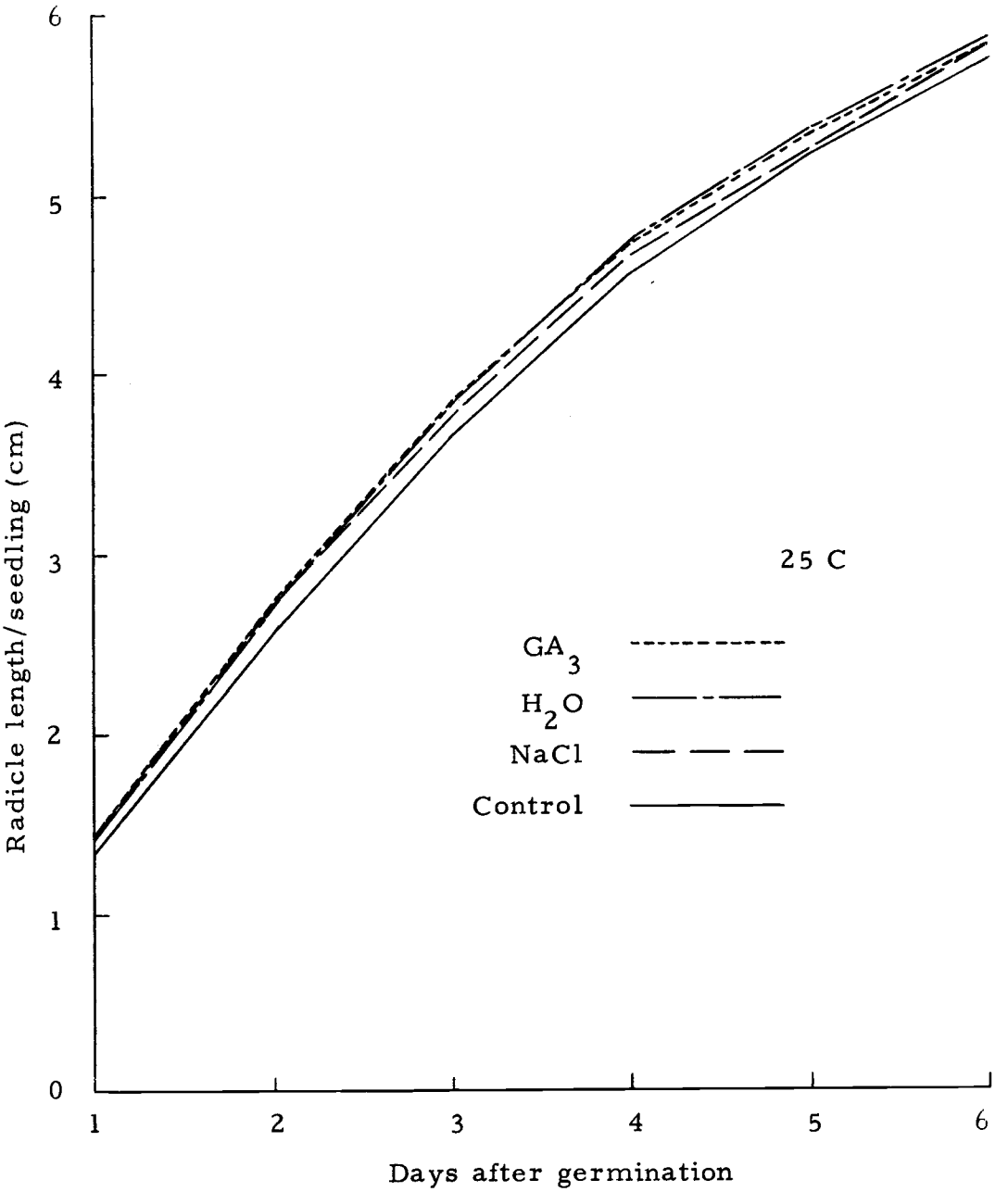

Figure 14. Radicle growth rate of 1970 Sterling orchardgrass seedlings after soaking and drying treatments.

