SHIITAKE MUSHROOM PRODUCTION ON SMALL DIAMETER OAK LOGS IN OHIO

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Abstract: Yields of different strains of shiitake mushrooms (*Lentinus edodes*) were evaluated when produced on small diameter oak logs in Ohio. Logs averaging between 3-4 inches in diameter were inoculated with four spawn strains in 1985. After 3-1/2 years, strain *S-1* produced a total of 432 lbs. of fresh shiitake per cord when log management included forced fruiting by soaking in water for 24 hours. Additional strain and fresh lbs. per cord results were *FWF*, 291 lbs.; *82A*, 120 lbs.; and *RA 3-2-E*, 39 lbs. For all spawn strains, forced fruiting increased shiitake mushroom yield when compared to a control. Foresters need to be aware of the dependency of shiitake mushroom yields on spawn strain and management practices when making recommendations to landowners on the utilization of small diameter oak logs. Foresters also can use shiitake mushroom production as another tool in stimulating private non-industrial forestland management.

INTRODUCTION

Foresters working in the hardwood regions of the U.S. are continually searching for methods to increase management on non-industrial private forestland. An accompanying goal, which often is a pre-requisite to management, is increased utilization of low quality tree species. Leatham (1982) presented documentation on how shiitake mushrooms (*Lentinus edodes* [Berk.] Sing.) could be grown on underutilized wood harvested from low-grade hardwood trees, particularly oak. With a 1988-89 wholesale price of $4.70 per lb. (USDA 1989), it is not surprising that foresters are eager to learn if shiitake mushroom production can be used as a tool to stimulate forest management.

Shiitake mushrooms can be cultivated on either intact hardwood logs or wood particles (Royse, Schisler and Diehle 1985). Relatively little scientific information has been published in the U.S. on cultivating shiitake mushrooms on logs (Leatham 1982, San Antonio 1981, San Antonio and Hanners 1983). Published information is also scanty on the potential yields and economic returns from shiitake cultivation on logs (Anon. 1989, Baughman 1989, Haney 1989, San Antonio 1981).

This paper compares shiitake mushroom production on mixed oak logs using a combination of different mushroom strains and management practices (soaking versus non-soaking of logs). Results are useful for making recommendations to foresters and forestland owners.

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MATERIALS AND METHODS

Spawn Selection

During January 1985, four spawn strains from three commercial U.S. spawn suppliers were purchased. The specific strains obtained were: *S-1* from Elix Corporation, Arvonia, VA, *82A* and *RA 3-2-E* from Mushroompeople, Inverness, CA, and *V3A*, *V3B*, *R56B*, and *R569* from Far West Fungi, South San Francisco, CA. Since it was not known that four, rather than one strain from Far West Fungi would be received, the four strains (after being mixed uniformly) were grouped together for testing purposes and named "FWF" strain. Therefore, the experiment was designed to test differences between the following strains: *S-1*, *82A*, *RA 3-2-E* and *FWF*. Strains *S-1* and *RA 3-2-E* were on a sawdust medium and *82A* and *FWF* were on wood dowels. All spawn was refrigerated until inoculation.

Obtaining the Logs

Two and one-half cords of wood, which came from tree tops and branches of harvested sawlogs and pulpwood, was cut in late February 1985. The unsplit logs consisted of 50 percent oak (*Quercus* spp.) and 50 percent American beech (*Fagus grandifolia*). Log diameters ranged from two to eight inches with lengths up to 12 feet. The average log diameter was slightly over three inches.

The harvested logs were taken to the Elizabeth L. Evans Outdoor Education Center in Jackson county, Ohio, site of the experiment. In early March 1985, logs were cut into four foot lengths and stacked firewood style until inoculation. A total of 801 logs, 386 oak and 415 beech, comprised the two and one-half cord sample. Spawn strain and management practice were randomly assigned to the logs. An aluminum tag was stapled on the ends of each log for coding purposes.

Inoculation Procedure

Approximately 90 percent of the logs were inoculated between March 25 and April 4, 1985. The remainder of the logs were inoculated May 3, 1985. The number of inoculation sites per four foot log was determined by log diameter with the log diameter in inches translating to the number of rows drilled in the log lengthwise. For example, a log with a diameter of four inches had four lengthwise rows of inoculation sites. Inoculation sites were spaced six inches apart within rows with each inoculation site offset three inches from the neighboring row. Regardless of the number of rows per log, rows of inoculation sites were spaced approximately three inches apart.

