Effect of Planting Depth, Planting Season, and Fungicide Treatment on Establishment of Black Cohosh in a Poorly Drained Soil

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Abstract. Black cohosh [*Actaea racemosa* L., *Cimicifuga racemosa* L. (Nutt)] is a perennial herb commonly used for treatment of menopausal symptoms in humans. The increasing demand for this plant is leading to serious over-harvesting from the wild and presents an opportunity for potentially profitable cultivation. The plant produces a large rhizome, the principal medicinal organ, which appears to be especially sensitive to heavy soil, and prone to fungal attack if soil water drainage is not adequate. After an earlier crop failure (attributed to a *Phytophthora*–*Pythium* disease complex) in an established black cohosh nursery bed, two experiments were conducted in the same soil to determine if certain horticultural approaches could help to avert fungal infection under less-than-ideal conditions. Treatments included single postplanting applications of the fungicide mefenoxam, transplantation in fall versus spring, and shallow (0.5 cm) versus deep (6.5 cm) placement of rhizomes. Shallow placement significantly improved long-term rhizome survival, but was still not able to compensate adequately for a poorly-drained soil. The horticultural approaches we studied do not appear to be reliable alternatives to proper site selection in the cultivation of black cohosh.

Black cohosh (*Actaea racemosa* L., Ranunculaceae) is an herbaceous woodland perennial and an economically important medicinal plant. It is commonly referred to as *Cimicifuga racemosa*, but molecular evidence has demonstrated that *Actaea* and *Cimicifuga* are better treated as a single genus (Compton et al., 1998). Black cohosh is the most widespread of four *Actaea* species in eastern North America, occurring in moist or dry woods from Massachusetts west to Illinois, Missouri, and Arkansas, and south to Georgia. The plant has an extensive history of Native American medicinal use for a variety of indications (Morman, 1986). Its primary contemporary use is to treat symptoms associated with menopause (e.g., McKenna et al., 2001).

Positive clinical trials, combined with public awareness of the poor risk-benefit profile of hormone replacement therapies in treating menopausal symptoms, have created considerable demand for black cohosh products in North America and Europe. The American Herbal

Products Association (2000) estimated that 500,000 kg dry weight of roots and rhizomes were harvested from 1997 through 1999. Black cohosh has not been commercially cultivated in North America except for a small number of ornamental selections, and almost all material in commerce is wild-collected. There is considerable concern that current levels of wild harvest may not be sustainable, much less potentially increased levels in the future (Lyke, 2001), and the species has been proposed for listing under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). An increase in cultivation of black cohosh will therefore be necessary to meet consumer demand.

Little has been published on methods of black cohosh cultivation, including its disease management. McCoy (2004) and Popp et al., (2002) both studied seed propagation of black cohosh and the quantification of triterpene glycosides related to its cultivation. McCoy (2004) further evaluated rhizome propagation, development, and yields within different habitats, and determined that managed shade-house-grown plants can be more productive than wild-grown plants. In a guide on the general horticulture of black cohosh, Cech (2002) suggested that only moderately good soil water drainage is required, but that black cohosh rhizomes are especially sensitive to root rot in the transplant phase.

In Fall 2001, several black cohosh cultiva-

tion experiments (not described here) were planted into the same shade house nursery bed that was later used in this study. After these earlier plantings succumbed to a root rot during their first winter, apparently facilitated by poor soil water drainage combined with above-average rainfall, we were presented with the opportunity to study whether certain horticultural approaches might be able to help black cohosh plants compensate for a poorly-drained soil. Cech (2002) suggested that shallower-than-normal placement of transplanted black cohosh rhizomes can help remediate inherent soil drainage problems. The rhizomes are traditionally transplanted in fall, but doing so forces them to lie dormant in cold soil for several months over winter before resuming growth and possibly being able to adapt to their new-found surroundings. Over-winter protective cold storage of rhizomes followed by spring transplanting was hypothesized to reduce the incidence of root rot in a poorly-drained soil. The objectives of the study, therefore, were to determine if variations in planting depth, planting season, and/or soil drench fungicide treatments of mefenoxam could improve rhizome survival under a set of unfavorable conditions that may be faced by many potential producers.

Materials and Methods

Two experiments were conducted at Shaw Nature Reserve of the Missouri Botanical Garden, located near Gray Summit in east-central Missouri (lat. 38°28'N, long. 90°48'W, alt. 183 m). A shade house, measuring 73 × 12 m and built of wooden poles and steel cabling, was divided into 12 plots of 6 × 12 m each. Black, woven, polypropylene shade cloth permitting passage of 60% of incident sunlight was installed 2.5 m over each plot during the growing seasons (15 Apr. to 15 Oct.). The soil within the shade house bed was a Hartville silt loam (fine, mixed, mesic Aquic Hapludalfs) with a 5% slope. The drainage classification of this soil is somewhat poorly drained, with ponding present up to 14% of the time (Held, 1989). The site had previously been used for a successful tree nursery and, despite this dubious soil drainage classification, we believed the site would be satisfactory for black cohosh cultivation. A laboratory analysis in 2001 revealed a fertile soil with pH 6.9, organic matter 3.9%, cation exchange capacity 13.7 meq/100 g, and adequate levels of P, K, Ca, and Mg based on recommendations for vegetable production.

