California Turfgrass Culture

FORMERLY, SOUTHERN CALIFORNIA TURFGRASS CULTURE

VOL. 14 NO. 1 JANUARY 1964

IRRIGATION SYSTEMS AND PROCEDURES

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PREFACE

Words and phrases used are defined in the following manner:

Soil Porosity or soil pore space.

Spaces occur between soil particles and may contain air or water. Very small spaces (on the order of millionths of an inch) may contain water that is so tightly held by physical forces such as capillarity that plant roots cannot remove the water from the soil under ordinary conditions.

Larger spaces (but still small) may hold water with such force that gravity will not cause the water to drain out but the plant roots can remove it from these pores and then it is replaced by air. The larger pores may contain water during irrigation but gravity and capillary forces will pull the water out of these pores and air passes in.

Porosity is expressed as the % of the soil volume not occupied by soil – e.g., a soil porosity of 50%.

Field Capacity

When gravity has pulled the water out of the larger pores the water remaining in the smaller pores, held there by capillarity, is water at field capacity.

The field capacity of a soil is most frequently expressed as a % of soil weight. The field capacity of most California soils falls between 10 and 30% by weight.

Permanent Wilting Point

When a plant has used practically all of the water it can get out of a soil, it will wilt and not revive unless water is added to the soil. Even at this wilting point some water remains in the soil.

Again this is expressed as % of soil weight and in most California soils it is in the neighborhood of 1/2 of the field capacity.

Available Water

The water between Field Capacity (FC) and Permanent Wilting Point (PWP) can be used by the plant in growth and is referred to as available water. Available water varies from 3/4" to 2-1/2" per foot depth of soil depending on soil texture (see Appendix C).

IS SPRINKLER DESIGN ADEQUATE?

Our sprinkler irrigation systems have improved greatly over the past twenty years. Most improvements have resulted from past failures of then current practices to do a job adequately. Today with increasing numbers of automatic systems going in, our system cost is much higher and is justified by savings in labor. With these expensive systems, we cannot be tolerant of inadequate design.

There are several approaches to the irrigation design problem. The architect is likely to begin by thinking in terms of equipment. He may look up available sprinkler heads and study the data on g.p.m., precipitation rates, and head spacing, and from these design a system.

A soils and irrigation man might arrive at his design with thinking colored by his background. He might start by regarding the soil as a reservoir for water. From the soil texture and the depth of rooting he might calculate the water available to the plant, the time to depletion, and the conditions for replenishment.

An engineer might start with the capacity of the well and the horsepower of the pump as initial working points.

However, regardless of approach, many sprinkler irrigation systems in California are not doing a good job. In this paper, I wish to explore a different approach to the design problem. In this way, I hope to indicate the weakness in some of our designs, and to present some checkpoints that can be used to evaluate whether or not a sprinkler system is adequate. I should like to begin by defining the term evapo-transpiration.

Evapo-transpiration (ET) is a term used to express the combined water lost by evaporation from the soil and leaf surface plus the water lost by plants through transpiration. In a small landscape-the pocket handkerchief-size city garden-ET is influenced by kinds of plants, by nearby buildings, and many other factors, but in the large landscape, such as we deal with in parks, the ET is a function of the amount of energy received from sunshine.

Efforts have been made to write equations that will give the ET. Such equations can be quite complex as they must take into account the extent of cloudiness, wind movement, reflection, etc. However, in California outside the fog belt, the lack of cloud cover and a general uniformity of the climate results in a fairly uniform peak evapo-transpiration for any particular area. Heat energy from the sun which is not reflected, re-radiated, or convected, is used to vaporize water at the rate of about 520 calories of heat for every gram of water evaporated. Thus ET is a function of solar energy, and once the ground is covered by vegetation the sunshine largely determines the water loss - not the kind of plants.

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In the coastal fog belt the amount of sunshine fluctuates and peak use is less predictable.

The following table from the data of Dr. Pruitt, of the Irrigation Department at Davis, gives the evapo transpiration (ET) at Davis for a rye-grass sod for several years.

TABLE I

EVAPO.TRANSPIRATION

Inches of water per month.

Data of W. O. Pruitt - for ryegrass - UCD, Davis, Dalif.

