National Turfgrass Evaluation Program Required Protocols, Standards, and Applications for the Visual Field Assessment of Turfgrasses

(Not for Publication)

An NTEP Publication

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Introduction

The National Turfgrass Evaluation Program (NTEP) is a not-for-profit organization that facilitates the assessment of experimental and commercial turfgrasses for the turfgrass seed and sod industries in cooperation with university turfgrass scientists. The collection of turfgrass species and cultivars presently used in the home and commercial landscapes is driven by consumer choice. Commercial and public scientists involved in the development and evaluation of turfgrass species and cultivars have strived to adopt means of evaluating turfgrasses that coincides with the criteria underlying consumer choice. Assessment approaches used by turfgrass scientists have included visual field assessments (VFAs) and quantitative measures of turfgrass characteristics. The visual assessment approach has emerged as the most reliable and accurate method of turfgrass evaluation. Quantitative measures of turfgrass performance are recognized as valuable supplements to the visual assessment approach, but these measurements alone are challenged to coincide with consumer choice criteria. The VFA of turfgrasses is NTEP's principle means of turfgrass evaluation.

NTEP references the person conducting turfgrass evaluation the "turfgrass rater". The rater may be the principle investigator or scientist responsible for the NTEP contractual obligation, or a research technician or associate responsible to the principle investigator (i.e. principle rater). In 2007, NTEP undertook a survey to determine a profile of protocol and standards used by university raters during their VFA of turfgrasses[1]. This survey revealed significant variation among raters in terms of definitions, protocols and standards used in their evaluations. Based on these findings, NTEP has written the following text as a guide for raters to normalize their evaluation methodology.

Definitions

Turfgrass Quality

Turfgrass scientists adopted the *Turfgrass Quality* term in the 1950's as the field of turfgrass science emerged and a need arose for assessing the performance of turfgrass plantings. The turfgrass quality term is defined as the degree to which a turf conforms to an agreed standard that is a composite of uniformity, shoot density, leaf texture, growth habit, smoothness, and color[2]. The VFA scale utilized to rate turfgrass quality is widely accepted as 1 to 9; with 1.0 = poorest possible quality and 9.0 = best possible quality.

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[1] Krans, J.V., and Morris, K. 2007. Determining a profile of protocols and standards used in the visual field assessment of turfgrasses: A survey of National Turfgrass Evaluation Program – sponsored university scientists. Online. Applied Turfgrass Science dol:10.1094/ATS-2007-1130-01-TT.

[2] Beard, J.B., and Beard, H.J. 2005. Beard's turfgrass encyclopedia for golf courses, grounds, lawns, and sports fields. Michigan State Univ. Press, East Lansing, MI.

Each component of turfgrass quality stands alone in its contribution to the overall quality score.

The “agreed standard” stated in the turfgrass quality definition is a pivotal and sometimes controversial term. This standard serves as a reference for the rater to idealize when assigning the quality score. Past experience and knowledge of the quality components, weight transfers, and score assignments are necessary for raters to accurately and consistently allocate scores. Characterization and use of a reference standard will be discussed in detail in the *Standards* section of this document.

Components of Turfgrass Quality

The turfgrass quality term, by definition, includes six components of quality. The descriptions of each component are designed to provide focus and direction to the rater while he or she assesses a planting. The components of turfgrass quality adopted by NTEP include uniformity, shoot density, leaf texture, leaf orientation, smoothness, and color. These components have been found to mirror the phenotypic traits of a turfgrass planting that coincide with consumer choice criteria.

Uniformity – Turfgrass uniformity is the degree to which a turfgrass community is free from variation in color, density, texture, and growth habit. Non-uniform turf may occur because of a heterozygous plant population, off-type seed or vegetative segments contaminating a uniform plant population, non-uniform seed distribution or establishment, non-uniform fertilizer or pesticide applications, abiotic and biotic injury, and/or cultural accidents i.e. scalping, chemical burns, etc. In most cases, a planting having low uniformity (regardless of the cause) will have a long lasting affect on the quality score. This negative influence on quality should be scored as such until the turfgrass planting has changed its phenotype or recovered from injury to a more uniform planting. NTEP requires the rater to determine the cause of a low uniformity score and record the degree of variation or injury. This record of injury is especially critical when biotic stresses are responsible for poor turfgrass uniformity. A rater’s ability to identify and rate a biotic stress is fundamental to plant improvement using host-plant resistance breeding. The documentation of turfgrass uniformity can be rated using a visual scale 1 to 9 or by recording the % variability from 0 to 100%. This requirement by NTEP to record the causes of poor uniformity is important for consumer information, but indispensable to the turfgrass breeder as a path to improve future turfgrasses.

