

NATIONAL EVALUATION OF COOL-SEASON TURFGRASS WATER USE AND DROUGHT RESISTANCE

Annual Progress Report – June 21, 2018
Washington Turfgrass Seed Commission

ABSTRACT

This is an exciting new project that evaluates, through a nationwide trial, Kentucky bluegrass and tall fescue for their water use and drought resistance. Data generated from this project will be used to identify, label and certify low-water using cool-season grass cultivars for use on lawns, parks, athletic fields and golf courses. We were awarded \$35,000 per year for three years (\$105,000 total) to help with the funding of this project.

Kevin Morris, NTEP and Michael Kenna, USGA

BACKGROUND AND UPDATE

As discussed at previous WTSC meetings, the United States Golf Association (USGA) budgeted considerable funding to conduct a national water use and drought tolerance trial, utilizing the National Turfgrass Evaluation Program (NTEP) as its evaluation organization. USGA funded the building of rainout shelters and irrigation infrastructure at several locations, and is working with NTEP in determining testing protocols, data collection methods, etc. Besides data collection on water use and drought resistance parameters, the goal of this effort is for the EPA Water Sense program to adopt these (or similar methods) and to agree to certify the first plant species with the Water Sense label. USGA has become a Water Sense partner and we have talked to the Water Sense staff about certifying grasses. EPA is very interested in the concept (they have never certified a plant or plants as water saving) as USGA Green Section Research Director Dr. Mike Kenna and I have met with them to discuss collaborative efforts. However, EPA needs to see more about the methods and tests, as well as we believe, some successful trials. Also, they will need our help in solving some legal requirements when certifying a product (could be unique for plants, however). Attachment A is our proposal that was submitted to WTSC and chosen for funding.

Because of space limitations (only around 30-35 entries can be accommodated), we limited the trial to only Kentucky bluegrass and tall fescue. We chose tall fescue over perennial ryegrass because of more interest from seed companies in submitting entries (than perennial ryegrass). Fortunately, when our deadline passed, we had received 32 entries (14 bluegrass, 18 tall fescue). We added three standards to the trial (one each of Ky. Bluegrass, tall fescue and perennial ryegrass). See Attachment C for the list of entries and sponsors.

Most locations planted the trial in fall 2016, while a few had to wait on infrastructure improvements (mostly irrigation), and therefore will plant in spring 2017. Planting plans were developed for both Approach 1 and 2 sites. Drought treatments were initiated in 2017 on those locations with mature plots.

Rainout shelters were ordered and delivered in spring 2017 to each of the five Approach 1 sites. Installation was performed by staff at each site. As a part of the grant agreement, NTEP returned a portion of the funding allocated for rainout shelter purchases back to each researcher to help with installation and other initial expenses. Approach 2 sites received \$15,000 initial set-up costs for irrigation installation and/or other expenses.

After the initial development of protocols, we have continued to meet with our cooperators to examine and tweak these protocols. This process is ongoing as we see what works, and what does not work, making additional changes to procedures, if necessary in the future.

The cost to run each trial location is high, and only a portion of that is covered by USGA's donation (\$250,000). Therefore, we sincerely appreciate the support received from WTSC for the initiation of this trial. Without your support, this trial would not be conducted.

PROGRESS REPORT – JUNE 2018

Of the ten locations planted, six were able to collect at least some data on drought response and recovery in 2017 (we agreed that the remaining four locations did not have test plots that were fully mature, and therefore not ready to apply drought stress). The locations that did not simulate drought in 2017 (Logan, UT; St. Paul, MN; Ft. Collins, CO; Amherst, MA), will initiate drought treatments in 2018.

Shelters were shipped directly from the manufacturer to each Approach 1 location, and with a significant commitment of time and resources., construction was completed by personnel at each site.

The six cool-season trial locations that did initiate drought treatments in 2017 include Fayetteville, AR, College Park, MD, Griffin, GA and West Lafayette, IN (rain exclusion shelter sites); and Riverside, CA and Las Cruces, NM (deficit ET_0 replacement sites).

