WATER REQUIREMENTS FOR CROP PRODUCTION WITH SALINE WATERS AND SALINE SOILS

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The following statement was made by Dr. C. A. Bower, Director of the U.S. Salinity Laboratory, in a paper presented at Lahore, Pakistan, in November, 1964, "By its very nature, irrigation agriculture is an intensive form of agriculture that cannot survive without a full supply of water". What Dr. Bower inferred here was that any extended period of deficient water supply could be disastrous to any irrigated area because gradual salinization of soils would be almost certain to occur, either through inadequate leaching or by upward movement of salts from ground water, or both.

The supply of water should be adequate to irrigate all cultivated soils within the project, because even fallow soils will gradually become salinized unless periodically irrigated. In any full irrigated area, therefore, it is not enough to consider only the water requirements of crops. The water needs of the entire project must be borne in mind. This includes periodic water needs of idle or fallow land, as well as cropland, for these need irrigation occasionally, if only for control of salinity.

Dr. Bower's remarks are particularly applicable where irrigation waters are saline and where underground waters are saline and quite shallow, as in the middle and lower Rio Grande Valleys of New Mexico and Texas. There is no actual lack of water in the Elephant Butte project, and there will be none within the foreseeable future. When surface water supplies become inadequate they can be supplemented by ground water pumping. What is lacking <u>is</u> an adequate supply of <u>good quality</u> water. Soil and water salinity can rapidly become an acute problem where surface supplies are undependable. We witnessed this during the four-year period, 1952 to 1956, in this area. The Pecos River Valley of Texas is another good example of an area always troubled by salinity because of unpredictable amounts of surface water.

Encroachment of salinity is usually a gradual process, and for this reason the more to be guarded against. Familiarity breeds contempt, and farmers in saline areas sometimes neglect to practice proven salinity control measures. We see local farmers pre-irrigating with salty ground water when project water should be used for this purpose, regardless of its scarcity. They have been told that germinating seedlings are more sensitive to salt injury, but they forget. We see

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farmers irrigating back after planting to be sure their seedbeds do not dry out. They have been told that irrigating back after planting will add salt to the beds, and cooler soils will make seedling disease worse, but they forget.

There is no way to estimate the annual income losses due to the subtle and often unrecognized effects of salinity in this area, but they probably are considerable. Many farmers in West Texas and New Mexico are casually applying waters considered by salinity experts to be so high in salt as to be unusable except supplementally or under special conditions. In other words, we have lived with the salinity devil so long that many have grown careless, and often fail to recognize salt injury until the situation becomes serious.

With this introduction I will try to devote my remarks more closely to the assigned title of my paper. Based on its contents, the title should more properly be "Limitations in Determining Water Requirements for Crop Production with Saline Waters and Saline Soils". As you will see, there is a lot more about this subject that we don't know than what we do know. The phrase "Water Requirements" is easy to say and extensively spoken but far more difficult to determine with any degree of accuracy. Presumably, "Water Requirement" takes in all of the water necessary for normal crop growth, together with provision for adequate leaching plus a suitable allowance for evaporation losses. Let us examine each of these separately.

First, how much water is necessary for "normal" crop growth, and how does salinity affect this situation? Before this can be answered, we need to define "normal" in terms of crop production, and this, too, defies precise definition. Is "normal" the average yield of a partular crop in a given area over a period of years, or does it refer to the production <u>capability</u> of that crop within the climatic limitations of the area? Since average yields are often far below what could be expected to be "normal", I prefer the latter definition. If we choose this, we assume that growth and yields are not being limited by a large number of other factors such as soil, physical and chemical conditions, fertility, insects and diseases, to name a few. To show how just one of these can affect normal growth and therefore water requirement, let us look at upland cotton <u>with</u> and <u>without</u> seedling disease damage on a deep, medium-textured soil.

Without seedling disease, cotton is a tap-rooted crop whose roots can penetrate to depths of 6 to 7 feet if root development is not limited. With deep root systems, research has shown that the crop will be (1) more drouth resistant, (2) will make more total vegetative growth, and (3) will use up to 30 per cent more water during the season than the same crop would use if its root system were restricted to the top 3 feet of soil. This restriction does occur where seedling disease destroys the taproots during the early seedling period, or where nematode damage is serious. With shallow roots, the crop suffers more quickly from water stress, and therefore must be irrigated more often, with consequent higher evaporation losses. The same situation can occur if rooting depth is restricted by other factors such as adverse soil physical conditions, excess salinity at deeper depths, or inadequate preplant irrigation.

Now let us examine the effect of two different varieties of the same crop species upon this thing called "Water Requirement".

