Growth and Nutrient Partitioning of ‘TifEagle’ Bermudagrass as Influenced by Nitrogen and Trinexapac-ethyl

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Abstract. Dwarf-type bermudagrasses [Cynodon dactylon (L.) Pers. × C. transvaalensis Burtt-Davey] tolerate long-term golf green mowing heights but require heavy nitrogen (N) fertilizations. Inhibiting leaf growth with trinexapac-ethyl (TE) could reduce shoot growth competition for root reserves and improve nutrient use efficiency. Two greenhouse experiments evaluated four N levels, 6 (N6), 12 (N12), 18 (N18), and 24 (N24) kg N/ha/week, with TE at 0 and 0.05 kg·ha⁻¹ a.i. every 3 weeks to assess rooting, nutrient allocation, clipping yield, and chlorophyll concentration of ‘TifEagle’ bermudagrass grown in PVC containers. In the first experiment, trinexapac-ethyl enhanced turf quality on every date after initial application. After 8 weeks, high N rates caused turf quality decline; however, TE treated turf averaged about 25% higher visual quality from nontreated turf, masking quality decline of high N fertility. ‘TifEagle’ bermudagrass treated with TE had clipplings reduced 52% to 61% from non-TE treated. After 16 weeks, bermudagrass treated with TE over all N levels had 43% greater root mass and 23% enhanced root length. Compared to non-TE treated turf, leaf N, P, and K concentrations were consistently lower in TE treated turf while Ca and Mg concentrations were increased. Root N concentrations in TE treated turf were 8% to 11% higher for N12, N18, and N24 fertilized turf than respective N rates without TE. Compared to non-TE treated turf, clipping nutrient recoveries were reduced 69% to 79% by TE with 25% to 105% greater nutrients recovered in roots. Bermudagrass treated with TE had higher total chlorophyll concentrations after 8 and 12 weeks. Overall, inhibiting ‘TifEagle’ bermudagrass leaf growth appears to reallocate nutrients to belowground tissues, thus improving nutrient use efficiency and root growth. Chemical name used: trinexapac-ethyl, [4-(cyclopropyl-α-hydroxy)methylene]-3,5-dioxy-cyclohexane carboxylic acid ethylester.

Hybrid bermudagrass is the most commonly used warm-season turfgrass for putting greens in the warm-humid climatic regions. Bermudagrass putting greens are the most heavily fertilized turfgrasses due to annual nitrogen (N) requirements ranging from 390 to 1,175 kg ha⁻¹ to meet growth requirements and compensate for nutrient loss through daily clipping removal (McCarty and Miller, 2002). Dwarf bermudagrass cultivars tolerate routine close mowing heights and provide southern golf courses putting green quality comparable to creeping bentgrass (Agrostis palustris Huds.) (Hanna and Elsner, 1999; McCarty and Miller, 2002). However, the close mowing of cultivars, such as ‘TifEagle’, has apparently restricted root systems compared to traditional putting green cultivars like ‘Tifwarf’ bermudagrass (White, 1998). Promoting root growth of dwarf bermudagrass may present challenges for successful long term culture. Low cutting height and frequent mowing are directly correlated with root growth restrictions of putting green turf (Fagerness and Yelverton, 2001; Liu and Huang, 2002). With potentially reduced photosynthetic capacity from finer leaves, dwarf-type bermudagrasses maintained at mowing heights as close as 3 mm may have a depletion of plant reserves available for root growth. Furthermore, high N requirements of bermudagrass putting greens may further exacerbate rooting problems of dwarf cultivars since shoots have priority for stored nutrients in belowground tissues.

Application of a plant growth regulator (PGR), trinexapac-ethyl (TE), to ‘Tifway’ bermudagrass has shown to reduce N allocation to leaf tissue while increasing N retention in rhizomes and roots (Fagerness et al., 2004). These findings may be of greater importance to dwarf-type cultivars due to higher fertility requirements for bermudagrass putting green maintenance. Greater nutrients stored in belowground tissues following TE applications may be readily allocated to prevent leaf deficiencies, thus improving nutrient use efficiency of heavily fertilized dwarf bermudagrass greens.

