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BRIEF REPORT

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Breakeven yields for cultivated morel mushrooms (*Morchella* spp.) in the US North Central region

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Societal Impact Statement

Morels (*Morchella* spp.) are specialty mushrooms that fetch high prices from wild-foraged or indoor grown suppliers. Outdoor cultivation could expand availability and diversify morel crops. Participatory research trials in the United States during 2021–2023 resulted in low, uneven yields. Cost accounting reveals that in 2023, a producer needed to achieve an average morel yield of 0.16 lb/ft of row to break even. This threshold was sensitive to prices and labor costs. While these findings are preliminary due to a small sample and experimental conditions, they establish baseline indicators for the yields needed for outdoor morel cultivation to break even financially.

KEYWORDS
breakeven yield, *Morchella spp*, morel, mushroom cultivation, on-farm trials, production cost

1 | INTRODUCTION

With their earthy flavor and distinctive, iconic oval honeycomb form, morels (*Morchella* spp.) are among the most sought-after specialty mushrooms. Yet in North America, they are seasonably limited and expensive, because supplies are mostly foraged from the wild rather than commercially cultivated (Malone et al., 2022).

Outdoor cultivation of morels has the potential to expand supply, but research to date at Pennsylvania State University (Guo, 2023) and Michigan State University has succeeded in harvesting morels on only 11%–30% of research plots. Under the risky production conditions that characterize outdoor morel production, breakeven yield offers a key benchmark for commercial viability. It is the minimum yield of marketable morels that would enable a producer to fully cover production costs.

The sparse literature on mushroom economics touches on wild-foraged morels (Malone et al., 2022; Pilz, 2007; Wurtz & Wiita, 2004) and offers only scant coverage of production costs and returns for US commercial mushroom production. Most studies employ hypothetical cases based on experimental data rather than actual grower conditions (Davis & Harrison, 2009; Frey, 2020; Szymanski et al., 2003). Liu et al. (2023) reports the costs of commercial morel production in China to be in the range of $16,000 to $25,000 per hectare per year, depending on the quality of production facility. However, there is no empirical data from the United States to compare. To address this gap, we conducted research and generated data from multi-year on-farm research trials for an ex ante profitability analysis to measure the costs of outdoor morel cultivation and to calculate breakeven yield.

2 | METHODS AND DATA

The breakeven yield is calculated as the total cost of production divided by the net price received per pound of morels produced (Equation 1) (Dillon, 1993; Herbst, 1976). Average cost of production per foot of row is the annualized total cost of inputs divided by the total length of rows planted. Breakeven yield is the average cost of production divided by the net price per pound of morels, which is the morel price minus the cost per pound of harvest activities. Calculations here are based on small research plots, so they are reported in US dollars per foot of row.

$$\textit{Break even yield}\,(lb/ft) = \frac{\textit{Average cost of production}\,(\$/ft)}{\textit{Price of morel}\,(\$/lb) - \textit{Cost of harvest}\,(\$/lb)} \quad (1)$$

The on-farm research trials had 14 participants in the fall 2021 through spring 2022 production cycle, of whom nine continued in 2022–2023. They consisted of farmers, students, researchers, agronomists, and a physician, with field plots located in Michigan, Ohio, Illinois, and Wisconsin. The climate in this region is characterized by cold winters and relatively short springs, with mean annual temperatures ranging from 2°C to 12°C and annual precipitation ranging from 206 mm to 1193 mm (EPA, 2024). Most participants reported their soil textures as sandy loam, while fewer reported loam or clay loam. Field plots had multiple rows of morels at three-foot spacing. The total length of rows per plot ranged from 50 to 1600 ft, with around 78% of plots measuring less than 300 total feet of row. Each participant received multiple different isolates of *Morchella sextelata* in 2021, each as 6 lb spawn bags, and spawn of *Morchella sextelata* and *M. importuna* in 2022 that were planted in the fall, as well as *M. rufobrunnea* sclerotia that were planted in the following spring. After planting spawn, the plots were then covered with row plastic to maintain soil moisture.

To track costs, participants logged their labor time, inputs, and outputs into a shared worksheet. Their morel cultivation tasks fell into three stages: (1) land preparation, (2) progress monitoring, and (3) harvest (Figure 1a). Land preparation takes place in autumn. It includes tillage, spawnbed preparation, planting spawn, and installing irrigation, row plastic, and shading (Figure 1b).

