Heat Tolerance Screening of Field-Grown Cultivars of Kentucky Bluegrass and Perennial Ryegrass[1]

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ABSTRACT

The quality of cool-season turfgrasses frequently declines during periods of high temperature stress. Simple tests are needed to rapidly identify heat tolerant germplasm for incorporation into breeding programs. Facilitative screening tests have been devised, however, in the few studies that have been performed only immature and greenhouse or growth chamber-grown plants have been evaluated. To be of practical value, results of screening tests, employing plants grown under artificial conditions, should correlate closely with results of tests involving field grown plants. The objective of this research was to evaluate the heat tolerance of several cultivars of Kentucky bluegrass (*Poa pratensis* L.) and perennial ryegrass (*Lolium perenne* L.) grown in the field under four different regimes of N fertilization (0, 98, 148, or 196 kg ha^{-1} yr^{-1}) in a Typic Hapludults, fine silty, mixed mesic soil for comparison with published results in which greenhouse and growth chamber-grown material was used. On six sampling dates, plants representing all cultivar and N combinations were exposed to 42, 44, and 46 °C by immersion in a water bath. Heat tolerance of the cultivars was compared using the mean percent recovery weight for the three temperatures. The Kentucky bluegrass cvs. Sydsport, Vantage, and Pennstar were more heat tolerant than the perennial ryegrass cvs. Pennfine, Citation, and Caravelle. When data were averaged over 2 years, it was shown that Sydsport was significantly more heat tolerant than all other genera and cultivars tested. Pennfine had higher recovery weights than the other two ryegrasses on four of six sampling dates. When data were averaged, however, no significant heat tolerance differences among the ryegrasses were discerned. The results from the screening of field grown material followed the same trends as published results using greenhouse or growth chamber-grown samples. This investigation therefore provides strong evidence that laboratory screening tests may be used to identify accurately and rapidly heat tolerant cultivars of Kentucky bluegrass and possibly perennial ryegrass. The overall heat tolerance of the cultivars on each sampling date correlated with the amount of precipitation (r = −0.91) and the average high temperature (r = 0.93) for the period just prior to and during sampling. The moderate N fertility regimes imposed had little effect on the heat tolerance of the grasses.

Additional index words: **Environmental stress, Turfgrasses, *Poa pratensis* L., *Lolium perenne* L.**

KENTUCKY bluegrass (*Poa pratensis* L.) and perennial ryegrass (*Lolium perenne* L.) are widely used in the Mid-Atlantic region as turfgrasses although their quality declines during periods of high temperature stress. Successful breeding programs to improve the heat tolerance of cool-season grasses depend upon the identification of heat tolerant germplasm. The use of screening tests to identify heat tolerant material can speed the selection process. To be useful, the results from a screening test must parallel the results of field performance trials. The results of these tests should correlate with the field performance of cultivars in locations where heat stress is encountered. This correlation may be difficult to obtain since laboratory heat stress testing isolates the plants from the effects of other stresses. Field cultivar evaluations, however, are influenced by other factors acting on the plant concommitantly with heat stress.

The optimum temperature for growth of cool-season turfgrasses is in the range of 15 to 24 °C (Beard, 1973). Above 24 °C, growth declines and at very high temperatures, severe injury or death can occur. In controlled-environment pot experiments, Kentucky bluegrass produced maximum dry weight of top growth at 21.6 °C, and growth declined as temperature was increased to 24.9 °C (Baker and Jung, 1968). Plants grown at 34.8 °C produced less than half the top growth of those at 21.6 °C. Julander (1945) found that Kentucky bluegrass plants were killed when exposed to 48 °C for 16 h.

Wehner and Watschke (1981) evaluated the heat tolerance of several cool-season turfgrass species by exposing 10-week-old growth chamber or greenhouse grown plants for 30 min to temperatures in the range of 41 to 49 °C. Plants, sealed in plastic bags, were heat stressed by immersion into a hot water bath. They found that Kentucky bluegrass was more heat tolerant than perennial ryegrass and annual bluegrass (*Poa annua* L.). The Kentucky bluegrass cultivars tested were similar in heat tolerance; whereas, among the ryegrasses, 'Loretta' was less heat tolerant than 'Pennfine', 'Diplomat', and 'Citation'.

Nitrogen fertilization has been shown to influence heat tolerance in turf. Carroll (1943) fertilized field

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Table 1. Nitrogen application schedule in 1979 and 1980.

