Food Distribution Research Society

Journal of Food Distribution Research
Volume 50, Issue 1

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

Esendugue Greg Fonsah,[a①] Chen, Yu,[b] Stan Diffie,[c]
Rajagopalbabu Srinivansan,[d] and David Riley[e]

[a]*Professor, Department of Agricultural Economics,*
University of Georgia
Tifton, GA 31793, USA

[b]*Graduate Student, Department of Agricultural Economics,*
University of Georgia
Athens, GA 30206, USA

[c]*Research Professional, Department of Entomology,*
University of Georgia
Tifton, GA 31793, USA

[d]*Associate Professor, Department of Entomology,*
University of Georgia
Tifton, GA 31793, USA

[e]*Professor, Department of Entomology,*
University of Georgia
Tifton, GA 31793, USA

Abstract

Tomato yellow leaf curl virus (TYLCV), transmitted by whiteflies, is a major threat to tomato production worldwide (Moriones and Navas-Castillo, 2000; Lefeuvre et al., 2010). Yield losses up to 100% in affected fields are common (Rakib et al., 2011; Pan et al., 2012; Wu et al., 2012). This study investigates the economic productivity and profitability of treatment for TYLCV management. The economic models adopted for this study include farm enterprise budgeting, sensitivity analysis, and break-even analysis. Results show that total preharvest variable cost was $4,200/acre and the expected net return of $1,958/acre was attainable 50% of the time.

Keywords: enterprise budget, fixed costs, productivity, profitability, tomato, TYLCV, variable cost, white flies

①Corresponding author: Tel: 229-386-3512
Email: gfonsah@uga.edu

Introduction

Worldwide, fresh market tomato (*Lycopersicon esculentum* Mill.) production was 156.1 million pounds in 1978 (Fonsah and Hudgins, 2007), rising rapidly to about 3.0 billion pounds between 2009 and 2012. Thereafter, annual production experienced a slight decline to 2.6 billion pounds in 2013 and 2.7 billion pounds in 2014. Tomatoes are also the leading processed vegetable crop in the United States (Kelley and Boyhan, 2006), with average production of 26.2 billion pounds during 2009–2012, rising to 24.6 billion pounds in 2013 and 29.3 billion pounds in 2014. In 2015, an estimated 30 billion pounds of tomatoes were contracted by U.S. processors—an 11% increase compared to 2014 (Wells, Bond, and Thornsbury, 2015).

Background

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 sweet potato 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, McGovern, and Brown, 1999) possibly from the Caribbean (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 and California (Isakeit et al., 2007). Incidence of TYLCV has been steadily increasing ever since.

Though there is no official estimate of 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. U.S. tomato production is predominantly in the field. In many parts of the world, TYLCV also infects greenhouse tomato due to spikes in *B. tabaci* populations (Rakib et al., 2011; Adi et al., 2012). Tomatoes infected by the virus exhibit various symptoms such as stunting and flower abortion, curling of the leaflet margins, yellowing of young leaves, inferior fruit quality, and decreased yields. Plant symptoms depend on many factors including the selected cultivar, management options, and environmental conditions (Moriones and Navas-Castillo, 2000; Wu et al., 2012; Chen et al., 2013; Rakib et 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 management tactics is required (Polston and Lapidot, 2007; Van Brunschot et al., 2010).

Resistant Cultivars and Mulches

Planting TYLCV-resistant cultivars is probably the most important management option available to growers 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 United States, and a number of additional breeding accessions are in the pipeline. The resistance imparted is generally mediated by a single semidominant gene (*Ty*). These cultivars are not immune to the virus and accumulate TYLCV, but they are known to exhibit only 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 production acreage is planted with resistant cultivars. There are several reasons why growers have not resorted to planting resistant cultivars. Growers believe that the resistant cultivars have poor horticultural attributes compared with the standard TYLCV-susceptible tomato cultivars (Srinivasan et al., 2012). However, recent breeding efforts have resulted in currently resistant cultivars with horticultural attributes comparable to grower-preferred, TYLCV-susceptible cultivars.

Economic Evaluation

Although several studies have discussed the economic evaluation for preventing tomato with respect to pesticide use (Awondo et al., 2012; Engindeniz, 2006; Engindeniz and Cosar, 2013; Fonsah and Hudgins, 2007; Fonsah et al. 2008; Fonsah et al., 2010; Fonsah and Chidebelu ., 2012; Yardim and Edwards, 2003), exclusion screens (Taylor et al, 2001), intercropping and cultivars (Adeniyi, 2011; Cembali et al, 2003; Cembali, Folwell and Wandschneider, 2004; Rudi et al., 2010), limited recent studies have provided economics analyses of TYLCV prevention. This study developed an economic productivity and profitability analysis aimed at determining the financial and economic viability (if any) of managing TYLCV.

