TURF CULTURE

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TURF CULTURE

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THE VIABILITY OF FESCUE SEED

VIVIAN KEARNS TOOLE and EBEN H. TOOLE *

It has long been known that the percentage of germination of fescue seed, particularly Chewings fescue, fell off very rapidly under certain conditions. In other cases this did not occur, so the question naturally was raised as to why there should be these great variations. It was soon recognized that these differences were not merely questions of age or quality of the seed for there were cases where seed of a new crop with a high germination when tested in New Zealand showed a ruinous drop in vitality when it was received in the United States. In other cases after the stock arrived American seedsmen had germination tests made when the seed was first placed in the warehouse and were embarrassed to learn, through the complaints of customers, that an unexplainable drop in the germination percentage had occurred during the short interval of storage.

The work reported here was undertaken several years ago and was conducted over a period of years by the former Division of Seed Investigations, Bureau of Plant Industry. Studies were made on how best to determine the viability of the seed of several species of fescue and on the factors affecting the retention of viability during storage.

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For the study of the germination requirements six kinds of fescue were used: (1) Chewings or New Zealand fescue (*Festuca rubra* var. *commutata*), (2) commercial strains of *Festuca rubra,* (3) Creeping red fescue, a commercial strain of *Festuca rubra,* (4) Hair fescue (*F. capillata*), (5) Reed fescue (*F. elatior* var. *arundinacea*) and (6) Meadow fescue (*F. elatior*). The seed was raised from plantings made at the Arlington Experiment Farm, Arlington, Va., and harvested in 1934, 1935 and 1936.

In determining the optimum conditions for germination, the rate of germination as well as the maximum final germination was considered.

In the studies on the effect of temperature on germination, all tests were made at temperature intervals of 5 degrees on the

OPTIMUM GERMINATION TEMPERATURES FOR FRESH SEED

Fescues Tested	Temperature
Chewings fescue Creeping red fescue Reed fescue	59° to 77° daily alternation
Hair fescue	50° to 77° daily alternation
Meadow fescue	59° or 68° continuously 59° to 77° daily alternation
Red fescue	50° continuously

Centigrade scale, or at 10°, 15°, 20°, 25° and 30° C. A temperature of 10° C. equals 50° F. and an interval of 5 degrees on the Centigrade scale is equivalent to 9 degrees on the Fahrenheit scale. The usual division of 5 degree intervals in the Centigrade scale therefore gives the odd scale of 50°, 59°, 68°, 77° and 86° when converted to the Fahrenheit scale. For the convenience of the reader all temperatures are expressed in degrees Fahrenheit.

When the seed was tested immediately after harvest all kinds of fescue studied required a relatively low temperature for germination. The optimum temperatures for germination of fresh seed of various fescues are given in the table on page 2.

The need of a low temperature for germination was more pronounced when the seed was immature or barely mature at collection than when it was harvested dead ripe. With increase of age after harvest the seed became more tolerant of higher temperatures; a few months after harvest all kinds germinated completely at the comparatively warm alternation 68° to 86°, although even then the rate of germination was slower than at the lower temperatures.

Fresh seed of hair fescue, reed fescue, and creeping red fescue germinated very poorly at any constant temperature. The seed of Chewings fescue differed from the other kinds in the changing response to constant temperature. The best constant temperature for fresh seed was 50°. As the seed aged, the best constant temperature increased to 59° and then to 68° but, contrary to the behavior of other kinds, germination of this older seed of Chewings fescue was lower and also slower at 50°.

When seed of reed fescue and hair fescue was stored dry at a low temperature it maintained its need of low germination temperatures much longer than seed stored at room or higher temperatures. This would probably be true for other fescues also. Hair fescue was the only kind that at optimum temperature responded to exposure to light and to moistening the substratum with dilute potassium nitrate solution. Light and potassium nitrate were beneficial to the other kinds only at temperatures unfavorable for best germination.

The duration of the test necessary for maximum germination at the optimum condition was 14 days for meadow fescue, 21 days for Chewings, creeping red, reed and commercial red fescue and 28 days for hair fescue.

The seed of Chewings fescue was used largely for the work on seed storage. Comparative studies with seed of commercial strains of red fescue gave similar results. The earlier storage studies were made on seed shipped under different conditions from New Zealand. The effect of conditions of shipment on viability on arrival has been discussed by N. R. Foy of the Plant Research Station of New Zealand, as reported on page 59 of this issue.

Later studies were based on seed raised at Arlington, Va., and in Oregon.

Loss of vitality of fescue seed is directly associated with a high moisture content of the seed and with a high temperature. Fescue seed is not necessarily short-lived, as seed with a low moisture content stored at a low temperature showed no loss of viability after 2 years. If temperature of storage is high the moisture content of the seed must be low, or if the moisture content of the seed is high a low temperature must be maintained in order to keep the viability of the seed high.

The advantage of shipping seed overseas in cool storage was lost a few months after arrival in the United States unless the seed was held in subsequent storage at a temperature as low as 36°, or unless it was dried after arrival to a moisture content not exceeding 10 percent. Seed shipped in cool storage tended to have a high moisture content on arrival. There is an indication from this study that seed with a high moisture content (approximately 14 percent) that had been held in cool storage for a few months and then transferred to storage at 68° lost viability more rapidly than seed stored at 68° over the entire period.

Germination of seed artificially dried before shipment over seas and kept dry was as good after storage in the laboratory for 18 to 26 months as that of newly arrived seed shipped without artificial drying.

A number of experiments were carried out with domestic seed stored at different temperatures and with different moisture content. The seed was stored in sealed containers to prevent change of moisture content. The general trend of the deterioration of seed as influenced by temperature and moisture content is shown in the accompanying table which is based on the results obtained in the several experiments.

APPROXIMATE GERMINATION OF CHEWINGS FESCUE SEED AFTER STORAGE AT DIFFERENT TEMPERATURES AND MOISTURE CONTENTS

Temperature of storage	Approximate period of storage (months)	Approximate percentage of germination at approximate moisture content of			
		14%	12%	10%	8%
86°	0	95	95	95	95
	1	65	95	—	—
	4–5	0	65	95	—
	12	—	0	65	—
	15	—	—	25	95
	24	—	—	0	—
68°	4–5	95	—	—	—
	8–10	75	95	—	—
	12	35	90	—	—
	15	10	88	—	—
	18	0	—	—	—
	24	—	—	95	95
50°	12	95	—	—	—
	24	70	—	95	—

The following recommendations for the storage of fescue seed for 18 months to 2 years seem justified. If the moisture content can be kept at 8 percent or lower, the seed can be kept safely even at temperature as high as 86°, but with 12 percent moisture at this temperature viability will begin to fall in a very few months. With 12 percent moisture the viability will begin to fall within a year even at a storage temperature of 68°. Seed with 13 to 14 percent moisture (which is not uncommon with imported seed) will lose its viability in a few weeks at summer temperatures such as 86° and cannot be stored safely longer than a year at 50°. Stated in another way: If the storage temperature approximates 86° the moisture content should not exceed 8 percent; for a storage temperature of approximately 68° moisture should not exceed 10 percent; but if the storage temperature is 50° the moisture may be as high as 12 percent. It must be remembered that seed with a moisture content of 13 to 14 percent when removed from cold storage to high summer temperatures will fall in germination very quickly unless it is dried out. The fall in germination can be checked by drying the seed to a moisture content that is safe for the temperature to which the seed will be exposed. Seed dried before shipment and kept dry can be stored safely at ordinary temperatures for from 18 to 26 months.

It is recognized that the vitamin content of grass leaves is much greater than that of any of the four standard classes into which fruits and vegetables are divided. Generally speaking, grasses contain 10 times as much vitamin B_1 as any of the fruits and vegetables. Recognizing this fact, it might be expected that grasses growing under favorable conditions would not respond as remarkably to applications of this vitamin as do certain other plants, the leaves of which possess less of it.

RAPID CHEMICAL TESTS OF SOILS

M. S. Anderson *

Terms such as the pH of soil to express its acidity as well as pounds of available phosphorus per acre as an expression of the status of this constituent are no longer reserved for use exclusively by chemists or technically trained agriculturists. Today magazines, newspapers, fertilizer dealers and others use these terms freely and often advise farmers, gardeners or lawn keepers to have their soils tested to see what they need. The extensive present-day use of rapid chemical tests of soils has promoted an insistent demand for knowledge concerning the reliance that may properly be placed upon results by such methods. A widely expressed opinion is that such tests are easy to make but difficult to interpret. The greatly accelerated interest in quick tests which has been particularly evident during the last decade would seem to be due more to an intense desire to obtain helpful information from such tests than from the development of any highly satisfactory procedure applicable to the growing of different kinds of plants on different soils. Great advances in chemistry along many lines have no doubt led to the general idea that chemistry can surely go a long way toward giving information indicating the state of fertility of a soil as well as its fertilizer needs. As a result, first one test and then another has been proposed, so that today a large number of soil-testing procedures are found to give much more reliable results locally than do the original methods. No standard procedure is recogized although some of them are widely used in different localities. Some tests call for an expression of the results as pounds per acre of an available constituent while others group the re-

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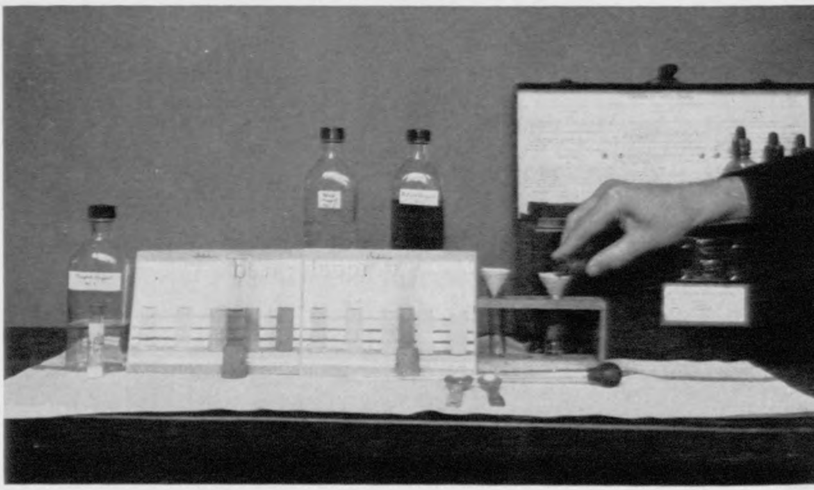
sults into three or more classes, such as high, medium, and low.

Information from soil tests is frequently furnished the layman showing that his soil contains a certain number of pounds per acre of available phosphorus, potassium, or other constituents and that it needs a certain number of tons of lime per acre to neutralize an acid condition. It must be admitted that



One of the soil-testing outfits used for phosphorus and potash. On the right is shown a step in the preparation and filtration of the test solution. At the left is shown color comparison against a standard color chart for phosphate. In the center is shown a turbidity test for potash, in which the intensity of the black lines visible through the turbid solution is compared on a standard chart.

the quantities involved in such reports do not always mean the same thing in terms of treatment needed for maximum response in the growth of grass or other crops.

The results by different methods may vary several fold in pounds per acre of available constituents shown. Results by some particular method may be much more helpful than those by another method, but even here comparable values are often more helpful than are specific expressions of pounds per acre of a certain constituent taken alone. If the user of the tests has knowledge of the results accomplished in former years by particular treatments, such history aids greatly the interpretation of chemical results.