Trinexapac-ethyl, a cyclohexadione gibberellic acid (GA) inhibitor, interferes with GA biosynthesis by blocking 3β-hydroxylase conversion of GA₃ to GA₄ (Rademacher, 2000). Sequential applications of TE on ‘Tifway’ bermudagrass provide consistent growth suppression, avoidance of post inhibition growth enhancement, improvements in turf color, and delay fall dormancy (Johnson, 1997; Fagerness and Yelverton, 2000; Richardson, 2002). Trinexapac-ethyl also improves turf grown under stressful conditions that may restrict root growth. ‘Diamond’ zoysiagrass (Zosia matrella (L.) Merr) treated with TE at 0.048 kg·ha⁻¹ monthly and 0.096 kg·ha⁻¹ bimonthly under reduced light conditions displayed higher root mass, higher root viability, and improved photosynthesis (Quan and Engelke, 1999). Applications of TE at 0.042 and 0.070 kg·ha⁻¹ on creeping bentgrass greens under 80% shade have shown to increase turf cover, tillering, and fructose content but had no effect on root mass compared to untreated turf (Goss et al., 2002). In a 2-year study, monthly applications of TE at 0.05 kg·ha⁻¹ did not affect rooting of a ‘Penncross’ creeping bentgrass golf green (Fagerness and Yelverton, 2001).

Since TE is an effective PGR for higher mowed bermudagrasses and creeping bentgrass putting greens, research is warranted on physiological responses of dwarf bermudagrass putting greens to TE applications. Although turf color and quality enhancements have been documented from TE applications, effects on primary, secondary, and micronutrient partitioning are limited. The objectives of this experiment were to investigate effects of four weekly N inputs with TE on nutrient allocation, clipping yield, rooting, and chlorophyll concentrations of ‘TifEagle’ bermudagrass.

Materials and Methods

Two studies were conducted at the Clemson University Greenhouse Research Complex, Clemson, SC from September 2002 to January 2003 (Study 1) and January to May 2003 (Study 2). Greenhouse day/night temperatures were about 24/19 °C. The experimental design was a randomized complete block with four replications of eight experimental units per block. To minimize local environmental variations, blocks were rotated weekly and experimental units re-randomized within. Supplemental lighting was added at approximately 50 μmol·m⁻²·s⁻¹ for about 3 h·d⁻¹ to compensate for reduced natural lighting during winter months.

Soil was collected from a ‘TifEagle’ bermudagrass green established in July of 2002 at the Turf Service Center, Clemson, S.C. Soil was washed and plugs placed in polyvinyl chloride containers with 40 cm depths and 324 cm² surface areas built to U.S. Golf Association specification (U.S. Golf Association Green Section Staff, 1993) with an 85 sand : 15 peatmoss (by volume) rootzone mix. Start-
Bermudagrass was irrigated to field capacity and mowed daily with grass shears (Black and Decker, Towson, Md.) at 4 mm. The eight treatments were a fractional combination of four N levels and two TE levels. Ammonium nitrate (34N–0P–0K) solution was applied at 6, 12, 18, and 24 kg N/ha/week. Beginning 9 weeks after initial N treatments in Study 1 and 4, 8, 12, and 16 weeks after initial N treatments in Study 2. Chlorophyll concentrations were measured by a spectrophotometer (GeneSys 20 Thermo Spectronic model 4001/4, Waltham, Mass.) in mg g⁻¹ of fresh weight clippings. Light absorbance was measured at 663 nm for chlorophyll a and at 645 nm for chlorophyll b. Procedures for chlorophyll concentration analysis were similar to those described by Moran and Porath (1980). Data were subjected to analysis of variance with SAS General Linear Model procedure (SAS Institute, Cary, N.C.). Orthogonal polynomial contrasts examined linear and quadratic relationships between treatments and level of N.

