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THE A-B-C's OF PLANT-SOIL-WATER RELATIONS

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In regions like Southern California, the maintenance of attractive and useful turfgrass areas probably depends upon proper irrigation more than upon any other management practice. Turfgrasses are frequently injured by both under-irrigation and over-irrigation. Faulty irrigation is often a major cause of serious disease, weeds, fertility, and soil compaction problems. Irrigation usually takes a large fraction of the turfgrass maintenance budget to meet the costs of water itself and particularly for irrigation labor. Thus the adoption of sound irrigation practices will pay off in terms of:

- (1) Better grass
- (2) Fewer weeds
- (3) Less disease
- (4) Lower fertilizer costs
- (5) Improved soil structure
- (6) Lower irrigation costs
- (7) Water and labor

Whether on a golf course, park, school grounds, or cemeteries the job of the turfgrass manager usually calls for producing acceptable turf at as low a cost as possible. Certainly the challenging possibilities of achieving better grass at less cost through sound irrigation management deserves careful attention.

It is worthwhile for all of us to review from time to time just what we are doing in our irrigation practices. What factors should guide us in irrigation? What factors are actually determining our present irrigation practice? How far does our present practice depart from a theoretically desirable irrigation program?

A statement of basic principles of irrigation is really as simple as the A,B,C's. The difficulties arise when one sets out to apply these basic principles

in actual practice. We must face up to special conditions imposed by the use to which the turfgrass is to be put and by budgetary limitations particularly on the availability and cost of labor.

Briefly, a sound program of irrigation management depends upon answering three questions well. These are:

- (1) How much water to apply?
- (2) When to irrigate?
- (3) How to apply the water?

The first two of these questions must be answered by the irrigator every few days. How well these questions are answered will determine the quality of the turfgrass and the cost of its maintenance.

Although the basic principles of irrigation are as simple as ABC, the development of a sound and economical irrigation program depends upon the intelligent application of the ABC's to your particular conditions. We are repeatedly asked to make a simple general recommendation on how much?, when?, and how?. Unfortunately, we must realize that no definite answers of general application can be given to these apparently simple questions.

You cannot rely on getting by successfully by applying definite amounts of water on a prescribed irrigation interval in accordance with some published articles. One must realize that--

YOUR IRRIGATION PROBLEM IS DIFFERENT

Your irrigation program must be tailored to:

- (1) Your soil
- (2) Your grass
- (3) Your weather and exposure
- (4) Your irrigation equipment
- (5) Other special factors you may have.

Good irrigation management is a personal thing--something that YOU MUST ARRIVE AT BY:

- (1) Your understanding the basic ABC's of irrigation
- (2) Analyzing your conditions
- (3) Wisely applying the basic principles to your conditions.

Although it will require some analysis of thought, the efficiency of your irrigation operations can easily be improved if you know what factors govern the amount of water to apply at each irrigation and the proper interval between irrigations. It is also important to understand the operational characteristics of sprinkler equipment.

Now let's review our A B C's of irrigation:

Amount of Water Held by Different Soils

A barrel with a top and small drain helps illustrate some important soil moisture principals. If water is added quickly to the barrel or to soil, all the air spaces fill and we say the soil is saturated. As you know, a saturated soil is a very unhealthy environment for grass roots. Like this barrel with a drain, a normal-drained soil soon loses some water until a new level is reached when drainage essentially ceases. A soil in which drainage has become very slow is said to be at field capacity. Grass growing on that soil will extract water until it becomes too slowly available to keep up with water lost from the leaves. The moisture content at which the grass wilts is called the wilting point. The available water in soils is the difference between the water left after drainage (field capacity) and the water left when the plants cease to get it (the wilting point). Different soils hold different amounts of available water.

<u>Texture</u>	<u>Available Water (inches per foot of soil)</u>
Sands	3/4
Loams	1 1/2
Clays	2 1/2

The B of our A B C's may conveniently represent -

Behavior of Different Grasses

The most important behavior characteristic of grass is the depth and density of the root system. As illustrated in the figure, grass roots are most abundant near the surface with their number diminishing gradually with depth.

