Understanding the Hydrology of Modern Putting Green Construction Methods

Dr. Ed McCoy
Ohio State University

Executive Summary

This research program investigates putting green construction issues and their impact on the hydrology of the root zone. The hydrologic processes include water infiltration, redistribution within the root zone, drainage, and uptake by the turf. The study is subdivided into Phases I and II. Phase I focuses on water redistribution and drainage as influenced by presence or absence of a gravel layer, root zone composition and green slope. Phase II focuses on turf water use in a USGA profile as influenced by root zone composition (unamended sand, sand + peat, sand + peat + soil) and depth (9 and 12 inches).

The Phase II research of this report was conducted as a water balance study wherein daily measurements were made of rainfall or irrigation amounts, root zone water contents, drainage volumes, and turf evapotranspiration (ET) from the experimental greens. Additionally, water was withheld for varying intervals at two times during the study. During these rain free intervals, turf response was additionally recorded using digital photography for subsequent image analysis and using spectral reflectance measurements. End of season measurements include root weights and soil physical properties.

Sand texture (coarse vs. fine) of the unamended root zones did not yield any appreciable difference in soil moisture throughout the study period. There was, however, an interaction between sand texture and amendment. For coarse sand mixes, progressively higher soils moistures were observed with increased levels of amendment. Thus, the peat + soil amendment yielded the highest soil moistures. For fine sand mixes, the ordering between peat + soil and peat alone was reversed so that amending fine sand with only peat resulted in the highest water contents.

During rain free intervals, turf water uptake occurred throughout the root zone regardless of root zone depth. Consequently, the 9-inch root zone exhibited lower soil moistures than the 12-inch root zone for all measurement depths. Further, we did not observe strong evidence for the creation and/or maintenance of perched water in the experimental root zones during the entire study period.

Selected treatments of this study yielded turf ET differences during the two rain free intervals. During the first and more severe rain free interval the 12-inch root zone showed higher cumulative ET than the 9-inch root zone. Additionally, the unamended sand had lower cumulative ET as compared with amending the root zone with peat. The peat + soil amendment was intermediate, particularly for the 12-inch root zone. A similar amendment effect was observed during the second rain free interval.

Understanding the Hydrology of Modern Putting Green Construction Methods
Progress Report
November 2000

Dr. Ed McCoy
Ohio State University

Most putting greens constructed today have high sand content root zones to minimize soil compaction. This root zone is placed within an excavation of the soil native to the site that commonly has a much smaller hydraulic conductivity. An obvious challenge with this form of greens construction, is achieving the proper balance between air-filled and water-filled porosity both uniformly across the green and throughout the turf-growing season. Consequently, to aid their hydraulic performance modern putting greens also employ some form of soil profile design. The putting green soil profile extends from the putting surface to the native subsoil and includes 1) a variably amended, but specified root zone sand, 2) either none or multiple, specified gravel layers, and 3) a subsurface drainage system. Issues with greens construction that may influence hydraulic performance include the presence or absence of gravel layers, the depth of the root zone and gravel layers, the precise composition of these layers, the drainage elements and their placement, and the effects of sloping surfaces fundamental to green design.

This research program, co-funded by the USGA and GCSAA, investigates several putting green construction issues and their impact on hydrologic processes within the root zone. These hydrologic processes include water infiltration, redistribution within the root zone, drainage, and uptake by the turf. The study is subdivided into Phases I and II. Phase I focuses on water redistribution and drainage as influenced by presence or absence of a gravel layer, root zone composition and green slope. Phase II focuses on turf water use in a USGA profile as influenced by root zone composition and depth.

Experiments supporting the Phase I study were previously conducted in 1997 and 1999. Our plan was to conduct these experiments during alternate years and, therefore, no observations were made in year 2000.

The Phase II results of this report examine turf water use as influenced by green construction method. This was conducted as a water balance study wherein daily measurements were made of rainfall or irrigation amounts, root zone water contents, drainage volumes, and turf evapotranspiration (ET) from the experimental greens. Essentially, during a 3-month period, an accounting was made of all water entering and leaving the root zone through all available pathways. Additionally, water was withheld for varying intervals at two times during the study. During these rain free intervals, turf response was additionally recorded using digital photography for subsequent image analysis and using spectral reflectance measurements. End of season measurements include root weights and soil physical properties.