### Results

**Visual quality.** Study × treatment interaction was not significant for visual quality. Nitrogen × TE interactions were not significant on the first three dates but treatment interactions were significant on the last five dates (Table 1). Trinexapac-ethyl significantly enhanced turf quality on every date after week 2. Turf quality linearly improved with increased N rate by week 4. However, bermudagrass receiving 18 and 24 kg N/ha/week without TE reached their peak quality ratings by week 8; thereafter, quality declined. Conversely, turf receiving 18 and 24 kg N/ha/week with TE did not have quality decline, rather, quality was enhanced similar to bermudagrass receiving 12 kg N/ha/week with TE. After week 6, quality enhancements from TE were most substantial when bermudagrass received 12 kg N/ha/week or greater. From week 10 to 16, TE treated turf averaged about 25% higher visual quality than non-TE treated turf, apparently masking quality decline caused by higher N fertility.

**TifEagle** bermudagrass growth. Study × treatment interactions were not detected for clipping yield, roots, or stolon/rhizome mass. The N × TE interaction was significant for total clippings harvested. Bermudagrass receiving 12, 18, and 24 kg N/ha/week with TE had similar total clipping yield to non-TE treated turf receiving 6 kg N/ha/week (Table 2). Compared to respective N rates, applications of TE reduced clippings by 52%, 61%, 56%, and 61%, for 6, 12, 18, and 24 kg N/ha/week, respectively. The N × TE interaction was not significant for root length, dry root mass, or thatch mass. 'TifEagle' bermudagrass treated with TE had 43% greater root mass than non-TE treated turf (Table 2). Increased N rate linearly and quadratically reduced root length and dry root mass, respectively. However, TE enhanced root length by 23% and bermudagrass receiving 18 and 24 kg N/ha/week plus TE had root masses similar to low N (6 and 12 kg N/ha/week) without TE. Treatments did not affect stolon or rhizome mass after 16 weeks (data not shown).

**Nutrient concentrations.** Tissue test results were pooled from two studies due to a lack of meaningful study × treatment interactions. Sample × TE interactions were detected for leaf nutrient concentrations; therefore, results are presented by sampling date (Fig. 1). Sample × N interactions were not detected for leaf nutrient concentrations so results were pooled over all

Table 1. Turf quality for 'TifEagle' bermudagrass treated with N and trinexapac-ethyl in two combined greenhouse experiments.

| Trinexapac-ethyl¹ (kg·ha⁻³/3 weeks) | N (kg·ha⁻¹·wk⁻¹) | WAIN² | Turf quality (1–9 scale) |
|-------------------------------------|-----------------|-------|--------------------------|
| 0                                   |                | 2     | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
| 6                                   | 6.9            | 6.3   | 7.0 | 7.0 | 7.1 | 6.9 | 6.9 | 7.0 |
| 12                                  | 6.4            | 6.4   | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 |
| 18                                  | 6.6            | 6.5   | 6.1 | 6.5 | 6.0 | 5.6 | 5.9 | 6.3 |
| 24                                  | 6.8            | 6.8   | 6.5 | 6.8 | 6.4 | 5.8 | 5.8 | 5.5 |
| 0.05                                | 6.9            | 7.3   | 7.6 | 7.4 | 7.8 | 7.5 | 7.5 | 7.3 |
| 12                                  | 7.0            | 7.3   | 8.4 | 8.4 | 8.4 | 8.3 | 8.5 | 8.3 |
| 18                                  | 7.0            | 7.5   | 8.3 | 8.1 | 8.5 | 8.3 | 8.6 | 8.3 |
| 24                                  | 7.1            | 7.9   | 8.3 | 8.1 | 8.4 | 8.1 | 8.1 | 8.0 |

