

Temperature Amelioration of Synthetic Turf Surfaces through Irrigation

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ABSTRACT

Researchers have found that the surface temperatures of synthetic turf playing surfaces are significantly higher than natural turfgrass surfaces when exposed to sunlight. Reports indicate the surface temperatures of traditional synthetic turf can be as much as 35-60 °C higher than natural turfgrass surface temperatures. Surface temperatures of infill synthetic turf systems have been reported to be as high as 93°C on a day when air temperatures were 37°C. Researchers have concluded that the heat transfer from the surface to the sole of an athlete's foot is significant enough to contribute to greater physiological stress that may result in serious heat related health problems. The objective of this study was to evaluate various methods of reducing the surface temperature of synthetic turf surfaces. Various irrigation and tarping regimes were used in an effort to reduce surface temperature. Infill was also amended with calcined clay in an effort to increase the water holding capacity and potential evaporative cooling of the infill media. Many of the regimes tested were initially very successful in lowering surface temperature to that of natural turfgrass; however, these low temperatures could not be maintained for periods of time equal to the length of standard sporting events, although synthetic surfaces receiving irrigation did measure lower in surface temperature after 3 hr compared to unirrigated synthetic surfaces.

INTRODUCTION

Researchers have found that the surface temperatures of synthetic turf playing surfaces are significantly higher than natural turfgrass surfaces when exposed to sunlight. (Buskirk et al., 1971; Koon et al., 1971; and Kandelin et al. 1976). Buskirk et al. (1971) found that the surface temperatures of traditional synthetic turf were as much as 35-60 °C higher than natural turfgrass surface temperatures. Buskirk et al. (1971) placed thermocouples on the inner soles of cleated shoes and had individuals walk on the synthetic surface to determine the amount of heat transferred directly from the surface to the individual's foot. Any heat gain to the foot must be dissipated by blood flow. Buskirk et al. (1971) concluded that the heat transfer from the surface to the sole of an athlete's foot was significant enough to contribute to greater physiological stress that may result in serious heat related health problems regardless of similar air temperatures one meter above the surface.

Surface temperatures of infill synthetic turf systems have been reported to be as high as 93°C on a day when air temperatures were 37°C (Brakeman, 2004). Researchers at Brigham Young University measured the surface and air temperature above an infill synthetic turf system before and for a period of time after water had been applied through irrigation (Brakeman, 2004). The researchers reported that after 30 minutes of irrigation the surface temperature was lowered to that of a nearby natural turfgrass surface (29°C). However, the researchers reported that the surface temperature rose very quickly and within 5 minutes had risen to 49°C. This rapid rise in temperature could be due to the lack of thorough wetting of the infill media, which was found to be hydrophobic. This author personally observed this field on 19 May 2004. The infill media was very hydrophobic and water was observed to bead-up and run over the surface rather than penetrate. After a 10-minute irrigation cycle, water was observed to be moving laterally over the surface while the infill media was only wet to an average depth of 1 - 2 mm. The use of a surfactant and more thorough wetting of the infill material may lead to differing results.

Morehouse (1992) suggests that the evaporation of $1.2 \text{ L m}^{-2} \text{ h}^{-1}$ of water should be sufficient to cool a traditional synthetic surface to a level near that of a natural turfgrass surface and notes that water routinely applied to traditional synthetic surfaces, used for women's field hockey to slow ball bounce, will dampen the surface for at least one-half game even under favorable evaporative conditions (i.e. elevated air temperature and brisk air movement). The amount of water suggested for application prior to a field hockey event is 8,000 to 10,000 L spread evenly across a 105 m x 64 m surface. In this study, the authors have observed that after equal quantities of irrigation were applied to the treatment plots, the traditional synthetic turf (Astroturf) remained damp for a longer period of time than nine infilled synthetic turf systems. These results indicate that the formula Morehouse (1992) suggested for water application to traditional synthetic turf may not be applicable to infill systems.

MATERIALS AND METHODS

Plot Construction

Test plots were established at the Joseph Valentine Turfgrass Research Facility (University Park, Pennsylvania, USA) in fall of 2002. Topsoil was removed and the subsoil was compacted using a larger roller. Approximately 10 cm of drainage gravel was installed and compacted with the roller. After the gravel was compacted approximately 2.0 cm of a fine gravel and coarse sand mixture (>90% of particles between 1.0 and 4.0 cm) was applied using a topdressing machine and compacted using the roller.

