A PROGRESS REPORT:

Electricity in Climate Control for Winter-Green Bermudagrass

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CLIMATE EXERTS A MORE POWERFUL INFLUENCE on the physiology of plants than any other single factor in the environment. Resulting from the interaction of solar energy and the physical features of the environment, varying intensities and periods of heat and light have a determining effect on plant development and behavior.

Bermudagrasses have a high heat and light requirement. Even when other conditions are optimum, bermuda will lose vigor and fail to grow proportionately when these factors become limiting as in shaded locations or during sub-tropic or temperate zone winters. Having no definite dormant period, bermuda will grow proportionately as heat and light from natural or artificial sources approach its maximum requirements. Loss of color from bermuda foliage is due to the high rate of destruction of its chlorophyl under conditions of high light intensity and low temperature and a concomitant low rate of chlorophyl synthesis. Thus the familiar straw-colored, 'dormant' bermuda of our winter season reflects only the inadequacies of climate in our particular environment.

In a broad sense, home gardeners are generally aware of the response of plants to horticultural practices such as mowing, watering, fertilizing and the like. Seldom do they realize that the visible effects in plant growth may have been produced indirectly by changes such practices exert on the climatic environment.

For example, close mowing permits more light to reach the soil surface, thus increasing soil temperatures and stimulating light-sensitive seeds (often weed seeds) to germinate. The surface soil, being more exposed, loses moisture faster through evaporation which results in a lower humidity, thus inhibiting the spread of disease-producing fungi or of competing plants having a high moisture requirement.

Certain Benefits and Limitations of Water

WATER HAS A WIDE RANGE of influences on climate, according to its use and disposition within the terrain. In large bodies, such as lakes or oceans, it tends to alternately absorb and release large amounts of heat energy so as to modify extremes of temperature. In metered amounts and timed applications, water was used recently in an experiment at the University of California South Coast Field Station, Santa Ana, to maintain night temperatures adequate to keep bermudagrass green through the winter. Because of the large volume required to be effective, this method does not appear to have a wide practical application except in areas such as Santa Ana where winter temperatures are modified by coastal influences.

In Europe and other places, heated water or steam has been piped under turf to maintain soil temperatures adequate for the growth of grasses during the winter. This practice, also, has not proven to be economically feasible.

The evaporation of water is promoted through the absorption of heat energy and contributes to an increase in humidity and a decrease in temperature, a condition which would reduce transpiration. This is the principle involved in the horticultural practice of syringing to alleviate incipient (temporary) wilting.

Singularly, water has the capacity to absorb large quantities of heat without a comparable rise in its temperature. For this reason it is generally inadvisable to irrigate lawns in the late afternoon when higher temperatures and lower humidities are desirable into the night for improved disease control, or even for better germination of seed in a newly planted lawn. For this same reason, also, it has been shown to be undesirable to permit excessive amounts of water as rain or irrigation to infiltrate into the soil when attempts are being made to maintain higher than normal soil temperatures. Tarps of clear plastic have been used to protect turf areas from this unwanted precipitation.

Certain Benefits and Limitations of Plastic Tarps

ACTING TO TRANSMIT incoming solar radiation and to inhibit re-radiation of heat from the soil, a similar protective covering of clear plastic, supported a few inches above the turf, has been shown to be effective in maintaining soil temperatures adequate to sustain winter color in grasses and certain other plants in mild climates. Esthetic considerations and problems such as excessive humidity, reduced air circulation, and the difficulty of application and removal make this practice one of questionable value in many situations.

A new type of plastic is being developed that shows promise in modifying the spectrum of the light it transmits in favor of the wave lengths that are most effectively used by plants. This added value of a plastic covering could enhance its usefulness tremendously if used in combination with all the other factors previously mentioned for climate control.

Varieties and Management

Certain improved varieties of bermudagrass inherently remain greener through longer periods of the year than others. Good management practices such as thatch control and the prudent use of nitrogen fertilizers can induce vigor and contribute to an even longer period of green, even with common bermuda. However, color is lost, regardless of the excellence of care and other considerations when temperatures drop sufficiently and light intensities are high. Increasing light levels over large turf areas is at present impractical, but the problem of maintaining adequate temperatures in the soil is within the ability of present day technology.

