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ARMILLARIA ROOT DISEASE AFFECTS OAK COPPICE REGENERATION IN UPLAND MISSOURI OZARK FORESTS

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Abstract

Coppice regeneration is favored in North America for oak (*Quercus* spp.) regeneration. Although models of oak stump sprouting do not consider Armillaria root disease, many oak stumps in upland Ozark forest stands carry active *Armillaria* root crown infections. The spatial pattern of sprouting on oak stumps is related to the circumferential distribution of *Armillaria*-infected roots. We draw attention to the proper interpretation of sprout "tree" age, re: root system age and the ages of *Armillaria* infections present. The pattern of channels left by decay of stump root systems seems well-suited to attracting roots into contact with *Armillaria* inocula.

Key words: Armillaria root disease, stump sprout regeneration, oak decline, *Quercus*

Introduction

In the eastern United States, oak forest types cover 30 million ha or 52% of all timberland (Johnson et al. 2002). Over 75% of Missouri's six million ha of forestland currently support oak-hickory or oak-pine forests (Leatherberry and Treiman 2002). Oak decline is restructuring Missouri's upland Ozark forests, due to mortality of growing stock, particularly on stressful landform positions. Because this particular oak decline syndrome has affected red oak species (*Quercus* section *Lobatae*) more severely than white oak species (*Quercus* section *Quercus*) (Johnson and Law 1989, Bruhn et al. 2000), the sapling and overstory species composition is shifting away from red oak species (Shifley and Kabrick 2002). Because Armillaria root disease is consistently associated with Ozark oak decline, declining trees are eventually killed completely, failing to sprout. Armillaria root disease appears to influence landscape-level vegetation dynamics by hastening the natural successional replacement of red oaks by white oaks in vulnerable landform positions.

In 1989, the Missouri Ozark Forest Ecosystem Project (MOFEP) was initiated to evaluate the impacts of even-aged and uneven-aged silviculture and no-harvest management on an array of ecosystem components and processes (Brookshire and Shifley 1997, Shifley and Brookshire 2000, Shifley and Kabrick 2002). Having observed *Armillaria* infections in the basal vascular cambium of recently killed oak sprouts, Bruhn (unpublished) hypothesized that the abundance and circumferential distribution of surviving oak stump sprouts corresponds with the circumferential distribution of *Armillaria* infections at the stump root crown. In 2003, we began evaluating oak stumps created by the 1996-1997 MOFEP harvest (Bruhn et al. 2002, Dey and Jensen 2002). The overall objective of this ongoing study is to assess and explain the impact of Armillaria root disease on oak coppice regeneration with respect to geographic landform position and oak decline in upland Ozark forests.

Materials and methods

Site and stump selection

MOFEP comprises nine sites in southeastern MO, ranging from 260 – 500 ha in size (Shifley and Brookshire 2000). The distributions and ecology of *Armillaria* spp. on these sites have been studied on 180 permanent 0.2 ha study plots since 1993 (Bruhn et al. 2000). Harvest disturbance (including vehicle activity, logging damage, and stump creation) was mapped and characterized on the 56 plots which experienced either even-aged thinning or uneven-aged single-tree selection treatment in the 1996-1997 MOFEP harvest (Bruhn et al. 2002). Dey and Jensen (2002) produced models of coppice regeneration based on a sample of 701 oak stumps selected from the vicinities of 70 MOFEP study plots to include all even-aged as well as uneven-aged silvicultural treatments administered in the 1996-1997 MOFEP harvest.

We are currently evaluating sprout production and survival as well as *Armillaria* activity for representative stumps documented in these studies. We will characterize enough stumps to permit us to compare performance of red and white oak species over a range of diameters growing on three landform positions (ridges and thermally exposed and thermally protected slopes). The preliminary results presented here represent the evaluations of 234 oak stumps on 25 plots since July 2003. Due to the limited sample size at present, data are combined for white and red oaks, and for the three landform positions.