APPROACH 1

Rain exclusion shelters are used to simulate 100-day drought periods in higher rainfall regions. Under the rain exclusion shelters we measured the amount of water needed to maintain 50% green cover, rate turfgrass quality as well as evaluate recovery from drought when irrigation is resumed.

Irrigation amounts needed to maintain 50% green cover varied significantly among entries, and in some cases was more than double the best entry. For instance, at Fayetteville, AR, 'BAR PP 110358' Ky. Bluegrass used 38 mm of water during the 100-day period, while the best tall fescue, 'RS4' used 46.7 mm.

At Griffin, GA, several tall fescue entries used less water (76.3 mm) than the best Ky. Bluegrasses (110 mm), but that was still less water than many tall fescues. As an aside, Hurricane Irma passed directly over the shelter in Griffin but did no significant damage (see pictures below).

The issue with the Approach 1 sites was the small, or non-existent statistical differences among these numbers. As a result, we have met with the five cooperators and have decided to tweak the protocol by changing the percent green cover from 50 to 65%. We feel this will allow grasses to maintain growth better during the drought period and hopefully, will allow for greater statistical significance.

Also, we are standardizing the digital image collection and analysis settings, starting with each site's camera, as well as the software used to process images. We have purchased licenses of a new program, *TurfAnalyzer*, developed by Dr. Doug Karcher and others at the University of Arkansas and distributed to each cooperator. This will allow all Approach 1 and Approach 2 sites to use the same settings, and hopefully will lead to more consistent results.

APPROACH 2

The drier climate ET_o-based sites evaluate performance at three deficit irrigation levels for 100-120 day periods. Data recorded includes percent green cover over time, turfgrass quality and recovery rate after sufficient irrigation is applied. The ET_o-based locations allow us to determine the minimum level of deficit irrigation appropriate for, and thus the water savings from each entry. It was determined that 80, 60 and 40% ET_o replacement levels would be utilized in 2017.

The ET_o-based site at Riverside, CA recorded less than 1 inch of rainfall during the testing period, and consequently saw >95% grass loss in the 40% ET_o replacement treatment. We will evaluate these plots over the winter and spring to gauge if sufficient recovery occurs to warrant continuing the 40% ET_o replacement at this location. The 60% ET_o replacement level also saw some significant grass loss, and it will be interesting to see plant recovery, as well as each entry's ability to withstand this level of deficit irrigation in 2018.

At the Las Cruces, NM site, large differences in percent green cover were noted among entries across the season, as well as differences in recovery from drought. However, very few statistical differences were noted, maybe due to the summer thunderstorms in the area that somewhat confounded the data in 2017.

Surprisingly, several of the Kentucky bluegrasses performed as well as many of the tall fescues at several of the sites in 2017. Having all locations testing in 2018 will give us much more information to decipher and interpret.

Data from 2017 can be found here: http://www.ntep.org/reports/cs16w/cs16w_18-2.htm.



LAS CRUCES, NM – 60% ET₀ TREATMENT (L), RECOVERY AFTER 100% ET₀ IRRIGATION (R)



