Watermelon Planting Decisions with Multiple Risks: A Simulation Analysis

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SUMMARY. Watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] growers choose transplanting dates every year considering multiple risk factors. Earlier harvests linked to earlier planting typically find more favorable markets, but earlier planting has higher risk of freeze damage. Research also indicates that risk of fusarium wilt (caused by *Fusarium oxysporum* f. sp. *niveum*) is higher during cooler weather, adding to the risk of planting earlier. Thus, growers need to balance market risk (e.g., getting a low price) and production risk (e.g., lower harvest or higher cost due to freezing temperatures or disease) in selecting a planting date. The objective of this analysis is to examine the effect of planting date on the distribution of potential economic returns and evaluate whether late planting could be a favorable risk-management strategy. Probability distributions are estimated for key risk factors based on input from watermelon growers, published price data, historical freeze data, experiment station trials, and expert discussions. The distribution of economic returns is then simulated for three planting windows (early, middle, and late) using simulation software. Results demonstrate planting date risk–return tradeoffs and indicate that late planting is unlikely to be preferable to middle planting, even when risk of fusarium wilt is high.

Watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] as harvested from more than 25,000 acres in Florida in 2020, generating a free-on-board (FOB) packinghouse value of $157 million (USDA–NASS, 2021b). About one-third of the state's watermelon production occurs in the Suwannee Valley region of north Florida.

Watermelon is grown in north Florida as a spring crop in multiyear rotations with other crops and pasture. Common practices are to grow watermelon in rows spaced 8 ft apart with plastic mulch and drip irrigation. Transplants are first grown in greenhouses before being planted (transplanted) in the field. For watermelon growers, planting date refers to the date of transplanting in the field.

Fusarium wilt is a disease caused by a fungal pathogen *Fusarium oxysporum* f. sp. *niveum*. Infected watermelon plants wilt and may die. Marketable watermelon yields can be drastically reduced in fields where fusarium wilt infections occur. The fungus can persist in soil for many years and infect watermelon seedlings planted in a field where it is present (Amaradasa et al., 2018; Roberts et al., 2019).

Tactics used to reduce the likelihood or severity of fusarium wilt in watermelon include crop rotations of 5–10 years, soil fumigation, grafted transplants, resistant varieties, and delayed planting (Elwakil et al., 2022; Keinath et al., 2019; Roberts et al., 2019). In north Florida, crop rotation of 5–10 years is the only tactic commonly used. In this paper, we consider the feasibility of delayed planting to reduce fusarium wilt risks and possibly to improve financial outcomes for growers.

In north Florida, most watermelon seedlings are transplanted into fields between the last week in February and the middle of March. Moderate soil temperatures (e.g., 77–80 °F) and wet weather increase fusarium wilt incidence in watermelon plants (Keinath et al., 2019; Roberts et al., 2019), conditions common during March in north Florida. Later transplanting and higher soil temperatures have been shown to reduce fusarium wilt incidence in Georgia and South Carolina (Keinath et al., 2019). In north Florida, April and May are typically hotter and drier than March (US Climate Data, 2021). Delaying transplanting until the end of March or early April could reduce fusarium wilt risks.

Production and market risks in agriculture make financial outcomes uncertain. Watermelon growers must consider these risks in making planting decisions. North Florida growers report that timing their harvest to coincide with the best market window is their primary consideration in choosing a planting date. Earlier harvests typically find higher prices and easier access to markets, but earlier planting has higher risk of freeze damage and fusarium wilt. Thus, growers need to balance market risk (e.g., getting a low price) and production risk (e.g., lower harvest yield or higher cost due to freezing temperatures or disease) in selecting a planting date.

Pre-season risk assessment tools could help growers make better informed decisions to manage these risks. For example, a soil bioassay procedure has been developed to detect the presence of the fusarium wilt pathogen in a field (Gatch and du Toit, 2015). Climate-prediction tools can estimate the likelihood of freeze events or periods of cool, wet weather. A pre-season assessment that considers parcel history, soil bioassay results, and climate predictions could rate fusarium wilt risk as high, medium, or low before planting and help growers manage risks.

Units To convert U.S. to SI, multiply by	U.S unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
0.4536	lb	kg	2.2046
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
(°F − 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

We investigate two main questions: 1) how does planting (transplanting) date affect financial outcomes for growers, and 2) would delayed planting be financially advantageous when fusarium wilt risk is high? We use the terms planting and transplanting interchangeably for planting seedlings in a field.

