Are Tomato-Spotted Wilt Virus Management Tactics Good Enough?

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Abstract

Management of tomato-spotted wilt virus is complex and requires more than one treatment for near optimum results. We investigated tomato and pepper growers' perception on the effectiveness of tactics using Bayesian Logistic regression. The perceived chance that each tactics will control the disease was about a coin toss.

Keywords: TSWV, Pest and Disease Management, Bayesian Logistic Regression

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1. Introduction and Background

Tomato-spotted wilt (TSW) caused by tomato spotted wilt virus (TSWV) is one of the main diseases affecting tomato production in southern states of the U.S. It is capable of inflicting huge damages through plant mortality, reducing fruit yield, and ruining fruit quality through scarring and irregular ripening (Riley and Pappu, 2004, Fonsah, 2002,). Studies have long revealed that most of the losses from TSWV come from primary infection, which insecticide use alone cannot prevent (McPherson et al., 1995, Puche et al., 1995, McPherson et al., 1997). Losses attributed to TSWV for affected crops in the State of Georgia were estimated at over $326 million over the last decade (USDA). Management of the virus is complex requiring more than one treatment in specific combinations depending on the disease incidence (Riley and Pappu, 2000, 2004; Riley, 2008; Kennedy, 2008; Olson, 2008; Riley et al., 2009a; Riley et al., 2009b; Fonsah et al., 2010). Improved techniques available today for TSW control include use of resistant cultivars, use of reflective metalized mulch (UV-mulch), and treatment with chemicals such as imidacloprid and acibenzolar-S-methyl (Actiguard). For example, early season foliar sprays of effective insecticide targeting the thrips vector applied for a minimum of two consecutive weeks after transplant in combination with imidacloprid soil treatment was found to cause significant reduction in incidence of TSW only in years during which the disease incidence was greater than 17% (Riley, 2000). In another field experiment, Actiguard was found to be most effective during years when disease pressure was greatest, while UV-reflective mulch performed better than black polyethelene mulch in reducing colonization of thrips, regardless of thrips pressure. However, a combination of UV-reflective mulch, acibenzolar-S-methyl and insecticides was found to be the most effective in controlling TSWV incidence in tomato (Momol et al., 2004). In a more recent study conducted under field conditions, Actiguard was found to significantly reduce the spread of the virus (R. solanacearum) when used with moderately resistant cultivars (Pradhanang et al., 2005). Due to the degree of uncertainty and cost involves in the use of these management practices, growers' have been reluctant to adopt some of them (Fonsah et al., 2010).

This study investigated tomato and pepper growers' perception of the chance that each tactic or combination of tactics will effectively control TSWV. We also compared simulated estimates with those derived in an earlier study by Awondo et al (forthcoming) under a different modeling framework. In the subsequent sections we review risk factors in agriculture and then discuss methods used in the study. This is followed by a description of the data, presentation of results and discussions and conclusion.

2. Risk factors in Agriculture

Risk and uncertainties in agricultural production are often associated with farmers' limited ability to predict the weather, prices, incidence of pest and diseases, and biological response to different farm management practices (Panell et al., 2000). Past studies have categorized risk in agriculture into production, marketing and change in government policies that may affect output and marketing. The latter is difficult to account in the farmer decision process. The incidence of TSWV represents part of the production risk in tomato and pepper production. Decisions on which tactics to use for managing the virus largely depend on individual farmers' risk preferences, their expectation of the disease incidence that year, and the risk and benefits associated with the specific management tactics. A farmer who is risk averse is likely to be more careful to choose the management tactics that will give her optimal control whereas a farmer who is risk neutral may be indifferent between choosing optimal combination of tactics and any other conventional method. Most empirical studies that assess risk in crop and animal production have focused on estimating farmers risk preferences and vary from one another based on the type of risk being assessed, the expected utility function used and the risk modeling approach. Some authors have suggested the need to represent both tactical farm management practices and risk aversion in the model so that the researcher can examine their relative importance vis-a-vis expected outcome (Schroeder and Featherstone, 1990, Featherstone et al., 1993; Pannell and Nordblom, 1998). However, using a risk aversion model as opposed to risk-neutral model to analyze farmers' decisions derives little additional information to assist farmers' management of risk (Pannell et al., 2000). A more recent study revealed large differences between risk preference estimates and true parameters. This disparity existed even with restricted utility functions, and more so when the sample size use in estimation is small as in our case (Lence, 2009).

