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Economic Productivity and Profitability Analysis for Whiteflies and Tomato Yellow Leaf Curl Virus (TYLCV) Management Options

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Abstract

The United States is the second largest producer of tomatoes (Lycopersicon esculentum Mill.) in the world. In the U.S. tomato is produced for fresh and processed markets, respectively, and both markets contribute over $2 billion in annual farm cash receipts (Wells, 2012). Tomato yellow leaf curl virus (TYLCV), transmitted by whiteflies, is a major threat to tomato production in the United States and around the world (Polston et al. 1999, Moriones and Navas-Castillo, 2000; Lefeuvre et al., 2010). The spread of the virus in the field is directly correlated to increase in B. tabaci populations (Rakib et al., 2011; Adi et al., 2012). Infected plants display severe symptoms, are less vigorous, and produce fruits with reduced market value. It is common to experience yield losses of up to 100% in affected fields (Rakib et al., 2011; Pan et al., 2012; Wu et al., 2012, Srinivasan et al. 2012). There are several management tactics available. However, there is no single most effective 'silver bullet' management tactic to manage whiteflies and TYLCV. Therefore, it is vital to integrate several tactics to suppress pest and virus incidences and to boost yields. This study investigates the economic productivity and profitability of combining management options such as insecticides, reflective mulch, and virus-resistant cultivars for whiteflies and TYLCV management. The economic models adopted for this study include farm enterprise budgeting, sensitivity analysis and break-even analysis. Results show that total pre-harvest variable cost was $4,200/ac and the expected net return was $1,958/ac was attainable 50% of the time.

Keywords: tomato, enterprise budget, variable cost, fixed costs,

Introduction

The United States is among the top five tomato (Lycopersicon esculentum Mill.) producing countries in the world with a production value of 12.9 million metric tons (MT) in 2010, equivalent to 11.7 percent of world production (Ranking America, 2012; FAOSTAT, 2010).

In the USA, tomato ranks 3rd in terms of vegetable production after onion and head lettuce. These three vegetables contribute to 40 percent of the total vegetable production, "excluding potatoes, sweet potatoes and mushrooms" and generating 32 percent of vegetable farm income. For instance, about 32.6 billion pounds of tomatoes were produced in 2014 contributing 25.2 percent of total commercial vegetables and pulses (Wells, Bond and Thorns bury, 2015). According to Fonsah and Hudgins (2007), fresh market tomatoes production was 156.1 million pounds in 1978. This figure rapidly increased to about 3.0 billion pounds between 2009 and 2012. Thereafter, annual production experienced a slight decline to 2.6 billion and 2.7 billion pounds in 2013 and 2014, respectively.

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On the other hand, tomatoes are also the leading processed vegetable crop in the United States (Kelley and Boyhan, 2006). The production of processed tomato was on the average 26.2 billion pounds during the period of 2009 and 2012. In 2013, this figure was 24.6 billion pounds, and reached 29.3 billion pounds in 2014. In 2015, an estimated 30 billion pounds of tomatoes was contracted by the U.S. processors –an 11 percent increase compared to 2014 (Wells, Bond and Thornsbury, 2015). At the state level, tomato is one of the most important commercial vegetable crop in Georgia. For the past decade, it ranked amongst ten top vegetables in terms of farm gate value. For instance, in 2009, it generated $64 million while in 2014, tomato ranked 7th out of the 35 different conventional vegetables produced in the state and contributed $54 million or 5.3 percent of the total vegetable value. From 2009 to 2014, tomato contributed over $265 million in terms of farm gate value to the Georgia economy (GFGVR, 2015). Import and Export Trend Although the United States is the second leading producer of tomatoes in the world, it still needs to import large volumes to add to the domestic shortage (Fonsah and Hudgins, 2007). In 2016, the U.S. imported 323 million pounds of fresh market tomatoes equivalent to 28 percent of all fresh vegetable. In 2007, the United States was the highest importer of tomato in the world by importing 2.36 billion pounds estimated at $1.07 billion (ERS, USDA, 2010). Moreover, the North American Free Trade Agreement (NAFTA) was instrumental in increasing trade between the U.S., Mexico and Canada (Fonsah and Hudgins, 2007). The U.S. imported 2.3 billion pounds and 287.2 million pounds of fresh tomato from Mexico and Canada, respectively. A small amount of tomato entering the U.S. comes from Netherlands, Dominican Republic, Israel and Italy. Roughly 6 percent of processed tomatoes consumption in the U.S., such as ketchup, paste and sauces are ordered from other countries (ERS, USDA, 2010; Wells, 2012; Wells, Bond and Thornsbury, 2015).

