SOAKING AND DRYING TREATMENTS USED TO INCREASE EMERGENCE RATES OF FOUR COOL-SEASON TURFGRASSES

ABSTRACT

The object of this study was to find a seed soaking or combination soaking-drying treatment which would increase the rate of shoot emergence and thus reduce losses during establishment due to erosion, suboptimal growth conditions, or weed competition. Four cool-season turfgrasses, Manhattan perennial ryegrass (Lolium perenne L.), Merion Kentucky bluegrass (Poa pratensis L.), Pennlawn red fescue (Festuca rubra L.), and Penncross creeping bentgrass (Agrostis palustris Huds.) were used in this study.

Seeds were soaked at temperatures of 5, 10, 15, 25, 15-25 C, with soaking times of 6, 12, 24, 48, and 168 hours. Soaking solutions of distilled water and polyethylene glycol were also compared. Drying treatments were either air dried at 23.9 C for one week or oven dried at 45 C for 18 hours. Petri dish studies in a growth chamber were used for the majority of the studies, along with one field experiment.

The Penncross soaking treatments of 5, 15, and 15-25 C for 168 hours along with the soaking-drying treatment of 10 C soaking for 48 hours followed by air drying; and the soaking treatment for Merion of 25 C for 168 hours and the soaking-drying treatment of 10 C soaking for 48 hours followed by air drying were effective in increasing the rate of shoot

emergence. Only soaking treatments of 25 C for 6 hours and 5 C for 48 hours were found effective for Pennlawn, while no soaking or drying treatments were effective with Manhattan. None of the 24 polyethylene glycol seed soaking treatments increased the rate of shoot emergence of Merion Kentucky bluegrass. Also, air drying was significantly better than oven drying for Merion and Penncross, while with Manhattan and Pennlawn, oven drying after soaking was more detrimental to germination than air drying.

Thus hydroseeding, and in the case of Merion Kentucky bluegrass dry seeding, after a seed soaking treatment will increase the rates of emergence of Merion, Pennlawn, and Penncross, and would be adaptable to establishment of most turfgrass areas. No one treatment was found to be effective for all turfgrasses, since each reacted differently to soaking time and temperature.

INTRODUCTION

Several cool season turfgrass species including Kentucky bluegrasses (Poa pratensis L.) have a slow rate of germination (Parks and Henderlong - 1967). The advantage of rapid germination rates is reduced proneness to soil erosion, the potential for weed infestation, and the need to use seeding mixtures containing rapidly germinating species and cultivars. Thus the advantages of being able to decrease the time between seeding and germination are extremely significant and worth investigating, especially since nearly 100 million pounds of cool-season turfgrasses were established last year specifically for permanent cover. Another 200 million pounds of turf type seed was sold in 1974 for winter cover and agricultural purposes (temporary cover).

Kentucky bluegrass seed sold, excluding Merion, totaled 52.3 million pounds in 1974, while Merion was 5 million pounds. Red fescue produced in 1974 was 7.5 million pounds, Bentgrass produced was 9.2 million pounds, and all ryegrass produced was 220 million pounds with perennial ryegrass being 10-15 million pounds (personal communication with R.W. Schery, The Lawn Institute). Therefore, since some of the cool-season turfgrasses require more than

fifteen days to germinate and such a large quantity of seed is produced each year, there is a definite need and justification for research leading to increased rates of germination of the four major cool-season turfgrasses.

Many statements, both positive and negative, have been made regarding the effects of pregermination seed soaking, drying, and the use of chemical stimulants. Yet, little research has been done with perennial grasses, especially cool-season turfgrasses (Frischknecht - 1959).

The objectives of this study were to determine: 1) if soaking turfgrass seeds in distilled water would stimulate the rate of seedling emergence; and, if so, what soaking temperature and time combinations are optimal, 2) if turfgrass seeds could be dried after being soaked and still retain an emergence rate significantly better than an untreated control, 3) if the rate of emergence of Merion Kentucky bluegrass could be improved by soaking treatments with polyethylene glycol, and 4) if, when Merion Kentucky bluegrass seed treatments selected from the three above mentioned treatment categories were established in the field, the rates of emergence would be significantly faster than an untreated control.

LITERATURE REVIEW

Soaking With Water

The effects of soaking seeds of different crop species in water before establishment has been reported by many investigators. Cases where soaked seeds germinated more rapidly than untreated seeds include: Kidd and West (1918b), Kidd and West (1918a), and Kidd and West (1919) with various crop seeds; Chippendale (1934) with some Gramineae spp.; Haight and Grabe (1972) with orchardgrass (Dactylis glomerata L.). Keller and Bleak (1968) found that crested wheatgrass (Agropyron cristatum L.) emerged more rapidly from the soil than the control when the seed was soaked for two to three days at room temperature; and Bleak and Keller (1969) also reported that crested wheatgrass which was soaked, but not submerged, emerged more rapidly than untreated seeds. The response was in direct proportion to the duration of seed soaking, with soaking also improving shoot and root growth.

Although the initial rate of emergence and growth was often better than the control, Kidd and West (1918b) with various crop seeds, Keller and Bleak (1969) with crested wheatgrass, and Haight and Grabe (1972) with orchardgrass found that the final total germination and growth were nearly equal.

Frost and cold resistance have been found to increase in seedlings whose seeds had been soaked prior to establishment. These low temperature stress responses were reported by Kushnirenko (1957) with tomato (Lycopersicon spp. Mill.) and corn (Zea mays L.), Kydrev (1959) with Mercury wheat (Triticum aestivum L.), Thomas and Christiansen (1971) with cotton (Gossypium spp. L.) and Cole and Wheeler (1974) with cotton.