Because of the decreasing abundance of roots with depth, there is a corresponding decrease with depth in the amounts of water removed at the time the grass leaves show dryness. Thus near the surface (as indicated by the longer bars in the illustration), all of the available water is generally removed by the time the grass shows distinct wilting unless conditions are extremely unfavorable and the grass roots are very sparse. Such a condition may occur in the presence of excess of water. Considering, however, the conditions in well drained soils, deeper we probe into the soil the less of the available water has been removed when the grass shows dryness because there are fewer and fewer absorbing roots. There can be appreciable difference in the extraction patterns for two varieties of the same general species of grass. Research has shown that young stands of varying blue-grass have more deep roots than the Kentucky. Deeper roots mean that irrigation intervals can be longer.

The rooting depth of the grass is affected by many things:

Species	Fertilization
Clipping	Disease
Soil	Climate
Irrigation	Age of stand

What are some of the rooting depths we have observed under the deep favorable soil conditions at Davis?

Bents	10-12 inches
Bluegrass	24-36 inches
Bermuda	more than 48 inches

These rooting depths are those from which grasses will take all of the available moisture from the soil before they show signs of wilting under favorable conditions. Of course there are many roots that run down deeper than these figures indicate. These might be considered to be the effective rooting depths of these grasses.

While I recognize that the height of clippings is often governed by other considerations, I think we should be aware that clipping may be a factor

affecting root depth of grass at least to a minor extent. The soil on which the grass is growing also has a major influence. Certainly another major factor is irrigation practice. Some grasses are forced to be shallow rooted despite a deep rooting potential because of the irrigation practice we follow. Either excessive irrigation or insufficient irrigation can contribute to shallow-rooted grass. Fertilization probably has some effect on rooting depth of grasses as well. Disease and climate also have an effect. We are getting some evidence that the age of the grass may also be an important factor in depth of rooting as illustrated by the rooting patterns for young and old stands of Marion bluegrass. Because of the loss of these deeper roots with time needs to be explored further. Thus we see that there are many factors which influence the depth of rooting and thus the total moisture reserve that we can draw on between irrigation intervals.

Another behavior aspect of grass deserves mention. Some grasses under some conditions are very sensitive to drying out, and if allowed to show appreciable drought they quickly die. Others under other conditions will slowly turn brown but will immediately send out new green leaves when water is applied. Depth of rooting and inherent drought resistances characteristics of the grasses are both involved. Practical use can be made of drought tolerance characteristics of grasses under favorable conditions when faced with water shortages or desirability of reducing maintenance budgets as for example on little used school grounds during summer vacation. Play fields can often be allowed to go until quite dry during the periods of low use and be brought quickly into excellent condition for the fall term. The illustration of water use by Meyer's Zoysia at Davis illustrates the possibilities of considerable savings of water by taking advantage of the drought tolerance characteristics of the deep rooted grass on a deep soil. In this case zoysia looked somewhat dry although it was still green at the end of 45 days. No water was applied.

During the next 50 days, the grass extracted water as shown by the longer bars in the illustration. At the end of the 95 days the grass was brown although it was still green next to the soil surface. Comparison of the area cross-hatched bars to that of the longer bars shows that during the last 50 days as the grass was becoming progressively drier it used far less water than it did during the first 45 days when it was green and growing. By postponing irrigation for the additional 50 days, less than half the water was required to maintain the zoysia although, of course, it did look dry near the end of the test period. When irrigated, it came back to a green color rapidly and it looked fine. The same thing can be done with bermuda on deep soils.

The C of our A B C's stand for Consumptive Use or Climate. The rate of water used by grass depends on:

Climate
Exposure
Season of the year
Competition with other plants

The following figures illustrate typical consumptive use values during the summer months and illustrate the range and consumptive use values one can find even over a small geographical distance:

Regions in California	Consumptive Use of Water (inches per day)
Dry desert areas	.35
Interior valleys	.30-2.5
Interior coastal areas	.20
Coastal slopes	.15-1.0

These values apply to areas exposed to the full sunlight and normal air movement. Differences in shading will make large differences in rate of use even on a single piece of turf. The rate of use of water by grass varies of course appreciably with the season of year, and irrigation practices should

be adjusted accordingly. Recognition also needs to be given to the difference in rate of use of grass shaded by a building and that shaded by trees since the later will compete with grass for water. One must know the approximate consumptive use rate for your area and season of the year if irrigation needs are to be predicted with accuracy and water and labor used efficiently.

