Seaweed Extract, Humic Acid, and Propiconazole Improve Tall Fescue Sod Heat Tolerance and Posttransplant Quality

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Abstract. Decline of sod quality during the transportation, storage, and transplant stages of sale is a primary economic concern of sod producers. However, the mechanisms of extending sod quality during storage, transportation, and transplantation remain unclear. This study was conducted to investigate the influences of selected plant metabolic enhancers (PMEs) seaweed (Ascophyllum nodosum Jol.) extract (SWE), humic acid (93 % a.i. (HA)), and propiconazole (PPC), on sod tolerance to stress during storage and posttransplant root growth of tall fescue (Festuca arundinacea Schreb.) sod. The SWE + HA, and PPC were applied alone, or in a combination, to tall fescue 2 weeks before harvest. Photochemical efficiency (PE) of photosystem II was measured immediately before harvest. The harvested sod was subjected to high temperature stress (40 °C) for 72 or 96 hours. The heated sod was replanted in the field and posttransplant injury and root strength were determined. On average over 1999 and 2000, application of SWE (50 mg·m–2) + HA (150 mg·m–2), PPC (0.30 mL·m–2), and a combination of SWE + HA with PPC (0.15 mL·m–2), enhanced PE of preharvest sod by 8.5%, 9.1%, and 11.2%, respectively, and increased posttransplant root growth by 20.6%, 34.6%, and 20.2%, respectively. All PME treatments reduced visual injury except SWE + HA and SWE + HA + PPC in 1999. Extension of heat duration from 72 to 96 hours caused significantly more injury to the sod and reduced posttransplant rooting by 22.9% averaged over 2 years. The data suggest that foliar application of SWE + HA, PPC alone, or in a combination with SWE + HA, may reduce shipment heat injury and improve posttransplant rooting and quality of tall fescue sod. Chemical name used: 1-(2-(2,4-dichlorophenyl)-4-propyl-1,3-dioxolan-2-yl)methyl-1H-1,2,4-triazole [propiconazole (PPC)].

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Inc., Tyngsboro, Mass.). The ratio of variable length fluorometer (OS-50, Opti-Sciences Nordenkampf and Oquist, 1993; Miles, 1990). or relative photochemical activity (Bolhar-cator of the photochemical efficiency of PSII 290 kPa 784 L·ha–1 water solution of the chemicals at 290 kPa 2 weeks before harvest in both 1999 and 2000. Plots (1.8 × 1.8 m) were arranged in a randomized complete-block design with four replications. Data were subjected to analysis of variance and mean separations were performed with a protected least significant difference (LSD) test (SAS, 1988).

For the heat treatment, two pieces of sod (0.3 m × 1.8 m) were removed from each plot on 2 Aug. 1999 and 25 Aug. 2000, rolled and placed in a storage building set to maintain a uniform 40 °C. This building was engineered to heat sod similar to that stored during summer months in the center of pallet stacks or rolls (Heckman et al., 2001; King et al., 1982). A thermocouple was inserted into the center of each roll to ascertain temperature. The temperature inside the rolls and air temperature inside the storage building were uniformly 40 °C during the heat treatment period. A sod roll from each treated plot was removed from the building after 72 and 96 h, respectively, and transplanted 30 cm apart onto a prepared field (Grosccelosilt loam soil (clayey, Kaolinitic, mesic Typic Hapludult, pH 6.2, OM 2.2%)). A piece of sod (0.3 m × 0.3 m) was cut from the center of the roll and a 0.5 m × 0.3 m sheet of expanded metal was inserted under this piece of sod for subsequent root strength determination (Schmidt et al., 1986). Sidorun [α.i. 50.0%; Tuperasan; 1-(2-methyl-cyclohexyl)-3-phenylurea] was applied at 1.2 mg·m–2 (α.i.) over and between the sod pieces to prevent weed germination. Irrigation was applied to prevent dessication. Three weeks after transplanting, injury was rated based on a visual scale of 1–9, with 9 indicating the most injury. Six weeks after transplanting, root strength was determined by measuring the force required to vertically lift the ex- panded sheet of metal through which the sod roots had grown (Goatley and Schmidt, 1991; Schmidt et al., 1986). Briefly, the amount of force required to lift the roots free from the soil was recorded with a 100-kg handheld push/pull scale attached to the corners of the steel squares with hooks and steel cable.

