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EFFECTS OF FERTILITY ON BIOMASS, PHYTOTOXICITY, AND ALLELOCHEMICAL CONTENT OF CEREAL RYE

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Abstract—Studies were conducted to evaluate biomass production, tissue phytotoxicity, and allelochemical content of rye (*Secale cereale* L.) shoots grown in three fertility regimes (low, medium or high) in the greenhouse. Wheeler rye or a polyculture of rye and hairy vetch (*Vicia villosa* Roth) grown with high fertility produced the greatest biomass (78.7 and 82.7 g), with the lowest root-to-shoot ratio (0.22 and 0.43) produced in the high-fertility treatments. The polyculture treatment grown with low fertility had a greater proportion of hairy vetch (18%) than when grown with high fertility (6%). Rye shoot residue phototoxicity was affected by fertility regime. Radicle elongation of cress (*Lepidium sativum* L.) and barnyardgrass [*Enchinochloa crus-galli* (L.) Beauv.] was inhibited by rye shoot residues in a modified Parker bioassay. Rye shoot residue grown with low fertility was less inhibitory to cress radicle elongation than rye residue from the medium- or high-fertility regimes. Extracts of dried rye shoots grown with high fertility were less inhibitory than extracts from other fertility regimes. The concentrations of ether extracts of rye causing 50% inhibition (I_{50}) of cress radicle elongation were between 125 and 276 μg/ml for greenhouse-grown and 60 and 138 μg/ml for the field-grown rye shoots. The major phytotoxic compounds in the rye shoot extracts were identified as DIBOA and BOA. The concentration of DIBOA in the greenhouse-grown rye shoots ranged between 128 and 423 μg/g while BOA concentration ranged between 2.5 and 31 μg/g. DIBOA and BOA levels were lowest in rye shoots grown with high fertility. Correlations between rye shoot biomass,

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DIBOA and BOA concentration, and cress barnyardgrass radicle length were significant.

Key Words—*Secale cereale* L., *Vicia villosa* Roth, allelopathy, phytotoxicity, fertility regime, 2,4-dihydroxy-1,4(2H)-benzoxazin-3-one, 2(3H)-benzoxazoline, reduced tillage, weed suppression

INTRODUCTION

Rye (*Secale cereale* L.) is a winter-hardy, erect, herbaceous plant that grows well on marginal soils (Bushuk, 1976; Nuttonson, 1958). It is a long-day plant capable of developing an extensive root system that reduces erosion and nutrient loss (Nuttonson, 1958). In the Midwestern United States, rye is widely grown as a cereal, interseeded with legumes in winter pastures, or as a green manure crop (Amador and Gliessman, 1990).

Rye and its residues reduce weed and crop growth by modifying the microenvironment and releasing allelochemicals (Putnam et al., 1983; Rice, 1984). Rye produces a dense canopy, which is more competitive than weeds for light, moisture, and nutrients. In addition, rye residues on the soil surface reduce weed germination and growth by shading, lowering soil temperatures, moderating diurnal temperature fluctuations, and acting as a physical barrier (Barnes and Putnam, 1986; Putnam et al., 1983; Rice, 1984; Vidal et al., 1994). Rye and its residues can release allelochemicals that accumulate near the soil surface inhibiting seed germination and seedling growth (Barnes and Putnam, 1983; Barnes et al., 1987).

Environmental factors influence allelochemical production in higher plants and also related biological activity (Putnam, 1988; Rice, 1984; Tukey, 1969). For example, increased air temperatures enhanced allelochemical concentration and consequent inhibition of plant growth (Putnam and Tang, 1986; Rizvi and Rizvi, 1992). Stowe and Osborne (1980) reported reduced plant growth and increased allelochemical concentrations due to limited nutrient availability. Fast-growing plants in fertile environments contained lower allelochemical concentrations than slow growing species in areas of limited ferility. Besides affecting allelochemical concentration, allelopathy was enhanced in soils of low fertility (Stowe and Osborne, 1980).

The phytotoxicity of rye and its residues has been attributed to cyclic hydroxamic acids, phenylacetic acid, 4-phenylbutryic acid, and a complex of benzoic and cinnamic acids (Barnes and Putnam, 1986; Einhellig and Leather, 1988; Putnam and Tang, 1986; Rizvi and Rizvi, 1992; Shilling et al., 1985). Two benzoxazinones, 2,4-dihydroxy-1,4(2H)-benzoxazin-3-one (DIBOA) and its decomposition product, 2(3H)-benzoxazolinone (BOA), have been identified in extracts of rye shoots and their allelopathic activity characterized using cress