Source of variation

N | NS | NS | NS | * | NS | NS | NS | * |
L | NS | * | NS | NS | NS | NS | NS | NS |
Q | NS | NS | NS | NS | NS | NS | NS | NS |
Trinexapac-ethyl (TE) | * | * | * | * | * | * | * | * |
N × TE | NS | NS | NS | * | * | * | * | * |
N without TE
L | NS | * | NS | NS | NS | NS | NS | NS |
Q | NS | NS | NS | NS | NS | NS | NS | NS |
N with TE
L | * | * | * | NS | NS | NS | NS | NS |
Q | * | NS | * | NS | NS | NS | NS | NS |

¹Turf quality was rated 1 to 9 where 1 = dead or dormant and 9 = dark green, uniform turf.
²WAIN = weeks after initial N treatment.
³NS nonsignificant or significant at the 0.05 probability level. L = linear, Q = quadratic.
sampling dates (Table 3). Bermudagrass treated on week 3, one WAIT (Fig. 1). Leaf N concentrations were lower in TE treated turf, ranging from 2% to 6% reductions, through week 12. N concentrations in leaves and belowground tissues ascended linearly with increased N rate (Table 3). Root N concentrations increased in TE treated turf by 8% when fertilized at 12 kg N/ha/week and 11% when fertilized at 18 and 24 kg N/ha/week compared to respective N rates of non-TE treated. Higher N rates increased P concentration in leaf tissue and reduced P concentrations in roots, stolons, and rhizomes. Similarly, increased N rate reduced root, stolon, and rhizome K concentrations. ‘TifEagle’ bermudagrass treated with TE had similar root K concentrations across N rates and approximately 25% greater K concentrations than nontreated turf after 16 weeks.

Table 2. Total clipping yield, dry root mass, and root length after 16 weeks for ‘TifEagle’ bermudagrass treated with N and trinexapac-ethyl in two combined greenhouse experiments.

| Trinexapac-ethyl (kg ha⁻¹/3 weeks) | Total clippings (kg ha⁻¹/3 weeks) | Root mass (g m⁻²) | Root length (cm) |
|------------------------------------|-----------------------------------|-------------------|-----------------|
| 0                                  | 6                                 | 12.2              | 26.9            |
| 12                                 | 26.9                              | 23.5              | 21.0            |
| 18                                 | 32.7                              | 18.8              | 16.1            |
| 24                                 | 37.6                              | 19.9              | 16.8            |
| 0.05                               | 6                                 | 5.8               | 44.2            |
| 12                                 | 10.4                              | 28.8              | 26.7            |
| 18                                 | 14.3                              | 28.9              | 22.2            |
| 24                                 | 17.6                              | 28.8              | 23.4            |

Source of variation

| N  | * | * | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
|----|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|
| L  | * | * | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Q  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| N x TE | * | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| L  | * | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Q  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| N without TE | * | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| L  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Q  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| N with TE | * | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| L  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Q  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

Total of 16 dry weight clipping yields harvested from weekly samples.

Root mass and root length samples were harvested 16 weeks after initial N treatment from entire containers.

N × TE interaction was detected for root Mg concentrations, as TE masked concentration reductions caused by increased N rate (Table 3). Increased N rate caused reductions in stolon and rhizome S concentrations but TE treated turf was similar to non-TE treated.

Table 3. Leaf, root, and stolon–rhizome nutrient concentrations after 16 weeks for ‘TifEagle’ bermudagrass treated with N and trinexapac-ethyl in two combined greenhouse experiments.