Our ABC's remind us of an important approach to irrigation matters:

Apply By Calculation

Applying irrigation water by simple calculations will point out to us many opportunities to improve our irrigation program. The following simple calculation will, I am sure, be found very useful:

$$II = \frac{SAM}{CU}$$

Irrigation interval in days (II) is equal to the supply of available moisture in inches (SAM) divided by the consumptive use in inches per day (CU). Let's predict an irrigation schedule for a situation where the grass has an effective rooting depth of one foot on a loam soil in an area where the consumptive use rate or water use rate is .2 inches per day. The number of days between irrigations can be very easily worked out as follows:

$$\text{Days} = \frac{1.5 \times 1}{.2} = 7\frac{1}{2}$$

With an effective rooting depth of one foot on loam soil (which holds $1\frac{1}{2}$ inches per foot), the total supply of available water is $1\frac{1}{2}$ inches. This divided by the rate of use (.2 per day) means that the grass should not wilt before $7\frac{1}{2}$ days. Although you may not want the grass to become quite so dry, this calculation will allow you to make estimates for planting purposes.

Some of you have seen the following charts which have been reproduced for previous turf conferences. The first chart gives the approximate number of

between irrigations as a function of the soil depth containing roots which has been wet by irrigation. The greater the depth which has been irrigated, the longer one can allow the grass to go between irrigations. This is simply a graphical representation of the simple calculation I showed you just above. You will notice that some of the irrigations of those predicted are very long ones where the grass had deep roots on clay soils. You may wonder whether grasses have ever been demonstrated as being able to go for such long periods without irrigation. This can be done where we have deep soils and deep rooted grasses provided under practical conditions, you may not be able to take advantage of the potential savings of long irrigation intervals because of the difficulty in again wetting the deep depth of soil because of runoff problems or use conditions imposed.

It is important to emphasize that if you allow the soil to be dried out to a considerable depth by allowing long irrigation intervals, then you must plan to apply a deep irrigation if you are going to recharge completely the soil moisture reservoir. The second chart shows you how much water it takes to wet these soils to given depths. For example, on a loam soil if you wet it to a depth of one foot after it has been dried out, you will need to apply $1\frac{1}{2}$ inches. If you have a clay soil, five inches would be required to wet it to a depth of two feet. Again it must be emphasized that if advantages be taken of deep roots and long irrigation intervals, it must be possible to apply and secure penetration of considerable depths of water. In areas (other than southern California) where the irrigation season is short, you may be able to allow the subsoil moisture to be gradually depleted and depend upon fall and winter rains to provide rewetting of the deep soil. However, one finds many examples of very touchy situations created by allowing the subsoil

moisture reserve to be depleted. In such cases the grass is dependent only on a limited supply of water. When this supply is exhausted, the grass may dry out suddenly and probably be lost unless quickly irrigated.

The simple calculation given here for predicting irrigation frequency can be employed as a useful check on your irrigation operations and on the effective depth to which the grass is rooting or the soil is being wet under your conditions. The effective depth of either the grass roots or of the soil wet by irrigation is equal to the irrigation interval times the use rate divided by the water-holding characteristics of the soil.