Each synthetic turf company sent representatives to install their product(s). Treatment plots were 4.5 m square. There were 3 replications arranged in a completely random design for experiments 1 and 2. There were no replications for experiments 2 and 3. Simulated traffic was applied to the test plots using a Brinkman traffic simulator (Cockerham and Brinkman, 1989). Simulated foot traffic started during July of 2003. Plots received 12 passes with the traffic simulator each week starting the first week in

May and ending the last week in October of each year. Traffic was applied as 4 passes with the simulator 3 times per week.

Data Collection

Experiment 1

Both the temperature of the playing surface and the temperature of the air approximately 1 m above the surface were measured on three dates, in 2003 and 2004, using an infrared thermometer (Scheduler Model 2 LiCor Corporation) (Fig. 1) in order to evaluate differences in temperature due to synthetic turf system. Three temperature measurements were made on each treatment plot and the average was used to represent the temperature reading at a specific time. Clear bright days were chosen to collect data. In central Pennsylvania clear bright days are rare and at times some scattered clouds moved through during parts of the data collection period. The means of the three temperature measurements were analyzed using the analysis of variance and Fisher's Protected Least Significant Difference (LSD) test at the 0.05 level. A LSD was not calculated when the F ratio was not significant at the 0.05 level.

Experiment 2

During 2004 and in 2005 we evaluated the effect of irrigation on surface temperatures. Approximately 2 cm of water was applied to all plots using hand held irrigation. Surface temperatures were collected immediately after irrigation and at regular time intervals thereafter using the procedure described in Experiment 1. On 30 Jun 04 irrigation began at 12:40 pm. Air temperature during the test period averaged 23°C with 36% relative humidity and a wind speed of 3-5 k h^{-1} . On 3 Aug 04 irrigation also began at 12:40 pm. Air temperature during the test period averaged 30°C with 33% relative humidity and a wind speed of 1-3 k h^{-1} . On 2 Jun 05, irrigation began at 11:15 am. Air temperature averaged 25°C during this period with 39% relative humidity and wind speed was 6-8 k h^{-1} . The means of the three temperature measurements were analyzed using the analysis of variance and Dunnet's test was used compare the temperatures of the surfaces at each time interval with the temperature of the treatment plots prior to irrigation.

Experiment 3

In 2004, the effect of predawn irrigation and surface tarping on the temperature of test plots were evaluated. On 24 Aug 2004 two of the Fieldturf plots were irrigated with approximately 2 cm of water before dawn (6:10 am). One of these plots was covered with a white tarp used on American football fields prior to events to prevent natural precipitation from falling on the turfgrass (CoverMaster Inc. Rexdale, Ontario, Canada). The other plot was left uncovered. A third plot was irrigated with the same amount of water 7 hr after the first two plots were irrigated. The tarp on plot one was removed at this time. A fourth plot had no tarping or irrigation applied and served as a control. Surface temperatures were collected at regular time intervals after the tarp was removed using the procedure described in Experiment 1.

Experiment 4

On 7 Jul 2006 and on 1 Aug 2006 four surfaces were evaluated for changes in surface temperature after irrigation. These were Astroturf, Fieldturf, Sprinturf, and Sprinturf with infill material amended with calcined clay (Profile Products, Buffalo Grove, IL, USA). The Sprinturf was amended with calcined clay (80:20 M³M⁻³) in an attempt to prolong the cooling effect of the irrigation. Surface temperatures were collected at regular time intervals after irrigation using the procedure described in Experiment 1. Irrigation began at 1 PM each day.

RESULTS

Experiment 1

The Geoturf and Nexturf treatments trended higher in surface temperature than other treatments. Compared to the other treatments Geoturf and Nexturf had the least amount of infill other than Astroturf which had no infill. In general the surface temperatures of the various treatments were not significantly different from Astroturf which has been in use for 40 years. Few meaningful air temperature differences 1 m above the surfaces were detected. Among the treatments containing infill there seems to be a relationship between infill depth and temperature as the treatments with less infill tended to have a slightly higher temperature compared to the treatments with more infill. More research is needed to fully describe the effects of infill depth, underlying pad, and upright fiber type and density on surface temperature.

