Using your lawn as a Biological Tensiometer: Irrigation with a standard amount of water but at varying time intervals

Scheduling irrigation by lawn demand.

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Update of earlier versions that appeared in Hebrew in:
Gan veNof (Garden and Landscape), May 1983, p. 521
Mayim ve Hashkaya (Water and Irrigation), 1998/9 No. 383, p. 36 (monthly publication of the Israel Water Works Association)

Introduction

Observations and experiments on lawn irrigation have been conducted at Kibbutz Nir Oz since the late 1960s. The local soil is a deep sandy loess; annual potential evaporation amounts to 1,990 mm and average precipitation is 250 mm a year. Our data set has given us the opportunity to develop an accurate and water-efficient protocol for general use. A tensiometer is an instrument used for measuring the energy status of soil water which tells us about the ability of plant roots to extract that water. There are many mechanical tensiometers on the market but the simplest and, arguably, most accurate method is to use the plants themselves. Many lawn grasses are highly water responsive and easily recover from water stress. Thus, the lawn acts as a 'biological tensiometer'.

Basic Assumption

Since we are not interested in obtaining a grass sward with maximum growth, with the exception of sports fields, we can delay irrigation until the first signs of water stress. These are expressed as changes in the color of the grass from fresh to dull green and these signs disappear rapidly after irrigation.

Table 1. Grass species and varieties tested.

Species	Common name	Varieties
Pennisetum (Hochst. ex Chiov.)	Kikuyu grass	
Stenotaphrum secundatum (Walter)	Buffalo grass	Common, Dwarf
Zoysia		
Z. matrella (L.)		Emerald (*Z. japonica* × *Z. matrella*)
Cynodon dactylon (L.)	Bermudagrass	Santa Anna, Bradley, Gilboa
Paspalum vaginatum (Sw.)	Seashore paspalum	

The lawns at Nir Oz are planted with mixtures of these species and varieties.

Irrigation

Watering all the lawns at Nir Oz takes 22 dusk-to-dawn time periods. This is termed the 'irrigation cycle'. Each lawn is usually irrigated once every 25 to 35 days, depending on the condition of the grass (30 days on average), with a fixed application of 130 mm.

In principle, the first irrigation cycle after the rainy season is started when the first signs of water stress are detected. However, experience has shown that irrigation should be started on the first lawns before they show water stress to ensure that the last irrigation of the cycle will not be not unduly delayed. In the Autumn, watering finishes with the first rains; this accounts for the differences between lawns in terms of the number of irrigation cycles applied and for water wastage on those lawns that are the last in the irrigation cycle.

The depth of the active root zone is 1.5 m in all the species examined (Adar, 1979; Lipschitz, 1980). In dry years, when the boundary zone of moist soil (wetting front) is less than 1.5 m at the end of the winter, the time between irrigations must be reduced; accordingly, the time between irrigation cycles is shortened to 22 days. These conditions result in a continuous irrigation cycle.

Irrigation Coefficient (See Glossary)

The Irrigation Coefficient (IC) is determined as the ratio of plant transpired water to evaporation from a Class A evaporation pan (See Glossary) in the Nir Oz area, expressed as a percentage. IC values for the varieties tested range from 74% to 101% in the Nir Oz area (experiment conducted in June, Lipschitz 1980) .

Table 2. Irrigation Coefficients of the Various Types of Grass (Lipshitz, 1980)

Species	Coefficient
Pennisetum clandestinum	74%
Cynodon dactylon cv. Santa Anna	74%
Stenotaphrum secundatum cv. Common	77%
Zoysia matrella	80%
Stenotaphrum secundatum cv. Dwarf	80%
Cynodon dactylon cv. Bradley	82%
Cynodon dactylon cv. Gilboa	82%
Zoysia cv. Emerald	95%
Paspalum vaginatum	101%

Actual Water Consumption

Irrigation and rain provide between 62% and 92% of the needs of the Nir Oz lawns. This amount – equivalent to 62% - 92% of the IC listed in Table 1 is termed the 'actual water consumption factor'. This begs the question of how the grass meets the rest of its water needs? The answer is that by utilizing the remaining soil moisture at the end of winter, deduced from observation that the Wetting Front (see Glossary) rises from 1.5 m in early spring to 0.9 m before the onset of the rainy season (we note that in most years the local precipitation does not penetrate below the lower limit of the root zone – 1.5 m).