On a turfgrass area in a hot-dry climate where the water use rate is .3 inches per day and the soil is a loam holding $1\frac{1}{2}$ inches of available water per foot, assume experience indicates that irrigation is required every 2 days to avoid wilting.

$$\begin{array}{lcl} \text{Effective depth of rooting or} & & \text{Irrigation interval x water use rate} \\ \text{Depth of soil wet} & = & \text{divided by water-holding characteristic} \\ & & \text{of soil} \\ & = & 2 \times .3 \text{ divided by } 1\frac{1}{2} = .4 \text{ foot} \end{array}$$

In other words, if irrigation under these conditions is needed every two days, it means either that the roots of our grass are for some reason restricted to less than a six-inch depth or the water being applied is penetrating to a depth of only six inches. When you encounter this situation, it is quite likely that the irrigation water is not penetrating below the depth. A soil tube, probe, or some other sampling device will help check on this. If you have this condition on your turf, it will be very worthwhile to take the time required to find out what is going on below the surface.

Let's take another illustration of a golf course where the fairways were very dry yet they were being irrigated every second night using one-hour sets on

the sprinklers. The water use rate in the area is about .25 inches per day. Why are these fairways so dry? Check on what is happening by a simple calculation. Many sprinkler systems will put on about 1/3 of an inch of water per hour. Assuming this application rate, these fairways are receiving .33 divided by 2 or about .17 inches of water per day - about one-half of the irrigation requirement in the area. Thus it is no wonder the fairways were dry despite irrigation every second night. This schedule was begun early in the spring and maintained right on into the summer. However, this trouble did not show up until rather late in the summer. During the first part of the summer, the grass got by without wilting by drawing some moisture from the subsoil to make up for the deficient irrigations. As the summer wore on, the grass used up the deep soil moisture reserve and became dependent upon the one-third inch handout it got every two days. If the weather turned hotter and drier, there was real danger of losing the grass since there was no reserve left to draw on. It had been depleted by borrowing on it all summer.

Applying water By Calculation can allow you to determine whether you are applying approximately the correct amount of water. This will give you insight into the efficiency of your irrigation system and may point the way to savings in water costs. The following calculation will allow you to convert the figures which appear on your water bills (gallons) into average precipitation in inches per day.

$$\text{Precipitation} = \frac{36.7 \times \text{gallons water applied per day}}{1,000,000 \times \text{acres irrigated}}$$

If you will carry out this calculation for your turfgrass area, you may well come up with some surprising and informative results. Here is an illustration. A superintendent told me that according to his water records he was applying

an average of 900,000 gallons of water per day to an 18-hole golf course with an irrigated area of about 60 acres. Is this sufficient irrigation? Is this anywhere near what he needs to buy and apply? Plugging these figures into the above formula shows that he is applying an average of .55 inches of water per day. For the time of year in his area, the water use rate was only .2 inches per day. Since there are some unavoidable losses during any irrigation, he would, of course, have to apply more than the .2 inches of water per day. Assuming an irrigation efficiency of 75 per cent, and this is conservative, he should be applying about .25 inches per day. Actually in using 900,000 gallons per day he is applying more than twice as much as required. Yet because of an inadequate irrigation system he still had dry areas because he could not get uniform distribution of the water applied. To keep these dry spots green, he was forced to apply too much water over most of the course. Better irrigation equipment would have helped him save water, labor, and thus money.

Even in water-short desert areas you sometimes find turfgrass superintendents using a great excess of water. The colored slide shows a situation where water was standing in numerous puddles from the previous irrigation and yet this spot was ready to be irrigated again. Excessive use of water in arid areas may in time produce a very serious problem of drainage followed by salinity. When the groundwater level is near the soil surface, water carrying salts rises to the surface. The water evaporates - leaving behind salt. I have seen cases where consistent over-irrigation is raising the water table and with the water is coming salt. As a result of unwise water management and improper planning for drainage, a large investment is soon to be lost.

Up to this point we have been considering the "how much" and "when" questions. Of at least equal importance is the problem of "how to apply" the water. Other speakers will go into this matter in more detail, but I must call a few points to your attention.

Sprinkler manufacturers are doing their best to provide you with sprinkler patterns which will meet your requirements. A typical sprinkler operated in one spot may give a distribution pattern where most of the water falls near the sprinkler head with less and less degree of distance from the nozzles. This is the so-called "conical" pattern. By properly overlapping the patterns of adjacent sprinklers, a nearly uniform precipitation over the wetted area can be obtained.