Evaluation of stump sprouting and the influence of *Armillaria*

For each stump, we are recording the diameter outside bark, the species, the numbers of living and dead sprouts, and the height and diameter (5 cm above point of initiation) of the dominant sprout. The presence/absence of active *Armillaria* infections is being evaluated as follows. Each of two buttress roots which do not have living sprouts originating from them, and which are as nearly as possible on opposite sides of the stump are examined. The root surface is carefully exposed to a maximum distance of 10 cm from the stem unless the root is severely decayed and limited additional excavation may likely expose diagnosable evidence of *Armillaria* activity. *Armillaria* activity is being noted as either absent, present but not likely to persist, or active (e.g., healthy mycelial fans in the cambium or white moist decay with pseudosclerotial plates). Wherever feasible, observed *Armillaria* is being isolated into pure culture for diagnostic confirmation and species identification through pairings with identified tester strains (Korhonen 1978) and/or PCR-RFLP methods modified from Harrington and Wingfield (1995).

Data will eventually be analyzed using a combination of contingency table analysis with the χ^2 statistic (Sokal and Rohlf 1995) and logistic regression with Akaike?s information criterion (PROC LOGISTIC, SAS/STAT System Release 8.2, SAS Inst., Inc., Cary, NC, USA) including both continuous and categorical variables (e.g., Bruhn et al. 2000, 2002, Dey and Jensen 2002).

Results

Seven years after harvest, over 75% of the 190 evaluated oak stumps supporting ≤ 3 live sprouts also supported at least one active *Armillaria* root crown infection (Fig. 1). Over 40% of the 30 oak stumps with ≥ 5 living sprouts also supported at least one such infection.

The majority of stumps < 10.0 cm dia supported at least one live sprout 7 years after harvest, whereas the majorities in the larger dia classes did not (Fig. 2). Over 75% of the 50 stumps ≥ 20 cm dia supported no live sprouts 7 years after harvest and supported at least one active *Armillaria* root crown infection (Fig. 2). The majorities of stumps in each dia class which either did or did not support a live sprout 7 years after harvest also supported at least one active root crown infection (Fig. 2).

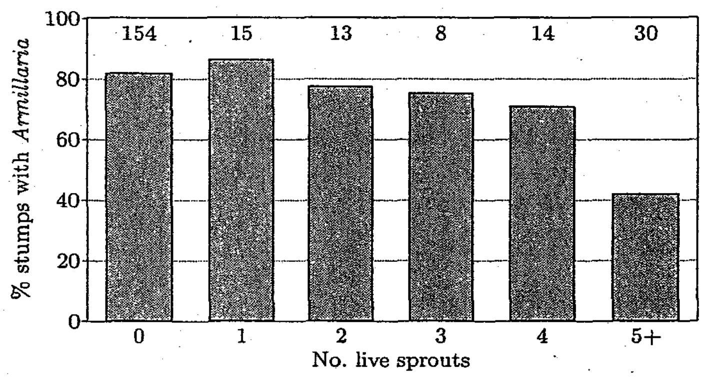

Fig. 1. Relationship between sprout abundance and presence of *Armillaria* on stump buttress roots