Nitrogen regimes	Spring 4-11-79	Summer 6-13-79	Fall 9-15-79	Fall 9-30-79	Spring 4-18-80	Summer 6-20-80	Total N per year
	kg N ha⁻¹						
1	0	0	0	0	0	0	0
2	49	0	49	0	49	0	98
3	25	25	49	49	25	25	148
4	49	49	49	49	49	49	196

plots of Kentucky bluegrass with either 0 or 245 kg N ha^{-1} and found reduced stress tolerance with the high rate of N fertilizer. Wehner and Watschke (1981) applied either 12.5 or 98 kg N ha^{-1}, over a 4-week period, to growth chamber grown Kentucky bluegrass and annual bluegrass and found reduced stress tolerance at the highest N level.

Turfgrass managers generally use moderate (98 to 196 kg N ha^{-1}) levels of fertilizer per growing season. Research on heat stress, however, has generally been conducted on plants grown at extremes of N fertilization, i.e., either no applied N or high levels of N. In this research, N programs were used which employed zero and modest levels of N nutrition (0, 49, 98, 148, or 196 kg N ha^{-1} per growing season) to determine the effects of N on the ability of turfgrass cultivars to recover from a short exposure to high temperature.

The objective of this research was to evaluate the heat tolerance of several Kentucky bluegrass and perennial ryegrass cultivars using field grown plants. The plants were grown under four different N regimes and given a short exposure to 42, 44, and 46 °C.

MATERIALS AND METHODS

Field plots of three Kentucky bluegrass cultivars, (Pennstar, Vantage, and Sydsport) and three perennial ryegrass cultivars (Pennfine, Citation, and Caravelle) were established in April of 1978 in Fairland, Md. Soil was a Chillum silt loam (fine-silty, mixed, mesic Typic Hapludults), with a pH of 6.2. At the time of establishment, 49 kg N, 22 kg P, and 41 kg K ha^{-1} were incorporated into the seedbed. Plot size was 3.1 × 6.1 m with four replications in a randomized complete block design. For the remainder of 1978, plots were maintained at 3.8 cm mowing height and were fertilized with 98 kg N, 22 kg P, and 41 kg K ha^{-1}. Irrigation was provided during establishment, and subsequently only to prevent severe moisture stress of the turf. In 1979, the plots of each cultivar were split into four subplots, each subplot receiving a different level of N applied under a specific timing regime. The amount and timing of the N applications are listed in Table 1. Nitrogen was applied in the form of urea (46-0-0). No P or K was applied during 1979 or 1980.

Heat stress was imposed on plants taken from the field three times during 1979 (5 June, 2 July, 6 August) and three times during 1980 (2 June, 14 July, 18 August) using the technique described by Wehner and Watschke (1981). This technique involved removing 9.0 × 9.0 cm cores from the field plots, washing the soil free and sealing individual plants in plastic bags, which were then immersed in a hot water bath for 30 min. Plants were then placed in a greenhouse and recovery was observed. For each sampling date in 1979 and 1980, a fresh set of plants representing all cultivar and N combinations (five plants per subplot) was heated between 40 and 50 °C. As explained below, only data from plants heated at 42, 44, and 46 °C will be discussed. Because of the large number of plants involved, only one replication could be heated per day. Thus, the reported sampling date represents the 1st day of a 4-day period. Following heat treatment, the plants were replanted in Jiffy-Mix (50:50 peat and vermiculite) and placed in the greenhouse to observe recovery. The average high and low temperatures for the greenhouse were 35 °C and 18 °C, respectively. After a 2 week recovery period, the plants were washed of Jiffy-Mix, dried, and weighed. A recovery weight was calculated for the heat stressed plants as a percentage of the weight of nonstressed control plants, and this value was used as a measure of heat tolerance.

Table 2. Mean recovery† for six field grown turfgrass cultivars heated at 42, 44, and 46°C on three sampling dates in 1979 and 1980, averaged over all fertility levels.

Cultivar	1979 5 June	1979 2 July	1979 6 August	1980 2 June	1980 14 July	1980 18 August	Mean§
	%						
Sydsport	60.2a	65.0ab‡	78.8a	77.7a	87.3a	66.1a	72.5a
Pennstar	47.3a	67.7a	76.2ab	77.0a	82.3a	50.6bc	66.9b
Vantage	49.5a	68.5a	69.7bc	72.1b	80.7a	53.1b	65.6b
Pennfine	46.1a	57.9abc	64.4cd	68.8bc	77.8a	44.5bc	59.9c
Citation	50.3a	52.7c	60.7d	64.1c	76.7a	43.7cd	58.0c
Caravelle	47.1a	56.2bc	67.8c	57.5d	76.3a	32.9d	56.3c
Mean	50.1c¶	61.3b	69.6b	69.5b	80.2a	48.5c	

† Percent recovery (i.e., recovery weight) is the stressed plant weight expressed as a percentage of the nonstressed control plant weight.
‡ Means followed by the same letter in the same column are not significantly different at p = 0.05 according to the FLSD test.
§ Mean recovery weights were obtained by averaging over all dates in 1979 and 1980.
¶ Means followed by the same letter in the row are not significantly different at p = 0.05 according to the FLSD test.