Genkel (1964) with several crops and Lyles and Fanning (1964) with grain sorghum (Sorghum vulgare Pers.) found that seeds germinating under drought stress which had been soaked before sowing emerged more rapidly than the control (Lyles) and produced drought tolerant plants (Genkel).

On the other hand, some researchers state that soaking with water was not beneficial to increased germination rates and development of a plant: a) Kidd and West (1918b) state that soaking seeds in large volumes of water reduces the beneficial effects, and may even be harmful to seeds, b) With orchardgrass Linehan and Mercer (1936) found no acceleration in laboratory germination after soaking seeds with water, c) Sorghum height, weight, and yield were lower under drought conditions with seeds which had been soaked and dried than with untreated seed (Evenari - 1964).

Temperature of the soaking water appears critical, since 70 C soaking for 5 minutes reduced cotton seed germination (Cole and Wheeler - 1974). Young, Kay, and Evans (1974) state that high temperature soaking must be with aeration and of very short duration.

Soaking or Treating With Gibberellin, Hormones, and Other Compounds

Gibberellic acid (GA), hormones, and various other extract compounds have been used as seed treatments at varying concentrations for the purpose of stimulating seed germination and seedling growth. Button (1959) found that GA hastened the germination of red fescue (Festuca rubra L.), domestic ryegrass (Lolium perenne L.), tall fescue (Festuca arundinacea Schreb.), and Kentucky bluegrass. Kentucky bluegrass, perennial ryegrass, and creeping red fescue each reacted with increased germination rates and leaf growth when Behrendt (1960) applied specific amounts of GA to soaking solutions for each species. Cole and Wheeler (1974) reduced chilling injury to cotton plants by soaking the seed in either GA or cyclic AMP. Young et al (1974) worked with bermudagrass (Cynodon dactylon L.) and reported that adding GA_3 to the soaking solution enhanced the rate of germination and total germination, and than when kinetin was added to the GA_3 in the soaking solution, seedling size increased. Seaweed extract used at 0.5% and 1.0% in a soaking solution for creeping red fescue increased the speed of seedling emergence (Button and Noyes - 1964). Since a water control was inferior to the seaweed treatment, it appears that the seaweed extract was effective.

Nonstimulatory effects with GA have been reported by Andersen (1957) with Merion Kentucky bluegrass and by Haight and Grabe (1972) with orchardgrass. Both reported that GA

and water were of equal value in stimulating seed germination. Porter (1950) found that the following compounds had minimal response or were detrimental to dormant and nondormant seed species germination: ascorbic acid, colchicine, Hormodin "A", indoleacetic acid, indolebutyric acid, indol-3-acetic acid, K-a-naphthalene-acetate, lacto flavin, levulinic acid, naphthalene acetamide, naphthalene acetic acid, thiourea, vitamin B_1, or 13 commercial hormone dusts.

Soaking with Dilute Nutrient Solutions or Fungicide

Nelson (1927) stated that the speed of germination and total number of seeds germinating in Poa spp. were increased by presoaking the seed in a potassium nitrate (KNO_3) solution. Andersen (1935) found that Canada bluegrass (Poa compressa L.) germination was not affected by nitrate solution when the seeds were in soil, but the percent germination increased substantially when seeds were given nitrate solution on filter paper. Bluegrass and tall fescue seedling survival was reported improved with potassium chloride but not with soaking in urea (Daniel and Goetze - 1957). With Cougar and Newport Kentucky bluegrass seed, Maguire and Steen (1971) found that 0.1% - 0.2% KNO_3 soaking solution was more effective than water in increasing the germination rate, as well as increasing respiration rates. Martyanova (1960) reported that soaking barley seeds (Hordeum vulgare L.) with boric acid produced the best results in terms of emergence rates when compared to low temperature hardened and control treatments.

Others feel that dilute nutrient solutions and fungicides have no positive effect on seed germination. Tyler, Murphy, and MacDonald (1956) found that, except where smut was present, fungicide treatment of seed had little value in terms of increased stand or yield. Daniel and Goetze (1957) and Daniel (1958) found that among five fertilizers (potassium chloride, ammonium nitrate, nitrogen plus phosphorus, superphosphate, or urea), none enhanced germination or seedling growth over water soaked seeds. Daniel (1958) also reported that potassium salts are less toxic to seeds during soaking than are ammonia salts. Finally, Dickens and Moore (1974) found that KNO_3 did not affect the rate of emergence or the total number of seeds germinated in cogongrass (Imperata cylindrica L.).

Drying After Soaking Treatments

In order to facilitate seed planting, soaked seeds are often dried before being sown. The effects of the drying methods on the germination advantage derived from soaking are both positive and negative. Kreyger (1963) classified grass seeds as quick drying. He states that when drying by the bulk method the drying layer thickness should be much less for quick drying seeds than for slow drying seeds, such as peas (Pisum sativum L.) and beans (Phaseolus spp. L.).

Chippindale (1934) reported that the imbibition of water in soaked and untreated seeds proceeds at about the same rate. Kidd and West (1918b) found the opposite to be

true. They stated that seeds soaked in a minimum amount of water and slowly dried imbibe water and develop more quickly than untreated seeds. Berrie and Drennan (1971) reported that imbibition in tomato seed was greater in soaked than in untreated seed. Chippindale (1934) stated that since extreme desiccation after soaking does not remove the beneficial effect of the soaking, it is clear that the effect is independent of the absolute water content of the grains. Chippindale (1934) concluded that the acceleration of germination by presoaking is not associated directly with the water relations of the seed.