Shoot density – Shoot density is the number of shoots per unit area and may be expressed in shoots per square inch or square centimeter. This component has an obvious quantitative dimension and is widely reported in the turfgrass literature as such. The VFA of shoot density has also been recognized as an effective and alternate means of quantifying shoot density. High shoot density surpasses low shoot density as a desirable trait and should translate to high quality scores. In ranking shoot density, the rater should recognize that there may be exceptions to assessing density desirability. In all cases, NTEP will highlight these exceptions in the study protocol for the rater to properly allocate a quality score. For example, a golf course rough must serve as a player penalty, but must also provide easy ball location. Given this example, NTEP will highlight the desirability of low shoot density and the application of this turfgrass use in assigning a quality score. Shoot density also has an intrinsic relationship to a species or cultivar’s morphology. Turfgrass species or cultivars with a close concentration of axillary buds and contracted space compatibility among sister plants have the necessary pre-requisite to generate high shoot density (i.e. greens-type creeping bentgrass and bermudagrass). Among these grass types, shoot density should be weighted as a critical component in the quality score. Shoot density values can also be altered by culture and environmental parameters. Environmental and cultural factors such as shade, salinity, drought, nitrogen (N) fertility, mowing, irrigation and cultural errors or accidents can artificially alter density scores. In these cases, altered shoot density may occur, but eventually will self-regulate and reach a sustained level.

Leaf Texture – Leaf texture is the width of a turfgrass leaf viewed collectively over the turfgrass planting. Leaf texture, similar to shoot density, has a quantitative dimension and a direct morphological origin. For example, fine leafed fescues have a narrow leaf width (or fine texture) due to filaform leaf morphology. In contrast, tall fescue and St. Augustinegrass have coarse leaf texture due to dome shaped stem apexes yielding wide and flat leaf forms. Narrow (fine) leaf texture surpasses broad (course) leaf texture as a desirable trait and should translate to high quality scores. Among quality components, leaf texture and shoot density can be viewed as linked traits. Turfgrass planting with high shoot density have fine texture and vice-a-versa. Leaf texture is also a plastic trait because leaf width can be altered by cultural and environmental parameters. Environmental and cultural factors such as shade, drought, salinity, nitrogen (N) fertility, mowing and irrigation have been shown to alter leaf texture values. Similar to shoot density, leaf texture altered by specific environments and culture will eventually readjust and reach a sustained width.

Leaf Orientation – Leaf orientation is the point of direction of shoots and an important component of turfgrass quality for greens and other closely mowed turfgrass. Leaf orientation is divided as random or upright. Leaf orientation is determined by species growth habit as well as cultural practices. Turfgrass plants with close proximity of stem apexes (bunch-type and compressed rhizomatous and stoloniferous types) have a more upright leaf orientation compared to turfgrass plants with a wide proximity of stem apexes (elongated stoloniferous and rhizomatous types); yielding a prostrate and random orientation. Leaf orientation is most important for species and cultivars having a playability uses (i.e. putting greens or grass courts) and frequently is manipulated with cultural practices. Mowing direction, vertical cutting and grooming are examples of cultural tools that alter leaf orientation. Upright leaf orientation surpasses random orientation and should translate to high quality scores.

Smoothness – Smoothness is a term that characterizes canopy irregularities and is an important component of turfgrass quality for greens and other closely mowed turfgrass surfaces. A poor smoothness assessment is generally caused by leaf shredding immediately after mowing or irregular growth among plants (i.e. heterozygous plant populations) found within the same turfgrass planting. A flat or good smoothness assessment surpasses a variable or poor assessment and should translate to high quality scores.

Color – Color is usually the first component of turfgrass quality recognized by raters and consumers. Color is a visual perception of light reflected or emitted by a turfgrass planting. The light emitted from the planting results from to a composite of turfgrass and weed pigments (chlorophyll, anthocyanin, and carotene) combined with a background reflection of soil and dying and dead leaves. Human preference of turfgrass color generally favors hues of green, bluish green or greenish blue having high saturation and moderate brightness. These turfgrass colors are often characterized in terms of their therapeutic value that gives people a sense of richness and tranquility. In most situations, a dark green color surpasses a light green or yellow-green color and should translate to high quality scores. There may be exceptions to a dark green color preference and NTEP will highlight this exception when needed in the study protocol to allow the rater to allocate a representative quality score. An example of this may occur in a climatic zone of high naturalized annual bluegrass populations. In this situation, a turfgrass planting with a yellow-green color may be more desirable than a dark green planting because of the likely contamination by annual bluegrass (a yellow-green colored plant) that would be masked by a yellow-green turfgrass. As such, a more uniform color is sustained.

Protocol

Protocol Categories

Rating protocol provides a framework for the rater to follow when conducting VFAs of turfgrasses. Accurate, consistent, and repeatable quality scores are based on the rater's ability to follow a prescribed rating protocol. Protocol categories that NTEP requires raters to follow are (a) time of day; (b) sky conditions; (c) orientation to the sun; (d) length of time post-mowing; (e) direction of mowing; (f) plot identity; (g) establishment of the quality scoring range; (h) whole number values; (i) compromised plot(s); and (h) maintenance of plot integrity. A description of protocol requirements are listed below and summarized in Table 1.