The Electrical Resistance Cable

A very practical source of heat energy is the electrical resistance cable. These cables have been used in colder parts of the country for many years, implanted in walks and driveways to keep them snow-free in winter. They have been used in plant propagation to supply bottom heat in seed and cutting beds. Studies conducted here at the Arboretum and at other places across the country have demonstrated the practicality of using these cables embedded in the lawn to help maintain temperatures adequate for growth and color in grasses during the winter. This excursion into climate control by supplying supplemental heat electrically to the soil in the root zone has resulted in opening the possibility for many practical applications, such as in athletic fields, golf or bowling greens, and other high value, high use turf areas, not excluding the home lawn.

History of Existing Installations

Perhaps the first attempt at using this electrical resistance cable in turf was made by J. R. Escrit at Bingley, England, as early as 1951. Several commercial installations were subsequently made in England, Scotland and Sweden. The Farm Electrification Research Branch of the U. S. Agricultural Research Service, working cooperatively with the Departments of Agronomy and Agricultural Engineering at Purdue University in Indiana were the first to investigate the use of the cable in America.

Later installations have been successfully operated at Lethbridge in Alberta, Canada, at Busch Stadium in St. Louis, at Falcon Stadium at the U. S. Air Force Academy in Colorado Springs, at Texas A. & M. University in College Station, and at several other locations.

The grasses used have included the full range of the varieties used for lawns, chiefly St. Augustine, bermudagrasses, bentgrasses, bluegrasses, zoysia and rye.

Studies at the Arboretum

INVESTIGATIONS AT the Arboretum were initiated during the late summer of 1966. Ten reels of heating cable were supplied by the Easy-Heat Division of the Singer Company of Lakeville, Indiana, along with accompanying thermostat controls. The cost of installing electrical service to the research site and connecting the cables to the control panels was underwritten through a grant by the Southern California Edison Company. Specialized equipment used in inserting cable into the sod was supplied by The Ryan Equipment Company of St. Paul, Minnesota and the Pacific Toro Company, including its affiliate Moist-O-Matic Division, of Los Angeles and Riverside. Recording Thermographs were loaned by California Turfgrass Nurseries of Camarillo. Installation and inspection of electrical service and connections were performed by the Mechanical Division of Los Angeles County.

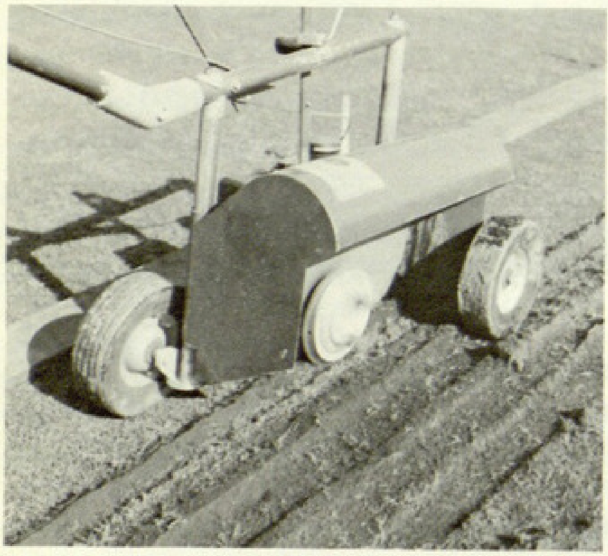
Ten plots were laid out in a well-established stand of Tifgreen bermudagrass, each 3′x20′, and separated by a 3′x20′ control plot. These were arranged in two rows of five plots each, spaced 6′ apart. An additional control plot was added along one length of each of these rows at the east and west end.

The plots were randomized but, due to the limitation of equipment, were not replicated. Based on information then available, a spacing and burial depth of 6″ was selected. Plots were designated as follows:

Plot No.	Key	Wattage of Cable* per lineal foot	Watt Density of Plot per Square Foot	Operating Temperature (Degrees F.)
1	D	1.25	2.5	50
2	A	5.0	10.0	50
3	C	2.5	5.0	50
4	C	2.5	5.0	60
5	A	5.0	10.0	55
6	B	3.75	7.5	50
7	B	3.75	7.5	60
8	C	2.5	5.0	55
9	A	5.0	10.0	60
10	B	3.75	7.5	55

* Physical Description of Cable: Solid core resistance wire (Nichrome and copper alloy) with P. V. C. primary insulation 3/64″ and nylon jacket, with copper overbraid grounding provision. Hot to cold lead junction of waterproof, encapsulated, pressure type sleeve connectors joining heating section to 10′ U. F. type cold leads of stranded #10 AWG copper conductors. — Courtesy Easy Heat Division, Singer Co.