Phase II Methods

This study employs 6 root zone mixes and 2 root zone depths constructed as a 2-tier soil profile with a USGA specified gravel layer overlying the root zone. Two of the root zones are 100% sand where the sands are relatively coarse and fine as based on USGA specifications. Two root zones are sand:sphagnum peat blends using the coarse and fine sand materials, and the final 2 root zones are sand:soil:peat blends again using the coarse and fine sands. Each root zone is placed in a 2-tier profile with root zone depths of 9 or 12 inches. Each root zone mix and profile depth treatment combination is replicated 3 times for a total of 36 experimental greens. The treatments were arranged in a randomized complete block design.

The water balance and turf water use study required a complete accounting of all water inputs and outputs from the root zone. For this reason, the greens soil profile was constructed within 6-ft diameter non-weighing lysimeters where drainage from individual greens was collected in an adjacent service pit. Daily rainfall was recorded from a rain gage adjacent to the site. Irrigation inputs to each green was recorded by placing collection tins on each green prior to an irrigation event. Subsequently, irrigation depths were recorded from the tins. Finally, TDR probes for soil moisture measurement were located at 3 and 6 inches depth for the 9-inch root zone and 3, 6 and 9 inches depth for the 12-inch root zone. Daily turf ET was determined from the change in water content within the root zone minus the drainage depths. The greens were seeded to Penncross creeping bentgrass in the spring of 1998 and maintained at a mowing height of 5/32th inch.

At two rain free intervals during the study period (from days 201 to 210, and days 220 to 230) irrigation was withheld to generate a dry down cycle. In addition to the water balance measurements, digital photographs of the turf surface were collected daily (except weekends) from each experimental green. We intend to use these photographs along with image analysis software to quantify turf drought stress. Also, on selected days during the rain free intervals, spectral reflectance measurements were collected from each green. Again, our aim is to examine the spectral reflectance data to determine its suitability to assess minor turf drought stress symptoms (i.e. wilting). Analysis of data from digital images or from spectral reflectance measurements has yet to be conducted.

Finally, at the end of the study period, soil cores were collected from the 1 to 3 and 6 to 8 inch depth increments from each green. Turf roots were collected from these cores, dried and weighed. Double ring infiltration measurements were conducted on each green and soil cores were collected for water retention measurements. These end-of-season measurements have yet to be analyzed.

Phase II Results

The bulk of the water balance study spanned the period from day 192 to 258 of the year 2000. Soil water contents and rain plus irrigation depths are shown in Figs 1 to 4 for the various treatments and for the shallowest and deepest measurement depths. In these figures, the rain plus irrigation depths (inch) are show as bars for a given day, and the soil moisture measurements (% by vol.) are shown as lines. Within this entire period, there were two rain free intervals (days 201 to 210, and days 220 to 230) where soil moistures declined and a single interval (days 231 to 242) of frequent rain, where soil moistures increased and were maintained at comparatively high levels. Throughout, soil moistures ranged from a minimum of about 6% by vol. to a maximum of about 27% by vol.

Sand texture (coarse vs. fine) of the unamended root zones did not yield any appreciable difference in soil moistures throughout the study period. There was, however, an interesting interaction between sand texture and amendment. For the coarse sand mixes throughout the water balance period, progressively higher soils moistures were observed with increasing levels of amendment. Thus, the peat + soil amendment yielded the highest soil moisture and the unamended sand yielded the lowest soil moisture with the peat alone intermediate. For the fine sand mixes, on the other hand, the ordering between peat + soil and peat alone was reversed. Thus, amending the sand with only peat resulted in the highest water contents for the fine sand mixes. Further, this interaction was consistent regardless of the root zone depth employed in the study.

During the rain free intervals, water uptake by the turf occurred throughout the root zone regardless of root zone depth. This is illustrated by the consistent decline in water content for both the shallow and deepest measurement depths. Consequently, the 9-inch root zone exhibited lower soil moistures than the 12-inch root zone for all measurement depths. This observation was also generally true regardless of sand texture and amendment. During the frequent rain interval, on the other hand, the 9-inch root zone had water contents very similar to the 12-inch root zone except for the fine sand mixes at the 3-inch measurement depth where the 9-inch root zone was about 4% by vol. wetter. Consequently, the shallower root zone did not lead to an appreciably wetter soil condition.