The stage at which drying takes place after seed soaking, or even germination, appears to be the determining factor in plant survival according to Kydrev (1959). He also reported that drying exerts a favorable response on caryopses which are at the stage of incipient germination, and plants grown from such caryopses develop most vigorously, accumulate the greatest amount of dry matter, and are most frost resistant. Berrie and Drennan (1971) showed that soaked tomato and oat (Avena spp. L.) seeds could be returned to air dry condition provided that desiccation occurs before the onset of active cell division. Desiccation that occurred prior to cell division resulted in more rapid germination when the seeds were next wetted (Berrie and Drennan - 1971). The observation (Berrie and Drennan - 1971) that drying after cell division could be detrimental is supported by Kydrev (1959), who reported that Mercury wheat seeds were unable to

resume the dormant condition after formation of the coleoptile and emergence of the first leaf. Kydrev (1959) also showed that death of roots on germinating wheat seeds did not mean the seed (plant) would die, instead new roots often appeared shortly before the second soaking. Berrie and Drennan (1971) found that dehydration of tomato and oat seeds may be done more than one time, and the effects may be accumulative if prior imbibitions are of proper duration. The observation and conclusion that seed coverings do not return to their original state, thus leading to more rapid imbibition upon rewetting was reported by Berrie and Drennan (1971).

Andersen (1938) indicated that two to three weeks of daily moistening and drying prior to germination gives a higher percent germination than untreated seeds under the same 20-30 C room temperature-germination environment. May, Milthorpe, and Milthorpe (1962) concluded that soaking seeds and then air drying produced plants which had increased drought tolerance. In dallisgrass (Paspalum dilatatum L.) the drying temperature did not appear to reduce seed viability, and in many cases seed dried at 60 C actually had stimulated germination to the point of being equal or better than seed dried at 37.8 C (Bennet and Marchbanks - 1969). Canode, Law, and Maguire (1970) found that Kentucky bluegrass seed which was dried in the swath, was able to withstand a temperature of 49 C without influencing germination. Ries, Seward, Schweizer, and Ayers (unpublished data) found that soaking seeds in organic solvents and then drying can increase the

growth and protein content of grains, under greenhouse and field conditions. Wheat seeds which were soaked in a large tank for 24 hours, then dried in a kiln at 36-38 C to 12% moisture (approx. ten hours) had a positive yield increase only when the plants were subjected to stress, as reported by Woodruff (unpublished data). Bass (1953) reports that Kentucky bluegrass seed with 54% moisture was injured by 30 C drying for 24 hours, but 44% moisture seed withstood 60 C drying without loss in germination. Keller and Bleak (1968) and Bleak and Keller (1969) agree that although drying of seeds after being soaked produced more rapid germination rates than the control, there was still some loss in rate of emergence from the soaked seeds which were not dried.

Several researchers have reported that in general, drying or certain drying techniques are ineffective in improving or retaining the advantage obtained by soaking seeds. Kidd and West (1918b) found that seeds which had been soaked and then dried rapidly germinate slower than untreated seeds. Waisel (1962) found that winter wheat which was soaked and dried or treated with calcium (Ca^{+}) had no effect on true hardiness (frost, drought, and heat hardiness). Kreyger (1963) found that drying grains at temperatures greater than 65 C reduced seed viability. Finally, no improvement in emergence rates of cotton, after soaking in water at several temperatures and then drying overnight at ambient temperature, were found by Thomas and Christiansen (1971).

Polyethylene Glycol (PEG) Soaking Treatment

Heydecker, Higgins, and Guliver (1973) treated vegetable seeds with several soaking concentrations of PEG by placing the seeds in petri dishes on filter paper soaked in varying concentrations of the solutions. Following treatment, the seeds were washed, surface dried, and placed on water soaked filter paper to germinate. Heydecker et al. (1973) stated that PEG cannot pass through the cell wall, produces an osmotic pressure, is chemically inert so it will not harm the seed during long term exposure, and its concentration is critical. Also, Heydecker et al. (1973) reported that soaked onion (Allium cepa L.) seeds that were fully dried took three days to germinate in comparison to one day when not dried, yet even the drying treatment was significantly more rapid in germination than the control. The need for aeration during soaking was one problem which was also mentioned. Finally, the PEG treatments were found to increase both the rate and uniformity of germination, Heydecker et al. (1973).

Field Results After Seed Soaking Treatments

Adapting soaking treatments to a large scale for field establishment may present some potential problems due to volume. For example Kidd and West (1918b) reported that soaking seeds in large volumes of water may be harmful instead of stimulatory to seeds. Young et al. (1974) noted difficulties with fermentation of the soaking liquid and seeds when hydroseeding.

Preplant soaking treatments of corn seeds showed a positive effect on the growth, development, and harvest of late planted corn according to Zubenko (1959). He also reported that the most effective treatments were those where single and double 24-hour soakings of seeds were followed by drying after each soaking to an air dry condition. Zubenko (1959) also found that corn seeds which sprouted during soaking had a lower germination than unsprouted seeds. Martyanova (1960) stated that boric acid soaking treatments appeared to be most effective during spring and summer droughts, after the appearance of shoots. New shoots of treated barley seeds appeared a day or two earlier than the control (Martyanova - 1960).

Reduced germination at high osmotic pressures, simulated drought conditions, appears to be related to lower respiration and moisture absorption. Yet, improved germination at high osmotic pressures was noted by Carry and Brown (1965) when wheat seeds were soaked prior to establishment. Following that line of thinking, Woodruff (1968) found no evidence of increased soil moisture usage by hardened wheat plants when compared to a control.

Haight and Grabe (1972) noted up to a 40% increase in the rate of emergence from the soil of orchardgrass after a seed wetting and drying treatment. Bleak and Keller (1970) noted that with crested wheatgrass a soaked and a control did equally well in the greenhouse, while in the field the soaked seed emerged more rapidly than the untreated control.

