Advances in Science and Technology, Vol. 13, No 1&2, September / October 2019, pp 15 - 21

Enhancing Year-Round Outdoor Mushroom Production and Utilization

Worlanyo Segbefia and Patrick Igbokwe
Department of Agriculture, Alcorn State University, Alcorn State, Mississippi 39096, USA
(Submitted: July 14, 2019; Accepted: September 23, 2019)

Abstract

Field experiments conducted in Claiborne and Jefferson counties were used to determine the effect of year-round row-intercropping on shiitake (Lentinula edodes) and oyster (Pleurotus ostreatus) mushroom growth, yield potential, soil and water quality, product development and consumer acceptance. Both outdoor and indoor-grown shitake mushroom growth and yield potentials were also compared. Findings indicate that the ready to fruit shiitake and oyster mushroom blocks introduced outdoors were unproductive during the first growing season until adequate overhead sprinkler irrigation and partial shading from companion vegetables and herbs were provided during the rest of the growing seasons. Both productivity and profitability were greater for Shiitake mushroom compared to Oyster mushrooms. The average marketable mushrooms from each block for the three-year study periods were significantly higher (17.59 lbs) for shiitake mushrooms compared to 12.56 lbs reported for oyster mushrooms. However, both mushrooms can be grown year-round outdoors in Southwest Mississippi if proper strain(s) for each growing season are introduced into field plots and growth factors are not limiting. Consumer acceptable recipes can be developed with freshly harvested field-grown shiitake mushrooms.

Keywords: Shiitake and Oyster Mushrooms, Year-Round Intercropping, Yield Potential, Water Quality, Recipe Development, Macronutrients, Economics of Production.

1.0 Introduction

Over the centuries, man has selected, arranged and managed mixtures of plant species in many ways to achieve sustainable yields of food and other products in a companion planting.

In Mississippi, vegetable crops have traditionally been produced on small acreages in a single growing season and in a mono-cropping system. This tradition leads to inefficient utilization of farm resources, inadequate year-round food supply, lack of employment opportunities and high level of poverty, among others. Poverty and health status are interrelated, and their effects on each other are often bidirectional. This relationship could account for the serious cases of obesity, Type 2 diabetes, cancer and heart diseases among Mississippians (Wakefield et al., 2007).

For decades, public health professionals have emphasized the importance of fruit and vegetable consumptions in human health. In fact, low fruit and vegetable intakes, including intake of such special crops as mushrooms are among the top ten risk factors related to mortality in humans (Cyzman et al., 2009. Today, interest in mushroom research is health related in most parts. Chen et al., (1993) found several mushrooms with high concentrations of aromatase, which interrupts the conversion of androgens to estrogens, significant for postmenopausal women at risk of breast cancer. Community mushroom gardens, like any other fruit or vegetable garden can increase access to fresh mushrooms thereby providing numerous health benefits, including improved nutrition, decreased childhood and adult obesity, diabetes, and heart diseases (Wakefield et al., 2007). The oyster mushroom, Pleurotus ostreatus, is characterized by its rapid growth on agro-wastes such as sawdust (Ajonima and Tatah, 2012). It is one of the best fungal organisms for producing food rich in protein, using agro-wastes. The shiitake mushroom has several health benefits that include protection against cancer, diabetes, blood pressure and microbial activities (Wasser, 2005). Studies have indicated that it contains a cholesterol-lowering compound known as eritadenine (Enman and Rova, 2007) and possesses anti-bacterial properties (Hirasawa et al., 1999). In an indoor study, shiitake mushroom blocks with crop/soybean pellets had significantly higher marketable yields, compared to those with either cotton pellets or peanut pellets (King, 2013). With regard to corn/soybean pellets, the high protein content provided by these pellets is a good sources of nitrogen that effectively reduce the levels of carbon in the substrate (Zied and Pardo, 2011). Although, series of studies on outdoor mushroom production on logs have been documented, similar studies on mushroom blocks are limited.