Time of Day - The time of day is the time period during the daylight hours when the rater is required to conduct a VFA. **NTEP's required protocol for the assessment time period is from 10:00 AM to 3:00 PM.** This period is selected to avoid the early morning and evening hours when light quality is altered by the low angle of the sun's rays passing through high concentrations of the earth's atmosphere. Quality components assessments of color, shoot density, and leaf texture are most affected by the time of day.

Sky Condition – The sky condition is the absence or presence of clouds in the sky during the time period the rater is conducting a VFA. **NTEP's required protocol for optimal sky condition for assessing a turfgrass planting is overcast.** An overcast sky condition dampens the brightness of the sunlight and reduces radiant glare from leaf surfaces and reduces interleaf shadowing. The alteration of light quality due to radiation passing through an overcast sky is recognized as a potential artifact in scoring quality; however the glare of the sunlight from the grass and the interleaf shadowing surpasses the negative affects of altered light quality.

Orientation to the Sun – The orientation to the sun is the person's view of the turfgrass planting as either face-to-the-sun or back-to-the-sun. Orientation to the sun is only considered when the assessment of a turfgrass planting is made under full sun due to a geographic location dominated by full sun or a rater's time schedule that restricts his or her choices on day selection. **NTEP's required protocol for orientation to the sun is the rater's view is back-to-the-sun.** Back-to-the-sun reduces the sun's brightness on the rater's vision and the indirect reflection from the rater's recording paper (usually white).

Length of Time Post-Mowing – The length of lapsed time post-mowing prior to conducting a VFA affects the assessment of a turfgrass planting. **NTEP's required protocol for the length of time post-mowing prior to conducting a VFA is 24 hours.** Assessing a turfgrass planting immediately following a mowing is not recommended because mowing can partially mask quality components of color, leaf texture and shoot density. Surface smoothness is also difficult to assess immediately following mowing because some re-growth is required to assess this component.

Direction of Mowing - The view of the plot being assessed can be altered by the direction of travel of the mower. Mowing affects the leaf orientation by collectively driving the turfgrass canopy in the direction of mower travel. This folding of the grass canopy in alternating directions affects the saturation level and reflection of the grass color. To avoid this striped mowing affect, **NTEP's required protocol for direction of mowing is the plots should be mowed in a single direction or the rater should maintain a consistent directional view of the plots based on mower direction.**

Plot Identity - The maintenance of plot identity is a critical responsibility of the rater. Lack of accurate plot identity invalidates the quality score. The identity of plots can be established in one or more ways. The rater should always have a plot and treatment plan in-hand to provide a map of treatment locations. However, because some entries are very similar, determining the plot borders and corners can be difficult, especially when treatment numbers are high. **NTEP's required protocol for plot identity is the plot corners or borders should be marked temporarily or permanently during the assessment process.** Possible means of marking may include metal, plastic or wood inserts at plot corners, paint marks at plot corners or along borders, string placement along borders, or non-selective herbicide treatments that cause turfgrass mortality at plot corners or along borders.

Establishment of Quality Score Range – The establishment of a quality score range prior to the systematic assessment of scores is an important protocol requirement. **NTEP's required protocol for establishment of the quality score range is that the rater "walk-over" all plots prior to the systematic assessment of scores to establish a scoring range.** During this walk-over, the rater scores and marks example high and low quality plots as well as minimally acceptable plots with colored flags or stakes to identify each type. These scored and marked plots serve as standards and set the score range and level that will be used during the complete assessment of the trial that day. This action is required to avoid "score drift". Score drift can occur when the rater does not establish a scoring range and score values are inconsistent or different among same quality level plots. In addition, **NTEP's required protocol is that the rater scores the entire trial during a single day.** Dividing the assessment process among two or more days is not recommended. If unfavorable weather or a rater's time schedule does not permit complete scoring of the trial, the rater should rate all entries within a single replicate block before the end of the day. The assignment of scores and the standards used for assessing plot quality will be discussed in detail in the *Standards* section of this document.

Whole number values –**NTEP's required protocol of score values is only whole numbers are to be used to assign a turfgrass quality score.** This requirement is designed to simplify the assessment process and compel raters to make definitive decisions.

Compromised Plot(s) - The nature of field plot research lends itself to management errors or accidents that can result in one or more compromised plots during the life of a trial. **NTEP required protocol for compromised plots is that all compromised plots are eliminated from assessment or data collection.** The responsibility to recognize compromised plots lies with the turfgrass rater. A compromised plot can be reconstituted and brought back as a representative treatment; however, in most situations, this action is rare. When a plot is classified as compromised by the rater, NTEP requires the rater to contact NTEP's Director to register this action.

Maintenance of Plot Integrity – NTEP provides guidelines for the culture of all turfgrass trials in the contractual agreement. **NTEP required protocol is the rater execute all designated cultural requirements, and to use personal judgment to maintain plot integrity.** A devastating pest invasion or aboitic event may occur that threatens the integrity of one or more treatments. In either of these cases, the rater is expected to take all necessary action to control or modify the pest or aboitic threats to preserve plot integrity.

