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Effects of aromatic plants incorporated as green manure on weed and maize development

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ABSTRACT

A 2-year field experiment was conducted in northern Greece to study the mulch effects of seven annual [anise (*Pimpinella anisum* L.), sweet fennel (*Foeniculum vulgare* P. Mill.), sweet basil (*Ocimum basilicum* L.), dill (*Anethum graveolens* L.), coriander (*Coriandrum sativum* L.), parsley (*Petroselinum crispum* (P. Mill.) Nyman ex A.W. Hill) and lacy phacelia (*Phacelia tanacetifolia* Benth.)] and three perennial [mint (*Mentha X verticillata* L.), oregano (*Origanum vulgare* L.) and common balm (*Melissa officinalis* L.)] aromatic plants, used as incorporated green manure, on the emergence and growth of barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.], common purslane (*Portulaca oleracea* L.), puncturevine (*Tribulus terrestris* L.), common lambsquarters (*Chenopodium album* L.) and maize (*Zea mays* L.). In addition, the phytotoxic potential of the abovementioned aromatic plants extracts was determined in the laboratory using a perlite-based bioassay with maize and barnyardgrass. The bioassays indicated that germination, root elongation and fresh weight of barnyardgrass were reduced by the most aromatic plant extracts. However, maize growth parameters were only affected by the extracts of anise, sweet fennel, coriander, common balm and oregano. In the field, emergence of barnyardgrass, common purslane, puncturevine or common lambsquarters was reduced by 11–50%, 12–59%, 26–79% or 58–83% in green manure-treatment plots, respectively, as compared with green manure-free plots (control). On the contrary, maize emergence was not affected by any green manure. At harvest, maize grain yield in green manure-herbicide untreated plots was 10–43% greater than that in the corresponding green manure-free plots. In particular, maize grain yield in anise, dill, oregano or lacy phacelia green manure-herbicide untreated plots was 27–43% greater than that in the green manure-free-herbicide untreated and slightly lower than that obtained in the corresponding herbicide treated plots. These results indicated that green manure of aromatic plants, such as anise, dill, oregano or lacy phacelia could be used for the suppression of barnyardgrass and some broadleaf weeds in maize and consequently to minimize herbicide usage.

1. Introduction

The reduction of chemical inputs into agricultural systems has renewed interest in the use of cover crop mulches to suppress weeds. Studies, using cover crops for weed control in summer crops, have shown that some legumes or winter cereals used as living mulches (grown simultaneously under the crop) or incorporated into the soil as green manure or herbicide killed or used as a stubble can significantly reduce density and biomass of several weed species in maize and soybean (*Glycine max* (L.) Merr.) (Teasdale et al., 1991; Liebl et al., 1992; Moore et al., 1994; Yenish et al., 1996; Nagabhushana et al., 2001; Dhima et al., 2006). The ability of cover crops to release toxic substances into the soil and to create an unfavorable environment for weed germination and establishment could account for the observed weed suppression (Crutchfield et al., 1985; Barnes and Putnam, 1987; Mohler and Teasdale, 1993; Ben-Hammouda et al., 2001).

Most studies related to cover crop effects on weed suppression and crop development have focused on winter cereals or legumes (Teasdale et al., 1991; Liebl et al., 1992; Moore et al., 1994; Yenish et al., 1996; Dhima et al., 2006). However, studies on the effects of aromatic plants, used as cover crops incorporated into the soil as green manure or left on top of the soil as mulches, on crops and weeds, as well as studies on the inhibitory effects of aromatic plant extracts on weed germination are limited in literature. In particular, Dudai et al. (1999) found that palmer amaranth

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(*Amaranthus palmeri* S. Watson) germination was inhibited by essential oils of lemon basil (*Ocimum citriodorum* L.), oregano and sweet marjoram (*Origanum majorana* L.). In addition, Tworkoski (2002) found that essential oils from red thyme (*Thymus vulgaris* L.), clove [*Syzgium aromaticum* (L.) Merr. & Perry] and cinnamon (*Cinnamomum zeylanicum* Blume) caused electrolyte leakage resulting in death of dandelion (*Taraxacum officinale* Weber in Wiggers) cells. Also, Vasilakoglou et al. (2007) found that essential oils extracted from four sweet basil cultivars and six oregano or marjoram populations reduced germination and root growth of barnyardgrass and common lambsquarters. These results constitute evidence that aromatic plants incorporated as green manure into the soil or left on top of the soil as mulches, with the capacity to produce phytotoxic essential oils, could play an important role for weed suppression in sustainable agriculture systems.

The objectives of this research were (i) to assess under laboratory conditions the phytotoxic potential of the aromatic plants anise, sweet fennel, sweet basil, dill, coriander, parsley, lacy phacelia, mint, oregano and common balm on barnyardgrass and maize and (ii) to determine under field conditions the effects of these aromatic plants used as cover crops incorporated into the soil as green manure on emergence and growth of barnyardgrass and three annual broadleaf weeds (common purslane, puncturevine, common lambsquarters), as well as on maize growth, silage and grain yield.

