Indoor Tea-Crop Production:
Tea Camellia and Rooibos

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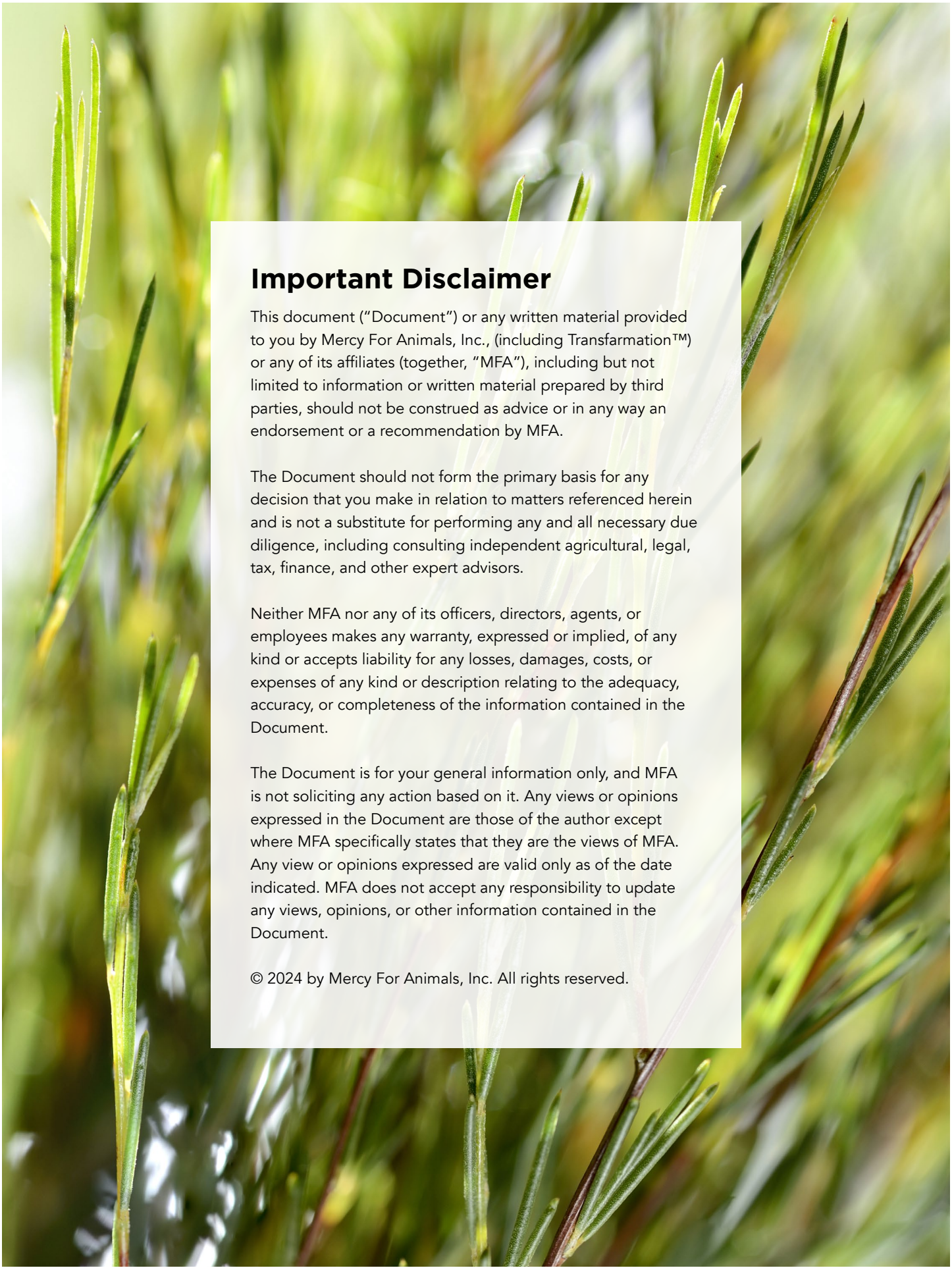
Highland ECONOMICS



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1. Introduction

Tea is the world's most popular nonalcoholic beverage, with a history dating back nearly two millennia (Harvard School of Public Health 2023). Tea generally consists of leaves steeped in hot water, primarily leaves of the evergreen shrub *Camellia sinensis* (hereafter "tea camellia"). The two main cultivars of tea camellia are *Camellia sinensis* var. *sinensis*, native to China, and *Camellia sinensis* var. *assamica*, native to India (Miles and Shrestha 2023).