Table 1. A listing of protocol categories and NTEP's required action to be taken by the rater.

Protocol Category	NTEP's Required Action
Time of Day	VFA between 10:00 AM and 3:00 PM
Sky Condition	VFA during overcast sky conditions
Orientation to the Sun	Rater's view is back-to-the-sun for VFA
Length of Time Post-Mowing	24 hours lapsed time prior to VFA
Direction of Mowing	Rater views plots from one or same mower direction
Plot Identity	Mark plot corners or borders prior to VFA
Quality Score Range	Rater determines score range prior to VFA
Whole Numbers	VFA score values in whole numbers
Compromised Plots	Rater eliminates compromised plots prior to VFA
Maintenance of Plot Integrity	Rater takes necessary action to preserve plot integrity

Standards

Quality Reference Standard

The turfgrass quality score is assigned to a turfgrass planting based on an agreed reference standard. This standard represents an idealized image of the "best possible" and "poorest possible" turfgrass quality in terms of uniformity, shoot density, leaf texture, leaf orientation, smoothness, and color. The rater uses this standard to compare against all treatments. The turfgrass quality score is <u>not</u> a relative ranking of treatments.

There are two sets of criteria that can be used to idealize the reference standard. One set of criteria is based on an optimal growth environment (i.e. optimal light, temperature, moisture, and nutrients) and management regime (i.e. optimal mowing, soil cultivation and use) (**OEM reference standard**). The second or other set of criteria is based on the current environment or management regime (**CEM reference standard**). Using either criteria, the rater must idealize his or her reference standard to compare against all treatments and assign a quality score using a scale of 1 to 9; with 1 = poorest possible turfgrass quality and 9 = best possible turfgrass quality. An example of the difference between the OEM and CEM reference standards is illustrated for bermudagrass growing in the early spring season following winter dormancy. Turfgrass quality of bermudagrass in the early spring is low because the grass is recovering from winter injury and temperatures are not optimal {less than 80 to 95°F (27 to 35°C)} for its best possible quality. If the rater conducting assessments at this time of year uses the OEM reference standard, the assessments will be in the low range of the 1 to 9 scale because the reference standard is optimized and the grass is growing at a suboptimal environment. However, if the rater conducting assessments of bermudagrass in the early spring uses CEM to formulate his or her idealized reference, the assigned scores could be distributed throughout the full range of the 1 to 9 scale because the reference standard accounts for a suboptimal environment. Both the OEM and CEM reference standards have advantages and disadvantages in their use. The advantages of the OEM standard is a single idealized standard (species specific) can be applied across all environments and management regimes; and the OEM standard allows for valid comparisons to be made between environments due to the effects of location thereby allowing for year-to-year and month-to-month natural variations in quality to be expressed. Idealizing the OEM standard should also require less experience among raters and different raters assessing the same trail should assign similar scores. The disadvantage of the CEM is the rater must identify a non-optimized environment or limited management regime and interpret the affects of a non-optimized environment and limited management regimes on his or her idealized standard. In addition, the CEM standard does not permit natural variation due to the lack of full expression of the growing environment thereby minimizing the overall effect of the environment on turfgrass quality. **NTEP requires that the rater use the OEM reference standard.**

The OEM reference standard must be species specific. **NTEP requires that the rater idealize an OEM reference standard that is species specific.** A single or universal reference standard that applies across all turfgrass species is not applicable. For example, a rater hosting both a perennial ryegrass and Kentucky bluegrass trial must idealize an OEM reference standard for each species and to apply the appropriate reference standard to each species respectively.

Minimal Acceptance Standard

The minimal acceptance standard is based on the OEM reference standard and represents a treatment that has low quality, but sufficient or acceptable quality for its intended use. **NTEP requires that the "6" score is assigned to all treatments that meet the minimal acceptance standard.** This score stands alone as a "borderline" quality score. The borderline or "6" score represents a treatment that has a low quality score, but is borderline or minimally acceptable for its intended use. Scores less than "6" are treatments that have low quality scores and the planting is unacceptable for its intended use. An example of a minimally acceptable treatment should be identified among the entries during the "walk over" action. Compared to all other score values, NTEP anticipates that when the rater assigns a "6" score, he or she has identified the quality deficiencies contributing to the low score value, but has also identified the quality attributes that makes this treatment acceptable for its intended use. Using the above bermudagrass example that was used to illustrate the difference between OEM and CEM reference standards, the very early season quality scores of bermudagrass would most likely not reach the minimal acceptance standard or “6” score.