After land preparation and spawning of the soil is complete, morel mycelium emerges from the soil, and grain-filled nutrient bags are placed on the rows to encourage sclerotia production. In late autumn and winter, participants monitor development of mycelium and manage pests, pathogens, and problems as they emerge. May through mid-July is the season for morel harvest, so more frequent monitoring is necessary.

Morels grow from and consume the carbohydrate substrates in which they are planted; thus, morels are cultivated as an annual crop. For statistical purposes, we pooled all annual observations across the 2 years of this study. In the 2021–2022 season, 14 plots were prepared, but only seven participants observed mycelium in spring and proceeded to the monitoring stage. Five successfully harvested morels. In the 2022–2023 season, nine participants continued, of whom five observed mycelium and three were able to harvest morels. Hence, there were a total of 12 plot-year observations where the participant continued managing the plot through the full production cycle.

Land preparation required an average of 4 min of labor per foot of row on all plots and roughly 5 min on the harvested plots (Figure 2a). Average monitoring time dropped by more than half

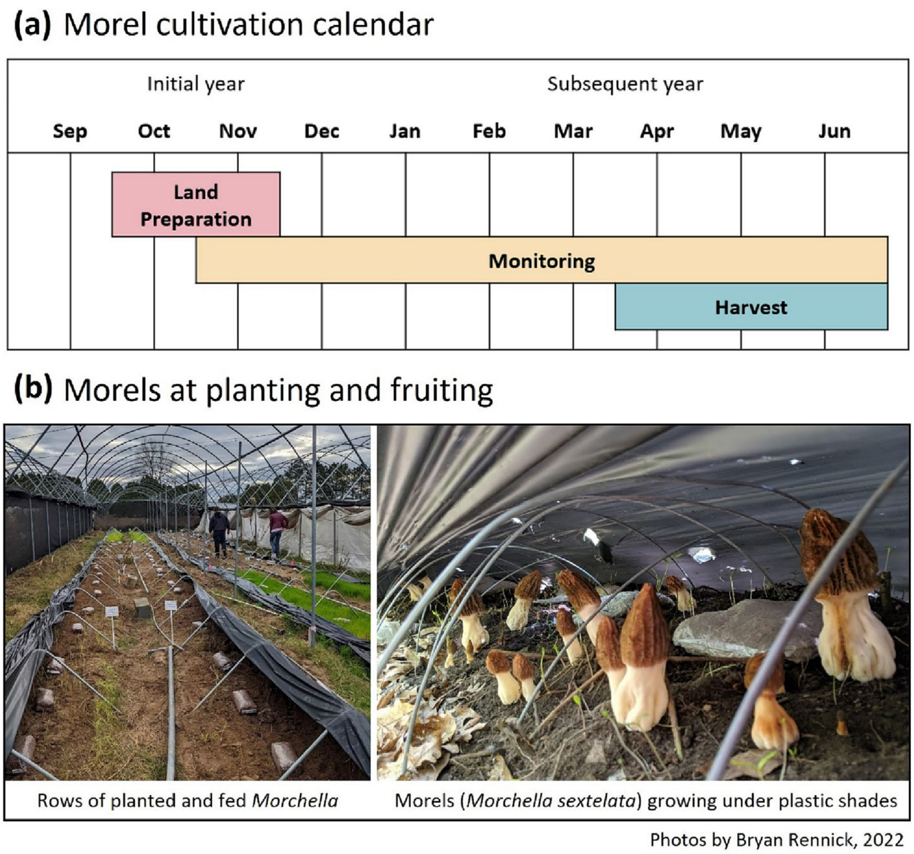

FIGURE 1 The method used for cultivating morels (*Morchella* spp.) outdoors during on-farm trials in the United States. (a) Morel cultivation calendar showing the months during which land was prepared for cultivation, morels were grown, and morels were harvested. (b) Photographs showing an outdoor morel cultivation bed just after planting (left panel) and at the fruiting stage (right panel), in which the morels (*Morchella sextelata*) are growing under plastic shades.

