TURF CULTURE

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ARLINGTON TURF MEETING

The annual Arlington Turf Meeting, sponsored jointly by the Greenkeeping Superintendents Association and the United States Golf Association Green Section, was held this fall on Monday and Tuesday, September 16 and 17, with headquarters at the Hamilton Hotel in Washington, D. C. At 9 o'clock Monday morning the visitors assembled on the Turf Garden at the Arlington Experiment Farm for the annual review of the experimental work conducted there by the Green Section in collaboration with the Bureau of Plant Industry of the United States Department of Agriculture. The primary purpose of this meeting has been to make it possible for greenkeepers, green committee chairmen, and others interested in establishing and maintaining better turf to see first hand the results of these experiments and to discuss their special problems with the staff of the Green Section in the light of these results. This year there were 200 or more in attendance, some coming from points as far distant as Miami and Kansas City.

The visitors were first conducted in a group over the plots on the Turf Garden as well as those which are located in various other sections of the Arlington Farm. The nature and purpose of the experiments were described, and the significance of the results which were apparent at the time were discussed by members of the Green Section staff. The plots were fully labeled so that it was possible for the visitors to go back at their leisure and look over the results of the experiments in which they were particularly interested.

Selected Strains of Grasses in Turf

On the Turf Garden the visitors were shown plots of many selected strains of the various turf grasses growing in turf. Each strain had been developed from a sample of turf selected because, for one reason or another, it had appeared to be particularly desirable. This single plant had been propagated vegetatively in the nursery until sufficient material was available for the vegetative planting of quadruplicate plots on the Turf Garden.

Bent Grasses

The plots of creeping and velvet bents have been maintained under putting green conditions. Two plots of each strain have been treated regularly for disease and two have not been treated in order to determine variations in disease resistance. Washington and Metropolitan strains were used for comparison purposes among the creeping bents and Piper and Kernwood among the velvet bents.

Among the treated plots, the strains of creeping bents showed much less contrast than did those of velvet bents so far as color, density, and texture were concerned. Among creeping bent plots which have not been treated with fungicides since they were planted in 1937, C-1, C-16, C-11, and C-9 showed the most disease resistant turf. C-52 and C-19 were also resistant but to a lower degree. Later in the day when plots of some of these same strains were shown growing in a low pocketed area, it was seen that some of them which produced superior turf on the Turf Garden with its better air circulation did not do so well under such adverse conditions. In this area, the

The Greenkeeping Superintendents reviewing a portion of the series of plots established on the Arlington Turf Garden to test the value of various combinations of fertilizers in the maintenance of bent turf. The plots were marked with cards showing graphically the relative amounts of nitrogen, phosphoric acid, and potash which they had received, as well as with the names of the materials used and the pH of the surface 2 inches of soil at the time of the meeting.

plots of C-1, C-32, and C-27 were in best condition whereas Metropolitan, seaside, and the Colonial bents were particularly severely injured.

Among the velvet bents planted on the Turf Garden in 1937, V-8, V-26, and V-19 appeared to be superior in most respects to Piper and Kernwood, the turf being generally denser and more resistant to disease.

A series of Colonial bent plots which had been planted with seed from various sources was also observed, but except for highland bent, which was lighter and more bluegreen in color, the turf on all of these plots was almost indistinguishable.

Kentucky Bluegrass

Similar plots of Kentucky bluegrass strains were shown. These plots, which had been planted vegetatively, were compared with plots which had been seeded at the same time with good commercial seed and also with plots which had been planted vegetatively with random samples of old established bluegrass. These plots were maintained under lawn conditions and were not watered after the grass had become established. Variations were particularly striking in the 1937 series.

Considerable variation between the various plots was evident. Some strains have produced a turf which is much denser and more resistant to invasion by clover and weeds than is that of commercial bluegrass. Other strains have been decidedly resistant to disease, particularly leafspot, and still others have been particularly tolerant to being cut as low as ½ inch. Also there were striking variations in the color and texture of the grass among the strains growing in turf. Plantings made in 1940 showed that some strains fill in following vegetative planting much more quickly than random samples of bluegrass. In general, the outstanding strains are superior in most of these qualities.

Attention was drawn particularly to a plot of strain B-12, one-half of which has been cut at ½ inch, and the other half at 1¼ inches. Another plot of B-12 which had been grown from selfed and open-pollinated seed was contrasted with a plot seeded with the best available commercial seed. This plot was not unlike plots of the same grass planted vegetatively and was superior in color, density, and texture to the turf resulting from commercial seed. The fact that seed from such strains as B-12 will produce turf which is decidedly better than that produced from commercial seed and not unlike that produced by vegetative planting of the parent plant indicates the possibility of propagating at least some of these superior selections on a large scale by means of seed.

Fescue

Vegetative plantings of numerous selected strains of fescue were also observed growing in plots comparable to the bluegrass plots. Like the latter, the fescue plots were located on an open and exposed area and were not watered after the stand had become established. Plots of Chewings fescue served as the standard of comparison.

The turf on most of the plots showed scars as a result of severe summer injury, but there were decided differences in the various strains, particularly as to ability to resist invasion with clover and weeds, as well as to color and density. The 1937 plot of Q-4 was marked and labeled as an example of a strain which is superior in most respects to Chewings fescue. Among the 1940 plots, the turf on one seeded with seed from Q-2 was much denser and generally superior to a plot seeded at the same time with Chewings fescue.

Other Grasses

Many other grasses were seen growing in turf, some of the most interesting of which were several species of *Zoysia* and various selections of Bermuda grass cut at different heights. The dense, durable turf produced by *Zoysia matrella* cut at ¼ inch, ⅜ inch, and 1½ inches attracted considerable attention. In other areas the visitors were shown plots of turf of Buffalo grass which is used in the West, crested wheatgrass which is used in the dry areas of the Northwest, and St. Augustine grass, centipede grass, the two carpet grasses and others which are used in the South.

Soil Texture Plots

Plots were viewed which had been established 10 years ago, in the soil of which various materials such as manure, cottonseed hulls, buckwheat hulls, and peat moss were used to varying depths to improve the texture of the soil. Since their establishment, the levels of the plots have dropped varying amounts, depending on the material used and the depth to which it was incorporated in the soil. In most of the plots more than half of the original mixture has been lost. Plugs of these soil mixtures made to a depth of 8 inches had been placed on the most interesting plots to show the structure and texture of the soil to that depth.

Experiments With Disease Treatments

During the past season, more than 100 different chemicals have been tested extensively for their usefulness in connection with the control of turf diseases. In response to a recent renewed interest in the possibilities of copper compounds for the control of turf diseases, various copper preparations were again included this year among the materials tested. Large scale tests of all of these compounds have been made on bents growing in sod nurseries on nearby golf courses. The visitors were shown small plots on the Turf Garden which indicated the nature of the large scale tests and some of the results.

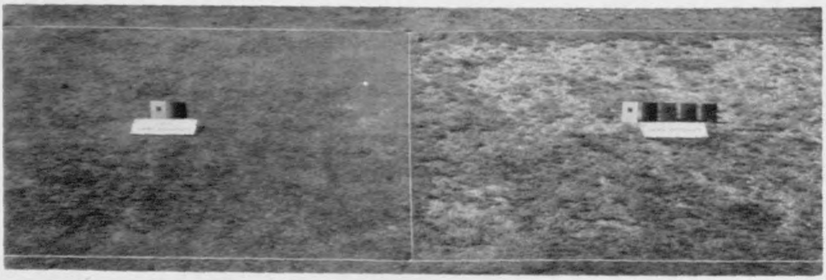
The best control of dollarspot was obtained with mercury fungicides, although one of the newer organic non-mercury compounds showed considerable promise. Lime had no permanent effect. As did the tests many years ago, Bordeaux mixture with the normal amount of lime as well as with twice the normal amount of lime when applied daily gave little control of dollarspot and caused a decided yellowing of the turf. Copper sulfate alone burned the turf.

Turf Fertilizers

On the Turf Garden were seen 64 plots of bent turf to which various fertilizers and mixtures of fertilizers have been applied. These are the plots the results from which were discussed in the article on "Experiments with Fertilizers on Bent Turf" in the December, 1939, issue of Turf Culture. The unfertilized check plots were covered with a weedy, loose, open turf which had a starved appearance. Among the best plots at the time of the meeting were those which had been receiving combinations of ammonium phosphate and urea, and sulfate of ammonia and bonemeal, and the latter combination plus muriate of potash. The cottonseed meal and activated sludge plots were also in excellent condition.

The turf on excessively acid plots (pH 4.5 or less) was thin and had conspicuous large, bare areas, regardless of the type of fertilizer applied. At comparable levels of acidity, the plots which had received equal amounts of nitrogen and phosphoric acid did not show as much turf injury as did the plots which had received four times as much phosphoric acid as nitrogen.

On the farm lawn the visitors saw two series of fertilizer tests, identical except that one had been watered and the other had not. There were no apparent contrasts in the watered series, all of the plots having been about equally overrun with crab-



Differences in the quality of bent turf resulting from the use of different fertilizer combinations for a period of 16 years at the Arlington Turf Garden. The plot on the left has received urea and ammonium phosphate in such a proportion as to supply equal quantities of nitrogen and phosphoric acid. It was one of the best plots in the series at the time of the meeting. The plot on the right has received ammonium phosphate alone at such a rate as to supply the same quantity of nitrogen as that supplied to the left-hand plot. Note the large bare areas and thin turf on the right-hand plot, which was one of the poorest in the entire series at the time of the meeting. This plot has received four times as much phosphoric acid and has developed a greater soil acidity than has the plot on the left, which received urea as well as ammonium phosphate.

grass and clover. The unwatered series presented decided contrasts between the plots which had received different combinations of nitrogen, phosphoric acid, and potash. Aside from the fact that the plots which had recently received their fall applications of inorganic fertilizers showed some burn due to high temperature at the time of application, the turf appeared as described in the results from this series of experiments discussed in the December, 1939, issue of Turf Culture in the article on "Experiments with Fertilizers on Bluegrass Turf."

The visitors were reminded that these contrasting plots had resulted entirely from the different fertilizer programs used. The plots had been started on an old lawn established on acid soil. No seed has ever been sown on the plots since the experiment was begun and no hand-weeding nor chemical control of weeds has been attempted on them. Those plots which had received nitrogen in combination with equal quantities of phosphoric acid showed a decided increase in turf grasses and a decrease in clover and weeds as compared with the unfertilized plots. Plots which had also received potash were not so good as corresponding plots without potash. On plots which had received lime in addition to these fertilizer elements there were still fewer turf weeds, but clover was decidedly encouraged.

Turf Nurseries

The visitors were shown the stock nurseries in which the strains of bents, bluegrasses, fescues, Bermuda and other grasses are propagated vegetatively for subsequent planting purposes. They were also shown the nursery in which the grass breeding program is conducted on bluegrasses and fescues. In this nursery, individual plants of these grasses, each produced from a single seed, are grown in rows for comparison with every fifth plant which is propagated vegetatively from the parent plant. All the plants in any one row originate from the same parent plant.

