Research Technical Note
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How does shade affect *Zoysia matrella*? Learning observations of *Zoysia* turf under tentage

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Introduction

The recent Community Garden Festival held at HortPark from 21 August to 13 September, 2015 saw a relatively large tentage structure installed over the *Zoysia* lawn (**Fig. 1**). The tropical turfgrass, *Zoysia matrella* (carpetgrass) is of relatively lower shade tolerance compared to *Axonopus compressus* (cowgrass) [RTN06-2012: Selecting turfgrass species for shady conditions]. Inevitably, the extended period of shade on *Zoysia* will result in some expected reduction in turf quality. Some operational related questions with regards to survival and aesthetic of the lawn under shade are brought up:

1. Can the turf survive under the shade during this period?
2. Will there be unsightly chlorosis (pale green to yellowing) of turf under the shade?
3. Should a turf cover e.g., timber deck be used over the lawn to mask the unsightly display of chlorosis?

There was no previous quantification or documentation of light and shade profile generated by an artificial shade shelter. In addition, limited studies have been performed to describe and quantify how artificial shade impacts *Zoysia* turf in terms of morphological changes and turf quality. Therefore, this study was conceived to quantify the changes in *Zoysia* turf quality under shade. The significance of such documentation could potentially assist turf managers to better manage *Zoysia* turf under shade e.g. selection of appropriate shade structures (e.g., color and design of shade structure) for event management as well as turf management practices of *Zoysia* turf under shade e.g., frequency and height of cut.

Fig. 1 The event tentage was installed over the lawn in preparation for the Community Garden Festival

Effects of shade on plants

During photosynthesis, plants use light energy to synthesize raw carbon into carbon-compounds for growth and development. However, only light radiation in the wavelength range of 400-700nm is used. This wavelength range utilized by plants is known as Photosynthetically Active Radiation (PAR). The two properties of shade that influence plant growth in different ways are light quantity and quality. A reduction in light quantity affects the total amount of light energy the photosynthetic plant organs receive. Hence, this will impede the overall growth of the plants as less biomass is synthesized. Shade tolerant plants displaying **shade tolerance** under prolonged reduced light quantity conditions will result in slow and long term developmental changes of photosynthetic organs such as large and thinner leaves. In contrast, reduction in light quality, particularly in visible red spectrum, changes plant morphology such as elongation of shoots and increased flowering known as shade avoidance response. The **shade avoidance** response is a rapid adaptive trait to search and compete for better light quality. These responses are also frequently described as being shade intolerant behaviors and are manifested by sun-adapted plants under shade.

The lights profile within tentage structure

Fig. 2 The side views of tentage and spatial light profile received by turf under tentage.

The openings to the right and left flanks of the tentage were facing an East-West direction, respectively. The light intensity received by the turf under the tentage therefore varies spatially and temporally throughout the day (**Fig. 2**).

Relative light/ shade indicators

The relative brightness (luminosity) of the shade structure at ~1600 hr (26 August, 2015) was quantified using an uncalibrated light meter software (Lightmeter, Whitegoods©) installed on an Apple-Iphone™ machine. The light meter software has effectively shown that the center of the shade structure received least amount of light with the highest received on the left flank at 1600 hr (**Fig. 3**).

