Plants and Light

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The 1962 Yearbook of Agriculture is entitled "After A Hundred Years." It is a review or "a sampler" of progress in the field of agriculture in the 100 years since the establishment of the U. S. Department of Agriculture.

One area in which new knowledge has had a tremendous impact on plant management is that of light influences upon plants. The following paragraphs are quoted from an article written by Dr. Harry A. Borthwick. The article appears in the 1962 Yearbook. Dr. Borthwick is one of the world's outstanding authorities on the effects of light upon plants. Dr. Borthwick and Dr. Sterling Hendricks, a co-worker, have just been announced winners of the Hoblitzelle prize for 1962.

"Two men in the United States Department of Agriculture in 1918 set themselves the task of finding a way to make a certain tobacco plant flower. Most tobacco plants flower without any prompting, but this particular plant was different. It arose as a mutation and had great promise for commercial use if only seed could be produced. But seeds come from flowers, and plants like this one, seen occasionally in previous years, had always been killed by frost before they could flower. As autumn approached in 1918 and no flowers were evident, the men moved the plant into a greenhouse so it could continue to grow. The plant flowered about Christmastime and produced seed. The immediate problem thus was solved.

"This event attracted little attention at the moment because only a few persons were aware of it and understood its significance. But to W. W. Garner and H. A. Allard, the two men with the problem, the production of those tobacco flowers opened up an entirely new area of plant science. They had discovered the fundamental principle that the relative length of day and night controls flowering. They named the phenomenon photoperiodism. They tested the principle of photoperiodism on several other plants and found it worked on many. Some kinds, the 'short-day' plants, like the tobacco, they learned, flower when days are short and nights are long, but do not flower under other conditions of daylength. Other plants, the 'long-day' ones, such as spinach, flower only when the days are long and nights are short. Still others, 'day-neutral' ones, have no preference as to daylength.

"When that one tobacco plant flowered in 1918, probably even Garner and Allard did not appreciate the impact their discovery would presently have on agriculture and on scientific understanding of the growth and development of plants. It led to the essential knowledge on which the multimillion-dollar industry of year-round production of blooms of chrysanthemums was founded. It gave the wheat breeder a tool that permitted three times the former rate of progress in producing disease-resistant strains, a tool that was used when strain 15B of stem rust threatened ruination of the country's wheat production. It opened the door to understanding many problems of plant production not outwardly related to flowering. It prepared the way for basic investigations of the response of plants to environment. Research on photoperiodism at an ever-increasing rate is creating a backlog of knowledge useful in new ways to improve further our agricultural efficiency and contribute to our enjoyment of flowering plants.

"The story of the further development of our knowledge of the control of flowering by daylength is the story of how a single bio-chemical reaction of plants to light not only controls flowering but also prepares trees and other plants of temperate climates for the onset of cold weather; causes seeds of some crops and many kinds of weeds to germinate; controls the coloring of apples, tomatoes, and other fruits; and brings about other plant responses. The discovery of photoperiodism was turned immediately to practical use—for example, in the control of time of flowering in commercial production of chrysanthemums. Garner and Allard found chrysanthemums to be short-day plants in their original experiments. Artificial light added to the end of short autumn or winter days to make the days long and the nights short delayed blooming until later, more desirable dates. Conversely, shortening the exposure to light and lengthening the dark periods artificially in the summer induced early, out-of-season blooming.

"Scientists have wondered, however, why chrysanthemums require an interruption of darkness of as much as 3 or 4 hours while the soybean, another short-day plant, requires only 3 or 4 minutes to prevent flowering. We now have the answer. Chrysanthemums do not require 3 or 4 hours of light. They can be kept from flowering by much less than 3 or 4 hours if the light is divided into short periods and distributed throughout 3 or 4 hours. near the middle of the night. For instance, 18 minutes of continuous light given at midnight does not prevent flowering; but if it is divided into nine 2-minute exposures at 30-minute intervals throughout a 4-hour period in the middle of the night, the total of 18 minutes is as effective as continuous light for 4 hours. Other equally effective lighting schedules have been found, and better ones may be possible.

"This method of cyclic lighting during a part of the night was just being developed when this was written. It has promise of profitable application by the grower because it permits him to use a limited amount of power for lighting a large area. By lighting each of several small areas briefly, in succession, instead of a big area continuously for a long period, he greatly reduces both the demand charge for service and the actual amount of current he uses. Progress in applying light to chrysanthemums since 1925 has come largely as a byproduct of fundamental studies of the action of light on plants in general. One of the first underlying facts scientists discovered about photoperiodism was that red light is more effective than that of any other color when used as a dark-period interruption to control flowering. This discovery has obvious practical importance; it indicates the best kind of lamps to use. Lamps giving light that is rich in the red are more efficient than those giving light that is poor in red.