Attention was drawn particularly to the uniformity evident in both open- and self-pollinated lines among the bluegrasses. This uniformity among the progeny and the resemblance to the parent plant indicate the possibility of reproducing these strains by seed with little effort. Among the fescues, on the other hand, there were decided differences in vigor among the seedlings, particularly in the self-pollinated lines.

Chemical Weed Control

Numerous series of experiments in connection with the chemical control of weeds in Kentucky bluegrass turf were seen on the farm lawn. In one series of plots treated last fall with three or more applications of arsenicals and other herbicides, plantain, chickweed, and in the case of arsenicals clover, had been eliminated and the turf was decidedly superior to that on the untreated plots.

Other plots on which summer treatments had been made were shown to the visitors. Severe injury to the turf grasses had resulted from the use of some of the herbicides, notably the arsenicals, and this was followed by the invasion of crabgrass, so that at the time of the meeting those plots were overrun with the crabgrass. Still other plots were seen which illustrated the burn from recent applications of herbicides; reduction of effectiveness of the herbicides caused by rains immediately following the applications; effect of recent applications on plantains; and results from treatments with arsenicals in which the injury to the turf grasses was reduced by subsequent applications of ferrous sulfate.

Another area was seen in which all of the vegetation and seeds in the top few inches of soil had been killed with tear gas (chloropicrin) and then seeded with Kentucky bluegrass. Two flats were also seen, one of which contained compost which had been treated with chloropicrin and the other untreated compost. Both flats had been maintained under conditions favorable for the germination of seeds. In the untreated compost there was a generous sprinkling of weed seedlings whereas in the treated compost there were none, indicating that the chloropicrin had killed the weed seeds.

Vitamins and Hormones

Several 4- by 8-foot plots of creeping bent were seen which had been watered during the difficult month of August with a solution of vitamin B_1 three times a week. The turf on the plots which had received the same amount of water over the same period of time seemed to be equally as good in every way as that on the treated plots.

The visitors also saw a rather extensive series of plots which had been seeded in August with Kentucky bluegrass seed which had been treated with numerous different growth substances at different rates. As may be seen in the picture on page 112 there was no significant difference evident between the turf from any of the treated seed and that resulting from untreated seed.

Luncheon Program

After the luncheon which was served on the lawn at the Arlington Farm, there were reports from 17 districts on turf conditions in their section of the country. Plans for this part of the program were worked out by Ed Cale, Chairman of the Education Committee of the Greenkeeping Superintendents Association. Large charts had been prepared previously and as the reports were given they were recorded graphically on the charts under the headings of weed infestation, insect injury, and diseases of turf grasses, as well as temperature and rainfall figures as compared with the normal for each district. These charts made it possible at a glance to get a comprehensive idea of turf conditions over those sections of the country represented.

These reports were followed by an interesting talk on the subject of "Forecasting Weather" by Kenneth S. Norquest of the United States Weather Bureau. He explained that the synoptic weather map is the basis of all weather forecasting systems today and then discussed the procedures which are followed in the construction of such maps. Data on present weather conditions are obtained from weather observations made simultaneously at about 750 stations in North America and on ships in the Pacific, Atlantic, Gulf of Mexico, and the Caribbean Sea. These observations which are made every 6 hours describe and measure the meteorological conditions at each place. They are then coded and transmitted to central stations or forecast centers where they are uncoded and the results charted to form an instantaneous picture of the weather over an extensive area of the Northern Hemisphere. Thus, a comprehensive weather map is produced.

However, in order to study and interpret such a surface weather map it is necessary to know conditions in the atmosphere above the earth, say to 50 or 60 thousand feet. For this purpose observations of wind direction and velocity at various levels up to 18,000 feet are now made every 6 hours at about 75 stations in the United States. In addition, observations of temperature and humidity from the surface of the earth to about 70,000 feet are made each day at about 30 stations. By charting and studying all of these observations and by observing and following the changes from day to day on the weather charts, it is possible for the forecaster to predict the weather for a day or two ahead. It is evident, therefore, that in spite of all the improvements in the technique of map analysis and the greater knowledge of the physical processes of the weather, a great deal depends on the ability of the forecaster to properly interpret the facts which are revealed on the weather maps and charts.

Another interesting talk was that on the "Milky Diseases of Japanese Beetle Grubs" given by R. T. White of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. The nature of the disease was described and examples of its natural occurrence discussed. Experiments with the inoculation of the bacteria into soils were described and examples cited of such tests on several golf courses including West Chester Golf Course at West Chester, Pennsylvania; the Maplewood Country Club at Maplewood, New Jersey, and Northampton Country Club at Cape Charles, Virginia.

Such inoculations have usually resulted in satisfactory reductions in numbers of grubs. On the Maplewood course, for instance, the disease germs were introduced into the soil in October, 1938, when the average grub population was 36 to a square foot. The following June the population had been reduced to 13 to a square foot and 53 percent of these 13 were diseased. During the summer the number never exceeded 14 to a square foot and in October there were only 7 to a square foot and 30 percent of these were diseased. In the untreated areas at that time there was an average population of 51 to a square foot. In June, 1940, the treated areas were again examined. At that time four plugs, 1-foot square, were lifted and of these two contained no grubs, one contained one diseased grub and one contained two diseased grubs. Also, 50 percent of the grubs found 75 to 100 feet from the treated area were found to be infected.

A summary of the highlights of this discussion has been prepared by Mr. White and appears on page 84 of this issue. A review of other articles on this same subject will be found on page 121.

Establishment of New Bluegrass Turf

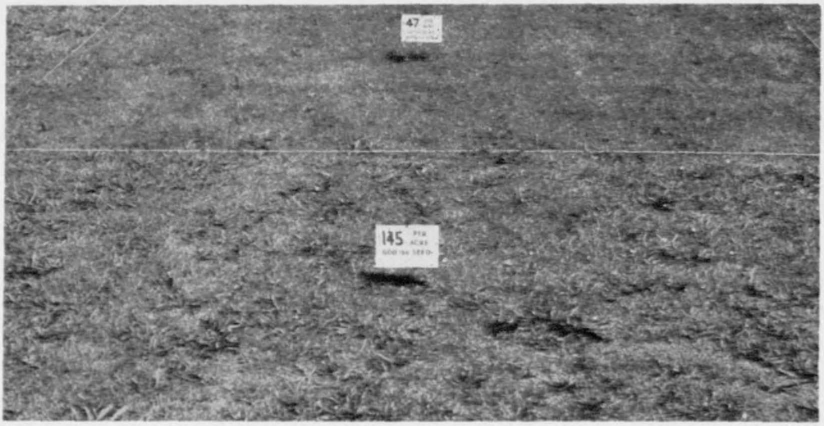
Following the luncheon and the talks, the visitors were conducted to another area where numerous series of demonstration plots have been set up by the National Capital Parks in collaboration with the Green Section. These plots told an interesting story in dollars and cents of the relative importance of seed and fertilizer in the establishment of new turf; illustrated comparative results from fall and spring seeding; and showed 1-year-old turf resulting from the use of various seed mixtures. The soil in the area on which these plots have been established was poor in all essential plant food elements, and was covered with a profusion of weeds which were merely plowed under immediately before seeding. The ground was never fallowed and the plots have not been watered nor weeded.

Relative Importance of Seed and Fertilizer

The fertilizer applied in all of the plots of this series was a 10-6-4 mixture and pure Kentucky bluegrass seed was used. Seed was sown at rates varying from 1 to 15 pounds to 1,000 square feet. The plots were seeded and fertilized in September, 1939. The best plots of the series were the ones which had received seed at the rate of 2 and 3 pounds to 1,000 square feet and fertilizer at the 40-pound rate. The total calculated cost of the fertilizer and seed used was $47 and $57 an acre respectively. Even the plot which had received seed at only the

1-pound rate but fertilizer at 40 pounds to 1,000 square feet showed a good stand of grass, although slightly more weedy than the $47 and $57 plots. This plot represented a cost of only $37 an acre.

Standing out in marked contrast with these plots which were heavily fertilized but seeded at low rates, were plots which



Relative importance of seed and fertilizer in establishing new bluegrass turf on poor soil. The dense, vigorously growing turf on the plot in the background was the result of combining an application of 10-6-4 fertilizer at the rate of 40 pounds to 1,000 square feet with seeding Kentucky bluegrass at the rate of 2 pounds to 1,000 square feet. The estimated cost of materials used in this practice was $47 an acre. Contrasted with this good plot is the thin, weedy turf on the plot in the foreground, which resulted from seeding at the rate of 15 pounds to 1,000 square feet with seed from the same source but not applying any fertilizer. This practice involves a cost of $145.

had been seeded at heavy rates. The plot, for instance, which had been seeded at the 15-pound rate but not fertilized had produced a very thin, weedy turf, although the cost for such a practice was $145 an acre. When this same seeding rate was accompanied by fertilizer at the 40-pound rate, the turf was not so good as it was on plots which had been seeded at the

2- or 3-pound rate. Earlier in the season the turf had looked good but disease had killed out much of the grass, and weeds had come in so that the final result was not so good as the result from seeding at lower rates, although the estimated cost was $173 an acre. Similar results were seen on the plot seeded at the 10-pound rate and heavily fertilized at a total cost of $125 an acre.

Fall and Spring Seedings

The above plots demonstrated the results obtained from seeding and fertilizing programs carried out in September and October. Similar programs were carried out the first of May on a corresponding series of plots. At the time of the meeting all of these latter plots were severely infested with crabgrass. In this series, however, the plots which had received the most fertilizer were covered with 100 percent crabgrass, whereas those which had been fertilized at low rates still had some bluegrass present.

Seed Mixtures

Plots which had been seeded last fall with pure Kentucky bluegrass were compared with plots seeded at the same time with mixtures of Kentucky bluegrass and 10 to 60 percent Italian ryegrass in one series, 5 to 25 percent redtop in another, and 1 to 10 percent of Astoria, highland, and seaside bents in still other series. Some of the best turf was that on plots seeded with Kentucky bluegrass alone or in combination with small amounts of Astoria or highland bents.

The mixture containing 10 percent ryegrass had produced a spotted, shabby turf but the plot did not contain as many weeds as did the plots seeded with higher percentages of ryegrass. As the percentage of ryegrass increased, the amount of weeds on the plots increased and the turf became progressively thinner.

Plots which had been seeded with mixtures in which the proportion of redtop was more than 10 percent had been badly diseased during the summer and weed invasion had followed in

Contrasting turf resulting from the use of two different seed mixtures. The plot on the left was seeded with a mixture of Kentucky bluegrass and ryegrass; the plot on the right, with a mixture of Kentucky bluegrass and highland bent. The picture was taken in September, I year after the plots were established. Note the abundance of weeds in the plot on the left, which was seeded with the ryegrass mixture, as compared with the dense stand of turf grasses and lack of weeds in the plot on the right. The right-hand plot was typical of those seeded with mixtures of Kentucky bluegrass and small amounts of Astoria, seaside, or highland bents.

the path of the disease. At the time of the meeting, therefore, the plots presented a thin weedy turf. The plots which had been seeded with 5 to 10 percent redtop had better turf than any of the other combinations in the redtop series.