In 2013, the U.S. sold a total of 467 million pounds of tomatoes (FAOSTAT, 2013), equivalent to 4 percent of the world's total tomatoes sold to other countries with a net worth of $365 million in 2014 (World's top export, 2016; Bentley, 2015). Canada and Mexico are the U.S. top tomato trade partners where 243.3 and 127.3 million pounds were shipped to in 2009 respectively (ERS, USDA, 2010).

Tomato yellow leaf curl virus (TYLCV)

Tomato yellow leaf curl virus (TYLCV), which causes yellow leaf curl disease in tomato, is a major threat to tomato cultivation Worldwide (Czosnek, 2008). TYLCV is transmitted by the sweetpotato whitefly, Bemisia tabaci (Genn.) (Moriones and Navas-Castillo, 2000; Lefeuvre et al, 2010). TYLCV was first identified in Israel in late 1950s and is now documented throughout the world (Czosnek, 2008). In the United States, it was introduced to Florida (Polston et al. 1994, 1999) possibly from the Caribbean islands (Alvarez and Abud-Antún, 1995). Subsequently the virus spread into Georgia and the Carolinas (Momol et al., 1999; Polston et al., 2002; Ling et al., 2006). More recently the virus was detected in Texas (Isakeit et al., 2007) and California (Rojas et al., 2007). The incidence of TYLCV has been steadily increasing ever since. Though there is no official estimate due to TYLCV-induced losses in tomato, losses are assumed to be in tens of millions of dollars with quite a few fields suffering up to 100% yield loss. Tomato production in the United States is predominantly in the field. In many parts of the world, TYLCV also infects greenhouse tomato due to spikes in B. tabaci populations (Rakibet al., 2011; Adi et al., 2012). Tomatoes infected by the virus exhibit different forms of symptoms such as stunting and flower abortion, curling of the leaflet margins, yellowing of young leaves, inferior quality of the fruits and decreased yields. The symptoms on the plant also depends on many factors including, the selected cultivar, management options adopted, and environmental conditions (Moriones and Navas-Castillo, 2000; Wu et al., 2012; Chen et al., 2013; Rakibet al., 2011; Pan et al., 2012)

Strategies for managing whiteflies and TYLCV

Management of TYLCV is challenging and costly. A combination of management options is necessary to successfully manage the disease and limit losses. For instance, a combination of cultural and chemical are required (Polston and Lapidot, 2007; Van Brunschot et al., 2010).

Resistant cultivars & mulches

Planting TYLCV-resistant cultivars is probably the most important management option that growers have available today. TYLCV resistance to cultivated tomato was successfully introgressed following breeding with numerous wild Solanum species (Lapidot and Friedman, 2002). Several commercially available TYLCV-resistant cultivars such as Tygress, Shanty, Security, and Inbar are currently available in the southeastern USA, and a number of breeding accessions also are in the pipeline. The resistance imparted is generally mediated by a single semi-dominant gene (Ty).

These cultivars are not immune to the virus and accumulate TYLCV, but they are known to exhibit mild symptoms following TYLCV infection. However, these cultivars do not possess any resistance to whiteflies and support substantial whitefly populations (Srinivasan et al., 2012; Legarrea et al., 2015). Several resistant cultivars are available, but less than one-third of the production acreage is planted with resistant cultivars. There are a number of reasons attributed as to why the growers have not resorted to planting resistant cultivars. Growers believe that the resistant cultivars have poor horticultural attributes when compared with the standard TYLCV susceptible tomato cultivars. However, the recent breeding efforts have resulted in currently resistant cultivars with desirable horticultural attributes that are comparable to the grower-preferred TYLCV susceptible cultivars.