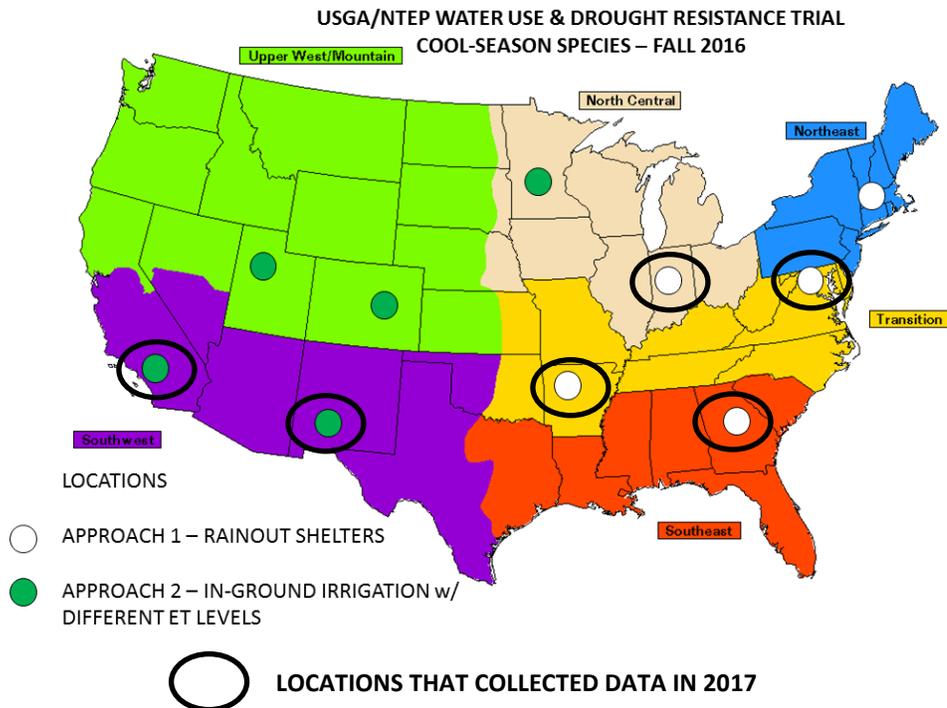
RIVERSIDE, CA - TOP LEFT 60% ET₀, TOP RIGHT 40% ET₀, BOTTOM - TRIAL OVERALL



SHELTER CONSTRUCTION AT THE UNIVERSITY OF MARYLAND, COLLEGE PARK, MD



THE GRIFFIN, GA SITE...NOTE MOVEMENT OF SHELTER FROM GUTTER (RIGHT) BY HURRICANE IRMA



ATTACHMENT A

EXECUTIVE SUMMARY

Project Title: National Evaluation of Cool-Season Turfgrass Water Use and Drought Resistance

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Project Description:

With water restrictions becoming more commonplace, and with turfgrass being scrutinized for its water use, there is great need to highlight those cool-season turf cultivars that use less water and are appropriate for home lawns, athletic fields, golf courses, etc. Therefore, this project addresses that need to identify cool-season turfgrass cultivars that deliver high quality turf while using significantly less water. We propose a trial established at multiple locations nationwide that does the following: 1) measures the actual amount of water required to maintain a prescribed level of quality or green cover, and 2) documents the performance of cultivars under varying levels of reduced evapotranspiration (ET) levels. We will collect three years of data on Kentucky bluegrass, perennial ryegrass, fineleaf fescue and tall fescue at 6-8 trial locations. This data will be used to develop and apply U.S. EPA WaterSense® <http://www3.epa.gov/watersense/> certification (or another certification organization) label to grasses that qualify.

How Ours is Different:

This is the first national trial conducted specifically to document the amount of actual water needed to maintain a prescribed level of quality or green cover. The USGA has committed \$250,000 to this project (as well as \$250,000 to a warm-season grass version of this project), and has selected NTEP to develop and coordinate the trial. However, this trial is very expensive to conduct, costing between \$600,000 and \$750,000, considering the need to build rainout (rain eliminating) shelters, experimental areas with different irrigation zones (about \$15,000 per location) and extensive data collection costs. NTEP will assess a fee per entry for testing, however, NTEP is soliciting additional funding from several sources besides Washington Turfgrass Seed Commission.

Potential Benefits or Impact on the Turfgrass Seed Industry:

This trial will provide specific information on the amount of water each cultivar needs, which is data not available at this time. This will allow us to show water utilities, municipalities and other groups that cool-season turfgrass can survive, and even thrive, with less water than previously understood. In addition, EPA WaterSense® or other certification, will justify the low water use of qualified grasses.

Deliverables:

Three years of data collected from summer 2017- 2019. Data will be published on the NTEP web site and will be used to consider grasses for certification. The Washington Turf Seed Commission will benefit from its sponsorship of this project from not only having grasses certified as low water users, but also from partnership with, and publicity from this project.