2.0 Purpose and Objectives

Field experiments conducted in Claiborne and Jefferson counties in Southwest Mississippi were used to determine the effect of year-round row-intercropping mushrooms with their vegetable and herb companions on mushrooms growth, yield potential and quality, soil fertility, water quality, economics of production and recipe development. The specific objectives of this study are: i. To determine the effect of multiple-cropping on mushroom yield potential and quality. ii. To determine the impact of inter-cropping vegetables/herbs and mushrooms on soil fertility and farm runoffs. iii. To enhance mushroom consumptions by rural communities and food outlets in Mississippi. iv. To determine the economic benefits of year-round inter-cropping mushrooms with their vegetable and herb companions.

3.0 Materials and Methods

3.1 Plan of Operations

A tractor was used for disking and bed preparations for all cropping systems during each growing season. The planting sites had at least 2 hours of light exposure daily. Each bed was 6.1m long x 1.2m wide x 0.15m high, and replicated 4 times in a Randomized Complete Block (RCB) experiment design. Extraneous debris was removed to avoid competition for nutrients with native fungi. Bed solarization before the initial planting period served as additional protection against weeds and soil pathogens. Sawdust was spread over each bed to a depth of at least 5.08 cm to 7.62 cm. A thin layer of cool season grass seeds (Tall Fescue) was sprinkled over each bed in the spring and fall planting seasons, whereas warm season grass seeds (carpet grass) were sprinkled over each bed in the summer planting season. The idea was to stimulate mycelia growth by providing nutrients and additional shade to mushroom blocks. The rate of grass seed applications was about 10 to 20% less than recommended usage for a healthy lawn. The beds were allowed to rest to permit for mychorizal colonization. After colonization, watering was initiated, using watering hose and watering can during the first planting season. Overhead sprinkler irrigation was later used to provide one hour or more of water in the morning and early evening during the second and third planting seasons.

3.2 Planting Sequence

During each growing season, both the companion vegetables (sweet corn, hot pepper, collard greens) and companion herbs (feverfew, sweet basil or valerian) seedlings raised in the greenhouse were planted immediately after each bed preparation. Selected mushroom strains for each growing season were introduced into the field plots three weeks later. During each spring planting season (March 10-15), spring oyster, (Pleurotus ostreatus) (test crop) was introduced into the field alone (mono-cropping) and intercropped with sweet corn and feverfew (companion crops). In the summer (June 10-15), warm temperature tolerant strain of shiitake mushroom (Lentinula edodes) was introduced into the field alone (mono-cropping) and intercropped with hot pepper and sweet basil (companion crops). In the fall (September 25-30), cool weather strain of shiitake mushroom, was again introduced into the field alone and intercropped with collard green and valerian (companion crops), except for fall 2017. Shiitake blocks with corn/soybean pellets for indoor study were similar in nutrient compositions to those for field study. However, the indoor study was limited to summer 2017 planting season. The mushroom blocks for the indoor study were arranged on a row of metal rack 4.6 m long. They were assigned to different spots on the rack at a between block spacing of 38.1 cm. The recommended changes in length of days for temperature and humidity supplies at the "grow room" were maintained throughout the study period. Data collections were as for the outdoor-grown mushrooms.

3.3 Other Activities

Soil fertility levels were a measure of extractable soil macronutrient levels, soil organic matter and acidity before and after the third year of study. The cations were determined by the atomic absorption spectrometry, organic matter by wet and dry combustion techniques, and acidity by barium chloride-tricthanolamine method. Mushroom yield potential was a measure of marketable mushroom harvests from both shiitake and oyster mushrooms using table-top scale for their weight determinations. Mushroom nutrient composition is determined by the macronutrient contents for field-grown shiitake and oyster mushrooms. The environmental impact of the study was also based on the macronutrient levels for the indoor and outdoor-grown shiitake mushroom. Water quality determination was based on the levels of nitrate-nitrogen, nitrite-nitrogen and phosphates in the runoffs from the study plots. Runoffs from the study plots after three major rainfalls were subjected to chemical analysis at the State Soil Testing Laboratory at Mississippi State University.

The 9-point Hedonic scale was used to determine the extent to which the four mushroom recipes developed were acceptable to the evaluators. A score of 1% represents a product that is extremely unacceptable, whereas a score of 100% represents a product that is extremely acceptable by the evaluators. Each of the 20 evaluators for the organoleptic evaluation represents an experiment unit, whereas each set of 5 evaluators represents a treatment. Each of the 4 treatments were assigned to different laboratory benches in a Completely Randomized Design (CRD) Experiment. Data on their levels of each product acceptance were analyzed by the analysis of variance (ANOVA) and means separated the Least significant difference (LSD) test (Steele and Torrie, 1980). The projected percent incomes from harvested marketable mushrooms were based on their average sale prices at five major supermarkets around the study locations. Data collections were from each block within each growing season. The marketable yields for the growing seasons were also analyzed by the analysis of variance (ANOVA) and means separated by the paired-comparison t-test.