| Trinexapac-ethyl (kg ha⁻¹/3 weeks) | N (kg ha⁻¹/week) | P (%) | K (mg kg⁻¹) | Ca (mg kg⁻¹) | Mg (mg kg⁻¹) | S (mg kg⁻¹) | Zn (mg kg⁻¹) | Cu (mg kg⁻¹) | Mn (mg kg⁻¹) | Fe (mg kg⁻¹) |
|------------------------------------|-----------------|-------|-------------|--------------|--------------|-------------|--------------|--------------|--------------|--------------|
| Leaves 6                           | 4.38            | 0.44  | 1.59        | 0.37         | 0.24         | 0.38        | 61           | 21           | 71           | 205          |
| 12                                 | 5.22            | 0.47  | 1.62        | 0.35         | 0.24         | 0.38        | 66           | 21           | 102          | 189          |
| 18                                 | 5.58            | 0.48  | 1.63        | 0.39         | 0.24         | 0.38        | 73           | 22           | 125          | 189          |
| 24                                 | 5.72            | 0.49  | 1.65        | 0.36         | 0.24         | 0.37        | 70           | 21           | 135          | 174          |
| L 0                                | *               | *     | *           | NS           | NS           | NS          | *            | NS           | *            | *            |
| Q 0.05                             | NS              | NS    | NS          | NS           | NS           | NS          | *            | NS           | NS           | NS           |
| N without TE                       | *               | NS    | NS          | NS           | NS           | NS          | *            | NS           | *            | *            |
| L 0.05                             | NS              | NS    | NS          | NS           | NS           | NS          | *            | NS           | NS           | NS           |
| Q                                  | NS              | NS    | NS          | NS           | NS           | NS          | NS           | NS           | NS           | NS           |
| N x TE                            | NS              | NS    | NS          | NS           | NS           | NS          | NS           | NS           | NS           | NS           |
| L 0.05                             | NS              | NS    | NS          | NS           | NS           | NS          | NS           | NS           | NS           | NS           |
| Q                                  | NS              | NS    | NS          | NS           | NS           | NS          | NS           | NS           | NS           | NS           |

Source of variation

| N  | * | * | NS | NS | NS | NS | NS | NS |
|----|---|---|----|----|----|----|----|----|
| L  | * | NS | NS | NS | NS | NS | NS | NS |
| Q  | NS | * | NS | NS | NS | NS | NS | NS |
| N x TE | * | NS | NS | NS | NS | NS | NS | NS |
| L  | * | NS | NS | NS | NS | NS | NS | NS |
| Q  | NS | NS | NS | NS | NS | NS | NS | NS |
| N without TE | * | NS | NS | NS | NS | NS | NS | NS |
| L  | NS | NS | NS | NS | NS | NS | NS | NS |
| Q  | NS | NS | NS | NS | NS | NS | NS | NS |
| N with TE | * | NS | NS | NS | NS | NS | NS | NS |
| L  | NS | NS | NS | NS | NS | NS | NS | NS |
| Q  | NS | NS | NS | NS | NS | NS | NS | NS |

Stolons and rhizomes

| 6   | 1.27 | 0.15 | 0.47 | 0.20 | 0.47 | 0.09 | 95 | 20 | 44 | 602 |
|----|-----|------|------|------|------|------|----|----|----|-----|
| 12  | 1.57 | 0.12 | 0.37 | 0.18 | 0.37 | 0.08 | 97 | 20 | 59 | 692 |
| 18  | 1.93 | 0.11 | 0.32 | 0.15 | 0.32 | 0.07 | 100| 23 | 77 | 820 |
| 24  | 2.13 | 0.12 | 0.31 | 0.18 | 0.31 | 0.08 | 110| 25 | 104| 990 |
| L   | *   | *    | NS   | NS   | NS   | NS   | NS | *  | *  | *   |
| Q   | NS  | *    | NS   | NS   | NS   | NS   | NS | NS | NS | NS   |
| 0   | 1.7  | 0.1  | 0.4  | 0.2  | 0.1  | 0.1  | 108| 24 | 88 | 821 |
| 0.05 | 1.8  | 0.1  | 0.4  | 0.2  | 0.1  | 0.1  | 93*| 20*| 75*| 731 |

*Initial trinexapac-ethyl treatment was week 2.