Methods

This experiment was conducted at the Coastal Plains Research Station in Tifton, Georgia, on the Horticulture Farm during the summers of 2013 through 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 no insecticide check, respectively. 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 subeffect, and TYLCV-resistant cultivars acted as the subsubeffect.

Tomato cultivars used included Shanty (Hazera, Coconut Creek, FL), Security (Harris Moran, Rochester, NY) Tygress (Seminis Vegetable Seeds, St. Loius, Missouri), and the susceptible cultivar FL-47 (Seminis Seeds, California,). Types of mulch used were reflective (Agricultural Metallized Mulch Film, Imaflex USA, Thomasville, NC) and a standard nonreflective white mulch (Intergro, Inc., Clearwater, FL). Insecticides used were cyantraniliprole (Verimark 20 SG, Dupont Crop Protection, Wilmington, DE) applied at 13.5 fl oz/acre, imidacloprid (AdmirePro 4.6F, Bayer

CropScience, Monheim am Rhein Monheim, Germany Global Headquarters) at 10.5 fl oz/acre, and water as a control. Each treatment was replicated four times.

Results

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

Table 1. Preharvest Variable Costs of Producing Tomatoes in the Presence of Whitefly-Transmitted Tomato Yellow Leaf Curl Virus (TYLCV) in the Southeast United States, 2017

Preharvest Variable Costs	Unit of Application	Quantity of Application	Price per Application ($/unit/year)	Total Cost ($/acre/year)
TYLCV-resistant line plants	Thousand	3.97	117.50	466.48
Lime and gypsum	Ton	1.50	108.00	162.00
Fertilizer, granular[a]	Ton	1.00	350.00	350.00
Fertilizer, liquid (7-0-7)	Gallon	120.00	1.50	180.00
Plastic mulch[b]	4000-foot roll	2.23	230.00	512.90
Fumigation	Acre	200.00	2.85	570.00
Insecticide + TYLCV[c]	Fl oz	24.50	6.50	159.25
Fungicide	Application	3.00	63.33	189.99
Herbicide	Acre	1.90	31.34	59.55
Stakes	Thousand	4.00	40.00	160.00
String	Acre	30.00	1.55	46.50
Labor, machine operation	Hour	5.00	7.00	35.00
Labor, production transplant	Hour	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 and 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 rent	Acre	1.00	0.00	0.00
Interest on operation capital.	$	4048.25	0.08	151.81
Preharvest variable costs[d]				**4,200.06**

[a] Fertilizer use and quantities should be based on soil test.
[b] Metalized silver plastic mulch was used for this study.
[c] AdmirePro (Imidacloprid) and Verimark (cyantraniliprole) were used for the trials.
[d] Totals may not round up because of rounding errors.

A sensitivity analysis based on total cost of production indicated that the expected net return from producing tomatoes in the presence of TYLCV, obtainable 50% of the time, was $1,958/acre. 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 of Net Return of Producing Tomatoes in the Presence of Whitefly-Transmitted Tomato Yellow Leaf Curl Virus (TYLCV) in the Southeast United States, 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**
Net return levels ($)	4,802	3,854	2,906	1,958	1,010	62	-887
Chance of obtaining this level or more (%)	7%	16%	31%	50%			
Chance of obtaining this level of less (%)				50%	31%	16%	7%
Chances of Profit		**85%**		**Net Revenue**			**$1,958**

These results were based on an expected yield of 1,700 boxes/acre and an expected price of $8.00/box. The results also indicated that there was an 85% chance of obtaining a profit from adopting the appropriate recommended whitefly and TYLCV management production techniques.

Conclusions

Tomato yellow leaf curl virus (TYLCV) is a major problem for tomato farmers. The virus can reduce production and profitability if not managed, to the point of destroying an entire tomato farm. Studies conducted in the Coastal Plain by the University of Georgia scientists show that farmers can successfully produce tomato by adopting a combination of management tactics 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 TYLCV in tomato production were slightly different from the conventional tomato production practices. A sensitivity analysis based on total cost of production indicated an expected net return of $1,958/acre for producing tomatoes in the presence of whiteflies and TYLCV, obtainable 50% of the time.

Our results show preharvest breakeven variable cost of $2.47/carton, while the breakeven total cost of production is $6.85/carton.

Acknowledgments

We acknowledge the technical help rendered by Mr. Simmy Meckeown, and numerous student workers at the vector biology laboratory, UGA, Tifton, during the course of this study. This project was partially funded by USDA AFRI Grant 2012-67007-19870, for which the authors are grateful.

References

Adeniyi, O.R. 2011. "Economic Aspects of Intercropping Systems of Vegetables (Okra, Tomato and Cowpea)." *African Journal of Plant Science* 5(11): 648–655.