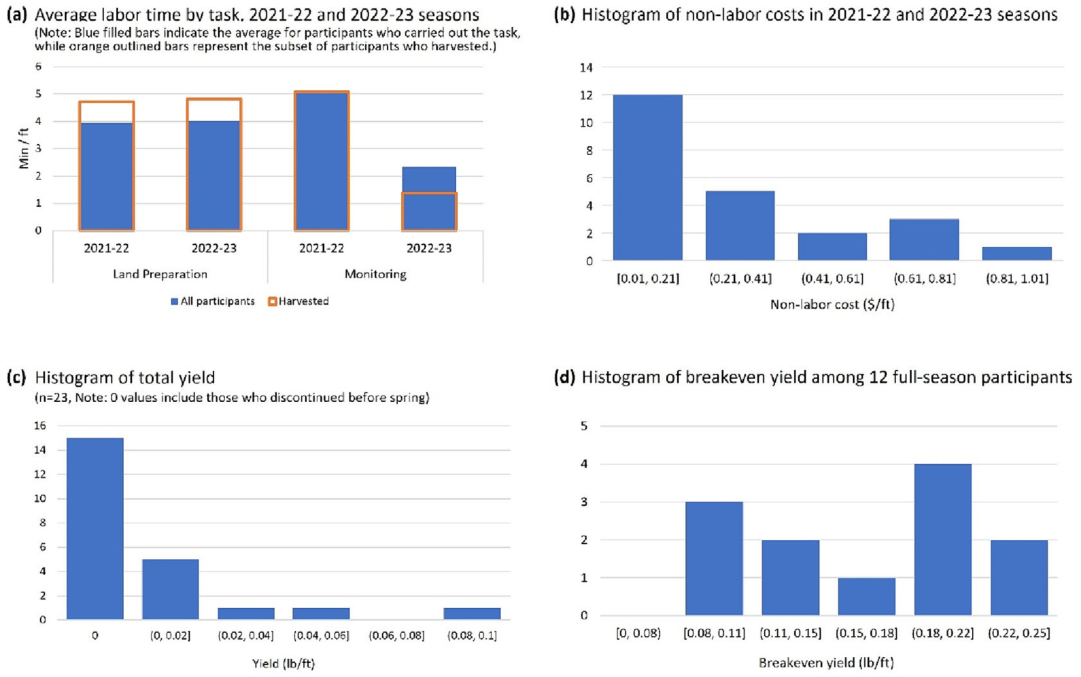

FIGURE 2 Economic factors influencing the feasibility of outdoor morel (*Morchella* spp.) cultivation during on-farm trials in 2021–2022 and 2022–2023 in the United States. (a) The average labor time by task for the outdoor cultivation of morels (*Morchella* spp.) for each trial period. Note that blue-filled bars indicate the average for participants who carried out the task, while orange-outlined bars represent the subset of participants who harvested. (b) Histogram of non-labor costs. (c) Histogram of total morel yield from the two trial periods. Note that 0 values in panel (c) include those who discontinued the trials before spring. (d) Histogram of the breakeven yield from 12 full-season participants of the trial.

between years, from 5 min per foot of row in 2021–2022 to 2 min per foot of row on all plots in 2022–2023.

Labor costs were calculated as the sum of the 2022 median hourly wage in farming, fishing, and forestry occupations in Michigan of $17.92/h (Bureau of Labor Statistics, 2023) plus fringe benefits, averaging 31.2% the total compensation in the US East North Central region (Bureau of Labor Statistics, 2022), for a total hourly labor cost of $26.05.

Non-labor costs included spawn ($6.02/bag) and nutrition bags ($3.96/bag), plus capital goods. Motorized equipment was budgeted at $11 per hour (median daily rental rate for a 13-horsepower, rear-tine rototiller in 2022) (Table S1). Small agricultural tools made a negligible contribution to total costs, so they are assumed to be costless. The costs of black plastic sheeting (to manage soil moisture and humidity), shade cloth, posts, and rope were annualized using linear amortization over a useful lifespan of 10 years. The distribution of non-labor costs per foot of row is described in Figure 2b. The average annual non-labor cost was calculated at $0.29 per foot (median is $0.20/ft), with more than 50% of participants spending less than $0.21 per foot.

The market price of fresh black morels came from Malone et al. (2022). Among the 23 forager respondents who reported selling black morels, they report an average price of fresh black morels in 2020 of $35 with standard deviation of $16.