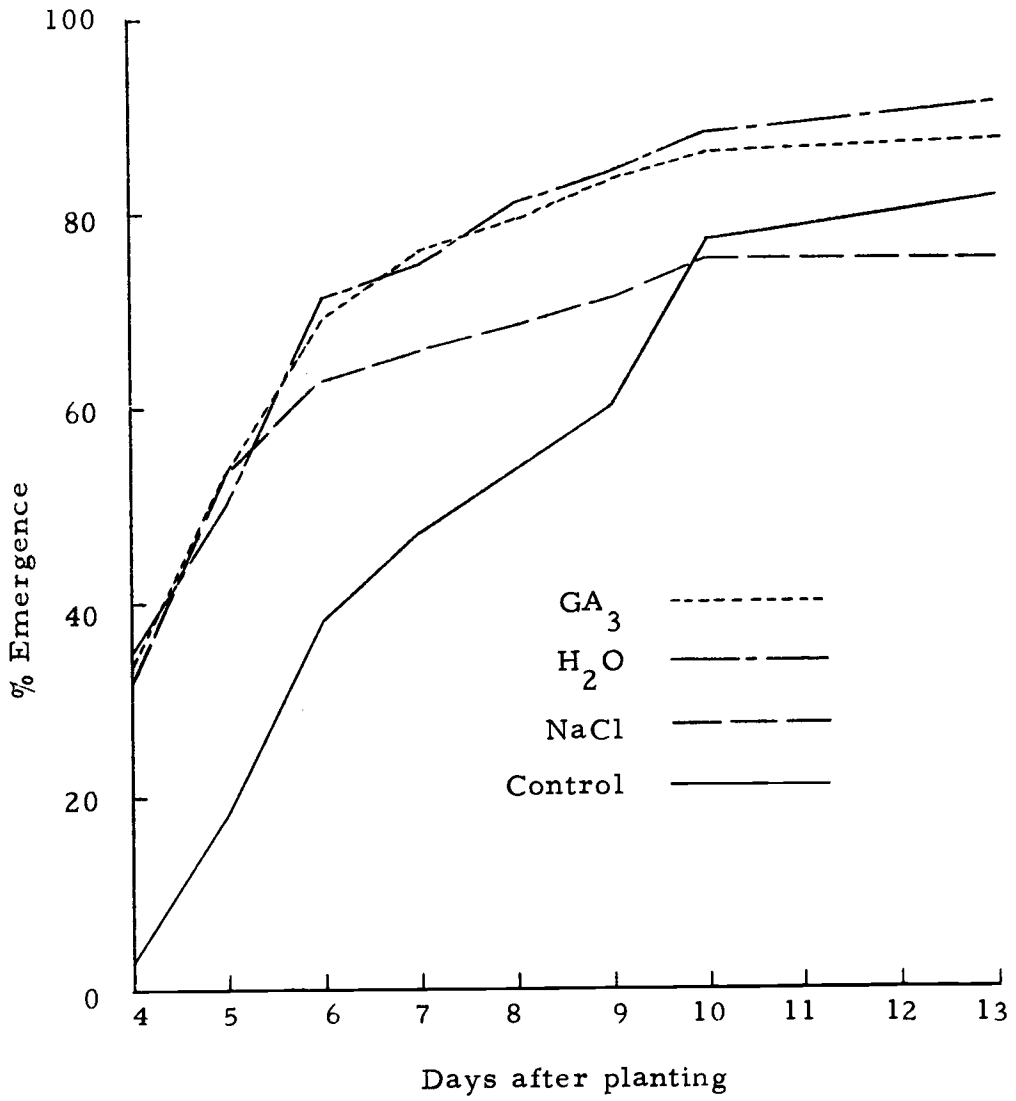

Figure 15. Speed of emergence of 1970 Sterling orchardgrass seedlings from soil after soaking and drying treatments.

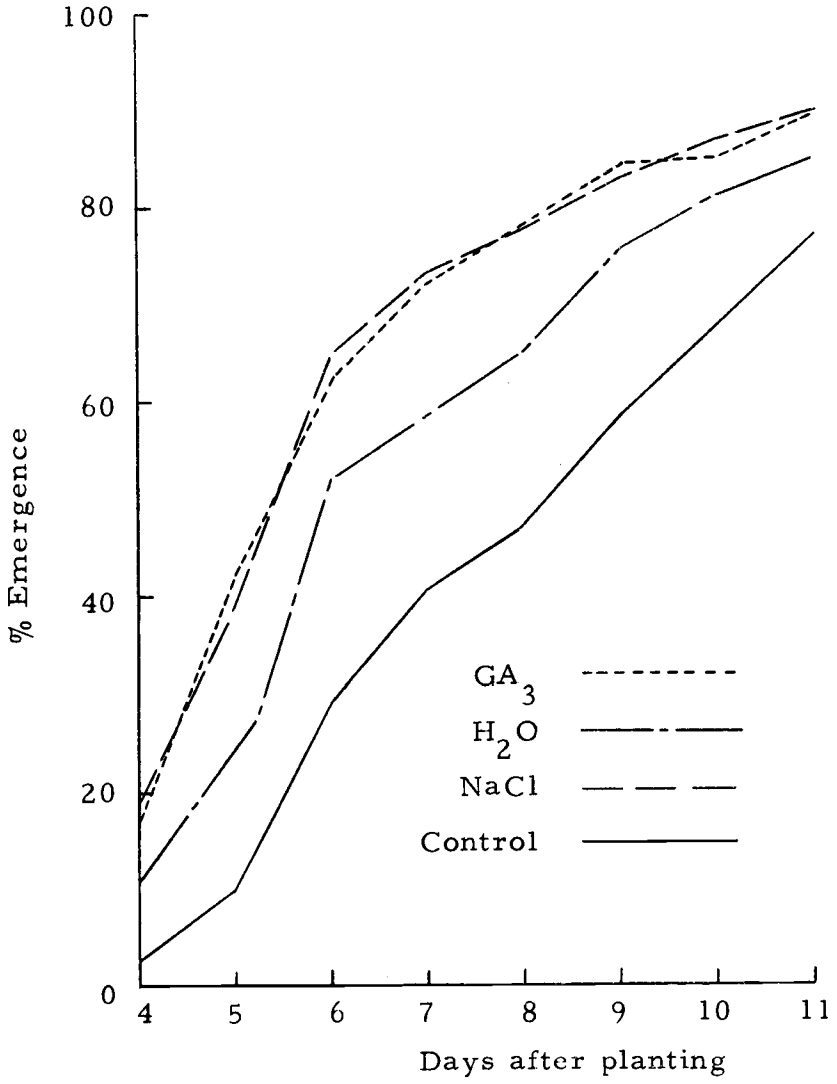

Figure 16. Speed of emergence of 1969 Sterling orchardgrass seedlings from soil after soaking and drying treatments.