Adi, M., P. Jens, Y. Brotman, K. Mikhail, S. Iris, C. Henryk, and G. Rena. 2012. "Stress Responses to Tomato Yellow Leaf Curl Virus (TYLCV) Infection of Resistant and Susceptible Tomato Plants are Different." *Metabolomics* S1: 1–13.

Alvarez, P.A., and A.J. Abud-Antún. 1995. "Reporte de Republica Dominicana." *CEIBA (Honduras)* 36: 39–47.

Awondo, S.N., E.G. Fonsah, D. Riley, and M. Abney. 2012. "Stated Effectiveness of Tomato-Spotted Wilt Virus Management Tactics." *Journal of Economic Entomology* 105(3): 943–948.

Cembali, T., R. J. Folwell, P.Wandschneider, K. C. Eastwell, and W. E. Howell. 2003. "Economic Implications of a Virus Prevention Program in Deciduous Tree Fruits in the US." *Crop Protection* 22(10): 1149–1156.

Cembali, T, R.J. Folwell, and P.R Wandschneider. 2004. "Economic Evaluation of Viral Disease: Prevention Programs in Tree Fruits." *New Medit* 3(4): 23–29.

Chen, T.Z., Y.D. Lv, T.M. Zhao, N. Li, Y.W. Yang, W.G. Yu, X. He, T.L. Liu, and B.L. Zhang. 2013. "Comparative Transcriptome Profiling of a Resistant vs. Susceptible Tomato (Solanumlycopersicum) Cultivar in Response to Infection by Tomato Yellow Leaf Curl Virus." *PLoSONE* 8(11): e80816.

Czosnek, H. 2008. "Tomato Yellow Leaf Curl Virus." In B.W.J. Mahy and M.H.V. Van Regenmortel, eds. *Encylcopedia of Virology*, vol. 5, 3rd ed. Oxford, UK: Elsevier, pp. 138–145.

Engindeniz, S. 2006. "Economic Analysis of Pesticide Use on Processing Tomato Growing: A Case Study for Turkey." *Crop Protection* 25(6): 534–541.

Engindeniz, S., and G. O. Cosar. 2013. "An Economic Comparison of Pesticide Applications for Processing and Table Tomatoes: A Case Study for Turkey." *Journal of Plant Protection Research* 53(3): 230–237.

Fonsah, E.G., C.M. Ferrer, D.G. Riley, S. Sparks, and D. Langston. 2010. "Cost and Benefit Analysis of Tomato Spotted Wilt Virus (TSWV) Management Technology in Georgia." Paper presented at the annual meeting of the Southern Agricultural Economic Association, Orlando, Florida, February 6–9. Available online: http://purl.umn.edu/56386.

Fonsah, E.G., and A. S. N. D. Chidebelu. 2012. *Economics of Banana Production and Marketing in the Tropics: A Case Study of Cameroon*. Mankon, Cameroon: Langaa Research and Publishing CIG.

Fonsah, E.G., and J. Hudgins. 2007. "Financial and Economic Analysis of Producing Commercial Tomatoes in the Southeast." *Journal of the ASFMRA* 70(1): 141–148.

Fonsah, E.G., G. Krewer, K. Harrison and D. Stanaland. 2008. "Economic Returns Using Risk Rated Budget Analysis for Rabbiteye Blueberries in Georgia." *HortTechnology* 18: 506–515.

Isakeit, T., A.M. Idris, G. Sunter, M.C. Black, and J.K. Brown. 2007. "Tomato Yellow Leaf Curl Virus in Tomato in Texas, Originating from Transplant Facilities." *Plant Disease* 91: 466–466.

Kelley, W.T., and G. Boyhan. 2006. "History, Significance, Classification and Growth." In *Commercial Tomato Production Handbook*. University of Georgia Extension, Bulletin 1312, July, p. 3. Available online: http://extension.uga.edu/publications/detail.cfm?number=B1312

Lapidot, M., and M. Friedmann. 2002. "Breeding for Resistance to Whitefly-Transmitted Geminiviruses." *Annals of Applied Biology* 140: 109–127.

Lefeuvre, P., D.P. Martin, G. Harkins, P. Lemey, A.J.A. Gray, S. Meredith, F. Lakay, A. Monjane, J.M. Lett, A. Varsaniand, and J. Heydarnejad. 2010. "The Spread of Tomato Yellow Leaf Curl Virus from the Middle East to the World." *PLoS Pathogens* 6(10): e1001164.

Legarrea, S., A. Barman, W. Marchant, S. Diffie, and R. Srinivasan. 2015. "Temporal Effects of a Begomovirus Infection and Host Plant Resistance on the Preference and Development of an Insect Vector, *Bemisia tabaci*, and Implications for Epidemics." *PLoS ONE* 10(11): e0142114. doi: 10.1371/journal. pone.0142114.

