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Full Length Research Paper

Economic evaluation of bell pepper production under colored shade nets system in the southeast region of the USA

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Abstract

Bell pepper (*Capsicum annum* L.) is one of Georgia's top ten commercial vegetables and an essential crop in the southeast and the United States at large. In 2020, Georgia reported a farm gate value of $126 million. Economic Research Service report shows that bell pepper production fell by 11% in 2020 compared to 2019. The annual US utilized production was 1,200.4 million pounds in 2017; in 2020, it decreased to barely 821.9 million pounds, hence a 31.5% decrease. As a result, the University of Georgia started researching bell pepper production under the colored shade nets in 2015 to determine if plant growth and fruit yields would be superior to the conventional system. The research aimed to determine whether the bell pepper produced under the colored shade nets will provide a superior return to investment to the growers vis-à-vis the conventional system. Our findings will be crucial to the vegetable industry and stakeholders in their crop production decision-making process and profit-maximizing goal.

Keywords: Bell pepper, colored shade, costs, risk-rated returns, sensitivity analysis.

INTRODUCTION

The US economy depends heavily on the production of vegetables and pulses. However, there has been a decrease in the US production of vegetables in recent years. In 2021, the value of utilized vegetable production was around $12.7 billion, which is a 10% reduction compared to $14 billion in 2020 (NASS, 2022). The declining crop value can partially be blamed on the continued decline in the area harvested. In 2017, the harvested area was 8,016 thousand acres compared to 7,083 thousand acres in 2019 (USDA, ERS, 2021).

Despite the size of the US vegetable production, import demand increased in 2021 compared to 2020 by 5.1%. On the other hand, the U.S. vegetable export experienced growth in 2021 compared to 2020 by 3.4%. In terms of value, the US imported almost 320 percent more in 2021 than they exported (Davis et al., 2022).

Out of 125 different countries, Mexico and Canada are the top exporters of vegetables to the United States (Migration Dialogue, 2021). While imports from Canada have remained stable at 11% over the previous ten years, fresh vegetable imports from Mexico have climbed from 69 percent in 2008 to 77 percent in 2020. (Davis & Lucier, 2021A). Bell pepper imports from Mexico climbed by 110, 120, 742, and 70 percent in the winter, spring, summer, and autumn seasons, respectively, between 2008–10 and 2018–20. As a result, they competed with market windows of the southeast region of the US, notably Georgia (Davis & Lucier, 2021B).

In a few years, the consumption of vegetables has decreased. Davis et al. (2022) report that the per capita consumption of vegetables (fresh, processed, potatoes, dry beans, peas and lentils, and mushrooms) was 384.3 pounds in 2020, which is an approx. 5% decrease compared to 2018 (402.6 pounds).

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Bell pepper (*Capsicum annum* L.) is an important vegetable crop in the United States, particularly in the southeast. In Georgia, one of the southeast states, bell pepper is in the top ten commercially produced vegetables. Georgia recorded the bell pepper's farm gate value of $133.5 million in 2020. (GFGVR, 2022). According to USDA/ERS data, the production of bell peppers decreased by 11% in 2020 compared to 2019. In 2019 and 2021, the United States produced 1.3 and 1.1 billion pounds of bell peppers annually, a decline of 15.1% in 2021. (NASS, 2022). Over the past decade, there have been fluctuations in the production of bell peppers. Therefore, in 2015 and 2016, researchers at the University of Georgia began studying the production of bell peppers beneath colored shade nets to see if plant growth and fruit harvests would be superior to the traditional technique. Technologies for growing vegetables indoors or under protection are not new in Mexico, our top supplier and rival. According to a study, Mexico has around 105,000 acres of covered vegetable production, of which 36% are shade houses, 31% are greenhouses, and 32% are tunnels (Migration News, 2021). Our research aims to determine whether the productivity and profitability of bell pepper produced under the colored shade nets will provide a superior return to investment to the growers vis-à-vis the conventional system.