Soil Acidity Tests

The helpfulness of almost all of the soil acidity and lime requirement tests in the hands of an agriculturist is so marked and so well recognized that little argument need be advanced in their behalf. By far the greater number of soil tests made by most of the state experiment stations and local governmental agencies involve tests for the need of lime applications to soils. The methods used are usually not very precise but are adequate to meet practical needs. The proximity of a limestone supply to the place of use of the product of course greatly influences the cost of the material. As a result the full amount of lime shown by a chemical test as desirable is frequently reduced somewhat for economic reasons. Practical local experiments, guided by the results of tests made on part of the field or turf area in question, are particularly valuable.

Phosphorus and Potassium

Tests for available phosphorus and potassium in soils are widely used but their interpretations are much more difficult than are those for acidity and lime requirement. Local experience must play a very important part in translating pounds per acre of available phosphorus, for instance, into the grade and quantity of fertilizer best suited for use. Some agriculturists find certain of the tests highly helpful while others feel that such tests are not worth the time and effort involved in their making. Both extremes of opinion are probably at times justified. Oral opinions from various persons dealing with soil tests in state soil testing laboratories and other similar institutions indicate that they make use of chemistry in various ways. It is frequently said that chemical results contribute perhaps 10 percent of the information upon which advisory judgment is based. Others find them of even greater value than this while still others find them less useful. Very frequently chemical tests are particularly useful in cases where soils have been over-fertilized or, where from various causes, the relationships of quantities of constituents is unusual. In this way the 10 percent estimate just referred to may be of considerable importance.

It is interesting to note in current technical literature something of the character of data from which agriculturists are called upon to interpret prospective crop yields in relation to pounds per acre of available phosphorus or potassium shown by different methods in specific series of soil plots. Such experiments involve a wide variety of cultivated crops but data for soils under continuous grass cover are scarce. For example, a report from New Jersey concerning soils of plots on Sassafras loam usually showed an increase in crop yield when both phosphorus and potassium were added. However, the phosphorus values determined by different methods varied in certain cases several fold while differences shown by five potash methods were less marked. An unfertilized, but limed, plot showed not more than 3 pounds of available phosphorus per acre by any method but it grew a fairly good crop of wheat.

In South Carolina the Truog-Myer method for available phosphorus was found to be definitely correlated with availability of this constituent to plants. A case is presented, however, which would be particularly perplexing without local information regarding the response of different soil types to plant growth and fertilization. An Orangeburg fine sandy loam soil showing about 40 pounds of available phosphorus and 10 pounds of available potassium per acre grew nearly three times as much seed cotton in the 1937 season as did a Cecil sandy loam soil in the same locality which showed 70 pounds of phosphorus and 80 pounds of potassium. In another set of results a Carrington loam soil from Iowa produced good farm crops year after year without mineral fertilization while the tests for phosphorus and potassium showed low availability of both constituents. Furthermore, additions of fertilizers containing these elements gave little or no crop response. These examples illustrate some of the problems encountered in the interpretation of chemical tests in different parts of the country.

Summarizing, it would seem that while soil tests have a definite place in the United States, their limitations are becoming fairly well recognized. Definite values for pounds per acre of available phosphorus and potassium should not be regarded as having the same significance in different soils but comparative values in a locality under comparable conditions may be of considerable value in aiding judgment as to what fertilizer treatment should be given. Emphasis is being more and more placed on the idea that soil testing is a local problem and that particular values for available constituents do not have the same significance with different soils. There is still no short cut which adequately supersedes field tests, but the soil tests can be a distinct aid in the choosing of experimental treatments to be applied to a portion of a field, lawn or golf course. Such a field experiment does not require technical skill and it ordinarily involves no losses. Successful results observable throughout a season bring conviction to every observer and after a few years it may be possible to tell better what statements such as 5, 25

Chemical laboratory showing some of the quick-testing outfits used for evaluating the available nitrogen, phosphorus, potassium, and other elements contributing to crop productiveness. Laboratory results aid experienced agronomists in determining soil fertility and specific deficiencies and in recommending suitable fertilizer materials or other soil-improving processes.

or 100 pounds of available phosphorus or potassium per acre mean when related to the growth of grass under the local conditions.

EFFECTS OF SOIL TEMPERATURE, ACIDITY AND NITROGEN NUTRITION ON THE DEVELOPMENT OF KENTUCKY BLUEGRASS

ROBERT A. DARROW *

Few studies have been made in which grass has been grown under the combined influence of controlled nitrogen nutrition, temperature, and reaction of the culture medium. In the present series of experiments Kentucky bluegrass (*Poa pratensis* L.) was chosen as a representative grass. It is sometimes grown in the field under semi-controlled nutrient conditions and differs widely in development with seasonal variation in temperature and soil reaction. The experimental plants were grown in crocks in which the supply of nitrogen as nitrate or ammonium, the soil temperatures, and the acidity of the nutrient solutions were controlled. Measurements of leaf and root growth were taken to express development under the environmental conditions maintained and to determine the effects of periodic clipping.

METHODS

In these experiments, plants obtained by vegetative propagation from a single plant were grown in 2-gallon crocks filled with sand free of nutrients. Plants were supplied daily with nutrients in the form of solutions prepared from pure chemicals. Two nutrient solutions were prepared containing potassium phosphate, magnesium sulfate, and nitrogen. In one solution the nitrogen was in the form of calcium nitrate while the other solution contained sulfate of ammonia and calcium

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chloride. About 400 cc. (0.7 pint) of solution were added to each culture twice daily after flushing out the old solution with distilled water. By this periodic flushing with pure water and by addition of either hydrochloric acid or sodium hydroxide to the nutrient solutions, the reaction of the solution in each culture was adjusted twice daily to the desired pH.

The 2-gallon crocks containing the plants were set in a water-filled tank which was regulated at constant temperatures.

Results with Unclipped Plants

Tests have been made as to the effect of nitrogenous fertilizers on growth of Kentucky bluegrass at various soil acidities, both in the field and in greenhouse studies. The present experiment was set up to determine the effect of different soil temperatures on bluegrass grown with ammonium and with nitrate nitrogen at pH 4.5, 5.5, and 6.5.

Plants were grown for 11 weeks from March 3 to May 10, 1936, under greenhouse conditions with a relatively large amount of sunshine and at three different soil temperatures, 59°, 77°, and 95° F. Three sets of cultures were supplied with nitrate nitrogen in the form of calcium nitrate at pH 4.5, 5.5, and 6.5, respectively, and three other sets received ammonium nitrogen in the form of sulfate of ammonia at the same pH values. Four plants were used under each of these conditions.

The plants were allowed to grow uncut for a period of 11 weeks. At the end of this time they were removed and measurements taken as to length and number of leaves, number of rhizomes, and dry weights of leaves and roots. The information thus obtained is summarized in the tables on pages 16 and 22. Nitrate-supplied plants were decidedly superior to plants receiving ammonium in the number and length of leaves and in the number of rhizomes produced at all temperatures and pH conditions with but one exception. This superiority of nitrate-supplied plants was more in evidence at pH 4.5 than at pH 6.5. Differences in reaction had no appreciable effect on leaf development of nitrate plants at 59° and 77°. At 95°, however, a slight increase in the number of leaves and rhizomes of pH 4.5 plants over the other plants at that temperature was noted. Ammonium-supplied plants showed the best development of leaves and roots at pH 6.5 under all temperature conditions and the least increase in length and number of leaves at pH 4.5.

Temperature effects on leaf development were also quite marked as shown in the table on page 16. High temperatures reduced the amount of leaf growth in length and numbers. The greatest number of leaves was produced at 59° under all conditions of acidity and nitrogen nutrition. Growth in length of leaves was found to be greater at 59° and 77° than at 95°. At 77° the largest number of rhizomes was produced.

The superiority of nitrate nitrogen over ammonium shows also in the green and dry weights of roots and tops as given in the table on page 22. The dry weights were approximately the same at 59° and 77° and much smaller at the higher temperature. Nitrate-supplied plants produced approximately equal weights of roots and shoots at all pH values except under high temperature conditions at which pH 6.5 plants were poorest. Ammonium-supplied plants produced the greatest weights of leaves and roots at pH 6.5.

Limited observations on the root systems of these and other grass plants grown for shorter periods showed considerable difference between plants grown at 59° and 95°. At the lower temperature, roots were large in diameter, white, and very succulent. High temperatures produced a densely tufted root system of small, light brown, finely-branched roots. It

Leaf and Rhizome Development of Kentucky Bluegrass Plants Grown at Three Soil Temperatures with Nitrogen from Calcium Nitrate and Sulfate of Ammonia Respectively at pH 4.5, 5.5, and 6.5. The Figures Are Averages for Four Plants.

Temperature and pH	Percentage of increase in length of leaves		Percentage of increase in number of leaves		Number of rhizomes	
	Nitrate	Ammonia	Nitrate	Ammonia	Nitrate	Ammonia
59° F.						
4.5	198	31	955	85	17	3
5.5	194	54	942	229	18	3
6.5	191	144	1,046	524	32	8
77° F.						
4.5	173	75	600	35	28	1
5.5	233	115	401	148	33	3
6.5	182	192	620	314	38	11
95° F.						
4.5	140	23	263	0	29	0
5.5	133	55	226	53	24	1
6.5	148	66	170	80	15	2

appeared that roots were produced more rapidly at the lower temperature. The unthrifty condition of ammonium-supplied plants grown at pH 4.5 and 5.5 was evident in the limited root system developed. On the other hand, little variation could be noted in the roots of nitrate-supplied plants with the different pH values of the nutrient solutions.

The leaves of plants grown for 11 weeks as well as of those grown under these same cultural conditions for shorter periods of time showed marked differences in the degree of succulence with various acidities and temperatures. The leaves of both nitrate- and ammonium-supplied plants were more succulent at low temperatures than at high ones. The nitrate-supplied plants showed little difference with respect to pH value of the nutrient solution at any one temperature, but in the case of ammonium-supplied plants those grown at pH 6.5 were more succulent than plants grown at pH 4.5 and 5.5. This difference in succulence was more marked at 59° than at 95°.

Results with Clipped Plants

To furnish information more directly applicable to turf production, an experiment was initiated involving the clipping of Kentucky bluegrass plants at two heights. Plants were supplied with either nitrate or ammonium nitrogen at pH 6.5 and at a constant soil temperature of 77°. Plants were grouped into three series: clipped at 1 inch weekly, clipped at 2 inches weekly, and unclipped control. Ten plants were used for each combination of nitrogen nutrition and clipping height and the experiment was conducted from May 30 to September 14, 1936.

Clipping treatments were started on June 26 and were made weekly thereafter, and the number of leaves clipped and dry weights of clippings recorded. Weekly counts were also taken of the total number of leaves on all clipped and control plants to determine the effect of clipping on density of turf. The table on page 19 shows the percentage of increase in number of green leaves over the original number during the experimental period. These observations, given for 2-week intervals, show the effects of clipping in the smaller number of leaves produced in the 1-inch and 2-inch series as compared with the unclipped control. Ammonium-supplied plants produced new leaves more rapidly than nitrate-supplied plants in the unclipped and in the 1-inch series and during the latter part of the experiment in the 2-inch series. There was, therefore, a greater improvement in the density of the grass when sulfate of ammonia was used as a source of nitrogen than when calcium nitrate was used. When grass is grown for turf purposes, the density of the turf, rather than the yield of clippings, is the primary consideration. This is particularly true during the hot summer months when leaf replacements are so desirable because of injuries caused by diseases, insects, and other factors.

Figures for the dry weights of the clippings for 2-week intervals are given in the table on page 25. Nitrate-supplied cultures showed consistently higher yields of clippings than the ammonium cultures, although at the 1-inch cut this difference was not so great as at the 2-inch cut. With the exception of a brief period in July in which insect infestation reduced the number of leaves, there was a consistent week-by-week increase in the yield of clippings in both the nitrate and ammonium cultures, throughout the experimental period. This was particularly striking in the series clipped at 2 inches. Comparison of the yields obtained from the 1-inch and 2-inch series shows that in the nitrate series the yield of the plants cut at 2 inches was approximately twice that of those cut at the 1-inch height. On the other hand, the total weight of clippings produced from the ammonium-supplied plants cut at 2 inches was only about one-third larger than that obtained from the 1-inch plants.