In October 2001, >1,000 large, healthy black cohosh rhizomes were transplanted into the shade house soil to initiate several cultivation studies (not described here). During the ensuing winter, rainfall was well above-average (Missouri Climate Center, 2005) and the majority of these rhizomes succumbed to a *Phytophthora*–*Pythium* root rot disease complex called black root and crown rot of black cohosh (Abad et al., 2005), presumably facilitated by inadequate soil water drainage. During Summer 2002, in an attempt to remediate this poor drainage situation, and in anticipation of the present studies, we amended the soil by

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incorporating a 10-cm layer of composted leaf litter evenly across the shadehouse.

The black cohosh plant material for these experiments was acquired from Elixir Farm Botanicals, Brixey, MO, who originally obtained propagules from wild plants occurring in the surrounding Ozark forests. These materials were vouchered and confirmed to be *Actaea racemosa* L. [A. Thomas 35, 36, 37(MO)]. The rhizomes were transplanted into the study plots (or stored according to treatment) within two weeks of their harvest from the propagation beds. Hundreds of rhizomes from this same lot were also planted in separate studies elsewhere and did not become diseased, indicating that the disease was inherent at the site and did not arrive with the plant material.

Planting depth study. This study evaluated the effect of planting depth and fungicide on rhizome survival under marginal soil conditions. Four treatments were replicated twelve times across the shade house in a factorial randomized complete block statistical design. Within each block, 24 large, robust black cohosh rhizomes were sorted, randomized, and assigned to one of four randomly designated treatments—six plants per treatment for a total of 288 plants. Treatments were 1) shallow planting, 2) shallow planting with fungicide, 3) deep planting, and 4) deep planting with fungicide. The tops of the rhizomes were set just under the soil surface (0.5 cm) for shallow planting and 6.5 cm below soil surface for deep planting (normal planting depth is usually 2.5 cm). All were transplanted on 8 Oct. 2002. The fungicidal treatment was prepared by diluting 21.3% a.i. mefenoxam [Subdue Maxx (Novartis, Basel, Switzerland)] at a rate of 26.5 mL/10.0 L water. A soil drench using 0.5 L of this solution was applied to 0.1 m² of soil surface surrounding the appropriate experimental plants two days after planting.

Planting season study. This study evaluated the potential benefit of delaying transplanting until spring so that rhizomes do not lie susceptible to pathogens in cold, wet soil over winter before becoming established. As in the

first study, four treatments with six plants each were randomized within each of 12 blocks across the shade house in a factorial randomized complete block design. Treatments were 1) fall planting, 2) fall planting with fungicide, 3) spring planting, and 4) spring planting with fungicide. The 288 rhizomes were sorted, randomized, and divided into two groups. Half were assigned fall planting while the remaining half were stored loosely within a composted sawdust medium inside plastic bags in a 2 °C refrigerator for 6 months. The fall planting occurred on 8 Oct. 2002, while the spring planting of winter-stored rhizomes occurred on 2 Apr. 2003. The tops of all rhizomes were set about 2.5 cm below the soil surface. Two days after the fall planting, and eight days after the spring planting, a soil drench fungicidal treatment of mefenoxam was prepared and applied as above to the appropriate plants.

For both studies, plots were hand-weeded and irrigated as needed in summer. No fertilizers or pesticides were used, except for the noted experimental materials. Emergence and survival of plants in response to the four treatments within both experiments were documented twice during the 2003 growing season (13 May and 17 July). Ultimate survival (determined by plant emergence) was documented a year later on 17 May 2004 to ensure that temporary dormancy in response to negative environmental conditions did not skew results. Diseased rhizomes were sent to the Plant Pathogen Identification Laboratory at North Carolina State University for analysis. Statistical analyses on treatment means were conducted using the SAS GLM Procedure, orthogonal contrasts, and Fisher's LSD test (SAS Institute, Cary, N.C.). Treatment effects were considered significant at $P \leq 0.05$.

Results and Discussion

Tables 1 and 2 provide plant emergence and survival data from the two studies on three different dates over 2 years. The majority of fall-planted rhizomes in both studies

survived the initial relatively dry winter and emerged well in spring, but began to quickly succumb to black root and crown rot (Abad et al., 2005) after well-above-average rainfall in late winter and spring, 2003 (Fig. 1). The spring-planted rhizomes likewise emerged well soon after transplanting, but also quickly became diseased during the wet spring. This disease is manifested by the weakening and collapse of leaves, accompanied by the darkening, softening, and eventual disintegration of rhizome tissues. By July 2003, more than 90% of emerged plants were dead, dying, or dormant. In some cases (Tables 1 and 2), the long-term plant survival count was higher in May, 2004 than the emergence/survival count taken the previous summer, which we attribute to the tendency of black cohosh to sometimes go dormant when conditions are not ideal.