	Amount requested
Year 1 (2016)	\$ 35,000
Year 2 (2017)	\$ 35,000
Year 3 (2018)	\$ 35,000
Requested Total	\$ 105,000

ATTACHMENT A (page two)

National Evaluation of Cool-Season Turfgrass Water Use and Drought Tolerance

Background/Justification

Water use on lawns, athletic fields, parks and golf courses is being increasingly scrutinized by municipalities, water utilities, regulatory agencies and the general public. The severe drought in California has brought the issue to the forefront with the mainstream media often focusing on turf and lawn water use. Gov. Jerry Brown's executive order requiring water savings, as well as calling for the removal of 50 million sq. ft. of lawns has heightened awareness of the issue, and the subsequent need to reduce water use. As a result, several California jurisdictions are offering up to \$5 per sq. ft. to remove turf (and in some cases, allowing synthetic turf as a replacement). As the western states in particular become more populated, the struggle between water utilities, commercial water users, domestic water users and agriculture for finite water resources will escalate. This trend will spread to other states and regions as well, with increasing population in many areas and a need to provide more domestic and commercial water.

Some information on turfgrass water use has been generated by universities and groups within the turfgrass industry. Currently, research has documented the relative water use among turfgrass species (see Table 1).

Table 1. Summary of Mean Summer Daily Rates of Turfgrass Evapotranspiration (ET₀).

Turfgrass species ¹				
Cool Season	Warm Season			Relative ranking
		Mean Summer ET rate ² (mm per day)		
	Buffalograss	5.0	– 7.0	Very low
	Bermudagrass hybrids	3.1	– 7.0	Low
	Centipedegrass	3.8	– 9.0	
	Bermudagrass	3.0	– 9.0	
	Zoysiagrass [†]	3.5	– 8.0	
Hard fescue		7.0	– 8.5	Medium
Chewings fescue		7.0	– 8.5	
Red fescue		7.0	– 8.5	
	Bahiagrass	6.0	– 8.5	
	Seashore paspalum	6.0	– 8.5	
	St. Augustinegrass	3.3	– 6.9	
Perennial ryegrass		6.6	– 11.2	High
	Carpetgrass	8.8	– 10.0	
	Kikuyugrass	8.5	– 10.0	
Tall fescue		3.6	– 12.6	
Creeping bentgrass		5.0	– 10.0	
Annual bluegrass			> 10.0	
Kentucky bluegrass		4.0	> 10.0	
Italian ryegrass			> 10.0	

¹ Based on the most widely used cultivars of each species.

² Mean rates of water use under well-watered conditions from several research studies.

ATTACHMENT A (page three)

Turfgrass Water Conservation Alliance (TWCA) members have conducted several studies that demonstrate turf water savings if appropriate cultivars are used. TWCA members, Kansas State University, the University of Arkansas, Texas A&M University and others have shown that the actual amount of water needed by drought tolerant cultivars is less than previously thought (see Attachment A). Subsequently, labeling/certification programs have been developed and endorsed by several companies (TWCA, A-List, for example).



For turfgrass to be considered low water using by regulatory agencies, water utilities, municipalities, etc. (i.e. those groups that pay to remove or restrict turf), then we need a nationally accepted certification program such as U.S. EPA WaterSense® <http://www3.epa.gov/watersense/>. WaterSense® is a program that tests and certifies low water use items, such as faucets, toilets, shower heads and irrigation parts. They are now interested, and are discussing with us the certification of turfgrass, making turfgrass the first plant material they are considering certifying.

With all of this information in mind, the USGA Executive Committee agreed to provide \$500,000 total to initiate a new, nationwide trial that evaluates both cool-season and warm-season turfgrass water use and drought tolerance. This amount is seed funding to start the project, with the hopes that entry fees and other grant funds can be secured to adequately and properly fund the following project objectives. Therefore, the Washington Turfgrass Seed Commission request of \$105,000 is one of several requests for cooperative funding we have made, or will make of various turfgrass organizations.

Objectives

The objectives of this trial are the following:

1. Determine the 100-day, summer water use of cool-season turfgrass species and cultivars.
2. Determine turfgrass recovery of grasses after 30 days and 60 days without water.
3. Determine the %ET replacement required by each entry to maintain a prescribed level of green or quality.
4. Develop requirements for water use and drought tolerance/recovery to be certified as a low-water use turfgrass.
5. Work with U.S. EPA WaterSense® or another organization to develop and apply a national water saving certification to qualified turfgrasses.

The research outcome will identify cultivars within turfgrass species that reduce water use by 20 percent or more, as well as those that can completely recover after 30-day or 60-day period of drought.