Comparison of root and rhizome production in nitrate- and ammonium-supplied plants showed in general the same relationship as in the previous experiments. Nitrate-supplied plants produced a greater number of crown roots than did those receiving ammonium although the average length of roots was greater in the case of ammonium-supplied plants. The unclipped plants showed the greatest number of roots and

Percentage of Cumulative Increase in Number of Leaves Produced by Kentucky Bluegrass Plants Grown in Sand at pH 6.5 and 77° F. with Nitrate and Ammonium Nitrogen Under Clipped and Unclipped Conditions. Figures Are Given for 2-Week Intervals Except for the Final Date.

Treatment	Percentage of cumulative increase of number of leaves					
	July 11	July 25	August 8	August 24	Sept. 8	Sept. 14
Nitrate:						
Check	10	72	130	181	219	243
2-inch cut	5	61	112	163	192	160
1-inch cut	6	39	70	93	100	100
Ammonium:						
Check	7	74	137	205	285	307
2-inch cut		51	105	165	209	201
1-inch cut	2	38	72	124	157	193

rhizomes with both forms of nitrogen and the plants cut at 1 inch showed the most poorly developed root systems. More rhizomes were produced in the nitrate than in the ammonium cultures.

Temperature Relations

If the factor of temperature is considered apart from the complex of environmental conditions under which the plants were grown, certain relations of development to temperature differences may be established. The character of the top growth varied considerably within the range of soil temperature used. Low temperatures appeared to be the most favorable both for the production of new leaves and the growth in length of leaves. The type of growth resulting at 59° was bushy with long, succulent leaves and numerous new leaves. Combined measurements of length and number of leaves showed the best growth temperature of those tested to be about 59°. At soil temperatures of 95° the plants were short and rigid, many of the leaves remaining erect when allowed to grow uncut for 3 months. Bud initiation and leaf production were limited under the high temperature conditions.

Bluegrass plants in the present experiments showed the greatest amount of root and top growth at the lower temperatures. Equal dry weights of top growth were produced by plants grown at 59° and 77°, whereas under soil temperatures of 95° the lowest weight of tops and smallest number of rhizomes were produced.

The character of the root systems produced was also influenced strongly by temperature. At the lowest temperature the roots of bluegrass were large in diameter, succulent, white, with few scattered branches, whereas at 95° the roots were small, light brown, and very finely branched into a dense tufted system. The entire root systems at 59° and 77° were almost twice as deep as those produced at 95°. As measured in terms of dry weight, the total root growth was approximately equal at 59° and 77° and the least amount was produced at 95°.

Acidity Relations

Under controlled nutrient conditions with nitrogen supplied in the form of calcium nitrate, the plants differed in top and root development with varied pH, depending in part upon their age. After 6 and 11 weeks growth, plants grown under similar conditions showed no significant differences in weight of tops with pH at the lower temperatures, but at 95° plants grown at pH 6.5 were slightly inferior to those grown at pH 4.5 and 5.5. Under the condition of these experiments the range of pH used apparently had little effect upon absorption and assimilation of nitrate nitrogen except at a soil temperature of 95°. Root development and rhizome production in nitrate cultures were influenced by pH in the same manner as top development. Weight of roots varied little with differences in pH except at 95°, under which conditions the plants grown at pH 4.5 produced a greater weight of roots.

Plants supplied with nitrogen in the form of sulfate of ammonia at the three pH values showed best development in tops, roots and rhizomes at pH 6.5, throughout periods of 3, 6, and 11 weeks of growth at all temperatures. The roots of the plants grown in ammonium-supplied crocks at pH 6.5 showed the most extensive branching, whereas at pH 4.5 and 5.4 there was a predominance of stunted, knobby branches, particularly near the base of the main branches.

Nitrogen Relations

Unclipped Series

Within the pH range of the experiments, the plants supplied with nitrate nitrogen showed a markedly better development than those supplied with ammonium nitrogen, at soil temperatures of 59°, 77° and 95°. Throughout the duration of these experiments with unclipped grass from March 3 to May 10, the top growth of the nitrate-supplied plants was superior to that of ammonium-supplied plants in both number and length of leaves produced as well as in dry weight of leaves. This superiority of nitrate nitrogen over ammonium nitrogen in producing an extremely vegetative plant under

DRY WEIGHTS OF KENTUCKY BLUEGRASS PLANTS GROWN FOR 11 WEEKS AT THREE SOIL TEMPERATURES WITH NITROGEN FROM CALCIUM NITRATE AND SULFATE OF AMMONIA RESPECTIVELY AT pH 4.5, 5.5, AND 6.5. THE WEIGHTS, EXPRESSED IN GRAMS, ARE AVERAGES FOR FOUR PLANTS.

Temperature and pH	Dry weight in grams: Leaves		Roots	
	Nitrate	Ammonia	Nitrate	Ammonia
59° F.				
4.5	3.40	0.26	4.06	0.85
5.5	3.48	0.58	3.96	1.07
6.5	3.59	1.71	4.50	2.65
77° F.				
4.5	2.58	0.24	5.62	0.91
5.5	3.27	0.88	4.25	1.10
6.5	3.13	1.77	4.78	2.00
95° F.				
4.5	1.62	0.14	3.31	0.44
5.5	1.56	0.27	2.91	0.65
6.5	1.13	0.43	2.21	0.87

these conditions is probably a result of more rapid assimilation of nitrate than ammonium nitrogen.

Rhizome and root production varied also with the type of nitrogen nutrition. The number of rhizomes to a plant was significantly greater in nitrate-supplied than in ammonium-supplied plants. Plants supplied with nitrate showed a greater dry weight of roots than corresponding plants supplied with ammonium, although the actual extent of the root systems of the two types was similar. More rapid elongation of roots took place in nitrate-supplied plants at 59° and 77° than in ammonium-supplied plants, but at 95° the latter excelled slightly.

Clipped Series

The effects of clipping at 1- and 2-inch heights were studied on plants supplied with nitrate and ammonium nitrogen at pH 6.5 and a constant soil temperature of 77° from May 30 to September 14, 1936. The plants used in this series were transplants and were placed under cutting treatment soon after transferral, a fact which should be considered in the interpretation of the results obtained.

Weekly clipping yields showed a consistent increase over the 11 weeks from June 26 when clipping was begun to September 14, except for the few weeks in July when there was some insect injury. The increase was more pronounced in the series cut at 2 inches than in the plants of the series cut at 1-inch height.

Greater yields, as expressed in terms of dry weight of clippings, were obtained from nitrate-supplied plants than from those receiving ammonium. On the basis of the studies over a range of pH conditions, it may be concluded that nitrogen in the form of nitrate was more readily available even at pH 6.5 than was ammonium nitrogen, under the conditions of these experiments. Thus with a more readily available form of nitrogen, a greater stimulus was given to vegetative growth and yield with nitrate nutrition over the period in which the clipping studies were conducted.

Weekly observations of the number of leaves in the plants in this series showed a consistent and progressive increase in the production of new leaves from May 30 to September 14. After the first few weeks, denser tufts with more new leaves were produced by the plants growing in the ammonium-supplied crocks than by those growing in the crocks receiving calcium nitrate. This held for both the unclipped control plants and the plants clipped at 1- and 2-inch heights. The unclipped plants, however, initiated most leaves, and those clipped at 1-inch the fewest leaves throughout the experiment, as shown in the table on page 19.

In growing Kentucky bluegrass for turf purposes, however, the density of the turf is of more concern than the yield of clippings, since an increase in yield simply involves the necessity of more frequent cutting. July and August are perhaps the most difficult periods for turf. Any fertilizer, therefore, such as sulfate of ammonia which will increase the density of the turf by increasing the production of new leaves, during that time particularly, will be highly desirable for turf purposes.

Comparison of the results from the series of clipped plants with those from comparable portions of the unclipped series brings out several discrepancies with regard to the best nutrient conditions for leaf production. In the first 11 weeks series from March 3 to May 10, the nitrate-supplied plants grown in sand with a temperature of 77° and pH 6.5 showed almost twice as great an increase in number of leaves as ammonium-supplied plants. In the last series from May 30 to September 14, the unclipped plants receiving nitrates had but one-third as much leaf production as corresponding plants grown under the same conditions of acidity and soil temperature for the same length of time in the earlier series. However, the ammonium-supplied plants showed almost identical production of new leaves in the two series. These discrepancies may be due in part to the differences in length of day, atmospheric temperature, or other environmental conditions over the two experimental periods. As noted from the first series, the greatest number of leaves was produced under the lower soil temperature conditions, and thus the higher air temperatures pre-

Dry Weight in Grams of Clippings Obtained from Kentucky Bluegrass Plants Grown in Sand with Nitrate and Ammonium Nitrogen and Clipped at 1- and 2-Inch Heights. Figures Are Given for 2-Week Intervals.

Treatment	Dry weight in grams of clippings						
	July 11	July 25	August 8	August 24	Sept. 8	Sept. 14	Total
Nitrate:							
2-inch cut......	0.74	0.51	1.54	2.45	3.09	1.00	9.33
1-inch cut......	0.67	0.47	0.76	1.12	1.12	0.49	4.64
Ammonium:							
2-inch cut......	0.47	0.36	0.72	0.98	1.79	0.59	4.92
1-inch cut......	0.60	0.43	0.63	0.73	0.92	0.38	3.68

vailing during the later series may have played some part in reducing the leaf production of the unclipped nitrate-supplied plants. However, the ammonium-supplied plants showed almost identical production of new leaves in the two series. The reasons are not clear for this difference in leaf-production of nitrate-supplied plants in the two series of experiments. These discrepancies indicate the necessity for further investigations before the full value of these two forms of nitrogen for bluegrass turf can be thoroughly understood.

The number of rhizomes produced on the clipped plants was much smaller than on the unclipped plants under both forms of nitrogen, a fact which has been observed by many workers.

Summary and Discussion

Kentucky blugrass plants were grown in sand in crocks under greenhouse conditions in one series of experiments from March 3 to May 10, 1936, and in another series from May 30 to September 14 of the same year. Nutrients were added in the form of solutions of pure chemicals.

One-half of the crocks in all of the experiments in both the first and second series received nitrogen in the form of calcium nitrate and the remaining ones received it in the form of sulfate of ammonia.

In the first series of experiments the effects of soil temperatures of 59°, 77°, and 95° combined with soil acidities of pH 4.5, 5.5 and 6.5 on the growth of leaves, roots, and rhizomes of the grass were observed.

In the second series of experiments the sand in all of the crocks was maintained at a temperature of 77° and a pH of 6.5 but the grass in some of the crocks was clipped at 1- and 2-inch heights, whereas that in others was left unclipped as controls in order to follow the effect of height of cut on the development of leaves, roots, and rhizomes.

Plants grown at 59° produced tall, succulent, bushy top growth with many new leaves, while those grown at 95° produced erect, non-succulent, short top growth with few leaves. Root systems of the low temperature plants were large, white, succulent, and coarsely branched, while roots of high temperature plants were small in diameter, light brown, and densely tufted. The largest number of rhizomes was produced at 77°.

Plants grown with nitrogen from sulfate of ammonia showed best leaf, root, and rhizome development at pH 6.5, whereas plants receiving calcium nitrate showed little difference within a range of pH 4.5 to 6.5.

In the first series of experiments, the nitrate-supplied plants were superior in leaf, root, and rhizome development to ammonium-supplied plants under the conditions of soil temperature and soil acidity in force throughout the experimental period.