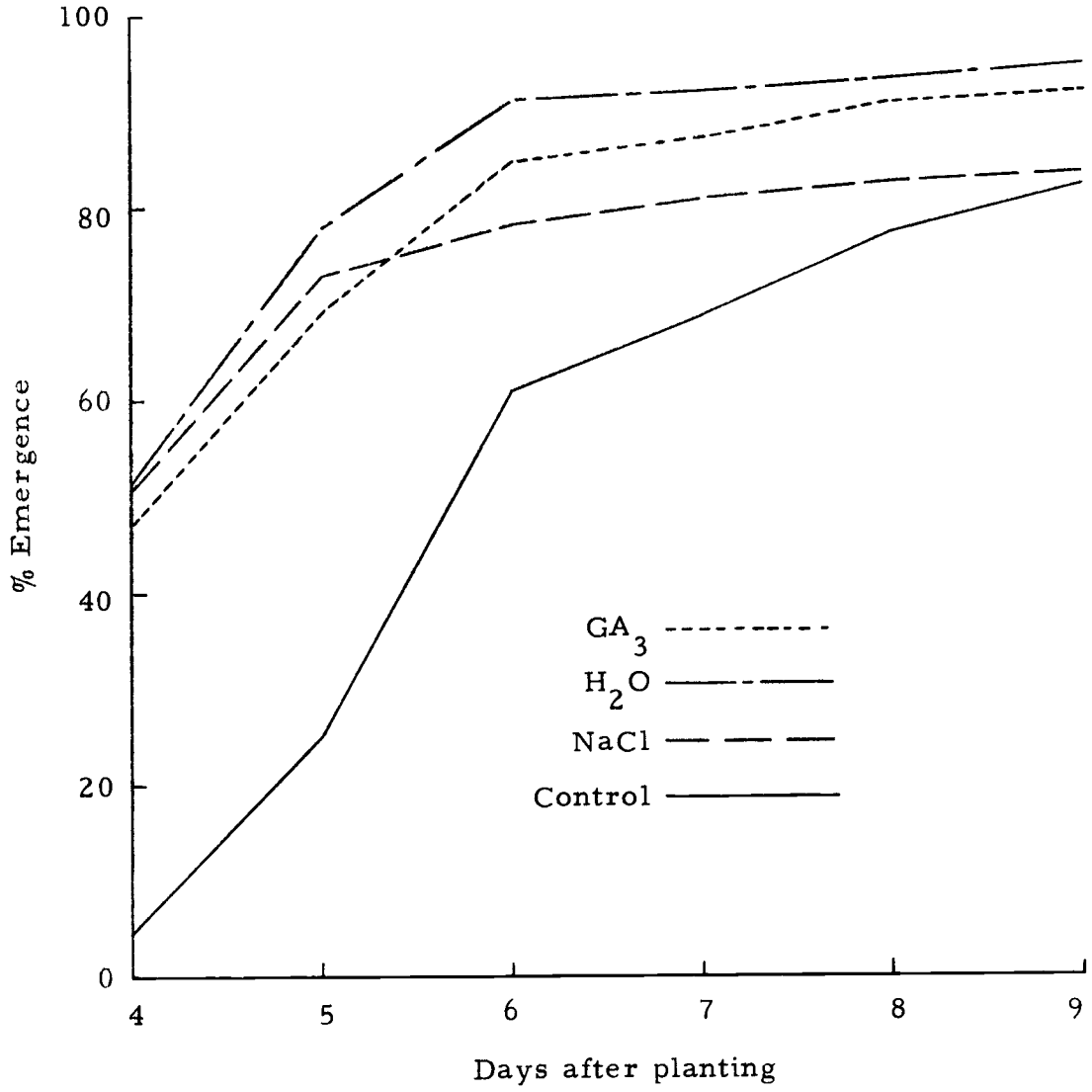

Figure 17. Speed of emergence of 1970 Potomac orchardgrass seedlings from soil after soaking and drying treatments.