Resistant cultivars do not possess any resistance to whiteflies and support substantial whitefly populations. Whitefly feeding, besides virus transmission, can also induce physiological disorders such as irregular ripening on the fruits. Therefore, insect populations should be managed to obtain marketable yields. One of the options is to use reflective mulch. Reflective metallic mulch is shown to reduce the incidence of pest species including whiteflies (Csizinszky et al., 1999; Nyoike et al., 2008, Simmons et al., 2010). Reflective mulch is known to interfere with insects landing on tomato plants and subsequently reduce the spread of insect-transmitted viruses. There are also several drawbacks associated with the usage of reflective mulch. It is more expensive than standard mulches such as black and white plastic mulch. So far, the there is no reliable data available to clearly justify the extra cost associated with using reflective mulch and this study attempts to address the issue.

Insecticides

The other option to reduce whitefly populations is to use insecticides. Insecticide applications are routinely used to manage whitefly populations and reduce TYLCV incidence. A number of insecticide classes such as neonicotinoids, pymetrozine, ryanodinereceptor targets, molt inhibitors, pyrethroids, and plant-derived compounds are used in rotations to manage whitefly populations (Polston, 2003, Schuster et al., 2010; Schuster 2011). Neonicotinoids have been extensively used to manage whiteflies and TYLCV in the Southeastern United States. Studies in Florida and Georgia have already documented resistance to neonicotinoids, such as imidacloprid and thiamethoxam (Polston et al., 2003; Schuster et al., 2010). A number of alternative insecticide chemistries have become available recently, usefulness of one such diamide chemical, cyantraniliprole, was evaluated in this study.

Therefore it is clear that the whiteflies and TYLCV cannot be managed with a single management tactic as there is no ‘silver bullet’. Combining management options is vital to ensure sustainability in tomato production in southeastern states such as Georgia and Florida. It then becomes imperative to assess whether the economics of integrating such management tactics in relation to yield boosts is justifiable. Studies documenting econometric analyses of integrating multiple management options are not available for this system exclusively. However, the economic justification for using insecticides alone to managing whiteflies in tomato has been studied extensively. Engindeniz (2006) analyzed the economics of pesticide use on processed tomatoes grown in Torbali-Izmir to determine the problems of pesticide use. This study, like others, captured both variable costs (VC) and fixed costs (FC) respectively (Fonsah and Hudgins, 2007; Fonsah et al., 2008; Fonsah and Chidebelu, 2012; Fonsah et al. 2010). More-so, the study utilized 3% simple interest rate in calculating the VC since tomato production cycle in Turkey is six months long. Engindeniz and Cosar (2013) not only used the same methods to analyze the farm-level economics of pesticide use on the processed and table tomato growing in selected regions of Turkey, they also estimated the breakeven yield for the production of tomatoes and adopted 4.5% interest rate to calculate VC. Yardim and Edwards (2003), conducted an economic study comparing “pesticide application regimes for processing tomatoes in Ohio, USA in 1994 and 1995”. Their study incorporated cost/benefit ratios in its calculations.

On the other hand, several studies adopted the risk rated enterprise budgets analysis to determine the lucrativeness of adopting new technology in fruits and vegetable production strategies (Fonsah et al., 2010; Awondo and Fonsah, 2012; Fonsah and Huggins, 2007; Fonsah et al. 2008). For instance, Fonsah et al. (2012) developed the economics of Tomato spotted wilt Virus (TSWV) management techniques. This study revealed that tomato grower’s profitability margin was twice as much if they adopted TSWV management techniques in their operation than if they maintained status-quo, i.e. continued with the conventional agricultural practices.

Economic Evaluation

Although several studies discussed the economic evaluation for preventing tomato with respect to pesticide use (Awondo and Fonsah, 2012; Engindeniz, 2006; Engindeniz and Cosar, 2013; Fonsah and Huggins, 2007; Fonsah et al. 2008; Fonsah et al., 2010; Fonsah et al., 2012; Fonsah, 2014; Yardim and Edwards, 2003), exclusion screen.