In the second series of experiments from May 30 to September 14, however, although the yield of clippings was greater in the nitrate-supplied plants the number of new leaves produced or density of the grass was greater in the ammonium-supplied plants. It should be borne in mind that when Kentucky bluegrass is grown for turf purposes, the yield of clippings is not so important a consideration as is the density of the turf, particularly during July and August which are the most difficult months for turf.

Both number of new leaves and dry weight of clippings were greatest in unclipped plants and least in those plants cut at 1-inch height, regardless of whether the plants received sulfate of ammonia or calcium nitrate.

When sulfate of ammonia is added to ordinary well-drained soil, the microorganisms present in the soil convert part of the ammonium nitrogen into nitrate nitrogen. In reality, therefore, when plants are grown in soil fertilized with sulfate of ammonia they are supplied with both nitrate and ammonium nitrogen.

THE INFLUENCE OF TEMPERATURE, CALCIUM AND ARSENIOUS ACID ON SEEDLINGS OF KENTUCKY BLUEGRASS

AUBREY W. NAYLOR *

The natural range of Kentucky bluegrass over the northern half of the United States and southern Canada indicates that it is adapted to cool conditions. In addition, it has been observed that bluegrass grows slowly in hot weather and, when well established, most vigorously at temperatures ranging between 60° and 75° F. Also it is known that bluegrass will flourish and grow well on calcareous soils, either because of their lime content or because of other associated nutritive conditions.

During recent years there have been reports that certain chemicals, other than those usually considered as nutrients, will stimulate growth. Thus arsenic salts have been found in some cases to cause a distinct increase in growth of well established bluegrass. These observations were made, as have been most other investigations, on mature plants.

Some preliminary work, however, has indicated that Kentucky bluegrass, once it has become established, will grow well under conditions which are unfavorable for the germination of its seed and for early growth. In the experiments reported here, attention is directed primarily to the effect of temperature, calcium content of soil, and arsenic on germination of seeds and on the growth of seedlings.

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Materials and Methods

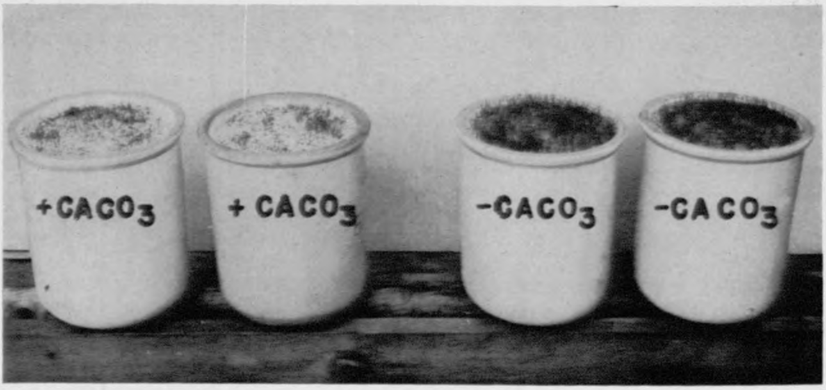
Kentucky bluegrass seed of high purity was planted in washed quartz sand contained in 2-gallon glazed crocks. Three grams of seed were used in each crock, except in the calcium carbonate series set up March 20, 1938, in which two grams were used. The seed was evenly distributed, then lightly covered with sand and watered daily with distilled water until germination began. Each crock then received biweekly applications of a nutrient solution containing nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and traces of zinc, boron, manganese, copper, and iron.

While making trial runs it was found that fine quartz sand was unsuitable for winter work, perhaps because damping-off fungi thrived under the prevailing warm, moist, cloudy conditions. The most successful practice was to use coarse quartz sand and to spray the seed at the time of planting and at frequent intervals thereafter with a dilute solution of a mercury fungicide.

Ninety days after the experiment was started, half of the pots in each series were sampled to determine the relative number of plants which survived. For this purpose, plants from 1 centimeter squares (about 1/6 of a square inch) along two diameters of each crock were counted. At the termination of the experiments dealing with calcium carbonate, fresh and dry weights of the grass were taken.

Experiments with Calcium Carbonate

In the calcium carbonate series started March 20, 1938, 33 crocks were filled with sand which had approximately one-half pound of calcium carbonate per crock mixed with it. This was equivalent to working limestone into the top 6½ inches of soil at the rate of 37,000 pounds to the acre. The solution which dripped from the crocks after watering had a reaction of pH 8.0. The crocks were watered at intervals with water



Effect of lime on germination and early growth of Kentucky bluegrass seedlings. The two crocks on the left marked "+ $CaCO_3$" each contained quartz sand mixed with one-half pound of calcium carbonate. The two crocks marked "—$CaCO_3$" contained only pure quartz sand. All of the crocks received equal amounts of a complete nutrient solution. Thirteen days after planting, when this picture was taken, there were noticeably fewer and smaller seedlings in the +$CaCO_3$ than in the —$CaCO_3$ crocks.

heavily charged with calcium carbonate to avoid any chance of a decrease in pH during the course of the experiment. Twenty-eight crocks were set up in the same manner except that no calcium carbonate was added. The reaction of the solution which dripped from these latter crocks was fairly constant at pH 5.6.

The effect of high calcium carbonate content of the sand on germination of the seed was noted and the effect on early growth of the grass seedlings was followed for 35 days after germination, at the end of which time the plants in 21 of the crocks containing calcium carbonate and 8 without calcium carbonate were harvested. During these early stages of growth the temperature of the sand was not controlled.

The remaining crocks were placed in tanks which kept soil temperatures constant to within 1° C. Half of these were maintained at a soil temperature of 15° C. (59° F.); the other half were kept at 25° C. (77° F.). Fifty-five days after making the temperature adjustments, photographs were taken and harvests made.

Effect of Calcium Carbonate on Germination

In the initial trials of this experiment it was very difficult to get an even stand with the various treatments. In the final one, germination began 6 days after planting (March 26) in the crocks lacking calcium carbonate. There were no signs of germination in the other crocks. This same condition had been observed, in a less pronounced form, in a previous experiment.

Germination was delayed approximately a week in the crocks containing calcium carbonate. After germinating, some of the grass grew for only a few days and then withered, leaving isolated clumps. If moist chambers were placed over individual crocks further germination ensued and fairly good growth followed, probably because of the high humidity produced. Even with this treatment, however, some grass died. It is not likely that death can be attributed to damping-off fungi because that disease generally produces different symptoms.

Shortly after germination in the calcium carbonate series the leaves appeared to be vigorous but the root systems of the seedlings were poorly developed. This may be contrasted with the grass grown without calcium carbonate, which germinated in about 6 days, produced leaves, and developed root systems rapidly.

Slow root development of the germinating seedlings in the calcium carbonate series may possibly have been caused by the low availability of phosphorus at high pH. Phosphorus is considered necessary for development of roots, and some work

EFFECT OF PRESENCE OF CALCIUM CARBONATE ON GROWTH OF BLUEGRASS SEEDLINGS DURING THE FIRST 35 DAYS AFTER PLANTING.

Treatment	Number of crocks	Portion of plant	Average length in inches	Average dry weight per crock in grams	Top/root ratio
High calcium carbonate		Tops	2.6	1.15	
(pH 8.0)	21	Roots	3.3	2.21	0.52
No calcium carbonate		Tops	2.0	2.1	
(pH 5.6)	8	Roots	1.9	6.05	0.35

with wheat seedlings has indicated that its uptake is greatest in the early stages of development. It is possible that in this experiment it was a limiting factor in the early stages. Later, absorption of phosphorus was sufficient for more extensive growth.

Thirty-five days after planting, 21 crocks treated with calcium carbonate and 8 not so treated were harvested. Average dry weights and lengths of tops and roots were taken. From the table on this page it can be seen that, on the basis of weight of both tops and roots, the stand of grass grown in crocks at pH 8.0 was much less than that grown at pH 5.6. This was to be expected since fewer plants were growing in those crocks containing calcium carbonate in which germination had been inhibited and many more young seedlings had died, than in the calcium carbonate-free crocks.

Once growth had started in the crocks containing calcium carbonate, the plants grew more rapidly than in those not having calcium carbonate. This may have been associated with the reduced competition due to the smaller number of plants in the crocks containing calcium carbonate. At this time, also, the growth was apparently equally as uniform in the crocks containing lime as in those without it. The average length of roots in the series high in calcium carbonate was almost twice as great as in the minus calcium carbonate series. Also the tops were about 0.6 inch longer in the former series than in the latter.

The root systems of the seedlings grown at pH 8.0 in the presence of calcium carbonate were characteristically long, thick, and white with few or no branches. Where root branches were present, they were short except near the growing point of the main root. In contrast with this, seedlings grown at pH 5.6 in the absence of calcium carbonate had shorter, thin, primary roots and a better development of root branches.

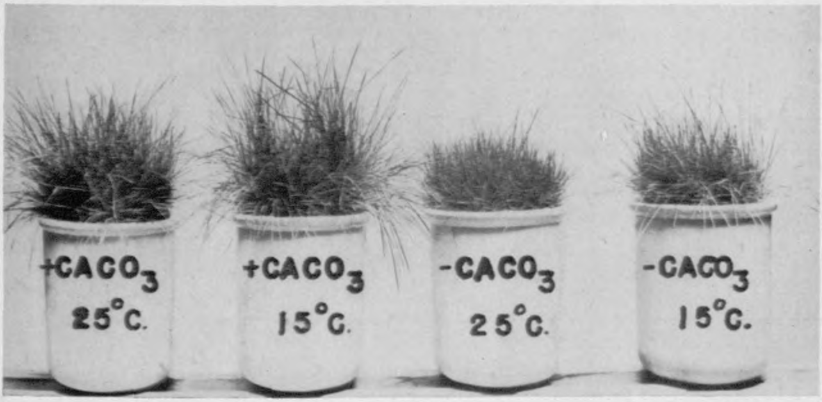
Effects of Temperature and Calcium Carbonate Content of Sand on Growth of Seedlings

After the harvest at the end of 35 days, the remaining crocks were used in soil temperature experiments as previously described. At the end of 55 days of growth, photographs were taken and harvests made.

The effect of calcium on the growth of the grass seedlings is difficult to judge because of the much larger number of seedlings present in the crocks without lime than in the ones with lime. Due to the effect of lime on germination and the very young seedlings, there were only approximately one-third as many seedlings in the calcium carbonate crocks as in those which had not received calcium carbonate, as is shown in the table on page 38. This means that in the calcium-free crocks, competition was three times as great as in those with lime. However, this early effect of lime was approximately the same at 59° as at 77°. It is possible, therefore, to estimate the effect of the temperature of the sand on the growth of the grass in the calcium-free crocks and in the crocks containing calcium.

Once the bluegrass seedlings were established in sand having a high calcium carbonate content they had longer and darker green leaves than those grown on sand lacking lime. Furthermore, as shown in the table on page 36, the average dry weight of tops produced by each crock was approximately one-third greater in the calcium carbonate series than in the series which did not receive calcium carbonate although the crocks in the calcium carbonate series contained only about one-third the number of plants present in the calcium-free crocks. Thus it becomes apparent that the individual seedlings increased many more times in dry weight when calcium carbonate was present than when absent. This may probably be explained, at least in part, by the decrease in competition between the plants for food and light and the consequent increase in rates of metabolism and growth of the plants in the crocks containing lime.

In considering the effect of the temperature of the sand on the growth of the seedlings it has been generally true that 59° was a more favorable soil temperature than 77°. From the figures in the table on page 38 it has been calculated that in the presence of calcium the dry weight of 100 seedlings was 27 percent greater at 59° than at 77° whereas in the absence of calcium it was 69 percent greater at 59° than at 77°.