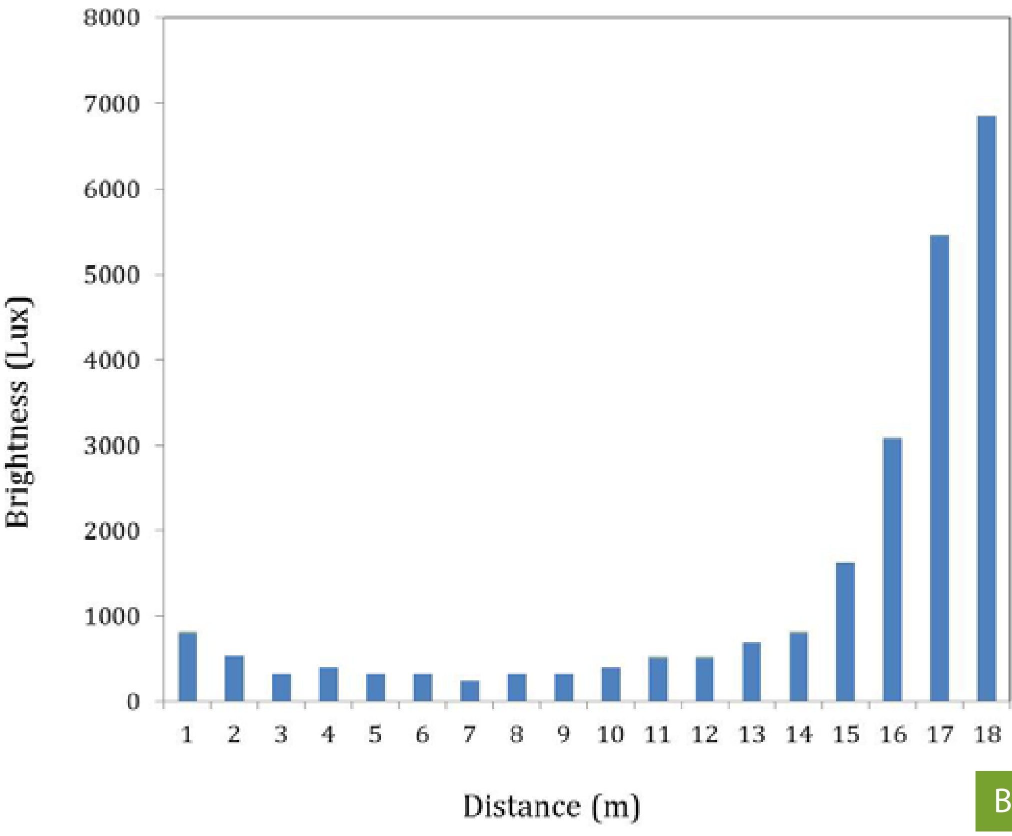

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Fig. 3 The image of the tentage at 1600 hr indicated higher luminosity (brightness) at the western opening of the tentage. (B) The brightness (Lux) readings obtained using the light meter from Right (East) to Left (West) of tentage. Cumulative distance from the right face of the tentage was plotted against Lux readings.

In general, level of shade (%) can be calculated as:
Shade level = $[(Light_{sun} - Light_{shade})/ Light_{sun}] \times 100\%$.

Based on the brightness (Lux) readings obtained at 1600 hr (26 August, 2015), the minimum shade level cast by the tentage was determined as >60% shade relative to the exterior of the tentage (0% shade). However, the luminosity measurement determines brightness as interpreted by the human eyes without providing useful information on the amount of light (Photosynthetic Active Radiation, PAR) needed for photosynthesis. Therefore, a similar light profile by distance using a portable quantum sensor (Li-Cor™ model LI 190SA with a LI-1400 datalogger machine) was characterized to understand the PAR profile on the sheltered turf. The readings obtained at 1000 hr (4 September 2015) also supported a minimum shade level of >60% within the tentage (**Fig. 4B**). In addition, the shade level immediately adjacent to the tentage (transition zone) was determined to be ~50% (**Fig. 4A**).

Based on the measured levels of luminosity (Lux) and PAR, the tentage structure was determined to effectively reduce both light quantity (Lux) and light quality (PAR) respectively. However, it should be cautioned that the level of shade (>60%) determined in this study only reflected the incident light level received at time of measurement. Hence, this will not truly reflect the total amount of incident light received by the entire turf surface daily. Thus, a better indicator of light received per unit day is to utilize the function **Daily Light Integral** which expresses the amount of PAR received per unit day. Future studies will be needed to examine hourly light profiles over several days in order to have a better quantification of shade profile created by a tentage.