The development of a national water savings label for commercial turfgrass cultivars will arise from this research effort. NTEP and USGA will negotiate with the U.S. EPA WaterSense®, the Alliance for Water Efficiency (AWE) or another organization to designate standards for the turfgrass water-conservation label.

Evaluation Procedures and Protocols

The trial will be established in fall 2016 at 6-8 locations nationwide (depending on funding provided – if more funding is provided, more locations can be established). One-half of those sites will be provided with a rainout shelter, and the other half will install individual zone level irrigation. Trials will be conducted to either measure actual water used (Approach 1 – see Attachment B) or performance under various reduced ET levels (Approach 2 – see Attachment B). Data will be collected for three years (2017-2019) using the protocols outlined in Attachment B. This data will be published via the NTEP web site, and will be used to determine which entries qualify for certification. Certification qualifications will be developed and applied via a committee of scientists, industry personnel and other qualified individuals.

ATTACHMENT A (page four)

Species Evaluated

For this first trial, we will evaluate *Kentucky bluegrass, perennial ryegrass and other cool-species (as space is available)* within the rainout shelters and zone level irrigation plots.

Deliverables

1. Data will be collected on the actual amount of water needed (inches) and ET replacement levels from multiple locations need to maintain turfgrass entries at a specified quality level or prescribed level of green cover. This data will be collected for three years (2017-2019) at multiple locations across the U.S.
2. The data collected will be published each year on the NTEP web site (www.ntep.org) in the same manner as other NTEP data sets.
3. We will work with EPA WaterSense® or another organization to develop a national certification/labeling program for low-water using turfgrasses. This program will be used to certify/label those entries that meet the requirements prescribed in advance for qualification of the label.
4. The certification program will be promoted and encouraged for use by water utilities, municipalities, golf courses, athletic field complexes, grounds managers and homeowners.

Benefits to Washington Turfgrass Seed Growers

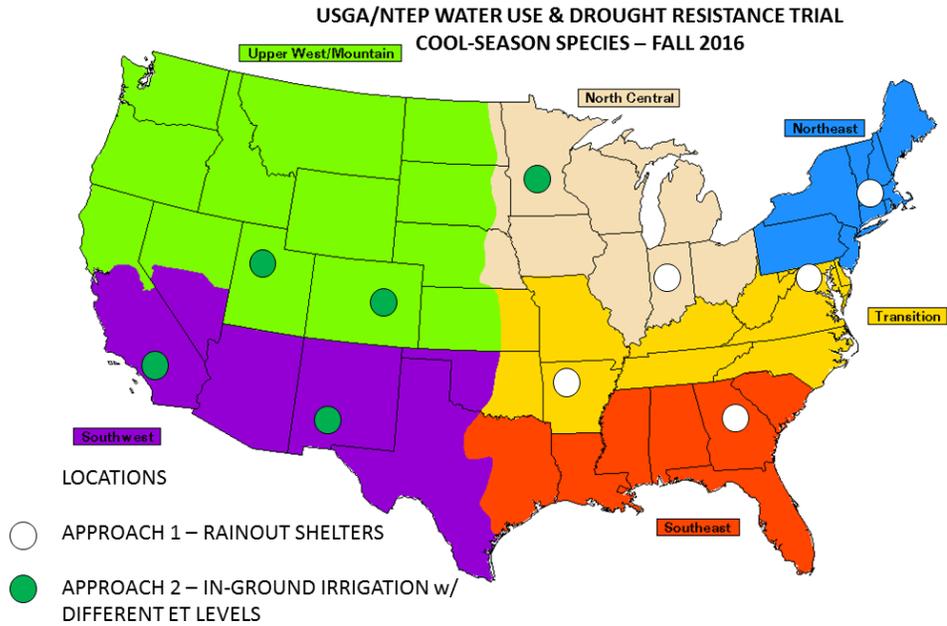
The support of this project from the Washington Turfgrass Seed Commission will help seed growers in the following ways: 1) it will increase the use of drought tolerant cool-season grasses, especially in those regions where drought conditions are a concern, 2) low-water use certified (EPA WaterSense® or other) turfgrasses will allow turf to be used again in places where turf and lawns are being restricted, 3) it will show the general public that the turfgrass industry is responding to drought conditions by reducing water use on turfgrass, and 4) it will bring positive publicity to the Washington Turfgrass Seed Commission as their sponsorship of this project is promoted in the media, alongside NTEP, USGA and other sponsors that we are able to attract.

