Risk-Return Trade-off of Novel Biocontrol Use for Pest Management in a Specialty Crop in Florida - Policy Implications

Lonege Ogisma[1] , Derick T. Adu[2], Pamela Roberts[1], Joseph Molnar[3]
[1]University of Florida, [2]Eastern Oregon University, [3]Auburn University

Abstract

Research on biocontrol was conducted to address concerns in the agricultural sector as an alternative to chemicals deemed harmful to the environment. Farmers, as decision-makers, need profitability clearly demonstrated, since they operate under stochastic climatic and market conditions that entail high risk. We employed a triangular distribution to run Monte Carlo simulations and draw meaningful conclusions from experiments on new biocontrol agents designed to combat pepper diseases at the farm level in southwest Florida. Further, we used partial budgeting and stochastic dominance to compare the risks associated with 11 spray programs aimed at reducing bacterial spot severity in pepper crops. Results highlighted variability in profit or net return both within and across programs. Three biocontrol programs generate profits exceeding $2,400 per acre. Stochastic dominance indicates that only one option offers the optimal risk-return trade-off. These findings offer insights for shaping agricultural and environmental policies to promote biocontrol for on-farm pest and disease management.

Motivation

- Novel biopesticides are being proposed to replace chemicals that have adverse effects on human health and the environment.



Chemical pesticides have adverse effects on human health and wildlife (bees).



Bacterial leaf spot, caused by *Xanthomonas campestris pv. vesicatoria*

Biocontrol-based treatment killed pests and diseases and reduced yield Losses up to 75%.

- Farmers demand that biocontrol-based pest management be profitable, and they would like to compare the results against the benefits offered by conventional production (NR=$3,289).
- Policy-makers need robust economic evidence from proposed novel biocontrol-based pest management to launch large-scale programs to improve the environment and water quality, and consequently, public health.
- This study analyzed the risks and returns of proposed novel biocontrol programs to address concerns about bacterial spots on bell peppers and derived some policy implications to support actors throughout the pesticide value chain.

Data

- Bell pepper yield is sourced from 11 program experiments from 2011 to 2013 at the Southwest Florida Research and Education Center (SWFREC);
- We sourced bell pepper prices from USDA NASS Quick Stats from 2010 to 2024.
- The inflation index is sourced from the US Bureau of Labor Statistics, 2024.
- The bell pepper budget is based on the North Carolina Tomato budget and the Farm pepper budget in Southwest Florida and is partially adjusted for bioagent costs.

Methods and Materials

1. Utility function

For $i = 1\ to\ n$ spray programs (SP) providing Y-yield, the farmers will choose i over alternatives j, if the i-utility is greater than any j-utility, noted $U_i(Yi) > U_j(Yj)$.

2. Brownian motion of yield

$$dY(t) = \mu(t)dt + \sigma_Y(t)dW(t), \quad (1)$$

Expected yield ($\mathbb{E}$Y), and hence the derived utility ($\mathbb{E}$U), follows Brownian motion, which is a continuous-time stochastic process with drift μ, risk σ, and a standard Wiener process (W). Farmers seek to achieve a better mean/drift with lower risk.

3. Triangular distribution and Monte Carlo simulations with 1,000 draws

$$\text{If } Rand() < \frac{LR}{TR}\ then\ Y_{stochastic} = Y_L + SQRT(Rand() * LR * TR) \quad (2)$$

$$\text{Else, } Y_{Stochastic} = Y_U - SQRT(1 - Rand()) * HR * TR \quad (3)$$

4. Net return : The differential between total revenues (Y*Price) and total costs (C).

$$\mathbb{E}(NR_t) = \mathbb{E}(Y_t) * \mathbb{E}(P_t) - \mathbb{E}(C_T(t)) \text{ and } \sigma_{NR} = \mathbb{E}(NR^2 - \mathbb{E}(NR)) \quad (4) \text{ and } (5)$$

5. Farmers' decision: second-order Stochastic Dominance

$$\text{If } \int_{-\infty}^{NR}[F_{SPj}(Y) - F_{SPi}(Y)]\,dY \geq 0, \text{ then } \mathbb{E}_{SPi}[u(Y)] \geq \mathbb{E}_{SPj}[u(Y)]\ \forall\ Y \quad (6)$$

Contact
Lonege Ogisma
Email: ogisma@gmail.com

USDA National Institute of Food and Agriculture, Specialty Crops Research Initiative project award 2019-51181-30010