One possible explanation for the absence of excess moisture in the 9-inch root zone is increased drainage. This increased drainage is indicated in Fig. 5 where cumulative drainage is shown for selected treatments spanning the interval from day 221 to day 230. This interval follows a heavy rain on day 219 and shows overall greater drainage for the 9 vs. the 12-inch root zone. Whereas this aspect needs further examination, there also appears to be a sand texture and amendment interaction effect on drainage amounts.

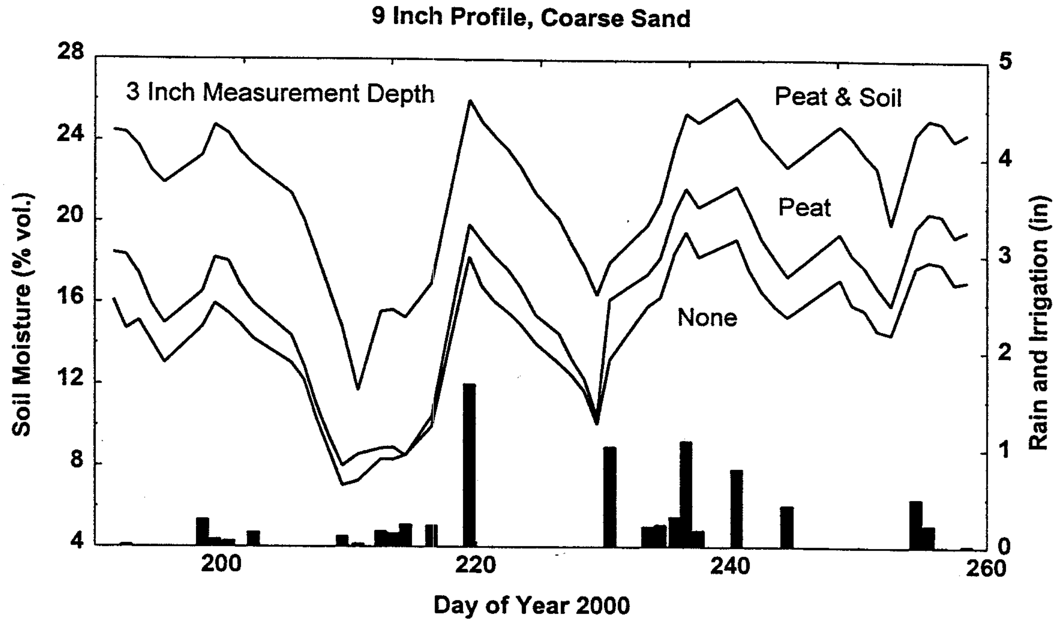
We did not observe strong evidence for the creation and/or maintenance of perched water in the experimental root zones. Under a perched water scenario, we would expect a substantial increase in soil moisture with depth. For all fine sand mixes and both root zone depths, deeper measurements depths yielded higher water contents only during the frequent rain interval (days 231 to 242) and then by no more than about 4% by vol. A similar tendency was observed for the coarse sand root zones, but in this case higher water contents with depth were only observed for the unamended sand. A possible explanation for this would be the presence of slight irregularities in the interface between the root zone and the gravel. These irregularities would occur from to the mix filtering slightly deeper into the gravel at isolated locations across the green. The result would be the formation of drip points that would continue to slowly drain the root zone immediately above their location. Consequently, lateral water movement toward these loci would eventually reduce or nearly deplete the perched water throughout the profile. Clearly, more research is needed to substantiate this speculation.

Selected treatments of this study yielded turf ET differences during the two rain free intervals. During the first rain free interval (days 201 to 210) from 19 to 28 July, root zone depth and amendment yielded significant difference in cumulative ET while sand texture did not (Fig. 6). Consequently, data for both the fine and coarse sands were combined. In this case, the 12-inch root zone depth showed higher cumulative ET as compared with the 9-inch root zone. Since water was taken up throughout all depths of the root zone, the shallower depth would have less of a water reserve. Additionally, the unamended sand had lower cumulative ET as compared with amending the root zone with peat. The peat + soil amendment was intermediate, particularly for the 12-inch root zone. The second rain free interval (days 220 to 230) yielded less severe drought as compared to the first. This is evident from the soil moisture data where water contents are higher at the beginning of this interval and soil moisture is not as thoroughly depleted. Consequently, neither sand texture or profile depth had a significant influence on cumulative ET (data not shown). Sand amendment did, however, influence ET through this interval where, again, the unamended sand had the lowest ET and the peat amended sand the highest.