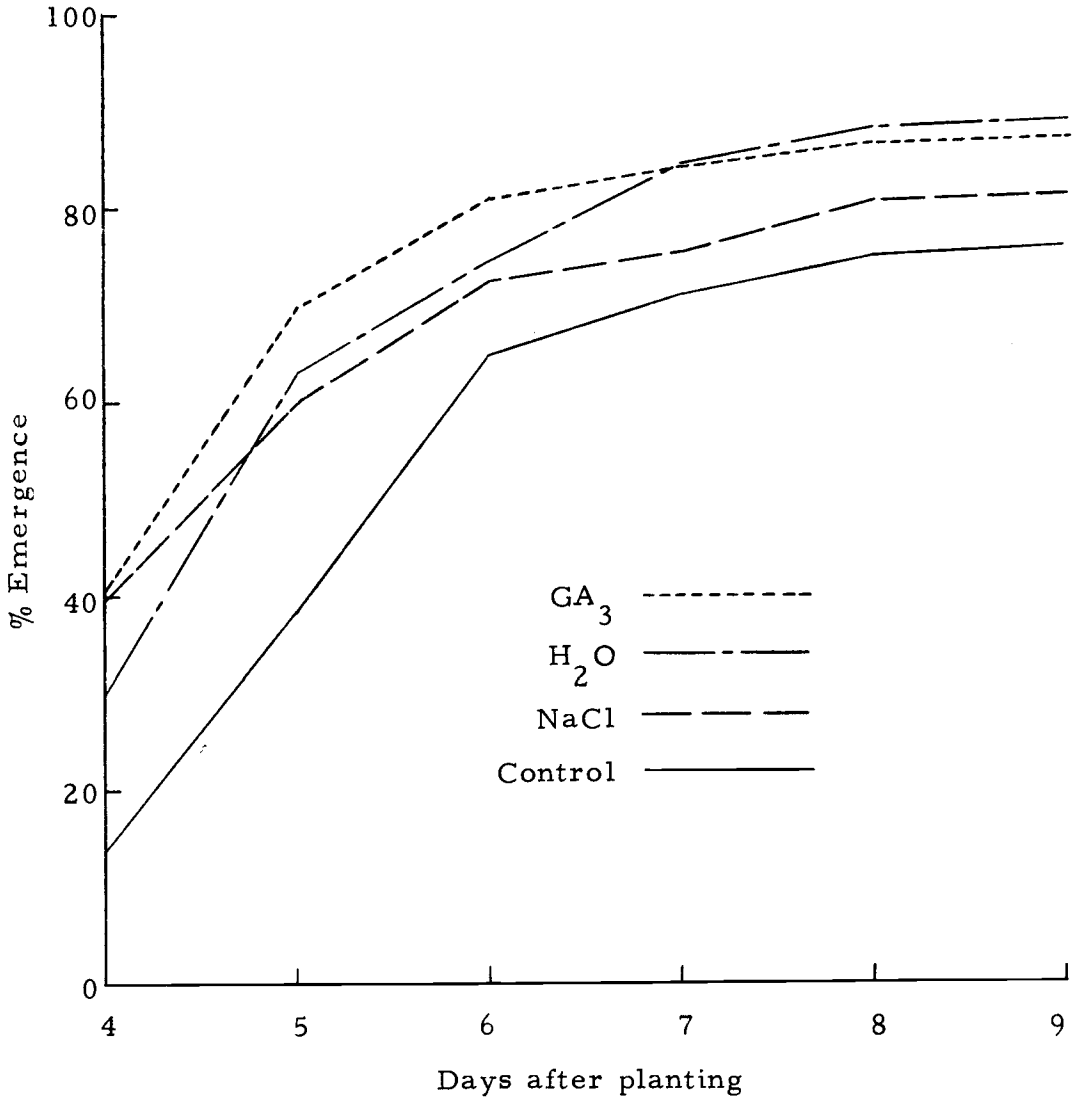

Figure 18. Speed of emergence of 1969 Potomac orchardgrass seedlings from soil after soaking and drying treatments.

Storability

Presoaking and drying had no adverse effect on the storage life of the seed. Treated Potomac orchardgrass seed did not show any loss of germination after 8 months of storage at room temperature (Table 9). Both bluegrass cultivars after treatment (Table 10, 11) also stored equally as well as the untreated control over the 8 month period.

Table 9. Percent germination (15-25 C) of Potomac orchardgrass seed one month and eight months after presoaking.

Treatment	1969 Potomac		1970 Potomac	
	Sept.	May	Sept.	May
GA_3	98	97	100	98
H_2O	99	98	100	98
NaCl	99	96	99	99
Control	98	97	99	99

Table 10. Percent germination (15-25 C) of Newport bluegrass seed one month and eight months after presoaking.

Treatment	1969 Newport		1970 Newport	
	Sept.	May	Sept.	May
GA_3	97	97	98	93
H_2O	96	97	94	92
NaCl	96	97	94	92
Control	99	99	96	94

Table 11. Percent germination (15-25 C) of Cougar bluegrass seed one month and eight months after presoaking.

Treatment	1969 Cougar		1970 Cougar	
	Sept.	May	Sept.	May
GA_3	96	97	95	96
H_2O	97	99	96	95
NaCl	94	93	95	95
Control	95	97	95	95

DISCUSSION

The results of these experiments demonstrate that presoaking and drying treatments were beneficial to orchardgrass and bluegrass seed. Certain aspects of seed vigor such as germination speed and emergence rate were enhanced by these treatments. Tests were designed to determine the mechanism of action of the treatments, and while they did not reveal the actual processes some indications of possible mechanisms were obtained.

Germination tests indicated that presoaked seed germinated more vigorously than control seed. Germination speed was increased as much as one day for certain seed lots. In most cases the greatest differences in germination speed occurred at the stress temperature. These findings tend to agree with the results reported by previous workers such as Chippindale (1934), Oyer and Koehler (1966) and Bleak and Keller (1970). The increased speed of germination was primarily responsible for the increased soil emergence rate since there were no differences in the growth rate of the seedlings.

Although several methods of presoaking gave equally beneficial results, one combination of length and temperature was selected for each solution and each crop. In order to obtain maximum benefit from presoaking, long soaking periods were utilized. Cold temperatures were used to prevent germination during presoaking. Both

5 C and 5-30 C gave satisfactory results but 5 C was chosen because it was easier to maintain. These presoaking conditions are not the same as those reported by Chippindale (1933b) and Linehan and Mercer (1936) who used warmer temperatures and shorter soaking periods.

Compared to water, there appeared to be little or no benefit from soaking in GA_3 or NaCl solutions, thus distilled water would be the most practical for commercial application. It requires no mixing and alleviates the possibility of chemical injury to subsequent plants. Chippindale (1933a) found that distilled water gave better results than several other solutions. If presoaking were to be done at warmer temperatures, however, hypertonic salt solutions would be necessary to prevent sprouting of the seeds. This was previously shown by Ells (1963) to be effective for tomato seed.

Orchardgrass responded to treatment to a greater extent than bluegrass. Chippindale (1934) also found that orchardgrass showed a greater response to presoaking treatments than several other Gramineae species.

