moisture is insufficient to maintain turgor. As a result, the plant rolls its leaves and wilts to conserve moisture.

The method of waiting until symptoms of moisture stress appear before watering does have some drawbacks. Certain areas or patches of turf tend to wilt before others due to poor irrigation distribution or due to localized dry spots or poorly developed root systems. Adequately irrigating these "hot-spots" may result in wasting water. Managers of golf greens also cannot afford to wait until these symptoms occur because unacceptable turf quality may result. Waiting until visual symptoms appear before irrigating is best used for low maintenance use areas such as golf course roughs and, possibly, fairways.

Evaporatory Pans

Another method of irrigation scheduling is the use of evaporatory pans. A United States Weather Service Class A Evaporatory Pan is 122-cm in diameter and 25-cm deep and is supported 15 cm above the ground. Evaporatory pans are filled with water, placed in a representative location, and water loss is measured over time. The amount of water evaporating from the pan correlates to the amount lost by the turf from evapotranspiration. This correlation is generally accurate except during windy conditions. Wind tends to exaggerate the amount of water lost by the evaporatory pan compared to actual ET rates.

Although this water loss correlates to ET rates, in general turf plants use less than the amount evaporated from the pan. Therefore, the amount of irrigation applied should be 55 to 80 percent of the depth lost from the evaporatory pan. More specifically, warm-season grasses generally use 55 to 65 percent and cool-season grasses from 65 to 80 percent of the depth lost from pan evaporation.

Tensiometers

Tensiometers are used to measure soil water status. Tensiometers are tubes filled with water with a porous ceramic cup at the base and a vacuum gauge at the top. As soil moisture is depleted, a tension is formed between the water in the soil and water in the tube. This tension is registered by the vacuum gauge and provides a relatively accurate reading on soil moisture availability, registered in centibars. Soil field capacity (water "held" after drainage) generally exists between 5 to 30 centibars with higher values indicating decreasing soil moisture levels. Tensiometers remain accurate when tensions are above 80 centibars. Commercial tensiometer models are available that can automatically regulate irrigation systems based on at a pre-set tension threshold.

Drawbacks of tensiometers include their readings only being appropriate in the area adjacent to the placement of the ceramic tips. This necessitates multiple units over different soil types, irrigation zones, terrain and increases labor costs. Tensiometers may affect play. Placing tensiometers in the center of golf greens also poses a problem since this interferes with plant and management practices such as aerification. Tensiometers require maintenance periodically and they have to be removed during periods of cold weather to prevent ice formation in the tube. Adequate contact between the ceramic tube and surrounding soil also is essential.

Additional Methods

Other methods of estimating soil moisture are available through gypsum, nylon, and fiberglass blocks which contain electrodes measuring electrical resistance. The porous blocks are buried in the soil and water is allowed to move in or out of them depending on soil moisture tension. These are accurate when measuring low soil moisture content and can be left in place for extended periods. However, they are sensitive to saline conditions, and like tensiometers, measure soil moisture only at the area immediately surrounding them. They also are not as accurate in predominately sandy soil.

Rough soil moisture estimates can be determined by using a soil probe to feel the depth of moisture. Resistance to penetration of a sharp object such as a screwdriver also can be used. Rain gauges are necessary measurement tools to track natural moisture inputs on a golf course.

Predictive models based on weather station data and soil types also are available. These are relatively accurate and applicable especially as long-term predictors of yearly turf water requirements. Models, however, are only as effective as the amount of data collected and the number of assumptions made. Weather data such as rainfall, air and soil temperature, relative humidity, and wind speed are incorporated into certain model formulae and estimated soil moisture content is made. Accessible weather data must be available as well as specialized computer equipment and programs.