Abdel Hafeez and Hudson (1967) suggested that hardening, under some circumstances, may confer greater advantage under favorable conditions than under adverse growing conditions. In complete disagreement with Abdel Hafeez and Hudson (1967) are Chippindale (1934), Haight and Grabe (1972), and Bleak and Keller (1970) who feel that the advantage of preplant seed soaking was enhanced as conditions favoring emergence deteriorated.

Germination Conditions In An Environmental Chamber

Harrington (1923) found that bluegrass seed germinated most rapidly with alternations of temperature and also gave the most complete germination. Nelson (1927) also reported that alternating temperature is the most effective stimulant for the Poa spp. Toole and Toole (1955) reported that an alternating temperature between 15 C and 25 C was best for chewings fescue (Festuca rubra var. Commutata Gaud.), and that proper germination temperature is important in reducing variability of germination counts. Frazier (1960) stated that tall fescue and red fescue germinated under constant temperatures, but Penncross creeping bentgrass (Agrostis palustris L.) and Merion Kentucky bluegrass required alternating temperatures for maximum germination. Also, initial germination was accelerated by higher temperatures, but did not always produce the highest percentage of germination. Regarding chamber germination temperature, Haight and Grabe (1972) stated that an alternating temperature between 15 C and 25 C produced results for all treatments

which were nearly equal in terms of their rates of seed germination, while at a 25 C constant germination temperature the rates of germination were different for each treatment.

In terms of light quantity during germination, Juhren, Hiesey, and Went (1953) found that Kentucky bluegrass did not benefit from high intensity, natural light.

MATERIALS AND METHODS

Determination of Optimum Soaking Time and Temperature

Penncross creeping bentgrass (Agrostis palustris Huds.), Pennlawn red fescue (Festuca rubra L.), Merion Kentucky bluegrass (Poa pratensis L.), and Manhattan perennial ryegrass (Lolium perenne L.), were the four turfgrasses used in this study. Seed from the same four seed sources were used throughout the study. Twenty-five different soaking time-temperature treatments were established for each turfgrass species. Approximately 50 cc. of seed was placed in each soaking bottle. Soaking was accomplished in distilled water placed in 120 ml. glass bottles with screw-on plastic caps. Under these conditions, there appeared to be minimal air present during soaking, probably near anaerobic conditions since the water level in the bottles was kept filled to the lip, and the water was never changed. Soaking bottles were shaken each day to eliminate any air pockets, but were never aeriated while soaking. The temperature treatments were 5, 10, 15, 25 and 15-25 C, with the 15-25 C treatment alternating every 6 hours between 15 C and 25 C. Soaking times were 6, 12, 24, 48, and 168 hours. Soaking treatments took place in controlled environment chambers which were maintained in total darkness.

After the designated times, the appropriate bottles with the turfgrass seeds in them were removed from the soaking treatment chambers, at which time 25 seeds from each treatment bottle were placed in each of three petri dishes. This process of placing the seeds in the petri dish will be referred to as establishment throughout this paper. Petri dishes were new 10 cm plastic dishes which had #3 qualitative Whatman filter paper in each in order to maintain moist conditions. Once the seeds were placed in the petri dishes, the dishes, with covers, were placed in a large controlled environment chamber which was maintained at standard conditions for germination of these turfgrasses. These conditions were 8 hours of light at 25 C and 16 hours of darkness at 15 C. Both flourescent and incandescent lighting were present in the chamber which produced light energy ranging from 560-960 microeinsteins $m^{-2}sec^{-1}$ within the chamber. Petri dishes were rotated weekly within the chamber, and were watered with distilled water as needed to maintain moist conditions.

Germination counts were made on specific days, 5, 10, 15, 20, and 30 days after establishment in the germination chamber. The point at which the shoot first emerged from the seed coat was defined as the point of germination for all four turfgrasses.

Comparison of Oven vs. Air Drying

Forty-five soaking temperature and time treatment combinations from the four turfgrasses studied in the above mentioned soaking study were dried in two different manners.

Soaking treatments took place exactly as described previously, then instead of placing the seeds in the petri dishes, the seeds from each bottle were divided into two groups. One-half of the treated seeds, approximately 25 cc, were air dried on paper towels at an average temperature of 23.9 C for one week, while the other half was oven dried on paper toweling at 45 C for 18 hours.

After drying treatments were complete, 25 seeds from each soaking and drying treatment combination were placed in each of three new 10 cm plastic petri dishes with #3 Whatman qualitative filter paper. These dishes were then placed in the germination chamber with 8 hours of light at 25 C and 16 hours of darkness at 15 C for the 30 day observation period. Dishes were watered with distilled water as needed to maintain moist conditions within each dish. Germination readings were taken at times of 5, 10, 15, 20, and 30 days after establishment.

Soaking in Polyethylene Glycol (Carbowax® '6000')

This study with Merion Kentucky bluegrass involving (a) two concentrations of polyethylene glycol (PEG), (b) several treatments soaked in distilled water, and (c) a control which was not soaked at all before established on the petri dishes, compared soaking treatments. Soaking time, soaking temperature, PEG concentration, aeration or no aeration, and the two previously mentioned drying techniques were the five treatment variables.

Soaking was done in one liter Erlenmeyer flasks with 200 cc of seed, at three times of 7, 12, or 21 days. Four temperature treatments were 10 C, 15 C, 23.9 C (room temperature), or alternating between 15 C and 25 C every six hours. The three concentrations were (1) 145 grams of Carbowax® '6000' in one liter of distilled water, (2) 290 grams of Carbowax® '6000' in one liter of distilled water, or (3) only pure distilled water.