The experimental design was a randomized complete block. The treatment arrangement for the heating procedure was a split-split plot with cultivars as whole plots, N regimes as subplots, and temperatures as sub-sub plots. A separate analysis of variance was run for each sampling date using the recovery weights for plants heated at the temperatures 42, 44, and 46 °C. The recovery weights for these temperatures were from the linear portion of the sigmoidal recovery weight-temperature response curve determined from recovery weights of plants heated between 40 and 50 °C. The temperature by cultivar interaction was significant on three of the six sampling dates. These temperature by cultivar interactions were due to changes in the magnitude of response rather than differences in the rank of the cultivars at each temperature. Therefore, the cultivar means averaged over the three temperatures are presented in the data tables. The cultivar by N interaction was not significant for any of the six sampling dates. All tests of significance were at $p=0.05$, and if significant, treatment means were compared using the FLSD test.

When fertilizer treatments were initiated in 1979, the mowing height of the plots was reduced to 3.2 cm with twice weekly mowings and clipping removal. Turf growth was evaluated prior to the heat stress treatments by collecting the clippings produced over a 1-week period prior to each of the six sampling dates. A mower, equipped with a basket to catch clippings, was operated down the center of each subplot. The clippings were dried at 70 °C and weighed. In 1980, a subsample of these clippings was analyzed by the Kjeldahl procedure for total N (Nelson and Sommers, 1973).

RESULTS AND DISCUSSION

The recovery weight percentages for the six turfgrasses that were exposed to short periods of high temperature on three sampling dates in 1979 and 1980 are listed in Table 2. The recovery weights represent the average weight of plants heated at 42, 44, and 46 °C, compared to nonstressed control plants after a 2-week recovery period. There were significant recovery differences among the genera and cultivars on four of the six sampling dates.

The Kentucky bluegrasses had significantly higher recovery weight percentages than the ryegrasses on all dates except the 5 June 1979 sampling. Among the bluegrasses, the cultivar Sydsport had the highest recovery on all but the 2 July 1979 sampling date. The difference between Sydsport, and Pennstar and Vantage was significant only on the 18 Aug. 1980 sampling date. Data averaged over all dates, however, showed that Sydsport was significantly more heat tolerant than all other genera and cultivars evaluated.

Pennfine perennial ryegrass had higher recovery weights than the other two ryegrasses on four of the six sampling dates (Table 2). In 1980, Pennfine perennial ryegrass exhibited significantly better recovery than Caravelle on two dates (Table 2). On one date (2 June 1980), Caravelle exhibited significantly lower heat tolerance than the other two ryegrasses tested. Data averaged over all dates, however, indicated that the three ryegrasses did not differ significantly in heat tolerance.

The results reported by Wehner and Watschke (1981) indicated that the Kentucky bluegrass cultivars were significantly more heat tolerant than the perennial ryegrass cultivars tested. In addition, the bluegrass cultivar Sydsport was significantly more heat tolerant than Pennstar on two of the three times they were compared. Sydsport was also significantly more heat tolerant than the cultivar Vantage both times they were compared. The ryegrasses Pennfine, Diplomat, and Citation were significantly more heat tolerant than Loretta.

The same trends were evident in this research using field grown plants. The bluegrasses were more heat tolerant than the ryegrasses, Sydsport was more heat tolerant than Vantage and Pennstar, and the ryegrasses Pennfine and Citation were equal in heat tolerance. Previous testing with greenhouse and growth chamber-grown plants showed obvious differences in heat tolerance (Wehner and Watschke, 1981). Heat stressed field grown plants, however, would be expected to be more variable than material grown under controlled conditions. The results from multiple sampling dates in this study were somewhat variable, thus indicating that the heat tolerance of cultivars should be judged only after several screenings have been compared. This investigation does, however, provide strong evidence that the screening test employed may be used to identify accurately and rapidly heat tolerant cultivars of Kentucky bluegrass and possibly perennial ryegrass.

The grasses exhibited their highest recovery after the 14 July 1980 sampling; whereas, the lowest recovery was found after the 18 Aug. 1980 sampling date (Table 3). Differences in the recovery among sampling dates were dependent upon the weather. When the grasses exhibited the highest recovery (14 July 1980), the sampling date was preceded by hot and dry weather. When the grasses exhibited the lowest recovery (18 Aug. 1980), the sampling was preceded by wet, cool weather. Recovery was significantly correlated with precipitation ($r = -0.914$), average high temperature ($r = 0.927$) and average low temperature ($r = -0.767$). The results of this study agree with comments by Levitt (1972) on the positive effects of hot, dry weather on heat tolerance.