The treatment induced ET differences show greens construction effects on turf drought avoidance. Comparative lower ET over a rain free interval indicates an earlier onset of drought stress and higher ET would indicate relative drought avoidance. Even though rather frequent rain precluded the occurrence of severe drought conditions, the use of amended sands and a 12-inch root zone clearly assisted in the avoidance of drought by the turf.

Plans for 2001

Our plans for the 2001 season are to repeat the water balance study of Phase II. Further, if weather conditions allow, we intend to superimpose a more typical and rational irrigation protocol during the data collection period. We also intend to conduct a drainage study using the Phase I greens. This would be similar to the measurements collected in 1997 and 1999, but with a reduced treatment set based upon the most pertinent experimental variables from the earlier studies. Other more routine analysis in support of both Phases of this research will also continue.



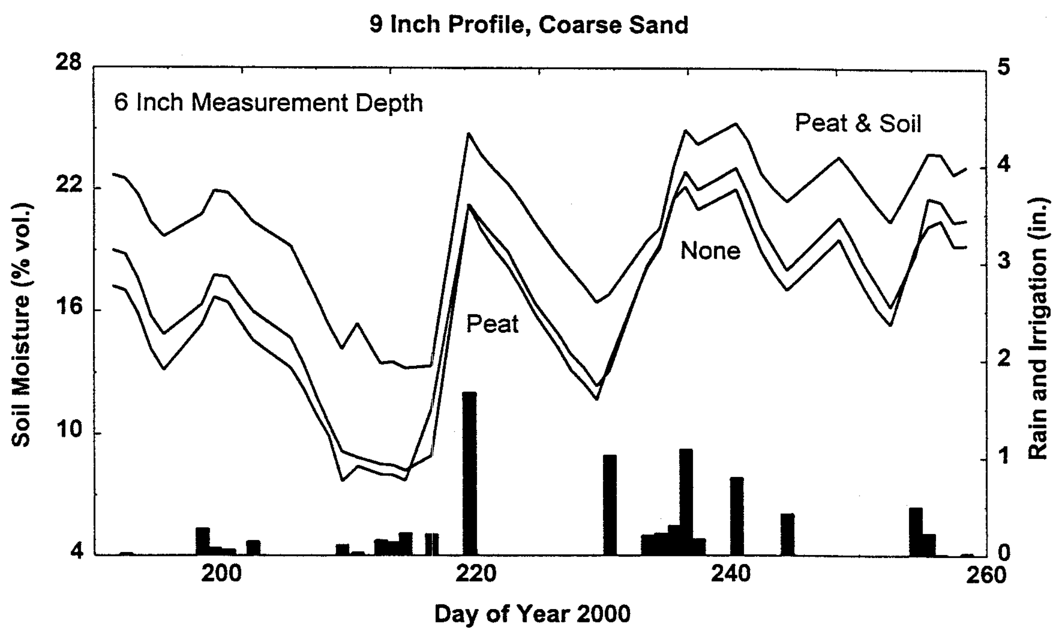
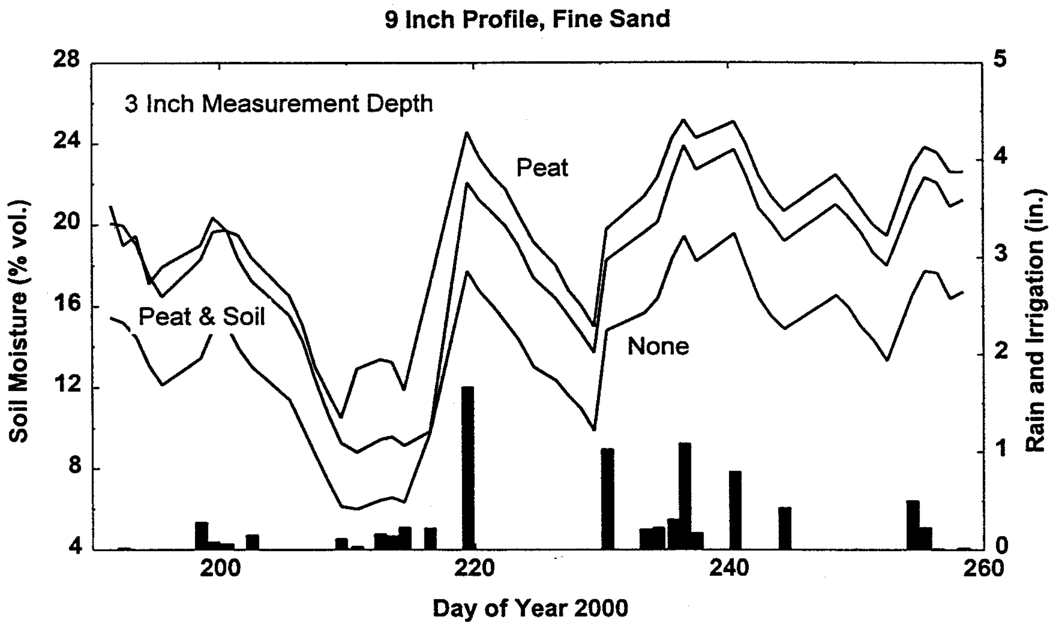