More recently, a perennial shrub native to South Africa known as rooibos (*Aspalathus linearis*) has become a popular caffeine-free alternative to tea camellia since it was first marketed at the beginning of the 20th century (Joubert and de Beer 2011). Reports suggest that the needle-like leaves from this previously little-known plant could become as common as tea camellia as a beverage ingredient (Joubert and de Beer 2011).

Both tea camellia and rooibos are valuable food products in international markets and can be shipped easily around the world. Their major production areas are well established in places where labor is inexpensive and large operations provide an economy of scale that is difficult for new growers to compete with. But some producers in the United States have seized opportunities for niche marketing and explored the unique potential of selling nursery plants rather than tea leaves.

This report outlines current market conditions for tea crops, presents information on typical indoor production practices (where available), and discusses the viability of converting a poultry house into a greenhouse for tea-crop production.

2. Market

In 2022 global tea production was valued at $17 billion and the tea trade around $9.5 billion (FAO 2022). The tea market is widespread, and steadily increasing demand in developing countries that produce tea has driven up production while decreasing the amount of exportable product over the past decade (FAO 2022). As figure 1 shows, the Food and Agriculture Organization of the United Nations forecasts production increases in every major tea-producing country by 2030, particularly for green tea in China. Conversely, the tea markets in Europe and the United States have slowly shrunk in recent years owing to the demand for diverse ingredients for tea blends and other specialty products (FAO 2022).