Experiment 2

The application of water significantly lowered the surface temperatures of all synthetic surfaces (Fig. 2 and 3). The temperatures rebounded somewhat after 15 minutes and then remained relatively stable for 90 and 210 minutes, respectively. There were intermittent cumulus clouds during the rating period for these days. The effect of the passing clouds can be seen in the erratic nature of the data especially at the 3 Aug 04 rating date. For this reason, data was also collected in 2005 (Fig. 4). The data in Fig. 4 was collected during a very clear day; however, air temperatures were not as high as the previous rating dates.

Using Dunnett's mean separation procedure, the temperature of the surfaces after irrigation was statistically lower than the pre-irrigation surface temperature for each rating time and for all surfaces on all three rating dates in Experiment 2.

On the 2 Jun 2005 rating date at 200 minutes after irrigation, the surface temperatures of the irrigated plots averaged 14 degrees lower than the non-irrigated plots. The Astroturf treatment had the highest pre-irrigation temperature and consistently measured lowest in post-irrigation temperature. A similar trend can be observed in the 2004 data. This may be due to the underlying pad retaining moisture. As previously mentioned, the authors observed that the Astroturf surface remained visually moist longer than the other treatments. Some of the infilled treatments (Nexturf, Sofsport, Astroplay) also contained

underlying pads. These pads were further from the surface than the Astroturf pad as they were covered with the indicated depth of infill. More research is needed to determine why Astroturf which contained no infill tended to be slightly higher in temperature before irrigation and lower post irrigation.

The temperature of corresponding unirrigated plots and a nearby Kentucky bluegrass (*poa. Pratensis*, L.) turf are shown for comparison purposes.

While this experiment indicates that the surface temperature of synthetic turf can be cooled for an extended period with irrigation, the cost associated with the installation of an irrigation system, versus the magnitude of surface temperature reduction should be considered.

Experiment 3

In an attempt to maximize the effective cooling of an irrigation application, irrigation water was applied predawn and the treatment plot was tarped (primary irrigation plus tarp). A second treatment was irrigated predawn but not tarped (primary irrigation no tarp). A third treatment was irrigated at 1 pm just prior to removal of the tarp from the predawn irrigated treatment (secondary irrigation). Surface temperature data collection began at this time and is shown in Fig. 5.

Predawn irrigation or tarping seems to have had little effect on the surface temperature of the synthetic turf later in the afternoon. The temperature of a nearby unirrigated infilled synthetic turf plot is shown in Fig. 5 for comparison purposes.

Experiment 4

In an attempt to prolong the cooling effect of irrigation, a calcined clay (Profile) was mixed with the crumb rubber prior to installation. Surface temperature data is shown in Fig. 6 and 7. Mixing 20% calcined clay with the crumb rubber infill did not reduce surface temperature of the infilled synthetic turf systems tested.

Again, Astroturf tended to have the highest surface temperature of the treatments tested prior to irrigation and the lowest surface temperature after irrigation. The surface temperatures of unirrigated treatment plots, nearby Kentucky bluegrass turfgrass, and nearby asphalt are shown in Fig. 6 and 7 for comparison.

CONCLUSIONS

Synthetic turf surfaces were found to have substantially higher surface temperatures than natural turfgrass.

The temperature of a synthetic surface depends on numerous variables including weather conditions, location and especially sunlight intensity. The benefit of surface cooling through irrigation will vary depending on conditions. Irrigation systems on synthetic

fields have other benefits such as reduction of wear by allowing the field manager to broom the surface when wet and wash in fabric softeners and/or wetting agents. The cost of an irrigation system compared to the magnitude reduction of surface temperature should be considered by athletic associations prior to installation.

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Table 1. Surface and air temperatures ($^{\circ}\text{C}$)¹ of ten synthetic turf systems measured at 3 dates in 2003 and 2004.