Effect of soil temperature and lime on the growth of Kentucky bluegrass seedlings. On the left there are two crocks marked "+$CaCO_3$" which contained one-half pound of calcium carbonate mixed with the quartz sand in which the grass was growing. The two crocks on the right marked "—$CaCO_3$" contained pure quartz sand. All four crocks had been watered throughout the 90 days of the experiment with equal quantities of a complete nutrient solution. The soil in one of each pair of crocks had been kept at 25° C. (77° F.) and that of the other at 15° C. (59° F.), for 55 days prior to the time the picture was taken. As a result of the effect of the lime on the germination and early growth of the seedlings there were only about one-third as many plants in the +$CaCO_3$ as in the —$CaCO_3$ crocks. Note more extensive growth in the crocks in which the soil was kept at 15° C. than in comparable crocks kept at 25° C.

In general, top growth was greatest at the lower temperature. The plants tended to be longer and to have more succulent blades and darker green leaves than grass grown at 77°. However, as shown in the table on page 36 the dry weights of tops of the plants of the two series show very little difference at the two temperatures.

The densest, most finely branched, and longest root systems were produced by plants grown at 59° in the presence of lime. The least root growth was produced by those plants grown at the higher temperature and in the absence of calcium. The plants grown under these conditions produced very little lateral growth and the primary roots failed to penetrate to the bottom of the crocks. The figures in the table on this page indicate that the lower temperature has been of much more importance

RELATIVE EFFECTS OF CALCIUM CARBONATE AND TEMPERATURE ON DEVELOPMENT OF KENTUCKY BLUEGRASS SEEDLINGS.

Soil treatment	Soil temperature (° F.)	Number of crocks	Average dry weight in grams of roots per crock	Average dry weight in grams of tops per crock	Top/root ratio
High calcium carbonate	59°	5	18.44	15.32	0.83
(pH 8.0)	77°	5	10.32	15.26	1.48
No calcium carbonate	59°	9	13.48	12.01	0.89
(pH 5.6)	77°	9	7.05	10.85	1.53

in the development of abundant root growth than has the calcium carbonate content of the sand. From the figures in the column of "Average dry weight in grams of roots per crock" it has been calculated that in the presence of calcium the root weight was 78.7 percent greater at 59° than at 77° and in the absence of calcium it was 91 percent greater at 59° than at 77°. It was found that, in spite of much less competition, the low temperature root growth was only 36.8 percent greater in the presence of calcium than in its absence. At the higher temperature, the root growth in the presence of calcium was only 46.4 percent greater than in its absence.

The top-root ratio was also predominantly influenced by temperature because those plants grown at 77° had much poorer root development than those grown at 59°. As may be seen in the table on page 38, this difference cannot be attributed to a difference in the degree of competition, since there were relatively equal numbers of plants per crock in the temperature series. On the basis of the figures in the table on page 36 the calcium carbonate content of the sand and the resultant decrease in competition among the grass plants played a negligible role in altering the top-root ratio.

Rhizome development, which was just beginning at the time of harvest, was most noticeable in the crocks with open and sparse growth.

The general conclusion from this experiment, therefore, is that calcium in large quantities has been detrimental to the germination of seed and the growth of young seedlings of Kentucky bluegrass. The effect of the calcium on the growth of the older seedlings was difficult to determine from these experiments because of the much smaller number of plants with the resulting decrease in competition in the crocks containing calcium carbonate. Whether as a result of the sparser distribution of the plants or as a direct effect of the calcium, the grass plants in the crocks containing calcium showed an increase in fine roots near the surface and an increase in length of the primary roots.

It should be remembered in considering these data, however, that the rate of application of lime was much heavier than the heaviest rates ever used in the field. Therefore, although the results are interesting they cannot necessarily be expected to follow the use of lime as applied at the customary rates of 1 or even 2 tons to the acre.

From the temperature series it was found that the grass seedlings grown at 59° had greener color, longer leaves, greater green and dry weights, and a lower top-root ratio than similar seedlings grown at a soil temperature of 77°. These results confirm the wisdom of the recommended practice of planting grass seed in the early autumn during periods of decreasing

RELATIVE NUMBERS AND WEIGHTS OF SEEDLINGS AS CORRELATED WITH TEMPERATURE AND CALCIUM CONTENT OF SEED.

Soil treatment	Soil temperature	Approximate number of seedlings per crock	Dry weight in grams of 100 seedlings
High calcium carbonate	59°	1,700	9.4
(pH 8.0)	77°	1,725	7.4
No calcium carbonate	59°	4,275	5.3
(pH 5.6)	77°	5,125	3.1

temperatures. Since an extensive root system is necessary for the survival of grass through the dry periods of summer, the superior root development obtained at the low temperatures promotes the establishment of turf from seed planted in the early autumn.

EXPERIMENTS WITH ARSENIOUS ACID

During the months of January to March, a series of experiments designed to show the effects of arsenious acid on germination and on seedling growth was set up in a greenhouse maintained at a temperature of approximately 60° F. In the first experiment, five crocks constituted a unit. Each unit was sprayed with a liter (1.06 quarts) of one of the following materials: distilled water, and 0.01, 0.025, 0.05, and 0.1 percent solutions of arsenious acid. The seeds were then sprinkled lightly with fine sand and moistened with distilled water.

In a second experiment two crocks composed a unit. The grass was grown until 1½ months old and the same treatments described above were given. In a third experiment the grass was 3½ months old before similar treatment was given. All three experiments were continued for 3 months following the initial treatment.

The application of arsenious acid at these rates was equivalent to applying it at the rates of approximately 0.6, 1.5, 3, and 6 pounds to 1,000 square feet. Arsenious acid applied at these rates contained arsenic in amounts equivalent to sodium arsenite applied at the rates of approximately 1, 2.5, 5 and 10 pounds to 1,000 square feet, respectively. Arsenious acid is much less soluble and does not have the burning effect on vegetation that sodium arsenite has and therefore could be applied at these heavier rates. These are much heavier rates than those ordinarily used on turf. Moreover, it should be remembered that the grass in these experiments was growing in crocks in quartz sand rather than in the field in the more complicated environment which the soil presents.

Results with Arsenious Acid on Seed

Sixteen days after planting and spraying the seeds, there was sporadic germination of those sprayed with distilled water, and some germination of those sprayed with arsenious acid at the lowest rate of 0.6 pound to 1,000 square feet. Two days later germination began in the crocks sprayed with arsenious acid at the rate of 1.5 pounds to 1,000 square feet. Thereafter, germination occurred in decreasing amounts in the crocks treated with arsenious acid at the rate of 3 and 6 pounds to 1,000 square feet. By the end of 27 days, it was apparent that the grass seed treated with arsenious acid at the 0.6-pound rate was germinating much more completely than the water-treated controls, while that treated at the 1.5-pound rate was germinating about as well as the controls. There was definite retardation in the crocks treated at the 3-pound rate and very marked toxicity to seed in the crocks treated at the 6-pound rate. The stimulating effects continued to be apparent after 2 months in the case of the seed treated at the 1.5 and 0.6-pound rates. As discussed in the January, 1939, issue of TURF CULTURE, such stimulating effects of arsenic on Kentucky bluegrass have been observed frequently in the United States Golf Association Green Section's experiments at Arlington and by others throughout the country who have been using arsenicals in weed control.

The slowness of germination of all the grass in these arsenic experiments may be partially attributed to the low temperature of the greenhouse. An essentially constant temperature of about 65° was maintained throughout the day. Constant low temperatures are not most conducive to the germination of Kentucky bluegrass seed.

RESULTS WITH ARSENIOUS ACID ON SEEDLING GRASS

In the experiments with the 1½- and 3½-month old grass it was observed 5 days after spraying that there was injury from the treatment at the 6-pound rate, the leaves appearing somewhat dried. A week after spraying, injurious effects became apparent as a result of the treatments at the 1.5, 3, and 6-pound rates, the most severe being brought about by the heaviest rate. In general the oldest grass was slowest to respond. Within 2 weeks it was apparent that the grass treated at the

Effect of arsenious acid on germination and early growth of Kentucky bluegrass. The crock on the left received no acid. The four remaining crocks received arsenious acid at the rates of 6, 3, 1.5 and .6 pounds to 1,000 square feet, reading from left to right. The crocks are marked 0.1, .05, .025 and .01, respectively, indicating the percentage of solution used immediately after the seed was sown, after which the seed were sprinkled lightly with fine sand and moistened with distilled water. The picture was taken 27 days later and shows a better stand of grass in the crocks marked .01 and .025 which received arsenious acid at the .6- and 1.5-pound rates respectively than in the untreated crock marked C., and a retardation in the crocks treated at the 3- and 6-pound rates. These effects remained evident 2 months after treatment.

6-pound rate would die, while with the remaining treatments, although there was injury, the severity decreased with decreased rates.

Slightly over a month after treatment with the very heavy arsenious acid sprays, the older grass treated at the 3- and 6-pound rates was almost completely killed. Thus an upper tolerance of Kentucky bluegrass seedlings for arsenious acid, when used as a spray, was found to be 3 pounds to 1,000 square feet. This is equivalent in arsenic content to approximately 5 pounds of sodium arsenite to 1,000 square feet. It should be remembered that these results were obtained on grass seedlings grown in crocks in quartz sand and that, therefore, the results cannot be expected to apply to grass of the same age grown in the field. The complications introduced by the colloidal nature of the soil solution in clay soils, the microflora of soils, and other factors may be expected to alter the results considerably. It has been shown by other investigators that the toxicity of arsenic is affected by the texture of the soil in which the plants are growing. Arsenic is much more toxic to plants grown in sand than in soil, and this toxicity is reduced materially even by the coarser soils.

After a few weeks the older grass, which had been injured severely, began to recover from the initial effects of arsenic "burning." The grass treated with arsenious acid at the 0.6-pound rate, however, showed no adverse effects from spraying. There seemed, on the contrary, to be a slight benefit.

In the crocks of grass which were sprayed, some seed germinated which had previously remained dormant. Practically all the seed germinating in the crocks treated with arsenious acid at the 6-pound rate were those of weeds present in the seed sample, but no weed seedlings were observed in the crocks sprayed at the lower rates. Apparently arsenious acid at the higher rates stimulated germination of weed seeds.

Another effect noted was that grass sprayed with the lower concentrations of arsenic was more drought resistant than the controls.

In the experiments reported here, seeds appear to be differentially affected by arsenious acid, a treatment at the 6-pound rate killing nearly all bluegrass seeds or seedlings, while seeds of weeds, which were present as impurities, were apparently stimulated to germinate and grow.

Summary and Discussion

Kentucky bluegrass was seeded in washed quartz sand contained in 2-gallon crocks and grown in the greenhouse. After germination each crock received bi-weekly applications of a complete nutrient solution.

In one series one-half pound of calcium carbonate was mixed in the sand in each of some of the crocks. This series was later grown at two different temperatures of 59° and 77° F.

Additional series of crocks were set up, some of which were watered with solutions of arsenious acid equivalent to applying it at the rates of .6, 1.5, 3, and 6 pounds to 1,000 square feet. These solutions were sprinkled on some of the crocks before the seed germinated and on others when the plants were at various stages of growth.

Germination of seed in crocks having a high calcium carbonate content (pH 8.0) began about a week after that in crocks having no calcium carbonate (pH 5.6).

Thirty-five days after planting, the roots of the plants growing in crocks containing calcium carbonate were long and had few if any branches, while those growing in the absence of calcium carbonate were shorter and more branched.

The average length of roots at the end of 35 days was almost twice as great when calcium carbonate was present as when it was absent.

At both 59° and 77° the average number of seedlings surviving after 90 days in the crocks containing calcium was about one-third of the number in the calcium-free crocks.