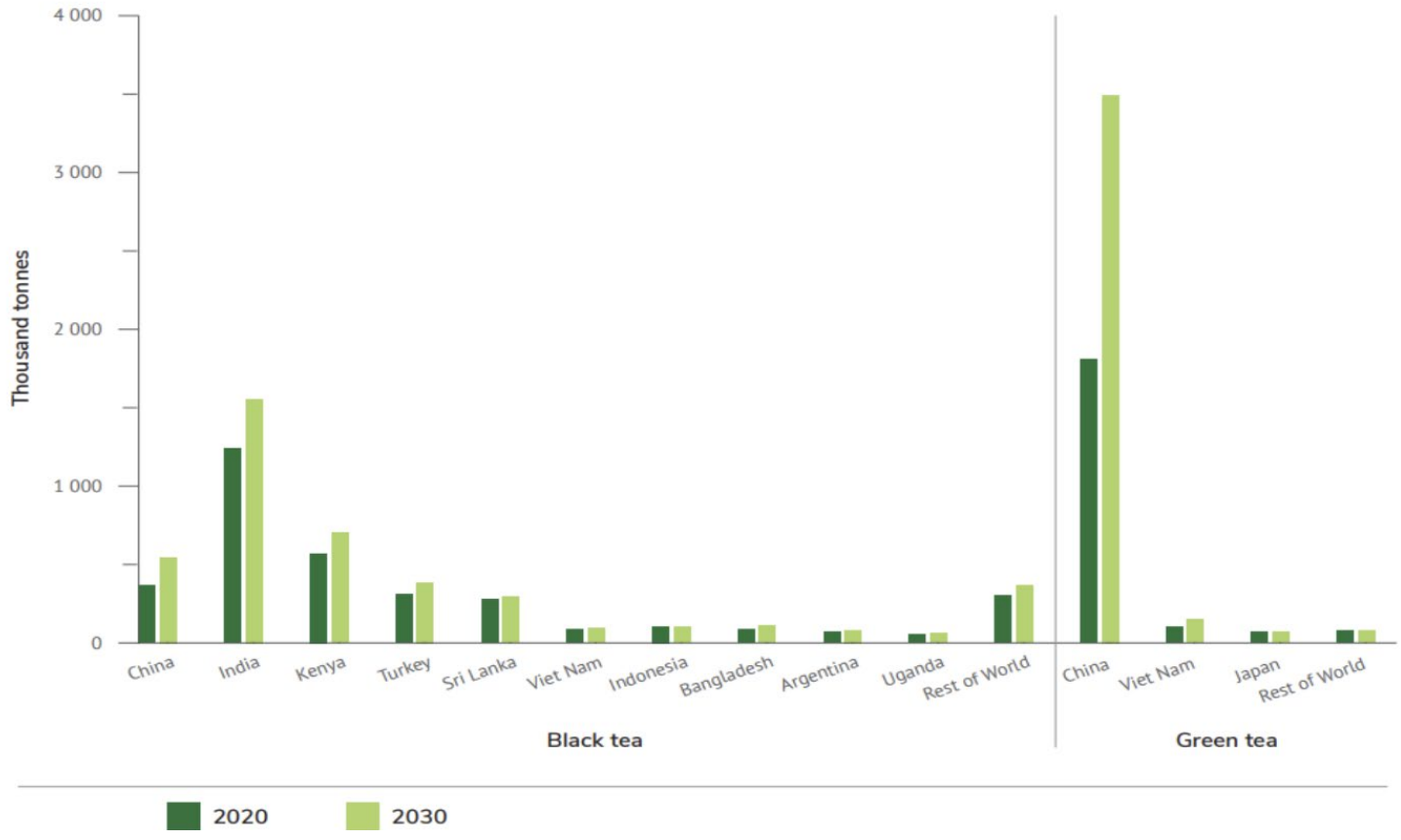

Figure 1. Tea production by major producing countries (FAO 2022).

The commercial rooibos market began in the early 20th century as descendants of European settlers in South Africa's Cederberg Mountains started cultivating the plant that Indigenous peoples in the region had harvested in the wild for generations (Trenchard 2023). As global popularity has grown in recent years, production has expanded. Exports of rooibos tea increased by 1,700% from 1996 to 2023 (Trenchard 2023). In 2019 the South African Rooibos Council negotiated an agreement with the South African government to guarantee an annual fee of 1.5% of the value of unprocessed rooibos production to Indigenous communities, and in 2021 the European Union officially granted rooibos "Protection of Designation of Origin" status, ensuring that only rooibos grown in a specific region of South Africa can be marketed as such in the EU (Trenchard 2023; Phys.org 2021). While these boons to traditional growers will help augment the rooibos market, they present difficulties for the viability of production outside South Africa.

3. Production Practices

Tea plants can be propagated in greenhouses but are primarily grown outdoors due to their size and long life spans. Tea camellia plants can grow 15 feet tall and eight feet wide, with a productive life span of up to 100 years (NC State Extension, n.d.; Tipton et al. 1990). Rooibos can grow up to six feet tall and six feet wide, with a productive life span of around six years (Govender 2007; Western Cape Government 2023). Greenhouse production of tea camellia has been conducted in research settings, and while some examples of commercial production exist, published information on relevant practices and economics is limited (Saito and Nakamura 2019; Vertical Farm Daily 2022). The production practices, growth parameters, and corresponding cost estimates discussed below are drawn from a combination of research trials and commercial operations growing plants outdoors.

Temperature and Humidity

Tea camellia is best suited to tropical or subtropical climates with ample precipitation and high relative humidity but can be grown in temperate climates with temperatures ranging from 70°F to 84°F in summer and 0°F to 40°F in winter (Miles and Shrestha 2023). Rooibos is more adapted to hot and dry climates as in the Cederberg region where it is predominantly cultivated (Govender 2007).