In summary, a general profile showing the spatial distribution of shade created by the tentage can be illustrated below:

Fig. 4 The transition zone (50% shade) was defined as the region between tentage and open turf. (B) A suggested general shade profile created by the tentage structure during the event as determined by PAR level at 1000 hr (4 September 2015).

Effects of shade on *Zoysia* turf

The significant reduction of light quality and quantity within the tentage has resulted in distinct shade avoidance responses such as morphological and biochemical changes in the shade intolerant *Zoysia* turf.

These include:

1. Elongation in internode of vegetative shoot
2. Elongation of inflorescence spike
3. Elongation and narrowing of leaf blade
4. Increase of chlorophyll content i.e. leaves get darker green
5. Loss in turf firmness

A) Shoot Elongation

Elongation of internode and inflorescence spike was visually significant by 5 days after shade treatment (DAT). A final increase of 90% in internode length was determined at 20 DAT (**Fig. 5A**). As a result of internode elongation, the height of turf has also increased. This corresponded to over 30% increase of turf height by 5 DAT. In addition, the leaf width of *Zoysia* turf under shade became considerably reduced compared to exposed turf (**Fig. 5B**). Furthermore, the elongated shoots became loosely packed and resulted in an open canopy and a loss of surface firmness (**Fig. 6**). Rapid vertical growth of shoots was observed throughout the shade profile i.e. 60% to 90% shade (see **Fig. 4B** for proposed shade profile). Interestingly, no vertical growth was observed in shade conditions under 50% (transition zone), **Fig. 4A**.

The elongation of internode is a rapid shade avoidance response displayed by shade intolerant plants to increase their capacity to compete for more light (Beard, 1973). Similar shoot elongation and decrease in leaf width was also observed in different *Zoysia* genotypes e.g. *Zoysia* 'Diamond' established under tree shade (Peterson et al., 2014) as well as artificial shade of more than 75% (Qian et al., 1998). Moreover, Qian et al. (1998) found that shade level <40% did not induce rapid vertical growth as observed in >75% shade. Thus, the lack of vertical growth in the shady transition zone (50%) in this study was rather consistent with what was reported for *Zoysia* 'Diamond' grass. Hence, it is tempting to suggest that the minimum shade level the local variant of *Zoysia matrella* could tolerate would be ~50%.