Product	Infill Depth	7 Sep 03		30 Jun 04		3 Aug 04	
		Surface	Air ²	Surface	Air	Surface	Air
Astroplay	40	46.8	25.6	51.9	25.7	59.5	30.5
Astroturf	7	51.9	25.9	52.4	25.5	53.8	28.9
Experimental	35	48.4	24.8	52.3	26.1	58.4	30.8
Fieldturf	43	46.8	26.1	58.1	25.6	64.8	28.3
Geoturf	33	53.1	26.5	61.1	25.9	70.8	29.5
Nexturf	22	51.1	25.1	56.4	25.1	71.5	30.6
Omnigrass 41	39	48.1	25.9	53.2	25.8	64.2	29.3
Omnigrass 51	49	49.2	26.3	55.6	25.6	63.1	29.4
Sofsport	33	49.9	27.0	54.6	25.5	62.6	29.1
Sprinturf	28	45.4	26.4	48.1	25.8	54.4	30.0
lsd _(0.05)		2.1	0.6	5.5	0.7	5.8	1.3

¹ Temperatures were measured using a LiCor Scheduler infrared thermometer.

² Air temperature was measured approximately 1 m above the synthetic turf surface at the same time surface temperature was measured.



Fig. 1. LiCor infrared thermometer.

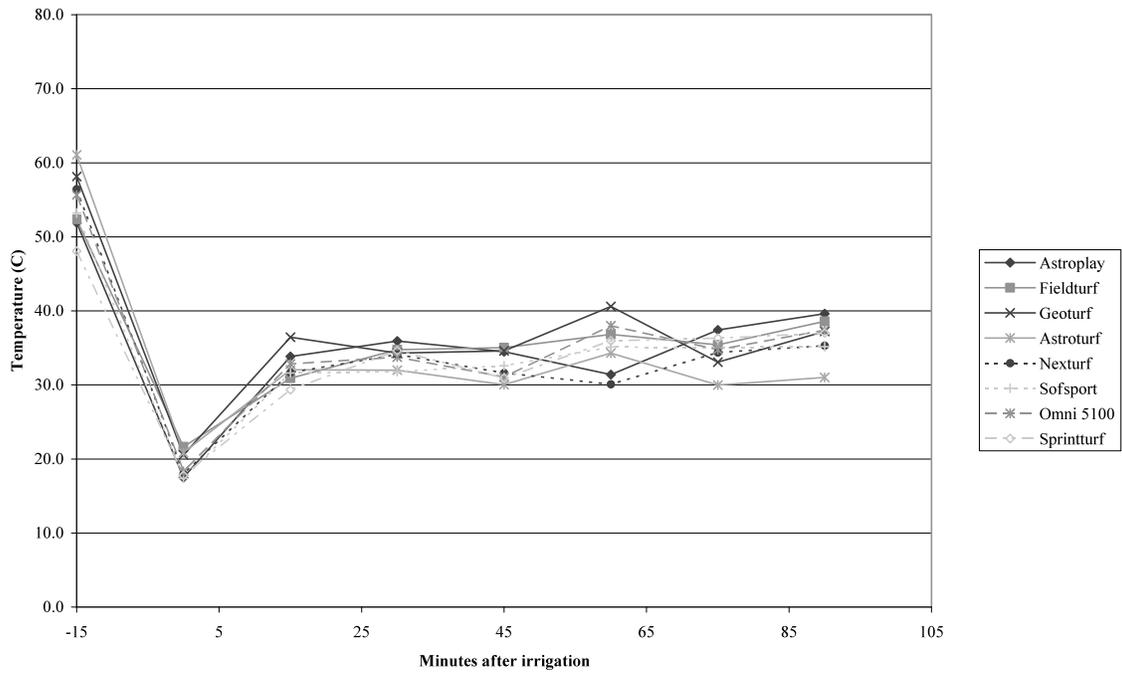


Fig. 2. Surface temperature of 8 synthetic turf surfaces on 30 Jun 2004.