About the PI's

Mr. Kevin Morris is the first, and longest tenured employee of the National Turfgrass Evaluation (NTEP), being named Executive Director in 1998. NTEP is the world's leading turfgrass evaluation program. Starting in 1980, NTEP has led the way by developing evaluation techniques and delivering high quality research results on cool-season and warm-season turf species. NTEP pioneered the delivery of unbiased research results on its web site (www.ntep.org), which is freely available. Currently, NTEP is evaluating over 600 grasses, encompassing fifteen species, utilizing testing facilities in 36 U.S. states and two Canadian provinces.

Dr. Michael P. Kenna has been the Director of USGA Green Section Research since February, 1990. He oversees the USGA's turfgrass and environmental research activities, including soliciting and evaluating research proposals, grant making, and development of cooperative funding with government and commercial sources. Dr. Kenna travels extensively to visit turfgrass and environmental research sites, speak at conferences about the USGA's research programs, and serves on advisory boards and research foundations. He has worked closely with the US Department of Agriculture on water and energy conservation research that relates to golf courses. Dr. Kenna has served as editor on several books concerning turfgrass biotechnology, environmental issues, and water conservation and reuse.

ATTACHMENT B



USGA/NTEP Water Use & Drought Resistance Trial Cool-season grass locations

Approach 1
(restrict water
For 100 days)



Amherst, Massachusetts
College Park, Maryland
Griffin, Georgia
W. Lafayette, Indiana
Fayetteville, Arkansas

Approach 2
(reduced
ET_o levels)



St. Paul, Minnesota
Las Cruces, New Mexico
Riverside, California
Logan, Utah
Ft. Collins, Colorado

ATTACHMENT C

2016 National Cool-Season Water Use/Drought Resistance Test

Entries and Sponsors

Entry No.	Name	Species	Sponsor
1	BAR PP 110358	Kentucky Bluegrass	Barenbrug USA
2	Barrari	Kentucky bluegrass	Barenbrug USA
3	Everest	Kentucky bluegrass	Jacklin Seed by Simplot®
4	Blue Note	Kentucky bluegrass	Mountain View Seeds
5	Babe	Kentucky bluegrass	Seeds, Inc.
6	NAI-13-132	Kentucky bluegrass	Columbia River Seed
7	NAI-13-14	Kentucky bluegrass	Columbia River Seed
8	Blue Devil	Kentucky bluegrass	Columbia River Seed
9	Dauntless	Kentucky bluegrass	Columbia River Seed
10	PST-K13-137	Kentucky bluegrass	Pure-Seed Testing, Inc.
11	PST-K13-143	Kentucky bluegrass	Pure-Seed Testing, Inc.
12	PST-K15-169	Kentucky bluegrass	Pure-Seed Testing, Inc.
13	PST-K11-118	Kentucky bluegrass	Pure-Seed Testing, Inc.
14	PST-K13-141	Kentucky bluegrass	Pure-Seed Testing, Inc.
15	Midnight	Kentucky bluegrass	Standard entry
16	SR 4650	perennial ryegrass	Standard entry
17	BarRobusto	tall fescue	Barenbrug USA
18	BAR FA 121095	tall fescue	Barenbrug USA
19	DLFPS 321/3677	tall fescue	DLF Pickseed USA
20	DLFPS 321/3679	tall fescue	DLF Pickseed USA
21	DLFPS 321/3678	tall fescue	DLF Pickseed USA
22	Nonet	tall fescue	Jacklin Seed by Simplot®
23	GO-AOMK	tall fescue	Grassland Oregon
24	Supersonic	tall fescue	Mountain View Seeds
25	Titanium 2LS	tall fescue	Mountain View Seeds
26	Thor	tall fescue	Columbia Seeds
27	Thunderstruck	tall fescue	Columbia Seeds
28	RS4	tall fescue	Landmark Turf & Native Seed
29	Kingdom	tall fescue	Site One Landscape Supply
30	MRSL TF15	tall fescue	Site One Turf & Landscape Supply
31	Catalyst	tall fescue	Standard entry
32	Stetson II	tall fescue	Site One Landscape Supply
33	PST-5SDS	tall fescue	Pure-Seed Testing, Inc.
34	PST-R511	tall fescue	Pure-Seed Testing, Inc.
35	LTP-SYN-A3	tall fescue	Lebanon Seaboard Corp.