No connection has been found between the actual water consumption factor, on the one hand, and total precipitation, potential evaporation, and the length of the summer, on the other.

We have found that extending the time between irrigation cycles from 7 days to c. 30 days can yield a savings of 15% - 25% in water expenditure annually, depending on the required quality of grass. Similar results were obtained by Stanhill and Mantell (1966). In agreement with the latter study, Adar (1979) and Lipschitz (1980) showed that actual water consumption is higher at the start of each IC than in the middle .

Grass lawn as a biological tensiometer

For lawns where fast growth is not required, irrigation can be delayed until the first signs of water stress, indicated by a colour change from fresh to dull green. These signs, easily observable in the early afternoon when the heat is greatest, rapidly after irrigation is applied with no permanent damage to the grass. This finding is supported by the work of Harav (1977). However, it should be noted that this method is not suitable for lawns subject to heavy use (such as sports fields), where a maximum growth rate is required.

Calculating the water dose

First Alternative (Professional)

1. Test the soil to determine soil depth, soil texture, and available water content.
2. In Spring water to a maximum depth of 1.5 m if Winter precipitation has not penetrated to this depth.
3. With the appearance of the first signs of water stress, irrigate with an amount corresponding to approximately 80% of the available water content as determined in Step 1. This is because, below a certain depth, roots are incapable of utilizing all the available water content; see Adar 1979, Lipschitz. 1980.
4. With the appearance of further signs of water stress, irrigate with an extra dose as in Step 3. Three days later, determine the depth of the wetting front (Glossary) and select one of the following alternatives:
   a. The moisture has penetrated below 1.5 m – reduce the dose of the next irrigation.
   b. The moisture has penetrated to a depth of 1.5 m – continue irrigating with the same quantity.
   c. The moisture has penetrated to a depth of less than 1.5 m – in arid areas, increase the quantity applied. In rainy areas, only increase the quantity if the wetting front has risen very considerably; otherwise it is desirable to reach the autumn with a wetting front above 1.5 m to maximize exploitation of precipitation. The rainier the area and the heavier the soil (i.e. the greater the soil's water holding capacity), the higher the wetting front may be allowed to reach in early autumn, since our aim is to have a large volume of soil to accumulate rainwater at the depth of the root zone.

Second Alternative (Amateur)

For the amateur an alternative protocol is described below. Let us assume a lawn area of 100 m^2:

1. Install a separate water meter for the lawn.
2. Note down the quantity of water supplied in the current irrigation cycle (number of days between irrigations). Example: 7 day cycle, 3 hours of watering, meter reading 3.2 m^3.
3. Wait for the first signs of water stress and increase the amount by 50% (to 4.8 m^3).
4. Count the days after irrigation to the first signs ofdehydration . There are now two alternatives:
   a. At 10 days after the Step 3 irrigation, irrigate again with 4.8 m^3. After a further 10 days, increase the amount to 6.4 m^3. If signs of water stress are visible 14 days later, irrigate again with 6.4 m^3. Continue increasing the amount of water by 1.6 m^3 and the length of the cycle by 4 days. If conditions are similar to those at Nir Oz, in Spring and Autumn an irrigation dose of 13 $m^3$and IC of 30 days will be achieved (in summer the cycle may have to be shortened; see Introduction).
   b. Despite increasing the water quantity to 4.8 m^3, return to a 7 day cycle. Continue using the increased amount (4.8 m^3). If, in the meantime, the grass develops a stronger root system, the present cycle should suffice for 10 days. Next, continue as explained in (a). If it becomes necessary to return to the 7 day cycle, it may be assumed that 4.8 $m^3$is too great a dose, a possible reason being that the soil is shallow or sandy and cannot retain all of the increased volume of water in the root zone. In such cases the amount applied should be 3.2 m^3in a 7 day cycle.