MONTH	1960	1961	1962	AVERAGE	*MAX.* DEVIATION FROM AVE.
Jan.	1.047	0.628	1.136	0.937	32.7%
Febr.	2.153	2.083	1.496	1.911	4.7%
March	3.222	2.953	2.856	3.010	7.1%
April	4.570	4.859	5.100	4.843	5.6%
May	5.582	6.376	6.269	6.076	8.1%
June	8.709	8.213	8.136	8.353	4.3%
July	8.353	8.555	8.187	8.365	2.3%
August	5.643	6.836	6.890	6.457	12.6%
September	5.194	4.993	4.929	5.039	3.1%
October	3.648	3.543	2.828	3.346	15.0%
November	1.568	1.715	1.738	1.674	6.4%
December	0.981	0.888	0.855	0.908	8.0%
TOTAL	50.690	51.642	50.420	50.584	

The peak amount of water used – and for which the capacity of the irrigation system must be designed for various areas in California is approximated in Table II.

TABLE II

Peak water used by plants for some California areas.

AREA	INCHES/ DAY	INCHES/WEEK	
Coastal fog belt	0.15	1.0	
Coastal valleys	0.20- 0.27	1.5-1.9+	(10 miles from fog belt summer use may not differ appreciably from the Central volley)
Delta region	0.25- 0.30	1.9-2.1	
Sacramento Valley and Son Joaquin Volley	0.30- 0.35	2.1-2.4	
Desert	0.32 · 0.42	2.3-3.0	

From Table II we now have a figure for our approximate peak use to use in designing an irrigation system.

The next information that would assist in designing a system would be the infiltration rate or rate at which our soils will accept water. This is often a difficult figure at which to arrive; some coastal and desert sands accept water at very high rates, but in general 1/4 to 1/2 inch per hour is considered a fairly rapid rate. Rates of only hundreths of an inch per hour are not uncommon on many soils.

Perhaps the simplest way to estimate infiltration is to flood a depression in the ground and measure infiltration with a clock and a ruler, or better, flood three or four low areas and average the results. This method gives results that are a bit low and another and better method is given in Appendix D.

The third item necessary to evaluate an effective system is the number of hours in a week that the irrigation system can be run. This may be determined by how the turf is used, or by labor policy (i.e., the work week).

We can now combine these three bits of information into an equation to give us a fourth bit of information.

$$\frac{\text{Infiltration rate (in./hr.)} \times \text{hours/week for irrigation}}{\text{Peak evapo-transpiration (in./week)}} = \text{No. of sprinkler settings.} \quad (1)$$

Or to put it another way – –

$$\frac{\text{No. of acres irrigated} \times \text{peak ET (in./week)}}{\text{Infiltration rate (in/hr)} \times \text{hrs./week for irrigation}} = \text{No. of acres being sprinkled at one time.} \quad (2)$$

To take an example, let's consider an area in the San Joaquin Valley with a peak ET of 2.3 inches per week; an infiltration rate of 1/4 inch per hour; and 12 hours a day x 6 days a week, or; 72 hours for irrigation. Substitutingin equation (1)

$$\frac{0.25 \times 72}{2.3} = 7.8 \text{ or about 8 settings}$$

Or in other terms, if this refers to a 100 acre area

$$\frac{100 \times 2.3}{0.25 \times 72} = 12.8 \text{ acres}$$

and we must have the sprinklers going on 12.8 acres at all times during the 72 hours to get our water on. We will need to be pumping about 1,450 gpm, plus an allowance for losses and inefficiencies = 1,850 gpm. (For gpm see equation3).

Now, this approach is not new to you. In the last few years there has been a general recognition that too much attention was paid to application rates and not enough to soil infiltration rates. As a result, there is an increasing tendency to design systems applying water at 0.1 to 0.2 inch per hour. This is a good change but along with this, there has sometimes been a failure to recognize the impact of this change on the work week. Unless the acreage under irrigation at one time is suitably increased, the irrigation time per week is too long and interferes with use of the land. If the acreage per irrigation is increased, the water man will have more heads to handle and may have further to go between sets.

In spite of lower precipitation rates, the fact seems to be that the sprinkler systems we see are often not able to do the job adequately. Many foremen manage to get the job done by working extra hours in June and July, by special supplemental applications of water in difficult areas, by changing nozzle sizes, or by other artifice which usually involves additional labor cost.