Growing Systems and Media

The growth cycle (length of time to harvest) influences the selection of soilless media used in greenhouse production. The most common soilless culture systems in greenhouse production of larger plants are bag or pot systems using containers filled with artificial media that are drip-irrigated with nutrient solutions. The media in these systems must be able to expand to accommodate root growth and usually consist of coir, clay, or combinations of peat and perlite, depending on the level of water retention (drainage) needed (Swain et al. 2021).

Seed and Planting Stock Selection

Tea camellia and rooibos can be started from either seed or tissue culture (plant cuttings). Tissue-culture plantings have the advantage of reaching maturity in a shorter period, which can be crucial for recovering capital and operating costs incurred before harvest is possible (Miles and Shrestha 2023). Tissue culture can be propagated from cuttings taken from mature plants. Tea camellia plants are relatively easy to purchase in the United States, but rooibos plants are less common. For purposes of the enterprise budgets in this report, we model tea camellia (for both leaf production and seedling sale) started from tissue culture and rooibos started from seed.

Spacing and Maintenance

Spacing and maintenance requirements for tea camellia and rooibos are similar, as plants grown for leaf production in high-density systems generally require eight square feet per plant (Kamunya et al. 2019; Western Cape Government 2023). Both plants should be pruned occasionally to maintain a manageable size.

Irrigation

Plants need an adequate supply of water and nutrients to their roots, but proper circulation is necessary in hydroponic systems to avoid fungal pathogens in the growing media. In outdoor systems, tea camellia and rooibos plants are primarily rain-fed. Greenhouse operators will need to experiment with irrigation frequency to establish best practices.

Sanitation and Sterilization

Many greenhouses have a sanitation process everyone must follow before entering the production area. In addition, a complete sterilization of the production area should occur between growing cycles.

Postharvest Processing and Packing
Postharvest processing of tea camellia consists of varying combinations of wilting, drying, or fermenting, depending on the type of tea (green, black, oolong, etc.) (Miles and Shrestha 2023). Rooibos is most often fermented, a process that involves chopping, bruising, and drying leaves to develop color and flavor in finished tea (Joubert and de Beer 2011). After processing, tea is commonly packaged in individual tea bags or bags of loose-leaf tea.

4. Enterprise Budget

No published or reported enterprise budgets exist for the tea crops and development context (greenhouse hydroponics) considered in this analysis. For purposes of estimating production costs for tea crops produced in a greenhouse setting, we rely on crop-production costs in similar systems. Tea camellia and rooibos are not typically grown indoors, likely due to their perennial nature, size, and suitability for growing outdoors. Tea leaf crops are assumed to be minimally processed (cut, rolled, dried, etc.) after harvest and packaged for retail sale via an e-commerce website where the customer assumes shipping costs (tea camellia seedlings are sold as whole potted plants). An e-commerce website is estimated to cost around $1,200 per year in membership fees, and order fulfillment costs a producer $3 per transaction (Barn2Door, n.d.; Shvetsova 2022; Shopify, n.d.).

4.1 CROPPING SYSTEM

For tea camellia and rooibos grown for leaves or seedlings, this analysis assumes that plants are placed in containers with a soilless media and watered via a Dutch-bucket system. We base substrate prices on retail data found online, and common materials that could be used cost an average of $12.20 per cubic foot. Container prices are based on online retail data and vary by size. Fertilizer costs are based on comparable budget estimates, though these costs are approximate and may differ if fertilizer is applied in the form of soluble nutrient solutions through a hydroponic system, estimates for which are unavailable.

4.1.1. Tea Camellia

We modeled separate budgets for two greenhouse tea camellia operations in a converted poultry shed: one for loose-leaf tea and one for seedlings. In the first, the whole greenhouse is dedicated to perennial tea camellia plants harvested for leaves that are processed and sold. In the second, part of the greenhouse is dedicated to raising perennial plants, but the plants are harvested for tissue culture, which is propagated in a separate part of the greenhouse for annual sale of tea camellia seedlings.