The wood dowel inoculation sites were drilled 5/16 inch in diameter and to a depth of approximately 3/4 inch. After drilling, the logs were moved to a work table where the dowels were tapped into the holes with a hammer. The inoculation sites were then painted with a hot, melted cheese wax.

Inoculation sites for the sawdust spawn were drilled 12mm (approximately 1/2 inch) in diameter and 3/4 inch deep. A sawdust spawn inoculation gun was used with the *S-1* spawn. The consistency of the *RA 3-2-E* spawn required the spawn to be placed by hand into the inoculation holes. Fifty percent of the sawdust spawn inoculation sites (*S-1* and *RA 3-2-E*) were randomly treated with melted cheese wax. The remaining fifty percent had a styrofoam plug placed into the hole on top of the sawdust.

Log Stacking

Following inoculation, all logs were restacked firewood style and covered with black plastic for one week and then with burlap. This log stacking pattern, known as a temporary laying position, was selected to conserve log moisture. The site for the temporary laying was the same site used for all other phases of the experiment (inoculation, permanent laying, soaking and raising). The location is a bottomland near the mouth of a large hollow or ravine. Air movement is good and the site is densely shaded by a stand of mature sugar maple. A small stream flows past the site.

In late May 1985, surface molds (*Trichoderma* spp. and *Daldinia concentrica*) appeared on the logs so the burlap was removed. One week following burlap removal, the logs were restacked into a cross-hatch or crib pattern. (Example: the first row of five to six logs were placed in a north-south direction, the second row in an east-west direction, etc., with the height of the stack approximately four feet). This stacking arrangement permitted better air movement around the logs in an attempt to control the surface molds. The cross hatch pattern was the chosen permanent laying position. The logs were restacked in late June 1985 in a more widely spaced cross-hatch of three to four logs per row in a successful effort to eliminate the surface molds.

The logs remained in the permanent laying cross-hatch pattern until October 1985 when mushrooms started to appear on a few oak logs. At this time, all oak logs were raised by leaning them against the fence which encircled the experiment. The beech remained in the cross-hatch pattern.

Log Irrigation and Soaking

During the summer of 1985, all logs were irrigated twice with a garden sprinkler. Since the effect of the irrigation was judged to be beneficial only to the surface molds, irrigation was

discontinued for the remainder of the experiment. During October and November 1985, 12.5 inches of rainfall (an unusually high amount) were recorded at the experimental site.

During 1986 and 1987 logs randomly selected for soaking were completely immersed in water for 24 hours. A total of four soakings were administered. All logs in the experiment were managed according to recommended shiitake management practices depending on whether or not they had been soaked. For example, soaked logs were placed in the upright fruiting position (leaned against a fence) immediately following a water soak while non-soaked logs remained in the cross-hatch pattern until fruiting occurred at which time they were placed in the upright fruiting postion.

RESULTS

Beech Logs

The beech logs in 1985 yielded one lb. of fresh shiitake per cord for both the *S-1* and *FWF* strains; there was no fruiting on the *82A* or *RA 3-2-E* logs. The beech logs were eliminated from the experiment during 1986 due to poor fruiting, low log moisture content, and splitting/sloughing bark.

Oak Logs

During the fall of 1985, which was prior to the water soaking treament initiated in 1986, the combination of logs designated for soaking and control yielded the following average fresh shiitake per cord: *S-1* strain, 38 lbs.; *FWF* strain, eight lbs. There was no activity on the *82A* or *RA 3-2-E* inoculated oak logs in 1985.

During 1986-88 mushrooms were produced during the period from April/May to November/December. Table 1 presents fresh shiitake yield in lbs. per cord for all four strains from 1986 through 1988.

The more prolific strains, *S-1* and *FWF* (as measured by total fresh lbs. per cord), had peaks in yield the first full year of production (1986) while strains *RA 3-2-E* and *82A* peaked during the last year of data collection (1988). All spawn strains showed mushroom yields to be greatest for the three-year period when log soaking was utilized as a management practice.

It is interesting to consider seasonal fruiting/harvest trends in addition to annual yields. For example, 78 percent of the 1987 *82A* yield occurred **after** October 14 while 98 percent of the 1987 *S-1* yield occurred **before** October 14 (on soaked logs). Even though the '87 *S-1* yield was nearly double the *82A* yield (79 to 40 lbs. per cord), the combinaton of the two strains would have extended the marketing season for a commercial grower.