During the first year the minimum operating temperature that would produce satisfactory results was to be determined, as well as the minimum watt density capable of sustaining that temperature. It was projected that during the second year, all plots would then be operated at this minimum temperature, with an overview on the performance at the various watt levels.



Opening trenches ½" wide and 6" deep with the Moist-O-Matic Mole Trencher. Accurate spacing of 6" was obtained by use of a 1" x 6" straightedge.

Installing the Cable

THE cable at Texas A. & M. University and at Falcon and Busch Stadiums was installed in bare soil, using a modified sub-soil plow to open the trenches. Turf was grown later. At Lambeau Field (Green Bay Packers), cable was installed in existing turf, using a rolling coulter to slit the bluegrass sod, followed by a cable-laying device. The Texas A. & M. University installation consisted of cable spaced variously from 3 to 12 inches and attached to ½" mesh hardware cloth which was then placed in their plots at depths of 2, 4 and 6 inches.

The Arboretum installation required a completely different approach due to the nature of the investigation. First, the well-established Tifgreen bermudagrass sod had a tough and extensive rhizome and root system that required heavy and powerful equipment to slit. With such equipment it would have been extremely awkward to make the numerous 3" radius turns required by the 6" spacing of the cable. Also, slits in this well-knit sod could not be closed accurately enough to insure good soil-to-cable contact necessary for reliable heat exchange.

The first approach to the problem involved the unsuccessful use of a Ryan Sod Cutter employing their Mole Attachment. This consisted of a vertical fin or blade, its leading edge sharpened, with a bullet-like tip at the bottom which opened a small diameter tunnel as it moved under the soil. An eccentric cam drive on the sod cutter rapidly oscillated the blade during forward movement. A specially designed, short woven wire device, called the Kellems Grip, attached the cable behind the bullet and pulled it through the tunnel as it was being opened. Due to the density of the sod, the blade did not cut effectively. The extreme drag thus created coupled with the succulence of the grass caused the rubber-covered traction drum to spin excessively, thus scuffing the turf quite seriously.

Even if this equipment had opened the trench successfully, it is doubtful if its effect on the cable would have been desirable. This cable had a rather fragile embroidery of copper around the outside for grounding, which was damaged by being dragged through the tunnel. Also, the jerking motion of the Mole as it pulled the cable could have broken the resistance wire in many places. This equipment was designed to pull plastic tubing underground in the installation of irrigation systems, but did not appear to be satisfactory for use with this elec-

Cable being installed by hand into the trenches cut in bermudagrass sod.

Backfilling trenches and firming soil over the cables was a tedious operation. Trenches totalled over 1/3 of a mile in length.

tric cable. Also, this system would have involved pulling the leading end of the cable through the entire length of the trench, the stress becoming progressively greater as more cable was being pulled behind it. The design and construction of the cable would not enable it to withstand such excessive stress.

The method that finally proved satisfactory involved excavating the trenches ½″ wide, using a modified arrangement of tynes on the Toro Mole Trencher, a piece of equipment especially designed by Ed Hunter of the Moist-O-Matic research Division, Riverside. These carbide-tipped tynes have staggered angular bends towards the end, enabling an operator to open a trench up to 3″ wide by selecting the proper set for mounting into a hub-disk. The depth of cut can be regulated to about 8″. Soil is removed by the whirling tynes and deposited at the surface, parallel with the trenches, by a chute.

Accurate spacing was obtained between the trenches by using a 1″ x 6″ straightedge, anchored in place, as a guide for the wheels of the Toro Mole.

In the absence of a laying device, the resistance cable was then inserted into the trenches of the test plots by hand from individual reels, and immediately secured at the 6″ depth with soil. This backfilling process was rather tedious since the trench was only ½″ wide and the soil had a tendency to bridge over rather than fall in. This necessitated much packing in of small quantities of soil at a time, using a contrived tamp of ½″ plywood.

The magnitude of this task is better appreciated when one realizes that the total length of the trenches amounted to over ⅓ of a mile. However, due to the extreme importance of eliminating all air spaces around the cables, every precaution was taken to firm the soil back into place.

The ten-foot cold leads from the cables were installed to the individual thermostat control, entering from underground through conduit. Similarly, the leads to temperature sensors left the thermostat through conduit to underground and the sensors installed in the center of each plot at a depth of 3″, positioned halfway between two cable-bearing trenches.

Duplicate trenches were excavated and backfilled in the two east and west control plots, although no cable was installed. Any possible effect of this vertical cutting could then be observed by comparison with the remaining checks.