OPERATION 1: Loose-Leaf Tea
A grower purchases tea camellia plants that are about one year old, transplants them into larger containers, and raises them for a minimum of four years before the first harvest. Labor estimates of 145 hours during establishment of the plants and 158 to 184 hours annually thereafter are based on published data for tea and similar crops (Khachatryan and Wei 2021; Tipton et al. 1990; Western Cape Government 2023).

Yields range from one-quarter to one-half pound of dried tea per plant, depending on variety, cropping system, and planting density (Kamunya et al. 2019). Typical prices for finished and packaged tea depend on tea type but generally range from $20 to $40 per pound. Our budget estimates a likely average price of $30, but higher price points are possible. An artisanal tea-growing operation in Oregon currently sells 24-gram boxes of loose-leaf tea for $30 each—upwards of $550 per pound (Helmer 2017; Minto Island Tea Company, n.d.). This price point is vastly beyond typical market value but appears viable in niche markets (Helmer 2017).

OPERATION 2: Seedlings

A grower purchases tea camellia plants that are about three years old, replants them in soilless growing media, and raises them as "mother" plants for the production of seedlings. Cuttings from each mother plant are taken during the first year in the greenhouse, dipped in rooting hormone, planted in smaller pots with soilless media, and grown for a minimum of one year before being sold as potted seedlings. This process requires a misting chamber with humidity control and a place where seedlings can be hardened off (Miles and Shrestha 2023). While the process can be repeated annually if mother plants continue to grow, the success rate of propagation may vary and is reflected in the enterprise budget (Miles and Shrestha 2023).

Figure 2. Sample misting chamber, 14′ long x 5′ wide x 3′ tall. (Image from Shrestha and Miles 2023.)

Figure 3. Recently matured tea shoots for propagation. (Image from Shrestha and Miles 2023.)

Annual labor estimates of about 639 hours are based on published data for tea and similar crops (Khachatryan and Wei 2021; Tipton et al. 1990; Western Cape Government 2023). Assuming that each mother plant can provide 10 cuttings for transplant per year, we estimate an average per-seedling price of $16.90 per potted plant according to a typical range of $13.75 to $20. Should plants need longer to develop before sale, the price per plant roughly doubles for two-year-old plants and more than triples for three-year-old plants (Camellia Forest Nursery, n.d.).

4.1.2 Rooibos

For our enterprise budget, we model rooibos grown similarly to tea camellia, with the exception of a roughly six-year production cycle, after which rooibos plants would need to be restarted, though potentially from cuttings rather than seed as in the first year. Rooibos yields in outdoor systems are based on long-term trials in Cederberg, South Africa, where yield per plant ranges from about 0.1 to 0.2 pounds of dried finished tea per plant, depending on the plant's age (Western Cape Government 2023).

Estimated labor hours of 158 during establishment and 170 to 220 annually thereafter, depending on harvest volume, are based on published data for rooibos and relevant crops (Khachatryan and Wei 2021; Western Cape Government 2023). The price for finished rooibos tea ranges from $12 to $45 per pound. For our budget analysis, we estimate an average price of about $33 per pound.

4.2 UTILITIES

Utility requirements of a greenhouse include fuel for heating, electricity for fans, water, sewerage, and communication. In this budget, we assume natural gas requirements of 2,180,000 cubic feet at a cost of $9.52 per 1,000 cubic feet. In addition, we expect the electricity requirements to be 50,000 kilowatt hours of energy per year and estimate a cost of $0.12 per kilowatt hour. Telephone (cell) and internet costs for the business are modeled at $1,400 per year. Utilities represent around 18% of the total variable costs of a greenhouse operation.

4.3 OTHER OPERATING COSTS

Miscellaneous costs include laboratory fees (such as for analysis of leachate, tissue, and nutrient solution), estimated at $1,440 per year; office supplies ($600); postage; and marketing materials ($600). In total, we expect such costs to be $2,640 per year.