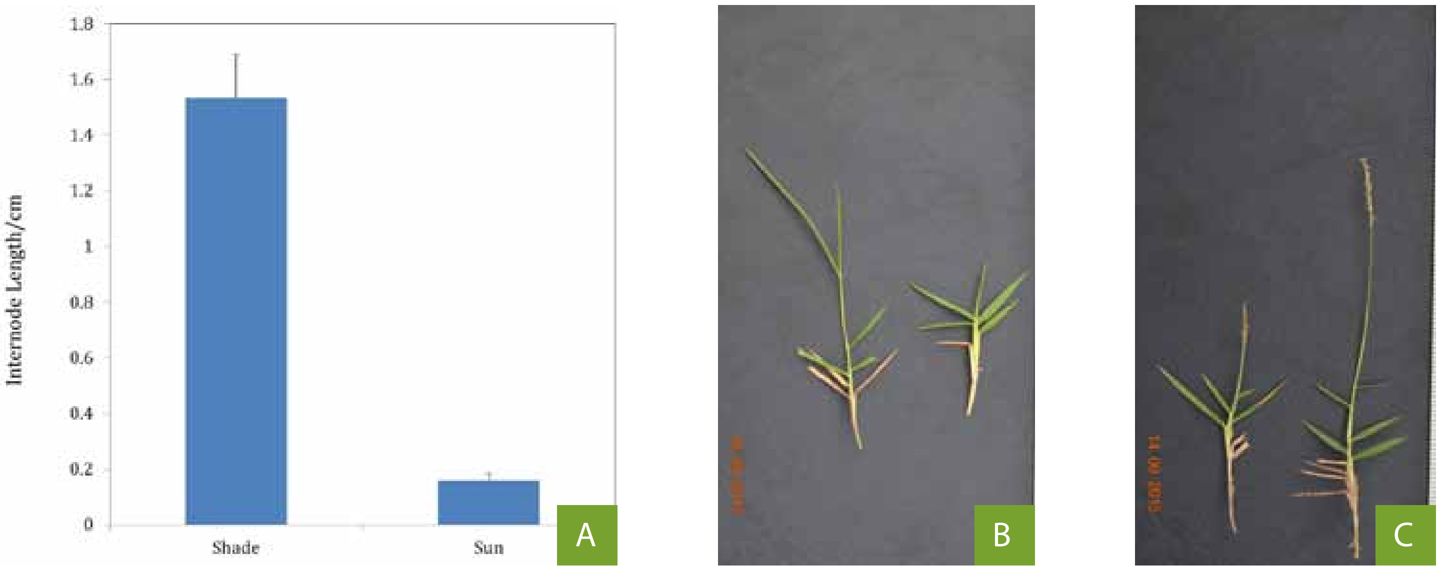


Fig. 5 Elongation of internode length (internode between 2nd and 3rd leaves) in vegetative shoots. Visual representations indicating elongation of (B) internode in vegetative shoot and (C) inflorescence spike.

Fig. 6 The turf surface of the sun-exposed turf was firm and compact. (B) The mean height of turf at 5 DAT (days after treatment) was <15mm. (C) The shaded turf surface lost its surface firmness. The shoots were loosely packed at 20 DAT. (D) The mean height of turf at 20 DAT was >30mm.

B) Chlorophyll content & green biomass

The chlorophyll content of *Zoysia* turf increased under the shade shelter by 5 DAT. The darkening of turf was inferred by a relative decrease of red reflectance readings (660 nm) obtained through a portable NDVI meter (Spectrum-FieldScout™), **Table 1**. In addition, the total amount of live green biomass in shaded turf showed a general reduction compared to the exposed turf (see **Fig. 6C**). This was implied from the decreased Near Infra-Red (NIR) reflectance (850 nm) obtained from shaded turf canopy using the NDVI meter (**Table 1**). In contrast, the patch of turf that was covered under the stage with dark linings (**Fig. 7A**) displayed distinct etiolation i.e. elongation of shoots with reduced leaf chlorophyll (**Fig. 7**); with a corresponding increase in red reflectance and lower NIR reflectance compared to the exposed turf (**Table 1**).

Chlorophyll pigments absorb light radiation strongly near 700nm (red); which inevitably left little red light to be reflected at the leaf surface. Thus, the lower red reflectance readings collected from shaded turf canopy (compared to 0% shade) would highly imply an overall increase in chlorophyll pigments since most of the red wavelengths were absorbed. This increase in chlorophyll concentration was also observed in *Zoysia* grasses that are subjected to 60% reduced light (Atkinson et al., 2012). Furthermore, Atkinson et al. (2012) reported reduction in chlorophyll content in *Zoysia* at 90% reduced light. Although no attempts were made to measure the PAR level under stage in this study, the shade level could be assumed to be more than 90% as implied from their findings.