MATERIALS AND METHODS

Our study originates from prior research entitled "Bell Pepper (*Capsicum annum* L.) under Colored Shade Nets: Fruit Yield, Postharvest Transpiration, Color, and Chemical Composition" by Diaz-Perez et al. (2020). The original field study and data collection were conducted in 2015 and 2016 at the University of Georgia Hort Farm, Tifton, GA. The authors adopted a randomized complete block experimental design with four replications and five colored shade net treatments. The five-colored shade net treatments are black, red, silver, white, and unshaded control. They used a 15 m wide, 6 m long, and 5 m high wooden rectangular structure covered with a net. The bell pepper cultivar used for the experiment was PS 09979325. They used black low-density polyethylene mulch with a slick surface texture to cover the soil. Diaz-Perez et al. (2020) discuss the detailed material and method.

After the completion of the study by Diaz-Perez et al. (2020), we found questions like "would producing bell pepper under colored shade nets technology be profitable or not?" and "will farmers be willing to adopt this new technology"? are crucial. It became apparent that an economic assessment was required for two reasons. First, the evaluation enables us to identify any profitability margin. Second, the evaluation's findings might persuade bell pepper growers to use the colored shade nets technology, mainly if the profit margin is higher (Byrd et al., 2006, Fonsah et al., 2010).

The data used in our study are from secondary sources. On September 29, 2021, a greenhouse model resembling this one was obtained from the Planta Greenhouses, Farmer "Alpine" website to calculate the price of the colorful shade netting house. Planta Greenhouses has branches and warehouses in the USA (Massachusetts) and Canada (Ontario and British Columbia) (Planta Greenhouses, 2021). Although we referred to the production method from the study conducted in 2015 and 2016, we used 2021 price and cost data for analysis. The latest possible price and cost data allows us to assess profitability in growing bell pepper in the current situation. The selected size closer to the one used in our research was 25 x 48 x 12.5 cubic feet, translated to 36 hoop houses/acre x $23,500 retail price per hoop house without discount. Further assumptions were made: a lifespan of 5 years, a salvage value of 20%, depreciation, and an interest rate of 6.5% in our fixed cost and amortization calculation.

We considered risk-rated prices and yields by defining five scenarios: best, optimistic, expected, pessimistic, and worst. The expected scenario represents the price (yield) that occurs 50% of the time. The best and worst cases are rare and assumed to occur only 7% of the time, while the optimistic and pessimistic scenarios indicate a 31% probability of occurrence (Kunwar and Fonsah, 2022; Fonsah et al., 2007; Fonsah et al., 2008; Fonsah et al., 2011; Fonsah et al., 2013).

RESULTS AND DISCUSSIONS

Table 1 offers the five different prices and yields used in the study. We used the mean bell pepper yields in 2015 and 2016 as an expected yield of 1,966 cartons per acre. The pessimistic and the worst scenarios yields are derived from the expected yield, as the former is 90% and the latter is 80% of the expected yield (Ferrer et al., 2011). Similarly, the optimistic and the best, respectively, are 110% and 120% of the expected yield (Table 1).

The expected price of bell pepper used in our study came from the Packer Magazine for bell pepper and was $13 per box. The best, optimistic, pessimistic, and worst scenarios' prices are calculated from the expected price, similar to how we computed yields (Table 1).

Bell pepper production costs have increased along with the cost of nearly every item due to the COVID-19 pandemic, which has disrupted the supply and value chain globally. The inputs with the highest costs were plants, fertilizers, insecticides, fungicides, nematicides, silver plastic mulch, and fumigation. The overall pre-variable cost per acre was $8,373.70 (Table 2).

Costs associated with picking, hauling, grading, packaging, and marketing or broker fees are included in harvesting and marketing costs. Total costs for harvesting and marketing bell peppers grown in the Southeast with colored shade nets were $6,617,56 per acre (Table 3). The total variable cost, equal to the entire pre-variable cost plus the harvesting and marketing costs, was $15,005.31 per acre (Table 3).