Sensitivity analysis was conducted with respect to morel price, wage, and the cost of spawn plus nutrient bags (Methods S1 and Table S2). Following Malone et al. (2022), we centered the morel price sensitivity analysis on $35/lb, with two intervals of $12/lb above and below, for a set of prices of $11, $23, $35, $47, and $59 per pound. The labor cost scenarios include (1) free, volunteer labor, (2) the 2022 Michigan minimum wage of $9.87/h, (3) the Bureau of Labor Statistics (BLS) 2022 baseline cost of $26.05/h (equal to the Michigan median wage in farming and forest occupations plus fringe benefits), (4) the BLS 2022 baseline plus 10%, and (5) the BLS baseline plus 20%. The sensitivity analysis for the price of spawn plus nutrient base is constructed around the baseline cost of $ 6.02 per bag (Gourmet Mushrooms, Inc.), including low-end costs at one quarter and one half of this rate, as well as high ends scenarios of 50% and 100% over the baseline (Tables S3 and S4).

3 | RESULTS AND DISCUSSION

Thirty percent (8 of 23) of grower plot-years succeeded in producing harvestable morels. The average harvest across those eight was less than seven pounds, which converts to less than 0.03 lb/ft of row (Figure 2c). Participants reported several reasons for the low yield, the two major ones being rodent damage under the covered rows and unfavorable weather conditions including excessive moisture or heat during the fruiting stage. Some participants set traps to control rodents that nested below covered morel rows and fed on the nutrient pack grains, but since the traps were designed for one-time use, they contributed more to variable costs than to increasing yield. Consequently, profitability was not improved.

The average annualized total non-land cost for the 12 plot-years that completed a full production cycle was $5.65 per foot of row. Labor accounts for 65% of total non-land cost, with spawn and nutrient bags accounting for 31% and 4% for all else. The breakeven yields of the 12 participants who completed a full production cycle ranged from 0.08 lb/ft to 0.25 lb/ft (Figure 2d). The mean was 0.16 lb/ft and the median 0.18 lb/ft. No participant harvested enough to fully cover their costs. The maximum yield was 0.082 lb/ft, which was slightly above the minimum breakeven yield among the 12 cases.

A sensitivity analysis (see methods in the Supporting Information) found that breakeven yields were most sensitive to the price of morels and to labor cost. Breakeven yields at the highest morel price of $59/lb were one-half to one-third the yield needed at the baseline price. Breakeven yield at the low morel price of $11/lb was roughly three times the baseline breakeven yield. Breakeven yield was especially sensitive to cheap labor, with yields at the minimum wage roughly one-half the baseline breakeven yield. The price of spawn-and-nutrient bags had negligible effect on breakeven morel yields.

Outdoor morel cultivation in the US North Central region will require further research before it is ready for commercial development. In this 2-year participatory research project, only 30% of the 23 plot-years culminated with harvested cultivated morels. A roughly contemporaneous experimental study in Pennsylvania achieved harvest in only 11% of instances (14 experimental plots, zero with harvest in Year 1 and three with harvest in Year 2) (Guo, 2023). Clearly, improved knowledge on the biology and management techniques for micro-climate and pest control are required and further refinement to achieve stable yield for outdoor cultivation of morels in the United States.

4 | CONCLUSION

The breakeven yields and associated cost accounting reported here provide a benchmark for future research on outdoor morel cultivation in the Midwest United States and perhaps other regions and countries. Breakeven yields of 0.16 lbs per foot of row correspond to roughly 580 lbs per quarter acre. Such yields are far below the average yields of 6–7 lb/ft^2 of commercially grown white and brown *Agaricus* mushrooms that dominate the US market (SureHarvest 2017). However, the high price of morels means that cultivated, outdoor morels can enter the market profitably at much lower yields than those of conventional button mushrooms. Thus, with improvements in morel yield and production evenness, morels could become a profitable crop in the United States.

AUTHOR CONTRIBUTIONS

Seo Woo Lee analyzed the data, and Seo Woo Lee and Scott M. Swinton drafted the manuscript. Scott M. Swinton and Gregory Bonito designed and supervised the project. All authors contributed to the manuscript and approved the final version.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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