Aeration treatment was either aeriated or not aeriated. This was done with an impeller type pump which had a porous stone bubbler on the end of the air line within the soaking flasks. The aeration was intense enough to keep the solution and seed in constant motion.

Drying treatments involved either air drying at 23.9 C for one week, oven drying at 45 C for 18 hours, or not drying at all before establishment.

In all cases the seeds soaked in PEG were rinsed with distilled water to remove PEG on the seed surface before the 25 seeds were counted out into each of the three replicate petri dishes for the germination test.

Controlled environment chambers maintained in total darkness were used for all soaking treatments, except for the room temperature treatments. Germination tests took place in another controlled environment chamber maintained at the standard germination conditions for these turfgrasses as stated previously. Also, distilled water was added to all petri dishes as needed to maintain moist conditions in

each dish. Germination observation times were the same: 5, 10, 15, 20 and 30 days after establishment.

Field Study

Thirteen promising treatments from the three previous studies (soaking, drying, and PEG) were established, on September 20, 1974, in a split-plot design in the field on 152.4 cm X 152.4 cm plots, (5 X 5 ft. plots), with 4 replicates of each treatment.

The plot area which had pH 6.6, phosphorus level of 70.62 Kg./ha. (63 lbs/A.) (high), and potassium level of 121.07 Kg./ha. (108 lbs/A.) (medium), was fertilized with 73.25 Kg./ha. (1.5 lbs/1,000 sq. ft.) of actual nitrogen (N) in the form of urea. This was applied with a gravity type spreader. Before seeding, the N was incorporated into the top 0.64 - 1.27 cm. (0.25 - 0.5 inch) of soil by a light raking. Another foliar application of urea at the rate of 24.41 Kg./ha. (0.5 lb/1,000 sq. ft.) was applied to the plots on November 9, 1974, to promote growth for the final field observations before snow cover.

A Merion Kentucky bluegrass monostand was used in the field study. A seeding rate of 48.83 Kg./ha. (1 lb/1,000 sq. ft.) was used for all plots. Seeding was done by hand within a perimeter seeding box, with the seed being mixed with sand for ease of distribution. Immediately after seeding, each plot was lightly raked to insure soil-seed contact in the upper .32 - .64 cm of soil, and then irrigated

lightly. Plots were neither rolled nor mulched. Alleyways were included to avoid walking on the actual plot area. Mulching would have made density measurement very difficult.

Two replicates of the plot area were irrigated, with a rose-head nozzle, to maintain a moist soil surface, while the other half was only irrigated to maintain a moist soil surface for the first week after establishment. See Appendix Table 9 for rainfall and temperature data.

Shoot density counts were taken in 10.16 X 10.16 cm steel grids on each plot, with three replicate random counts per plot, on both October 10 and October 15, 1974, 20 and 25 days, respectively, after establishment.

Statistical Analysis

The soaking, drying, and PEG studies were all completely randomized design within the growth chamber, while the field study was in a split-plot design. Means from all four studies were compared to the untreated control mean by using Dunnett's test at the 5% level. In all cases there were three replicates per each treatment, except in the field where there were four replicates. All percentages were transformed by arc sine transformation before the analysis of variance and the Dunnett's test were performed.

RESULTS AND DISCUSSION

Results for all four turfgrasses are based on the germination percentages measured at 5, 10, 15, 20 and 30 days after establishment, with establishment being the time at which the seeds were placed in the petri dishes.

Penncross creeping bentgrass

Improvement in germination rate was noted only at the 5-day count (Table 1 and Appendix Table 1). After five days there was no positive effect of soaking on seed germination including the end point percent germination. There was also no effect from the five soaking temperatures. Soaking time was a significant factor. In general, increased soaking time (up to 168 hours as measured in this study) caused improved germination percentage. In all cases, in Table 1, where the soaking time was 48 hours or more, the 168 hour time gave higher percentage germination than the 48 hour time at the same soaking temperatures. Also worth noting is that the 24 C for 10 hours treatment was the only treatment significant at the 24 C temperature. Although inhibitory effects on seed germination were noted at the 5, 15, and 25 C levels where soaking time was 24 hours or less, the net temperature effect over the five measurement times was such that temperature was not a significant factor.

These soaking treatments may have an important effect on reducing damping-off problems, since the seeds could germinate fast enough to avoid being affected. No damping-off was noted in any phase of these studies.

One of 14 treatments, 10 C soaking temperature for 48 hours and then air dried, gave significantly greater seed germination, and that was only at the 5-day observation date (Table 2 and Appendix Table 2). Detrimental effects of seed soaking followed by drying were noted primarily when the soaking temperature was greater than 15 C and soaked for 48 or 168 hours. Oven drying tended to be more inhibitory to early germination than air drying. The negative responses to drying seem to be related to the warmer soaking temperatures which may have induced respiration and cell division in the seed. Yet since the total germination percent was not effected, no reason for one positive response and several negative responses at the 5-day count has been hypothesized.

Since no previous work with bentgrass was found, there is no means of direct species comparison to past results. This study shows that there is a definite advantage in terms of germination rate when Penncross creeping bentgrass seeds are soaked in distilled water for between 48 and 168 hours. Since the soaking temperature was not significant, this soaking technique could be useful and easily adapted to Penncross bentgrass establishment to insure more rapid emergence, and thus less potential for losses and poor stands due to erosion or weed infestation. The advantage obtained

by soaking Penncross seed was not retained after drying, whether by air or oven drying. Thus, the hydroseeding method appears to be the best means of utilizing the benefits from soaking bentgrass seed.