Ling, K.S., A.M. Simmons, R.L. Hassell, A.P. Keinath, and J.E. Polston. 2006. "First Report of Tomato Yellow Leaf Curl Virus in South Carolina." *Plant Disease* 90: 379–379.

Moriones, E., and J. Navas-Castillo. 2000. "Tomato Yellow Leaf Curl Virus, an Emerging Virus Complex Causing Epidemics Worldwide." *Virus Research* 71(1–2): 123–134.

Momol, M.T., G.W. Simone, W. Dankers, R.K. Sprenkel, S.M. Olson, E.A. Momol, J.E. Polston, and E. Hiebert. 1999. "First Report of Tomato Yellow Leaf Curl Virus in Tomato in South Georgia." *Plant Disease* 83: 487–487.

Moriones, E., and J. Navas-Castillo. 2010. "Tomato Yellow Leaf Curl Disease Epidemics."*Annals of Applied Biology* 156(3): 401–410.

Pan, H.P., D. Chu, W.Q. Yan, Q. Su, B.M. Liu, S.L. Wang, Q.J. Wu, W. Xie, X.G. Jiao, R.M. Li, N.N. Yang, X. Yang, B.Y. Xu, J.K. Brown, X.G. Zhou, and Y.J. Zhang. 2012. "Rapid Spread of Tomato Yellow Leaf Curl Virus in China Is Aided Differentially by Two Invasive Whiteflies." *PLoS ONE* 7(4): e34817.

Polston, J.E., and M. Lapidot. 2007. "Management of Tomato Yellow Leaf Curl Virus: US and Israel Perspectives." In H. Czosnek, ed., *Tomato Yellow Leaf Curl Virus Disease*. Dordrecht, Netherlands: Springer, pp. 251–262.

Polston, J.E., T.R. Rosebrock, T. Sherwood, T. Creswell, and P.J. Shoemaker. 2002. "Appearance of Tomato Yellow Leaf Curl Virus in North Carolina." *Plant Disease* 86(1): 732–732.

Polston, J.E., R.J. McGovern, and L.G. Brown. 1999. "Introduction of Tomato Yellow Leaf Curl Virus in Florida and Implications for the Spread of This and Other Geminiviruses of Tomato." *Plant Disease* 83: 984–988.

Rakib, A.A., A.A. Mustafa, A.H.H. Samir and N.H.D. Saber. 2011. "Tomato Yellow Leaf Curl Virus (TYLCV), Identification, Virus Vector Relationship, Strains Characterization and a Suggestion for Its Control with Plant Extracts in Iraq." *African Journal of Agricultural Research* 6(22): 5149–5155.

Rudi, N., G. Norton, J. Alwang, and G. Asumugha. 2010. "Economic Impact Analysis of Marker-Assisted Breeding for Resistance to Pests and Post-Harvest Deterioration in Cassava." *African Journal of Agricultural and Resource Economics* 4: 110–122.

Srinivasan, R., D. Riley, S. Diffie, A. Sparks, and S. Adkins. 2012. "Whitefly Population Dynamics and Evaluation of Whitefly-Transmitted Tomato Yellow Leaf Curl Virus (TYLCV)-Resistant Tomato Genotypes as Whitefly and TYLCV Reservoirs." *Journal of Economic Entomology* 105: 1447–1456.

Taylor, R.A.J., S. Shalhevet, I. Spharim, M.J. Berlingerand, and S. Lebiush-Mordechi. 2001. "Economic Evaluation of Insect-Proof Screens for Preventing Tomato Yellow Leaf Curl Virus of Tomatoes in Israel." *Crop Protection* 20(7): 561–569.

Van Brunschot, S.L., D.M. Persley, A.D.W. Geering, P.R. Campbelland, and J.E. Thomas. 2010. "Tomato Yellow Leaf Curl Virus in Australia: Distribution, Detection and Discovery of Naturally Occurring Defective DNA Molecules." *Australasian Plant Pathology* 39(5): 412–412

Wells, H.F., J. Bond, and S. Thornsbury. 2015. *Vegetables and Pulses Outlook*. Washington, DC: U.S, Department of Agriculture, Economic Research Service, Situation and Outlook, VGS-355, May.

Wu, J.X., H.L. Shang, Y. Xie, Q.T. Shen, and X.P. Zhou. 2012. "Monoclonal Antibodies Against the Whitefly-Transmitted Tomato Yellow Leaf Curl Virus and Their Application in Virus Detection." *Journal of Integrative Agriculture* 11(2): 263–268.

Yardim, E.N., and C.A. Edwards. 2003. "An Economic Comparison of Pesticide Application Regimes for Processing Tomatoes." *Phytoparasitica* 31(1): 51–60.