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Effects of artificial amendments in potting media on *Orthosiphon aristatus* growth and development

Trung-Ta Nguyen [a,b,*], Daryl C. Joyce [a], Son-Quang Dinh [a]

[a] *The University of Queensland, Centre for Native Floriculture, School of Land, Crop and Food Sciences, Gatton, Qld. 4343, Australia*
[b] *Tay Nguyen University, Faculty of Agriculture and Forestry, Buon Ma Thuot City, Daklak, Viet Nam*

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ABSTRACT

Artificial polyacrylamide gel (PAG) and urea-formaldehyde resin foam (UFRF) amendments are used for putative enhancement of soil physical properties, including increasing their water holding capacity (WHC). Effects were investigated of these two amendments alone and combined on growth and development of *Orthosiphon aristatus* (Cats' Whiskers) grown in either composted pine bark or washed river sand, including under transient water deficit stress. UFRF and PAG were incorporated into these potting media substrates at recommended rates of 30% (v/v) and 0.1% (w/w), respectively. UFRF incorporation reduced bulk density and increased air-filled porosity of composted pine bark from 0.24 g cm^{-3} and 43.3% to 0.18 g cm^{-3} and 50.2%, respectively. UFRF also reduced bulk density of sand from 1.43 g cm^{-3} to 1.17 g cm^{-3} and increased its air-filled porosity from 18.5% to 25.3%. PAG slightly decreased bulk density of composted pine bark to 0.23 g cm^{-3} and also reduced sand bulk density to 1.32 g cm^{-3}. Water content of composted pine bark and sand was increased by PAG addition from 47.6% and 27.7% to 51.0% and 34.2%, respectively. However, UFRF and/or PAG did not increase plant available water (PAW) in either composted pine bark or sand. PAW was 23.8% and 14.4%, 23.6% and 15.8%, 22.8% and 14.8%, and 25.2% and 17.8% for composted pine bark and sand controls, these two substrates amended with UFRF, these substrates amended with PAG, and these substrates with UFRF plus PAG, respectively. Neither shoot length nor number was increased by adding UFRF and/or PAG. Similarly, neither shoot fresh nor dry weight was increased by UFRF and/or PAG amendments. UFRF and, moreso, UFRF plus PAG slightly delayed the onset of wilting by 4–15 h in water deficit stressed *O. aristatus* compared to control and PAG alone in composted pine bark (experiment 1), but PAG did not. However, in experiment 2, UFRF and/or PAG did not delay wilting in either composted pine bark or sand. Thus, when incorporated at suppliers recommended rates, neither UFRF nor PAG conferred appreciable benefits for *O. aristatus* plant growth in either composted pine bark or sand potting media.

1. Introduction

The physical properties of soil and potting media (substrates) are important for optimal plant growth and development. There is increasing interest in the use of artificial amendments to enhance available soil water for plant growth. Polyacrylamide gel (PAG) formulations have been trialled widely (e.g., Johnson, 1984; Henderson et al., 1991; Janczuk et al., 1991; Chan and Savapragasam, 1996; Huttermann et al., 1999; Vacher et al., 2003; Arbona et al., 2005; Ajwa and Trout, 2006). Urea-formaldehyde resin foam (UFRF) has been trialled recently for *Lantana camara* (Panayiotis et al., 2003), turfgrass (Nektarios et al., 2004; Nikolopoulou and Nektarios, 2004; Nikolopoulou et al., 2004) and potted *Flindersia schottiana* (Chan and Joyce, 2007). UFRF and PAG have markedly different characteristics. PAG is a homopolymer formed through polymerization of acrylamide molecules and related monomers (Barvenik, 1994). Anionic PAG is manufactured by copolymerization of acrylamide and acrylic acid or the salt of this acid (Mortimer, 1991). PAG has crosslinks within macromolecular chains which allow swelling upon hydration (Bouranis et al., 1995). PAG can absorb water and act as a reservoir to release moisture slowly during drought periods (Bouranis et al., 1995). PAG may absorb water up to ~500 times its own weight (Johnson, 1984). UFRF is made from a resin solution, a hardening agent and a foaming agent (Veili, 1964). UFRF is a lightweight (18–30 kg m^{-3}) porous material with a WHC of ~60% (v/v). UFRF amendment may increase overall substrate WHC, but release readily (Baader, 1999). UFRF can increase air-filled porosity and water infiltration of heavy soils, and water retention in light soils (Baader, 1999).