Experimental Greens

The following morning the visitors went directly to the Capitol Golf and Country Club where they viewed and rated the experimental greens and were shown the weed-control and fertilizer plots on the tenth and thirteenth fairways respectively.

On the fifteenth green which has been under play for 2 years, C-15 was first choice with C-1 a close second and C-52 and C-17 in third and fourth places respectively. Later in the morning the seventeenth green which had been under play for 3 years was also rated. On it, C-36 which was not planted on the other green was first choice. C-1, C-17, and C-15 took second, third, and fourth places respectively.

Fairway Weed-Control and Fertilizer Tests

Weed-control plots were seen on the tenth fairway. Arsenate of lead had been applied at rates varying from 5 to 40 pounds to 1,000 square feet. Arsenic acid and arsenic trioxide were applied at the same time at rates which would furnish the same amount of arsenic. The crabgrass had been controlled in all of these plots. The arsenate of lead had been injurious to the bluegrass at rates of 10 or more pounds to 1,000 square feet. The other two chemicals had also been injurious when applied at comparably high rates. When superphosphate had been applied at the rate of 2 pounds of P_2O_5 to 1,000 square feet, however, less injury to the bluegrass resulted from the arsenate of lead treatment.

On the thirteenth fairway, numerous series of fertilizer plots were shown the visitors. Only a few of the results which were most interesting to them can be mentioned here. In a recent series of plots which had been fertilized with various combinations of an inorganic fertilizer on the basis of a 9-9-4 mixture, applied at an annual rate of 2½ pounds of nitrogen to 1,000 square feet, it was apparent that crabgrass was more abundant on those plots which had received potash in amounts exceeding that supplied by the unmodified 9-9-4 mixture.

On a 6-year-old series, fall fertilized plots presented better turf than did those fertilized in the spring. There were fewer weeds and less clover on the plots which had received inorganic mixtures than on those to which organic fertilizers had been applied. Clover definitely had been stimulated by a single application of lime over this period of time.

Among other plots which had been planned to illustrate the results obtained on this course by fertilizing with each of the principal elements alone and in various combinations, the greenkeepers' choice was a plot fertilized with nitrogen, phosphoric acid, and potash applied in a 12-6-4 mixture at rates sufficient to give 1 pound of nitrogen each spring and fall, without lime.

Recent plots established in 1938 indicated quicker results from complete mixtures in which the phosphoric acid was supplied in the form of treble superphosphate rather than superphosphate. The explanation offered was that perhaps the treble superphosphate had released the phosphoric acid more quickly than had the superphosphate.

After luncheon which was served in the clubhouse the visitors returned to the Arlington Farm by way of a residential area in which they stopped to see a successful planting of *Zoysia matrella* in turf. Following informal group discussions at the Arlington Turf Garden, the third annual Arlington Turf meeting was adjourned.

If the ground remains soggy for several days in good weather, something is probably wrong with the drainage. Fall is a good time to look into this and perfect the drainage where necessary, thereby avoiding much injury to the grass this next season.

STATUS OF THE MILKY DISEASES OF JAPANESE BEETLE LARVAE

R. T. WHITE*

This article is a summary of a discussion given on September 16, 1940, at Arlington Turf Meeting sponsored by the United States Golf Association Green Section and the Greenkeeping Superintendents Association at the Arlington Experiment Farm, Arlington, Virginia.

Early work at the Moorestown, New Jersey, laboratory indicated that diseases of the Japanese beetle were playing a part in the reduction of this pest. It was not until 1933, however, that the organisms responsible for certain of these diseases were discovered, and not until 1935 was the use of these newly described species of bacteria attempted for control under field conditions.

Diseases of the Japanese beetle can be grouped into four major classes, namely, bacterial, nematode, fungus, and protozoan. The bacterial group may again be divided into the "white group" and the "black group." The white group seems at present to be of most importance, and thus it is with this group that we are primarily interested.

At least two diseases of the white group, known as type A and type B milky diseases, have shown promise for utilization in larval control. Two heretofore undescribed species of spore-forming bacteria, which develop in the blood of living larvae, are responsible for these diseases. The spores of these bacteria are microscopic in size and cause the blood to become turbid and of a milky-white color; hence the name "milky diseases."

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Repeated tests have shown the spores, not only to resist extended periods of drying, but also to be equally resistant to periods of exceedingly wet conditions. The spores have been held in soil with no grubs present for approximately 4 years. This ability of the organism to withstand such adverse conditions of moisture and temperature indicates its usefulness under field conditions.

Experimental field plots were started in 1935 in areas in which preliminary surveys indicated little, if any, disease present. At the present time over 256 experimental field plots have been established under a variety of conditions of dosage, interval of application, temperature, moisture, and soil type. They are located at different points in the states of Virginia, Maryland, Delaware, Pennsylvania, New Jersey, New York, and Connecticut, and in the District of Columbia. In certain of these plots larval reductions of over 90 percent have been obtained within a single season. In the earlier treated plots attempts to reestablish a grub population in the soil have failed owing to the high incidence of the disease organism which has developed; in other words, when the soil once becomes highly infectious it is impossible for larvae to survive therein long enough to mature.

In addition to the research work under way, a program of colonization of the type A disease has been undertaken by the United States Department of Agriculture and several cooperating State agencies. Programs of disease distribution are under way in New Jersey, Maryland, New York, and Connecticut. It is planned to expand the colonization program as rapidly as possible.

Numerous examples of natural occurrence and build-up of the disease have been followed closely, and two such instances may well be mentioned at this time. Early in the fall of 1939 at the Veterans' Administration Hospital and Facility, Perry Point, Md., an average larval population exceeding 38 per square foot was found. Under ordinary circumstances in the absence of milky disease, severe injury to the turf would be expected under these conditions. An examination of the turf

Inoculation of a 1-acre area of turf on the Mall in Washington with the causal organism of the Milky Disease of Japanese beetle larvae. The dust which was being applied here by the spot-colonization method consisted of talc containing a specified quantity of spores of the bacteria which produce the disease. The apparatus released 2 grams of the dust mixture at each spot and the spots in this test were placed every 10 feet. The estimation is that when grubs are present in the soil it will take 1 year for the disease to spread uniformly over the entire treated area from these spots placed at 10-foot intervals.

area showed that approximately 4 percent of all larvae present were infected with milky disease, and that some reduction in the grub population had already been caused by the disease. A survey over the entire area in June, 1940, showed that only six larvae per square foot remained and 67 percent of these were diseased. Thus, a reduction of 94.7 percent in the larval population occurred between September, 1939, and June, 1940, owing to the activity of the milky disease organism.

Surveys conducted at the Battle Hill Golf Course, Springfield, New Jersey, showed conditions paralleling those found at Perry Point, for during the same period a reduction of 94.5 percent was recorded.

The situation in the District of Columbia is interesting and somewhat typical of other areas of comparable infestation. The beetle has been established there for a number of years and the infestation in several sections of Washington is now quite general. There is evidence, however, that the milky disease is also established to a limited extent through natural occurrence. In the spring of 1936, among several larvae collected in the Benning's Road section, one was found to be definitely infected with milky disease. In larval collections made in June, 1940, from several parks in the southeast and southwest portions of the District, larvae infected with type A milky disease were found. Since the disease occurrence appears to be limited and of low degree of incidence, a number of plots have been recently treated in order to hasten the development of disease in Washington and adjacent areas in Virginia.

All but one percent of the world's supply of Jute, the material used in making burlap bags, comes from India. England has, therefore, been able to commandeer the supply for use as sandbags to be used in protecting the structures in London from air raids. With increased difficulty in obtaining burlap bags for fertilizers, cotton and paper bags can be substituted, although they are not as suitable under some conditions as are those made of burlap. It has been suggested that the use of cotton bags would help, in a modest way, to reduce our cotton surplus.

GROWTH SUBSTANCES IN PLANTS

F. F. Davis*

During the past few years a tremendous quantity of publicity has been given to the use of various substances to stimulate growth in plants. Most of the emphasis has been laid on the use of such substances for the rooting of cuttings of woody plants such as Camellia, rhododendrons, holly and others which ordinarily are extremely difficult to root, and for accelerating the rooting of other cuttings which are more easily rooted with the customary propagating practices.

More recently, the effect of these same substances on seed germination has been capitalized upon in the seed trade. As is frequently the case in commercial propaganda, promises are made which far exceed, and in some cases have but little bearing on, the actual facts which have been demonstrated in well-controlled scientific experiments. For this reason, as well as because of the confusion and disagreement which appears to exist among the various investigators themselves, it has seemed wise to make an effort at this time to give our readers some notion of the actual principles involved in the use of growth substances, and of what they can and cannot be expected to accomplish.

Materials having the ability to affect the growth and development of plants when applied in almost infinitesimal amounts are spoken of variously as hormones, phytohormones, auximones, auxones, phytamines, vitamins, growth regulators, growth promoting substances, and simply growth substances. The latter is perhaps the most generally accepted and widely

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used term, largely because it is all-inclusive and yet suggestive of the physiological activity of all of these substances.

Kinds of Growth Substances

The substances which have been found to stimulate growth of plant cells vary widely in characteristics from the gas, carbon monoxide, to the complex organic compounds such as vitamins. Various methods of classifying them have been proposed in the literature but the simplest, for our purposes, is to divide them into two groups.

Hormones

These are substances which are produced by the individual, the development of which they influence. The term was first applied to certain secretions present in man and other animals, and implies that they are "chemical messengers." By definition they are substances which are manufactured in one part of the animal or plant and carried to some other part of the organism where, in extremely minute quantities, they influence such physiological activities of the cells as growth.

To the group of plant hormones belong various organic compounds. The first to be recognized as such are two compounds, auxin a and auxin b, which have been isolated and purified from various plant tissues and from urine. They have not, however, been successfully synthesized in the chemical laboratory. Another compound intimately associated with auxins a and b is heteroauxin which has been shown to be indole-3-acetic acid or beta indole-acetic acid. Since this compound has been synthesized in the laboratory and was understood chemically long before it was recognized as a plant hormone, and since it is an active root-forming substance, it has naturally been among the first of the chemicals to be used extensively in investigations concerning the practical value of plant hormones to the propagator.

The vitamins, of which so much is written in connection with human and animal nutrition, are specific substances which are needed in minute quantities by, but not generally manufactured in, the animal body. They are manufactured by plants, but their function in the physiology of the plant has not been understood until recently. Now, it has been found that several of them, notably vitamin B_1 (known to the chemist as thiamin or aneurin), are growth substances for plants. Therefore, such compounds as thiamin are vitamins for animals and at the same time hormones for plants, because they are produced in one part of the plant and transported to other parts where, in extremely minute quantities, they influence physiological processes such as growth.