Results

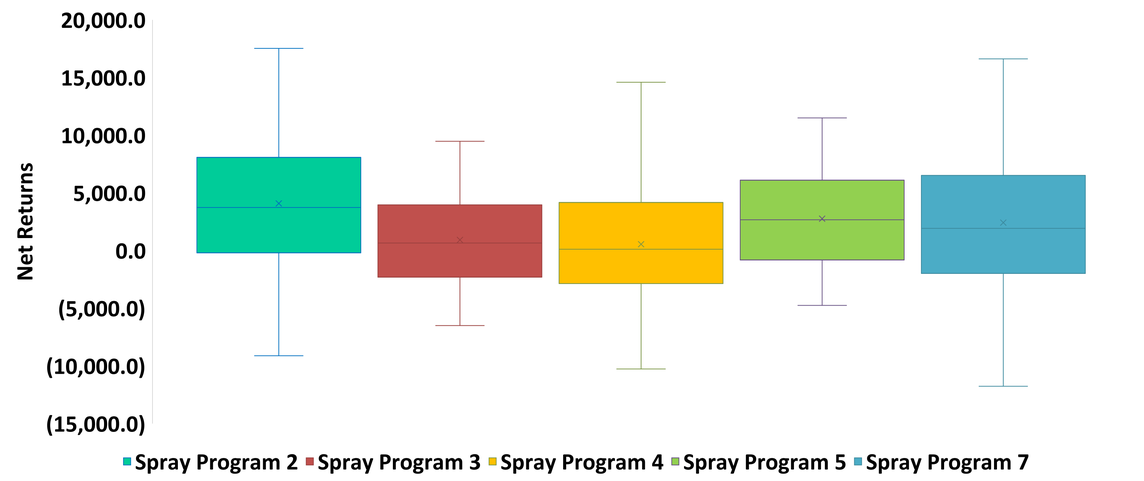


Figure 1: Spray Program with Positive Net Returns

Table 1: SP Mean-Variance – FO Stochastic Dominance and Probability of SP Net Return

Spray Programs	Net Returns (/acre) (μ)	Risk (σ)	Return-to-risk ratio	Pr (NR> $3,289)	Pr (NR> $2,500)
2	$4,263	$5,615	0.76	0.54	0.60
5	$2,898	$3,086	0.94	0.48	0.55
7	$2,461	$5,848	0.42	0.41	0.50
3	$988	$3,820	0.26	0.32	0.39
4	$846	$5,122	0.17	0.31	0.37

Discussions

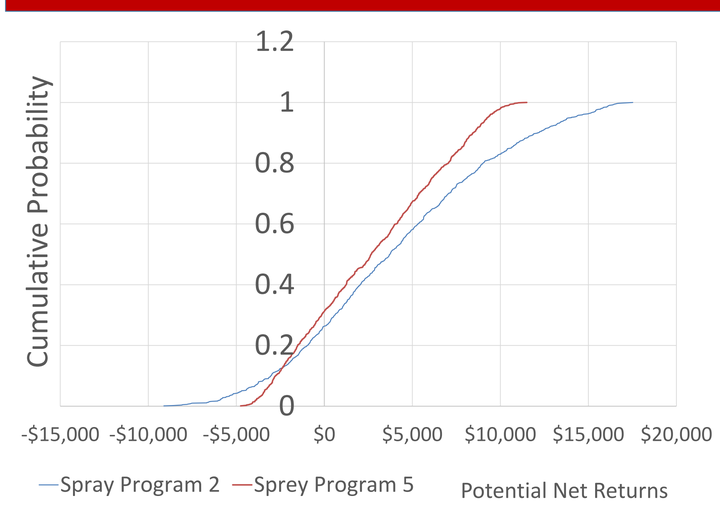


Figure 2: Second-Order Stochastic Dominance

The cumulative probability of SP2 is consistently lower than the cumulative probability of SP5 for any positive net return. Consequently, SP2 stochastically dominates SP5. As a result, $\mathbb{E}\boldsymbol{U}(\boldsymbol{NR_{SP2}}) > \mathbb{E}\boldsymbol{U}(\boldsymbol{NR_{SP5}})$. Farmers may trade risk in exchange for a better return by choosing SP2.

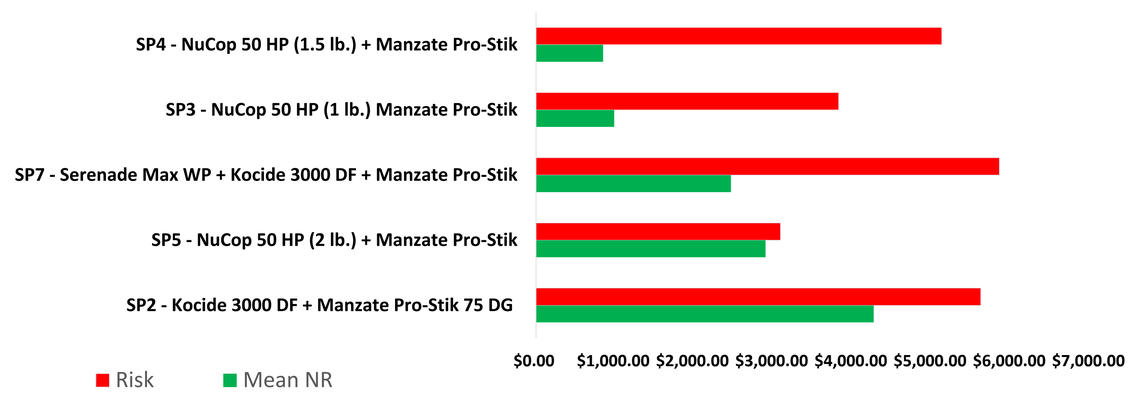


Figure 3: Risk and Return Sensitivity to Biocontrol Agents Used

Conclusion & Policy Implications

Our findings highlighted that spray programs 2 and 5 provide reliable net returns, with more than a 50% chance of providing a net return greater than $2,500 per acre. Further, NuCop 50 HP (2lb) might be added to spray program 2 to reduce the risk. Plant pathologists will need to assess their suitability for numerous specialty crops across the United States.

The federal government can support biocontrol use by (i) first, promoting large-scale farm development and showcasing nationwide; subsequently, (ii) leveraging pesticide-based chemical industries by retrofitting current facilities for biopesticides and establishing dedicated plots and Labs for biocontrol products; and finally, (iii) designing tailored crop insurance to foster the adoption of either spray program 2 by risk-taker farmers or 5 by risk-averse farmers.

References

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