2. Materials and methods

2.1. Laboratory experiment

2.1.1. Extract preparation

Plants of anise, sweet fennel, sweet basil, dill, coriander, parsley, lacy phacelia, mint, oregano and common balm were harvested at the beginning of blossom (time of their incorporation into the soil in the field experiment). The harvested plants were chopped into 5-cm long pieces, air dried at 24 °C for 72 h and grounded in a Wiley mill through a 1-mm screen. Then, aqueous extracts (w/v) were prepared in 400-mL glass jars by adding 4 or 8 g from each plant sample in 200-mL of deionized water and shaking in a horizontal shaker for 4 h at 200 rpm. The solutions were filtered through four layers of cheesecloth to remove fiber debris, centrifuged at 1750 × *g* in a centrifuge with 30-cm rotor diameter for 1 h and the supernatants were then filtered through a layer of filter paper (Whatman no. 42). The extracts were stored for 3 days at less than 5 °C until bioassayed. There were three replicates (glass jars) for each plant material by extract concentration (2 and 4 g per 100 mL) treatment.

2.1.2. Bioassay procedure

Petri dish bioassays were carried out to compare the germination, root elongation and fresh weight of maize and barnyardgrass in perlite treated with each of the aromatic plants extracts. Six maize (hybrid ‘Pioneer Ribera’) or 50 barnyardgrass seeds were placed in 8.5-cm diam plastic Petri dishes and were covered with 6 g of perlite. The open Petri dishes were moistened with 20 mL of aromatic plant extract per Petri dish from each of the aromatic plant extracts. Deionized water was used in control Petri dishes. There were two Petri dishes for each replicate extract and Petri dishes were arranged in a completely randomized design. Afterwards, the Petri dishes were stored on shallow trays and were placed inside a plastic bag to retain moisture. The trays were then placed in an illuminated (16 h light:8 h dark) growth chamber at 28 ± 2 °C for 8 days. At the end of the incubation period, plants were removed from the Petri dishes, carefully washed free of perlite, and average (mean of the two Petri dishes used for each replicate glass jar extract) germination, root elongation and fresh weight (of the germinated seeds only) were measured. The experimental procedure was conducted twice using the same aromatic plants extracts in both bioassay experiments. A 10 × 2 (10 aromatic plant extracts × two extract concentrations) factorial approach in a completely randomized design was used for the two experiments with three replicates. Electrical conductivity of all extracts was lower than 2 dS m^{-1} indicating that these solutions should not have a negative effect on germination or root elongation of maize and barnyardgrass. Also, fungal contamination was not observed during these experiments.

2.2. Field experiment

2.2.1. Aromatic plants cultivation

One field experiment was conducted during 2004 and 2005 growing seasons at the Technological and Education Institute Farm of Thessaloniki in northern Greece. The experiment was conducted in an area with naturally occurring populations of common purslane (approximately 40 plants m^{-2}), puncturevine (approximately 20 plants m^{-2}), and common lambsquarters (approximately 10 plants m^{-2}), as observed during the 2002 and 2003 growing seasons. The site is located at 22°44′10″ E, 40°37′06″ N. The soil was a sandy loam (Typic Xeropsamment) whose physicochemical characteristics were clay 56 g kg^{-1}, silt 180 g kg^{-1}, 1, sand 764 g kg^{-1}, organic matter 9 g kg^{-1} and pH (1:2 H_2O) 7.5.

Nitrogen and P_2O_5 at 80 and 40 kg ha^{-1}, respectively, were incorporated as diammonium phosphate (20-10-0) into the soil prior to planting the aromatic species. The seven annual aromatic plants (anise, sweet fennel, sweet basil, dill, coriander, parsley and phacelia) were planted on 25 April 2004 and 11 April 2005 (at seeding rates of 6, 5, 20, 25, 20, 6 and 20 kg ha^{-1} respectively). The three perennial aromatic plants (mint, oregano and common balm) were planted in early February and grown in a greenhouse for 5 weeks. Afterwards, they were transplanted in 40-cm rows at an approximate density of 62,500 plants ha^{-1} in middle March each year. A randomized complete block design with four replications for each treatment was used. Plot size was 6 m × 3 m and a 2-m wide alley separated all plots. Weed hand-removal from both unmulched (control) and mulched treatment plots was made before the aromatic plant incorporation into the soil in order to eliminate weed mulch effects on weed emergence after maize planting. In all mulched plots, weed species were observed at very low densities and were hand-removed during both growing seasons. In plots where aromatic plants had not been planted, weed control was achieved with 0.6 kg ha^{-1} of paraquat (1,1′-dimethyl-4,4′-bipyridinium) (a herbicide which is not active in soil due to its strong adsorption by inorganic colloids) applied post-emergence 3 weeks before aromatic plants incorporation into the soil. Irrigation and other common cultural practices were performed as needed.

2.2.2. Maize cultivation

The experiment was conducted in the area where the aromatic plants had been planted. In particular, in early summer of both growing seasons (normal planting time of double crop maize), the aromatic plants (at the beginning of blossom of all species) were incorporated as green manure into the soil (8–10-cm depth). The control (unmulched) treatment plots were also physically disturbed. Seven days later the experimental area was infested with barnyardgrass seeds by evenly broadcasting of 6 g m^{-2} on the soil (approximately 1250 seeds m^{-2} with 26% germinability). The barnyardgrass seeds had been collected from a nearby area during the previous year of each experiment and their germinability was evaluated before planting by carrying out Petri-dish experiments