Materials and methods

Monte Carlo simulation can be used to estimate a distribution of possible outcomes by repeatedly sampling from probability functions specified for each uncertain (stochastic) variable. The method estimates the likelihood of a range of outcomes occurring as the result of a decision or scenario (Bizimana and Richardson, 2019; Richardson et al., 2000, 2007). Simulation analysis is often used for economic evaluation of agricultural practices with considerable risk and uncertainty (Barrett et al., 2018; Evans et al., 2014; Rodriguez et al., 2012).

For this study, a Monte Carlo simulation model is created to evaluate field-level financial outcomes for watermelon production under different planting date and fusarium wilt risk scenarios. The model is set up using spreadsheet software (Microsoft Excel; Microsoft Corp., Redmond, WA) with simulation add-in (Simetar; Simetar, Inc., College Station, TX) to simulate stochastic variables (Richardson et al., 2008).

The key output variable is net return per acre (NR), which is a function of average watermelon price (P), marketed yield per acre (Y_m), harvesting and marketing cost per acre (C_{hm}), variable operating cost per acre (C_{vo}), and fixed production cost per acre (C_f):

$$NR = (P \times Y_m) - C_{hm} - C_{vo} - C_f \quad [1]$$

Price (P) is the average FOB packinghouse price for all the watermelon sold from a field. The marketed yield per acre (Y_m) is the potential yield per acre multiplied by the percentage harvested and the percentage of harvest sold. Next, harvesting and marketing cost (C_{hm}) is calculated as harvesting and packing cost per pound times pounds harvested plus marketing cost per pound sold. Variable operating cost (C_{vo}) varies by planting date and whether the crop is replanted because of loss due to a freeze event. Finally, fixed production costs (C_f) are unaffected by the planting date decision.

Seven stochastic variables are identified that affect the net return per acre: freeze occurrence after transplanting, percentage of a watermelon field that is replanted after a freeze occurs, incidence of fusarium wilt infection in watermelon plants, potential yield per acre, percentage of potential yield harvested, percentage of harvested yield sold, and FOB price. Probability distributions are estimated for each stochastic variable under different planting date and fusarium wilt risk scenarios.

Information to define the scenarios and estimate probability distributions was gathered from multiple sources. Sources included semistructured interviews with four watermelon producers, clicker survey responses from 23 watermelon producers, experiment station trials, weather station data, and discussions with crop specialists. Cost data are based on a 2020 watermelon production budget developed for north Florida (Athearn et al., 2021). Details on information sources for each scenario and stochastic variable are provided below.

Nine scenarios were examined, considering three transplanting windows (i.e., early, middle, and late) and three fusarium wilt risk levels (i.e., low, medium, and high). The 1-week planting windows and associated 3-week harvest windows were identified based primarily on the practices of commercial growers. Planting windows are 22–28 Feb. (early), 11–17 Mar. (middle), and 28 Mar.–3 Apr. (late). The early and middle planting windows are common for north Florida growers. The late planting window is less common but is proposed as a way to reduce fusarium wilt risk. Harvest windows are 17 May–6 June (early), 25 May–14 June (middle), and 2–22 June (late). Typically, a watermelon field is harvested three or four times over a 3-week period. The number of days between transplanting and harvest can vary depending on watermelon variety and growing conditions. Later planting typically has fewer days until harvest than earlier planting, but reliable growing-degree-day calculations to estimate days until harvest are not available. Harvest windows are determined based on interviews with growers and dates of price reports for shipments from north Florida packinghouses.

Field-level probabilities of fusarium wilt infection are estimated for the nine scenarios. Pre-season fusarium wilt risk assessment tools are being refined to connect risk indicators with probabilities of actual fusarium wilt outcomes. Probabilities are estimated based on the judgment of watermelon disease specialists working on a fusarium wilt risk calculator for watermelon (Dufault et al., 2021). The estimated probabilities of fusarium wilt infection in low-risk fields are 30% (early), 20% (middle), and 10% (late). Probabilities in medium-risk fields are 60% (early), 40% (middle), and 20% (late). Probabilities in high-risk fields are 90% (early), 60% (middle), and 30% (late). The estimated probabilities show substantial reductions in fusarium wilt occurrence when planting late relative to early planting. The higher the level of risk indicated by the pre-season assessment, the greater the gain (reduction in probability of fusarium wilt occurrence) by planting late. Because the

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Table 1. Average free-on-board (FOB) packinghouse prices for Florida watermelon in three market windows for the years 2012–19 (constant 2019 dollars).