Auximones

These are substances which alter the rate, kind, and direction of growth of plants when introduced from without in extremely high dilution. When present in sufficiently small amounts they stimulate the growth of plant cells, but when still less is present the stimulating effect is decreased. Moreover, the stimulation of growth diminishes rapidly with increasing amounts of these compounds until a concentration is reached above which the compounds become increasingly toxic.

To this group of substances which are sometimes collectively termed synthetic hormones, belong compounds with widely diverse physical and chemical properties. Investigators in plant research laboratories around the world have been working with such substances, with the result that scores of different compounds are now recognized as having the ability to influence plant growth. Materials as well known and as varied as the gas, carbon monoxide on the one hand, and the much talked-of drug, sulfanilamide on the other hand, have been shown to belong to this group of compounds.

Kinds of Effects Produced

The general effects on cell growth in plants may be expressed in various ways, such as increase in leaf and shoot development, increase in number or length of roots, and general increase in dry weight of plants produced. As a rule, these substances alter the distribution rather than the total amount of growth, so that when a given substance is applied at a rate to stimulate root-formation it will probably inhibit top-growth, at least temporarily. This is the reason why the term growth regulators or simply growth substances is preferred to growth-promoting substances.

Growth of plants takes place by two distinct processes, cell-enlargement and cell-division. The actual existence of plant hormones was first discovered through their stimulation of localized cell-elongation which resulted in the bending of the stem or other plant part to which the growth substances were applied. It has since been shown that the same substances applied at slightly greater rates or to other plant parts induced growth by the other process, cell-division. Growth by cell-division, for instance, results in the formation of new roots on cuttings of stems and in some cases even on leaves. In still larger quantities, these same substances become growth inhibitors rather than growth stimulants.

It is believed by some that the natural bending of shoots toward the light and away from gravity is due to a localized effect of plant hormones present in those organs. In the first case, the auxins, which are the hormones stimulating cell-elongation, concentrate on the shaded side of the stem or leaf with the result that the shaded side grows faster than the lighted side and the stem or other plant part concerned bends toward the light. In the case of the response to gravity, it has been shown that in horizontally placed stems the auxins accumulate on the lower side causing a localized increase in growth in that region. The result is that the stem curves up or away from gravity.

Various more or less localized effects can be induced in plants by the external application of these growth substances. When leafy shoots are exposed to dilute vapors of these compounds or when the same compounds are applied to limited areas of plant organs in lanolin paste, in solution, or in talc, the leaves may grow down, stem tips may become enlarged, root formation may be induced, or stems may be caused to grow in the direction of gravitational pull rather than away from it. There is some evidence that seed germination can be accelerated. In one laboratory it has been shown that the damage caused by disinfecting seed with formaldehyde, copper sulfate, and mercuric chloride is reduced by the addition of small amounts of some of the synthetic hormones.

Certain compounds when applied to the pistil of some flowers have the power to stimulate cell growth in the ovary so that sterile fruits are produced. By such means, seedless fruits of such plants as watermelon, crooked neck squash, pepper, holly, and others have been produced experimentally. However, because of the difficulty of preventing on a large scale the occurrence of natural pollination, this method has not yet come into commercial use.

The inhibiting effect of hormones not only occurs when the synthetic compounds are applied externally at excessive rates but also occurs commonly in nature. For instance, the well-known fact that many plants are pinched back to encourage the development of lateral shoots may now be explained by the fact that the auxins which are produced in the terminal bud stimulate the growth of the shoot but inhibit the development of the lateral buds. When the source of these growth substances is removed by taking off the terminal bud, the lateral buds are no longer inhibited. As they begin to develop, they in turn become sources of auxins for subsequent shoot growth.

Effects of Concentration

It appears that the concentration of growth substances used plays an important role in determining the effect which that substance will have on a given plant. Generally speaking, roots seem to be more sensitive than shoots to the synthetic hormones. A concentration which will stimulate root-elongation may not be sufficient to have any effect on shoot growth. When the same substance, however, is applied at a sufficiently high rate to stimulate shoot growth it may inhibit the elongation of roots. When applied at a still higher rate, the same substance may cause the development of new roots at the points where it is applied and at the same time inhibit shoot growth. Moreover, it may also inhibit the subsequent growth of the roots which it has initiated.

This effect of concentration is far-reaching in its applications. Natural growth hormones are present in varying amounts in most plant tissues. The quantity present varies with the species of the plant, the organ of the plant, the stage of growth, the environmental conditions under which the plant has been growing, etc. If all other factors necessary for growth are uniform, the plant which has the largest quantity of growth hormones in its tissues may be expected to give the least response to added growth substances.

When one considers that the concentrations with which the experimenter is dealing are rarely over 1 part in 1,000 and in many instances may be less than 1 part per million (p. p. m.), it becomes evident how careful the practical man must be in making up the solution or dust in which he intends to apply the growth substance.

Chemicals May Affect Specific Organs

The kind of response which may result from the application of growth substances to plants depends not only on the species of plant, its stage of development, and the rate at which the substance is applied, but also on the part of the plant to which it is applied and the kind of growth substance used. Certain compounds are decidedly specific in the effects they produce and the plant parts which they influence.

Vitamin B_1, for instance, has been shown to be indispensable for the elongation of roots but it does not actually initiate the development of new roots. So far, no direct effect on the growth of stems, the time of flowering, or the number and size of flowers and fruits, has been satisfactorily demonstrated. The increase in vegetative vigor of some plants in response to treatment with vitamin B_1 is believed by authorities to be caused by the increased vigor of the roots. Other vitamins such as B_2 and B_6, nicotinic acid, and thiourea have been shown to be necessary for root growth in some species but vitamin B_1 appears to be necessary universally.

On the other hand, the synthetic hormones such as beta indole-acetic, beta indole-butyric, and alpha naphthalene-acetic acids appear to be less specific in their effects, the exact nature of the effects being determined by the rate of application and the organ treated. When applied at the right concentration to cuttings they have the ability to induce the formation of roots at the site of application but may inhibit their subsequent growth. A combination of one or more of the synthetic hormones to initiate new roots with vitamin B_1 to stimulate their growth may, therefore, be expected to give the best results so far as rooting of cuttings is concerned.

In the following table the various kinds of effects are listed together with some of the compounds which have been shown to produce these effects, at least with certain species. This list is by no means complete and includes chiefly those compounds which are referred to most commonly in the literature on growth substances. A few compounds are included because they are well known for their physiological activity but are not generally recognized as having any influence on the growth of higher plants. The latter are included only to indicate the diversity of the compounds which produce these effects.

A few generalizations have been ventured by certain authorities concerning the use of some of the more commonly employed synthetic compounds. For instance, according to some investigators, indole-acetic acid and the naphthalene compounds tend to spread throughout the plant and produce general or systemic effects, whereas indole-butyric acid tends to induce a more localized response. According to some, there appears to be less danger of shock to the cuttings when the naturally occurring hormone, indole-acetic acid, is used to induce root-formation, although in many cases superior rooting results from the use of indole-butyric acid, alpha naphthalene-acetic acid and other synthetic compounds.

Generally speaking, the naphthalene-acetic acid is more potent than the indole compounds and should be used at lower

PLANT ORGANS AND COMPOUNDS AFFECTING THEIR GROWTH AND DEVELOPMENT

Roots:	
FORMATION OF NEW ROOTS	ELONGATION (NOT FORMATION OF NEW ROOTS)
Auxins a and b	Vitamin B_1 (thiamin or aneurin)
Beta indole-acetic acid (hetero-auxin)	Vitamin B_2 (riboflavin)
Potassium indole-acetate	Vitamin B_6
Beta indole-butyric acid	Nicotinic acid
Beta indole-propionic acid	Thiourea
Alpha naphthalene-acetic acid	
Phenyl-acetic acid	
Coumarin	
Vanillic acid	
Sulfanilamide	
Methylene blue	
Shoots:	
GENERAL TOP GROWTH	LEAF GROWTH
Auxins a and b	Adenine
Biotin	Alanine
Vitamin B_2 (riboflavin)	Arginine
Vitamin C (ascorbic acid)	Uric acid
Thiourea	Other amino acids and purines
Beta indole-acetic acid	
Beta indole-butyric acid	
Beta indole-propionic acid	
Alpha naphthalene-acetic acid	
Naphthalene-acetamid	
Indole-acetamid	

Ovaries:	
STERILE FRUIT PRODUCTION	
Beta indole-acetic acid Beta indole-butyric acid Beta indole-propionic acid Alpha naphthalene-acetic acid Ethyl alpha naphthalene-acetate Methyl alpha naphthalene-acetate	
Seeds:	
INCREASE OR ACCELERATION IN GERMINATION	EFFECT ON SUBSEQUENT SEEDLING GROWTH
Auxins a and b Beta indole-acetic acid Beta indole-butyric acid Alpha naphthalene-acetic acid Phenyl-acetic acid	Beta indole-acetic acid Beta indole-butyric acid Alpha naphthalene-acetic acid Vitamin C (ascorbic acid)

rates. Phenyl-acetic acid, on the other hand, is only about one-tenth as active as indole-acetic acid and must be applied at heavier rates. The metallic or ammonium salts of the acids are apparently less toxic to the plant and more effective in inducing formative effects than are the acids themselves. The same is true for the methyl and ethyl esters.

Also, there is apparently a difference in the quality of the roots formed as a result of treatment of cuttings with the various synthetic compounds. Those resulting from a treatment with indole-butyric acid are more nearly normal than those which develop after the use of alpha naphthalene-acetic acid.

NATURAL OCCURRENCE

The discussion thus far has been concerned with the response of plant organs to applications of various growth substances.

It should be remembered, however, that auxins and vitamins are manufactured almost universally by green plants for their own use and are, therefore, hormones in the true sense of the word. The actual amount of these compounds which may be synthesized by any particular plant depends on the species of plant and the conditions under which it is grown.

Auxins, for instance, are present throughout all parts of higher plants, but tend to be most abundant near the regions where they are manufactured or stored. They are synthesized in the tips of actively growing organs and are transported down toward the base of the plant. Long before the existence of auxins as such was understood, the fact was recognized that cuttings without leaves rooted better when at least one bud was present. It is interesting to note that as early as 1880 this fact was explained by the assumption that a specific substance was formed in the shoot and was normally transported toward the base. In cuttings, this substance was believed to accumulate at the base because it could go no farther, and there to result in the formation of roots. In recent years it has been shown that this assumption was correct and that the specific substance was an auxin which was synthesized in the growing bud.

Vitamins, on the other hand, are believed to be manufactured in the leaves of green plants, the slow-growing plants such as *Camellia*, *Rhododendron*, and *Azalea* producing materially less than the rapidly growing annuals. From the leaves, the vitamins are translocated to all parts of the plant, the seed frequently containing the highest percentage of them.

Moreover, it has been shown that manure, compost, plant debris, soil microflora, seed meal products, and other organic materials used to enrich soil contain appreciable amounts of vitamin B_1. Therefore, plants growing in soil which contains generous quantities of organic matter have an abundant supply of Vitamin B_1 even if they do not make it in sufficient quantity for themselves. In fact, the addition of Vitamin B_1 to plants growing in such soils may result in a reduced growth due to the toxic effect of an over-abundance of growth substance. It has been suggested that "sickness" of highly manured greenhouse soils which is sometimes described may be simply a matter of toxic concentrations of growth substances.