Motivated by a small sample size, we model growers' risk attitudes toward different TSWV management tactics using parsimonious hierarchical Bayes logistic regression model making no assumption of farmers' underlying risk preference. Bayesian models tend to perform better than frequentist models under small sample size.

3. Empirical Model

To assess farmers' perception on the effectiveness of TSWV management practices, we use a Bayesian logistic regression model. Logistic regression models the relationship between a dichotomous categorical response variable for given explanatory variables. The respondents were asked if they use each of the four tactics (imidacloprid, Actiguard, reflective mulch, resistant cultivar) of TSWV management in tomato and pepper respectively. They were then asked if all of the TSWV management practices that they used were effective in tomato and pepper. The responses where either yes, no, some or don't know. We created dummy variables from the responses with '1' representing yes and some, and '0' otherwise. The risk of using TSWV tactics, which is the response variable, was measured in terms of the perceived effectiveness of the management tactics in tomato treatment (y^t) and pepper treatment (y^p) with '1' indicating at least some level of effectiveness. For simplicity we denote all the treatments by $\mathbf{y}$. The explanatory variables for each of the four tactics assessed were recoded as indicator variables with '1' indicating at least some level of the tactic was used. Each of the responses then follows a binomial distribution (equation 3.1) with n_{airc} as the number of trials and θ_{airc} the probability of success of a TSWV treatment that includes the a^{th} Actiguard, i^{th} imidacloprid, r^{th} reflective mulch, and c^{th} resistant cultivar. Note that any of a, i, r, c can either be use(1) or not used (0).

$$y_i \sim Bin(n_{airc}, \theta_{airc}) \tag{3.1}$$

$$\theta_{airc} = logit^{-1}(\mathbf{X}\beta) \tag{3.2}$$

$$P(y|\beta) = \prod_{i=1}^{n} \binom{n_i}{y_i} (\theta_{airc})^{y_i} (1 - \theta_{airc})^{n_i - y_i} \tag{3.3}$$

$$\beta \sim N(0, \tau^2) \tag{3.4}$$

$$P(\beta, \tau^2|\mathbf{y}) = P(\mathbf{y}|\beta)\ P(\beta|\tau^2)\ P(\tau^2) \tag{3.5}$$

Where $\mathbf{X} = (1\ x_1\ x_2\ x_3\ x_4)$ is the model matrix and $\beta = (\beta_0, \beta_a, \beta_i, \beta_r, \beta_c)^T$ represents corresponding coefficients to be estimated including the intercept. The likelihood function for the data is then obtained as in (3.3). We assume a normal prior centered on zero with variance (τ) on the parameters to be estimated (3.4) and a noninformative hyperprior on its variance. Equation 3.5 gives the resulting posterior distribution which is finite and proper. We use the random walk metropolis algorithm to simulate the marginal posteriors for the parameters and then predicted probabilities. We estimate two separate models; one for tomato and the other for pepper.

4. Data

Data for the study was collected in an on-line survey from 76 tomato and pepper growers in FL, GA, SC and NC in fall 2008. Most of the questions were closed formed and required growers to check either yes, no, some and don't know. However, final sample size used for parameter estimation was less than 33, due to missing values.