Let us take a short-growing grain sorghum as compared to a tall-growing forage sorghum. Transpiration here is largely proportional to total leaf area. The tall forage sorghum has 10 to 20 times as much total leaf area as the small grain sorghum, and will therefore transpire much more total water over the season. Its overall water requirement would be much higher because of this, and because it must be kept in a succulent condition almost until harvest, whereas the grain sorghum would benefit from some moisture stress during the head maturity stage.

Crops which have different lengths of growing season would also have different water requirements, for obvious reasons. Alfalfa requires hugh amounts of water for maximum production because it is growing vegetatively from early spring until late fall. Cotton also falls into the category of a long season crop, but its water requirements could be reduced 1/4 to 1/3 if evaporation from the soil can be retarded. A two-bale crop of cotton actually requires only about 20 inches of water--for growth alone--twice this much usually has to be applied.

Water requirements for plant growth are therefore difficult to define, even in the absence of soil and water salinity. With salinity the situation becomes even more complex. Individual salt ions, absorbed by plants in excess quantities, each have some specific physiological effects. Some effects may be bad, but we also believe some effects may be good, depending upon the particular crop and the particular ion. Plant scientists are only now beginning to realize that these specific effects do exist. As yet not enough is known about this subject to draw any definite conclusions.

In addition to specific ion effects, soluble salts act upon all crops to render soil moisture less available to the plants. In a saline situation, the osmotic pressure of the soil solution is higher than in a non-saline situation. In order for roots to extract moisture from the soil, the osmotic potential of the plant must be higher than that of the soil solution. If it is not higher, moisture can actually move from the plant back into the soil. All plant species have the capability to adjust the osmotic pressures of their tissue fluids within a limited range. Near the upper limit of this range, so much of the plant energy is devoted to moisture extraction from the soil that vegetative growth is greatly reduced. Thus, within this range of osmotic variability, there is no sharp point above which plant growth ceases entirely. Vegetative growth of all species is gradually more restricted as salt concentrations in the soil solution increase. At restrictively high salt levels, growth will be short, and leaves will be thicker, more brittle, and of a darker green or blue-green color. Transpiration will be greatly reduced because leaf stomata will not be fully open and because high salt levels of leaf tissue fluids will physically retard evaporation. Plants in this condition often show little tendency to wilt, and farmers can be deceived into thinking the crop does not need water, when in reality it does.

Different crop species vary greatly in their ability to tolerate salinity. This is related partly to their varying ability to alter the osmotic pressure of their tissue fluids, but partly to other reasons not yet precisely determined. Some salt tolerant species apparently have a more or less selective root permeability, whereby they are able to largely exclude certain salt ions while at the same time absorbing other ions and water with little or no restriction. All of this is lumped together and called "salt tolerance", which term presently hides a great deal of ignorance on the part of plant scientists.

Salt concentrations in the soil can only be controlled by leaching. This is the process of removal of salts by carrying them below the bottom of the root zone in the drainage water. The more saline a water or soil, the more water must be applied to do an adequate job of leaching. This, of course, is water over and above the needs of the crop.

The U.S. Salinity Laboratory has developed a formula for determining leaching requirement based upon salt tolerance of the crop. At best, however, this formula is only a rough approximation because it involves assumptions that may or may not be valid. One of these assumptions that the farmer has to make concerns rooting depth of the crop to be grown. We have already discussed how root depth can be highly variable depending upon many factors.

Soil salinity, under conditions of good internal drainage, usually increases with depth. Highest salt levels therefore are usually found at the bottom of the root zone. Salt levels at this depth are synonymous, by definition, with salt levels in the drainage water. The leaching requirement formula is based upon permissible levels of salt at the bottom of the root zone. But if root depth varies greatly due to other factors, it becomes very difficult to apply this formula. An example will help to show what I mean.

For fair yields of cotton, the permissible level of soil salinity at the bottom of the root zone has been established at approximately 12 millimhos per centimeter conductivity in the soil extract. Keep in mind that this too is only an approximation, at best. Now let us suppose that, under a bed-and-furrow type irrigation, the salt levels at the one-to-five foot depths are 5, 6, 7, 9 and 12 millimhos under the furrow, and 7, 9, 11, 13 and 15 millimhos under the bed. If we choose the salt levels under the furrow, and if the cotton root is 5 feet deep, then the requirements of the leaching formula have been met. If we choose the salt levels under the bed, or if the cotton is 3 feet deep or 7 feet deep, then more or less leaching is required, but how much is difficult to determine.

Another shortcoming of the leaching requirement formula is its assumption of uniform water application across a field. With surface irrigation, uniform application is impossible.