In view of this universal distribution of growth substances it is not reasonable to expect phenomenal results from their addition to plants growing under normally good cultural conditions. When normal conditions are disturbed, such as occurs when cuttings are made, when well-established plants must be transplanted, or when an attempt is being made to germinate old or poor seed, there is a good possibility that some of the growth substances may become limiting factors in the growth of the plants concerned and that a favorable response might be expected if the right growth substance were added in the right concentration. When plants are grown in water or sand culture, or in poor soil lacking in organic matter, it may be that they do not have available a sufficient supply of hormones for best growth and will therefore respond to their addition from without.

Factors Complicating Results with Growth Substances

It should be remembered that growth substances represent only one group of factors necessary for plant growth. Among other factors involved, are the external ones such as light, temperature, soil moisture, and nutrients; and the internal ones such as proper activity of the various enzymes, normal synthesis of carbohydrates, and the stage of development of the plant or part of the plant concerned. For optimum growth, the status of all of these factors should be favorable. Moreover, increasing any one of these factors will not result in increased growth unless all of the other factors are already present in quantities sufficient to support such increased growth. Therefore, it is only when the growth substances are the factors limiting growth that their addition may be expected to stimulate growth. Even then, the proper compounds must be added at the right concentrations if growth is to be stimulated in any desired direction.

There is some evidence that these compounds give better results in acid than in neutral or alkaline media. Vitamin B_1, for instance, has been shown to decompose when in contact with alkaline materials and therefore may not be expected to give satisfactory results in alkaline or "sweet" soils or where lime-impregnated water is used. Some investigators also have found that beta indole-acetic acid and other synthetic compounds are more effective when applied in solutions with an acidity between pH 4 and 6 than in neutral or alkaline solutions. It would seem wise, therefore, in making up the final dilute solution to use water which had been acidified with a weak acid such as acetic acid. Vinegar is a readily available source of acid for this purpose. In field work, it would seem that better results might be expected generally on acid than on alkaline soils.

Frequently, the addition of two or more different growth substances may give better results than is obtained by the addition of either alone. For instance, Vitamin B_1, yeast extract, biotin (a component of the vitamin complex in yeast extract), and theelin (one of the female sex hormones in animals) have all been found on occasions to increase the results obtained with the synthetic hormones such as beta indole-acetic and beta indole-butyric acids. Also, a mixture of the synthetic hormones is sometimes better than any one of them alone. Such results are to be expected since it is entirely reasonable that more than one factor may be limiting the type of growth desired. Sometimes, also, the carbohydrate supply in the twig to be rooted is insufficient to support the growth of roots initiated by the hormones. If such is the case, merely supplementing the hormone treatment with honey or sugar solution will increase the results so far as rooting is concerned.

Recognizing the importance of the many interacting factors which influence the growth of plants, it is not surprising to find the literature filled with conflicting results following treatment of various plant organs with growth substances. Moreover, there are probably other internal and soil factors the importance of which is not recognized today. Particularly with plants grown under field conditions, it is difficult, if not impossible, to evaluate all of the factors influencing their growth and to determine which are limiting ones. Locally planned and executed field tests on a small scale may frequently indicate, however, whether or not favorable results can be expected from a given type of treatment.

Methods of Application

Growth substances have been applied to plants in various ways, the method depending on the compound used, the plant parts to be treated, and the kind of results desired. The most common method used practically is to immerse the bases of cuttings in dilute solutions for 12 to 48 hours, depending on the concentration of the solution and the kind of cutting. Immersion in talc mixtures of the same compounds just before planting the cuttings has also proved effective in many cases.

When decidedly localized areas are to be treated such as is necessary for the production of sterile fruit, the compounds are applied in a paste of lanolin or sheep's wool fat. On the other extreme, whole plants or parts of plants have been exposed to vapors such as carbon monoxide, ethylene and others.

The effect on germination of seed and on subsequent growth of seedlings has been investigated by soaking seed in solutions of these compounds or by dusting them with the talc mixtures and then following the rate and final percentage of germination as well as the vigor of resulting seedlings and mature plants.

Also, there are some experiments described in which solutions of these compounds have been sprayed on foliage of growing plants or applied to the soil in which they are growing.

As is to be expected from the foregoing discussion, the rates recommended in many cases vary over a wide range for the same compound. With vitamin B_1, however, investigators are comparatively well agreed that in solution a concentration of 0.01 to 0.1 p.p.m. is a safe starting point. The rates at which the synthetic hormones have given favorable results have varied from 0.01 to 1,000 p.p.m.

Practical Results with Growth Substances

Unquestionably the hormones play fundamental roles in the physiology of plant growth, some of which are now recognized and understood at least in part. However, because of the almost universal distribution of hormones throughout plant tissues and in fertile soils, and because of the minute concentrations required, beyond which the compounds become toxic, the problem of using them practically to stimulate various types of growth of plants or plant organs is not a simple one to solve. The results which have been published to date vary over a wide range from actual inhibition of growth, through failure to get either stimulating or inhibiting results to outstandingly successful stimulation. Therefore, it is impossible in the limited space of a few pages to summarize the results which appear in the literature. An attempt has been made in that direction, however, to give the reader an idea of where to start if he is anxious to try some of these materials on his plants.

Results with Cuttings

The immersion of the bases of cuttings in dilute solutions or dust mixtures of synthetic hormones has in many cases stimulated the formation of roots. The successful rates used have varied over a wide range from 0.01 p.p.m. to 1,000 p.p.m. Generally speaking, dust treatments can be made at the higher rates with less danger of injury. Also, the dust treatment is perhaps simpler because the base of the cutting can be immersed in it and planted immediately, whereas when solutions are used the cuttings must remain in them for 12 to 48 hours, the length of time depending on the concentration of the solution and the species of plant.

With solutions of indole-acetic and indole-butyric acids, rates as low as 0.1 p.p.m. have been effective in some instances but 5 to 20 p.p.m. may be considered a safe starting point. Less alpha naphthalene-acetic acid is required, effective stimulation having been achieved at rates as low as 0.01 p.p.m. In general, when applied at the base of cuttings, the highest non-toxic concentration of these synthetic compounds will give the best results. This concentration varies with the species of plant used, but generally is less for green cuttings than for dormant ones. With mixtures in talc, effective stimulation has resulted from use of mixtures varying in concentration from 50 p.p.m. to 1,000 p.p.m.

Subsequent treatment with vitamin B_1, biotin, or yeast extract has in many cases resulted in much improved final results, probably because of their stimulating effect on root elongation. Biotin has also stimulated shoot growth.

Hormone treatment, however, is not the "shot-gun prescription" which will solve all of the problems of the propagator. It should be regarded merely as an additional tool to be used in conjunction with the most careful practices which the propagator has at his disposal. Their use neither guarantees successful rooting of cuttings which are otherwise difficult to root nor the acceleration of rooting of cuttings which are normally easily rooted. In fact, numerous individuals have published the results of experiments in which they have been partially or entirely unsuccessful in stimulating root production in cuttings with growth substances.

Results with Entire Plant

Experiments have been performed in which whole plants grown in water or sand culture have responded favorably to hormone treatment. It should be remembered that plants grown under these conditions do not have access to the organic matter and microflora present in fertile soils which are natural sources of abundant supplies of growth substances. Stimulating effects might be expected, therefore, under these conditions which would not appear if the same plants were grown in good fertile soil.

Vitamin B_1, in extremely low concentrations, has stimulated root growth of seedlings which in turn has resulted in generally increased vegetative vigor of the entire plant. When various species were grown in sand, watered with nutrient solutions and treated with vitamin B_1 it was found that common crop plants such as tomato, peas, and corn, which contain relatively large quantities of vitamin B_1 in their leaves, showed no response. On the other hand, plants like *Camellia* which contain no detectable vitamin B_1 in the leaves, and other species which contain less than 10 milligrams to 1 kilogram (2.2 pounds) of dried leaf tissue, showed increased growth as a result of the addition of 0.01 p.p.m. of vitamin B_1. Moreover, the less vitamin B_1 there was present in the leaves, the greater was the increase in weight. For instance, trivialis bluegrass (*Poa trivialis*) which had a vitamin B_1 content of 4.2 milligrams gave more response than did Colonial bent (*Agrostis tenuis*) which contained 6.0 milligrams. It should be remembered that these experiments were performed on plants growing in sand rather than soil.

In other experiments, adenine, uric acid, riboflavin (vitamin B_2), and ascorbic acid (vitamin C) have been shown definitely to influence top growth under some conditions. The first two, used at the rate of 0.01 p.p.m. have also been shown to stimulate the plant to synthesize vitamin B_1. Solutions containing 2.5 p.p.m. of riboflavin or 10 p.p.m. of ascorbic acid when added to plants growing in sand have decidedly stimulated leaf growth, the leaves of the treated plants being consistently coarser in texture, thicker, and darker in color than those of the untreated plants. This increased growth was associated with a general increase in vigor of both top and root growth.

In field grown plants, root growth and resultant vegetative vigor has been increased by dipping the roots of the plants into solutions containing 1 or 10 p.pm. of vitamin B_1 at the time of transplanting. The transplants were dipped into the solutions momentarily and immediately reset into the soil. Such treatment not only resulted in helping the plants to become reestablished more quickly but also in increasing the ultimate size and vigor of the plants. In some cases, time of flowering came earlier and size of fruit was increased. In other experiments, stimulation of growth has resulted from watering the soil in which plants were growing with a solution containing 0.1 p.p.m. of vitamin B_1, and in a few cases stimulation has resulted from actually spraying the foliage of field grown plants with such a solution.

Field grown plants have also been stimulated to increased growth by some of the synthetic hormones. Plants growing in rich soil did not show as much response as those growing in poor soil or sand which was watered with nutrient solutions. Some plants have been stimulated when watered with solutions of the synthetic compounds at concentrations as low as 0.01 to 0.05 p.p.m. whereas others showed no effect at these concentrations and definite repression of growth with a concentration of 1.0 p.p.m. Another investigator reports that spraying seedlings with a solution of 1,800 p.p.m. of indole-acetic acid accelerated both vegetative growth and flowering.

When it comes to stimulating the growth of plants by incorporating the synthetic hormones in the soil, the optimum dosage apparently varies with the substance used, the method of application, the composition of the soil, the climatic conditions and the age and kind of plant. More field work is necessary before any conclusions can be drawn or recommendations made concerning the practical use of growth substances on plants growing in soil.

Results with Seeds

The results from seed treatment are as contradictory as are those from the treatments already described. Of 22 articles written in half a dozen countries, 12 give evidence showing either increase in or acceleration of germination, increase in vegetative vigor, shortening of time required to come into flower, or increase in size and number of fruits produced. On the other hand, the remaining 10 articles give equally as convincing evidence that germination and subsequent growth of seedlings were either not affected or were inhibited by similar seed treatments.