It is my belief that the trouble we find ourselves in is due to a misuse of the bid system. In asking for a bid, we seldom present a sound set of specifications based on good engineering principles. Instead, most systems are designed by the same companies who are later going to bid on them. They know their designs will be competing in price with those of their rivals.

To compound the problem, the supplier is often told to design to the sum which has been budgeted or which will be acceptable, when, in fact, the bid should determine the cost and engineering the design-not cost, the design.

One supplier, in talking with me about these problems, presented what he felt was an example of good practice. It consisted of an automatic system operating a sequence of 30 valves. We figured that in terms of a very good infiltration rate of 1/2" per hour that each valve would have to be on 4 1/2 hours a week in July. Thirty valves times 4 1/2 hours is 135 hours. With 168 hours in a week, this left 33 hours for golf or less than 5 hours a day.

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Another supplier-designer felt his designs often had weaknesses but blamed among other things poor specifications and limited budgets.

To me it seems the best answer to ourpresent problems is to have the system designed by a private engineering firm which is paid directly and whose success depends on continually doing a good job of designing fully functional systems.

With adequate engineering specifications, the bid system should work more nearly as it was intended to.

There is little doubt that many of the future irrigation systems that are installed will have compromises. But you are the one who should be in charge – who decides what compromises can be made in your program and you should not be saddled with hidden compromises based on the whim of a supplier.

It is my hope that in this paper I can help put you in the driver's seat by presenting formulas such as 1 and 2 which help you to quickly spot an unwieldy or unworkable system. I should like to present some other formulas and also suggest some possible liberties we may take when compromise is necessary.

First – what liberties can we take?

(I) With deep-rooted grasses, we can use water from the soil reservoir; thus, Alta fescue, Zoysia, and Bermuda have roots down 4 to 6 feet or more on a deep soil. A clay loam 4 feet deep holds about 8 inches of available water. Thus, if the irrigation system can supply all the needs and keep the soil reservoir filled through May and after August, these grasses can survive June and July and loose more water than irrigation supplies.

(2) The deep rooted grasses can go longer between irrigations. When the irrigation period is long, blades of the grasses will begin to roll and the stoma will close during the middle of the day. The result is a decrease in water use as the irrigation interval is increased.

Points 1 and 2 indicate the value of using bermuda when it is the adapted grass.

(3) If we have an infiltration rate of a few hundredths of an inch an hour, or we have slopes, our equations will not provide a practical answer. There are not enough hours in the week and sprinkler systems do not deliver at a slow enough rate. Here the answer may lie in management. Aerification to provide in every six inch square 1 hole 3/4" diameter x 4" deep will increase the absorbing surface of the soil about 24% and in addition the holes will store about 1200 gallons of water per acre. Thus the design can be deliberately tied to a management practice such as aerification, knowing full well in advance that failure to carry out the aerification will result in failure to adequately irrigate.

(4) Similarly, we may in a bad situation turn a malpractice to a useful practice. The thatch will hold water as a sponge and about 3/4" of thatch will hold about 1/2" of water. In the past, where light frequent irrigation has been used, grass roots have disappeared from the soil in the summer and the grass has rooted in the thatch. With very difficult soil and steep slopes, one can plan to build up a thatch by heavy use of fertilizer and to use this as the water reservoir during the summer peak. You won't expect a vigorous turf but it will be better than a brown sunburned hillside. Good water quality is essential for this borderline practice.

MORE EQUATIONS

Here are some useful check points that help to evaluate the system and whether it can do the job.

$$\frac{\text{Peak ET for one week in inches} \times \text{acres irrigated} \times 453}{\text{Hours per week system runs}} = \text{g.p.m.} \quad (3)$$

Equation 3 gives a check on whether our well capacity is adequate.

$$\frac{(\text{Depth of well in ft.} + \text{height of high outlet} + 120) \times \text{g.p.m.}}{2000}$$

approximate static h.p. (assuming 50% efficiency) (4)

This gives a rough check on the approximate h.p. to provide the g.p.m. calculated in Equation 3. If the pump pumps into a storage tank 24 hours a day, then the g.p.m. to be delivered by the well equals:

$$\frac{\text{g.p.m. (equation 3)} \times \text{hours sprinklers are on each day}}{24} \quad (5)$$

There are many factors which may be considered in the design and operation of a sprinkler system: e.g., how often to run the system? How long to run it at one time? Precipitation rates of available sprinklers and so on - but I find that to express the weaknesses in the design of a system, nothing is so helpful as equation 2 which tells you the fraction of your total acreage which must have water on at one set if you are to do a good job.