In the southeast United States, irrigation is a crucial component in colorful shade net bell pepper production. Our irrigation cost estimate covers installation, storage tanks, an 8-inch well, injection systems, and pipelines and fittings. In addition, we accounted for the price of the materials, lifespan, depreciation, interest rate, taxes, and insurance while estimating irrigation costs (Table 4). Since it is not economically sensible to invest a significant amount in irrigation for a land size less than 40 acres, the irrigation cost was estimated on a 40-acre basis. We finally retrieved the irrigation cost per acre basis from the cost for irrigating 40 acres of land. The total investment cost was $40,425 for ten acres. While after depreciation, interest, taxes, and insurance,

Table 1: Five prices and yield scenarios of bell pepper production under colored shade nets in the Southeast USA, 2022.

	Best	Optimistic	Expected	Pessimistic	Worst
Yield (cartons per acre)	2359	2163	1,966	1,769	1573
Price per carton	15.60	14.30	13.00	11.70	10.40

Table 2: Pre-harvesting variable costs of producing bell pepper under colored shade nets in the Southeast, USA, 2022.

	Unit	Quantity	Price ($)	Total ($)
Plants (PS 09979325) transplant	Thou	17.80	155.00	2,759.00
Lime, applied (gypsum)	Ton	1.00	113.40	113.40
Base fertilizer	Lbs.	12.00	25.00	300.00
Side-dressing Fertilizer (soluble)	Gal.	1.00	21.00	21.00
Insecticide	Acre	7.80	80.00	624.00
Fungicide	Acre	1.00	368.00	368.00
Nematicide	Acre	1.00	822.88	822.88
Herbicide	Acre	2.00	40.00	80.00
Silver Plastic	Roll	2.80	210.00	588.00
Plastic Removal	Acre	1.00	78.75	78.75
Drip Tape	Ft	8700.00	0.03	261.00
Fumigation	Acre	1.00	840.00	840.00
Strings	Acre	1.00	220.50	220.50
Stakes	Acre	1.00	105.00	105.00
Scouting	Acre	1.00	25.00	25.00
Machinery	Hr.	5.00	22.05	110.25
Transplant Labor	Hr.	20.00	10.75	215.00
Labor	Hr.	33.00	8.00	264.00
Land rent[1]	Acre	1.00	0.00	0.00
Irrigation (Mach + Labor)	Acre	1.00	80.04	80.04
Interest in Operation Capital	$	7875.82	0.065	511.93
Pre-Harvest Variable Costs (P-HVC)				$8,387.70

[1]Land rent varies too much, so we decided not to include it in this study.

Table 3: Harvesting and marketing costs of producing bell pepper under colored shade nets in the Southeast region, USA, 2022.

Description	Unit	Quantity	Price	Amt/acre
Picking and hauling	Ctn.	1769	$0.85	$1,503.99
Grading and packing	Ctn.	1769	$1.10	$1,946.34
Container	Ctn.	1769	$0.75	$1,327.05
Marketing	$	23002	$0.08	$1,840.18
Total Harvesting and Marketing			$2.78	$6,617.56
Total Variable Costs (TVC)				$15,005.31

the annual fixed cost of irrigation was estimated at $100.96 per acre (Table 4).

Tractor, plow, disk, herbicide applicator, bedder, transplanter, cultivator, sprayer, side dresser, and hoop buildings were all factored into the investment fixed cost estimates (Table 5). The hoop buildings and tractors were the most expensive pieces of equipment. Although we used five years as the hoop houses' lifespan, empirical evidence shows that they can

Table 4: Cost of drip irrigation to produce bell pepper under colored shade nets in the southeast, USA, 2022.