One laboratory in this country claims as a result of extensive work with oats, tomato, and wheat, that soaking seed in solutions containing beta indole-acetic acid at concentrations not exceeding 10 p.p.m. increased the percentage of germination, whereas treatments of seeds with solutions containing 100 to 200 p.p.m. of the same compound, retarded germination but eventually resulted in improving the seedling root system, hastening shoot growth, and possibly increasing the size of fruit.

As opposed to this, there are the results from another laboratory in which seeds of 29 species including Kentucky bluegrass and perennial ryegrass were used. The seeds were soaked for 24 hours in solutions of beta indole-acetic, beta indole-butyric, and alpha naphthalene-acetic acids at concentrations varying from 0.316 to 316 p.p.m. Seeds were germinated in the laboratory, in sand, and in the field, and the general conclusion had to be drawn that there was no effect on germination, vegetative growth of the seedlings, nor on time of maturity and flowering.

Others claim that dust treatment is more effective, safer, and easier to apply than solutions. In one series of investigations, the injury resulting to crop seeds from treatment with formaldehyde, copper sulfate, or hot water to kill fungus infections, was materially reduced by the addition of beta indole-acetic, alpha naphthalene-acetic, or phenyl-acetic acids in concentrations varying from 0.01 to 5.0 p.p.m. Such treatments did not accelerate the time of germination, although applications of the indole-acetic acid in dust to cereal seed at the rate of 2 p.p.m. did result in increased yield of roots and tops.

In another laboratory the application of this dust containing 1,000 p.p.m. of alpha naphthalene-acetic acid stimulated germination of tomato seeds, when applied at the rate of 1 ounce of dust to 9 or 10 pounds of seed. When combined with an immerson of the roots of the seedlings for 2 minutes in solutions containing 10 p.p.m. of beta indole-butyric acid at the time of transplanting, the treatments resulted in hastening the time of flowering and increasing the yield of fruit. Similar but preliminary treatments of Kentucky bluegrass and Chewing's fescue seed gave indications of an acceleration of germination, increase in root growth, and greater drought resistance of the turf the following summer, but these results have not been confirmed.

So far, as stated in the article on page 110 of this issue, preliminary tests which have been made by members of the Green Section staff on Kentucky bluegrass and perennial ryegrass seed, although made at the same rate and following the same method, have shown no such effects.

Absence of beneficial effect either on germination or subsequent growth and development of the seedlings has also been reported recently from an extensive series of dust treatments in which beta indole-acetic, beta indole-butyric and alpha naphthalene-acetic acids and a commercial preparation were applied to wheat and soybeans, although the plants were followed until maturity. In fact, the final results indicated slightly lower values for the treated lots of seed. This the investigator feels may have been due to the talc, since talc alone produced corresponding results. He applied the dusts, which contained the growth substances in concentrations ranging from 250 to 32,000 p.p.m., at rates varying from 1 ounce for 3 pounds to 1 ounce for 30 pounds of seed.

Other workers, applying vitamin B_1 and synthetic compounds to agricultural seed actually obtained inhibition and in addition found double the number of mold- and bacteria-infected seedlings. Since many fungi and bacteria do not manufacture their own growth substances and must therefore obtain them from the medium on which they grow, it is not surprising that, if present at all, they would be most abundant on the seeds coated with growth substances.

According to an article in *Science,* the vitamin content of grass leaves is much greater than that of any of the four standard classes into which all fruits and vegetables are divided. On an equal weight basis, grass leaves in general contain 10 times as much vitamin B_1 and 25 to 250 times as much vitamin A as can be obtained from any of the vegetables or fruits.

GROWTH SUBSTANCES ON TURF GRASSES

JOHN F. CORNMAN and JOHN W. BENGTSON*

In the preceding article the fact has been emphasized that, although growth substances are unquestionably significant in the life of plants, they are almost universally distributed in plants and in organic matter in the soil and are therefore normally accessible to plants growing under favorable conditions. It is, therefore, only in cases where they are the factors which limit growth that stimulation can be expected from their application. Even then, the right substance must be applied at the proper concentration if germination or growth is to be stimulated.

In spite of these well recognized facts, however, voluminous publicity has been given to the claims of commercial firms as well as of enthusiastic investigators concerning the amazing results achieved by their application. Little cans or bottles of these amazing chemicals to be used as dust or in solution, and even seed which has previously been dusted with one hormone or another, are now available on the market under various trade names, and results little short of miraculous are promised to those who use them.

Exploratory investigations have been necessary to determine whether or not hormones are as effective on turf grasses as scientists have found them to be on some other plants, or even a fraction as beneficial as some enthusiasts claim they are. So far, the most uniform and best results appear to have been obtained with cuttings. It was only logical to suppose, there-

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fore, that hormones might have some effect in accelerating the rooting of grass stolons, particularly those of the slow growing species such as Zoysia and velvet bent.

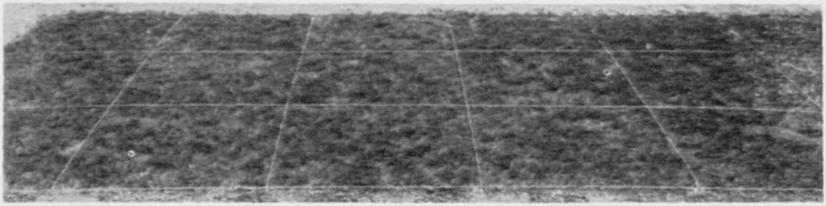
In addition, it appeared that some of these growth substances might prove to be valuable in midsummer when the failure of roots in turf is most pronounced. If, by adding them to turf at this time, root growth could be stimulated, injury from drought and other causes might be avoided. Also, it appeared that some of them might be useful in speeding up the germination of the seed of such slowly germinating grasses as Kentucky bluegrass when a quick establishment of turf is desired.

Therefore, during the past 2 years, the Green Section has been testing in a preliminary way the effects of a few of the growth substances on the rooting of stolons, root development of grass in turf, and the germination of grass seed. So far, no encouraging results have been obtained. The results have either been entirely negative or so inconsistent that no conclusions could be justified either in favor of or opposed to their use in the establishment or maintenance of turf.

Hormones on Stolons

In three series of greenhouse experiments in the fall of 1938 and the spring of 1939, stolons of *Zoysia matrella,* velvet bent, and the Washington and Metropolitan strains of creeping bent were used. The bent grass stolons, about 2 inches long, were taken from mature growth in the center of nursery rows and the Zoysia stolons from the old growth of plants growing in a warm greenhouse. Although an attempt was made to select uniform stolons, there was some difference in the number of nodes per stolon planted. The nodes on the Washington stolons were much closer together than were those on the other stolons.

Solutions of the commercial product, Auxilin (a beta indole-butyric acid preparation) as well as of beta indole-acetic, alpha naphthalene-acetic and ascorbic acids were used. In the first two series the stolons were immersed in the solutions to a depth of ¾ to 1½ inches and in the third they were completely immersed. Treatments were made at greenhouse temperatures



Turf resulting from the use of Kentucky bluegrass seed which had been treated with various synthetic hormones, compared with that produced by untreated seed. Front row, left to right—talc dust containing 1,000 p.p.m. of indole-butyric acid, the same at 100 p.p.m., Rootone, Hormone powder, Auxan; center row—untreated seed, Transplantone, Hormodin, untreated seed, Hormonized dust; back row—talc dust containing 1,000 p.p.m. of naphthalene-acetic acid, the same at 100 p.p.m., thiourea, talc and untreated seed. The seeds were dusted thoroughly with the chemicals at the rate of 1 ounce of dust to 10 pounds of seed and were immediately planted in 4 by 4-foot plots on August 10, 1940. This picture, taken on September 3, shows no significant difference between the turf resulting from the planting of untreated seed and that resulting from the use of seed given any of these various treatments.

of 80° to 85° F. The time of treatment varied from 24 to 96 hours in the first experiment, 12 to 48 hours in the second and 4 to 24 hours in the third. For comparison purposes, similar stolons were soaked for equal lengths of time in tap water. Immediately following treatment, the stolons were planted in flats of sand. The bent stolons were kept in a relatively cool house and the Zoysia in a warm greenhouse at 80° to 85° F.

In the first two series of experiments the Auxilin was used according to directions at the rate of one-half measure to a pint of water and the other substances at the rate of 10 parts per million (p.p.m.) of water. In the final series the rates were doubled.

In the first experiment, 3 days after the last of the stolons were planted, counts were made of the number of nodes which had no roots and the average number of roots to a node. On the Washington bent, roots were found on three to five of the nodes of each stolon, Metropolitan bent developed roots on one to two of the nodes of each stolon and velvet bent usually formed roots at only one node on each stolon. In the second and third experiments, only velvet bent and Zoysia stolons were used and counts were made 12 and 4 days respectively after the last stolons were planted.

Stolons of Washington and Metropolitan creeping bent, velvet bent, and *Zoysia matrella* were used in the first experiment. Those stolons which were planted with no treatment produced fewer roots per node and had a greater percentage of nodes with no roots than either the stolons which were soaked in water or in Auxilin solution, except in a few cases where the stolons had been soaked in the Auxilin for 96 hours. In general the stolons treated with Auxilin solution gave results similar to those soaked in water, but in some cases the number of roots per node was greater and the percentage of nodes with no roots was smaller than in the water-treated stolons. However, in an equal number of cases, the reverse of this was true, particularly following the Auxilin treatments for the longer periods of time.

After the results of the first series had been obtained, the creeping bent stolons were dropped from all subsequent series of experiments, since such stolons normally start growth rapidly within a few days after planting. The Zoysia and velvet bent stolons are much slower to establish themselves under field conditions and therefore they alone were used in the second and third series of experiments. In these experiments beta indolebutyric, alpha naphthalene-acetic and ascorbic acids were used in addition to the Auxilin and water treatments of the first experiment. Much the same results were secured in the second series as in the first except that the stolons planted without treatment produced a lower percentage of nodes without roots. In fact in this series the untreated stolons were as good in this respect as were the treated ones. Also, the untreated stolons produced as many roots per node as the treated ones, and in some cases more. As in the first series, there was a great deal of variation in the number of roots per node, so that the differences in average numbers could not be considered significant.

In the third series of experiments, however, all of the treated Zoysia and velvet bent stolons gave results far superior to those with untreated stolons in that they had many more nodes producing roots. All the treatments, including the water, doubled the number of roots per node in the Zoysia stolons. Most of the hormone-treated stolons of Zoysia produced more roots per node than did the water-treated stolons, but the number per node in all cases was so variable that differences in averages could not be considered significant. All of the velvet bent stolons which were treated in this series produced an equal or greater number of roots per node than did the freshly planted stolons. In most cases the chemical treatments produced a slight increase in the average number of roots per node, over water-soaked stolons, but again the individual numbers were so variable that this increase was not considered significant.

In May, 1938, stolons of *Zoysia matrella* and *Zoysia japonica* and the roots of three selected strains of Kentucky bluegrass were soaked in Auxilin solution for a 24-hour period before planting in field plots. The solution used contained beta indolebutyric acid at the rate of 10 p.p.m. Comparable lots of stolons and roots were soaked in water for the same period of time. As a check against these soaking treatments fresh stolons of Zoysia and fresh bluegrass roots were planted at the same time.