	Avg FOB price ($/lb)[z]		
Yr	Early harvest	Middle harvest	Late harvest
2012	0.2229	0.2139	0.1930
2013	0.2510	0.2247	0.2225
2014	0.2164	0.2131	0.2065
2015	0.1599	0.1570	0.1547
2016	0.1505	0.1537	0.1639
2017	0.2113	0.1966	0.1866
2018	0.2364	0.2386	0.2326
2019	0.1877	0.1621	0.1463
Mean	0.2045	0.1950	0.1883

[z]Early harvest = 17 May–6 June, middle harvest = 25 May–14 June, late harvest = 2–22 June; $1/lb = $2.2046/kg.

actual probabilities for this variable are not well understood, the estimated probabilities in our model can serve as a "what-if" scenario: how would the distribution of financial outcomes be affected if the probabilities are as shown here?

Most of the stochastic variables considered in this paper affect the producers' sales revenue, which is the product of the price and quantity sold (marketed yield). Watermelon prices fluctuate and typically trend downward later in Florida's harvest season. USDA data on daily shipping point prices from Florida packinghouses are used to calculate the average price during each of the harvest windows in 2012 through 2019 (USDA Agricultural Marketing Service, 2021). Prices are adjusted for inflation to constant 2019 dollars using the USDA prices paid index (USDA–NASS, 2021a). Average prices are calculated for each year and harvest window for red-flesh seedless-type watermelon, 45-size, in 24-inch bins (Table 1), a common market size in north Florida.

Using the historical prices reported in Table 1, an empirical distribution function for price in each of the harvest windows was generated using simulation software. The empirical distribution is based on the percent deviations from the mean and related probabilities estimated from the empirical data. We assume that the price distribution is unaffected by the presence of fusarium wilt or marketed yield from a grower's field.

Watermelon yield per acre is an uncertain variable that is affected by the presence and severity of fusarium wilt infection. A field-level yield distribution is specified for the case that fusarium wilt infection is detected in watermelon plants and for the case that fusarium wilt is not detected. Watermelon yield parameters in fields with fusarium wilt infection are estimated at 10,000 lb/acre (minimum), 35,000 lb/acre (middle), and 60,000 lb/acre (maximum). Yield parameters in fields without fusarium wilt infection are estimated at 30,000 lb/acre (minimum), 45,000 lb/acre (middle), and 65,000 lb/acre (maximum). Lacking sufficient empirical data on yields with and without fusarium wilt infection at the field-level, yield parameters are determined based on input from growers and crop specialists, as well as yield averages reported by USDA. A Gray-Richardson-Klose-Schumann (GRKS) distribution is used to represent yield. GRKS is a probability distribution that can be generated based on three parameters. The maximum and minimum parameters represent the tails of the probability density function, where the variable could take on values above the maximum or below the minimum 5% of the time (2.5% each). The middle parameter does not need to be centered between the maximum and minimum parameters. It represents the point where the variable will fall above 50% of the time and below 50% of the time (Evans et al., 2014; Richardson et al., 2008).

Although the yield parameters represent harvestable yield, only a portion of the potential yield may be ultimately harvested and sold. In addition to the price fluctuations discussed above, watermelon growers described market risks associated with finding labor crews, trucking, and buyers. Growers indicated that these risks are most apparent during later harvest windows. Based on input from growers, we assign probabilities for the percentage of potential yield harvested and percentage of harvested yield sold, depending on the harvest window. The percentage of potential yield harvested is estimated for the early harvest window to be 90% (minimum), 95% (middle), and 100% (maximum). Percentages for the middle harvest window are 60% (minimum), 90% (middle), and 100% (maximum) and for the late harvest window are 40% (minimum), 80% (middle), and 100% (maximum). The percentage harvested and percentage sold are estimated separately because harvesting and packing costs depend on the amount harvested, whereas broker fees depend only on the amount sold. Percentages of harvest sold are estimated to be 95% (minimum) and 100% (maximum) for the early harvest window, 90% (minimum) and 100% (maximum) for the middle harvest window, and 85% (minimum) and 100% (maximum) for the late harvest window. A GRKS distribution is used for percentage of potential yield harvested, and a uniform distribution is used for percentage of harvest sold.