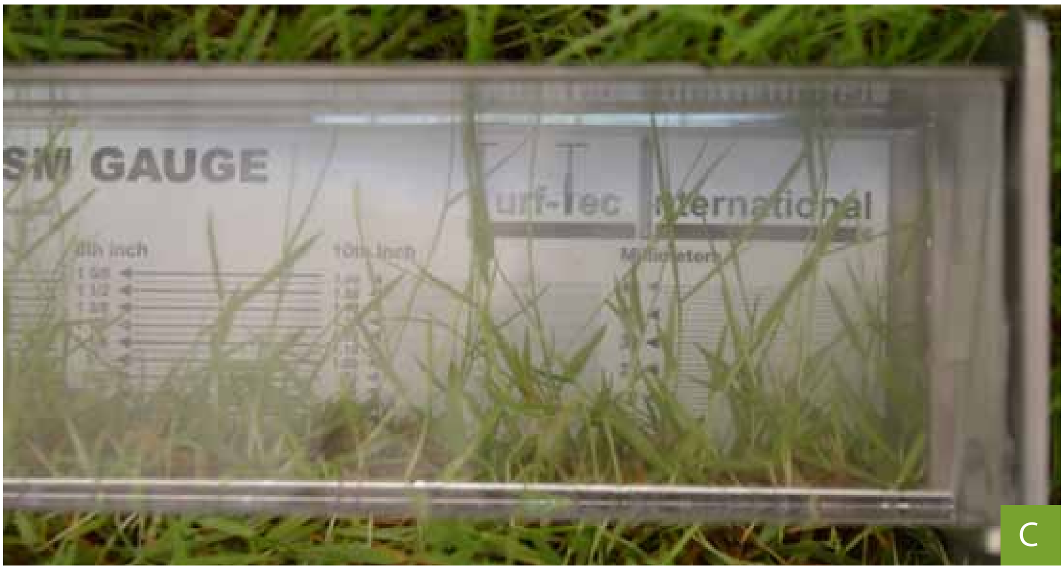
In general, higher NIR reflectance was recorded from turf canopy with higher density and lower amount of dead brown biomass (Bremer et al., 2011). Thus, the lower NIR reflectance from shaded turf suggested a declining turf density under shade. The declining turf density was plausibly due to the rapid depletion of carbohydrate reserves used during vertical shoot elongation response. This rapid depletion of carbohydrate reserves is detrimental to turf health since the low light intensity (quantity) would not be adequate to support optimal synthesis of carbohydrate reserves during photosynthesis.

Table 1 Time changes in canopy reflectance of Red (660 nm) and NIR (850 nm) readings in shade: under tentage, >60%; under stage (>90%) and open exposed turf, 0%

Shade level / Parameters	>60%	> 90%	0%
	5 DAT	20 DAT	Control
Red-660, %	6.26	9.80	8.40
NIR-850, %	44.31	45.91	54.90

Fig. 7 Stage with dark linings was positioned over the lawn. (B) *Zoysia* shoots showing distinct elongation and etiolation. (C) The mean height of etiolated shoots >40mm. (D) Etiolated and dead turf patches observed under support structures.

B



C

D

Conclusion

In summary, the artificial shade on *Zoysia matrella* lawn has impacted the turf in the following ways:

- Etiolation of turf was only observed in areas of lawn which were covered by the stage with dark linings. The stage likely acted as a siege that has precluded abundant light from reaching the turf; thereby creating a deep shade environment of possibly >90%. In contrast, no etiolation of turf was observed in the rest of the lawn (<90%) that was not covered.

- As a result of the sudden reduction in light **quality**, rapid vertical shoot growth was observed from turf that was under >60% shade as a shade-avoidance response.

- The rapid elongation of shoots has led to the decline of turf density which was evident by 5 days after shade. The decline has been suggested to be a result of accelerated depletion of carbohydrate reserves due to rapid shoot elongation and decreased photosynthesis under reduced light **quantity**.

Practical considerations: In order to prevent the occurrence of etiolated and elongated *Zoysia* turf, shelter/tentage should be selected to allow more than 50% of light into the turf canopy. Tentage design consideration should focus on having large unobstructed side flaps that are oriented from an East to West direction for maximal light penetration. Moreover, leaving the flaps open ensure adequate air movement to prevent build-up of humidity that potentially invites fungal disease incidence.

Turf Management Practices: If the shade level generated by an artificial structure was inevitably >50% and has induced rapid vertical shoots growth; mowing of turf under shade should be performed at a higher mowing height with lower frequency to reduce further loss of carbohydrate reserves. Nevertheless it is imperative that the lawn is healthy and dense before a tentage was installed. This will help ensure that the lawn is able to cope with a sustained period of shade with an adequate amount of carbohydrate reserves.

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