4.0 Results and Discussion

4.1 Soil Extractable Nutrients

The soil extractable nutrient levels from Claiborne and Jefferson counties are reported in Table 1. Soil extractable nutrient level from Claiborne County study location was significant for phosphorus (P) and sulfur (S), highly significant for potassium (K), calcium (Ca) and magnesium (Mg); nonsignificant for organic matter (OM) and soil acidity (PH).

The soil P level was higher before the study whereas other nutrients were higher after the study. In Jefferson County, the soil nutrient levels were significant for P and S, highly significant for K, Ca and Mg, and nonsignificant for OM and PH. The nutrients were higher after the study, compared to their levels before the study.

The generally higher levels of nutrient after the study could be due to the incorporation of organic materials during bed preparation and maintenance. Apart from the fertilizer 13N – 13P – 13K applied to support the growth of companion crops, plant decomposition and incorporation into the soil during each bed

Table 1: Soil Extractable nutrient levels[X]

Sampling Period	P (LB/A)	K (LB/A)	Ca (LB/A)	Mg (LB/A)	S (LB/A)	Orga Mat (%
CLAIBORNE COUNTY						
Before Planting	129.8	220.3	4,998.0	962.5	155.0	
After Planting	102.0	245.0	5,080.5	1080.5	200.0	
Significance[Y]	*	**	**	**	*	
JEFFERSON COUNTY						
Before Planting	71.3	293.0	2,029.0	765.3	224.5	
After Planting	82.3	521.0	4,041.3	1,154.0	386.3	
Significance[Y]	*	**	**	**	*	

[X]Values represent the soil fertility levels before and after planting seasons in Claiborne and Jefferson Counties in Southwest Mississippi.[Y]NS = non-significant; * = significant; ** = highly significant according to paired samples, t – test.

preparation could also result in their increase in the soil after the last harvest.

4.2 Yield Potential

The sequence of yield potentials is reported in Table 2. No results were reported for fall 2015, spring 2016 and summer 2016 due to inadequate moisture application, until summer 2016, when irrigation system was installed at the research plots. The effort to supply water by hand-held watering hose in the morning and in the evening did not prevent the blocks and/or mycelia from drying out between watering, indicating that adequate water is critical in growing mushroom outdoors. Since there was no planting in the fall of 2015 and spring of 2016, data on available pins and yields for the periods were not reported.

During the summer 2016 planting season, the average numbers of pins on each block used were 15.00 and 25.00 for shiitake and oyster mushrooms, respectively. Limited harvests were made from the oyster blocks (12.50 lb.), but non from shiitake block during the fall 2016 harvest. Although a good number of pins were observed on shiitake blocks, they were unable to develop into marketable mushrooms. This could be due to inadequate protective shade from the vegetable and herb companions during the growing season.

During the fall 2016 planting season, the average numbers of pins on each block were 56.67 and 5.33 for shiitake and oyster mushrooms, respectively.

Limited marketable yields were obtained because they were either too soft to handle or completely rotten due to the continuous rainy days that made timely harvest impossible.

Harvest was therefore limited to 0.59 and 1.09 lbs. for shiitake and oyster mushrooms, respectively during the spring harvest season.

For the spring 2017 planting season, the average numbers of pins were 25.83 and 9.83 for shiitake and oyster mushrooms, respectively. Their corresponding yields during the summer 2017 harvesting season were 26.00 and 12.33 lbs.

For the summer 2017 planting season, the average numbers of pins per block were 80.55 and 37.20 for shiitake and oyster blocks, respectively. Their corresponding yields during the fall 2017 harvesting season were 43.75 and 24.33 lbs.