"A second major discovery was that

the action of red light on flowering is nullified by light having somewhat longer wavelengths in the near infrared, the so-called far red. Thus, after one exposes a soybean to enough red light in the middle of the night to prevent flowering, the capacity to flower is easily restored by an exposure to far red immediately afterward. This discovery was very important, because these red and far-red wavelengths of light also caused peculiar reversals of the ability of certain seeds to germinate. Some kinds of seeds must have light to germinate, and the kind they need is red light. After they receive the red light, however, the seeds can be kept from germinating by promptly giving them far red. Since the same wavelengths of red and far-red light, respectively control both seed germination and flowering in the same reversible way, these two plant processes must be set in action by the same basic light reaction. This is startling, because germination of seeds and flowering are so different in appearance as to seem quite unrelated.

"The occurrence of reversibility in the ability of seeds to germinate and of plants to flower suggested the possibility that such photo-reversibility might also occur in other plant responses. A careful survey revealed that it is, in fact, involved in several other phenomena. It has much to do with the regulation of length of stems and the size of leaves and with pigmentation of fruits and other plant parts. It probably is responsible for many other responses not yet demonstrated. Discovery of the effectiveness of red light and the reversal of its action by far red led to a further step in the knowledge of how light affects plants. Red light obviously causes effects that other visible wavelengths either do not cause or cause far less effectively than red. The energy of light, of course, must be absorbed to induce these effects. Absorption of red in preference to light of other colors requires the presence of an absorbing compound, a pigment that is blue. We therefore look for such a blue compound in plants. Most plants are green, however; even albino plants are white, not blue. Either there is no blue pigment in certain plant parts, or so little is present that we cannot see it.

"Where do these studies of the light reactions lead? The answer in part comes from looking backward. As recently as 1951 we did not know that the photoperiodic reaction was reversible by light. We knew that a pigment was involved, but we did not know about its change of form in darkness. Extraction of the pigment had not been undertaken at the time. Control of many different kinds of plant response by a single reversible photochemical reaction was not even imagined in 1951. An obvious answer to the question is that we cannot predict where the results of this work will lead in the next few years. We can give assurance, however, that the work will lead to more complete understanding of how plants are influenced by their environment and will enable farmers and gardeners to grow and use plants to better advantage.

"Exactly how results of this kind of work may contribute in the future to more efficient agriculture is also difficult to predict. Looking backward again, we see many practical applications already made and many opportunities not yet realized. Plant breeders use daylength control to make potential parent plants flower at the time desired so they can be hybridized. They grow the progenies on daylengths favorable to flowering and thus shorten the time to maturity and increase the number of generations they can grow in a given time. Physiologists know that plants in different stages of development do not always give the same response to herbicides. Daylength treatments are used therefore to produce plants in vegetative and reproductive states for experimental purposes.

"Still another illustration of the action of light on seeds comes from experiments in burying seeds. Seeds mixed with moist sand in an unstoppered bottle were buried 3 feet deep in soil. The bottle was inverted so as not to accumulate any standing water and left for 80 years. Some of the seeds promptly germinated when they were dug up. How could they remain viable so long? Why did they not germinate earlier? They were moist, had presumably adequate aeration, and surely must have encountered temperatures favorable to germination many times in the 80 years. Then one wonders why they germinated as soon as they were taken from the soil and placed in a seed germinator. It seems that they did not germinate for 80 years because they were in the dark. In the process of being dug up, they received light and germinated immediately.

"Examples of how light affects plant growth are almost inexhaustible. Those I have given are merely selected illustrations of rather commonplace ways in which light affects our lives through its influence on the plants or plant products that we eat, wear, burn, or admire. Only enough is told of the direction in which the research is currently leading to indicate its rapid change. An advance in understanding of flowering pointed the way to a new approach to germination of seeds. Progress in extraction and study of the light-absorbing pigment confirmed the conclusions previously reached from physiological studies and provided the basis on which new experiments were designed. In research of this kind there is no new frontier. The ever-advancing old frontier, however, changes so fast that it always seems new and filled with promise."

The foregoing paragraphs are indicative of the state of our knowledge with respect to light. As golf increases in popularity and we hear more of lighted putting greens and even of whole golf courses, we may well find ourselves faced with a need to manipulate light quality in order to insure the normal growth of turf. This is an area where turf men will be obliged to borrow the knowledge developed by fundamental research efforts.

Questions Frequently Asked

Prepared by Southwestern Office, USGA Green Section

(Questions asked by superintendents during the past season are remembered. Some of these questions along with our explanations of at least one answer to them are printed here so that others, who likely have asked the same either to themselves or to others, may have our thoughts.)

In greens constructed according to USGA Green Section specifications, does all the free moisture drain when the "dumping phenomenon" occurs? Why?

Yes. To answer why, one should recall the incidents leading to the formation of the false water table initially. In general, they are as follows:

(a) The water enters the seedbed from the surface and fills all the micropores; at this point the soil near the surface reaches field capacity.

(b) While the micropores are filled near the surface, many micropores also are filled for short periods of time. This process continues downward until all the soil is wet down to the sand-gravel interface which is underlying the permeable seedbed.

(c) Surface tension of the water holds the free water against the force of gravity (the only force attracting the water downward).

(d) As water accumulates, a column is formed. When it becomes high enough so that its weight overcomes the ability of surface tension to retain the free water, the interface is then penetrated; and like sheep through a weak fence, each water molecule follows its leader until all the macropores have