NS,*Nonsignificant or significant at the 0.05 probability level. L = linear, Q = quadratic.
For micronutrients, higher N inputs increased bermudagrass leaf Zn and Mn concentrations (Table 3). Leaf Zn concentrations were reduced in TE treated turf on five sampling dates from the nontreated (Fig. 1). Other leaf micronutrients concentrations were similar to non-TE treated turf (data not shown). Increased N rate resulted in higher micronutrient concentrations in roots, stolons, and rhizomes. Bermudagrass treated with TE had Zn, Cu, and Mn concentrations reduced by about 15% and root Cu concentrations reduced 30% from non-TE treated turf. Increased N rate linearly increased Fe concentrations of belowground tissues and reduced N concentrated in leaves (Table 3). ‘TifEagle’ bermudagrass treated with TE had similar Fe concentrations to the nontreated (data not shown).

Nutrient recovery. An N × TE interaction was not detected for final leaf nutrient recovery in Study 1. After 16 weeks in Study 1, increased N rate generally increased clipping nutrient recovery while TE-treated turf averaged 30% to 75% reduced nutrient recoveries from non-TE treated (Table 4). From six sampling dates in Study 2, N × TE interactions were detected for total N, P, K, Mg, S, Zn, Cu, and Mn recovered in clippings. Increased nutrient recovery occurred with increased N rates; however, total nutrients recovered were reduced 69% to 79% in the presence of TE. Bermudagrass treated with TE, regardless of N input, had clipping N recovery less than turf receiving 12 kg N/ha/week without TE and had similar clipping recoveries to turf treated with 6 kg N/ha/week without TE for all other mineral nutrients. ‘TifEagle’ bermudagrass treated with TE had 50% greater N recovered in roots after 16 weeks compared to non-TE treated turf (Table 5). Bermudagrass treated with 24 kg

![Graphs showing nutrient concentrations over weeks after initial nitrogen treatments](image)

**Table 4. Clipping nutrient recovery for ‘TifEagle’ bermudagrass treated with nitrogen and trinexapac-ethyl in greenhouse experiments.**

| Trinexapac-ethyl (TE) (kg·ha⁻¹/3 weeks) | N (kg·ha⁻¹/ wk⁻¹) | N | P | K | Ca | Mg | S (mg·m⁻²) | Zn | Cu | Mn | Fe (µg·m⁻²) |
|----------------------------------------|-------------------|---|---|---|----|----|------------|----|----|----|------------|
| Study 1 (week 16)                      |                   |   |   |   |    |    |            |    |    |    |            |
| 6                                     | 12.8              | 1.1| 4.2| 1.7| 0.9| 1.1| 84         | 7  | 23 | 104|            |
| 12                                    | 14.7              | 1.2| 4.2| 1.4| 0.9| 1.1| 22         | 6  | 49 | 71 |            |
| 18                                    | 24.9              | 1.9| 7.1| 2.3| 1.4| 1.7| 45         | 11 | 122| 211|            |
| 24                                    | 27.4              | 2.2| 7.9| 2.5| 1.5| 2.1| 15         | 11 | 92 | 191|            |
| L                                     | NS                | NS | NS | NS | NS | NS |            | NS | NS | NS |            |
| Q                                     | NS                | NS | NS | NS | NS | NS |            | NS | NS | NS |            |
| 0                                     | 23.6              | 1.9| 6.9| 2.3| 1.4| 1.7| 78         | 11 | 92 | 191|            |
| 0.05                                  | 16.2              | 1.3| 4.7| 1.6| 0.9| 1.3| 19         | 6  | 42 | 93 |            |
| Study 2 (total)                        |                   |   |   |   |    |    |            |    |    |    |            |
| 0                                     | 6                 | 185.2| 6.6| 24.7| 4.5| 3.6| 5.4         | 90 | 40 | 110| 540        |
| 12                                    | 577.5             | 41.9| 147.8| 25.7| 20.5| 31.8| 600        | 200| 620| 1660       |
| 18                                    | 769.2             | 55.1| 170.9| 48.0| 26.7| 37.8| 830        | 260| 1060| 1890      |
| 24                                    | 973.6             | 67.3| 203.7| 38.6| 30.0| 42.4| 980        | 290| 1540| 2090      |
| 0.05                                  | 6                 | 64.8| 2.1| 6.1| 2.3| 1.5| 1.8         | 30 | 10 | 30 | 80         |
| 12                                    | 156.3             | 7.2| 24.0| 5.7| 4.1| 5.7| 90         | 40 | 120| 290       |
| 18                                    | 260.8             | 13.7| 43.6| 10.4| 7.5| 10.0| 190        | 70 | 270| 490       |
| 24                                    | 288.9             | 23.0| 52.3| 15.2| 9.9| 11.8| 220        | 90 | 440| 550       |
| Source of variation                    |                   |   |   |   |    |    |            |    |    |    |            |
| N                                     | *                 | **| * | * | * | * | *          | *  | * | * |            |
| L                                     | NS                | * | * | * | * | * | *          | *  | NS| NS |            |
| Q                                     | NS                | NS | * | NS | NS | NS |            | NS | NS | NS |            |
| Trinexapac-ethyl (TE)                  |                   |   |   |   |    |    |            |    |    |    |            |
| *                                     | NS                | NS | NS | NS | NS | NS |            | NS | NS | NS |            |