On the basis of the results obtained, some speculation can be made as to the nature of the favorable response to soaking treatments. Since seedling growth rates were not increased by the treatments, the effects appear to be strictly germination-related. The small increase in imbibition and respiration rates found in the present

study may not be great enough to account for the entire increase in germination rate.

A change in the level of dormancy occurred during soaking. The 5 C soaking procedure is quite similar to the cold moist pre-chilling periods used to break dormancy in many species (AOSA Rules, 1965). Although not specifically measured, soaking also might allow the leaching of germination-inhibitors from the seed. Further evidence of reduced dormancy is indicated by the reduced requirement for alternating temperatures by the presoaked orchard-grass seed.

Whatever the mechanism, it is evident that the changes brought about by presoaking are maintained after drying the seed. The true nature of these changes can only be elucidated after studies are made of the activation and inhibition of enzyme activities and levels of metabolites which regulate catabolic as well as anabolic processes during the presoaking and drying periods.

Soaking generally enhanced the germination rate of the more dormant cultivars (Sterling and Newport) to a greater degree than the less dormant cultivars (Potomac and Cougar). Also, the newer, more dormant seed (1970-crop) was stimulated to a greater degree than the older, less dormant seed (1969-crop). If this relationship holds generally true, then presoaking should normally be most effective on those species and seed lots exhibiting a higher degree of

dormancy. Less stimulation would be expected in those species and lots that are normally quick-germinating and less sensitive to environmental conditions during germination.

There may be several practical applications for presoaking and drying seed. Faster germination of crop seed may result in an earlier harvest date for farmers. Quicker establishment of grass in lawns and golf courses would be advantageous. This study and several others suggest that the benefits of presoaking increase as the conditions for germination and growth become less favorable (Kidd and West 1918b, Chippindale 1934, May, Milthorpe and Milthorpe 1962, Ells 1963, and Bleak and Keller 1970). If this relationship can be demonstrated in the field, then the possibility exists for presoaking seeds for better performance under stress conditions of moisture and temperature.

The fact that presoaked seed could be dried and stored for 8 months with no deleterious effects lends further support to the applicability of such a procedure. Other species, however, may not store as well as orchardgrass and bluegrass after treatment.

Before presoaking and drying can become commercially feasible, additional developmental work must be done. A method of treating bulk lots of seed must be developed. More work must be conducted to determine the effect of treatments on the stand, yield and quality of the resulting crop. Additional data must be collected

on the field performance of treated seed when planted under adverse conditions such as dry or cold soils.

SUMMARY AND CONCLUSIONS

Soaking and drying of orchardgrass and bluegrass seed improves certain aspects of seed performance such as germination and emergence. Seedling growth rate was not affected by the treatments.

The length and temperature of the soaking period were critical in some cases. In general, cold temperature (5 C) and longer soaking periods (3-6 days) were most satisfactory.

Greater benefits from the treatments were usually obtained when germination was conducted at a suboptimal temperature. Effects were evident at optimum temperatures, but were less pronounced. Differences between soaking in water, GA_3 and NaCl were minimal, but all treatments enhanced germination and emergence.

Soaking and drying treatments increased the imbibition and respiration rates of the seed. The level of dormancy was reduced as indicated by the reduced requirement for alternating temperatures. Treatments were most effective on cultivars and seed lots exhibiting the higher levels of dormancy.

A germination test conducted 8 months after the presoaking treatment indicated that no viability loss had occurred during storage.

BIBLIOGRAPHY

Allan, R. E., O. A. Vogel and J. C. Craddock. 1961. Effect of gibberellic acid upon seedling emergence of slow and fast emerging wheat varieties. Agron. J. 53:30-32.

Andrews, F. M. and C. C. Beals. 1919. The effect of soaking in water and aeration on the growth of Zea mays. Bull. Torrey Bot. Club 46:91-100.

Arny, D. C. and C. Leben. 1955. The effect of water-soaked seed treatment on the germination of certain barley varieties grown at different locations. Phytopathology 45:518-519.

Association of Official Seed Analysts. 1965. Rules for testing seeds. Proc. Ass. Off. Seed Anal. 54(2):1-112.

Audus, L. J. 1960. Magnetism: A new plant-growth response. Nature 185:132.

Austin, R. B., P. C. Longden and J. Hutchinson. 1969. Some effects of 'hardening' carrot seed. Ann. Bot. new ser. 33:883-895.

Barton, L. V. 1954. Effect of presoaking on dormancy in seeds. Contrib. Boyce Thompson Inst. 17:435-438.

Berrie, A. M. M. and D. S. H. Drennan. 1971. The effect of hydration-dehydration on seed germination. New Phytol. 70:135-142.

Bleak, A. T. and W. Keller. 1969. Effects of seed age and pre-planting seed treatment on seedling response in crested wheatgrass. Crop Sci. 9:296-299.

Bleak, A. T. and W. Keller. 1970. Field emergence and growth of crested wheatgrass from pretreated vs nontreated seeds. Crop Sci. 10:85-87.

Bradford, W. W. and E. C. Ewing. 1958. Preliminary studies on the application of gibberellic acid to cotton seed and seedlings. Agron. J. 50:648-650.

Breslavets, L. B. 1946. Plants and X-rays. American Institute of Biological Sciences, Wash. D. C. 122 p.

Chippindale, H. G. 1933a. The effect of some chemicals on germination of cocksfoot (Dactylis glomerata L.). Ann. Appl. Biol. 20:369-376.