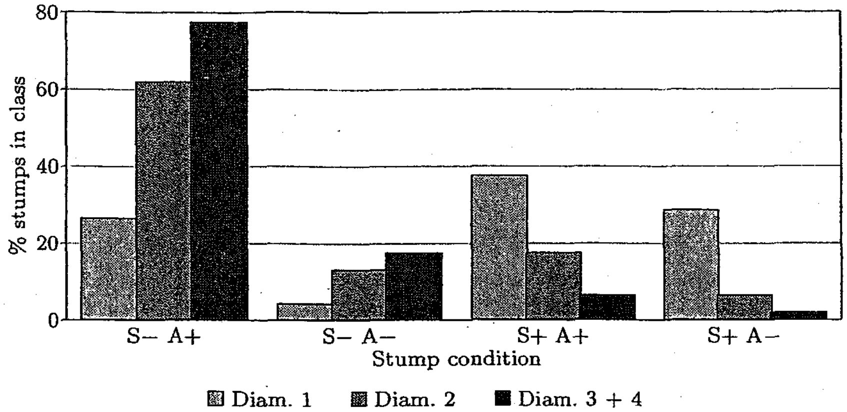

Fig. 2. Relationship between stump diameter, stump sprouting, and presence of *Armillaria*. Living sprouts present (S+) or absent (S−); persistent *Armillaria* infection detected at root crown (A+) or not (A−); stump diameter classes: < 10 cm (Diam. 1), 10.0 – 19.9 cm (Diam. 2), or ≥ 20.0 cm (Diam. 3 + 4)

Probing the courses of buttress roots from the root collars of stumps created in 1996-1997 has revealed that *Armillaria* decay of lateral roots gradually opens channels in the rocky Ozark soils, and these channels contain viable *Armillaria* inocula for some time.

Discussion

Because oak sprouts are generally faster-growing than oak seedlings, they are more likely to contribute to the future abundance of oak in regenerating stands (e.g., Dey et al. 1996, Dey and Jensen 2002). Though tree dia and age are important determinants of the sprouting capacity of oak stumps (Johnson et al. 2002), these relationships are highly variable. Stand structure also influences the long-term growth of sprouts, presumably by modifying the competitive ability of sprouts (Dey and Jensen 2002). Unfortunately, the models based on these relationships do not consider the influence of Armillaria root disease on decline-prone sites, where *Armillaria* spp. can function as pivotal opportunistic mortality agents (e.g., Shaw and Kile 1991, Manion and Lachance 1992, Bruhn and Mihail 2003). Although stumps of trees in relatively early stages of decline may sprout vigorously, they often also physically link their sprouts to a substantial legacy of *Armillaria* inoculum. Once the stump has disappeared, it is easy to fail to recognize that the living sprout stem is attached to a much older root system carrying substantial root disease inoculum.

The implications of sprout regeneration failure for stand management are clear. If stumps created in declining stands do not sprout as expected, or if the sprouts grow poorly or die prematurely, then predictions of oak regeneration may not be achieved. Poorer than expected levels of sprout production and survival could result in gap formation and/or altered overstory species composition. Models developed to predict the probability of successful sprout regeneration need to be re-evaluated in order to reflect the risk of Armillaria root disease impact on declining sites.

Evidence indicates that the MOFEP landscape overstory is shifting from red oak species toward white oak species due to silvical differences between these two species groups. This succession appears to be accelerated on vulnerable landform positions by Armillaria root disease-related forest decline. However, we observe substantial red oak seedling regeneration in expanding Armillaria root disease caused gaps. We are interested in the succession and form (seedling vs. coppice) of regenerating overstory species vegetation because of its long-term implications for successive waves of *Armillaria*-related forest decline.

In rocky Ozark soils, *Armillaria*-decayed root channels are attractive avenues for root development. These root channels seem ideally suited to attracting successive generations of plant roots into contact with active *Armillaria* inocula, providing a means for the transfer and perpetuation of extant *Armillaria* genets.

Summary

Preliminary data show that 7 years after harvest the majority of oak stumps, whether sprouting or not, supported at least one advanced *Armillaria* infection at the root crown. Over 75% of evaluated stumps supporting ≤ 3 live sprouts also supported at least one such infection, as did nearly half of the stumps with ≥ 5 living sprouts. The majority of stumps in each dia class, whether sprouting or not, supported at least one such *Armillaria* infection at the root crown. It will be important to identify the *Armillaria* spp. responsible for these infections in order to interpret their ecological role.

Sprout stem age is poorly related to root system age and *Armillaria* inoculum load. With the decay of the parent stump, the only evidence of a stem's origin may be the presence of decayed root channels. In rocky Ozark soils, *Armillaria*-decayed root channels are attractive avenues for root development. Growth of sprout or seedling roots into such channels would help ensure contact between sequential generations of roots and *Armillaria* inocula.

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