Ninety days after planting, the average top growth of grass grown on sand having a high calcium carbonate content was, on the basis of dry weight, approximately 33 percent greater than when calcium carbonate was absent. This may probably have been associated with the decreased competition in the calcium carbonate crocks.

The dry weight of seedlings was consistently greater at 59° than at 77°.

During the period of this experiment, root growth was definitely greater at 59° than at 77°. The data indicate that soil temperature is a more important factor in the growth of an extensive root system than is the calcium carbonate content of the soil.

The grass grown at a soil temperature of 59° had greener color, longer leaves, greater green and dry weights, and a larger top-root ratio than did grass grown at a soil temperature of 77°.

When arsenious acid was applied to Kentucky bluegrass seed at the 0.6 and 1.5-pound rates, germination and growth were greater than in the control crocks to which water alone had been applied. The treatment at the 0.6-pound rate was equivalent in arsenic content to the application of sodium arsenite at the rate of 1 pound to 1,000 square feet and produced a thicker and taller stand of grass in a shorter time than the controls. This advance was maintained throughout the 3 months of the experiment.

The harmful effects of arsenious acid progressively increased with increasing rates. There was a definite retardation of germination with the use of the 3-pound rate and a decidedly marked toxicity to the seed evident when the arsenious acid was applied at the 6-pound rate.

The upper tolerance of Kentucky bluegrass for arsenious acid in these sand cultures was found to be the 3-pound rate, a single application at the 6-pound rate being sufficient to kill seed or seedlings of grass.

Considerably higher concentrations of arsenious acid are required to kill the growing point of the stem than to kill the leaves of Kentucky bluegrass.

Arsenious acid is more toxic to Kentucky bluegrass seed than to seed of certain common weeds. In some cases the latter appeared to be stimulated to germination by the heavy applications of arsenious acid.

THE FEDERAL SEED ACT

The new Federal Seed Act which became operative on February 5, 1940, should be of interest to all turf culturists for this new act is another step toward providing the intelligent buyer with the facts concerning his purchases.

Heretofore seeds of turf grasses have received little attention from the various legislatures. The Seed Importation Act of 1912 covered only the importation of certain agricultural seeds and, except for the ryegrasses, seeds of interest to turf growers were not included. Most of the states now have legislation covering the labeling and quality of the seed sold in the state but these laws are not uniform and buyers of grass seed in many states have had little or no protection.

The Federal Seed Act promises to bridge many of the gaps in the existing seed laws since it regulates both the importation and the interstate movement of all of the major turf grasses.

The grasses of interest to turf culturists specifically mentioned in the Act are: *Agropyron cristatum,* crested wheatgrass; *Agrostis alba,* redtop; *Agrostis canina,* velvet bent; *Agrostis palustris,* creeping bent; *Agrostis* spp., bent grasses, the latter would cover Colonial bent among others; *Cynosurus cristatus,* crested dogtail; *Festuca* spp., fescue; *Lolium multiflorum,* Italian ryegrass; *Lolium perenne,* perrenial ryegrass; *Poa annua,* annual bluegrass; *Poa compressa,* Canada bluegrass; *Poa nemoralis,* wood bluegrass; *Poa pratensis,* Kentucky bluegrass; *Poa trivialis,* trivialis bluegrass (rough bluegrass); and *Trifolium repens,* white clover.

Seed Moving in Interstate Commerce

The Act provides that agricultural seeds or any mixture of agricultural seeds for seeding purposes may not move in interstate commerce unless each container bears a label carrying correct information regarding the following:

1. The name of the kind, kind and variety, or the kind and type for each agricultural seed component present in excess of 5 percent of the whole and the percentage by weight of each kind.

> Under this provision the label on turf seed mixtures must show the percentage of each kind present. It is not enough to say that the mixture consists of "5 percent or more" of each of certain specified seeds, as has so often been done in the case of lawn grass mixtures.

2. Lot number or other identification.

3. The origin of the seed, but this applies at present only to alfalfa, red clover, and corn.

4. Percentage by weight of weed seeds, including noxious weed seeds.

5. Kind of noxious weed seeds and rate of occurrence.

This must be expressed in accordance with, and shall not exceed, the rate allowed by the laws of the state into which the seed is to be sent. The Secretary of Agriculture may also determine that weeds, other than those designated by state seed laws, are noxious. It should be noted that weeds have been called noxious chiefly because of their effect in cultivated fields, though some are also noxious in turf.

6. Percentage by weight of agricultural seeds other than those included in paragraph 1 of this section.

7. Percentage by weight of inert matter. This includes dirt, chaff, and broken seeds.

8. For each agricultural seed in excess of 5 percent of the whole, the percentage of germination, exclusive of hard seed; the percentage of hard seed, if present; and the calendar month and year the germination test was completed. The germination test must have been completed within a 5-month period, exclusive of the month in which the test was completed, immediately prior to transportation or delivery for transportation in interstate commerce. The Secretary of Agriculture is authorized to fix a shorter or a longer period if he finds that desirable.

9. Name and address of the shipper or of the consignee or a code designation approved by the Secretary of Agriculture.

General Provisions

Besides the labeling provision, the Act provides that it shall be unlawful for any person to transport or deliver for transportation in interstate commerce any seeds having false labeling, or pertaining to which there has been a false advertisement, or to sell or offer for sale such seed for interstate shipment by himself or others. The use of a disclaimer or non-warranty clause shall be no defense against confiscation of seed found falsely labeled or transported contrary to the provisions of this Act.

Certain exceptions are made to the regulations outlined above. The one of possible interest to our readers exempts any farmer producing his own seed on his own premises provided he sells no seed but his own. A farmer shipping his own seed direct to the consumer in another state must, however, comply with any state seed laws governing the production and sale of seed within such state just as though the seed had been produced within that state.

Imported Seed

While the old seed importation act is repealed, the provisions of that act are retained and strengthened in the new act. Various restrictions are made on the importation of undesirable seed, the one of interest to our readers being the prohibition of the importation of seed unfit for seeding purposes. Seed is declared unfit for seeding purposes if any such seed contains noxious weed seeds in excess of one noxious weed seed in each 10 grams of seed of various named species including those of *Agrostis*, *Poa*, or any kind of seed of a size and weight similar to, or less than those named; if such seed contains more than 2 percent by weight of weed seeds; or if such seed contains less than 75 percent of pure live seed.

This last provision is not mandatory as to the percentage since it is provided that when the Secretary of Agriculture finds that any such seed cannot be produced to contain 75 percent of pure live seed he may set up such standards as he finds can be produced. Under this provision the requirement for species of *Poa* has already been reduced to a pure live seed content of 65 percent.

Provision is also made in the Act for the delivery under bond of seed for cleaning. If the cleaned seed meets the requirements of the Act it may be admitted.

The Secretary of Agriculture is given authority to make rules and regulations for its administration; and provisions for seizure, penalties, court procedure, and other administrative matters are made.

The Department of Agriculture has published in the Federal Register, Volume 5, number 2, for January, 1940, a complete set of rules, regulations, and orders covering the administration of the Act.

In brief, all seeds in which turf culturists are interested are covered by the Act. They may not enter interstate commerce unless labeled as provided, nor any imported seeds enter the country unless they meet certain requirements. These requirements are that each lot must contain at least 75 percent pure live seed, except that for the species of *Poa* this has been reduced to 65 percent; it must not be adulterated and must not contain more than one noxious weed seed in 10 grams (about 45 to the pound).

The labeling provisions of the Federal Seed Act do not differ materially from those in most state seed laws. Except in the case of imports, neither in the Federal nor in most state seed laws are definite minimum percentages of purity and germination required for turf grass seeds. The laws merely require that these fundamental facts about the seed be given and that the statements be true. It is then up to the buyer to use this information as he chooses in making his purchases.

WHAT OTHERS WRITE ON TURF

In this department will be given the substance of research in the various fields of scientific investigation which seems to have a definite bearing on turf improvement. The articles will summarize results of recent investigations made in various parts of the world. They are not published here as recommendations but simply as information for our readers and as suggestions which may have practical applications in many situations. Where the Green Section's tests or the information it has obtained from other reliable sources in this country substantiates or contradicts the results obtained by other investigators, comments to that effect may be included as a guide for our readers. In all other cases the reader will receive in brief the results and conclusions as given in the original papers.

DIFFERENCES BETWEEN STANDARD AND FAIRWAY STRAINS OF CRESTED WHEATGRASS

The Fairway strain of crested wheatgrass is frequently used for turf purposes in the dry areas of the Northwest. Where watering is possible, the Fairway strain is not so satisfactory as Kentucky bluegrass, but in areas where dependence must be placed on the limited rainfall, it is the best grass available for turf purposes.

As mentioned in the second issue of TURF CULTURE, the Fairway strain makes a better low-cut turf than does the ordinary crested wheatgrass. W. D. Hay of Montana has studied seeds, seedlings, and mature plants of two selected strains of crested wheatgrass, Standard and Fairway, and has described the differences between them in the Journal of the American Society of Agronomy.

The seed of the Fairway strain tends to be shorter and narrower than that of the Standard strain, and the awns tend to be longer. The best means for distinguishing between the seed of the two strains, however, lies in the 1,000-grain weight. The weight of 1,000 seeds of the Fairway strain was 1.38 grams, while 1,000 seeds of the Standard strain weighed 2.41 grams. The heaviest seed of the Fairway strain is lighter than the lightest seed of the Standard strain.

The seedlings of the Fairway strain can be distinguished from those of the Standard strain by the presence of fine hairs on the upper leaf surface. In the Standard strain there are sometimes a few scattered hairs, but as a rule the leaf is smooth. There are also some differences which are less readily seen, such as the spines on the leaf sheath, which are present in most plants in the Standard strain, but absent in the Fairway strain.

In the field the two strains are distinguished by the more conspicuous variations in characteristics of the spikes, height and color of the plants of the Standard strain, as contrasted with the greater uniformity among the plants of the Fairway strain. These variations are most conspicuous just before blooming, after which it becomes increasingly difficult to distinguish between the two strains.

"PRACTICAL LAWN CRAFT"

A new book on grass growing has recently been written by R. B. Dawson, Director of the St. Ives Research Station, Bingley, England. The book is entitled "Practical Lawn Craft" and is published by Crosby, Lockwood & Son, Ltd., London. Although the title indicates only an interest in lawns it, to a large extent, also covers the field for turf maintenance on golf courses and sports fields as well.

The book is written primarily for English conditions and therefore the turf under consideration is composed chiefly of bent and fescue. A mixture of these two grasses is said to produce the best lawn turf in England.

The whole range of turf maintenance is thoroughly covered in chapters on grasses, construction and drainage, the purchase of grass seed, seeding, mowing, fertilizing, weeds, diseases, and many other topics. Extensive references are given to scientific work in this field but unfortunately the author has apparently not carefully checked his references to give full credit to original sources.

The book is well prepared and is a definite contribution to the literature on turf culture. Even though it is written for conditions that are not generally common in the United States, it no doubt would be found to contain much useful information for those who maintain turf in this country.

NAME OF THE FUNGUS RESPONSIBLE FOR DOLLARSPOT

The fungus responsible for the dollarspot disease of turf grasses was first recognized and isolated in the United States. A description of the symptoms of the disease and of the organism was published in the Bulletin of the United States Golf Association Green Section. On the basis of the appearance of the mycelium or hair-like vegetative growth of the organism on the infected areas of the grass leaves, it was classified in the same group of disease-producing fungi as *Rhizoctonia,* which is the cause of brownpatch. At that time the spores, which are a much more certain basis for classification of fungi than the mycelium, could not be found on the fungus growing either on the grass or on culture media.