Figure 1. Soil moisture (% by vol.) and rain plus irrigation depths (in.) for the period from day 192 to 258 of year 2000. Data is shown for the 3 and 6-inch measurement depths for the 9-inch root zone containing the coarse sand mixes.



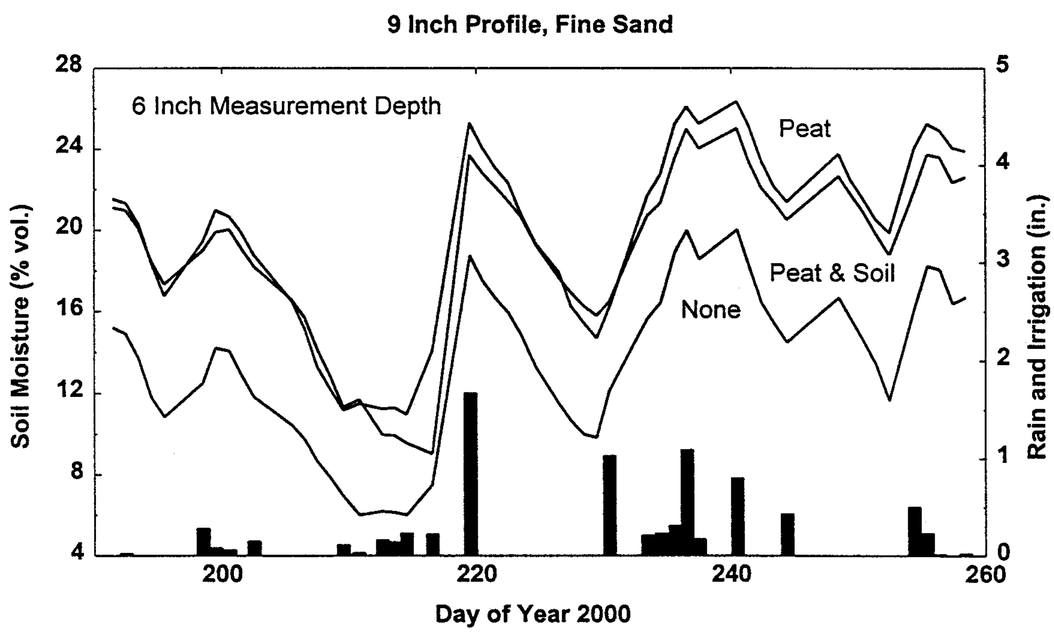
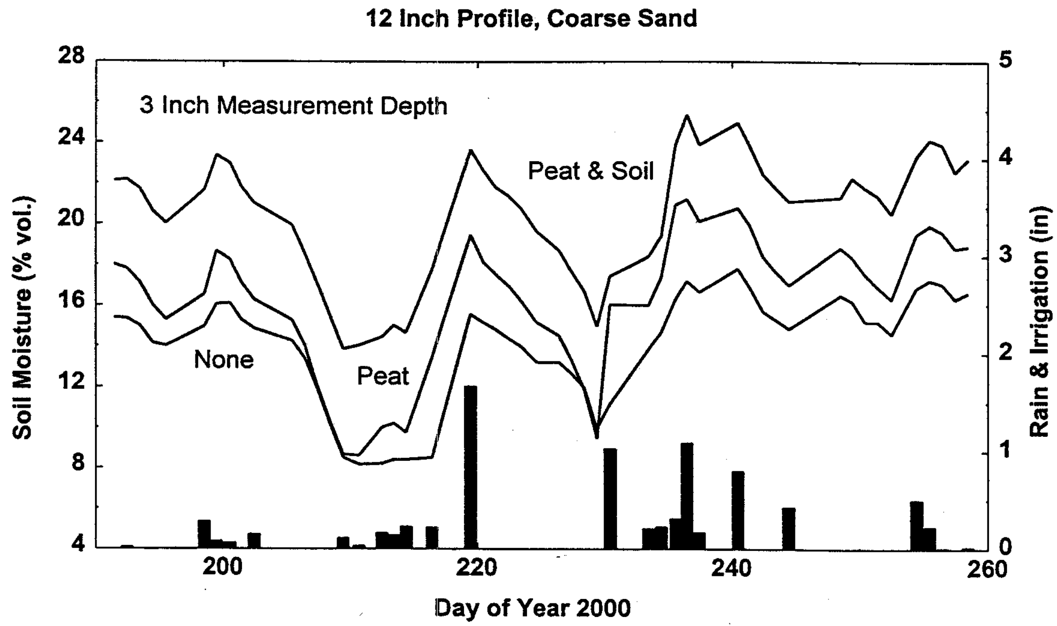