Before being soaked, the *Zoysia matrella* and *Zoysia japonica* stolons were stopped to two degrees of fineness, some being coarsely chopped and others merely shredded. In addition, some of the *Zoysia japonica* stolons were also finely chopped. Fresh stolons were chopped in the same way and planted without soaking.

The stolons and roots were then planted in soil which was low in fertility and contained but little organic matter, and all plots received the same treatment following planting. The following fall estimates were made of the percentage of cover on each of the plots. The stolons which had been soaked in water had produced the densest turf in all plots except those planted with coarsely chopped *Zoysia matrella* stolons. In no case did the Auxilin-treated stolons or roots produce a denser turf than did corresponding material soaked in water, although in most cases the turf was denser than on those plots planted with fresh stolons. In some cases, however, the turf produced by fresh stolons was significantly superior to that produced by Auxilin-treated stolons or roots. In these cases the Auxilin apparently inhibited the growth of the grasses.

There were no significant changes in the density of the turf on any of the plots the following spring. During the summer there was no significant difference in vigor or drought resistance on any of the plots.

Hormone-Treated Seed

In several series of experiments, Italian ryegrass seed and Kentucky bluegrass seed from two different sources were treated with talc dust containing various concentrations of several different hormones as given in the table on this page. The seeds were treated with the dust at the rate of 1 ounce of dust to 10 pounds of seed. Treatment simply consisted of coating the seeds with the dust by shaking them in a jar with the calculated amount of dust.

Table of Treatments Used on Seed of Italian Ryegrass and Kentucky Bluegrass

Key letter of treatment	Compound used	Proportions in talc	Parts per million (p.p.m.)
A	None		
B	Talc alone	Pure talc	
C	Alpha naphthalene-acetic acid	1:2,000	500 p.p.m.
D	Ditto	1:1,000	1,000 p.p.m.
E	Ditto	1:250	4,000 p.p.m.
F	Beta indole-butyric acid	1:2,000	500 p.p.m.
G	Ditto	1:1,000	1,000 p.p.m.
H	Ditto	1:250	500 p.p.m.
I	Rootone	As directed	
M	Thiourea	1:1,000	1,000 p.p.m.
N	Vitamin B_1 (thiamin)	1:1,000	1,000 p.p.m.
O	Thiourea, 1 part; Napthalene-acetic acid, 3 parts	1:1,000	1,000 p.p.m.
T	Hormodin A	As directed	

The seeds were then placed in sand, in flats or in petri dishes on filter paper for germination. In most of the experiments the petri dishes were kept in the dark in the laboratory, whereas in some of the Kentucky bluegrass experiments they were placed in thermostatically controlled germinators and subjected to the optimum conditions of alternation of temperature and light. In still other experiments, Kentucky bluegrass seed was treated with hormones and sown in well-prepared seed beds in order to follow the effects of the hormones on the establishment of turf.

Italian Ryegrass Seed

Duplicate lots of 50 Italian ryegrass seeds were dusted with hormone treatments A to O, inclusive, and the seed germinated in petri dishes in the dark in the laboratory. Germination counts were made after 48, 66, 72, and 96 hours. After 96 hours, the length of tops and roots of the best 25 seedlings in each lot were recorded and the average compared with that for the best 25 seedlings coming from untreated seed. The experiment was originally set up on January 31 and repeated on February 5 and February 17. In general, results which might have appeared significant in one experiment were not duplicated in other experiments.

Although at the end of 48 hours there were indications of increased germination in some of the lots of treated seed, notably those treated with 1,000 p.p.m. of beta indole-acetic acid, such increases were scarcely evident after 66 hours. At the end of 96 hours the untreated seed had germinated as well as any of the lots of treated seed. It was concluded that under these conditions and at the rates used, the final percentage of germination of Italian ryegrass seed was not significantly altered by any of the growth substances used. The stimulation in speed of germination which, in a few instances, appeared at the end of 48 hours was of such short duration that it could not be considered as worthwhile in practical large scale plantings of the seed.

Measurements of the 25 best seedlings showed considerable variation in length of roots and tops in both the treated and untreated seed. A comparison of the averages of root length shows that in both experiments in which measurements were taken there was a significant increase in length following 7 of the 14 treatments tried. However, the increase with talc dust alone was as great as or greater than that with any of the other treatments except for beta indole-butyric acid at 1,000 p.p.m. and Vitamin B_1 at 1,000 p.p.m. The only treatment which was accompanied by a significant increase in length of tops in both experiments was 1,000 p.p.m. of indole-butyric acid. It should be remembered that these seedlings were growing in petri dishes and were discarded after the ninety-sixth hour.

Kentucky Bluegrass Seed

In February, Kentucky bluegrass seed was dusted with hormones, using treatments A to T, inclusive, as given on page 116. Immediately after treatment the seeds were planted in flats of sand and germinated in the warm greenhouse at 80° F. Germination counts were made from the eighth to the twentieth day. Probably because of slight inequalities in watering, the results in duplicate flats varied over such a wide range that the significance of any differences which appeared was questionable. There was an apparent retardation in germination in evidence from the eighth to the twelfth or thirteenth day following treatments with talc alone, 1,000 p.p.m. and 4,000 p.p.m. of alpha naphthalene-acetic acid, 1,000 and 4,000 p.p.m. of beta indole-butyric acid, Rootone and Vitamin B_1. However, by the twentieth day germination was approximately equal in treated and untreated seed.

In April, Kentucky bluegrass seed was again dusted with hormone treatments A, B, D, G, H, I and T. Duplicate lots of 200 seed were placed on blotters in petri dishes and germinated under conditions of alternating temperature and light which are generally accepted as the most favorable for the germination of Kentucky bluegrass seed. Germination counts were made on the ninth, thirteenth, eighteenth, and twenty-seventh days but no significant differences appeared between the percentage of germination of the untreated and any of the treated seed.

At the same time, bluegrass seed from the same sources was treated with the same hormones and planted in field plots. There was no apparent difference in the rates at which the bluegrass seedlings appeared following any of the treatments as compared with the plots planted with untreated seed. As the season progressed, crabgrass invasion was equally severe in all of the plots.

In mid-August of this year the experiment was repeated and at the time of writing (3 months after planting) all of the plots are practically equally covered with bluegrass seedlings. To date, therefore, the field experiments as well as the germination tests indicate that under our conditions and at the rates applied, alpha naphthalene-acetic acid, beta indole-butyric acid, Vitamin B_1, Rootone and Hormodin A have had no significant effects in increasing the speed of germination or the total germination when applied to Kentucky bluegrass seed.

Vitamin B_1 on Turf

Turf of redtop (*Agrostis alba*) was grown on soil from which the topsoil had been removed to a depth of 1½ inches. Duplicate 4- by 4-foot plots of this turf were watered three times a week with 2½ gallons of a solution containing 0.1 p.p.m. of Vitamin B_1. Comparable plots received the same amounts of water; this was enough to soak the ground thoroughly. The treatments, begun in June, were continued until early in September. No effect of the treatment could be observed, either during the period in which the solutions were applied or until the plots were abandoned the following May.

In another experiment, duplicate 4- by 8-foot plots of two different stolon-propagated strains of creeping bent have been watered with a solution of Vitamin B_1. On these plots 1¼ gallons of a solution containing 0.2 p.p.m of Vitamin B_1 were used three times a week during the critical month of August when root growth on bent normally is at the lowest point of the season. No effect of the treatment on the grass was discernible.

From the results of the preceding tests in which stolons, seed, and turf of various grasses were treated with numerous preparations of different types of growth substances, there appears to be little or no likelihood of helping grass in a practical way with any of the growth substances now available.

Mowrah meal used on turf as an earthworm expellant is made from the beans of the *Bassia latifolia* tree, which grows to a height of 40 to 50 feet in tropical India. The tree is strictly tropical and probably cannot be grown anywhere in the United States. The wood is tough and the beans yield an edible oil. Mowrah meal is made from the cake left after the oil is expressed. The meal is not suitable for feed but is used as a fertilizer, and when finely ground as an earthworm expellant. It is used also to stupefy fish.

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.

GERMINATION OF CARPET GRASS SEED

E. H. Toole and V. K. Toole of the United States Department of Agriculture reported in the Journal of the American Society of Agronomy the results of their studies on the germination of carpet grass seed under laboratory conditions. Fresh seed was found to germinate about 90 percent. The same seed after being stored in the laboratory for 3 years germinated 81 percent. On the contrary, seed which had been stored for 1 year in a warehouse in the region of production in Mississippi showed only 67 percent germination at the end of the first year, 53 percent after the second year, and only 5 percent at the end of the fourth year. These figures would seem to indicate that the conditions under which carpet grass seed is stored profoundly influence the ability of that seed to germinate.

Several temperatures were tried in order to find the best temperature at which carpet grass seed will germinate. The best results were obtained with an alternating temperature of 68° F. for 17 hours and 95° for the remaining 7 hours.

MILKY DISEASE OF JAPANESE BEETLE GRUB

Milky diseases A and B of grubs of the Japanese beetle are caused by bacteria which grow and produce spores in large numbers in the blood of living grubs. It is the spores which give the blood of living grubs its characteristic milky appearance. As many as 20 billion spores have been found in the blood of a single grub. In recent issues of the Journal of Economic Entomology, Ralph T.

White and S. R. Dutky of the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture have described experiments demonstrating the possibility of using these bacteria to control the grubs in turf.

Grubs are inoculated with the bacteria and then incubated in soil kept at a temperature of 86° F. for 10 to 12 days, at the end of which time the grubs each contain between 1 and 3 billion spores, depending on the number of bacteria with which they were inoculated. These diseased grubs are then used to inoculate the turfed areas in which the grubs are to be controlled. When they are to be used immediately, the diseased grubs usually are ground and the resulting material suspended in water. If it is to be stored for future use, the ground material is mixed with talc and dried. The prepared infectious material is introduced into the soil in localized spots or distributed over the entire area by spraying the dilute suspension of spores in water or by mixing the talc preparation with enough sand or sieved soil to give sufficient bulk to spread like fertilizer. In some cases living inoculated grubs have been introduced on the plots, and even infected soil has been successfully used for inoculation purposes. Dosages of 25 to 1,500 million spores per square foot of turf have resulted in a reduction of healthy grubs to the point where no serious injury to turf has occurred.

The writers cite an experiment at Cape Charles, Virginia, in which the grub population was reduced from an average of 121 to 6 healthy grubs to a square foot during the period from July to September, 1939, whereas in the untreated areas 74 healthy grubs to a square foot were present at the end of that period.

The spores have been shown to be resistant to extreme cold as well as to excessive moisture or drought and consequently remain living in the soil in spite of most adverse conditions. To quote from Mr. White's article, "Data indicate that when once the soil becomes highly infectious with the causal agent, no substantial population of Japanese beetle larvae can exist. Serious turf injury can thus be reduced, if not entirely prevented, by the introduction of the causal agent of type A milky disease. A rapid build-up and spread of the organism may be expected when a reasonably heavy larval population occurs."