A higher percentage of respondents experienced the incidence of TSWV in pepper production in the last 5 years compared to tomato. About 55% and 14% of the respondents had experienced the incidence of TSWV in pepper and tomato respectively in the previous year compared to 39% and 22% within the past 5 years. Fifty nine percent and 73% of the respondents indicated they used at least some improved management practices to control TSWV in pepper and tomato respectively in the previous year. Actiguard, Imidacloprid and resistant cultivar were used more in the previous year compared to UV-mulch. Fifty six percent, 67% and 67% of the respondents reported using Actiguard, Imidacloprid and resistant cultivar respectively for controlling TSWV in the previous year compared to 33%, 60% and 54% in pepper. Only 20% and 16% reported using UV-mulch.

Table 1: Summary statistics

variable description	Obs	Mean	Std. Dev.
Experience incidence within last 5 yrs in tomato	49	.2245	.4216
Experience incidence within last 5 yrs in pepper	49	.3877	.4923
Experience incidence last yr in tomato	44	.1364	.3471
Experience incidence last yr in pepper	44	.5454	.5037
Use at least some TSWV in tomato	49	.7347	.4461
Use at least some TSWV in pepper	41	.5853	.4988
Actiguard use in tomato	48	.5625	.5013
Actiguard use in pepper	42	.3333	.4771
Imidacloprid use in tomato	45	.6667	.4767
Imidacloprid use in pepper	42	.5952	.4968
UV-mulch use in tomato	46	.1956	.4011
UV-mulch use in pepper	44	.1591	.3699
R. cultivar use in tomato	48	.6667	.4764
R. cultivar provide control in tomato	35	.7143	.4583
R. cultivar provide quality yield in tomato	33	.7273	.4523
Resistant cultivar use in pepper	41	.5366	.5049
R. cultivar provide control in pepper	31	.6774	.4752
R. cultivar provide quality yield in pepper	30	.7333	.4498
Treatment effectness in tomato	45	.6000	.4954
Treatment effectness in pepper	42	.5238	.5055
Amount spent for control in tomato	15	74	110.78
Amount spent for control in pepper	14	59.5	103.36
% loss per acre in tomato	19	14.26	22.69
% loss per acre in pepper	19	11.63	18.57
Acreage cultivated for tomato	29	63.32	106.45
Acreage cultivated for pepper	24	24.59	34.97

Most of the growers indicated that resistant cultivar provided control(71% and 68%) and quality yield (73% and 73%) in tomato and pepper respectively. Growers reported to have spent on average \$74 and \$60 for the control of TSWV in tomato and pepper respectively. On average 63 acres and 25 acres were cultivated for tomato and pepper in the previous year. The large deviation from mean on the amount spent in controlling TSWV and the acreage cultivated suggest wide variation in the sample. Average percentage loss in yields associated to TSWV in tomato and pepper were reported at 14% and 12% respectively. Also, only 25% of the respondents indicate they can predict how severe TSWV will be next season. Most of the respondents (90%) indicated that spring is their worst growing season in terms of incidence and yield loss. About 68% of the respondents indicated tomato as their worst crop affected by the pest.

5. Results and discussions

Posterior summaries and intervals for estimated parameters are show in Tables 2 through 5 for both tomato and pepper models. The mean estimates of the coefficients in both models are all positive. However, the 95% credible intervals for all the coefficients in both models are all negative on the lower bound and positive on the upper bound indicating high probability of both positive and negative effect of a tactics on effectiveness. This means that using any of the treatments to control TWSV was perceived to either increase or decrease the chances of controlling the disease. Such perception is most likely the reason why growers are reluctant to adopt some of the treatments. Comparing point estimates derived from the same model using maximum likelihood estimation (fig. 1 and 2) as in Awondo et al (forthcoming) with the mean estimates from MCMC simulation shows remarkable differences among most of the parameter estimated. The differences can be associated to the use of different modeling framework. Bayesian models are widely known to outperform their frequentist counterparts under small sample size. Mean predicted perceived probability of effectiveness of each of the treatments used in tomato and pepper (Table 6 and 7) are a little over a coin toss and not remarkably different across management tactics. A tactic made up of a combination of all four treatments is perceived to likely perform better than any other treatment combination. These findings strongly support the explanation that reigns in the complexity in managing the TSWV revealed in previous studies and the reason why growers are reluctant in adopting some of the improved tactics. The effectiveness of existing treatments varies with disease incidence in the season and also depends on which other treatments are included. This therefore allows for the possibility of a positive effect of the treatment as well as a negative effect as revealed by the 95% credible intervals. The wide variation in the mean estimates is also revealed by the large standard deviations in posterior mean.