Table 1.--Per cord 1986-88 shiitake yield on 1985 inoculated oak logs.*

Spawn Strain**	Treatment***	1986	1987	1988	Total
		---------- Fresh lbs./Cord**** ----------			
RA 3-2-E	Soak	0	13	26	39
RA 3-2-E	No Soak	0	7	3	10
S-1	Soak	350	79	3	432
S-1	No Soak	287	63	50	400
FWF	Soak	172	104	17	291
FWF	No Soak	149	43	13	205
82A	Soak	7	40	73	120
82A	No Soak	0	7	20	27

*Logs were inoculated at a spacing of approximately 6" by 3".
**RA 3-2-E and S-1 were on a sawdust medium. FWF and 82A were dowels.
***Logs soaked for 24 hrs. twice in 1986 (March/Sept.) and twice in 1987 (May/August).
****Approximately 330 logs/cord. Average log diameter slightly over 3".

Logs that were water soaked not only received additional moisture as compared to the control or non-soaked logs, but the soaking served as a forced fruiting with the peak growth flush occurring approximately seven days following soaking. The non-soaked logs were more dependent on weather conditions with growth flushes occurring in close proximity to natural precipitation.

Table 2 presents the same data as in Table 1 except Table 2 data is on a **per log** basis. The data for Table 2 was compiled for all logs originally inoculated in 1985 and thus represents mean production per log; mean production figures include individual logs which were poor, as well as good, producers.

DISCUSSION

Foresters recognize that landowners are often hesitant to invest in forest management activities when economic returns are in the distant future; timber stand improvement and non-commercial thinnings are two examples. However, if the management practice generates small diameter oak logs, then shiitake production is a potential source of short-term cash flow

Table 2.--Per log 1986-88 shiitake yield on 1985 inoculated oak logs.

Spawn Strain	Treatment	1986	1987	1988	Total
		---------- Fresh lbs./Log* ----------			
RA 3-2-E	Soak	0.00	0.04	0.08	0.12
RA 3-2-E	No Soak	0.00	0.02	0.01	0.03
S-1	Soak	1.06	0.24	0.01	1.31
S-1	No Soak	0.87	0.19	0.15	1.21
FWF	Soak	0.52	0.31	0.05	0.88
FWF	No Soak	0.45	0.13	0.04	0.62
82A	Soak	0.02	0.12	0.22	0.36
82A	No Soak	0.00	0.02	0.06	0.08

*Inoculated logs averaged slightly over 3" in diameter. All other footnotes from Table 1 apply to Table 2.

for the landowner. Foresters should be prepared to present this option to landowners since in certain instances it might be just the incentive needed to stimulate forest management.

Readers should be aware that the results reported in this paper are from an initial testing program. Since 1985 when this study was initiated, improved management practices and more desirable spawn strains have been identified. Experience gained in management technique is critical for optimal success. However, foresters who communicate with landowners about shiitake mushroom cultivation can use the methods and results of this study as general guidelines to move individuals through the process.

It is important to recognize that the optimum combination of host tree species, spawn strain and log management can be specific to a geographical area. For example, Haney (1989), using spawn from a local supplier found sycamore (*Platanus occidentalis*) to outperform other tree species in western North Carolina. The Forest Resource Center in Minnesota recently reported shiitake yields on force-fruited ironwood (*Ostrya virginiana*) to be nearly double red oak, the best species previously identified in the region (Anon. 1989). Based on the North Carolina and Minnesota research as well as the Ohio research presented in this paper, forest landowners interested in shiitake cultivation should be encouraged to experiment on a small-scale. Unfortunately, some individuals have jumped into large-scale shiitake production without understanding that tree species, spawn strain, log management and geographical area have an impact on mushroom production.

Management practices, such as force fruiting the logs by soaking, was shown in this study to increase the rate and amount of mushroom yields and is a management option that foresters can pass on to landowners. Although this article did not focus on economics, landowners need to be encouraged to analyze the economic impact of all management decisions. Landowners without available labor or a nearby source of water may choose not to soak their logs, thus decreasing mushroom yields but perhaps increasing net profit in their particular situation.

Finally, the concept of shiitake mushroom production goes beyond the idea of raising a gourmet mushroom on hardwood logs. Too often landowners and foresters think only in terms of traditional forest products such as pulpwood and sawtimber and overlook opportunities for economic returns from wildlife, recreation and food (Haney, 1989). Shiitake mushrooms could stimulate both foresters and landowners to broadened their vision of possibilities that can enhance both profits and forest management opportunities.

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