Figure 2. Soil moisture (% by vol.) and rain plus irrigation depths (in.) for the period from day 192 to 258 of year 2000. Data is shown for the 3 and 6-inch measurement depths for the 9-inch root zone containing the fine sand mixes.



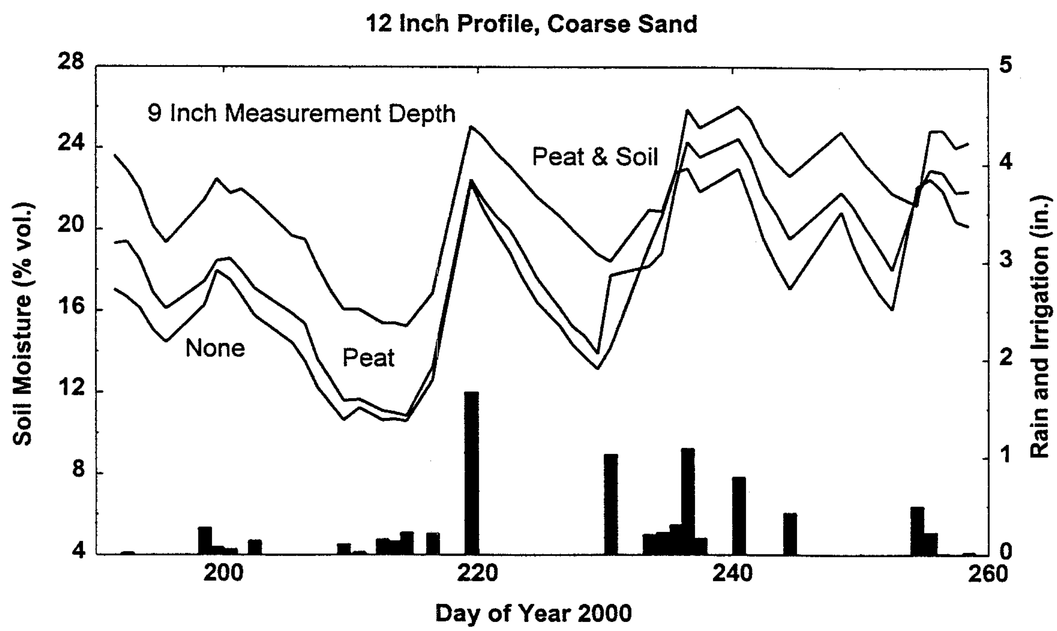
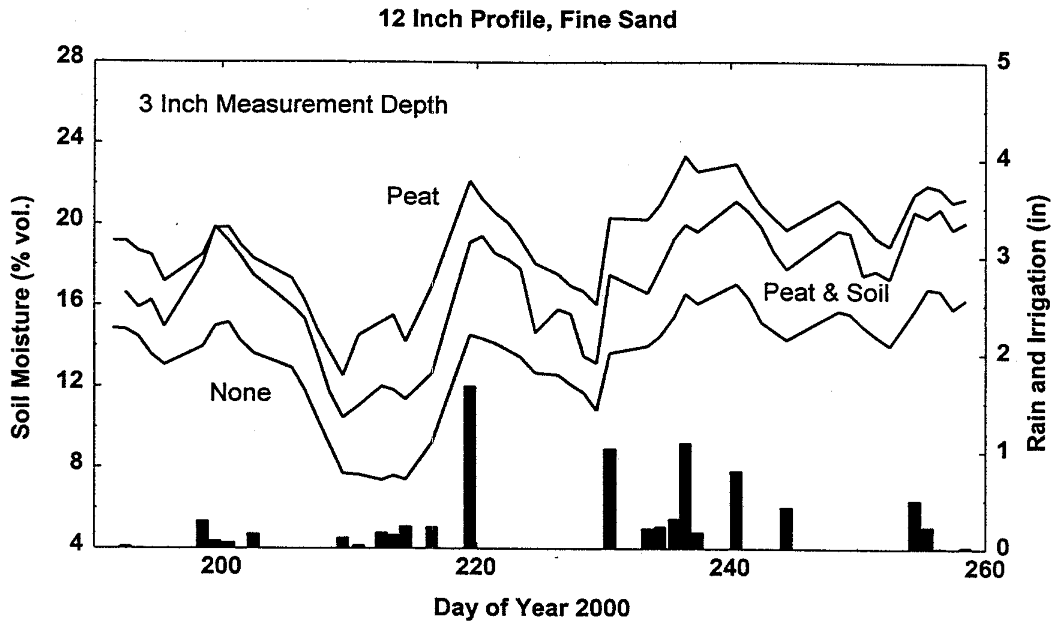