Freeze risk probabilities were estimated from historical temperature data at three Florida Automated Weather Network weather stations in the Suwannee Valley region from 2003 to 2019. A freeze is defined as a minimum daily temperature of 32 °F or below at a

Table 2. Simulated mean net return per acre for north Florida watermelon transplanted during three different time frames in fields with three different fusarium wilt risk levels.

	Net return ($/acre)[z]		
Fusarium wilt risk level	Early planting	Middle planting	Late planting
Low	$1,505 ($2,070)	$1,532 ($1,753)	$903 ($1,597)
Medium risk	$1,127 ($2,096)	$1,309 ($1,851)	$820 ($1,599)
High	$754 ($2,040)	$1,112 ($1,791)	$722 ($1,607)

[z]Early planting = 22–28 Feb., middle planting = 11–17 Mar., late planting = 28 Mar.–3 Apr.; $1/acre = $2.4711/ha.
Values are mean (SD).

Table 3. Simulated probability of negative net return for north Florida watermelon planted during three different time frames in fields with three different fusarium wilt risk levels.

	Probability of negative net return (%)[z]		
Fusarium wilt risk level	**Early planting**	**Middle planting**	**Late planting**
Low	25	20	32
Medium	32	27	33
High	40	29	36

[z]Early planting = 22–28 Feb., middle planting = 11–17 Mar., late planting = 28 Mar.–3 Apr.

weather station height of 2 m. Based on these data, the likelihood that a freeze will occur on or after the last day of each planting window is 55% for the early window, 12% for the middle window, and 4% for the late window. They are the average probabilities across the three weather stations. A Bernoulli (binomial) distribution is used in the simulation model.

Freezing air temperatures may or may not kill a watermelon plant depending on other factors. If watermelon plants are killed or seriously damaged by a freeze, growers will typically replant. A uniform distribution with a minimum of 50% and a maximum of 100% replanting, if a freeze occurs, is used in the model based on input from growers and crop specialists. The cost of replanting is added to the net return calculation, and replanted watermelon are assumed to be harvested during the late harvest window.

The simulation model was run with 500 iterations for each of nine scenarios: three planting windows by three levels of pre-season fusarium wilt risk. For each scenario, the simulation sampled 500 times from the probability distributions of each stochastic variable separately, and net return was calculated for each iteration.

Results

The simulation analysis reveals information about the expected net return, variability of net return, and risk of financial loss for each planting-window-Fusarium-risk scenario. Mean net return per acre and standard deviation are in Table 2. The probability of negative net return for each scenario is listed in Table 3.

On parcels with low fusarium wilt risk, the simulation results indicate that early and middle planting dates have the highest mean net return (Table 2). As fusarium wilt risk increases, early planting becomes less preferable relative to late planting. The late planting window has a lower mean net return than the early and middle planting windows across all three risk levels, but mean net return is similar for early and late planting when fusarium wilt risk is high. The middle planting window has the highest mean net return across all three fusarium wilt risk levels

The standard deviation provides an indication of the variability of the outcomes. Higher numbers represent greater variation. The standard deviation for each scenario is shown in parentheses in Table 2. Standard deviations are lower for late planting, indicating a narrower range of variation than for early or middle planting dates. With high fusarium wilt risk, early planting has a higher mean net return than late planting but also a higher chance of negative net return.

Figure 1 shows probabilities of net return less than $0, between $0 and $1000, and above $1000/acre. These probabilities are shown for each planting-window-Fusarium-risk scenario. The middle planting window has the lowest likelihood of negative net return (financial loss) and the highest likelihood of net return above $1000 across all three fusarium wilt risk levels. The late planting window has the highest likelihood of negative net return and the lowest likelihood of net return above $1000 for the low and medium fusarium wilt risk levels. With high fusarium wilt risk, late planting has a lower likelihood of negative return but also a lower likelihood of net return above $1000 compared with early planting.