Using the “9” Score

The “9” score is sometimes a controversial score. The “9” score represents the “best possible quality”. This score does not represent a perfect, future perfect or unattainable perfect treatment. **NTEP requires that the raters apply the ‘9’ score to all treatments reaching the best possible quality and should be available to all species and cultivars at all times.** However, the rater should also be conservative in the use of the “9” score because there is no value above this score to separate this treatment from a better performing treatment. By definition of the OEM standard, the culture and environment of a turfgrass planting will influence the use of the “9” score. For example, a turf grown under high management and an optimal environment will lend itself more to a “9” score than a turf planting grown at a less favorable environment and/or minimal management. In addition, history has shown that turfgrass quality has and will most probably continue to improve over time for all major species. History has also shown that the OEM reference standard used by raters for these species has changed to meet or match this improvement in turfgrass quality. This change in the OEM reference standard illustrates that this image or “9” score is not static, but has and will continue to change as the level and expectations of turf quality improves.

Using the “1” Score

The “1” score is seldom used by raters and signifies the “poorest possible quality”. **NTEP requires that the raters apply the “1” score to all treatments meeting the poorest possible quality and should be available to all species and cultivars at all times.** Some rater’s image of a “1” scored treatment is a plot without turf or bare soil. A plot of bare soil may exist, but should rarely occur in an NTEP trial because raters are required to provide the necessary management to maintain plot integrity. A turfgrass plot that reaches a bare soil status can not be evaluated for turfgrass quality because it lacks turf. A bare soil plot is most likely the result of a management error or accident and should be listed as a compromised plot.

Applications

Field Requirement and Minimum Plot Size

The VFA method of evaluation is NTEP’s principal means of assessing a turfgrass planting. As the method implies, the turfgrass quality definition, protocols, and standards are written for field grown plantings. The application of NTEP’s VFA methodology is not intended for turfgrass plants grown in pots or flats under glasshouse, growth chamber, or field environments. The acceptable field plot size of a turfgrass planting will vary depending on the turfgrass use and culture. **NTEP requires that the minimum field planting size for a VFA is 1.5 square meter.** Smaller field plot sizes limit the rater’s ability to assess components such as uniformity, smoothness and color. Smaller field plot sizes also limited the use of cultural tools such as coring, vertical cutting, etc. In addition, mower types and mowing itself can compromise small plots by unintended scalping. An enhanced "edge" affect is also recognized in small plot sizes and have been shown to compromise the assessment process. The configuration of the minimum 1.5 square meter planting can be square or rectangular.

Assessment of Quality Components

The turfgrass quality assessment is a composite score determined by the collective contribution of all components (i.e. uniformity, shoot density, leaf texture, leaf orientation, smoothness, and color). In some trials, NTEP may require the rater to assess one or more of the individual components of turfgrass quality. This assessment of individual components is conducted similar to the overall turfgrass quality assessment score, except only one component of quality is idealized using the OEM reference standard. Each treatment is rated using a 1 to 9 scale; with 1 = poorest possible component quality and 9 = best possible component quality. The "6" score is also the minimally acceptable value for the assessment of the individual components and should be assigned using the same criteria stated for the overall quality score. The rating of the individual components is undertaken to provide further quality characterization, insight in to the overall turfgrass quality score designation, and knowledge of specific biotic and aboitic stresses affecting turfgrass performance. When specific biotic stresses are suspected or identified, the rater is urged to collaborate with university plant pest specialists to make or confirm identification. In addition, NTEP recommends that the rater contact NTEP's Executive Director when any biotic or abiotic stress threatens the integrity of the trial. The recording, identification, and management of biotic stresses affecting NTEP trials are crucial responsibilities of the rater. **NTEP requires that the individual quality components are rated using a 1 to 9 scale; with 1 = poorest possible component quality and 9 = best possible component quality.** When this scale is applied to the each component, the rating follows the direction of the trait that promotes a higher quality score (Table 2).

Table 2. The components of turfgrass quality and corresponding description using the 1 to 9 rating scale.

Quality Component	**1 Score**	**9 Score**
Uniformity	Poor uniformity	Good uniformity
Shoot density	Low shoot density	High shoot density
Leaf texture	Course leaf texture	Fine leaf texture
Leaf Orientation	Random orientation	Upright orientation
Smoothness	Poor smoothness	Good smoothness
Color	Light or yellow green	Dark green

Assessment of Environmental, Developmental and Morphological Events

Turfgrass traits of establishment rate, thatch depth, weed encroachment, chill stress tolerance, frost stress tolerance, heat stress tolerance, winterkill tolerance, spring green-up, spring recovery, pest stress tolerance, traffic stress tolerance, drought stress resistance, salinity stress tolerance and seedheads are evaluated by NTEP to identify the factors that are contributing to the overall turfgrass quality score. These turfgrass traits are characterized in terms of the turfgrass performance (not the stress or injury) by assessments using % values or by using a scale of 1 to 9; with 1 = poor resistance, tolerance, or performance and 9 = excellent resistance, tolerance, or performance. A list of these turfgrass traits are defined,[3] characterized and summarized in Table 3. **NTEP requires that the rater assess these traits on a timely basis as outlined in the each contractual agreement.**

Establishment Rate – Establishment is the root and shoot growth following seed germination or vegetative planting needed to form a mature, stable turfgrass planting. The *establishment rate* is measured by recording the % turfgrass cover at sequential time intervals (weekly) until a uniform, stable turfgrass planting is reached (usually 95% turfgrass cover) or by recording the time (days) for a uniform, stable turfgrass planting (usually 95% turfgrass cover).