4.4 CASH OVERHEAD

Property taxes for the operation will be specific to the location but are modeled here at $250 per month, or $3,000 per year. Some states may impose income or other applicable taxes on top of property tax, but these are not modeled here. This analysis does not assume any land costs, so the profit identified below can be considered a return-on-land estimate. We model general liability insurance at $70 per month and property insurance at $200 per month. Total insurance costs are estimated at $3,240 annually. The table below outlines the operating costs common to all three crops.

Table 1. Operating costs for greenhouse tea-crop production common to all enterprises modeled

Description	Unit	Quantity	Price	Value
Sanitizer	Gallon	14	$24.00	$336
Natural gas	1,000 ft.^{3}	2,180	$9.52	$20,754
Electricity	kWh	50,000	$0.12	$6,000
Telephone and internet				$1,400
Miscellaneous				$2,640
Property tax				$3,000
Insurance				$3,240
E-commerce site				$1,200
Total common costs				**$38,570**

In addition to these common costs, production will entail operating costs that vary by crop and system. These are outlined in tables 2 through 4, followed by a discussion of debt-service coverage ratios.

Table 2. Budget for tea camellia seedling production

Description	Unit	Price	Year 1		Year 2+	
Gross returns				$0.00		$134,609
Seedlings	Count	$16.90		0		7,965
Variable costs:			**Quantity**	**Cost**	**Quantity**	**Cost**
Seedlings (with pots)	Seedling	$70.00	864	$60,508		
Propagation containers	Container	$0.49	9,000	$4,410	9,000	$4,410
Substrate	Cubic foot	$12.20	638	$7,790	292	$3,560
Fertilizer	Pound	$4.20	980	$4,120	980	$4,120
Rooting hormone	5 liters	$219.15	1	$219		
Fungicide and herbicide	Liter	$16.23	0.3	$4.43	0.3	$4.43
Labor	Hour	$17.58	639	$11,225	639	$11,225
Packaging	Tall box	$1.00	0	$0.00	7,965	$7,965
Fulfillment	Order	$3.00	0	$0.00	7,965	$23,895
Repairs and maintenance				$2,568		$1,605
Total variable costs				**$90,845**		**$56,785**
Total common costs				**$38,570**		**$38,570**
Operating profit				**-$129,415**		**$39,254**

Note: Individual figures may not sum to totals due to rounding.

Table 3. Budget for tea camellia loose-leaf tea production

Description	Unit	Price	Year 0 (establishment)		Year 1–3		Year 4+	
Gross returns				$0.00		$0.00		$11,885
Dried tea	Pound	$30.00		0		0		396
Variable costs:			**Quantity**	**Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
Seedlings	Seedling	$16.90	988	$16,695				
Containers	Container	$3.30	988	$3,260				
Substrate	Cubic foot	$12.20	605	$7,382				
Fertilizer	Pound	$4.20	0	$0.00	97	$410	98	$413
Fungicide and herbicide	Liter	$16.23	0.3	$5.06	0.3	$5.06	0.3	$5.06
Labor	Hour	$17.58	145	$2,543	158	$2,771	184	$3,236
Packaging	Bag	$0.40	0	$0.00	0	$0.00	396	$158
Fulfillment	Order	$3.00	0	$0.00	0	$0.00	396	$1,188
Repairs and maintenance				$869		$93		$145
Total variable costs				**$30,754**		**$3,278**		**$5,146**
Total common costs				**$38,570**		**$38,570**		**$38,570**
Operating profit				**-$69,324**		**-$41,848**		**-$31,831**