Chippindale, H. G. 1933b. The effect of soaking in water on 'seeds' of Dactylis glomerata L. Ann. Bot. 47:841-849.

Chippindale, H. G. 1934. The effect of soaking in water on the 'seeds' of some Gramineae. Ann. Appl. Biol. 21:225-232.

Commoner, B., J. J. Heise, B. B. Lippincott, R. E. Norberg, J. V. Passoneau and J. Townsend. 1957. Biological activity of free radicals. Science 126:57-63.

Conrad, H. M. 1968. Biochemical changes in the developing wheat seedling in the weightless state. BioScience 18:645-652.

Degby, Sir K. 1661. A discourse concerning the vegetation of plants. Second treatise (A discourse spoken at Gresham College on 23rd January, 1660 p. 10) (Cited in: Dastur, R. H. and L. T. Mone. 1958. Scientific aspects of the method of presoaking seeds in solution of salts for getting increased yields of crop plants. Indian J. Agr. Sci. 28:1-12.)

Ells, J. E. 1963. The influence of treating tomato seed with nutrient solutions on emergence rate and seedling growth. Proc. Amer. Soc. Hort. Sci. 83:684-685.

Evenari, M. 1964. Hardening treatment of seeds as a means of increasing yields under conditions of inadequate moisture. Nature 204:1010-1011.

Eyster, H. C. 1940. The cause of decreased germination of bean seeds soaked in water. Amer. J. Bot. 27:652-659.

Findley, W. R. and L. G. Campbell. 1953. Ultrasonic treatments of dormant hybrid corn seed. Agron. J. 45:357-358.

Geng, S. and F. L. Barnett. 1969. Effects of various dormancy-reducing treatments on seed germination and establishment of Indiangrass, Sorghastrum natans (L.) Nash. Crop Sci. 9:800-803.

Goodenough, J. L., R. B. Stone and J. J. McDow. 1970. Effect of direct current glow discharge on germination of cotton seed. Trans. ASAE 13:354-356.

Hafeez, A. T. A. and J. P. Hudson. 1967. Effect of "hardening" radish seed. Nature 216:688.

Hopkins, E. R. 1960. Germination stimulation in Pinus pinaster Ait. West. Aust. Forest Dept. Bull. 66.

Hull, R. 1969. Broom's Barn Experiment Station. (Cited in: Rothamsted Exp. Sta. Rep. for 1968, pt. 1:270-297.)

International Atomic Energy Agency. 1961. Proceedings of the symposium on the effects of ionizing radiations of seeds in Aug. 1960. Kaertnerring, Vienna I, Austria 655 p.

International Seed Testing Association. 1966. International rules for testing seed. Proc. Int. Seed Test. Ass. 31:1-151.

Jenkins, D. W. 1968. USSR and U. S. bioscience. BioScience 18:543-549.

Johnson, S. J. 1968. Biochemical changes in the endosperm of wheat seedlings in the weightless state. BioScience 18:652-655.

Keller, W. and A. T. Bleak. 1968. Preplanting treatment to hasten germination and emergence of grass seed. J. Range Manage. 4:213-216.

Keller, W. and A. T. Bleak. 1969. Root and shoot growth following preplanting treatment of grass seed. J. Range Manage. 22:43-46.

Kidd, F. and C. West. 1918a. Physiological pre-determination: The influence of the physiological condition of seed upon the course of subsequent growth and upon the yield. I. The effects of soaking seeds in water. Ann. Appl. Biol. 5:1-10.

Kidd, F. and C. West. 1918b. Physiological pre-determination: The influence of the physiological condition of seed upon the course of subsequent growth and upon the yield. IV. Review of literature. Ann. Appl. Biol. 5:220-251.

Kidd, F. and C. West. 1919. The influence of temperature on the soaking of seeds. New Phytol. 18:35-39.

Korneev, P. K. 1962. Effect of presowing stimulation on some physiological processes and yield of corn. Izv. Inst. po. Biol. Bulgar. Akad. Nauk. 12:245-252. (Abstr. in Chem. Abstr. 57(6):15550h.)

Kotowski, F. 1926. Chemical stimulants and germination of seeds. J. Amer. Soc. Hort. Sci. 23:173-176.

Krylov, A. V. and G. A. Tarakanova. 1960. Magnetotropism of plants and its nature. Fiziol. Rast. 7:156-159.

Kurbatov, V. and S. Gluckmann. 1930. The influence of inorganic ions on the properties of seeds. Protoplasma 9:34-96.

Linehan, P. A. and S. P. Mercer. 1936. Does pre-soaking accelerate laboratory germination in cocksfoot (Dactylis glomerata L.). Proc. Int. Seed Test. Ass. 8:42-45.

Lopez, A. 1972. Effect of seed protein content on plant growth of barley and wheat. Master's Thesis. Corvallis, Oregon State University, 87 numb. leaves.

Lyon, C. J. 1968. Growth physiology of the wheat seedling in space. BioScience 18:633-638.

Mart'yanova, K. L. 1960. Results of field experiments with barley seed which had undergone a pre-sowing hardening to drought. Fiziol. Rast. 7:301-302.

May, L. H., E. J. Milthorpe and F. L. Milthorpe. 1962. Pre-sowing hardening of plants to drought--an appraisal of the contributions by P. A. Genkel. Field Crop Abstr. 15:93-98.

Mikkelsen, D. S. and M. N. Sinah. 1961. Germination inhibition in Oryza sativa and control by preplanting soaking treatments. Crop Sci. 1:332-335.