These positive results with Penncross need to be compared with other bentgrass cultivars which have not been investigated.

Pennlawn red fescue

In this study there were two significant beneficial soaking treatments five days after establishment of the Pennlawn red fescue (Table 3 and Appendix Table 3). The best soaking treatments were for 48 hours or less. The temperature of the soaking treatments were not significant. Although, combining a soaking temperature of 25 C or 15-25 C with a soaking time of 168 hours resulted in permanent detrimental effects on germination as well as the total end point germination. Possible explanation for the detrimental effects could be that the seeds began to respire at the higher temperature, lost some of the nutrients in the seed by leaching, and reduced the endosperm, through respiration and metabolism to a point where germination was no longer possible.

As with bentgrass and most turfgrasses, little or no work has been done with soaking treatments on red fescue. Button (1959) and Behrendt (1960) have both worked with soaking red fescue with GA in the soaking solutions. Both found that the rate of emergence was hastened from a control.

Button and Noyes (1964) found that soaking red fescue with seaweed extract increased the rate of emergence.

When Pennlawn was dried following various soaking treatments, there were no significant beneficial responses (Table 4 and Appendix Table 4). No significant differences were found between the air and oven drying techniques. The thirteen treatments which were negatively significant from the control were that way since the control reached 100% germination at the 10-day count, while the drying treatments reduced the germination percentage. Explanation for reduction in germination was not determined in this study.

Soaking treatments that will increase seed germination of Pennlawn red fescue include 6 hours of soaking at 25 C, and 48 hours of soaking at 5 C. Most other soaking treatments with soaking times greater than 48 hours were permanently inhibitory to germination. In terms of drying, these results show that Pennlawn seed cannot be dried effectively after soaking without reducing the total end point percent germination, thus making drying after soaking of Pennlawn seed impractical. Based on these findings, the previously listed beneficial soaking treatments would be best used in combination with hydroseeding.

Manhattan perennial ryegrass

In the Manhattan perennial ryegrass tests there were no soaking treatments nor soaking and drying combinations which were significantly better than an untreated control (Tables 5 and 6, and Appendix Tables 5 and 6). In the

soaking treatments, soaking temperatures of 25 and 15-25 C and a soaking time of 168 hours reduced total end point germination after 30 days. Six of the eight treatments in the drying study were significantly lower in percent germination than the control. Over all five germination count times there was no significant difference between oven and air drying, but at the 5-day count there were significant differences between the air and oven techniques (Table 6 and Appendix Table 6).

There are no past findings to relate to these results. Since perennial ryegrass germinates so rapidly without treatment, developing a treatment to improve the rate of emergence may be of less importance. Manhattan perennial ryegrass may be losing necessary compounds for germination by leaching while soaking. This conclusion seems reasonable since most of the soaking and drying treatments have significantly lower germination percentages than the control. If drying was the cause of inhibition of germination then the soaking treatments should not have been affected as they were.

Merion Kentucky bluegrass

Soaking

The length of soaking time was significant in the Merion Kentucky bluegrass seed soaking study (Table 7 and Appendix Table 7). The rate of germination generally increased with increasing soaking time. The only treatment combination significantly greater than the control was

soaking at 25 C for 168 hours, which was significant 10 days after establishment. Only three treatments were significantly lower than the control. These were only at the 20-day count and are therefore of little concern.

Drying

In the Merion drying study one treatment, 48 hours of soaking at 10 C and air dried, was significantly greater than the control at the 15-day period only (Table 8 and Appendix Table 8). All other drying treatment combinations were far from being positively significant compared to the untreated control. Most oven drying treatments caused significantly lower germination than the untreated control. Air drying gave significantly higher overall germination than oven drying.

Polyethylene glycol (PEG) Soaking

(PEG) treatments differed significantly from each other, but none positively from the untreated control (Appendix Table 10). Many treatments were inhibitory up to 20 days when compared to the control, after which no significant differences existed from the control for all but 5 of the total 27 treatments. Although there were no positive effects in this study, the data seems to indicate: (a) oven drying ranked higher than air drying, (b) wet seed germinated more rapidly than air or oven dried seed, (c) PEG and distilled water performed equally, (d) 145 grams/liter and 290 grams/liter of water treatments responsed equally in

germination, and (e) aeriated treatments had a higher percent germination than non-aeriated soaking treatments.

Field Study

Results of the field study as determined by shoot density measurements made 20 and 25 days after establishment are reported in Table 9. Due to a wet fall, the irrigated vs. non-irrigated comparisons were not significant at the 5% level as determined by an F-test. Visual differences between the 12 treatments and the untreated control were quite apparent in terms of green cover, but none of the treatments were significantly different in terms of density counts at the 5% level according to the F-test (Table 9). A possible explanation for why visual differences appear to exist, yet there is no significance after the statistical analysis of the density data is performed, is that the sampling error was larger than would be expected. Since the seed was established by hand there was difficulty in achieving a uniform stand on each plot. Thus greater than usual sampling error was encountered in taking the density counts.

It should be noted that the best treatment from the growth chamber studies, 25 C soaking temperature with a soaking time of 168 hours and established wet, (see Table 7), was also one of the best ranking treatments in the field study (see Table 9). All other treatments from Tables 7 and 8 which were also in Table 9 responded in a consistent manner when compared between Tables. Therefore it appears that the

growth chamber is an effective means of evaluation and reducing seed soaking treatments before going to the field for confirming observations.

Had the fall not been so wet, it was hoped that any effects of soaking on drought tolerance and better emergence than untreated seed under suboptimal conditions would be determined. Thus further study is needed in the area of the effects of turfgrass seed soaking and drying where planted under suboptimal and stress conditions as discussed by Haight and Grabe (1972).

