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The effect of fertilizers on the efficacy of the bioherbicide, *Phoma macrostoma*, to control dandelions in turfgrass

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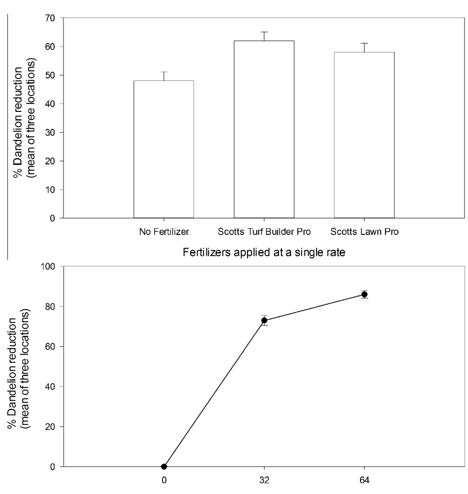
HIGHLIGHTS

- ▶ The bioherbicide, *Phoma macrostoma*, provided 70–100% control of dandelion.
- ▶ Dandelion reduction was greater by 10–20% with the use of nitrogen.
- ▶ Phosphate and lime had no effect on dandelion reduction.
- ▶ Potassium sulfate decreased bioherbicide efficacy.

GRAPHICAL ABSTRACT



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ABSTRACT

Phoma macrostoma is registered as a bioherbicide in North America to control broadleaved weeds species in turfgrass. A study was conducted to examine the effect of nitrogen, phosphorus, potassium, lime, and commercial fertilizers with or without applications of the bioherbicide on the reduction of dandelion under greenhouse and field conditions. The bioherbicide provided 70–100% reduction of dandelion. The addition of nitrogen with the bioherbicide, in the form of urea (45-0-0), Scotts Turf Builder Pro (32-0-4 plus 2% Fe), and Scotts Lawn Pro (26-0-3, with no iron), significantly reduced dandelion more than in soil that was not amended with fertilizers in the greenhouse and field locations. Bioherbicide efficacy on dandelion was 10–20% better with these fertilizer treatments. Phosphate (0-46-0), potassium sulfate (0-0-42), and lime had either no effect or did not reduce dandelions under greenhouse conditions. This study showed that *P. macrostoma* retained bioherbicide efficacy on dandelion in conjunction with typical fertility practices and the combination of the bioherbicide with nitrogen fertilizers improved bioherbicide efficacy, especially in low nitrogen soils.

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1. Introduction

Turfgrass quality is affected by nutrient availability and fertility levels, particularly on high traffic areas such as lawns, parks, sports field, and golf courses. Győrgy et al. (2008) demonstrated that the

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grass coverage of the lawn area, root and shoot density of the grass, and intensity of green color were dependent on the nutrient supplies, nitrogen in particular, being released slowly over time as compared to larger quantities of nitrogen being applied once at the beginning of the season. Fertilizers also have an impact on weed invasion in turfgrass. Demonstration plots at the University of Guelph, Canada showed that crabgrass (*Digitaria ischaemum* (Schreb. ex Schweig.) Schreb. ex Muhl.) was reduced by 70% and broadleaved weeds by 40% with a spring application of 2.0 kg N/ 100 m^2 (Charbonneau, 2009). However, other studies showed the effects on weed emergence and growth may be specific to each weed species. Lambsquarter (*Chenopodium album* L.) emergence and biomass accumulation was greater with nitrogen fertilizer than without (Dyck and Liebman, 1994; Sweeny et al., 2008).

The application of fertilizers not only affects the plants, but may also impact on the microbial populations in the soil. Linderman and Davis (2004) found that controlled release fertilizers with high phosphorus content eliminated arbuscular mycorrhize colonization, whereas organic fertilizers with low phosphorus only reduced colonization without entirely eliminating it. Shoot growth of onions was similar with or without arbuscular mycorrhizae when fertilized with controlled release fertilizers, but with organic fertilizers shoot growth was only enhanced when inoculated with arbuscular mycorrhizae. In general, soil microbial biomass, populations of bacteria, fungi, and actinomycetes, as well as enzymatic activities, were increased with the addition of either inorganic or organic fertilizers, although the greatest increases were observed with the latter (Chang et al., 2007; Lupwayi et al., 2010).

Phoma macrostoma Montagne is fungus that may be used as a bioherbicide to reduce several broadleaved weeds species in turfgrass (Bailey and Falk 2011). It was registered for that purpose in Canada and the USA in 2011 and 2012, respectively. The fungus is grown on grain and then formulated as granules for broadcasting to turfgrass or soil from spring through to autumn. The fungus germinates from the granules and enters the weed roots where it colonizes intercellularly beside the vascular trachea and releases phytotoxins called macrocidins (Bailey et al., 2011b). Macrocidins cause severe chlorosis, this symptom is also known as photobleaching, and inhibits shoot and root growth in susceptible plants (Graupner et al., 2003; Bailey et al., 2011a). There is little movement of *P. macrostoma* in the soil profile and no persistence from year to year (Zhou et al., 2004).