Thatch depth – Thatch is the intermingled organic layer of dead and living leaves, stems, and roots of grasses that develops between the turf canopy of green vegetation and the soil surface. The *thatch depth* is measured from an extracted 5 cm dia. turfgrass plug by cutting away the turfgrass canopy above the thatch, placing a 5 cm dia. x 1 kg weight on the exposed thatch surface and measuring the depth of thatch with a ruler.

Weed Encroachment – A turfgrass weed is a plant that is unsightly and objectionable, or that interferes with the activities or welfare of humans. *Weed encroachment* is measured by recording the type and % composition of the weed(s) in a turfgrass planting on a % scale of 0 to 100% weed cover.

Chill Stress Tolerance - Chilling stress is the exposure of a turfgrass planting to low or suboptimal temperatures in the absence of freezing. Turfgrass with tropical or subtropical origin, depending on species, are chill stressed at temperatures between 50 and 32^0 F (15 and 0^0 C). All stages of turfgrass growth and development are susceptible, and this susceptibility limits the season of growth. Chill stress tolerance is the ability of the chill sensitive turfgrass to survive chill stress temperatures. Warm-season turfgrasses species and cultivars vary in their chill stress tolerance, while the cool season turfgrasses are classified as chill-insensitive plants. *Chill stress tolerance* is measured by recording leaf chlorosis or bleaching on a scale of 1 to 9; with 1 = poor chill stress tolerance or high leaf chlorosis or bleaching and 9 = excellent chill stress tolerance or no leaf chlorosis or bleaching.

Frost Stress Tolerance - Frost is a deposit of one of several forms of ice crystals as a result of the condensation of water vapor on turfgrass leaf surfaces at temperatures colder than 32 F (0^0 C). Warm-season turfgrasses species and cultivars vary in their frost stress tolerance, while most cool season turfgrasses are classified as frost-insensitive plants. Frost tolerance is the ability of the sensitive turfgrass to survive frost deposits on the leaf surfaces. *Frost stress tolerance* is measured by recording leaf blade necrosis on a

[3]Beard, J.B., and Beard, H.J. 2005. Beard's turfgrass encyclopedia for golf courses, grounds, lawns, and sports fields. Michigan State Univ. Press, East Lansing, MI.

scale of 1 to 9; with 1 = poor frost tolerance or high leaf blade necrosis and 9 = excellent frost tolerance or no leaf blade necrosis.

Heat Stress Tolerance – Heat stress is the exposure of turfgrass plantings to supraoptimal-high temperatures. Mechanisms of heat stress may include high temperature disruption of metabolic pathways or high temperature degradation of pivotal proteins. Heat stress tolerance is the ability of the turfgrass to survive or grow under supraoptimal-high temperatures. *Heat stress tolerance* is measured by recording injury or dieback of existing roots followed by stunted growth and turf mortality using a scale of 1 to 9; with 1 = poor heat tolerance or widespread dieback of existing roots, stunted shoot growth, and significant thinning and mortality of the turfgrass planting; and 9 = excellent heat tolerance or no dieback of existing roots, normal shoot growth, and no thinning and mortality of the turfgrass planting.

Winterkill Tolerance – Winterkill is the injury of a turfgrass planting during the winter season due to freeze stress kill, winter desiccation, and/or low-temperature diseases. Winterkill tolerance is the ability of a turfgrass planting to survive these winter stress constraints. *Winterkill tolerance* is measured by recording winterkill injury two weeks after spring green-up using a scale of 1 to 9; with 1 = poor winterkill tolerance or stunted shoot growth and widespread thinning and mortality of the turfgrass planting and 9 = excellent winterkill tolerance or normal shoot growth and no thinning and mortality of the turfgrass planting.

Spring Green-up – Spring green-up is the initial seasonal appearance of green leaves originating from dormant axillary buds as spring temperatures and moisture conditions become favorable for growth. *Spring green-up* is measured by recording the calendar date of the sustained appearance of newly emerged leaves within the dormant turfgrass canopy.

Spring Recovery – Spring recovery is the re-growth of the turfgrass planting following the winter season. *Spring recovery* is measured by recording the time (days) from the spring green-up assessment date to the date the turfgrass planting forms a uniform, stable turfgrass planting (i.e. usually 95% green cover).

Pest Stress Tolerance – Turfgrass pest are certain insects, fungi, bacteria, viruses, nematodes, weeds, birds, and rodents that are detrimental to a turfgrass planting. Disease and insect injury is measured by recording turfgrass shoot or root injury or turfgrass mortality caused by an invading disease or insect. *Disease* or *insect stress tolerance* is measured by recording turfgrass shoot and root injury and turfgrass mortality using a scale of 1 to 9; with 1 = poor tolerance to disease or insect injury or widespread turfgrass shoot and root injury and turfgrass mortality and 9 = excellent tolerance to disease or insect injury or no turfgrass shoot and root injury and turfgrass mortality.