In summary then, I think many of our problems are due to failure to get adequate engineering which results in poor specifications. Associated with this is involvement of suppliers in the design so that the bid system breaks down.

There are two more topics I wish to cover under sprinkler irrigation. Many systems going in use today have pop up sprinklers instead of quick coupling units, and this is good. It greatly increases the efficiency and can effect important savings in manpower.

Also, an increasing number of systems are under time clock control so that they are automatic.

DAILY WATERING

With an automatic system, the question arises as to whether any advantage or disadvantage accrues from a daily irrigation cycle to replace each day the water lost by that day's evapo-transpiration, as compared for example to a schedule that replaces 4 times as much every 4 days.

My answer is that daily irrigation is not desirable for several reasons:

(1) Compaction – dry soil is difficult to compact with ordinary traffic. Saturated soil cannot be compacted since the pores are full of water and water is not compressable. However, in wet soil the aggregates will shear and the soil will slake or lose its granular structure under traffic with the result that it puddles and seals off, and the infiltration rate for both air and water is greatly reduced. The soil is most subject to compaction at intermediate levels of moisture near field capacity. With daily irrigation, our soil is in between field capacity and saturation most of the time so traffic results in compaction, loss of

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soil structure, and a sealing of the surface. This in turn results in a less healthy plant cover, more subject to disease, to insects, and weed pests.

(2) Many California soils ate clays which swell upon wetting and shrink upon drying. When such soils dry, they crack and crumble. With alternate cycles of wetting and drying, swelling and shrinking, the soil cultivates itself, keeps up its own structure, improves its own infiltration rate. With daily irrigation, the soil is always wet and we lose the advantages that come from drying cycles.

(3) Many of out most pestiferous weeds are tropical immigrants which thrive under hot moist conditions, for example, crabgrass and spotted spurge. Others are favored just by moisture – e.g. Poa annua, Dallis grass.

IRRIGATION AND DISEASE

My third and last topic covers Irrigation and Disease.

Many temperate zone grasses, such as Seaside bentgrass and Kentucky bluegrass, suffer under California summers. They are subject to two diseases in particular-Rhizoctonia, or large brown patch, and Helminthosporium, or melting out. Helminthosporium will go through as many as three generations in a day with free moisture on the grass surface. There are other evidences from the pathologists that such diseases are favored by moist conditions.

The only logical conclusion is that frequent irrigation must be avoided under disease conditions.

Wrong! The principal damage of these soil-borne fungi is to kill off the root system. The grass quickly turns brown – not from leaf infection – but from drying out. With understanding and skill, the grass can be kept alive by frequent sprinkling until a change in the weather reduces disease vigor and allows the grass to again reestablish a root system. This may mean two or three months of frequent sprinkling if the disease strikes early in the summer.

Such sprinkling cannot be programmed from an office desk but requires frequent, on the site, inspections and personal management by a responsible person.

The problem is to keep the grass alive – with little or no root system – until a change in the weather provides a good growth of new roots. Keeping the grass continually wet is not the answer as this may well lead to loss of the turf from other causes (e.g., the pythium water molds).

The problem can be handled by scheduling an every other day irrigation and carefully watching for the darkening of the grass, or the foot printing of the turf, both of which indicate incipient wilt. On the windy ot hot days when incipient wilt occurs, an immediate light irrigation should be given.

This program does not control the disease – it aggravates it, but it keeps the grass alive and so prevents expression of the disease as large areas of dead brown turf.

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Water and Its Relation to Soils and Crops. Reprint from Advances in Agronomy Vol. II. M. B. Russell, Ed. Academic Press, N. Y. ($4.00).

Turf Irrigation Manual. J. A. Watkins and M. E. Snoddy. Pub. by Telsco Industries. P. 0. Box 18205. Dallas 18, Texas. ($3.00).

APPENDIX A.

The following are data from a golf course using a new automatic sprinkler system which was designed by an engineer.

Total cost was $125,242, including $6,400 for designing fees, Fully automatic for fairways and tees. Greens semiautomatic.