6. Conclusion

Management of TSWV is costly and complex and near optimum control involves a combination of two or more management tactics applied in a timely manner and vary with disease incidence. Tomato and pepper growers find it difficult to plan and control the disease on a year to year base since disease incidence varies over the years. This study investigated tomato and pepper growers' perceived probability of effectiveness of individual tactics and combination of tactics available for controlling the disease. We employed a Bayesian logistic regression model motivated by our small sample size to simulate parameter estimates and then perceived predicted probabilities of treatments. Results show that each management tactic could induce mixed effects on the perceived effectiveness of each of the tactics investigated. Moreover, growers were found to see the chances of each of the management tactic controlling the disease as about the same and similar to a coin toss.

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7. Appendix

Table 2: Posterior summaries for Pepper (N=10000)

Parameter	Mean	Std Dev.	25%	50%	75%
Const.	0.0304	0.1714	-0.0923	0.0308	0.1514
Actiguard	0.1261	0.1913	-0.00444	0.1284	0.2584
Imidacloprid	0.1229	0.1841	-0.00357	0.1244	0.2456
R.cultivar	0.00582	0.1830	-0.1166	0.00943	0.1281
UV-mulch	0.0763	0.1949	-0.0560	0.0782	0.2095

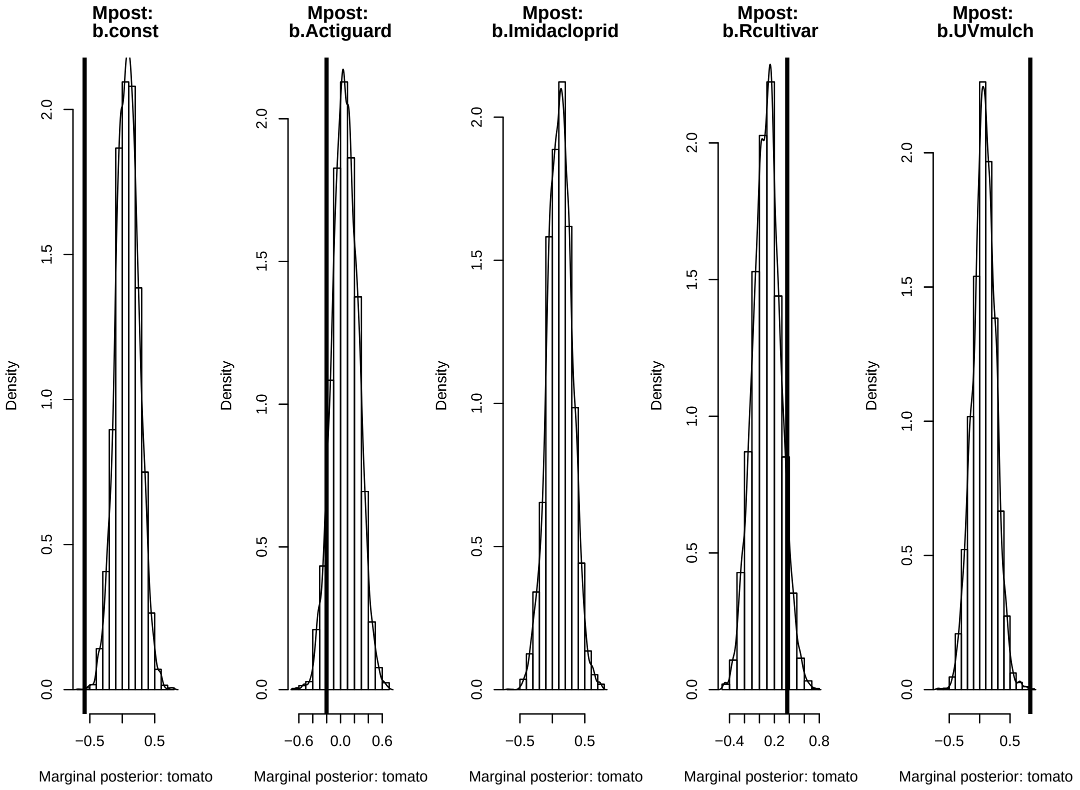

Table 3: Posterior Intervals for Pepper ($\alpha = 0.05$)

Parameter	Equi-tail Int. LB	Equi-tail Int. UB	HPD Int. LB	HPD Int. UB
Const.	-0.3036	0.3628	-0.2965	0.3656
Actiguard	-0.2619	0.4984	-0.2184	0.5309
Imidacloprid	-0.2362	0.4853	-0.2393	0.4790
R.cultivar	-0.3519	0.3650	-0.3379	0.3753
UV-mulch	-0.3003	0.4524	-0.2945	0.4558

Table 4: Posterior summaries for tomato (N=10000)

Parameter	Mean	Std Dev.	25%	50%	75%
Const.	0.0807	0. 1780	-0. 0403	0. 0789	0. 1997
Actiguard	0. 0674	0. 1840	-0. 0573	0. 0615	0. 1941
Imidacloprid	0. 1161	0. 1894	-0. 0137	0. 1174	0. 2450
R.cultivar	0. 0979	0. 1833	-0. 0265	0. 1010	0. 2173
UV-mulch	0. 0.0718	0. 1875	-0. 0453	0. 0739	0. 1959