Traffic Stress Tolerance – Traffic stress is turfgrass injury caused by human activity resulting in turfgrass wear, sod divoting, and/or soil compaction. Turfgrass wear stress causes the decline of shoot biomass and eventual thinning of the turfgrass planting. Turfgrass sod divoting is the displacement of localized (usually small) sod segments. Soil compaction stress causes high soil bulk density, and concomitantly a decrease in the soil porosity due to the application of the mechanical forces of traffic to the soil. Traffic stress tolerance is the ability of the turfgrass to survive all mechanisms of traffic stress (wear, divoting and soil compaction tolerance), and recover from the traffic injury (traffic recovery). *Wear tolerance* is measured by recording the lost of the turfgrass canopy mass following a simulated wear treatment using the formula: lost of canopy mass = pre-wear canopy mass – post-wear canopy mass. *Sod divoting tolerance* is recorded by measuring the opening size of a simulated divot treatment (cm). *Soil compaction tolerance* is measured by recording indicator of turfgrass vigor as demonstrated by leaf chlorosis, stunted growth, and plant mortality using a scale of 1 to 9 with 1 = poor tolerance or widespread leaf chlorosis, stunted growth and plant mortality; and 9 = excellent tolerance or no widespread leaf chlorosis, plant mortality and normal growth. Traffic recovery is the ability of the turfgrass planting to recover from traffic injury. *Traffic recovery* is measured by recording turfgrass re-establishment at sequential time periods (days) after traffic stress injury using a scale of 1 to 9 with 1 = turfgrass re-establishment; and 9 = excellent turfgrass re-establishment.

Drought Stress Resistance – Drought is a period of dryness in which the availability of soil water is insufficient to meet the requirements of the otherwise well adapted turfgrass. Drought resistance is the ability of the turfgrass to retard or delay drought stress despite the lack of available soil water to meet its requirements. Mechanisms of drought resistance include dehydration tolerance, dehydration avoidance, or drought escape. *Drought resistance* is measured by recording drought induced turfgrass leaf firing, permanent wilt and stunted growth using a scale of 1 to 9; with 1 = poor drought resistance or prominent leaf firing, widespread permanent wilt and stunted growth and 9 = excellent drought resistance or no signs of leaf firing or permanent wilt and normal growth.

Salinity Stress Tolerance – Salinity stress is the exposure of a turfgrass planting to soil salinity that adversely affect the uptake of waters by the turfgrass roots. Salt affected turfgrasses suffer from physiological water stress or tissue dehydration. Salinity stress tolerance is the ability of the turfgrass to survive and grow in salt affected soils. *Salinity stress tolerance* is measured by recording salinity induced turfgrass leaf firing, stunted growth and permanent wilt using a scale of 1 to 9; with 1 = poor salinity tolerance or prominent leaf firing, stunted growth and widespread permanent wilt and 9 = excellent salinity tolerance or no signs of leaf firing, normal growth and no evidence of permanent wilt.

Seedheads - Seedheads are inflorescence structures of turfgrass that consist of a flower cluster at the top of a reproductive or main stem. Seedheads are measured in terms of seedhead density, frequency and height. Density is measured by recording the number of seedheads per unit area; frequency is measured by recording the number of seedheads per unit area at sequential time intervals (days) and seedhead height is measured by recording the average height (cm) of the main stem including the flower cluster above the canopy surface.

Table 3. Turfgrass traits, measurements and the corresponding description of turfgrass performance, ranking or mortality.

Turfgrass Trait	**Measurement**	**Criteria or scale**
Seed Vigor	Time to 90% seed germination -	Days to 90% germination
Establishment Rate	Time to 95 % establishment -	Weeks to 95% turfgrass canopy cover