In general, available pins per shiitake mushroom block were highest (80.55) during the summer of 2017 planting season and lowest (15.00) during the summer of 2016. Similarly, the pins per oyster mushroom block were highest (37.20) during the summer of 2017 and lowest (5.33) during the fall of 2016. On the average, available pins were highest (44.51) for the shiitake mushroom compared to the 19.30 reported for the oyster mushroom. Data suggest that mushroom marketable yields are dependent on the number of pins per block at planting time if factors of production are not limiting. Greater marketable yields reported in this study for mushrooms initiated during the summer growing season also suggest that the summer growing conditions will favor more shiitake mushroom

Table 2: Sequence of Field Operations

Sampling Season	Available Pins / block Shiitake	Available Pins / block Oyster	Harvesting Season	Mushroom Yield (lbs)^X Shiitake	Mushroom Yield (lbs)^X Oyster
Summer 2016	15.00 C	25.00 B	**Fall** 2016	0.0 C	12.50B^Z
Fall 2016	56.67 B	5.33 C	**Spring** 2017	0.59 C	1.09 C
Spring 2017	25.83 C	9.88 C	**Summer** 2017	26.00 B	12.33 B
Summer 2017	80.55 A	37.20 A	**Fall** 2017	43.75 A	24.33 A
Average	44.51	19.30		17.59	12.56

X = values represent average marketable mushrooms from each block for fall 2016, spring, summer and fall 2017. Y = values represent average number of pins from each block before planting season. ^{Z}values with the same letter are not different at P<0.05 according to paired-sample t-test.

productions compared to oyster mushroom production, but both will be greater than their respective yields from the spring and fall planting seasons in Southwest Mississippi.

4.3 Mushroom Nutrient Compositions

The effect of the agronomic practices on mushroom macronutrient compositions is reported in Figure 1. The percent nitrogen, phosphorous and potassium compositions were highly significant for shiitake compared to their contents in oyster mushroom. The percent calcium, magnesium and sulfur were not different according to t-test statistical procedures. It is also nonsignificantly greater in calcium and sulfur. In general, data suggest that shiitake mushroom is a greater source of essential nutrients needed in human nutrition compared to oyster mushroom. Shiitake mushroom was significantly higher for nitrogen (6.9%), phosphorus (2.25%) and potassium (3.10%) compared to their respective values of 2.4%, 0.73% and 1.29% reported for the oyster mushroom. The nonsignificantly greater values for calcium (0.09%) and sulfur (0.32%) were for shiitake mushroom, whereas the nonsignificantly greater value for magnesium (0.23%) was for oyster mushroom, lower value (0.22%) was for shiitake mushroom. These could be due to the variations in nutrients used in the block preparations and the ease at which each block released available nutrients to the growing mushrooms.

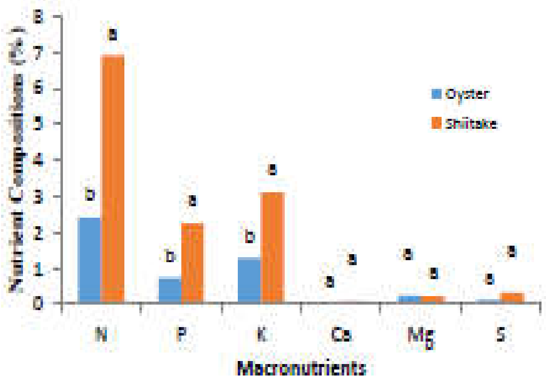

Figure 1: Mushroom Macronutrient Compositions

In Figure 1, bars represent percent macronutrient compositions for Shiitake and Oyster mushrooms. Bars with the same letter within each nutrient are not different at $P<0.05$ according to paired-sample t-test.

4.4 Environmental Impact

The effect of growing environment on mushroom macronutrient compositions is reported in Figure 2. Shiitake mushroom grown outdoors (field environment) had significantly greater percent nitrogen (6.9%), potassium (3.10%) and phosphorus (2.25%). Calcium, magnesium and sulfur contents were not different. Data suggest that shiitake mushroom grown in field environment will contribute more macronutrients in human nutrition than those grown indoors.