Description	Material Investment ($)	Years	Depreciation ($)	Interest ($)	Taxes & Insurance ($)
Pipe & fittings	2100.00	20	105	74	15.75
Storage tanks	4725.00	10	473	165	35.44
Well (8")	25200.00	25	1008	882	189.00
Injection system	6300.00	10	630	221	47.25
Installation	2100.00	20	105	74	15.75
Total investment	40,425.00		2,321	1,415	303.19
Total annual fixed cost of irrigation	4,038.56				
Total fixed cost per acre	100.96				

Table 5: Investment and Annual Fixed Costs of Producing Bell Pepper Under Colored Shade Nets in the Southeast, USA, 2022.

Item	**%**	**MC**	**SV**	**YOL**	**Depreciation**	**Int**	**Tax & Ins**	**FC/AC.**
Tractors (60-89 hp, MFWD 75)	25%	73500	14700	15	980	717	154	46
Chisel Plow-Rigid 24’	25%	23100	4620	10	462	225	49	18
Disk Harrow 14’	25%	23100	4620	10	462	225	49	18
Appl. Herb	25%	1785	357	10	36	17	4	1
Bedder	25%	3150	630	10	63	31	7	3
Transplanter	25%	12600	2520	10	252	123	26	10
Cultivator 4R-30	25%	6300	1260	10	126	61	13	5
Sprayer (Direct/Layby) 8R-30	25%	15750	3150	10	315	154	33	13
Side dresser	25%	4725	945	10	95	46	10	4
Hoop houses (25'x48'x12.5')	25%	846,000	169,200	5	33,840	8,249	1,777	1,097
Total		252,503	50,501		36,630	9,848	2,121	1,215
Interest on Investment (Ave. Inv. X Int. Rate)				$9,847.60				
Taxes and Insurance (Ave. Inv. X .014)				$2,121.02				
Total Annual Fixed Costs				$48,598.82				
Total Annual Fixed Costs Per Acre				$1,214.97				
Note:	MC denotes material costs S.V. denotes salvage value YOL denotes years of life Int denotes interest % denotes the percentage of time for this crop.							

endure ten or more years with good management. Our studies depicted that investment interest was $9,847.60, while taxes and insurance were $2,121.02. The total annual fixed cost was $48,598.82. Finally, the total fixed cost per acre, the total yearly fixed cost divided by 40 acres, was $1,214.97 (Table 5).
In the southeast United States, the projected and base budgeted net revenue for growing bell peppers under colored shade nets was $8,273 per acre. According to this research, the best return that can occasionally occur is $13,046 per acre, while the worst is $3,500 per acre. On the other side, the optimistic return with a 16% chance was $11,455, and a 31% chance was $9,864 per acre. Additionally, with a 31% and 16% chance, the pessimistic returns were $6,682 and $5,091 per acre, respectively. Lastly, the net return overcosts was $8,273 per acre (Table 6).
A recent study of conventional bell pepper production conducted at the University of Georgia depicted a net return of $4,931 per acre, compared to $8,273 for the colored shade nets system, representing an increase of 168% (Fonsah et al., 2022).
Five distinct pricing and seven case scenarios - "Best" (7%), "Worst"(7%), "Optimistic" (16% and 31%), "Expected" (50%), "Pessimistic" (31% and 16%) - were used in the sensitivity analysis. The starting cost per box was $13. Prices at the bottom rise by 10% and 20%, while prices at the top fall by 10% and 20%, respectively (Table 7). The grower's anticipated

Table 6: Price sensitivity risk-rated returns of producing bell pepper under colored shade nets in the Southeast USA, 2022.

	Best	Optimistic		Expected	Pessimistic		Worst
Returns ($)[1]	13,046	11,455	9,864	8,273	6,682	5,091	3,500
Chances[2]	7%	16%	31%	50%			
Chances[3]				50%	31%	16%	7%
Chances for Profits		99%		Net Returns over total costs ($)			8,273

[1]Net return level (Top row)
[2]The chance to obtain this level or more (Middle row)
[3] The chance to obtain this level or more (Bottom row)

Table 7: Price Sensitivity Analysis Over Total Cost of Producing Bell Pepper Under Colored Shade Nets in the Southeast USA, 2022.