ATTACHMENT D

July 25, 2016 version

Trial details:

1. Cool-season grass trials (two species) will be established in 10 locations for each species in fall 2016.
2. Data will be collected for three growing seasons: 2017, 2018 and 2019
3. Two approaches will be used:
Approach 1 – individual plot watering and
Approach 2 – zone level irrigation (see pages two and three for a description of each approach).
4. An equal number of rainout shelters and zone level irrigation plots will be built (see attached map and locations list). The rainout shelters will be utilized where summer rainfall is possible (and needs to be restricted).
5. Since plot space will be limited, the first priority for entries will include only Kentucky bluegrass and tall fescue. If space is not filled with those two species, some perennial ryegrass entries can be included in the trial.
6. Trial locations will be managed using a mowing height of 2 – 2.5” and fertilization of 0.25 – 0.33 lbs. of N/1000 sq. ft./growing month.
7. Digital image technology will be used to measure percent green cover on plots. Training will be provided to cooperators so that images are collected properly.
8. NTEP will hire additional staff to monitor the performance of trials, data and image collection, and to perform site visits.
9. Since the plot areas will be costly to build and the trial will require considerable labor to manage, each species trial will be limited to 30 total paid entries (plus 3 standards), 3 reps of each for a total of 100 plots at each test site.
10. USGA and NTEP will pursue certification/qualification and/or branding of drought tolerant or low-water using cultivars. Therefore, we anticipate that at the end of the trial period, the system will be in place to apply this certification (or brand) to those entries that qualify (qualification requirements will be in place before entry submission).



Rainout shelters similar to this will be built and installed at five locations (see map)

ATTACHMENT D (page two)

Here are more details on the two proposed water use/drought approaches. These approaches are based on similar protocols reported by Kansas State University, University of Arkansas and others (see selected references below):

- 1) **Approach 1- Individual Plot Level Irrigation:** The amount of plant material per entry would need to be sufficient to establish to a final area of approximately 32.28 sq. ft per entry per site. (10.76 sq. ft./plot x 3 reps)
 - a. Year 1- Plots are fully established under full irrigation levels (plot size is 1 meter x 1 meter or 10.76 sq. ft.)
 - b. Years 2, 3, 4, etc.- Following uniform irrigation of all plots to initiate the study, full scale, automated irrigation is terminated, and individual plots are thereafter monitored on a regular basis (could be daily, bi-weekly, or weekly to correspond to particular watering frequencies allotted by the region or budget provided the cooperator) during the morning hours of the dry-down 'season'.
 - c. When quality attributes (wilt/firing/% green cover, etc.) of a specific plot or plots are noted to have fallen below a defined threshold (i.e. 50% green cover or another prescribed level), it is hand-irrigated with an amount of water necessary to recharge the root zone to field capacity (between ½" to 1"). Irrigation events are recorded on a per plot basis, so that total irrigation applied over the season can be calculated on a plot basis and statistics applied.
 - d. A dry-down 'season' would last around 100 days, then plots would be fully irrigated to assess recovery. Turf quality ratings will be collected as well during dry down and recovery.
 - e. A rain-out shelter will be employed for this approach. Data produced through the work would document 1) 'water quantity required (inches) per entry' for each location, 2) turfgrass quality before and during dry-down, during and after recovery, and a 3) ranking of the entries used.

Selected References:

Lewis, J.D. et al. 2012. Wilt-Based Irrigation in Kentucky Bluegrass: Effects on Visual Quality and Irrigation Amounts Among Cultivars. *Crop Sci.* 52:1881–1890. doi: 10.2135/cropsci2012.01.0033

Richardson, M. D. et al. 2009. Drought Tolerance of Kentucky Bluegrass and Hybrid Bluegrass Cultivars. Online. *Applied Turfgrass Science*. doi:10.1094/ATS-2009-0112-01-RS.