Discussion and conclusions

The simulation results demonstrate that market incentives to plant early are strong and validate grower preferences for planting during early and middle planting windows (late February to mid-March) despite higher risk of freeze and fusarium wilt. Higher prices and greater marketability early in the harvest season make early and middle planting preferable. Even with a 55% risk of freeze associated with the early planting window and higher likelihood of fusarium wilt infection, early planting has a higher mean net return than late planting. However, as fusarium wilt risk increases, early planting becomes less preferable relative to late planting. Only for parcels with a high level of fusarium wilt risk and a large difference in fusarium wilt infection likelihood between early and late planting would late planting offer less risk of

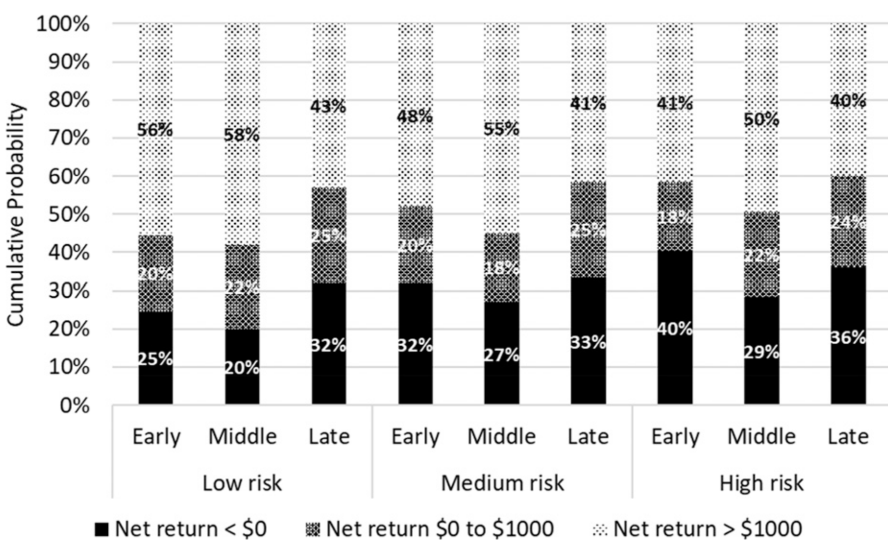

Fig. 1. Simulated cumulative probability of net return per acre less than $0, $0 to $1000, and greater than $1000 for watermelon with three fusarium wilt risk levels and three planting windows [early (22–28 Feb.), middle (11–17 Mar.), late (28 Mar.–3 Apr.)]; $1/acre = $2.4711/ha.

financial loss relative to early planting. The middle planting window has the highest mean net return and appears to be the least risky overall across all three levels of fusarium wilt risk.

The simulation results indicate that shifting to the late planting window is unlikely to be preferable for growers even when fusarium wilt risk is known to be high. Because most growers have multiple watermelon parcels and cannot plant them all on the same day, they may use fusarium wilt risk information to set the parcel planting order. They may plant the higher-risk parcels last but probably not as late as end of March. Instead of late planting, growers could take other measures to manage fusarium wilt risk, such as longer rotation, soil fumigation, or grafted transplants.

A pre-season disease risk assessment could be a valuable tool to help growers make decisions related to watermelon planting and risk management. Simulation modeling can help crop specialists and extension agents understand the risk and return tradeoffs that growers face and guide development of disease management tools that are most likely to be adopted by growers.

Limitations

The simulated outcomes depend critically on the parameters and distribution functions specified for each stochastic variable. Whereas freeze risk probability and price distribution in the model are empirically derived from historical data, other parameters are subjective probabilities based on perceptions of growers and crop specialists. Further research could help refine pre-season risk assessments and improve understanding of the relationship between assessment results and outcomes such as disease intensity and marketable yields.

Different watermelon types and varieties may have different days until harvest, yields, disease susceptibility, and market dynamics. For example, mini watermelon may be marketed differently and not subject to the same market fluctuations as regular seedless watermelon. Climate variability also could affect the conclusions. For example, warm weather in early March and cool weather in April could change the assumptions about early planting being more vulnerable to fusarium wilt. The temperature data used in this analysis are averages for the region. Actual freeze probabilities for individual parcels will vary by parcel location. Although our analysis examines several variables affecting financial outcomes for watermelon growers, it does not consider all relevant variables.

Literature cited

Amaradasa, B.S., K. Beckham, N. Dufault, T. Sanchez, T.S. Ertek, F. Iriarte, M. Paret, and P. Ji. 2018. First report of *Fusarium oxysporum* f. sp. *niveum* race 3 causing wilt of watermelon in Florida, U.S.A. Plant Dis. 102:1029, https://doi.org/10.1094/PDIS-10-17-1649-PDN.