Price ($/Carton)	Best	Optimistic		Expected	Pessimistic		Worst	Profit chance
	7%	16%	31%	50%	31%	16%	7%	
10.40	8712	7250	5788	4326	2864	1402	-60	93%
11.70	11268	9744	8221	6698	5174	3651	2128	99%
13.00	13046	11455	9864	8273	6682	5091	3500	99%
14.30	16435	14770	13106	11441	9777	8112	6448	99%
15.60	19042	17299	15556	13813	12070	10327	8585	99%

Note: Profits under all scenarios are expressed in USD.

Table 8: Break-Even (B.E.) cost of producing bell pepper under colored shade nets in the Southeast USA, 2022.

Description	Total Cost
B.E. pre-harvest variable cost per box	$ 4.14
BE harvesting & marketing cost per box	$ 3.37
BE fixed costs per box	$ 1.29
BE total budgeted cost per box	$ 8.79
BE yield per acre (boxes)	$1329.62

net return at $13 per carton of bell peppers is $8,273 per acre, with a 99% chance of success. With a 93% possibility of profit at $10.40 per box, the estimated return drops to $4,326 per acre, and in the worst-case scenario, the grower might incur a net loss of $60 per acre. On the other hand, a net return was $13,813/acre if the grower obtains $15.60/carton of bell pepper produced under the colored shade nets system (Table 7).

Break-even (B.E.) analysis is crucial because it identifies the point at which an organization is neither making profits nor incurring losses. In the southeast region of the United States, the B.E. yield for growing bell pepper under colored shade nets is 1,330 cartons per acre. Any production below 1,330 boxes will result in a loss for the company or grower (Table 8). The study further shows a B.E. total cost per box of $8.79 and a B.E. pre-harvesting variable cost of $4.14 per box (Table 8).

CONCLUSION

Vegetables and pulses are important industries to the U.S. agricultural economy. However, studies have shown that for the past few decades, vegetable import demand has consistently outpaced export resulting in a $9.41 million vegetable trade deficit in 2021 (Davis and Lucier (2021). Bell pepper (*Capsicum annum* L.) is one of the top ten commercial vegetables in the state of Georgia. Our study is based on research on bell pepper production under colored shade nets conducted by the University of Georgia in 2015 and 2016. The study was conducted to determine if plant growth and fruit yields were superior to those in the conventional system. Our economic study aims to assess if the bell pepper produced under the colored shade nets will provide a superior return on investment (ROI) to the growers vis-à-vis the conventional system. The expected base budgeted net revenue for producing bell pepper under colored shade nets was $8,273 per acre, with a 99% chance of profit. However, a recent study of conventional bell pepper production depicted a net return of $4,931 per acre, an increase of 168% in profit for the colored shade net system (Fonsah et al., 2022).

Additionally, a sensitivity analysis showed that the grower's anticipated net return at $13 per carton of bell pepper was $8,273 per acre. In a worst-case scenario, the grower may incur a net loss of $60 per acre at $10.40 per box, which reduces the estimated return to $4,326 per acre. However, if the producer sold each carton of bell pepper grown using colored shade nets at $15.60, they might make a net profit of $13,813 per acre. The total fixed costs, including tractor, plow, disk, herbicide applicator, bedder, transplanter, cultivator, sprayer, side-dresser, and hoop houses, were $1,214.97 per acre. Although the total drip irrigation investment cost was $40,425, after deducting depreciation, interest, taxes, and insurance, the total fixed cost was $100.96 per acre.

According to the study's findings, switching to the production of colored shade nets would result in a 168% higher profit margin than the traditional method. The takeaway from this study is that growers in the southeast region should start thinking out of the box by adopting new agricultural practices that would lead to increased productivity and profitability. Extension professionals could gradually disseminate this information to growers. Replicating the research and sharing results with growers would be the easiest way to educate and encourage farmers to adopt this new agricultural technology.

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