Experimental results apparently indicate that it should be possible to prevent severe turf injury from the Japanese beetle grubs by introducing the bacteria into the soil before the Japanese beetle arrives, or shortly after it has reached a given area and before numbers of grubs sufficient to cause severe turf injury have become established.

The Bureau of Entomology and Plant Quarantine, however, emphasizes the fact that this method of controlling the Japanese beetle is still in its early experimental stages. The material is being used only by the Department of Agriculture cooperating with official State agencies in this work. No material is available for general use at this time.

HARVESTING BUFFALO GRASS SEED

Buffalo grass is an important grass in the dry regions of the United States, but seed has been difficult to obtain. The seeds are borne on very short stalks, so that they cannot be reached by mowers, and hand gathering is too costly.

H. O. Hill of Texas has recently described in the Journal of the American Society of Agronomy a machine by which a man can collect about 1 pound of seed an hour. The cutter bar and the roller are removed from an ordinary lawn mower and a grass catcher is attached. A canvas shield is fixed over the lawn mower and the shield extends well up the handle bar. The rotating cutter blades then clip the seeds and beat them back into the catcher or against the shield, which in turn deflects them into the catcher.

The removal of the cutter bar reduces the amount of grass hay caught along with the seed, so that all but the finer particles of trash can be quickly removed by hand. The dirt can be removed by floating the seed out in a tub of water. This cleaning is not necessary when the collector himself is to use the seed.

SEED FORMATION IN KENTUCKY BLUESGRASS

In the April, 1939, issue of TURF CULTURE, page 144, investigations were reported which indicated that in Sweden the formation of seed without fertilization was found to be common in Kentucky bluegrass. E. Akerberg, whose work was mentioned in connection with that report, has since published in Hereditas a more detailed account of his work with Kentucky bluegrass.

According to him, it is possible to determine whether seed was set apomictically (without fertilization) or sexually (as a result of fertilization) by examining the progeny resulting from seed set in a single panicle. When the resulting seedlings exhibit a constancy in characteristics and resemble the mother plant, the conclusion is drawn that the seed was formed apomictically. On the other hand, when they are aberrant—that is, deviate from the typical plant—and exhibit striking variations among themselves and from the mother plant, it is safe to say that the seed was produced sexually. Microscopic studies of the number and nature of the chromosomes have verified the conclusion that lack of variability is associated with apomictic seed formation and that variability is associated with sexual seed formation.

Akerberg examined 703 plants of Kentucky bluegrass grown at the Plant Breeding Institution at Weibullsholm. These had been obtained either by isolation, free-flowering, or cross-pollinating of strains which were considered to be apomictic. Of these 703 plants only 9.2 percent were aberrants. In other words, 90.8 percent of the plants had come from seed which was produced apomictically.

Akerberg then studied Kentucky bluegrass elsewhere in Sweden and also in Norway and Germany. In these studies he considered the plants resulting from the seed of a single panicle as families. He grew 44 such families. Among the 185 plants examined belonging to these 44 families only 5.9 percent were aberrants and these were limited to seven of the families. Therefore, in nature he found 94.1 percent of the seed he examined was produced apomictically. These figures indicate that apomictic seed formation is common in other strains as well as in those cultivated at Weibullsholm.

CHLOROPICRIN MAY CONTROL SOME PLANT DISEASES

Treatment with chloropicrin is known to aid in the control of weeds by killing a large proportion of the weed seed in soil. This aspect of the problem has been discussed in TURF CULTURE for January, 1939. F. L. Howard and F. L. Stark, of the Rhode Island Experiment Station, writing in Seed World also call attention to this weed killing property of tear gas and point out that the susceptibility of weed seed to treatment varies, some being more susceptible than others.

They also give data showing that many soil diseases may be controlled and plants consequently make a better growth and yield larger crops after the soil has been treated with chloropicrin. Treatments were made in the field at rates of 201, 217 and 369 pounds to the acre and the material put into crowbar holes made 15 inches apart. Onions yielded 43 percent more in treated than in untreated soil, egg plants 206 percent more and millet 46 percent more. Other crops also yielded much better after the soil was treated.

The same men with J. B. Smith published in Phytopathology the results of a study on the use of chloropicrin for the control of nematodes in tomato greenhouses. They found that chloropicrin and carbon disulfide injected into the soil gave results that compared favorably with those secured by steam sterilization. Dosages of chloropicrin which delayed initial nematode infection until an extensive root system had developed were sufficient to give normal yields.

P. A. Young, of Texas, writing in Phytopathology, reported that chloropicrin injected into sandy soil at rates of 250 to 450 pounds to the acre usually controlled all or most of the Fusarium wilt troubles with tomatoes, and the root nematode of watermelons, besides killing weed seeds such as those of Johnson grass, crabgrass and pigweed.

A Russian investigator, Mr. Schepetilnikova, found that flax sick soils treated in the laboratory with chloropicrin and tested periodically showed no *Fusarium* or *Asterocystis* spores. The beneficial effect extended into the following year.

THE LEAF CUTTING ANT

While there have been no reports of the leaf cutting ant damaging turf, E. V. Walter, L. A. Seaton and A. Mathewson in the United States Department of Agriculture, Circular 494, state that few plants are immune to attack. Reports have been received of damage to cereal and forage crops in Texas by the species, *Atta texana*. It is not impossible, therefore, that this ant may attack turf.

The ant cuts green vegetation, carries it into its nest and on this decaying vegetation grows a crop of a special fungus on which it feeds. The ants are good gardeners and carefully keep down all fungi not wanted. The ants in a nest range in size from the queens through fighters to the smallest workers. The latter are the gardeners. Larger workers gather pieces of leaves and once they start on a particular tree or crop they seldom let up until all the foliage is stripped.

The best control so far worked out is with carbon disulfide. Under Texas conditions the authors advise that this be injected into the nests between late February and early April as during this time the queens are likely to be in the center of the nest. Later they leave the nest and establish homes of their own, increasing the centers of infection.

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 snowmold.—The end of our playing season comes rather early in the year, usually at the end of September. The ground gradually becomes frozen and sometimes we have snow covering our greens from the second week in October to the second or third week in April. When the snow is melting in the spring, some of our turf is covered in spots with a cobwebby fungus growth. The spots are from 6 to 9 inches in diameter and the grass usually dies. These spots may expand and merge and eventually the turf takes on a mottled or patchwork effect. Is this snowmold and what is the best remedy? (Ontario.)

ANSWER. — Undoubtedly the damage you describe is due to snowmold. The most effective control of snowmold involves the following principles:

1. Use no winter cover, such as straw or leaves.
2. Provide for a rapid run-off of water as the snow melts.
3. Use resistant grasses. Seaside bent and fescue are very susceptible.
4. Protect the turf by fall applications of corrosive sublimate.
5. Avoid late summer or early fall applications of fertilizers, which tend to stimulate a late growth of grass.

* * *

Resodding a green of established Bermuda grass.—The area on which we intend to build a green is already well sodded with Bermuda grass. This grass is used exclusively in this section for sodding greens. Must we dig up this old grass and replant or can we keep mowing it down close until the tender shoots start to grow? (Texas.)

ANSWER.—If the area you intend to use for turf is now well covered with Bermuda grass, keep it mowed closely and new shoots should soon thicken the turf so that it will be satisfactory for putting green purposes. The process can be hastened by applying sulfate of ammonia at the rate of 5 to 10 pounds to 1,000 square feet. Apply when the grass is dry and water it in. After mowing it would be well to rake the ground severely with a garden rake or topdress liberally with fresh soil. If necessary to thicken the sod, the surface can be leveled and Bermuda grass seed sown. The turf should then be kept well watered for a time.

* * *

Bumpy turf.—Our greens were planted vegetatively with Washington bent 7 years ago. This season the players are complaining that the greens are bumpy and that the surfaces are very uneven. Will you please advise us how often the greens should be topdressed and give us other information on the accepted practices of maintaining this grass? (New York.)

ANSWER.—From the standpoint of growth of grass, topdressing is desirable but by no means necessary. From the putting standpoint, however, topdressing is distinctly desirable since it provides a true putting surface.

It is well to topdress greens whenever the surfaces become uneven. This occurs more frequently on some types of soil than on others. Golf courses are definitely affected by the amount of play. No set rule can therefore be laid down as to the frequency of topdressing that is best for any set of greens. Sometimes topdressing is applied to surfaces that are badly matted and the topdressing, therefore, has no chance to work down into the lower layers. In such cases the more often greens are topdressed the more irregular they may become.

In handling Washington bent greens it is a common practice to rake or brush the greens severely to remove as much of the excess growth as possible and thereby enable the topdressing material to work down into the low areas where it is matted in. If there is a tendency to produce an excessive amount of mat the raking or brushing process may be repeated throughout the summer every week or two. In the summer, rakings or brushings should be very mild, however. Topdressing is applied as needed and thoroughly matted in.

* * *

Coarseness of redtop.—Can you tell us if redtop will start out coarse in the spring and gradually get finer because of cutting as the summer progresses? (Colorado.)

ANSWER. — Redtop ordinarily does not get finer during the summer. At seeding time redtop and many of the bents try to send up flower heads even in closely cut turf. The leaves attached to these flowering stalks are especially coarse. These will usually disappear by midsummer although the regular leaves of the redtop will remain coarser than those of some of the other turf grasses.

* * *

Slime mold on grass.—On our lawn there have suddenly appeared irregular shaped growths which are taffy-colored at first and later become black. When the lawn mower goes over the grass a fine black soot-like material blows over the lawn. Will you please tell me what this growth is and how to get rid of it? (Ohio.)

ANSWER.—The soot-like development which you describe is one of the fungi known as slime mold. It is a superficial growth which grows on grass when the conditions of temperature and moisture are favorable for its development. The black dust-like material consists of very fine grains which are the spores and act as seed to propagate the fungus. Ordinarily the fungus grows in the soil and is not detected until it suddenly sends up the fruiting bodies which you have observed. At first these fruiting bodies may be the large irregular, light brown or grey masses or tiny steel grey bodies, sometimes hundreds of them on a single grass blade or clover leaf. Both types of fruiting bodies mature rapidly and break open, exposing the masses of black spores inside. When mowers run over these areas they spread the spores over a large area of turf. Ordinarily if you take a hose at that stage you can rinse this black dust off the grass and you will find that it causes no permanent damage to the grass.

* * *

Commercial fertilizer vs. manure for topdressing turf.—We have had quite a bit of discussion about whether it is better to use sewage sludge or cow or horse manure when top-dressing the fairways on our course. We have no means of sterilizing the manure and must spread it by hand. We should be grateful for any advice you can give us. (Florida.)

ANSWER.—All our experimental work has shown that for fairway fertilizing it is better to use sewage sludge or some commercial fertilizers than cow or horse manure as top-dressing.

UNITED STATES GOLF ASSOCIATION

ORGANIZED 1894