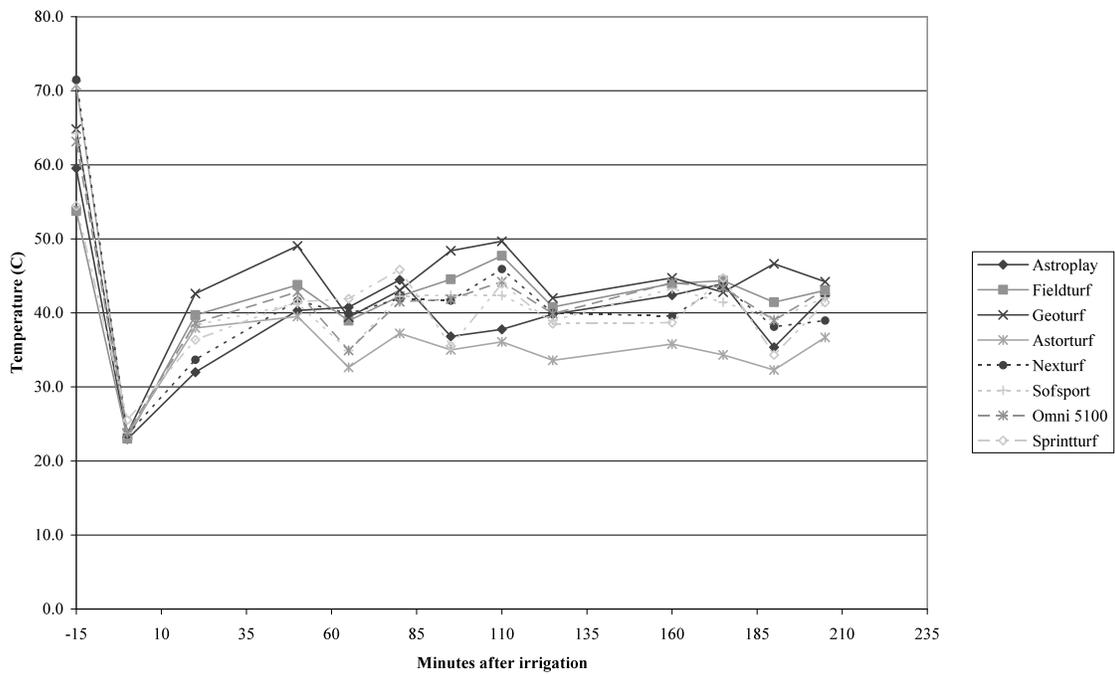


Fig. 3. Surface temperature of 8 synthetic turf surfaces on 3 Aug 2004

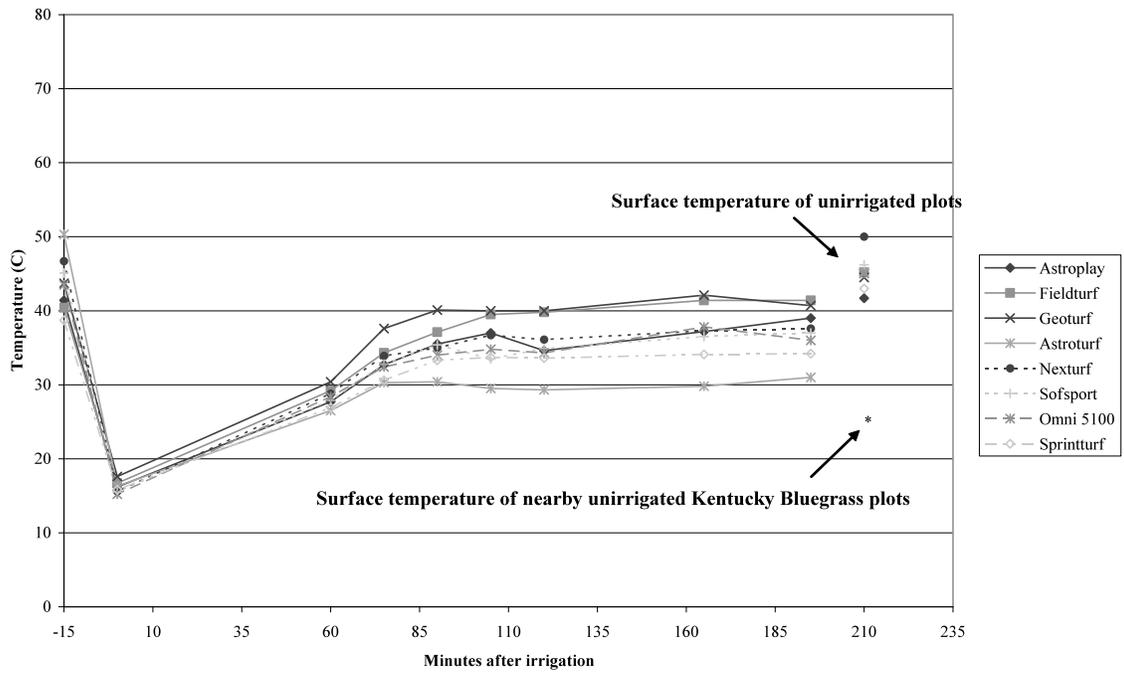


Fig. 4. Surface temperature of 8 synthetic turf surfaces on 2 Jun 2005.