Twenty-eight controllers for fairways and tees, four for greens.

Pop-up sprinklers operate at 65 PSI, discharging 17 gallons per minute, layed out at 65' on the lines with 70' to 75' triangular spacing. Greens use sprinklers (quick couplers), with 9/32" x 1/8" nozzles, discharging 24 gallons per minute.

Two 6" mains with a total of 900 gallons per minute service the system. One 7-1/2 HP booster pump, automatically controlled, services the higher elevations.

Transite pipe used for 3" and larger mains. Plastic schedule 30 PVC for all pipe beyond automatic valves and schedule 40 PVC for all lines under pressure. All pipe highly satisfactory, some problems with plastic fittings.

Two-hundred-fifty automatic valves (hydraulic controlled) and 750 pop-up sprinklers were used.

Labor comparison, before installation, 70 man hours per week were used for watering, after, only 10. Water cost, before installation, 52 acres were watered for $6,800 per year ($130/A) after installation 70 acres for $8,890 ($127/A).

System is designed to deliver a maximum of 1-1/2" of water per week, operating 11 hours 45 minutes per night. Normal use is about 1" so system only operates about 8 hours pet night.

APPENDIX B.

Supplement on water in soils in thin layers.

Today we find increasing numbers of areas of specially built-up soils. Bowling greens, golf courses, roof gardens, planter boxes, park and play areas on top of subterranean garages or water reservoirs, and downtown planters. These areas all have in common thin soil layers (i.e., 1-2 feet of soil). The universal problem associated with these thin layers is poor drainage.

The reason for this failure to drain may be illustrated in the kitchen with a cellulose sponge. Saturate the sponge and balance it on the finger tips until no more, water drains. Tip it up on its side and at once water begins to run out. When the sponge has stopped draining, tip it on end and there will be a new flow of water. When no more drains, hold the sponge by the corner so it hangs by the diagonal and still more water will flow out.

The principle: capillary forces hold the water up, gravity pulls it down. When the soil is deeper (sponge wider) the capillary columns are longer and therefore heavier (gravity pulls stronger) and the capillary forces cannot hold the water against the

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increased pull of gravity. More water runs out. Thus the deeper the soil, the longer the capillary columns and the better it drains-shallow soil drains poorly.

This particular drainage problem is not a problem of drainage rock ot of tile, and increasing these does not help. The problem is one of thin soil layers holding too much capillary water.

To date there have been three research approaches to this problem which I call the Pennsylvania, the Texas, and the California approach.

The Pennsylvania approach will not concern us. Both the California and Texas approaches result in soils with larger capillary pores which hold less capillary water.

The California system is to use a fine sand with a particle size range of 0.5 mm. to 0.05 mm, with no more than 10% above or 10% below these sizes. Ten per cent *or* more long-term organic amendment (e.g., peat-redwood sawdust) is added to this.

The Texas system requires you to have a source of soil, of sand, and of organic matter. You send samples of these to the Texas laboratory and for $100, an analysis is made that leads to a recommendation for mixing the three ingredients to get a soil, which, after it has been compacted, will still have good porosity and infiltration rates.

APPENDIX C.

Useful information:

1 acre foot = 43,560 cu. ft. = 325,850 gal.
1 acre inch = 3,630 cu. ft. = 27,158 gal.
1 million gal. = 3.07 acre-feet
1 GPM = 1,440 gal. peak (24 hr.) day
1 cu. ft/sec = 7.48 gal. per sec = 448.8 GPM = 1.98 acre ft. per day.
1 acre inch per day requires 18.7 GPM continuous flow

$$\frac{\text{ET inches per week}}{\text{Infiltration rate}} = \text{Hrs. per week water to run on one spot.}$$

Available soil moisture (ins.) = Soil moisture per foot x depth of rooting in feet.

Available soil water (ins.) per foot of soil at field capacity.

Sand	3/4
Loam	1-1/2
Clay	2-1/2

SPRINKLER RUNNING TIME
Time to wet soil to depth of one inch
Infiltration rate (inches per hour)

	0.1	0.2	0.5
Sand	38 min.	19 min.	8 min.
Loam	1hr. 15 min.	37 min.	15 min.
Clay	2 hr. 5 min.	1 hr. 1 min.	25 min.

$$\textit{Efficiency} = \frac{\textit{Energy put in}}{\textit{Energy gotten out}}$$

For electric motors we can expect efficiencies of ca 90%. For pumps, efficiencies run 40 to 60%.