It may be helpful to give a few short illustrations of serious water management problems which were built-in when the sprinkler systems were installed. When the turfgrass manager has this sort of built-in problem, it is very nearly impossible to apply the sound ABC's of irrigation. One such case is not uncommon situation where a circular area of turf is equipped with one sprinkler in the center. The sprinkler commonly plugged into the center spot will give most of the water near the center and less and less toward the outside edge. The superintendent with this set-up has a difficult problem. If he applies enough water to take care of the outside edge of the grass area, he is putting on too much for the center of the area. Sprinklers can be obtained which apply a more nearly uniform amount of water over the entire wetted area but this is only a partial solution. Another way to solve this problem is to place three or four sprinklers around the edge of the area so that by proper overlaps a more uniform application can be obtained over the entire area. This arrangement also has advantages in windy situations.

Along strips of grass as on golf course fairways presents similar problems. There are many fairways which have a single line of sprinklers down the center. As with the greens, if enough water is applied to keep the edges of the fairway from drying up, the center strip is badly overwatered and often soggy. With this sort of a system, you have built-in trouble and there isn't much you can do to avoid wet centers and dry edges. This problem is generally not so serious in the humid parts of the country because the rain helps to overcome the lack of uniform water application during irrigations. But in arid areas where one must depend almost entirely on irrigation for moisture, this system causes real trouble.

There are several types of layouts which will improve the uniformity of application on fairways. One is to run the center line down the fairway and then tee off short laterals to form a staggered pattern of sprinklers. Instead of having all the sprinklers in a line down the center, this gives an offset arrangement which helps to reach the edges and reduce some of the water in the middle. This and other systems designed to overcome the poor distribution of a single line system will cost more money initially. In general, money spent for a well engineered and thoroughly adequate system will pay for itself many times in reduced water and operations costs.

A brief comment about traveler sprinklers may be helpful. This is a very useful type of sprinkler, but the performance characteristics of the travelers should be recognized in planning irrigation operations with them. With average nozzling and under typical operation speeds, they apply between .18 and .25 inch of water in a single pass. If the soil is dry, this shallow depth of water will wet a sandy soil only 3 inches deep, a loam about $1\frac{1}{2}$ inches deep and a clay soil less than 1 inch. Unless more than one pass is used, the grass is given very little water to grow on, and it is no wonder it is dry the next day or two thus requiring very frequent irrigations.

In summary, do not depend upon some set of specific recommendations you've heard about or read somewhere. There is no substitute for applying the ABC's of irrigation to your own situation. Short answers to the three basic irrigation questions are as follows:

HOW MUCH TO APPLY?

"Connect" the moisture.

Avoid leaving a dry layer at some distance below the surface. If this layer remains dry, it will cause shallow roots and necessitate frequent irrigations.

WHEN?

Ideally when the grass needs it.

Basically irrigations should be applied only when the grass really needs water. The increased use of automatic systems is giving rise to weed and disease problems where attention is not given to the actual needs of the grass. It is unnecessary and generally creates disease, weed and other problems to apply water every day as is often done with the automatic timers. Most automatic systems can be set to apply water on a schedule which can be adjusted to the actual needs of the grass during that particular portion of the year. Users of automatic systems should have them adjusted in accordance with the ABC's-- Amount of water the soil holds, Behavior of the grass (depth of rooting and type of grass), and Consumptive use or Climate.

HOW TO APPLY?

Use good irrigation equipment and well-engineered systems.

Without good equipment and proper layout it is almost impossible to do a good job of water management. Those of you who have the misfortune of poor equipment and/or poor layouts have built-in trouble. A poor irrigation system is particularly serious in arid regions where you must depend almost entirely on irrigation. A square look at your present water costs and high labor requirements may well justify revamping your present system to permit efficient irrigation.

In closing, it may help us to remember that--

Always Be Careful

WITH WATER

USED UNWISELY IS DANGEROUS!

Irrigation is costly business. Apply your water By Calculation, and--

Always Be Centsible

In planning for irrigations

In operating your irrigation system.