Photochemical efficiency (Fv/Fm) was determined on preharvest sod by measuring chlorophyll fluorescence with a dual wave-length fluorometer (OS-50, Opti-Sciences Inc., Tyngsboro, Mass.). The ratio of variable fluorescence to maximum fluorescence at 690 nm (Fv/Fm) is an indicator of the photochemical efficiency of PSII or relative photochemical activity (Bolhar-Nordenkampf and Oquist, 1993; Miles, 1990). Chlorophyll fluorescence was measured on the whole turfgrass canopy consisting of mature and actively growing leaves. The sod canopy area in each plot was selected randomly and covered for 15 min by a PVC ring (10-cm diameter × 5 cm high) filled with Styrofoam (10 mm thick) for dark acclimation. A small opening (10-mm diameter) was made in the Styrofoam of each PVC ring and covered by a plastic plate. After the sod canopy was subjected to dark acclimation, the plastic plate was switched and the probe for the actinic light source was inserted immediately into the opening and pressed against the turf. Then the ring was rotated 90° three times after each reading and another fluorescence measurement was collected. The values of Fv/Fm were calculated based on averages of the three measurements.

**Results**

**Canopy photochemical efficiency.** All PME treatments enhanced PE significantly in 1999 and 2000 except SWE + HA treatment in 2000 (Table 1). The impacts of the PMEs on PE exhibited a similar trend in both years. On average over 1999 and 2000, application of SWE + HA, PPC at 0.30 mL·m–2, and a combination of SWE + HA with PPC at 0.15 mL·m–2 increased PE by 8.5%, 9.1%, and 11.2%, respectively.

**Visual injury.** Extending the heat treatment from 72 to 96 h caused more posttransplant visual injury in 1999 and 2000 (Table 2). The injury was less in 2000 than in 1999. This was most likely due to the mild environmental conditions (higher rainfall, lower irradiance) during the transplant period in 2000 relative to 1999 (Table 2).

There was no significant interaction between heat duration and PME treatment in either year. When averaged over heat durations, all PME treatments reduced visual injury in 2000. In 1999, although all treatments reduced visual injury, only the turf treated with PPC had significantly reduced visual injury (Table 2).

**Root strength.** All PME treatments increased root strength in 1999 and 2000 following 72 and 96 h heat treatment (Table 2). Averaged over 1999 and 2000, SWE + HA, PPC, and SWE + HA + PPC enhanced posttransplant root strength by 20.6%, 34.6%, and 20.2%, respectively. The PPC treatment consistently provided the greatest root strength. Extension of heat duration from 72 to 96 h reduced posttransplant rooting by 22.9% on average over 2 years. As with the visual injury data, a significant PME × heat duration interaction was not observed in either year.

**Discussion**

Foliar application of SWE + HA, PPC at 0.30 mL·m–2, or a combination of SWE + HA with 0.15 mL·m–2 PPC, significantly improved PE of field grown tall fescue sod. This is consistent with the results of Zhang (1997) and Zhang and Schmidt (2000a) who reported that folic application of SWE or PPC improved PE of tall fescue and creeping bentgrass under field conditions and under a water-stressed greenhouse environment. In this study, the values of PE, ranging from 0.61 to 0.69, were relatively lower in comparison to the PE of some non-stressed plants probably because the measurements were taken on a turf canopy consisting of leaves in various growth stages, rather than single leaves. Using the same technique under well-watered conditions, Zhang and Schmidt (2000a) obtained canopy PE values ranging from 0.31–0.55 in July to 0.58–0.75 in September. Liu and Huang (2001) reported a leaf PE ranging from 0.61–0.73 in August in field grown creeping bentgrass.

We speculate that the increased rooting and PE we measured due to PME treatment in this study may involve the hormone-like activity of these PMEs or their effects on plant hormone balance. Propiconazole, like other triazoleos, interferes with the biosynthesis of ABA through inhibition of C-14 demethylation reactions that block sterol and gibberellin biosynthesis (Rademacher, 2000). In addition, a complex of cytokinins and indole 3-acyclic acid (IAA) have been identified and quantified in extracts of Aglomeramus (Sanderson and Jameson, 1986; Sanderson et al., 1987; Tay et al., 1985). Bio-assays have also indicated that A. nodosum extracts exhibit cytokinin-like activity (Allen et al., 2001; Sanderson and Jameson, 1986). Polyamines and IAA have also been quantified in ampicic acid preparations and their hor- mone-like activity in stimulating root growth has been shown in biassays (Cacco and Drell Agnola, 1984; O’Donnell, 1973; Young and Chen, 1997). Yan (1993) showed that seaweed extract application significantly increased endogenous cytokinin level in perennial ryegrass (Lolium perenne L.).