Figure 3. Soil moisture (% by vol.) and rain plus irrigation depths (in.) for the period from day 192 to 258 of year 2000. Data is shown for the 3 and 9-inch measurement depths for the 12-inch root zone containing the coarse sand mixes.



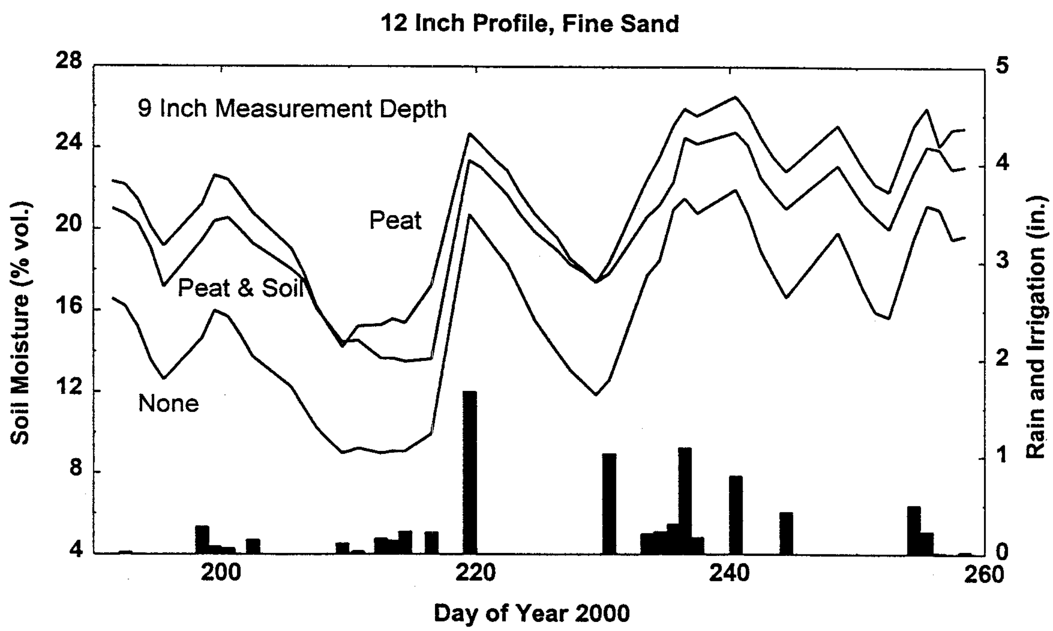


Figure 4. Soil moisture (% by vol.) and rain plus irrigation depths (in.) for the period from day 192 to 258 of year 2000. Data is shown for the 3 and 9-inch measurement depths for the 12-inch root zone containing the fine sand mixes.