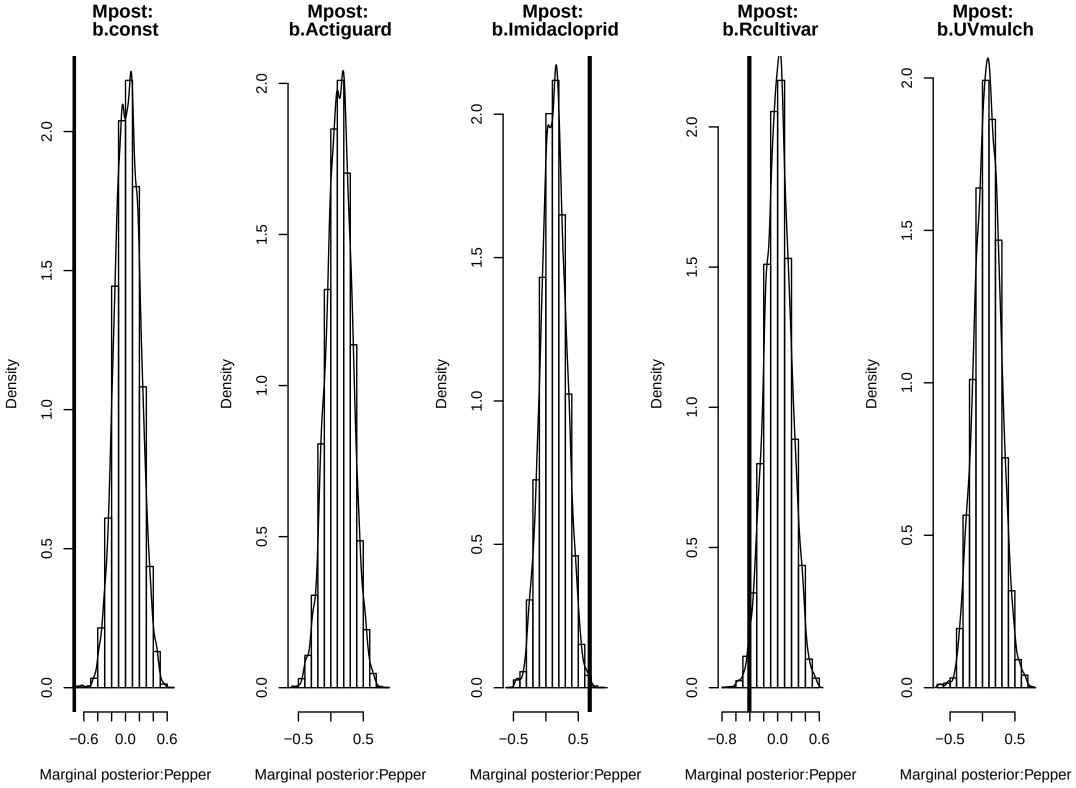

Table 5: Posterior Intervals for tomato ($\alpha = 0.05$)

Parameter	Equi-tail Int. LB	Equi-tail Int. UB	HPD Int. LB	HPD Int. UB
Const.	-0. 2662	0. 4273	-0. 2552	0. 4362
Actiguard	-0. 3015	0. 4298	-0. 3306	0. 3935
Imidacloprid	-0. 2703	0. 4833	-0. 2750	0. 4695
R.cultivar	-0. 2612	0. 4632	-0. 2533	0. 4682
UV-mulch	-0. 3024	0. 4348	-0. 3113	0. 4231

Table 6: Predicted perceived probability of effectiveness (pepper)

Tactic	Pred. Prob.	Std. Dev.	2.5%	25%	50%	75%	97.5%
ALL	0.5867	0.0840	0.4122	0.5312	0.5897	0.6424	0.7463
Act-Imi-Rcul	0.5691	0.0756	0.4209	0.5177	0.5692	0.6205	0.7165
Imi-Rcul-UVm	0.5571	0.0775	0.4029	0.5046	0.5580	0.6089	0.7091
Act-Imi	0.5679	0.0701	0.4292	0.5209	0.5693	0.6156	0.7023
Act-Rcul	0.5397	0.0701	0.3998	0.4918	0.5417	0.5877	0.6769
Imi-Rcul	0.5389	0.0667	0.4084	0.4932	0.5371	0.5865	0.6694
Imidacloprid	0.5377	0.0583	0.4257	0.4976	0.5362	0.5782	0.6507