* Corresponding author at: Tay Nguyen University, Faculty of Agriculture and Forestry, Buon Ma Thuot City, Daklak, Viet Nam.
E-mail address: nguyentrungta@yahoo.com (T.-T. Nguyen).

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Bulk density of soils is typically decreased by PAG (Terry and Nelson, 1986; Al-Darby, 1996; Chan and Savapragasam, 1996; Arbona et al., 2005) and UFRF (Panayiotis et al., 2003). Granulated PAG treatment (650 kg ha^{-1}) of fallow clay loam soil gave lower surface (5 cm) bulk densities than no treatment, ranges being 0.95–1.06 versus 1.17–1.21 g cm^{-3}, respectively (Terry and Nelson, 1986). PAG at 0.01% (w/w) can also reduce structural breakdown of degraded hard-setting soils (Chan and Savapragasam, 1996). Moreover, it can improve hydraulic properties of sandy soils (Al-Darby, 1996; Ozturk et al., 2005). PAG incorporated at 1 g kg^{-1} into a sandy soil increased plant available water (PAW) to 3–5 times higher than for the control (Johnson, 1984). Henderson et al. (1991) noted that composted pine bark plus sand with PAG (0.3%, w/w) improved *Rosa hybrida* water status as evidenced by higher leaf water potential, transpiration and stomatal conductance (G_s). Huttermann et al. (1999) reported that water retention of a fossil desert soil increased upon adding PAG at 0.4% (w/w). Consequently, *Pinus halepensis* in soil amended with 0.4% PAG (w/w) had almost double the survival time when water was withheld than control plants; viz., 82 and 49 days, respectively (Huttermann et al., 1999). PAG amendment (0.4%, w/w) also enhanced drought tolerance of citrus plants and prolonged seedling survival under water stress conditions (Arbona et al., 2005).

The bulk density of a sandy loam soil amended with UFRF (40%, v/v) was reduced by 46%, compared to the control (Panayiotis et al., 2003). Correspondingly, air-filled capacity was increased. UFRF amendment reduced compaction when incorporated into a sandy loam soil (Nikolopoulou and Nektarios, 2004). However, UFRF (40%, v/v) did not alter WHC of a sandy loam (Panayiotis et al., 2003; Tsiotsiopoulou et al., 2003). These findings imply that pore size distribution within UFRF may resemble that of sandy loam (Panayiotis et al., 2003). While PAW of sandy loam was not increased by UFRF addition, peat with UFRF incorporated (40%, v/v) exhibited a 2.5-fold increase in PAW.

Amendments with PAG and UFRF have been found to improve growth in some crop plant species. Vegetative yields of wheat and tomatoes grown in a Xerothents soil were improved by PAG at 1% (w/w) from 0.37 kg $plant^{-1}$ and 0.48 kg $plant^{-1}$ to 0.67 kg $plant^{-1}$ and 2.6 kg $plant^{-1}$, respectively (Wallace et al., 1986). Germination and biomass production of lettuce and ryegrass in a dune sand were also increased by PAG amendment (Ahmad and Verplancke, 1994). During drought, *P. halepensis* seedlings with PAG (0.4%, w/w) had 3-fold higher growth increment than control plants. However, Henderson et al. (1991) reported that composted pine bark plus sand with PAG incorporated at 0.3% (w/w) gave little or no effect on biomass of five low maintenance rose (*R. hybrida*) cultivars. Similarly, amendment with UFRF (40%, v/v) of a sandy loam soil or peat did not increase *L. camara* plant growth (Panayiotis et al., 2003). Moreover, UFRF was not beneficial to *F. schottiana* saplings during their initial growth in composted pine bark, and there were inconsistent effects of UFRF on plant height and stem diameter (Chan and Joyce, 2007). However, UFRF incorporated into sand and loam soils improved growth of potted *F. schottiana*. Moreover, UFRF amended composted pine bark increased *F. schottiana* leaflet number. Variations in UFRF or PAG effects on plant growth may be attributable to differences in types of PAG, and of soils and to variable application rates.