To be a useful bioherbicide, *P. macrostoma* must be able to retain efficacy on the target weeds in conjunction with other practices used for turfgrass management. It was hypothesized that fertilizers would interfere with the efficacy of the bioherbicide such that there would be smaller reductions in dandelion populations than when the bioherbicide was applied without fertilizer. The current study examined application rates of nitrogen, phosphorus, potassium, lime, and a commercial inorganic fertilizer with or without a simultaneous application of the bioherbicide on the reduction of dandelion under greenhouse conditions. The second objective examined the effect of inorganic fertilizer treatments applied with or without the bioherbicide on the reduction of dandelion under field conditions.

2. Material and methods

2.1. Greenhouse trials

A greenhouse bioassay applied bioherbicide and fertilizers sequentially to potting media (described below with fertilizer treatments) that were seeded with dandelion (*Taraxacum officinale* Weber ex F.H. Wigg.). Potting medium was placed in square pots (10 cm × 10 cm, which was equivalent to 0.01 m^2 surface area) and then lightly packed and moistened with water. Forty dandelion seeds were sprinkled over the surface prior to sprinkling the bioherbicide and fertilizer treatments. A thin layer, approximately 3× depth of the seed, was added to each pot. Pots were placed on a greenhouse bench and watered carefully using a misting nozzle to prevent displacement of the seed. The greenhouse provided a diurnal regime comprising a 16 h photoperiod provided by artificial light from high-pressure sodium lamps (230 $\mu E/m^2 s$) and temperatures ranging from a daytime high of 20 °C to an overnight low of 15 °C. After 10 and 21 days, the total number of plants and the number of severely chlorotic plants were counted. Typically dandelion emergence peaked by 10 days and the presence of chlorosis indicated that the bioherbicide was working. At the recommended label rate for the bioherbicide, mortality in greenhouse tests approached 100% by 21 days. Therefore, after the last rating, percent dandelion reduction was calculated per pot as follows:

$$\% \text{ dandelion reduction} = [(\#\ \text{plants}_{10\ \text{days}}) - (\#\ \text{plants}_{21\ \text{days}}) / (\#\ \text{plants}_{10\ \text{days}}) \times 100$$

The bioherbicide was made from the active ingredient *P. macrostoma* strain 94-44B which was grown on grain in vented bags and then ground to flour before being formulated as a granule using a proprietary technique. Batch analysis guaranteed application of a minimum of 10^3 cfu g^{-1} and 800 macrocidin units m^{-2}. The bioherbicide was applied to the pots at 4 g m^{-2} and compared to an untreated control.

There were five fertilizers tested at three or four rates based upon recommendations from soil testing (Table 1). Urea (45-0-0), super triple phosphate (0-46-0), potassium sulfate (0-0-42), and Scotts Turf Builder Pro (32-0-4 plus 2% Fe) were tested at four rates (high, medium, low, and zero) in a loam field soil. A soil analysis prior to experimentation determined the deficiencies and nutrient recommendations. The field soil was nonsaline with a pH of 7.1 and had sufficient N, K, S, Mn, Zn, B, Fe and Cl to grow a wheat crop. It was marginal in P and Cu. For the primary nutrients, the recommendations were to add between 0 and 0.0336 kg m^{-2} N, between 0.0168 and 0.0336 kg m^{-2} P, and between 0 and 0.0168 kg m^{-2} K. Even though Cu was marginal none was added. Lime fertilizer was used to determine whether the pH of the growing medium would affect dandelion control. A professional growing mix (Sunshine Mix #3, Sun Gro Horticulture Canada Ltd., British Columbia) which was made from Canadian sphagnum peat moss and vermiculite. Sunshine Mix #3 had a pH = 5.6. Preliminary tests were conducted to determine how much lime need to be added to change the pH of the medium to pH = 6.2 and pH = 7.0, and these rates are reported in Table 1.

A split plot experimental design was used to compare rates (subplots) applied with or without the *P. macrostoma* bioherbicide (main plots) on the % dandelion reduction. The five fertilizers were independently tested in separate experiments. Each experiment had four replications and was conducted twice. Data were analyzed by analysis of variance (SAS, Version 9) with Duncan's Multiple Range Test for mean comparisons at $P = 0.05$.

2.2. Field trials

The effect of two commercial fertilizers each applied with *P. macrostoma* at two rates was tested under field conditions at three locations as a factorial experiment using a randomized blocked design with four replications. Scotts Turf Builder Pro (32-0-4 plus 2% iron) was applied at the rate of 0.0138 kg m^{-2} which delivered 4.4 g of nitrogen m^{-2} and 0.55 g of potassium m^{-2}. Scotts Lawn Pro (26-0-3, with no iron) was applied at the rate of 0.0169 kg m^{-2} which delivered 4.4 g of nitrogen m^{-2} and 0.51 g of potassium m^{-2}. These treatments were compared to a no fertilizer control.

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