Overall efficiencies of the pump + motor run 30 to 50%.

Water application efficiency = average depth of actual water falling on ground between two lateral lines ÷ depth applied as calculated from the actual gallons discharged.

Application efficiencies of 80% are desirable.

APPENDIX D.

A method for estimating infiltration rate.

Most spring rocker rotary sprinklers have a conical pattern and deliver the most water near the sprinkler and less and less, further and further from the head. A single sprinkler with a radius of 30-50 feet is set up with cans placed every five feet. After one hour an observation is made at each can.

With standing water the soil is glistening. At the moment the water moves into the soil the appearance changes from glistening to matte or dull. Using this as a guide, a note is made at each can as to whether:

1. The moisture disappears from the surface before the sprinkler comes around again.
2. The moisture disappears from the surface just as the sprinkler is arriving for its next pass, or
3. Whether moisture is still standing when the sprinkler arrives on the next pass.

Condition number 2 represents water application at just the rate the soil can take it in and the inches of water in the can at the point where this occurs is a measure of the infiltration rate in inches per hour.

CALIFORNIA TURFGRASS CULTURE is sponsored by the Federated Turfgrass Council of California and is financed by the regional councils and other turfgross organizations of the state. Communications should be sent to the editor, Dr. Victor B. Youngner, Department of Floriculture and Ornamental Horticulture, 300 Veteran Avenue, University of Californio, Los Angeles 24, California. The Federated Council consists of the officers of the three regional councils. Subscription to this publication is through membership in one of the regional councils listed below:

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NEW FERTILIZER LABELS COMING*

Plant food users in several parts of the country noticed two sets of numbers explaining plant nutrient (plant food) guarantees on their fertilizer bags last spring. The system, called Dual Labeling, is aimed at a gradual change to a uniform method of expressing primary plant nutrients. The present system is a Mixture of elemental and oxide values (N-P_2O_5 -K_2O). The new method will guarantee all nutrients in the elemental form (N-P-K), according to the American Society of Agronomy.

With dual labeling, a fertilizer tag with the numbers 5-20-20 may also have a set of numbers like 5-8.7 – 16.6. The latter refers to the actual percentage by weight of nitrogen, phosphorus, and potassium guaranteed in fertilizer material.

The present oxide system of labeling phosphorus and potassium makes percentages of these plant nutrients look higher than they really are, because it includes the weight of oxygen combined with the elements. The elemental system is more meaningful and accurate and will eliminate some confusion. It will make the method of reporting phosphorus and potassium conform to that of nitrogen, which has long been reported in the elemental form.

A number of universities have started or will soon start reporting soil test results in both elemental and oxide values for phosphorus and potassium. This is part of the educational program planned by several universities, and an example of a national approach needed from industry and colleges. Simple fertilizer scales will make it easy to convert elemental to oxide values and vice versa.

Currently, fertilizer is labeled as required by law in each state. All states require fertilizer manufacturers to print a guaranteed analysis or chemical composition on the fertilizer bag and/or attached tag. In all states the analysis of complete fertilizers is expressed in percentage by weight in the order of N-P_2O_5-K_2O.

Inaccuracies Of Present Form

Nitrogen is legally expressed on the elemental basis as "total nitrogen" (N). Phosphorus is legally expressed on the oxide basis as "available phosphoric acid." This term, phosphoric acid, designates the available "phosphorus pentoxide "(P_2O_5). Potassium also is legally expressed on the oxide basis as "soluble potash." The term potash designates the soluble "potassium oxide". (K_20).

But, in reality, there is no P_2O_5 or K_2O in fertilizers. Phosphorus exists most commonly as monocalcium phosphate but also as dicalcium phosphate, tricalcium phosphate, calcium metaphosphate or one of the ammonium phosphates. Potassium ordinarily is in the form of potassium chloride or potassium sulfate.

The oxide is not the basic functional unit from either a physical or chemical standpoint. Furthermore, P_2O_5 and K_2O are not involved in plant nutrition. Plant roots absorb most of their phosphorus in the form of an orthophosphate ion, H_2PO_4 –, and most of their potassium as the elemental potassium ion, Kt.