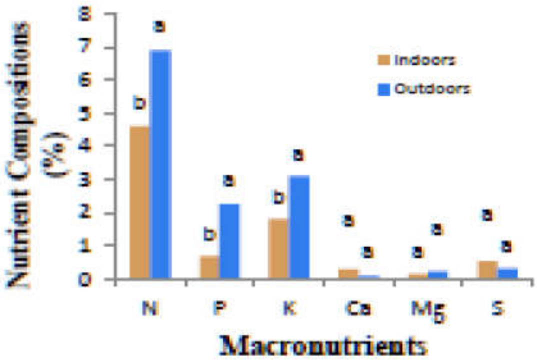

Figure 2: Macronutrient Compositions for Indoor and Outdoor-grown Shiitake Mushrooms^{X}

In Figure 2, bars represent the macronutrient compositions for shiitake mushroom grown on blocks indoors and those harvested from blocks in field plots. Bars with the same letter within each nutrient are not different at $P<0.05$ according to paired-sample t-test.

4.5 Water Quality

The effect of agronomic practices on water quality is reported in Table 3. Total phosphorous (P_2O_5) in the runoff was significantly higher (2.84ppm) for Claiborne County compared to (1.94ppm) reported for Jefferson County. These are considered high when compared to the (0.025ppm) level established by the Environmental Protection Agency (EPA) of United States Department of Agriculture (USDA). Both nitrate (NO_3-N) and nitrite (NO_2-N) were not different for Claiborne and Jefferson Counties. They were less than 10.00ppm set as enforceable regulation for maximum contaminant level (MCL) by EPA, (https:// world. epa. gov/aboutepa). Data suggest that when soil residual phosphates and nitrates are within normal range at the initiation of the field cultivation of both shiitake and oyster mushrooms, their levels in runoffs may not be

Table 3: Water Quality Determination[X]

Source (Counties)	Contaminant in Runoffs (PPM) [Y]			
	Phosphorous (P_2O_5)	Nitrate (NO_3 - N)	Nitrite (NO_2- N)	Nitrate + Nitrate
Claiborne	2.84	<0.100	<0.100	<0.100
Jefferson	1.94	<0.100	<0.130	<0.100
Significance	*	NS	NS	NS

[X] values are averages for contaminants from 3 separate runoff sampling periods.
[Y] NS = Nonsignificant; * = significant, at P<0.05 according to paired samples t-test.

significant. With judicious fertilization to support the growth and developments of companion crops, in addition to the application of uncontaminated sawdust during bed preparations, outdoor mushroom block cultivation may not lead to soil and water pollutions.

4.6 Mushroom Recipe Development

The data on the consumer evaluation of developed mushroom recipe is reported in Figure 3. For recipe appearance, the highest value (86.7%) for the sample liked extremely (LE) by the evaluators was reported for the Shiitake Mushrooms Herbal Patties (SBP), and lowest value (40.0%) was for the Layered Mushroom and Spinach Casserole (MSC). For recipe texture, the highest value (73.3%) was reported for the Stuffed Baked Potato with Mushroom Topping (PMT), and lowest (40.0%) was reported for the Parmesan Mushroom Rice (PMR), Layered Mushroom and Spinach Casserole, (MSC), and Shiitake Mushroom Herbal Patties (SBP). For recipe flavor, the highest value (80.0%) was reported for the Parmesan Mushroom Rice (PMR), whereas the lowest value (53.3%) was for Layered Mushroom and Spinach Casserole (MSC). The above scores indicate that the evaluators liked extremely Shiitake Mushrooms Herbal Patties (SBP) for its appearance; Stuffed Baked Potato with Mushroom Topping (PMT) for its texture; and Parmesan Mushroom Rice (PMR) for its flavor. Findings suggest that these three recipes will be acceptable to consumers more than Layered Mushroom and Spinach Casserole (MSC) which had least ratings for the recipe appearance, texture, and flavor.

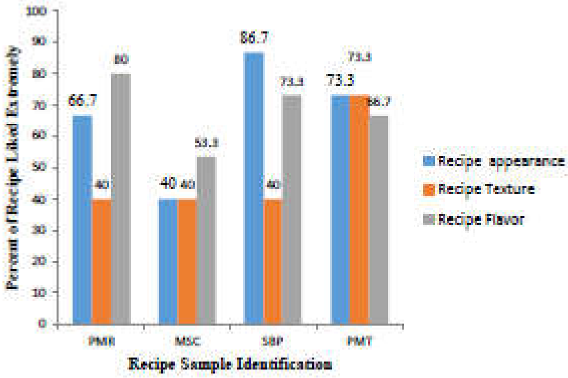

Figure 3: Consumer Evaluation of Mushroom Recipe[Y] (Recipe samples where: PMR= Parmesan Mushroom Rice, MSC = Layered Mushroom and Spinach Casserole, SBP =Shiitake Mushroom Herbal Patties and PMT = Stuffed Baked Potato with Mushroom Topping).