Table 3. Recovery weight (RW), precipitation, and average high and low temperature associated with each sampling date.

Sampling date	RW (percent of control)	Precipitation†	Average† high temperature	Average† low temperature
	%	cm	°C	
5 June 1979	50.1	2.6	25.6	16.4
2 July 1979	61.3	2.3	27.7	18.0
6 Aug. 1979	69.6	T	31.4	21.2
2 June 1980	69.5	0.9	30.6	18.7
14 July 1980	80.2	0.4	32.0	20.1
18 Aug. 1980	48.5	3.3	27.4	18.1

† Represents the total precipitation and the temperature averages for a 5-day periods beginning 2 days prior to the start of the sampling period and extending through the day before the last replication was sampled.
T = Trace.

Table 4. Mean recovery weights (RW) and clipping weights (CW) for six field grown turfgrass cultivars fertilized at four N rates and evaluated on three dates in 1979. Relative recovery weights and clipping weights were averaged over all cultivars and heat treatments.

	Date					
	5 June		2 July		6 August	
Nitrogen regimes	RW (Percent of control)	CW (gm^{-2})	RW (Percent of control)	CW (gm^{-2})	RW (Percent of control)	CW (gm^{-2})
1	53.9a	27.6c†	63.2a	15.8d†	71.5a	47.8c†
2	49.9a	45.5a	61.8a	21.0c	69.1a	52.0c
3	48.4a	35.3b	60.2a	42.5b	69.1a	66.1b
4	48.2a	46.0a	60.1a	78.5a	68.7a	93.4a

† Means followed by the same letter in the same column are not significantly different at p = 0.05 according to the FLSD test.

Table 5. Mean recovery weights (RW), clipping weights (CW), and percent leaf tissue N levels (percent N) for six field grown turfgrass cultivars fertilized at four N rates and evaluated on three dates in 1980. Mean recovery weights, clipping weights and percent tissue N data were averaged over all cultivars and heat treatments.

	Date								
	2 June			14 July			18 August		
Nitrogen regimes	RW (Percent of control)	CW (gm^{-2})	% N‡	RW (Percent of control)	CW (gm^{-2})	% N	RW (Percent of control)	CW (gm^{-2})	% N
1	69.0a	20.7b†	2.5b	81.7a	20.0c	2.8c	44.7b	69.0a	3.3c
2	67.8a	42.8a	2.6a	80.7a	23.3c	2.8c	46.3b	64.1a	3.5b
3	70.9a	42.3a	2.6a	78.7a	62.8b	3.2b	51.1a	72.0a	3.6a
4	70.4a	44.7a	2.6a	79.6a	107.8a	3.5a	51.8a	68.3a	3.6a

† Means followed by the same letter in the same column are not significantly different at p = 0.05 according to the FLSD test.
‡ % N was determined from leaf tissues collected prior to imposing heat stress.

Nitrogen fertilization regimes had no significant effect on relative recovery weight except on the 18 Aug. 1980 sampling date (Tables 4 and 5). On 18 Aug. 1980, the plants under the higher N regimes (i.e., regimes 3 and 4) exhibited better recovery than plants grown under the lower N regimes. The clipping weight data for this date (used as an indicator of overall growth) revealed that the plants from all fertilizer treatments were growing at approximately the same rate. The tissue analyses indicated that there was a slight difference (3.3 vs. 3.6%, Table 5) in N tissue levels in leaves between plants receiving no N fertilization (regime 1) and those receiving 196 kg N ha^{-1} per year (regime 4). This difference was apparently not enough to markedly affect growth or decrease the heat tolerance of the high N plants, but instead provided some N to aid in recovery. The normal range in N content in all turfgrass tissues is between 3 and 6% (Beard, 1973). Thus, even though there was a large difference in the levels of total N applied (0 to 196 kg N ha^{-1}), leaf tissue N differences were minimal. The largest differences in leaf tissue N levels were found on 14 July 1980, 23 days after the final fertilization. Although it was the largest difference observed, it was a relatively small difference (2.8 vs. 3.5%, Table 5) in percent N, and it occurred between plants from the 0 and 196 kg N regimes. There also was a substantial difference in clipping weight (20 vs. 108 g m^{-2}), but no difference in recovery weight occurred between plants from the aforementioned treatments. The genera and cultivars exhibited highest recovery weights after this sampling, indicating they had attained high levels of heat tolerance. Hence, the difference in leaf tissue N levels may not have been large enough to affect the recovery of the stressed, heat hardened plants.

Neither Carroll (1943), nor Wehner and Watschke (1981) reported the N tissue levels found between the high N and low N treatments employed in their heat tolerance research. It can be concluded from our results that the relationship between N and the tolerance of exposure to a short period of high temperature is affected more by previous temperature and precipitation, than modest levels of N fertilization.

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