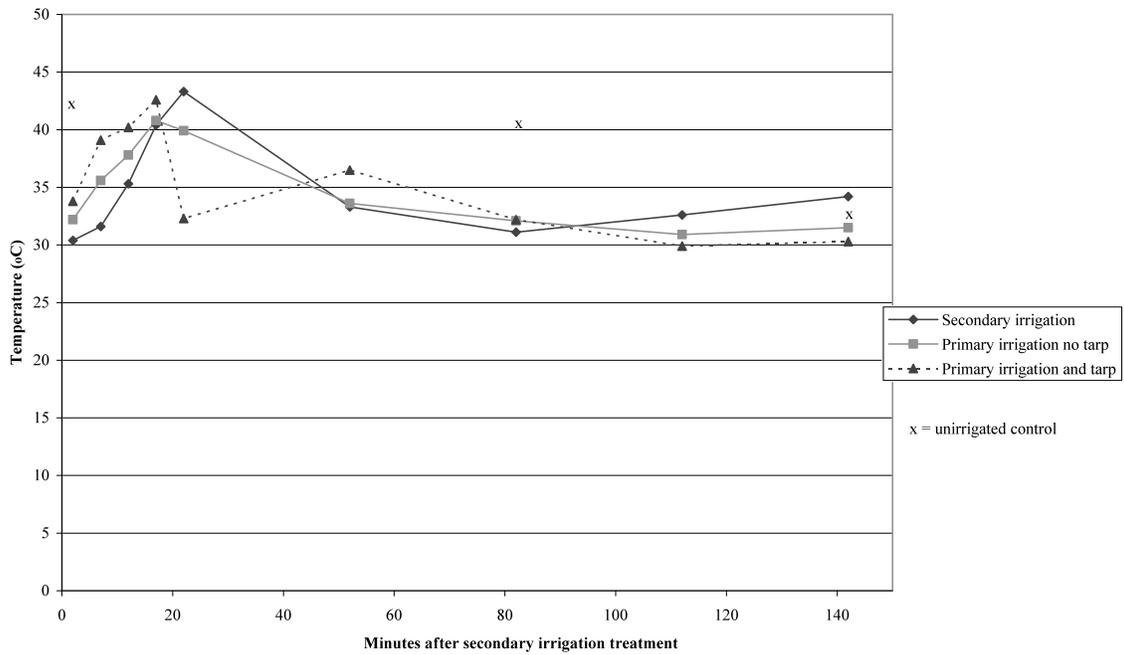


Fig. 5. Surface temperature of Fieldturf synthetic infill system treatments on 24 Aug 2004