(Taylor et al, 2001), intercrop and cultivars (Adeniyi, 2011; Cembali et al, 2003; Cembali, Folwell and Wandschneider, 2004; Rudi et al., 2010), there were limited recent studies that provided economics analyses of TYLCV prevention. As a result, the objective of this study is to develop an economic productivity and profitability analysis aimed at determining the financial and economic viability if any of managing TYLCV.

Material and methods

This experiment was conducted at the Coastal Plains Research Station in Tifton, GA on Horticulture Farm during the summers of 2013-2015. We specifically evaluated the use of TYLCV-resistant cultivars, metallic silver mulch, and the use of the insecticides AdmirePro (imidacloprid) and Verimark (cyantraniliprole) relative to white mulch, a TYLCV-susceptible tomato, and a no insecticide check, respectively. The experimental response variables measured were whitefly adult, immature and egg incidence, TYLCV symptom severity, and marketable yield. The experiments were split-split-split plot designs with four replicates so that both main mulch treatment effects and treatment interactions could be compared relative to providing TYLCV and whitefly control. Reflective mulch acted as the main effect, insecticides acted as the sub effect, and TYLCV resistant cultivars acted as the sub-sub effect. Tomato cultivars used included Shanty (Hazera, Coconut Creek, FL, USA), Security (Harris Moran, Rochester, NY, USA), Tygress (Seminis Vegetable Seeds, St. Loius, Missouri, USA), and the susceptible cultivar FL-47 (Seminis Seeds, California, USA). Types of mulch used were reflective (Agricultural Metallized Mulch Film, Imaflex USA, Thomasville, NC) and a standard non-reflective white mulch (Intergro, Inc., Clearwater, FL). Insecticides used were cyantraniliprole (Verimark 20 SG, Dupont Crop Protection, Wilmington, DE) applied at 13.5 fl. oz. per acre, imidacloprid (AdmirePro 4.6F, Bayer CropScience, Monheim am Rhein Monheim, Germany Global Headquarters) at 10.5 fl. oz. per acre and water as a control. Each treatment was replicated 4 times.

Tomato transplants were purchased from Lewis Taylor Farms in Tifton, GA. Transplants were planted in raised beds 9.14 m by 1.83 m beds separated by a 1.52 m alleyway. Each main treatment plot had three adjacent subsections of four 9.14 m by 1.83 m beds. Reflective mulch was applied to all beds in the main treatment plots. White mulch effect was achieved by spray painting reflective mulch with white paint. For the sub plot insecticide treatments, holes were drenched with aforementioned insecticide treatments in one of the three randomly selected subsections prior to transplant. The sub-subplot treatments were randomly assigned single beds in the subplots with each of the four aforementioned tomato cultivars. Plants were irrigated with drip irrigation installed underneath the plastic beds and tomatoes were staked to maintain plant vigor. Fungicides were applied as needed throughout the course of the study. Yield data were taken at the end of the study. Over the course of several harvests throughout the season, fruit was graded, sorted into various fruit sizes (XL, L, M, S, and unmarketable), and weighed.

The economic models adopted for this study include farm enterprise budgeting, sensitivity analysis and cost-benefit analysis. Farm enterprise budgeting is the most widely adopted non-stochastic approach for evaluating profitability due to its simplicity. This approach combines revealed and stated data from farm operations and inputs to estimate cost, revenue and profitability of producing tomato under specific agricultural practices such as insecticide treatments, virus-resistant cultivars, and mulches. Estimated cost and returns stemming from the enterprise budget were used to evaluate and develop price sensitivity analysis and net return sensitivity analysis based on total cost. Finally, cost-benefit analysis was conducted to determine different thresholds break-even points.

Economics Assumptions: Five price and yield scenarios were adopted, thus: best, optimistic, expected, pessimistic and worst. For a more details, see Fonsah and Hudgins 2007 and Fonsah, 2014. We assumed 6.5% interest rate in the fixed cost and irrigation cost calculations. The expected cost per box of tomato was $8 whereas the price sensitivity analysis used the expect cost of $8/box as base while $6 and $7/box were considered negative or decrease and $9 and $10/box as increase. The expected yield of 1,700 boxes/ac was obtained from field-harvested data and broken down into five afore-mentioned scenarios as well. We assumed 13% and 31% decrease in yields as negative and 11% and 19% increase as positive.