Summary Discussion

Rates of emergence can be increased in Penncross creeping bentgrass, Merion Kentucky bluegrass, and Pennlawn red fescue by soaking the seeds at a specific temperature and time combination in distilled water and sowing while wet. Penncross creeping bentgrass and Merion Kentucky bluegrass rates of emergence can also be improved by soaking in distilled water for a specific temperature and time combination followed by air drying before sowing the seed. No soaking or drying treatment combination was found which would significantly increase the rate of emergence of Manhattan perennial ryegrass.

From these studies it was concluded that no one treatment will be effective for all four of the turfgrasses studied, thus indicating that each species and cultivar will have its own unique stimulatory treatment. This conclusion is also supported by Young et al. (1974), Salim and Todd (1968),

Griswold (1936), Chippindale (1934), and Kidd and West (1918a and 1918b). Also, a possible explanation for some of the variability within treatments could be that single seeds within a source differ in response to seed treatments, which was suggested by the data of Keller and Bleak (1969) when working with preplant treatment of grass seed.

Kidd and West (1919) stated that soaking in an excess amount of water was injurious at all temperatures, while in this study excess amounts of water were used for all soaking treatments with some positive results obtained. Also, this study showed that the rate of seed germination increases for some turfgrasses (Merion and Penncross) with increased soaking time which contradicts the results of Kidd and West (1919).

Since it is not practical to report all daily germination percentages, one is not able to determine from the Tables when each turfgrass initiated germination. Therefore, the following are ranges for initiation of germination of each turfgrass: Penncross creeping bentgrass 5-10 days, Manhattan perennial ryegrass 4-6 days, Pennlawn red fescue 5-8 days, and Merion Kentucky bluegrass 8-17 days.

In regard to the drying treatments, oven and air dried, this research only reports the effect of oven drying for 18 hours at 45 C and air drying at 23.9 C for 1 week, not the general effect of all oven and all air drying treatments on seed which has been soaked.

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TABLE 1. Bentgrass Soaking Treatments: Penncross creeping bentgrass seed soaking treatments which were significantly different from the untreated control, at a specific observation date, at the 5% level using Dunnett's test for two-sided comparisons (Dunnett - 1955).

Treatment		Observation Date		
Soaking Time (hrs.)	Soaking Temperature (°C)	(Days after sowing the seed)	Percent Seed Germination	Difference from the control in percent germination
6	15	10	66.6	-22.4
6	25	5	0	-15.0
6	25	10	69.3	-20.0
12	15	5	0	-15.0
12	15	10	61.3	-28.0
24	5	10	66.6	-22.4
24	10	5	58.6	+43.6
48	5	5	57.3	+42.3
48	10	5	66.6	+51.6
48	15	5	77.3	+62.3
48	15-25	5	58.6	+43.6
168	5	5	81.3	+66.3
168	10	5	69.3	+54.3
168	15	5	81.3	+66.3
168	25	5	77.3	+62.3
168	15-25	5	81.3	+66.3

Note: None of the treatments which were positively significant from the control were significantly different from one another according to Tukey's test at the 5% level.

TABLE 2. Bentgrass Drying Treatments. Penncross creeping bentgrass seed soaking-drying treatments which were significantly different from the untreated control, at a specific observation date, at the 5% level using Dunnett's test for two-sided comparisons.

Treatment			Observation Date		
Soaking Time (hrs.)	Soaking Temp. (°C)	Drying Treatment	(Days after sowing the seed)	Percent Seed Germination	Difference from the control in percent germination
48	10	air	5	89.3	+25.3
48	15-25	oven	5	32.0	-32.0
168	25	air	5	34.6	-29.4
168	25	oven	5	26.6	-37.4
168	15-25	oven	5	29.3	-34.7

TABLE 3. Fescue Soaking Treatments. Pennlawn red fescue seed soaking treatments which were significantly different from the untreated control, at a specific observation date, at the 5% level using Dunnett's test for two-sided comparisons.

Treatment		Observation Date		Difference from the control in percent germination
Soaking Time (hrs.)	Soaking Temperature (°C)	(Days after sowing the seed)	Percent Seed Germination	
6	25	5	12.0	+12.0
24	25	10	82.7	-13.3
48	5	5	8.0	+ 8.0
168	15	10	77.3	-18.7
168	25	10	66.7	-29.3
168	25	15	78.7	-20.0
168	25	20	81.3	-17.4
168	25	30	82.7	-16.0
168	15-25	10	65.3	-30.7
168	15-25	15	76.0	-22.7
168	15-25	20	81.3	-17.4
168	15-25	30	81.3	-17.4

TABLE 4. Fescue Drying Treatments. Pennlawn red fescue seed soaking-drying treatments which were significantly different from the untreated control, at a specific observation date, at the 5% level using Dunnett's test for two-sided comparisons.

Treatment			Observation Date		
Soaking Time (hrs.)	Soaking Temp. (°C)	Drying Treatment	(Days after sowing the seed)	Percent Seed Germination	Difference from the control in percent germination
6	25	oven	5	0	-13.3
24	10	oven	5	0	-13.3
48	5	oven	5	0	-13.3
48	5	oven	10	86.7	-13.3
48	5	oven	15	89.3	-10.7
48	25	oven	5	0	-13.3
48	25	oven	10	89.3	-10.7
168	10	air	10	89.3	-10.7
168	15	oven	5	0	-13.3
168	15	air	10	82.7	-17.3
168	15	air	15	85.3	-14.7
168	15	air	20	86.7	-13.3
168	15	air	30	88.0	-12.0

TABLE 5. Perennial Ryegrass Soaking Treatments. Manhattan perennial ryegrass seed soaking treatments which were significantly different from the untreated control, at a specific observation date, at the 5% level using Dunnett's test for two-sided comparisons.