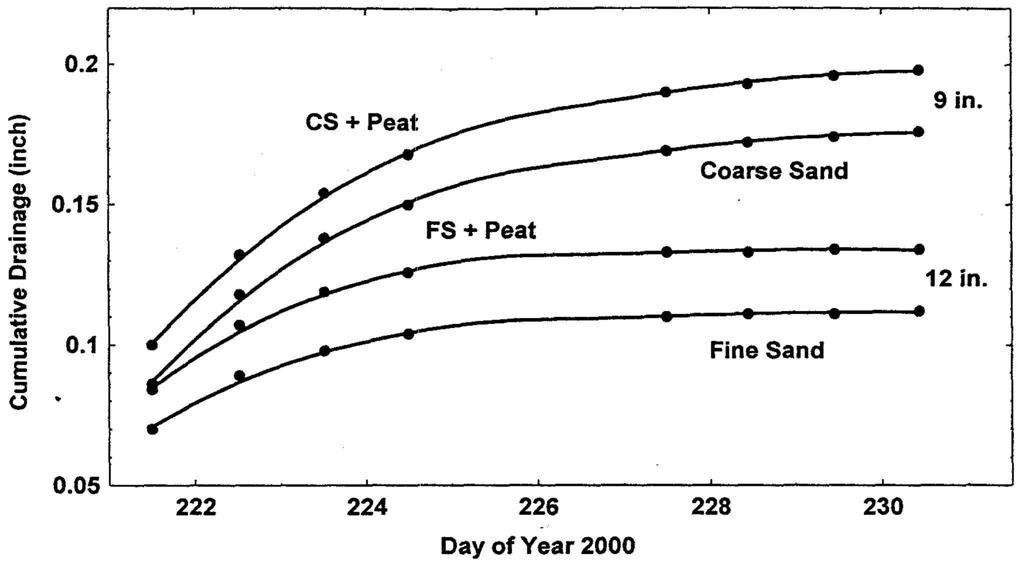


Figure 5. Cumulative drainage (in.) from selected experimental greens for the interval from day 221 to 230 of year 2000.

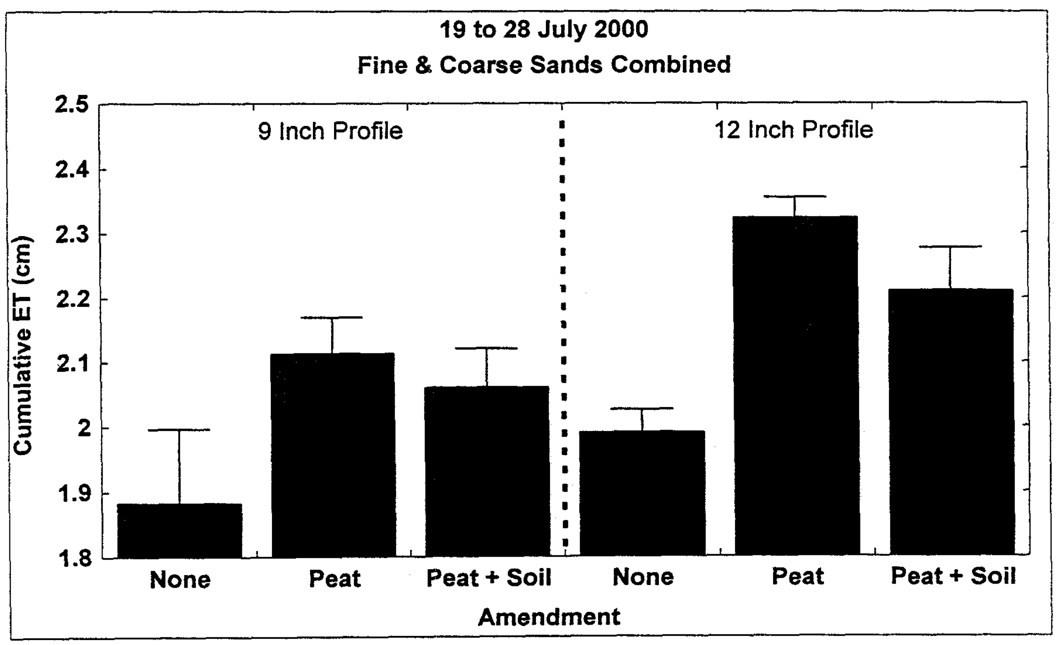


Figure 6. Cumulative turf ET (cm) from 19 to 28 July for the 9 and 12-inch root zones containing the unamended or amended sands.