Results and Discussions

The inputs used in the economic analysis of insecticides for the management of whitefly-transmitted TYLCV in tomato production were slightly different from the conventional tomato production practices. For instance, the planting materials were TYLCV-resistant cultivars, which cost $466/ac. Silver mulch was $513/ac while insecticide used to control white flies was $159/ac. The combined fertilizer cost was $692/ac. Fumigation, fungicides and labor costs were $570, $189 and $550/ac respectively. Total pre-harvest variable cost (P-H VC) was $4,200/ac (Table 1).

Table 1: Pre-variable costs of producing tomatoes in the presence of whitefly-transmitted *Tomato yellow leaf curl virus* (TYLCV) in the Southeast USA, 2017.

Pre-Variable Costs	**Unit of application**	**Quantity of application**	**Price per application ($/unit/year**	**Total cost (US$/ac/ year)**
TYLCV-resistant lines plants	Thou	3.97	117.50	466.48
Lime & gypsum	Ton	1.50	108.00	162.00
Fertilizer granular1	Ton	1.00	350.00	350.00
Fertilizer liquid (7-0-7)	Gal	120.00	1.50	180.00
Plastic mulch2	Roll 4000'	2.23	230.00	512.90
Fumigation	Acre	200.00	2.85	570.00
Insecticide + TYLCV3	Fl. Oz	24.50	6.50	159.25
Fungicide	Appl.	3.00	63.33	189.99
Herbicide	Acre	1.90	31.34	59.55
Stakes	Thou	4.00	40.00	160.00
String	Acre	30.00	1.55	46.50
Labor, machine operation	Hr.	5.00	7.00	35.00
Labor, production transplant	Hr.	100.00	5.50	550.00
Crop Insurance	Acre	1.00	140.00	140.00
Consultant	Acre	1.00	70.00	70.00
Cleanup (plastic & stakes)	Acre	1.00	150.00	150.00
Machinery	Acre	1.00	25.76	25.76
Irrigation	Acre	1.00	220.83	220.83
Land rent4	Acre	1.00	0.00	0.00
Interest on Operation Capital.	$	4048.25	0.08	151.81
Pre-Harvest Variable Costs5		**$4,200.06**		

1Utilization of fertilizers and quantities was based on soil test.
2Metalized Silver plastic mulch was used for this study.
3AdmirePro (Imidacloprid) and Verimark (cyantraniliprole) were used for the trials.
4Land rent was excluded because the price varies significantly in Georgia.
5Totals may not round up because of rounding errors.

A sensitivity analysis based on total cost of production depicted that an expected net return of producing tomatoes in the presence of TYLCV was $1,958/ac and obtainable 50% of the time. The result further showed that $-887 may be obtained 7% of the time in a worst case scenario while a rare net return of $4,802 is also realizable 7% of the time. This also means that good agricultural practices and adherence to management recommendations from research and extension scientists are necessary and sufficient conditions for success (Table 2).

Table 2: Sensitivity Net Return of producing tomatoes in the presence of whitefly-transmitted Tomato yellow leaf curl virus (TYLCV) in the Southeast USA, 2017

Net return levels (TOP ROW); The chances of obtaining this level or more (MIDDLE ROW); and The chances of obtaining this level or less (BOTTOM ROW).							
Best		**Optimistic**	**Expected**		**Pessimistic**	**Worst**	
Returns ($)	4,802	3,854	2,906	1,958	1,010	62	-887
Chances (%)		7%	16%		31%	50%	
Chances (%)		50%	31%		16%	7%	
Chances for Profit		**85%**		**Net Revenue**		**$1,958**	

These results were based on an expected yield of 1,700 boxes/ac and an expected price of $8.00/box. The results also depicted that there was 85% chances of obtaining a profit adopting the appropriate recommended whitefly and TYLCV management production techniques. Price volatility is the most unpredictable in fresh produce marketing.