Orthosiphon aristatus is an ornamental rainforest species of Australia and tropical Southeast Asia. It prefers moist garden soils for best growth (Nicholson and Nicholson, 1996) and is considered to have low drought tolerance (Kjelgren et al., 2009). Two pot experiments were implemented to evaluate the efficacy of UFRF and/or PAG in delaying wilting time of *O. aristatus* under transient water deficit stress, and on plant growth and development. It was hypothesized that UFRF and/or PAG would increase substrate water content and thereby reduce, or at least delay, transient water deficit stress effects on plants.

2. Materials and methods

2.1. Plant material

Tip cuttings of *O. aristatus* Blume, Miq. (Lamiaceae; Cats' Whiskers) were obtained from stock plants grown at The University of Queensland's Gatton Campus Nursery (27°33′S, 152°20′E). Tip cuttings of ~12 cm and ~8 cm long were used for experiments 1 and 2, respectively. Cut ends were immersed into liquid rooting hormone (indole butyric acid, 4 g L^{-1}) for 5–10 s and rooted in a 100-cell tray in a propagation house at ~30.5 °C and ~80% relative humidity (RH). Eighteen-day-old *O. aristatus* tube stock plants were potted up into 1.5 L plastic containers (125 mm top diameter and 140 mm height) of either composted pine bark or washed river sand, each with or without UFRF and/or PAG. Temperature and RH were recorded at 30 min intervals during experiments with a data logger (TGP-4500; Gemini Data Loggers Ltd.; West Sussex, UK). Average day and night temperatures and RH for experiments 1 and 2 were ~25.1 °C and ~19.1 °C, ~57.6% and ~70.8%, and ~23.9 °C and ~17.9 °C, and ~67.0% and ~83.5%, respectively.

2.2. Substrate preparation

Composted pine bark and washed river sand were obtained from The University of Queensland's Gatton Campus Nursery. One cubic meter of composted pine bark or sand was fertilised with 2 kg of Osmocote® (15N:3.9P:9.1K), 1 kg of Basacote® (13N:6P:16K), 2 kg of Nutricote® (16N:4.4P:8.3K), 1.3 kg of Osmoform® (18N:5P:13K), 1.3 kg of coated iron (27% iron and 16.2% sulphur), and 1.3 kg of Dolimite® (33% magnesium carbonate and 35% calcium carbonate).

2.3. Substrate amendments

PAG (Waterwise™; Arthur Yates and Co Limited; NSW, Australia) and UFRF (Hydrocell™; Verheijen Resins BV; Boven Leeuwen, The Netherlands) potting mix amendments were procured from local retail outlets. In experiment 1, treatments were control (composted pine bark with no amendment) and amendments with 30% (v/v) UFRF (suppliers recommended rate), 0.1% (w/w) PAG (suppliers recommended rate) and UFRF plus PAG. In experiment 2, treatments were substrate controls (either composted pine bark or sand with no amendments) and composted pine bark or sand amended with 30% (v/v) UFRF, 0.1% (w/w) PAG and UFRF plus PAG. For individual pots, substrate components were put into a plastic bag and shaken to mix thoroughly. Filled pots were each dropped from 10 cm high for 20 times to compact the potting medium (Panayiotis et al., 2003). *O. aristatus* plantlets were then transplanted one per pot.

2.4. Substrate properties determination

Three extra pots of each treatment in experiment 2 were prepared and used for the determination of substrate physical properties. Prepared pots were saturated with water, drained to FC and subsequently irrigated normally by dripper for 5 days. This protocol was to ensure that all particles had time to become completely wetted. The substrate was again watered to saturation and drained to FC for 17 h before transfer into heat resistant plastic bags. The substrate was weighed to determine weight at FC and then dried in a well ventilated oven at 105 °C for 6 days to constant weight for dry weight determination. Physical properties of bulk density, water content and air-filled porosity were determined after Jury and Horton (2004) and Cresswell and Hamilton (2002). Bulk density was mass of dry substrate per unit volume.