A shift in the balance of plant hormones in response to stress has been frequently reported (Itai, 1999). During heat and moisture stress, cytokinins, auxin, and gibberellins fall, while ABA and ethylene levels rise, usually initiating senescence. Exogenous applications of PPC, SWE, and HA may be causing endogenous shifts in the balance of hormones during the stress, increasing cytokinins, IAA, and gibberellin levels while decreasing ABA and ethylene (Rademacher, 2000; Yan, 1993). Previous work has demonstrated that a consequence of this supposed shift is an increase in antioxidants such as superoxide dismutase, α-tocopherol, and ascorbic acid resulting in greater tolerance to various stresses (Mackay et al., 1987; Zhang and Schmidt, 1999, 2000a, 2000b).

### Table 1. Photochemical efficiency (PE) of tall fescue (Festuca arundinacea Schreb.) sod before harvest as influenced by plant metabolic enhancers (PMEs) 

| PMEs          | Rate (m–2) | PE efficiency (Fv/Fm)  |
|---------------|------------|------------------------|
|               | 1999       | 2000                   |
| SWE + HA      | 50 mg + 150 mg | 0.689 a              |
| PPC           | 0.30 mL    | 0.676 a                |
| SWE + HA + PPC| 50 mg + 150 mg + 0.15 mL | 0.685 a           |
| Control       | 0          | 0.615 b                |

*PE was measured on 2 Aug. 1996 and 25 Aug. 2000, 2 weeks after PME applications.
*SWE = seaweed extract; HA = hamic acid; and PPC = propiconazole.
*Values with same column each year with same letter are not different significantly at P = 0.05.
PME-induced increases in antioxidant content and related PE increases prior to harvest may protect photosystem II during heat stress (Table 1). Consequently, posttransplant photo-oxidative injury exacerbated by a high UV environment is decreased (Table 2). The photosynthetic apparatus is a primary target of UV environment is decreased (Table 2). The vest may protect photosystem II during heat stress better than PE caused by UV irradiation of Kentucky bluegrass sod. The results of this study are consistent with the findings by Schmidt and Zhang (2001), who found that sod experiences during storage and transplant injury. In summary, this research has demonstrated the use of salicylic acid on shelf life of turfgrass sod. 2001 Agronomy Abstr. (CD-ROM). ASA, CSSA, and SSSA, Madison, Wisc. Fike, J.H., V.G. Allen, R.E. Schmidt, X. Zhang, J.P. Fontenot, C.P. Bagley, R.L. Ivy, R.R. Evans, R.W. Cuellor, and D.B. Wester. 2001. Tasco-Forage: L. Influence of a seaweed extract on antioxidant activity in tall fescue and in ruminants. J. Anim. Sci. 79:1011–1021. Fletcher, R.A., G. Hofstra, and J. Gao. 1986. Comparative fungitoxic and plant growth regulating properties of triazole derivatives. Plant Cell Physiol. 27:367–371. Giese, M.S., R.E. Gaussoin, R.C. Shearman, and T.P. Riordan. 1997. Seed production characteristics of turf-type Buchloë dactyloides. Int. Turfgrass Soc. Res. J. 8:455–465. Goatley, J.M., Jr. and R.E. Schmidt. 1990. Antisense activity of chemicals applied to Kentucky bluegrass. J. Amer. Soc. Hort. Sci. 115:654–656. Goatley, J.M., Jr. and R.E. Schmidt. 1991. Biostimulator enhancement of Kentucky bluegrass sod. HortScience 26:254–255. Heckman, N.L., G.L. Horst, R.E. Gaussoin, and K.W. Frank. 2001. Storage and handling characteristics of trinexap-acetyl treated Kentucky bluegrass sod. HortScience 36:1127–1130. Itai, C. 1999. Role of phytohormones in plant responses to stress. In: H.R. Lerner (ed.). Plant responses to environmental stress, p. 287–301, Marcel Dekker, New York. King J.W., J.B. Beard, and P.E. Rieke. 1982. Factors affecting survival of Kentucky bluegrass sod under simulated shipping conditions. J. Amer. Soc. Hort. Sci. 107:634–637. Liu, X. and B. Huang. 2001. Seasonal changes and cultivar difference in turf quality, photosynthesis, and respiration of creeping bentgrass. HortScience 36:1131–1135. MacKay, C.E., T. Senaratna, B.D. McKersie, and R.A. Fletcher. 1987. Ozone-induced injury to cellular membranes in Triticum aestivum. J. Plant Physiol. 124:225–228. Miles, D. 1990. The role of chlorophyll fluorescence.
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