5.0 Conclusion

Findings suggest that outdoor mushroom production may not be successful and/or profitable without adequate overhead moisture supply and partial shading from direct afternoon sunlight and heat in Southwest Mississippi. Both shiitake (Lentinula edodes) and oyster (Pluerotus ostreatus) mushrooms can be successfully produced in a multiple cropping system outdoors if proper vegetable and/or herb companions are incorporated in the cropping system and production factors are not limiting.

Field-grown shiitake mushrooms will contain more macronutrients than similar types grown indoors. The level of environmental pollution from phosphates and/ or nitrates due to outdoor production of shiitake and oyster mushrooms in Southwest Mississippi will depend on the residual fertilizer levels in the soil before the initiation of the study, their levels in the blocks used and amount of fertilizer applied to support the growth of the companion crops.

In general, shiitake and oyster mushrooms grown year-round on blocks, in home vegetable garden in Southwest Mississippi will produce marketable yields that could enhance the income and nutrient intake of the growers. Although both shiitake and oyster mushrooms evaluated can be grown outdoors in Southwest Mississippi, shiitake production may be more profitable than oyster production.

Acknowledgments
The authors wish to thank USDA (NIFA) for funding this project. Special appreciations are extended to Alcorn Administration for supporting research in Agricultural Science. In addition, we wish to extend special gratitude to Dr. Victor Njiti, Dr. Leonard Kibet, Dr. Franklin Chukwuma, Mr. Richardson Boateng, Mr. Allen Ellis, Ms. Monique Brown, student-workers at Alcorn State University Experiment Station for their assistance and Mrs. Juliet Huam for assisting with product development.

References

Ajonina, A.S, and L.E.Tatah. 2012. Growth performance and yield of oyster mushroom (Pleurotus Ostreatus) on different substrates compositions in Buea Southwest Cameroon. Science Journal of Biochemistry, V. 2012, P 1-6, 2012.D01:10.7237/sjbchl/139.

Chen, S, D. Zhou, K. M. Swidereck, N. Kadohima, Y. Osawa, and P.F Hall. 1993. Structure function studies of human aromatase. J. Steriod Biochem, Mol. boil. 44:347-356.

Cyzman, D., J. Wierenga and J. Sielawa. 2009. Pioneering healthier communities, West Michigan: A community Response to the Environment. Health Promotion Practice 10:1465-1555.

Enman, J. and B. Rova. 2007. Quantification of the bioactive compound eritadenine in selected strains of shiitake mushroom (Lentinus edodes). Journal of agricultural and food chemistry 55(4):1177

King, D. 2013. Indoor production of shiitake mushrooms in Southwest Mississippi. Thesis Research, Alcorn State University, Alcorn State MS 39096.

Hirasawa, M., N.Shouji, T. Neta, A. Fukushima, and K. Takada 1999. Three kinds of antibacterial substances from Lentinus edodes (Berk) Sing. Shiitake, an edible mushroom. International Journal of Antimicrobial Agents 11(2):151-157

Steele, R.G.D and Torrie. 1980. Principles and Procedures of statistics. A Biometrical Approach. 2nd ed. McGraw Hill Book Company.

Wakefield, S., F.Yeudall, C. Taron, J. Reynolds, and A. Skimmer, 2007. Growing Urban Health; Community Gardening in South-East Torento. Health Promotion International 20(2): 92-101.

Wasser, S. 2005. Radiocesium contamination of wild-growing mushrooms in Ukraine. International Journal of Medicinal Mushroom 5:61-86.

Zied, D. and A. Pardo-Gimenez. 2011. Soybeans, the main nitrogen source in cultivation substrates of edible and medicinal mushrooms. Retrieved from In Tech on May 2013, http://cdn.intechopen.com/pdfs/1993/In Tech-soybean_the_main_nitrogen_source_in_cultivation_substrates_of_edible_and_medicinal_mushrooms.pd.