Thatch Depth	Depth of thatch -	Measured depth (cm)
Weed	Weed type -	ID weed type
Encroachment	Weed cover -	Percent weed composition
Chill Stress Tolerance	Mortality or injury of selected warm season turfgrasses to temperatures between 50 and 32 F (16 to 10 C).	Ranking usingn a 1 to 9 scale; with 1 = poor chilling stress tolerance; and 9 = excellent stress tolerance
Frost Stress Tolerance	Injury of turfgrasses due to foliar ice crystal formation -	Ranking using a 1 to 9 scale; with 1 = poor frost stress tolerance; and 9 = excellent frost stress tolerance
Heat Stress Tolerance	Mortality or injury of turfgrasses due to supraoptimal - high temperatures	Ranking using a 1 to 9 scale; with 1 = poor heat stress tolerance; and 9 = excellent heat stress tolerance
Winterkill Tolerance	Mortality or injury of turfgrasses caused by the loss of over-wintered buds due freeze stress kill, winter desiccation, and/or low-temperature diseases. -	Measured two weeks after the date of spring-up. Ranking using a 1 to 9 scale; with 1 = poor winterkill tolerance; and 9 = excellent winterkill tolerance.
Spring-up	First visible leaf growth within the turfgrass canopy after winter dormancy-	Calendar date.
Spring Recovery	Turfgrass re-establishment after winter dormancy-	Measured from date of spring green-up to the date of re-establishment. Time (days) required to form a uniform, stable turfgrass planting (i.e. usu. 95% green cover).
Pest Stress Tolerance	Mortality or injury of plants due to pest infestations -	Ranking using a 1 to 9 scale; with 1 = poor pest tolerance; and 9 = excellent pest tolerance.
Traffic Stress Tolerance	Canopy defoliation due to wear -	Lost of canopy mass = pre-wear canopy mass – post-wear canopy mass.
	Injury due to compacted soils -	Ranking using a 1 to 9 scale; with 1 = poor soil compaction tolerance; and 9 = excellent soil compaction tolerance.
	Turfgrass re-establishment after wear defoliation -	Ranking using a 1 to 9 scale; with 1 = poor re-establishment; and 9 = excellent re-establishment.
Drought Stress Tolerance	Mortality or injury of turfgrasses as a result of water deficient soils -	Ranking using a 1 to 9 scale; with 1 = poor drought stress tolerance; and 9 = excellent drought tolerance.
Salinity Stress Tolerance	Mortality or injury of turfgrasses due to salt affected soils-	Ranking using a 1 to 9 scale; with 1 = poor salinity stress tolerance; and 9 = excellent salinity

		tolerance.
Seedheads	Density -	Number of seedheads/unit area.
	Frequency –	Number of seedheads/unit area at sequential time intervals.
	Height -	Measured height (cm).

Weight Transfer Among Quality Components

The weight of a quality component is the emphasis or importance the rater places on a single component. A component with high weight assignment will have a greater influence on the quality score compared to a low weight assignment or lesser influence on the quality score. The components of turfgrass quality should be weighted depending on turfgrass use (i.e. golf courses, grounds, lawns, and sports field) and the level of culture (i.e. N fertility, mowing, irrigation etc). For example, color is a heavily weighted component for plantings that call for high aesthetic appeal i.e. commercial grounds and lawns. In plantings that allow low aesthetic appeal i.e. putting greens, weight is transferred from color to playability i.e. upright leaf orientation, high shoot density, etc. In the commercial use example, a turfgrass planting having a dark green color, medium shoot density and random leaf orientation may score an 8 or 9. In contrast, the same features of quality of turfgrass planting used for putting green may score only a 6 or 7. Turfgrass attributes vary according to aesthetic appeal, stabilization of soils, traffic tolerance, playability etc. Turfgrass culture level changes with N fertility, irrigation, mowing, cultivation and pesticide use.

Weight Transfer Based on Use

Aesthetic Appeal – Aesthetic appeal emphasizes the quality components associated with the therapeutic value of a turfgrass planting. The quality components associated with aesthetic appeal and subject to weight transfer are color, shoot density, uniformity and smoothness.

Stabilization of Soils - The stabilization of disturbed soils is a critical function of a turfgrass planting. The fibrous root system of the turfgrass planting holds the soil matrix stable and limits soil movement. The quality components associated with stabilization of distributed soils and subject to weight transfer are uniformity and shoot density.

Traffic Tolerance – Traffic tolerance is the ability of the turfgrass to survive traffic stress, and to quickly recover from traffic injury. Traffic tolerance of a turfgrass is determined by measurements of canopy wear, divoting, compacted soil tolerance and canopy recovery rate. The quality components associated with wear tolerance are shoot density and uniformity. The quality components associated with canopy re-growth following wear and subject to weight transfer are also shoot density and uniformity. The quality components associated with turfgrass tolerance to compacted soils and subject to weight transfer is uniformity.

Playability – Playability of a turfgrass planting is a critical function important to sporting events of golf, football, baseball, soccer etc. The quality components associated with playability and subject to weight transfer are shoot density, leaf texture, leaf orientation and smoothness.

Weight Transfer Based on Culture

High Levels of Culture – High levels of culture including optimized N fertility, mowing, cultivation and irrigation emphasize the components of color, shoot density and uniformity.
Low Levels of Culture – Low levels of culture including deficient or excess N fertility and lack or excessive mowing, cultivation and irrigation emphasize the component of uniformity.

Ethics and Responsibility

NTEP's mission is to generate unbiased and accurate assessments of turfgrass quality and performance. The assignment of unbiased quality scores to a turfgrass planting is solely guided by each rater's ethical standards. NTEP relies on the codes of high ethical standards as pledged to by all university scientists. Raters are required to adopt and adhere to the protocols, standards and applications as stated herein. These methods and applications are intended to normalize the VFAs of turfgrasses and minimize the experimental error associated with raters. In all cases, NTEP advocates the scientific method of discovery, impartial assessment of turfgrass performance and complete reporting of all data.

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