Table 4. Budget for rooibos loose-leaf tea production

Description	Unit	Price	Year 0 (establishment)	Year 1	Year 2	Year 3	Year 4	Year 5
Gross returns			$0.00	$3,627	$5,441	$7,254	$5,441	$3,627
Dried tea	Pound	$32.98	$0.00	$110	$165	$220	$165	$110
Variable costs:								
Rooibos seeds	Seed	$0.25	$513					
Fertilizer	Pound	$4.20	$2,162.49					
Containers	Container	$3.30	$3,377.29					
Substrate	Cubic foot	$12.20	$7,647.31					
Fungicide and herbicide	Liter	$16.23	$2.73	$2.73	$2.73	$2.73	$2.73	$2.73
Labor	Hour	$17.58	$2,780	$2,986	$3,319	$3,651	$3,319	$2,986
Packaging	Bag	$0.40	$0.00	$44	$66	$88	$66	$44
Fulfillment	Order	$3.00	$0.00	$330	$495	$660	$495	$330
Repairs and maintenance			$480	$98	$113	$128	$113	$98
Total variable costs			**$16,962**	**$3,461**	**$3,995**	**$4,530**	**$3,995**	**$3,461**
Total common costs			**$38,570**	**$38,570**	**$38,570**	**$38,570**	**$38,570**	**$38,570**
Operating profit			**-$55,531**	**-$38,403**	**-$37,124**	**-$35,846**	**-$37,124**	**-$38,403**

For tea camellia seedling production, we expect positive operating profits by year 2. For loose-leaf tea production, both crop budgets indicate break-even prices that are outside the range of prices growers would likely receive: $110 per pound for tea camellia and $195 to $382 per pound for rooibos. In commercial hydroponic production systems, crop yields could raise or lower the break-even retail price for tea camellia and rooibos, but information on such systems for these crops is lacking.[1] And increases in yield would likely not be significant enough to change our determination of viability.[2] Some companies in the United States have captured niche markets for loose-leaf tea and charge customers prices that would make production viable. As the operation in Oregon discussed above has shown, a received price for tea camellia of over $100 per pound is not impossible in the right market (Minto Island Tea Company, n.d.).

4.5 CAPITAL COSTS AND NONCASH OVERHEAD

The capital cost of converting a poultry house into a greenhouse is estimated at $6.02 per square foot, or $96,272 for the structure (16,000 square feet of production area).[3] We estimate the cost of the hydroponic system used in production at $39,336, according to a quote from Carolina Greenhouses for a Dutch-bucket system adjusted to 2023 dollar values. In addition, we estimate a cost of $27,369 for necessary equipment, mostly identified from a list of requirements developed by The Ohio State University Extension, with costs indexed to 2023 dollar values:

- Postharvest equipment, which includes a commercial dryer for postharvest drying of tea crops, estimated at $1,342, and a misting chamber system for seedling production, estimated at $783[4] (Anderson 2012; Hydrobuilder, n.d.): $2,125
- Backup generator: $5,720
- Cooling system: $2,640
- Fan jets (two): $2,860 ($1,430 each)
- Computer for environmental controls: $3,630
- Heating system: $2,860
- Miscellaneous building supplies: $2,200
- Sprayer: $110
- CO2 generator: $550
- Fertilizer mixing pump: $55
- Feeding system: $3,520
- Meters, monitors, sensors, and scale: $1,100

Thus, the total capital expenditure estimate is **$162,977**. This analysis further assumes the owner could finance the conversion through existing programs offered by the Small Business Administration (SBA), the United States Department of Agriculture, and possibly other lenders. Our analysis models the debt-service terms of the SBA 504 program: 10% equity requirement (90% financed), or $16,219.[5] The SBA loan would cover 40% of the total cost; thus 50% of the capital costs would need to be financed through a bank. With these conditions, we anticipate the entire financing package would be close to the prime rate (currently 8.5%).

4.6 PROFIT POTENTIAL

According to the cost assumptions outlined above, including projected yield, break-even prices for tea crops are likely beyond what growers could reasonably expect to receive, except perhaps in small local or niche markets where customers are willing to pay premium prices. The projected operating profit of the seedling concept modeled is nearly $40,000 per year beginning in the second year of production. Such an enterprise, akin to a nursery, would require an additional (beyond the capital costs) $129,414 in operating costs during the establishment period, which is amortized over a 10-year period in this analysis at a rate of 8.5% (annual payment of $19,724). After accounting for establishment costs, we estimate the profit potential of the seedling concept to be $19,530. This translates to an operating profit margin of 15%, which is on par with other potential crops.