Treatment		Observation Date		
Soaking Time (hrs.)	Soaking Temperature (°C)	(Days after sowing the seed)	Percent Seed Germination	Difference from the control in percent germination
6	5	5	5.3	-22.7
6	25	5	12.0	-16.0
6	25	10	76.0	-18.7
6	15-25	5	10.7	-17.3
24	25	5	9.3	-18.7
48	25	10	76.0	-18.7
168	25	5	0	-28.0
168	25	10	41.3	-53.4
168	25	15	76.0	-18.7
168	25	20	82.7	-12.0
168	25	30	82.7	-12.0
168	15-25	5	2.7	-25.3
168	15-25	10	66.7	-28.0

TABLE 6. Perennial Ryegrass Drying Treatments. Manhattan perennial ryegrass seed soaking-drying treatments which were significantly different from the untreated control, at a specific observation date, at the 5% level using Dunnett's test for two-sided comparisons.

Treatment			Observation Date		Difference from the
Soaking Time (hrs.)	Soaking Temp. (°C)	Drying Treatment	(Days after sowing the seed)	Percent Seed Germination	control in percent germination
12	10	air	5	29.3	-48.0
12	10	oven	5	13.3	-64.0
12	15	air	5	29.3	-48.0
12	15	oven	5	10.7	-66.6
12	15-25	air	5	26.7	-50.6
12	15-25	oven	5	18.7	-58.6
24	5	air	5	48.0	-29.3
24	5	oven	5	8.0	-69.3
48	15	air	5	28.0	-49.3
48	15	oven	5	10.7	-66.6
48	15-25	air	5	29.7	-47.6
48	15-25	oven	5	8.0	-69.3

TABLE 7. Kentucky Bluegrass Soaking Treatments. Merion Kentucky bluegrass seed soaking treatments which were significantly different from the untreated control, at a specific observation date, at the 5% level using Dunnett's test for two-sided comparisons.

Treatment		Observation Date		
Soaking Time (hrs.)	Soaking Temperature (°C)	(Days after sowing the seed)	Percent Seed Germination	Difference from the control in percent germination
6	5	20	29.3	-28.0
12	25	20	25.3	-32.0
24	10	20	33.3	-24.0
168	25	10	10.7	+10.7

TABLE 8. Kentucky Bluegrass Drying Treatments. Merion Kentucky bluegrass seed soaking-drying treatments which were significantly different from the untreated control, at a specific observation date, at the 5% level using Dunnett's test for two-sided comparisons.

Treatment			Observation Date		
Soaking Time (hrs.)	Soaking Temp. (°C)	Drying Treatment	(Days after sowing the seed)	Percent Seed Germination	Difference from the control in percent germination
12	10	oven	10	0	- 5.3
12	10	oven	15	18.7	-27.9
12	10	oven	15	18.7	-27.9
12	15-25	air	15	20.0	-26.6
12	15-25	oven	15	18.7	-27.9
24	15	oven	15	18.7	-27.9
24	15-25	oven	15	9.3	-37.3
24	15-25	oven	20	36.0	-36.0
48	10	air	15	74.7	+28.1
48	15	air	10	0	- 5.3
48	25	oven	15	20.0	-26.6
48	15-25	oven	15	9.3	-37.3
48	15-25	oven	20	32.0	-40.0
168	15	oven	10	0	- 5.3
168	15	oven	15	13.3	-33.3
168	15	oven	20	44.0	-28.0
168	25	oven	15	5.3	-41.3
168	25	oven	20	36.7	-45.3
168	25	oven	30	54.7	-30.6
168	15-25	air	15	10.7	-35.9
168	15-25	oven	15	9.3	-37.3

TABLE 9. The effect of 12 seed treatments on seedling establishment of Merion Kentucky bluegrass in the field, counted in shoots per dm^2 and as percent cover ratings.

Seed Treatment (soaking temp. (°C)/ soaking time (hrs.))	After 20 days mean of 12 counts	After 25 days mean of 12 counts	Irrigated mean of 6 counts from 20 and 25 days	Non-Irrigated mean of 6 counts from 20 and 25 days	Visual % Cover ratings after 25 days mean of 4 observations
15/6 planted wet	6.2	957	548	415	24.5
15/24 planted wet	3.3	763	365	402	11.8
25/168 planted wet	2.5	905	390	518	5.8
15-25/24 planted wet	1.6	789	363	427	8.8
15-25/12 planted air dried	4.0	802	351	455	16.5
15/24 planted air dried	4.4	634	443	196	13.5
5/48 planted oven dried	1.3	595	260	337	4.8
15/21 days/(290g. PEG) planted wet	0.9	633	337	298	4.3
15-25/7 days/Aeriated/(145g. PEG) planted wet	3.5	570	339	234	9.3
15/21 days/Aeriated/(290g. PEG) planted wet	4.4	621	236	390	13.0

TABLE 9. (Cont'd.)

Seed Treatment (soaking temp. (°C)/ soaking time (hrs.))	After 20 days mean of 12 counts	After 25 days mean of 12 counts	Irrigated mean of 6 counts from 20 and 25 days	Non-Irrigated mean of 6 counts from 20 and 25 days	Visual % Cover ratings after 25 days mean of 4 observations
15/21 days/Aeriated/(145g. PEG) planted wet	2.9	698	274	427	10.0
Room Temp./12 days/(290g. PEG) planted wet	4.6	777	468	313	14.0
Control (untreated) planted dry	3.0	674	326	350	14.5

None of the means are significantly different at the 5% level as calculated by an F test.