Nuttall, V. W., L. H. Lyall, D. H. Lees and H. A. Hamilton. 1968. Response of graden crop plants to low doses of gamma irradiation of seed. Can. J. Plant Sci. 48:409-410.

Orphanos, P. I. and W. Heydecker. 1968. On the nature of the soaking injury of Phaseolus vulgaris seed. J. Exp. Bot. 19:770-784.

Oyer, E. B. and D. E. Koehler. 1966. Seed and seedage. Proc. Int. Hort. Congr. 17th. vol. 1. abstr. 626.

Pittman, U. J. 1963. Effects of magnetism on seedling growth of cereal plants. Biomed. Sci. Instrum. Vol. 1. Plenum Press, New York. 475 p.

Pittman, U. J. 1964. Magnetism and plant growth. II. Effect on root growth of cereals. Can. J. Plant Sci. 44:283-287.

Pittman, U. J. 1965. Magnetism and plant growth. III. Effect on germination and early growth of corn and beans. Can. J. Plant Sci. 45:549-555.

Pittman, U. J. and D. P. Ormrod. 1970. Physiological and chemical features of magnetically treated winter wheat seeds and resultant seedlings. Can. J. Plant Sci. 50:211-217.

Pittman, U. J. and D. P. Ormrod. 1971. Biomagnetic responses in germinating malting barley. Can. J. Plant Sci. 51:64-65.

Popov, M. D. 1962. Effect of gibberellin and other stimulants and stimulating combinations on the growth and development of beans. Izv. Inst. po. Biol. Bulgar. Akad. Nauk. 12:153-178. (Abstr. in Chem. Abstr. 57(6):15550b)

Puma, M. 1952. Experimental researches on the magnetic field in biology. Riv. Biol. 442.8 R. 52.

Ries, S. K., O. Moreno, W. F. Meggitt, C. J. Schweizer and S. A. Ashkar. 1970. Wheat seed protein: Chemical influence on and relationship to subsequent growth and yield in Michigan and Mexico. Agron. J. 62:746-748.

Ries, S. K., C. J. Schweizer and H. Chmiel. 1968. The increase in protein content and yield of simazine-treated crops in Michigan and Costa Rica. BioScience 18:205-208.

Salim, M. H. and G. W. Todd. 1968. Seed soaking as a pre-sowing, drought-hardening treatment in wheat and barley seedlings. Agron. J. 60:179-182.

Sax, K. 1963. The stimulation of plant growth of ionizing radiation. Radiat. Bot. 3:179-186.

Schweizer, C. J. and S. K. Ries. 1969. Protein content of seed: Increase improves growth and yield. Science 165:73-75.

Shull, C. A. and J. W. Mitchell. 1933. Stimulative effects of X-rays on plant growth. Plant Physiol 8:287-296.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw Hill, New York. 481 p.

Tarakanova, G. A., V. Yu. Strekova, V. P. Prudikeva and Yu Novitskii. 1965. I. Some physiological and cytological changes in germinating seeds in a constant magnetic field. II. The effect of a uniform magnetic field of low intensity. Fiziol. Rast. 12:804-813.

Thomas, R. O. and M. N. Christiansen. 1971. Seed hydration-chilling treatment effects on germination and subsequent growth and fruiting of cotton. Crop Sci. 11:454-456.

Vergara, B. S., M. Miller and E. Avelino. 1970. Effect of simazine on protein content of rice grain (Oryza sativa L.). Agron. J. 62:269-272.

Watanaba, S. 1955. On germination of the kintoki-carrot seeds. II. Effects of pericarp removal, soaking and drying of seeds on their germination. J. Hort. Ass. Jap. 23:237-244.

Whelan, E. D. P. 1970. Effect of gamma radiation on seedling emergence of Cucumis sativus. Can. J. Plant Sci. 50:606-607.

APPENDIX

APPENDIX

Appendix Table 1. Analysis of variance for time and temperature of presoaking in GA_3 on the germination percentage of 1970 Potomac orchardgrass seed. Germination recorded after 4 days at 25 C.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Temperature	1983.83	7	283.40+
Length	18507.54	5	3701.51**
T x L	7807.97	35	223.09**
Replication	512.06	2	256.03
Pooled error	10464.62	94	113.26
Total	39275.99	143	

\+ Significant difference at 10% level.
** Significant difference at 1% level.

Appendix Table 2. Analysis of variance for time and temperature of presoaking in H_2O on the germination percentage of 1970 Potomac orchardgrass seed. Germination recorded after 4 days at 25 C.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Temperature	1965.10	7	280.73*
Length	12004.79	5	2400.96**
T x L	3481.27	35	99.47
Replication	60.60	2	30.30
Pooled error	8027.40	94	85.40
Total	25539.16	143	

* Significant difference at 5% level.
** Significant difference at 1% level.

Appendix Table 3. Analysis of variance for time and temperature of presoaking in NaCl on the germination percentage of 1970 Potomac orchardgrass seed. Germination recorded after 4 days at 25 C.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Temperature	7121.23	7	1017.32**
Length	22150.62	6	3691.77**
T x L	7301.48	42	173.85*
Replication	946.58	2	473.29
Pooled error	11834.09	110	107.58
Total	49353.99	167	

* Significant difference at 5% level.
** Significant difference at 1% level.