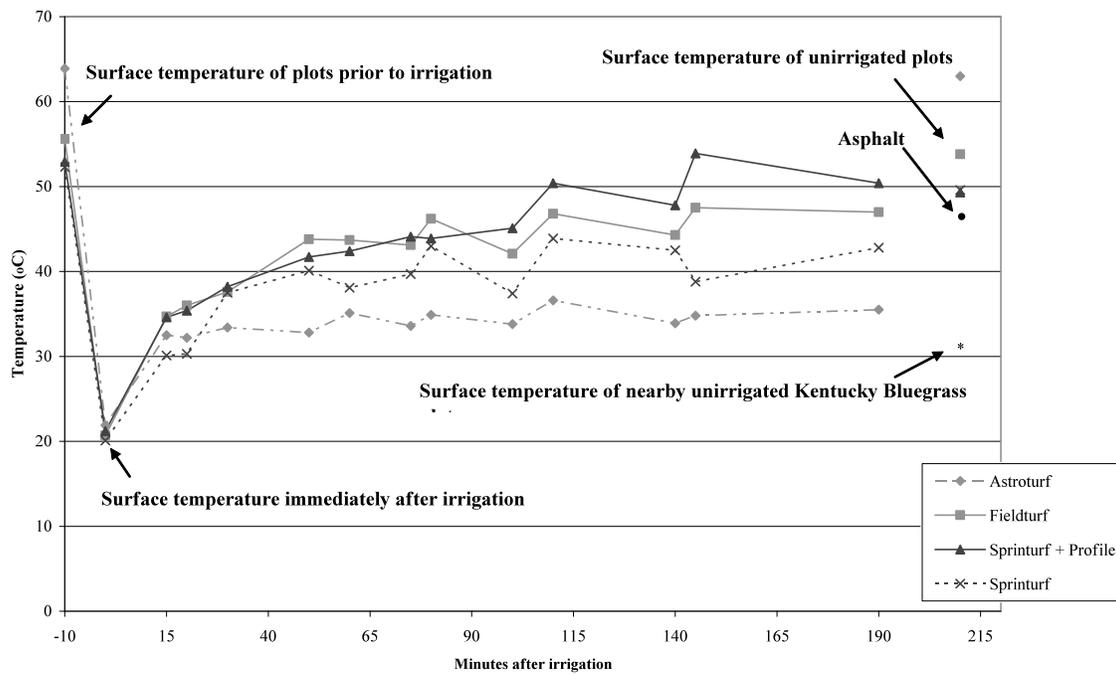


Fig. 6. Surface temperature of four synthetic turf surfaces on 7 Jul 2006

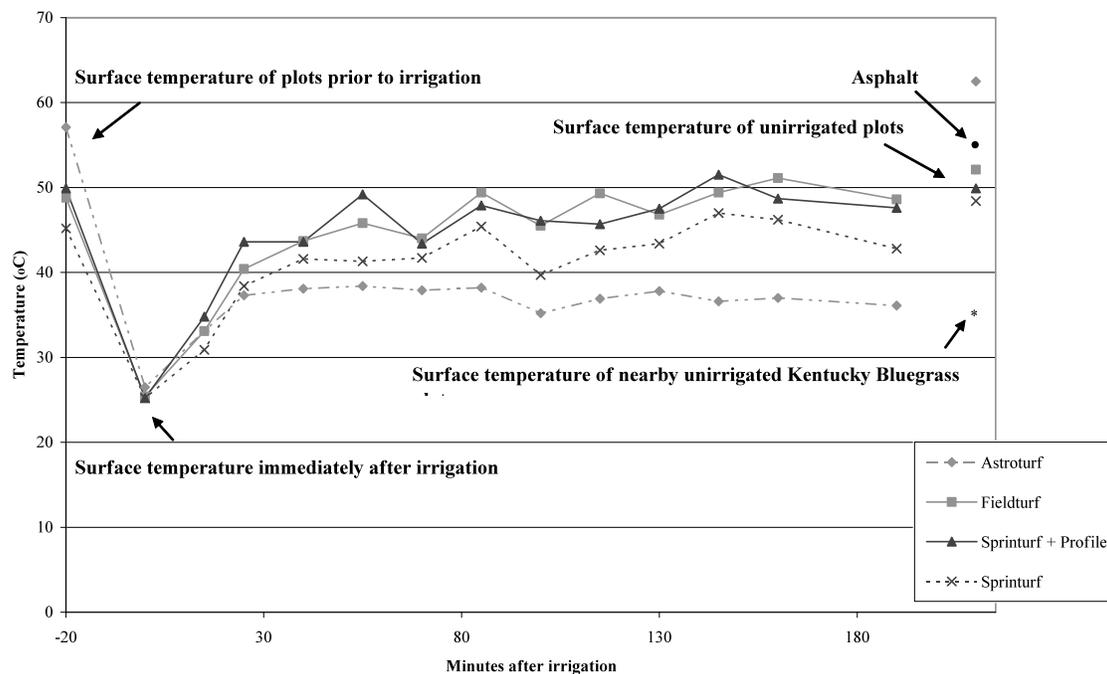


Fig. 7. Surface temperature of four synthetic turf surfaces on 1 Aug 2006