Debt-service coverage ratio (DSCR) is a measurement of a firm's available cash flow to pay current debt obligations, calculated as the net operating income divided by debt obligations (principal and interest

[1] Information was obtained from research trials measuring plant characteristics such as oil content, but no yield information from commercial hydroponic systems is readily available.

[2] The hydroponic systems modeled here would need to have five times or greater the yields estimated in this analysis to achieve a positive operating profit.

[3] Quotes for the conversion of a chicken house to crop production range from $3 to $8 per square foot, depending on the type of material used in covering the structure (Sullivan and Howard 2022). $6.02 represents the adjusted (indexed to 2023 dollar values) midpoint estimate between double-layer film and corrugated polycarbonate. This cost includes fans, groundcover, ventilation control, and shade cloth, along with the labor and material costs for conversion of the structure (Kardos, Kuzma, and Ragon 2022; Sullivan and Howard 2022).

[4] This assumes a price of $0.50 per square foot to cover the cost of PVC, indexed to 2023 dollar values, and that environmental controls can be used to operate the misting chamber.

[5] Depending on several factors, including the age of plants initially acquired and the corresponding ability to take cuttings from those plants, a loan to cover operating expenses during the first production cycle (up to one year of operation) may be needed. In this analysis we amortize this establishment cost over a 10-year period, as mentioned in section 4.6.

payments). A DSCR less than 1.00 would indicate potential solvency problems, while a ratio of at least 2.00 is generally considered very strong. The DSCR of the modeled tea plant concept is 1.20, which is typically the minimum ratio that banks would consider lending but indicates that the operation should be able to cover all operating and financing costs.

4.7 SENSITIVITY

We undertook a sensitivity analysis to evaluate the impact of key assumptions on the profit estimate for a tea seedling enterprise. These assumptions are as follows:

- Yield (6,930 to 9,000 plants produced and sold annually)
- Price received ($13.72 to $20 per plant)
- Labor requirements (479 to 798 hours required—75% to 125% of reported labor requirements)
- Natural gas use (1,744,000 to 2,616,000 cubic feet)
- Natural gas price ($7.62 to $11.42 per thousand cubic feet)

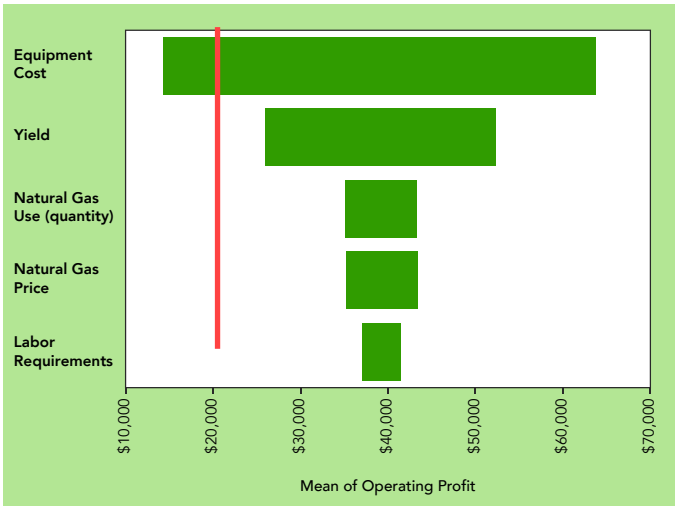

Figure 4. Sensitivity analysis results.

Price received is the most sensitive variable modeled, and the highest profit potential is for operations selling plants at the high end of the price range considered ($20 per plant). Yield is the second-most sensitive variable. As shown in the figure, all the variables considered indicate positive profit potential, and most operating profits are above the principal and interest payments modeled for the loan to cover capital costs.

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