Athearn, K., M. Burani Arouca, R.C. Hochmuth, J.H. Freeman, N. Dufault, B. Broughton, T. Sanchez, M. Warren, L. Harlow, and H.T. Pittman. 2021. Watermelon production budget for north Florida. Univ. Florida, Inst. Food Agric. Sci. FE1104, https://doi.org/10.32473/edis-FE1104-2021.

Barrett, C.E., L. Zotarelli, L.G. Paranhos, P. Dittmar, C.W. Fraisse, and J. VanSickle. 2018. Economic feasibility of converting from a bare ground system with seepage irrigation to plasticulture for cabbage production: Where is the risk? HortScience 53:875–881, https://doi.org/10.21273/HORTSCI12966-18.

Bizimana, J.C. and J.W. Richardson. 2019. Agricultural technology assessment for smallholder farms: An analysis using a farm simulation model (FARMSIM). Comput. Electron. Agric. 156:406–425, https://doi.org/10.1016/j.compag.2018.11.038.

Dufault, N., M. Cullen, and K. Athearn. 2021. New fusarium wilt risk calculator for watermelons. 3 May 2022. <https://nwdistrict.ifas.ufl.edu/phag/2021/10/08/new-fusarium-wilt-risk-calculator-for-watermelons/>.

Elwakil, W.M., N. Dufault, J.H. Freeman, and M.A. Mossler. 2022. Florida crop/pest management profile: Watermelon. Univ. Florida, Inst. Food Agric. Sci. CIR1236:19, https://doi.org/10.32473/edis-pi031-2013.

Evans, E.A., F.H. Ballen, and J.H. Crane. 2014. Economic potential of producing tahiti limes in southern Florida in the presence of citrus canker and citrus greening. HortTechnology 24:99–106, https://doi.org/10.21273/HORTTECH.24.1.99.

Gatch, E.W. and L.J. du Toit. 2015. A soil bioassay for predicting the risk of spinach fusarium wilt. Plant Dis. 99:512–526, https://doi.org/10.1094/PDIS-08-14-0804-RE.

Keinath, A.P., T.W. Coolong, J.D. Lanier, and P. Ji. 2019. Managing fusarium wilt of watermelon with delayed transplanting and cultivar resistance. Plant Dis. 103:44–50, https://doi.org/10.1094/PDIS-04-18-0709-RE.

Richardson, J.W., S.L. Klose, and A.W. Gray. 2000. An applied procedure for estimating and simulating multivariate empirical (MVE) probability distributions in farm-level risk assessment and policy analysis. J. Agric. Appl. Econ. 32:299–315, https://doi.org/10.1017/S107407080002037X.

Richardson, J.W., B.K. Herbst, J.L. Outlaw, and R. Chope Gill. 2007. Including risk in economic feasibility analyses: The case of ethanol production in Texas. J. Agribusiness 25:115–132, https://doi.org/10.22004/ag.econ.62291.

Richardson, J.W., K.D. Schumann, and P.A. Feldman. 2008. Simulation and econometrics to analyze risk. 1 Oct. 2021. <https://www.simetar.com/wp-content/uploads/2021/03/Simetar-2011-Users-Manual.pdf>.

Roberts, P., N. Dufault, R. Hochmuth, G. Vallad, and M. Paret. 2019. fusarium wilt (*Fusarium oxysporum* f. sp. *niveum*) of watermelon. Univ. Florida. Inst. Food Agric. Sci. P 1:352, https://doi.org/10.32473/edis-pp352-2019.

Rodriguez, H.G., J. Popp, M. Thomsen, H. Friedrich, and C.R. Rom. 2012. Economic analysis of investing in open-field or high tunnel primocane-fruiting blackberry production in northwestern Arkansas. HortTechnology 22:245–251, https://doi.org/10.21273/HORTTECH.22.2.245.

US Climate Data. 2021. Monthly, climate Live Oak – Florida. 1 Oct. 2021. <https://www.usclimatedata.com/climate/live-oak/florida/united-states/usfl0280>.

USDA–AMS. 2021. Run a custom report. 30 Apr. 2021. <https://www.ams.usda.gov/market-news/custom-reports>.

USDA–NASS. 2021a. Agricultural prices, monthly crop farms. 8 Apr. 2021. <https://www.nass.usda.gov/Charts_and_Maps/Agricultural_Prices/index.php>.

USDA–NASS. 2021b. Florida agriculture overview. 7 Mar. 2021. <https://www.nass.usda.gov/Statistics_by_State/Florida/index.php>.