*Tissue tests in Study 2 were conducted 3, 6, 9, 12, 15, and 16 weeks after initial N treatment. 
**NS** Nonsignificant or significant at the 0.05 probability level. L = linear, Q = quadratic.
growth competes for root reserves. Reducing uneven shoot growth with applications of TE may promote surface uniformity and balance nutrient partitioning within the plant. Redirected plant energy away from new leaf growth may therefore provide more favorable growing conditions for dwarf bermudagrass root systems.

Increased N rates resulted in higher P concentrations in leaf tissue and reduced P concentrations in roots and rhizomes. Conversely, leaf N, P, and K concentrations were reduced 1 week after initial TE application, while increased concentrations were observed in roots after 16 weeks. Results are consistent with reports of TE reducing N allocation to 'Tifway' bermudagrass leaf tissue while increasing N retention in roots (Fagersen et al., 2004). More importantly, these results exemplify an altered source and sink relationship under shoot growth inhibition which likely is attributed to root mass and root length enhancements using TE. 'TifEagle' bermudagrass, under shoot growth inhibition, reallocated N and all other nutrients away from leaf tissue. Greater nutrients stored in belowground tissues could therefore be allocated to prevent leaf nutrient deficiencies. Since bermudagrass putting greens are heavily fertilized, improved nutrient use efficiency could reduce high fertility requirements of these grasses. Reductions in leaf micronutrients concentrations in TE treated turf were not consistent with primary and secondary nutrient concentrations. However, it could be inferred that requirements for micronutrients may be reduced under long-term leaf growth inhibition.

Inhibiting shoot growth with TE reduced nutrients removed through clippings and caused higher chlorophyll concentrations per unit leaf area. Consequently, color enhancements resulted to where fertilizations may be unnecessary to promote turf quality. 'TifEagle' bermudagrass may necessitate between 6 to 12 kg N/ha/week to promote turf quality and color enhancements when using TE. Moreover, bermudagrass quality enhancements from TE applications were most substantial when fertilized greater than 6 kg N/ha and may only be significant when adequate N is available for growth.

The absence of a significant N x TE interaction suggests TE applications helped mitigate but did not completely mask the influence of N fertility on 'TifEagle' bermudagrass growth.
root growth. Inhibited leaf growth apparently reduced shoot competition for root reserves, thus providing more favorable conditions for growth. Nitrogen distribution away from leaves may have stimulated ‘TifEagle’ bermudagrass root growth from increased nutrient and energy partitioning to roots. ‘TifEagle’ bermudagrass shoot growth, under regulation by TE, may no longer be as competitive with roots for nutrients and plant reserves. Overall, routine applications of TE may encourage bermudagrass root growth and enhance nutrient use efficiency, thus making an effective tool for long-term dwarf bermudagrass culture.

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