Current oxide labeling of phosphorus and potas-

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**ASA Farm Press News, reprinted from USGA Green Section Record, November 1963.*

CONVERSION MADE EASY

P_2O_5—K_2O conversion Table in Either Percent or Pounds*

This percent or pounds as the Oxide gives	This percent or pounds as P	and This percent or pounds as K	This percent or pounds as the Element	This percent or pounds as gives	and This percent or pounds as K_2O
1	0.44	.83	1	2.29	1.20
5	2.18	4.15	5	11.45	6.01
8	3.49	6.64	8	18.32	9.62
10	4.37	8.30	10	22.90	12.03
12	5.24	9.96	12	27.48	14.43
14	6.11	11.62	14	32.06	16.84
18	7.86	14.94	18	41.23	21.65
20	8.73	16.60	20	45.81	24.05

* Weight of 1 atom: Phosphorus (P) = 30.975; Potassium (K) = 39.1; Oxygen (0) = 16.0

Weight of 1 molecule of the compound:

P_2O_5	K_2O
2 phosphorous atoms = 61.95	2 potassium atoms = 78.2
+5 oxygen atoms = 80.00	+1 oxygen atom = 16.0
141.95	94.2

EVAPOTRANSPIRATION FOR TURF MEASURED WITH AUTOMATIC IRRIGATION EQUIPMENT

S.J. Richards – L.V. Weeks

University of California
Riverside

Tensiometers measuring soil water conditions have been in use since about 1935 and the principles of automatic irrigation using a. tensiometer were established as early as 1943. Commercial development of fully automatic irrigation has progressed first in connection with systems for irrigating turf and ornamental plantings. One such system, available for about 10 years, uses a tensiometer-type hydrostat to indicate a need for irrigation and a small electric clock motor to control the time of day or night when water is to be applied. The duration of irrigation on each of several pipeline sections is independently controllable.

This study was conducted on a 120 x 220-foot turf plot located south of a large intramural field at the University's Riverside campus. Asphalt parking and play areas occupy portions of the east and west sides. To the south is a relatively wide expanse of trees and turf plantings. The immediate turf area is enclosed by shrubbery borders which are watered from separate irrigation lines.

The regular sprinklers on the north half of the area were capped in July, 1961, and a separate irrigation system was installed using gear-driven rotary pop-up sprinkler heads. The porous cup of the hydrostat was located at an average depth of 3% inches. When soil suction exceeded 20 centibats at this depth, a one-hour sprinkling was started at 2 a.m. At each irrigation, an average of 1/2 inch of water was applied automatically by meter readings. The south half was irrigated from a semiautomatic system operating the sprinklers for a specified period each night when turned on manually. A separate meter was installed to measure the water used under this system.

Automation Evaluation

To evaluate the automated control, tensiometers were installed at five depths in two locations selected for average turf vigor. Cans were used to measure the depth of water applied at the two instrument areas and near the hydrostat. One instrument area and the hydrostat area received similar amounts of water, although less than the average for the area as a whole. Water application at the hydrostat and instrument areas was thus measured eleven times directly, and the ratio of application depth to meter reading was obtained. The average ratio was then used to convert the monthly water use, as read on the meter, to the depth of water applied at the hydrostat and instrument areas. Early morning timing reduced the effects of wind on the sprinkler distribution pattern to a minimum.

The table shows monthly irrigation applications for a full year. It also includes rainfall and air temperature records from the Citrus Research Center Weather Station located about one mile away. Correcting the total metered values to the amounts of water applied at the instrument area, and adding the rainfall, gives a reasonable approximation of the monthly evapotranspiration for turf.