Since that time the organism has been found to occur in Great Britain and in Australia as well as in the United States and Canada. With the further study of dollarspot the early investigators agreed in all major respects with the first findings, and F. T. Bennett suggested the name *Rhizoctonia monteithianum* for purposes of reference.

Recently Bennett published a paper in the Annals of Applied Biology, describing his work on the dollarspot disease in England. In his article he emphasized the spores which he found in some cases after much experimenting with specimens of the organism from the United States, Canada, Great Britain and Australia. Bennett discovered that several strains could be distinguished. He found that one strain of the fungus produced two kinds of spores; some strains produced only one kind or the other, and others never produced spores in cultures. The strains from the United States and Australia do not produce spores in cultures.

On the basis of his findings concerning the types of spores formed, Bennett concluded that the fungus causing dollarspot is a *Sclerotinia* and suggested the name *Sclerotinia homoeocarpa* for the species represented by the various strains found in America, Australia and Great Britain.

As a result of physiological studies on the various strains of the organism he found several interesting facts concerning the response of the fungus to acidity and temperature. The rate of growth was not affected by changes in acidity between pH 4.0 and 8.0. The optimum temperature for the growth of the organism was, for the British strains 68° to 77° F., and for the American strains 86° F. The American strains have apparently become adapted to higher temperatures.

SPREADERS TO INCREASE THE WETTING PROPERTY OF SPRAYS

Spreaders have not been adequately tested with sodium chlorate or other weed eradicators when used on turf areas, but they have been found of service in spraying shrubs as *Ribes petiolare* in the white pine blister rust campaign. The use of sodium secondary-alcohol sulfates in this way has been mentioned by H. R. Offord and L. P. Winslow, of California, in Northwest Science. They tested various proprietary and other preparations and give a list in descending efficiency of the spreaders found most satisfactory with sodium chlorate.

Tergitol 7, a commercial preparation of a sodium secondary-alcohol sulfate, in concentrations of 0.01 to 0.1 percent was found to be the best of these products. Spreaders may also be used with other poison sprays, but the authors think it probable that the order of efficiency may vary with different materials.

RESPONSE OF DIFFERENT STRAINS OF KENTUCKY BLUEGRASS TO CUTTING

Work done on the effect of cutting on grass has invariably shown that frequent and severe cutting reduces the growth of foliage, roots, and rhizomes. For the most part, such work has been done with mixed populations of different grasses, but A. O. Kuhn and W. B. Kemp of the Maryland Agricultural Experiment Station have studied the effect of cutting on contrasting strains of Kentucky bluegrass.

One strain was tall with long leaves, the other an extremely low-growing type. Both strains had been grown at the Maryland station under uniform soil conditions for three years prior to the starting of the experiment. The methods followed and the results secured have been described in the Journal of the American Society of Agronomy.

In the series of experiments reported here proportionate amounts of foliage were removed from 24 plants of each of the two strains. Five cutting treatments were used as follows: none, mid-blade, 1 inch beyond the ligule (the point at which the leaf blade joins the sheath), at the ligule, and below the ligule. Each leaf was cut separately on each plant at 2-week intervals beginning April 28, and the clippings were dried and weighed. The average height resulting from each removal of clippings on both strains was determined by a number of measurements of the tops remaining after clippings were made. At the completion of the experiment the plants were lifted, dried at 100° F. for a week, and weighed. The root, rhizome, and forage production in grams were recorded. Under the heading "Forage," the authors give the total production of clippings throughout the season as well as the foliage left on the plants at the end of the experiment.

Increasing severity of defoliation

was accompanied by similar and decidedly significant decreases in the production of roots, rhizomes, and tops in both the tall-growing and low-growing strains when the same proportions of foliage were removed from each strain. When cut at the ligule, for instance, the reduction in root production was 87 and 80 percent, that in rhizome production was 82 and 86 percent, and that in top production was 44 and 29 percent for the tall-growing and low-growing strains, respectively. The weight of the season's clippings also decreased equally in the two strains, with increase in severity of defoliation.

The removal of comparable proportions of foliage, however, resulted in strikingly different heights of cut in the two strains. For instance, clipping the leaves of the tall-growing strain just above the ligule resulted in a mean height of 1.4 inches, while a comparable height of 1.6 inches was only attained by the plants of the low-growing strain when they were permitted to grow unclipped. At these two comparable heights of top growth remaining on the plants after clipping, the low-growing strain produced approximately one and a half times as much weight of tops, more than five times as much weight of roots, and more than eight times as much weight of rhizomes as the tall-growing strain.

The conclusion is drawn, therefore, that when compared on the basis of comparable height of cut rather than comparable proportions of foliage removed, the low-growing strain produced strikingly more tops, roots, and rhizomes than did the tall-growing strain cut to a similar height. For practical purposes, then, a low-growing strain will produce a much better turf than taller strains.

Their table indicates that when neither strain was cut the tall-growing plants produced far more "forage" than the low-growing ones. From the standpoint of turf, the lower production of forage is an advantage because it necessitates less cutting during the season.

SULFUR MAY IMPROVE THE PHYSICAL CONDITION OF A HEAVY CLAY SOIL

Owing to the high proportion of the colloidal fraction, some heavy clay soils are difficult to work. They drain poorly and remain wet in spite of drainage lines. The remedy is to flocculate the soil so as to produce a crumb structure. In farm practice this is often done by a liberal use of lime. Since lime tends to encourage certain weeds and earthworms, R. B.

Dawson and B. M. Boyns of the St. Ives Research Station, Bingley, England, tested the value of elemental sulfur on a heavy clay course at the Malone Golf Club near Belfast, and have reported on their work in the Journal of the Board of Greenkeeping Research.

In November, 1934, applications of flowers of sulfur were made on plots in a fairway at the rates of 3.5, 7, 14, and 28 pounds to 1,000 square feet. Examination of these plots in February, 1936, showed that conditions in the soil had been much improved, but that the 14-pound rate had slightly damaged the grass and the 28-pound rate had completely killed it.

Further areas of the fairway were treated at the 14-pound rate, and in the spring of 1938 a marked improvement was noted. Following the sulfur treatment, applications of sulfate of ammonia and calcined sulfate of iron were made. The result was an absence of weeds and worm casts on the treated areas.

The writers warned against the adoption on other soils of the rate of sulfur found suitable on this course. The proper rate of application probably varies on different soils. Too high a rate can do irreparable damage to the turf, due to the direct burning action or to the increased soil acidity. Sulfur should never be applied to light soils.

CHLOROPICRIN FOR CONTROL OF NUTGRASS

Nutgrass, *Cyperus rotundus*, which is a sedge and not a true grass, is a serious weed in parts of the South. The control is difficult since hand weeding merely removes the leafy part, leaving the tubers on the underground stems to grow again. On a large scale it may be controlled by cultivating the soil every 3 weeks during the growing season for 2 years.

This is out of the question on small areas where intensive work must be carried on. G. H. Godfrey, of the Texas Agricultural Experiment Station, writing in Soil Science, has shown that on such small areas nutgrass may be eradicated in a few weeks by injections of chloropicrin. In his experiments the ground was spaded and the chloropicrin injected to a depth of 7 inches. In various trials, rates of approximately 9, 13 and 17 pounds to 1,000 square feet were used and the treated areas covered with glue-coated paper. In one trial no paper was used but the soil was wetted down about 2 inches and the water renewed 3 times during the afternoon. Control was perfect at the heavier rates and practically so at the 9-pound rate, both when the area was covered with paper and when it was kept wet. When present in sufficient amount, the water prevented the escape of the gas.

While the cost of treatment would be too great on a large area, it seems quite practical for small areas. The cost is given as $1.00 per 100 square feet for chloropicrin, plus a few cents for paper. The use of chloropicrin for killing weeds in soil and in compost has been described in the January, 1939, number of TURF CULTURE, pages 63-79.

CONTROL OF SOD WEBWORMS

There are several species of sod webworms, but they all have similar habits and cause the same kind of damage to turf. They are present in turf from early spring to late fall, but during periods of abundant rainfall the grass plants are not severely injured. In dry seasons, particularly in midsummer, severe injury may result from their feeding on the grass blades, and the grass may even be killed. In a Kentucky Agricultural Experiment Station Bulletin, H. H. Jewett has described three species of webworms common in Kentucky bluegrass sod and has given an account of control experiments carried out during 1934, 1935, and 1937.

Preliminary trials were run with kerosene emulsion, barium carbonate, nicotine oleate, pyrethrum, arsenate of lead, beta dichloroethyl ether, Loro, Lethane Jr., Derris powder and a poison bait composed of cornmeal, Paris green and nitrobenzene. The kerosene emulsion, pyrethrum, and arsenate of lead were found to be the most efficient and were given more extensive trials during the three seasons, 1934, 1935, and 1937.

The kerosene emulsion was prepared from ½ pound of hard soap, 1 gallon of water and 2 gallons of kerosene. One part of this emulsion was diluted with 10 parts of water and applied at the rate of 1 gallon to 10 square feet. When carefully prepared, this emulsion did not injure the grass except for a slight burn to the tips of newly clipped grass or grass bruised with trampling.

The arsenate of lead was applied in a spray prepared from 1 pound of arsenate of lead in 10 gallons of water at the rate of 1 quart to 10 square feet. This was the equivalent of applying arsenate of lead at the rate of 2.5 pounds to 1,000 square feet. It was recommended that soap or some other material should be added to the spray to make the arsenate stick to the grass. No injury to the grass resulted from this treatment.

Pyrethrum extract containing 2 grams of pyrethrin in 100 cc. was diluted at the rate of 1 ounce in 4 gallons of water and applied at the rate of 1 gallon to 10 square feet. This was equivalent to applying pyrethrin at the rate of approximately one-half ounce to 1,000 square feet. It did not injure the grass.

With these three materials 86 to 96 percent of the webworms were killed in different trials during the three seasons, 1934, 1935, and 1937. Considering all trials, it was concluded that the pyrethrum extract gave slightly better control than either the kerosene emulsion or the arsenate of lead, and the latter gave the least control, particularly in 1937.

MANAGEMENT OF LAWNS IN NEW ENGLAND

The Rhode Island Agricultural Experiment Station has carried on lawn experiments for a number of years and H. F. A. North, T. E. Odland and J. A. De France have reported on this work in Rhode Island Bulletin 264.

Some plots have been under continuous observation for 30 years, but in the main the report covers the results for the 5 years 1931-1935. The plots were variously treated as to fertilizers, lime, compost and other factors studied, and were rated during each season for vigor, color, texture, density and uniformity.

The continuous use of sulfate of ammonia is said to have produced a very acid reaction in the soil, but when an equal weight of lime was added with the sulfate of ammonia the resulting turf had a higher rating than when the nitrogen was applied as nitrate of soda. Where sulfate of ammonia alone was used the increasing acidity favored the accumulation at the surface of a felty mass of dead grass roots.

A mildly acid soil condition was found to be more desirable than a very acid or alkaline one. The grass on plots fertilized with nitrate of soda became green earlier than that on plots receiving sulfate of ammonia, but there appeared to be a gradual decline in the quality of the grass on the nitrate of soda plots.

Plots receiving sulfate of ammonia and lime contained less white clover than those receiving nitrate of soda. Cottonseed meal added to the regular fertilizer in an amount equal to 1 pound of nitrogen to 1,000 square feet improved the color, vigor and density of the turf but increased the number of worm casts.

Turf cut to a height of 1¼ inches was greener and more vigorous than that cut at three-fourths of an inch, and there was slightly more clover in the longer turf.

CAN GRASSES BE HYBRIDIZED?