Richardson, M.D. et al. 2012. Irrigation Requirements of Tall Fescue and Kentucky Bluegrass Cultivars Selected Under Acute Drought Stress. Online. *Applied Turfgrass Science* doi:10.1094/ATS-2012-0514-01-RS.

Steinke, K. et al. 2010. Drought Response and Recovery Characteristics of St. Augustinegrass Cultivars. *Crop Sci.* 50:2076-2083. doi:10.2135/cropsci2009.10.0635. Published online 16 June 2010.

USGA Turfgrass and Environmental Research Online. Vol. 11, No. 6, June 1, 2012, p. 1-12.
<http://www.lib.msu.edu/cgi-bin/flink.pl/?recno=205406>



Plots would be individually watered after they reach the desired drought stress threshold.

ATTACHMENT D (page three)

Approach 2- Zone Level Irrigation: Larger study area size (~3 to 4 times more area and plant material) would be needed for accommodating multiple studies or 'zones' of irrigation. The amount of plant material per entry would need to be sufficient to establish to a final area of approximately (3 ET levels x 3-6 entry reps/ET level x 10.76 sq. ft) ~200 sq. ft. per location (*depends on location irrigation design and availability*). This trial would not be conducted under rainout shelter due to size constraints.

- a. Year 1- Similar to Approach 1, a full set of replicated entries would be established, but within each of 3 target irrigation ET levels (zones). Plots (*1 m x 1 m or similar size*) will be fully established under full irrigation levels.
- b. Years 2-4- Irrigation treatments imposed. ET levels will correspond to 3 levels of historical reference evapotranspiration (ET_o) for the location, the maximum of which should be near full water requirement (~0.75 x ET_o for cool-season) and lowest of which should be ~1/4 of this maximum level. Alternatively, if ET_o data are unavailable, one could arbitrarily apply defined amounts (i.e. 3/4" per week, 1/2" per week, and 1/4" per week to the respective zones.
 - i. Cool-season: 0.75 x ET_o , 0.5 x ET_o , 0.25 x ET_o applied 2x weekly
- c. Frequency of irrigation to plots would also be a constant 1 or 2 day per week irrigation schedule (*a single frequency should be decided on for all locations*).
- d. Irrigation scheduling to account for rainfall
 - i. Approach 1- Let system run regardless of rainfall, do not adjust irrigation
 - ii. Approach 2- Do not adjust schedule for any events <0.25". Account for 50% effective rainfall for all other events in adjusting irrigation applied for each zone. (For instance, if a 1" rainfall is received; all plots are turned off for one event. If 1/2" is received, only the low irrigation level may be turned off, but others receive appropriate % adjustments to account for 1/4" effective rainfall.
 - iii. Ultimately the key will be accurate accounting of total water received within each zone on a weekly basis.
- e. Quality attributes (*wilt/firing/% green cover, etc.*) of all plots within each irrigation level will be noted regularly during the study, just prior to an irrigation day during the morning hours.
- f. At the conclusion of the study, irrigation + rainfall for each zone would be totaled by week (~10-14 weeks in duration). Quality (>6) or other parameter (>75% green cover) of interest in determining acceptability would also be noted on a per plot basis for each week. Finally, the particular amount of water needed to sustain acceptable quality each week would be determined on a plot by plot basis and totaled for the study. This amount might fluctuate by week or month. For example, bluegrass may maintain acceptable quality with only 0.5 x ET_o in June, but in July or August, may require 0.75 to maintain acceptability. This method will account for weekly or monthly changes in minimal irrigation levels required.
- g. This approach is best suited for areas of the US that likely see visible drought stress arise in summer months where irrigation is not applied, i.e. (New Mexico, California, Colorado, etc.).
- h. Repeating the studies over three years will allow for upper and lower end seasonal requirements to be determined for each location.
- i. Data produced through the work would also document 1) 'water quantity required (inches)' per entry for each location, 2) turfgrass quality ratings at regular intervals, and a 3) ranking of the entries used.