Installation was completed too late in the 1966-67 winter to gain much information. However, preliminary tests were made that yielded very promising results. The system was again energized on December 1, 1967. Outside temperatures were sufficiently low to engender observable results by December 27. Numerous records of temperatures and ratings of the plots were taken before the termination date of the 14th of February, 1968. These were considered too inconclusive to be included here.

Similar tests were run between December 1, 1968 and March 1, 1969, except all plots were operated by thermostat control at 60° F. During this period the weather was characterized by some of the coldest periods ever recorded at the Arboretum, as well as the wettest. The abnormal amount of precipitation nullified any meaningful performance by the cable, especially so, since no provision had been made for employing plastic tarping. However, all the heated plots were satisfactorily green except 1-D with only 2½ watts per foot heat density. Results were further obscured by a heavy invasion of *Poa annua,* Annual Bluegrass, which grew well even in the check plots.

Extensive studies are now under way at the Arboretum to determine effective measures for pre-emergence control of *P. annua.* The more promising of these results will be employed next winter when further trials with the heating cables will be conducted.

Observations And Results

A review and analysis of the data taken so far during this investigation has revealed several interesting trends, some deficiencies in the equipment used and a glaring shortage of recording instrumentation.

A very high quality of turf was produced on the plots designated to be maintained at 55° and 60°, minimum, by thermostat control. Theoretically, this imbalance in soil and air temperature, especially at night, would encourage the development of a greater root system, retard top growth, increase nutrient intake, stimulate chlorophyl formation, increase carbohydrate levels, and produce a dense, fibrous leaf and stem tissue. To date, no laboratory tests or measurements have been made to ascertain the degree to which any of these may have occurred. However, visual results observed suggested that all or most of these physiological processes were taking place.

The growth of the turf was very slow and did not necessitate mowing during the test run of over two months. This would suggest that the lower air temperature acted as a growth retardant. It is probable that leaf temperature was elevated above that of unheated plots but may have lost heat by radiation and convection air currents. The resultant leaf temperature was probably adequate for chlorophyl formation and for photosynthesis to proceed at productive rates, which would have resulted in the excellent leaf color and texture observed.

There was a differential between the growth of turf proportionate to the temperature maintained in the soil. Physical limitations precluded more extensive tests that might have disclosed a maximum growth rate under the environmental limitations of the season. In situations where a higher growth rate would be required, such as in areas of high traffic and use, adequate temperatures might be provided but light might become limiting in both quantity and quality for the satisfactory growth of bermudagrass.

Preliminary tests involving three nitrogen levels were not adequate to show any significant results. However, it is almost certain that nitrogen could become an important factor under more controlled conditions.

The low maintenance of the plots and the high quality turf resulting could suggest that the cost of supplying electricity for the heat energy might be equally offset by a lower maintenance cost than that of other methods used to sustain winter color in bermuda, such as overseeding. This would make this type of installation one of great interest to the home gardener.

Unfortunately, no meters were available to determine the actual power consumption. Also, various management programs would need to be investigated that might minimize heat loss such as the use of plastic tarps, permissible thicknesses of thatch in the turf as a natural insulation, regulation of the amount of water applied, mowing height, etc.

Data on temperatures were taken during the late afternoon and proved to be of limited validity in this study. Only a one-week period of night temperatures was recorded and this indicated a range of 18° in the soil while air temperatures for the same period ranged through 48°. Several factors might be involved: Inaccurate thermostat, unfavorable location of sensor, maladjustment of recording thermograph, or inadequate watt density of cable. Further study is needed to make a determination.

It appears that the cable could have been spaced to a more economical 12″ apart since check plots adjacent to the heated ones showed considerable response.

Conclusions

THE resistance cable energized by low-cost electricity available in most parts of Southern California proved to be an excellent method of maintaining adequate temperatures in the soil for the production of a beautiful, green bermudagrass turf throughout the winter. There appears to be a practical application of this method in all types of lawns, but especially in high value turf such as athletic fields, golf and bowling greens.

Installation costs could be expected to be lowered by the use of improved implements to implant the cable into established turf. Electrical service at many sites is already adequate, especially at athletic fields where facilities for night lighting exist. Cables may be operated during off-peak hours and at even more favorable rates where night lighting is used. Accessories such as plastic tarp for control of moisture and prevention of heat loss could further reduce operating costs.

Thus it is projected that sustaining winter color in bermuda and other lawn grasses can be accomplished successfully through the use of the electric resistance cable and at a cost competitive with other methods now being used.

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