New and better methods need to be devised to predict leaching requirement for salinity control. These should, in some way, be related directly to physiological conditions within the plant itself. The soil and water portions of the plant-soil-water integral unit are primarily physical-chemical systems which can vary considerably both vertically and laterally throughout the root zone. The combined effects of the soil-water system are reflected in physiological responses within the plant itself. The plant, therefore, will be the only reliable indicator of its water needs and its salinity status as well. Up until now, such methods have not been developed.

The best measurements we have of water needs <u>other than for leaching requirement</u> are found in consumptive use data. These data have been compiled for various crops in various parts of the country, and include the combined needs of the plant plus evaporation losses from the soil. They have also been called evapo-transpiration data.

Presumably, water requirements of any crop in a saline situation would therefore consist of consumptive use needs plus whatever is needed for leaching requirement to control salts. But consumptive use data also are approximations at best, and may involve many errors. Here again, a specific root depth must arbitrarily be selected for each particular crop. Moisture leaching below this depth is assumed to be unavailable to the plant. In river valley areas with shallow ground water tables, this error may be considerable. Many deep rooted species such as cotton, alfalfa, grapes, and most trees can obtain a good part of their water from upward movement of moisture from shallow water tables. Difficulty of determining root depth, however, is probably the biggest source of error.

Consumptive use measurements also assume the existence of upper and lower available soil moisture limits called "field capacity" and "wilting plant", which actually may or may not exist depending upon internal drainage characteristics of the soil. At best, these soil moisture values are ranges rather than specific points on the soil moisture curve. Calculations of available water for consumptive use data are based upon the amount of moisture held by the soil between field capacity and wilting point, and can involve considerable error, particularly on texturally stratified soils such as we have in most valley areas.

Consumptive use also is in <u>no</u> way directly related to yields. It is related, rather, to moisture uptake by the plant and therefore only to <u>vegetative</u> growth. Most of you know there is no good relation between seed cotton yields, for example, and total vegetative growth of the cotton plant. Quite often there is an inverse relationship--too much vegetative growth and too little fruit set.

Consumptive use values are useful therefore only as general guides to moisture use by crops. Researchers in the Salt River Valley of Arizona have reported that the mean annual consumptive use of water by cotton over a 9-year period averaged 41.2 inches per year. However, this value varied between years from 27 to over 50 inches. With such great variability between years, how is it possible to come to any valid conclusions concerning water requirements of crops?

Evaporation, too, can vary widely, even from field to field depending upon soil texture, crop management, and climatic variability. Evaporation from soil depends to a great extent upon the amount of total plant cover, air movement near the soil surface, and relative humidity. A low-growing or slow-growing row crop will lose much more water by evaporation because of less shading of the soil. Also, a soil which shrinks and swells badly will lose more water than one which does not, or one that is mulched properly by cultivation.

In conclusion I can only say that it is easy to find fault with existing methods of doing things, but sometimes this becomes necessary in order to show how little we know. Regarding water requirements of crops, we hate to admit it but we must still deal with approximations and generalizations. In order that I might leave you with at least something constructive, I will close with a few of the generalizations. Most of these are simply common sense.

1. A summer-grown crop will require much more water for both transpiration and evaporation than a crop grown in cooler parts of the year.

2. A fast-growing or highly vegetative crop will require more water for transpiration and require more frequent irrigation than a slow-growing crop or one with less total leaf area.

3. The greater the total leaf cover, and the denser the shade, the lower will be losses by evaporation.

4. Evaporation is in proportion to the total wetted and unshaded soil area. Therefore, using double beds or irrigating alternate furrows would result in less evaporation loss because some of the unshaded area would not be wetted.

5. A long-season crop will require more water than a short-season crop of the same type.

6. Deep-rooted crops will consumptively use more water than shallow-rooted crops, but shallow-rooted crops will need irrigation more often. Sprinkler irrigation of shallow-rooted crops could save a lot of water over a season. Surface irrigation of these crops, such as lettuce or onions, is very wasteful of water because too much is usually applied at each irrigation.

7. Crops on coarse-textured sandy soils will usually require water more often than the same crops on finer-textured soils because sandy soils do not hold as much available water.

8. With water of any given salinity, salt-tolerant crops will require less water for leaching purposes than crops with lower tolerance to salt.

9. The saltier the water, the greater the amounts which must be used to control salinity in addition to crop needs.

10. The pre-plant irrigation is by far the best time to apply the extra water needed for salinity control.

And finally, crops grown for seed or seed products, such as cotton, can be considerably stressed for moisture during the seed maturation period without appreciable losses in yield.