A price sensitivity analysis conducted assuming five case scenarios, i.e., what would happen if the price/box dropped to $7 or $6 respectively? On the other hand, what would happen if the price instead increased from $8/box to $9 or $10/box? By so doing, growers can gauge the risk involved with price fluctuations. Our results show that a decrease in price from $8/box of tomato would reduce net profit from $1,958/ac to $258/ac. More so, a 25% fall in price, i.e. if the price fell from $8/box to $6/box, the grower would obtain a loss of $-1,442/ac in his tomato business.

Table 3: Price Sensitivity Analysis of producing tomatoes in the presence of whitefly-transmitted *Tomato yellow leaf curl virus* in the Southeast USA, 2017.

Price	**Best**		**Optimistic**	**Expected**	**Pessimistic** 1,700 lbs.		**Worst**	**Net Returns**	**% Profit**
$6.00	1192	314	-564	-1442	-2320	-3198	-4076	-1442	21
$7.00	2982	2074	1166	258	-651	-1559	-2467	258	56
$8.00	4802	3854	2906	1958	1010	62	-887	1958	85
$9.00	6647	5651	4654	3658	2661	1665	668	3658	97
$10.00	8514	7462	6410	5358	4306	3254	2201	5358	99

However, if the price were to increase from $8/box to $9/box, i.e. 12.5% increase in price would lead to an increase net return of $3,658/ac and to $5,358/ac if the price increased to $10/box, i.e., 25% increase (Table 3). We also investigated the break-even cost of producing whitefly-transmitted tomato yellow leaf curl virus tomatoes in the southeast. A break-even analysis is simply a safety net analysis that tells us the borderline where we are not losing or making profit. In order words, total revenue equal total cost of production. Our results show that the pre-harvest variable cost per carton is $2.47 whereas the break-even total cost of production per carton is $6.85. This means, if the price per cartons is lower than $6.85 the grower will be losing money.

Table 4: Break-even (BE) cost analysis per carton of producing tomatoes in the presence of whitefly-transmitted *Tomato yellow leaf curl virus*, 2017.

BE Pre-harvest variable cost per carton	2.47
BE Harvest & marketing cost per carton	3.80
BE Fixed Cost per carton	0.58
BE Total budgeted cost per carton	6.85
BE Yield per acre (cartons)	1,455

An easier way to look at it is to make sure the price per carton is higher than $6.85 to be profitable (Table 4). In Table 3, with a price of $7/box, expected net revenue decreased from $1,958 to barely $258/ac. On the other hand, table 4 shows the break-even yield per acre is 1,455 boxes. Any yield less than 1,455 boxes/ac will results in negative net returns (Fonsah, 2014; Fonsah and Hudgins, 2007).

Conclusion

Tomato yellow leaf curl virus (TYLCV) is a major problem to tomato farmers. The virus can destroy an entire tomato farm, reduce production and profitability if not managed. Studies conducted at the Coastal Plain by the University of Georgia scientists show that farmers can successfully produce tomato if a combination of management tactics is adopted including resistant cultivars, reflective mulch, and insecticides. The inputs used in the economic analysis of integrating multiple management tactics adopted for the management of whitefly-transmitted *Tomato yellow leaf curl virus* in tomato production were slightly different from the conventional tomato production practices.

A sensitivity analysis based on total cost of production depicted that an expected net return of producing tomatoes in the presence of whiteflies and TYLCV was $1,958/ac and obtainable 50% of the time. Results show that a fall in price from $8/box of tomato would reduce net profit from $1,958/ac to $258/ac.

More so, a 25% fall in price, i.e. if the price fell from $8/box to $6/box, the grower would obtain a loss of $-1,442/ac in his tomato business. However, if the price were to increase from $8/box to $9/box, i.e. 12.5% increase in price would lead to an increase net return of $3,658/ac and to $5,358/ac if the price increased to $10/box, i.e., 25% increase. Our results show that the pre-harvest variable cost per carton is $2.47 whereas the break-even total cost of production per carton is $6.85.

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