Plant improvement generally is achieved by one of several methods, perhaps the two most common being by selection and perpetuation of the most desirable individuals and by hybridization. The improvement of turf grasses so far has been accomplished largely by the process of selection, but the possibility of hybridizing has not been overlooked. In 1937 and 1938 Walter Hertzsch in Germany made 57 crosses between various species of fescue, ryegrass, brome, wheatgrass and others. The results of these crosses, as published in Der Züchter, are not encouraging. He emasculated and cross-pollinated nearly 16,000 flowers in making these crosses, and a total of only 333 seeds were set. In 42 of the 57 crosses no seeds were set, and in 5 there was just one seed set.

Most of the grasses used were pasture grasses, but numerous crosses were tried with *Festuca rubra.* When it was used as the male parent crossed on *Festuca pratensis,* only 8 seeds were developed out of 765 crosses. However, when used as the male parent crossed on *Lolium perenne,* 41 seeds were produced out of 303 crosses. No seeds were produced when *Festuca rubra* was used as the female plant.

LOSS OF VIABILITY IN NEW ZEALAND CHEWINGS FESCUE

Decline in the germination capacity of Chewings fescue seed during shipment from New Zealand to the northern hemisphere has for many years been a constantly recurring trouble. In spite of this fact, our annual import totals have remained reasonably steady. American buyers appear to have accepted Chewings fescue seed as being delicate and short-lived, and, although periodic complaints have followed unsatisfactory deliveries, particularly in unfavorable seed production seasons, the demand has been well sustained.

Many theories have been advanced, both in the United States and abroad, as to the causes of deterioration of grass seed during shipment, but results from experimental work have shown that it is largely due to unfavorable conditions of shipment. These unfavorable shipping conditions, to which seed of Chewings fescue was found to be particularly susceptible, were high temperature and humidity in the ship's hold. Although no reliable data concerning temperature and humidity in ships' holds are available, it is known from observation that both are invariably high.

Foy carried on experiments on the effect of temperature and moisture content of seed on viability and presented his results in the New Zealand Journal of Agriculture. Reference to this article is made on page 4 of this issue. Foy's results showed that high temperature, together with high moisture content of the seed, effected a rapid decline in germination capacity. He found that when one of these conditions was at normal level and the other unfavorable, a slow loss in viability followed, and that when one condition was extremely favorable the other might be very unfavorable without causing harmful results.

A temperature of 104° F. was considered the average for a ship's hold in the tropics and 13 percent as the normal moisture content of Chewings fescue seed.

The results of Foy's experiments are shown in the table below. It will be noted that the moisture content of the seed was the more important factor. At a moisture content of 5 percent there was practically no loss of viability at any temperature; at moisture contents of 13 and 20 percent there was sooner or later a loss of viability at each temperature.

Results of Storage of Chewings Fescue Seed with Initial Germination Capacity of 98 Percent. The Number of Days of Storage Are Given in Parentheses at the Head of the Columns Showing Percentage of Germination Capacity.

Storage temperature °F.	Moisture content of seed Percent	Percentage of germination capacity (1)	(7)	(14)	(21)	(35)	(42)
122	5	97	97	98	97	98	97
122	13	96	9	..	..	..	..
122	20	94	..	..	..	..	..
104	5	98	97	98	98	96	98
104	13	96	73	38	21	15	10
104	20	94	66	12	2	1	..
86	5	98	98	98	98	97	96
86	13	97	85	82	85	79	75
86	20	95	79	57	39	10	5

OUR LETTER BOX

The Green Section receives numerous inquiries concerning local turf problems and is always glad to reply to them. With the hope that some of these questions and answers may be helpful to others besides the original correspondent, a few of them will be published. While most of the answers will have a general application, it should be remembered that each recommendation is intended for the locality designated at the end of the question.

Control of fungus diseases on lawns.—The past summer my lawn has been damaged by a web formation which killed the grass beneath it. I was told this was a fungus growth and that it could be controlled by raking and thereby breaking the web each morning. What is the cause of this condition? Can you suggest any other control? (New York.)

ANSWER.—The damage to which you refer was no doubt due to one of the diseases which we commonly know as brownpatch or dollarspot. These diseases are caused by a fungus growth and, due to the abundance of moisture, were unusually prevalent in your district the past summer.

Diseases caused by fungi can be reduced by avoiding excessive watering and also by avoiding excessive fertilizing, especially during the summer months. If you wish to go to the added expense of making chemical treatments to prevent these diseases you may control them very effectively by the application of corrosive sublimate or calomel, applied at rates of from 1 to 3 ounces to 1,000 square feet.

* * *

Bermuda grass in Maryland.—We have been experimenting with Bermuda grass with considerable success. Our soil is quite sandy with some clay mixed with it. Do you believe Bermuda grass satisfactory for turf purposes in this section? In planting Bermuda grass is it necessary to plant grass that has roots formed or will the "knuckles" or "joints" of the stalk take root? Can you suggest a better grass for this type of soil? (Maryland.)

ANSWER.—Bermuda grass may do well in Maryland in certain areas that have a southern exposure. For general planting, however, it is likely to be unsuccessful due to the fact that it may partly winterkill. In planting Bermuda grass it is not necessary to have roots on the stolons for new roots will be produced at each of the "joints." Ordinarily Kentucky bluegrass will give best results for turf in your section. It may be mixed with 20 percent redtop for general seeding purposes.

* * *

Establishing Bermuda grass on alkaline soil.—On a golf course which we are building we find that tests of surface soil show an alkaline reaction of pH 8.5 and an average salt content on a moisture free basis of approximately 0.24. What procedure would you recommend in bringing this soil to a neutral condition suitable for the development of Bermuda grass? (Florida.)

ANSWER.—The best way to do this would be to apply finely divided sulfur. However, this would probably not be worthwhile. Good Bermuda grass is grown on soil with a pH of 8.5. Also, you may find that as the salt leaches out the pH will be lowered. Most likely if you feed the Bermuda grass well it will thrive in spite of the alkalinity. It would be important, however, to get a good cover of grass on this soil as rapidly as possible. This would prevent an excessive concentration of salt on the surface in hot dry weather.

Liberal applications of sulfate of ammonia would no doubt give you more for the money than any other material you could apply under these conditions. It would not only have the effect of stimulating the grass to give a good protective covering to the surface soil but it would also ultimately neutralize some of the alkalies in the soil.

* * *

Watering turf.—It has been my understanding that proper watering is fundamentally deep watering, and that the guide as to the quantity of water needed to be supplied is the degree to which the rainfall varies from normal. Should an attempt be made through irrigation to supply the soil with the exact deficiency from normal? Any information on the subject of watering will be appreciated. (Pennsylvania.)

ANSWER. — Your statement about the desirability of deep watering in preference to shallow watering is correct. In a general way, in your district normal rainfall will keep turf in reasonably good condition. Heavy showers with excessive run-off or extreme drought will, however, modify these requirements.

If on the first of April you have a deficiency of 2 inches and the early part of April continues dry, we would add no water until the grass shows definitely that it is suffering from lack of water. This will be expressed in the wilting and gradual browning of the turf, particularly in rather limited spots. Then use water to wet the soil down to a depth of at least 4 or 5 inches.

* * *

Use of mercurials in the control of turf diseases.—In connection with the use of bichloride of mercury and calomel for combating dollarspot and brownpatch, we would like to inquire whether it is possible to use mercury without discoloration of the grass. We would like to have your advice also as to the amount of water to be used with the powdered mercury and calomel and whether or not these chemicals deteriorate when mixed with water and allowed to stand in open glass jars before using the material. (Michigan.)

ANSWER.—It is possible to use these mercury compounds on turf without any discoloration. In hot humid weather, however, there is more apt to be injury than in cooler or dryer weather. Therefore, it is necessary to use much lower rates on such occasions. Ordinarily we recommend the application of 3 ounces of these materials alone or in combination, to 1,000 square feet. In especially hot humid weather, however, we advise that the rates be cut to 1 ounce and in some cases even to one-half ounce to 1,000 square feet.

These chemicals do not deteriorate when standing in water. It is well to water the grass lightly after an application of mercury compounds. If you are applying them by the spray method the amount of water required will vary somewhat with the type of spray equipment you are using—the size of nozzles, etc. Ordinarily 10 or 15 gallons to 5,000 square feet will be sufficient to give a good coverage.

* * *

Control of mouse-ear chickweed.—Under separate cover I am sending a sample of a weed for identification. I would greatly appreciate any additional information you could give me as to its habits and eradication. (Pennsylvania.)

ANSWER.—The weed specimen you sent to us is mouse-ear chickweed. If this weed is too well distributed to justify hand weeding it may be checked with sulfate of ammonia or other chemicals. This species, like other chickweeds, is likely to be very sensitive to arsenical poisoning and may often be checked by applications of arsenate of lead. A more certain method is to spray with sodium arsenite or arsenic acid using 3 to 4 ounces dissolved in 2 to 5 gallons of water to 1,000 square feet.

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Algae on greens.—I would like to know what treatment you would recommend for algae in turf. (Ohio.)

ANSWER. — Algae are minute green plants that form a scum on turf wherever there is sufficient moisture and where the grass has been injured by disease or other causes. Scums of algae are usually troublesome in low, heavily watered areas. Thick growths should be raked with an iron rake or spiked to break up the scum. The affected areas should then be treated with corrosive sublimate and topdressed. Also, it would be well to curtail the watering decidedly. (mercuric chloride)

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Grass for shady areas.—I would appreciate very much some information from your office regarding suitable grasses for shady and semi-shady spots. (Virginia.)

ANSWER.—For your shaded areas where the soil tends to remain moist or which can be watered regularly, we think you will find that *Poa trivialis* can be expected to give the best results. It will have, however, a weak period during the summer months. For the areas that are well drained and tend to be rather dry the best grass for shade is Chewings fescue. Kentucky bluegrass should do well in partial shade and out in the open. It will, however, die during the summer months in most heavily shaded places.

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Night or day watering.—Our watering system is of the hose and sprinkler type and in order to make the necessary coverage we are often compelled to water our turf in the daytime. Criticism has been expressed of our day watering in that it results in heavy losses of water. I would like to have your opinion on day watering as opposed to night watering. (New York.)

ANSWER.—All of the tests that have been made with watering seem to indicate that from the standpoint of grass there is little difference whether the water is applied during the night or during the day. There is no doubt a little more loss of water during the day than during the night applications. On the other hand, where the hose and sprinkler system is used, there is a distinct advantage in watering in the daytime, since the men operating the sprinklers can see in the daytime where the sprinklers should be placed to get the most water on the driest areas.

On turfed areas, such as golf fairways or sportsfields where there may be heavy play in the daytime, another question arises. In such cases the question of day as against night watering may be decided on the basis of convenience from the standpoint of play as well as convenience in handling the labor and equipment. Grass seems to be well satisfied with an adequate supply of water either in daylight or dark.

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Planting Washington bent.—We have in mind planting Washington bent stolons, and would like to know how late in the season this can be done. What is the rate at which stolons should be planted? (Minnesota.)

ANSWER.—You can plant stolons successfully up until the end of September. Earlier plantings, however, are to be preferred. If it is impossible to make the plantings in the fall, you can do so to good advantage in the early spring.

We ordinarily recommend that the stolons be planted at the rate of 1 square foot of nursery stock to 10 square feet of turfed area. Lighter plantings are practical but come along more slowly.

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Turfing daisy too expensive.—Can the turfing daisy (*Matricaria tchihatchewi*) be used as a substitute for grass on an acre lawn? (Connecticut.)

ANSWER. — The turfing daisy has a place on small areas where grass does not do well, but it would cost too much to use it on an acre basis. Seed is scarce and nurserymen charge $1.00 for 15 plants. Set 15 inches apart each way, about 30,000 plants would be needed for an acre planting. At present prices this would amount to $2,000. If set closer for quicker results the cost would be still higher.

UNITED STATES GOLF ASSOCIATION

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