It is also important to carefully monitor for the appearance of early signs of water stress in individual patches of the grass. The reasons may be as follows:

1. A fault in the design or setting up of the irrigation system. This can be checked by placing a number of containers (of uniform size and shape) both in the dehydrated patch and outside it to collect the irrigation water. If all of the quantities collected are not the same, then the fault lies with the system, which can then be adjusted.
2. If it is established that the fault does not lie in the system, use a soil drill to check the depth of wetting inside and just outside the early-wilting patches. If it is found that the

irrigation has not penetrated as deeply there as elsewhere, this points to soil compaction, thatch (see Glossary), or soil fungi (rare). Again, the cause of the patch must be dealt with. However, if the reason for the patch is that it consists of sandier soil than the rest of the lawn, it is generally difficult to remedy the situation and the whole lawn must then be irrigated as if its requirements were the same as those of the patch. If the patch is small, it may be worthwhile replacing the soil inside it.

3. If none of the reasons listed in (1) and (2) account for the early dehydration of a patch, one may assume that the cause is some disease. This should be diagnosed and treated, and irrigation of the rest of the lawn should proceed as usual.

Application of the irrigation method

After the correct water dose has been established, with the first signs of water stress we irrigate with the full dose of water. We irrigate again when signs of water stress appear again, and so on.

In summer, the watering system and schedule are programmed in such a way as to make it possible to apply the shortest irrigation cycle and deal with possible mishaps.

Advantages

1. The lawn acts as a 'biological tensiometer' that can be read by any gardener with a minimum of experience.
2. Irrigation is applied in response to the actual needs of the grass without requiring an evaporation pan data (which some regard as of doubtful accuracy) or tensiometer.
3. Intervals between irrigations are maximized, thereby optimizing water use, reducing stress due to compaction of wet soil, and increasing the lawn's resistance to episodes of extreme drought.
4. In areas of low rainfall, where seasonal precipitation is unable to wet the soil down to the full depth of the root zone, moisture deficits can be made up in early Spring, alleviating the need for water during the months of peak demand in the Summer.

Disadvantages

1. In gardens with highly variegated soil types and depths (shallower than the potential root

zone, for instance), adapting the irrigation cycles to the different soil types can be problematic.

2. Calculating the water dose requires some minimal knowledge of soil/plant/water relations as well as investment in time and labor.

Conclusions

Since the entire expanse of lawn acts as a biological tensiometer that can be 'read' continuously, it is possible:

1. to provide irrigation (in terms of quantity and length of cycle) to suit the actual condition of the grass rather than based on prior calculations by the planner;
2. to identify faults in planning and maintenance of the irrigation system and detect localized drops in water penetration due to soil compaction, thatch, or soil fungi.

Acknowledgements

I would like to thank Dominic Standing for his helpful comments and suggestions.

Glossary

1. **Class A evaporation pan**: a pan of a certain size filled with water and placed at a standard point in the field. Evaporation from the exposed surface of the pan is measured at fixed intervals.
2. **Irrigation Coefficient (IC):** due to its structure, height and physiological features, the plant evaporates less water than the surface of an evaporation pan. For each plant variety and depending on local conditions and specific growth factors, there is a fixed ratio between actual evaporation from the plant and evaporation from a standard pan; this ratio is the irrigation coefficient.
3. **Field capacity:** the quantity of water that soil can hold against the force of gravity, which causes moisture to drain down to deeper levels. This water is retained at a tension of between 0.01 and 0.03 MPa (Megapascal, 1 MPa = 10 atm) depending on soil typel.
4. **Wilting point:** the water content of the soil at a tension of 1.5 MPa, a tension at which

most plants are unable to absorb water into their roots and consequently wilt and do not recover – as opposed to temporary wilting often observed in the afternoon, from which plants later recover.

5. **Available water content:** the range of water content that lies between the wilting point and the field capacity. This is the sum total of the water available to plants. Available water content is expressed as a percentage of the soil's weight or volume.
6. **Wetting front**: horizontal boundary between moist soil and dry soil. The depth of this boundary varies depending on the degree of replenishment of soil moisture by precipitation or irrigation; maximum replenishment corresponds to 100% available water content.
7. **Thatch**: thatch is a compressed layer of grass stems, dead roots, clippings, and debris that settle on the ground and slowly decompose and/or accumulate over time; prevents water and nutrients from reaching the soil.

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