R.cultivar	0.5089	0.0571	0.3997	0.4698	0.5072	0.5481	0.6245
UV-mulch	0.5262	0.0624	0.4025	0.4840	0.5270	0.5675	0.6482

Table 7: Predicted perceived probability of effectiveness (Tomato)

Tactic	Pred. Prob.	Std. Dev.	2.5%	25%	50%	75%	97.5%
ALL	0.6041	0.0781	0.4434	0.5486	0.6082	0.6605	0.7438
Act-Imi-Rcul	0.5877	0.0694	0.4466	0.5418	0.5910	0.6351	0.7181
Imi-Rcul-UVm	0.5885	0.0746	0.4386	0.5382	0.5910	0.6413	0.7259
Act-Imi	0.5645	0.0653	0.4301	0.5209	0.5667	0.6095	0.6908
Act-Rcul	0.5600	0.0675	0.4266	0.5145	0.5600	0.6067	0.6878
Imi-Rcul	0.5719	0.0641	0.4411	0.5295	0.5720	0.6152	0.7001
Rcul-UVm	0.5610	0.0704	0.4209	0.5129	0.5619	0.6103	0.6975
Act-UVm	0.5536	0.0719	0.4135	0.5041	0.5543	0.6038	0.6915
Actiguard	0.5364	0.0588	0.4215	0.4964	0.5356	0.5770	0.6490
Imidacloprid	0.5484	0.0576	0.4322	0.5102	0.5498	0.5871	0.6582
R.cultivar	0.5439	0.0576	0.4306	0.5046	0.5442	0.5827	0.6573

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