Appendix Table 4. Analysis of variance for time and temperature of presoaking in GA_3 on the germination percentage of 1970 Newport bluegrass seed. Germination recorded after 8 days at 25 C.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Temperature	14563.10	7	2080.44**
Length	8837.95	5	1767.59**
T x L	15258.44	35	435.95**
Replication	46.01	2	23.01
Pooled error	5636.66	94	59.96
Total	44342.16	143	

** Significant difference at 1% level.

Appendix Table 5. Analysis of variance for time and temperature of presoaking in H_2O on the germination percentage of 1970 Newport bluegrass seed. Germination recorded after 8 days at 25 C.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Temperature	7757.55	7	1108.22**
Length	5377.03	5	1075.41**
T x L	10786.58	35	308.18**
Replication	5.18	2	2.59
Pooled error	2720.82	94	28.94
Total	26647.16	143	

** Significant difference at 1% level.

Appendix Table 6. Analysis of variance for time and temperature of presoaking in NaCl on the germination percentage of 1970 Newport bluegrass seed. Germination recorded after 8 days at 25 C.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Temperature	13925.05	7	1989.29**
Length	4879.40	5	975.88**
T x L	8927.66	35	255.08**
Replication	290.29	2	145.15
Pooled error	6709.04	94	71.37
Total	34731.44	143	

** Significant difference at 1% level.

Appendix Table 7. Analysis of variance for the speed of germination of all orchardgrass treatments on the 22nd day after planting at 15-25 C.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Lots	.56	1	.56
Cultivars	16.00	1	16.00*
L x C	9.00	1	9.00**
Presoaks	32.31	3	10.77**
L x P	7.06	3	2.35
C x P	39.87	3	13.29**
L x C x P	4.13	3	1.37
Replication	12.69	3	4.23
Pooled error	79.31	45	1.76
Total	200.94	63	

* Significant difference at 5% level.
** Significant difference at 1% level.

Appendix Table 8. Analysis of variance for the speed of germination of all bluegrass treatments on the 21st day after planting at 15-25 C.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Lots	540.56	1	540.56*
Cultivars	663.06	1	663.06*
L x C	517.56	1	517.56*
Presoaks	1120.06	3	373.35**
L x P	343.31	3	114.44+
C x P	785.81	3	261.94**
L x C x P	333.06	3	111.02+
Replication	108.06	3	36.02
Pooled error	1507.44	45	33.50
Total	5918.94	63	

\+ Significant difference at 10% level.
* Significant difference at 5% level.
** Significant difference at 1% level.

Appendix Table 9. Analysis of variance for the speed of germination of all bluegrass treatments on the 28th day after planting at 15-25 C.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Lots	54.39	1	54.39
Cultivars	.02	1	.02
L x C	37.52	1	37.52
Presoaks	56.05	3	18.68
L x P	7.80	3	2.60
C x P	34.67	3	33.56
L x C x P	15.17	3	5.06
Replication	15.80	3	5.27
Pooled error	577.65	45	12.84
Total	798.86	63	

Appendix Table 10. Analysis of variance for the speed of germination of all bluegrass treatments on the 35th day after planting at 25 C.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Lots	2093.06	1	2093.06*
Cultivars	100014.06	1	100014.06**
L x C	1580.06	1	1580.06+
Presoaks	1335.69	3	445.23**
L x P	279.69	3	93.23
C x P	548.69	3	182.90
L x C x P	465.69	3	155.23*
Replication	686.69	3	228.90
Pooled error	3172.32	45	70.49
Total	110175.94	63	

\+ Significant difference at 10% level.
* Significant difference at 5% level.
** Significant difference at 1% level.

Appendix Table 11. Analysis of variance of radicle growth for treated 1970 Sterling orchardgrass measured on the 2nd day after germination.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Presoaks	1.88	3	.63*
Error	6.05	36	.17
Total	7.93	39	

* Significant difference at 5% level.

Appendix Table 12. Analysis of variance of radicle growth for treated 1970 Sterling orchardgrass measured on the 3rd day after germination.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Presoak	2.82	3	.94
Error	1.21	36	.34
Total	4.03	39	

Appendix Table 13. Analysis of variance for the speed of emergence of treated 1970 Potomac orchardgrass.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Presoaks	11889.18	3	3963.06**
Days	34313.46	6	5718.91**
P x D	5921.82	18	328.99**
Replication	2090.68	3	696.89
Pooled error	2084.82	81	25.74
Total	56299.96	111	

** Significant difference at 1% level.

Appendix Table 14. Analysis of variance for the speed of emergence of treated 1969 Potomac orchardgrass.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Presoaks	4490.68	3	1496.89**
Days	37373.71	6	6228.95**
P x D	1682.57	18	93.48*
Replication	107.54	3	35.85
Pooled error	3595.46	81	44.39
Total	47249.96	111	

* Significant difference at 5% level.
** Significant difference at 1% level.

Appendix Table 15. Analysis of variance for the speed of emergence of treated 1970 Sterling orchardgrass.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Presoaks	13668.08	3	4556.03**
Days	49369.89	8	6171.24**
P x D	3737.67	24	155.74**
Replication	968.75	3	322.92
Pooled error	4484.25	105	42.71
Total	72228.64	143	

** Significant difference at 1% level.

Appendix Table 16. Analysis of variance for the speed of emergence of treated 1969 Sterling orchardgrass.

Source of variation	Sums of squares	Degrees of freedom	Mean squares
Presoaks	12858.89	3	4286.30**
Days	84697.89	8	10587.24**
P x D	1996.11	24	83.17
Replication	874.89	3	291.63
Pooled error	8365.11	105	79.67
Total	108792.89	143	

** Significant difference at 1% level.