Statistical analyses revealed no significant differences ($P \leq 0.05$) in rhizome survival among any individual treatments in either of the two experiments. However, the planting depth–fungicide treatments did approach significance ($P \leq 0.067$), indicating that there may be potential for a treatment response. When using orthogonal contrasts to segregate planting depth treatments from fungicide treatments, we detected a significant ($P \leq 0.015$) difference in long-term plant survival, with the more shallowly-planted rhizomes performing better. Overall fungicide effects, planting season effects, and interactions thereof (including interactions with planting depth effects) were not detected. The blocking effect throughout both studies was significant in most cases, indicating that rhizome survival varied within different areas of the shadehouse (data not shown). These differences were likely attributable to variations in soil and soil water drainage across the large shade house area.

Because the previous black cohosh planting (not described here) succumbed during an unusually wet winter, while the plants in these studies survived a relatively dry winter in good order but then succumbed during a wet spring, adequate soil water drainage ap-

Table 1. Mean percent emergence and survival of black cohosh rhizomes in response to planting depth (shallow, deep) and fungicide treatment at Gray Summit, Mo., 2003–2004.

Date ^a	Treatment ^b				Depth effect ^c		Fungicide effect ^c	
	Shallow	Shallow	Deep	Deep	Shallow	Deep	No Fungicide	Fungicide
	No Fungicide	Fungicide	No Fungicide	Fungicide				
13 May 2003	93.1 a	97.2 a	93.1 a	95.8 a	95.2 a	94.5 a	93.1 a	96.5 a
7 July 2003	4.2 a	6.9 a	4.2 a	1.4 a	5.6 a	2.8 a	4.2 a	4.2 a
17 May 2004	8.3 a	12.5 a	2.8 a	4.2 a	10.4 a	3.5 b	5.6 a	8.4 a

^aMeans within rows having common letters are not significantly different according to Fisher's LSD test ($P \leq 0.05$).

^bMeans within rows having common letters are not significantly different according to orthogonal contrasts ($P \leq 0.05$).

^cRhizomes planted 8 Oct. 2002.

Table 2. Mean percent emergence and survival of black cohosh rhizomes in response to planting season (fall, spring) and fungicide treatment at Gray Summit, Mo., 2003–04.

Date ^a	Treatment ^b				Season effect ^c		Fungicide effect ^c	
	Fall	Fall	Spring	Spring	Fall	Spring	No Fungicide	Fungicide
	No Fungicide	Fungicide	No Fungicide	Fungicide				
13 May 2003	93.1 a	98.6 a	98.6 a	93.1 a	95.9 a	95.9 a	95.9 a	95.9 a
7 July 2003	2.8 a	4.2 a	0 a	2.8 a	3.5 a	1.4 a	1.4 a	3.5 a
17 May 2004	6.9 a	5.6 a	5.6 a	6.9 a	6.3 a	6.3 a	6.3 a	6.3 a

^aMeans within rows having common letters are not significantly different according to Fisher's LSD test ($P \leq 0.05$).

^bMeans within rows having common letters are not significantly different according to orthogonal contrasts ($P \leq 0.05$).

^cRhizomes planted 8 Oct. 2002 for fall planting; 2 Apr. 2003 for spring planting.

Fig. 1. Total monthly precipitation received during the study, compared with monthly precipitation averaged over the past 30 years. Data recorded at Union, Mo., located 18 km southwest of the study site (Missouri Climate Center, 2005).

pears to be critical to successful black cohosh cultivation. Except for the apparent benefit that may be achieved from shallower planting, we found little promise for horticultural techniques being able to circumvent problems associated with poor site selection in black cohosh cultivation. Indeed, even with the putative benefits of shallower planting revealed in this study, only 10% of those rhizomes survived into the second year. Black cohosh seems to have a predisposition to fungal infection, and neither shallow planting, spring planting, nor a single postplanting fungicide application successfully compensated for poor soil drainage in the presence of pathogenic fungi and fungi-like organisms. If a marginal soil is suspected, planting into raised beds might benefit the rhizomes, as might a fungicide program that was more aggressive than our single post-planting application. However, few, if any, fungicides are likely to be labeled for

treatment of black cohosh in the near future, and furthermore, such approaches may not be acceptable to most processors who are accustomed to purchasing wild-harvested material that has not been treated with pesticides. The potential of establishing black cohosh plantings by seed or seedlings in marginal soils rather than by fleshy disease-susceptible rhizomes might also merit examination.

Molecular and morphological characterizations of pathogenic organisms found on our diseased black cohosh rhizomes identified *Phytophthora citricola*, *P. dreschleri*, and *P. megasperma*; *Pythium dissotocum*, *P. irregulare*, *P. sylvaticum*, *P. ultimum*, *P. vexans*, and *P. chamaehiphon*; *Rhizoctonia solani*; and *Fusarium* spp. (Abad et al., 2005). This long list of potentially pathogenic fungi and fungi-like organisms associated with black cohosh further underscores the importance of site selection for successful cultivation of black cohosh.

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