CONTINUED

MONTHLY IRRIGATION APPLICATIONS AND VALUES CORRECTED FOR NONUNIFORM DISTRIBUTION OF WATER BY SPRINKLERS, INCLUDING RAINFALL AND AIR TEMPERATURE DATA FROM THE CITRUS RESEARCH CENTER WEATHER STATION

1962	Depth at water from meter readings, inches		Depth of water on instrument area, inches	Rainfall, inches	Evapotranspiration, inches	Mean monthly air temperature °F	Evaporation, inches
	Without hydrostat control	With hydrostat control					
January	2.14	2.17	1.4	1.9	3.3	53	
February		0.57	0.4	3.7	4.1*	51	
March	0.78	2.71	1.8	0.8	2.6	51	
April	8.64	7.76	5.2		5.2	64	
May	9.34	7.45	5.0	0.3	5.3	62	
June	9.16	7.35	4.9		4.9	68	
July	11.35	8.61	5.7		5.7	74	
August	11.96	8.36	5.5		5.5	77	8.5†
September	11.63	5.90	3.9		3.9	73	6.5
October	4.52	4.03	2.7		2.7	64	4.3
November	4.78	3.01	2.0		2.0	60	2.7
December	3.71	2.63	1.7		1.7	54	2.4
Total	78.01	60.55	40.2	6.7	46.9		

* Rainfall probably exceeded evapotranspiration for February.
t Estimated from measurements for only half of August.

Tensiometers with cups located at 1 1/2- 3-, 6-, 12-, and 20inch depths were read daily between 4 and 5 p.m. The readings indicated that the major amount of root activity was in the upper 4 inches of soil. Readings from the two shallower depths showed wide variations. Usually these instruments would read 10 to 15 centibars on the day following an irrigation and would read values above 50 on the evening before an irrigation.

During August, there were occasional days when suction values at these depths exceeded the range measurable with tensiometers. Since only 0.35 inch of water was applied at the instrument area per irrigation, very little day-to-day change in the readings occurred at the 12- and 20-inch depths. However, starting in July and continuing through August, values at the 12-inch depth slowly increased from 7 to about 40 centibars. With more moderate weather conditions in September, readings at the 12-inch depth gradually decreased. By the end of November, values at this depth were similar to those during the first six months of the year.

Some adjustment in monthly evapotranspiration values might be justified because of water storage changes in the soil profile, but the amounts added to the July and August periods would in turn need to be subtracted from the September and October values. The total change of water stored in the 4- to 16-inch layer of soil, based on laboratory data, was estimated to be about 1/2 inch.

Flow Velocity

While flow velocity of water through the profile cannot be measured explicitly, some indication of its direction was obtained by evaluating the hydraulic gradient tending to cause flow. Values of the hydraulic gradient between the 12- and 20-inch depths were such that downward flow occurred from January through June. Monthly means of daily values varied from 0.5 to 0.05. Values for July indicated flow was upward and the monthly mean hydraulic gradient was 21 for the month of August. Values indicating upward flow were 8 for September, 2 for October, and 1 for November. During December, the hydraulic gradient showed downward flow. Conductivity values for the decomposed granitic subsoil, estimated from laboratory measurements, indicated that total flow, between the 12- and 20-inch depths for any one month, probably did not exceed 0.1 inch. Again no attempt was made to correct the amounts of applied water for this transfer in the soil profile.

A 14-inch diameter insulated evaporation pan was installed in August with the water elevation about level with the turf. Evaporation values for the last four months of the year are included in the table. All of the measurements indicated were made while the irrigation program was completely under automatic control.

The automatic controller called for irrigation over 100 times during the year. This frequent irrigation with relatively low volume applications per irrigation appears to be well adapted for making evapotranspiration measurements. With relatively few additional modifications, this approach could be used to measure evapotranspiration for the wide range of conditions under which turf is being grown.

Reprinted from California Agriculture, July, 1963.

NEW FERTILIZER LABELS COMING

CONTINUED FROM PAGE 6

sium makes percentages of these two plant nutrients look higher than they are. The chemical compound P_2O_5 contains 5 oxygen atoms for each 2 phosphorus atoms and has a molecular weight of 141.95 of which only 61.95 parts are actual P. The chemical compound K20 contains 1 oxygen for each 2 potassium atoms and has a molecular weight of 94.2 of which only 78.2 parts are actual K. Oxygen's weight of 16 therefore makes up the difference in weight (see footnote below Table 1).

Nutrients cannot be put into fertilizers as N, P, and K elements, but as chemical compounds which are stable. That's why we do not and cannot have fertilizers containing 100 percent plant nutrients. But, with the current system of expressing P and K as oxides, high-analysis fertilizers of the future could have an analysis of more than 100 percent of plant nutrients (plant food).

The important information in a fertilizer guarantee is the actual amount of plant nutrient in the bag. For this purpose the elemental system is best.