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Crop Rotation Systems for High-Value, Cool-Season Vegetables in the Southern United States

Sam Kaninda Tshikala,[a]① Esendugue Greg Fonsah,[b] George Boyhan,[c] Elizabeth Little,[d] and Julia Gaskin[e]

[a]*Doctoral Student, Department of Agricultural and Applied Economics, University of Georgia, 309 Conner Hall Athens, GA 30602 USA*

[b] *Professor, Department of Agricultural and Applied Economics, University of Georgia, 4602 Research Way Tifton, GA 31793 USA*

[c]*Professor, Department of Horticulture, University of Georgia, 1111 Miller Plant Science Building Athens, GA 30602 USA*

[d]*Assistant Professor, Department of Plant Pathology, University of Georgia, 2105 Miller Plant Science Building Athens, GA 30602*

[e]*Sustainable Agriculture Coordinator, Department of Crop & Soil Science, University of Georgia, 4115 Miller Plant Science Building Athens, GA 30602 USA*

Abstract

Demand for organic food has increased tremendously over the last decade in the United States. In the Southeast, high demand for organic food has sparked interest in organic production techniques among conventional vegetable growers and put increasing demand on existing organic growers. However, little information is available on profitable organic vegetable crops suitable for the region. This study analyzes crop rotation systems for high-value, cool-season vegetables to develop production and economic models to help growers increase profit and reduce risk.

Keywords: demand, organic food, vegetables, crop rotation, southern region, U.S.

①Corresponding author: Tel: +243826639816
Email: samkaninda@live.com

Introduction

The organic market sector is among the fastest growing food sectors in the United States (Dettmann and Dimitri, 2007). From 1997 to 2012, organic retail sales increased from $3.7 to $28 billion, increasing to a record high of over $43 billion in 2015. The total value of farm-level organic sales reached $5.5 billion in 2014, up 72% since 2008 (Greene, 2013; Young, 2015). In addition, the market share of organic sales for different food categories has remained very stable over the last decade. In term of sales, vegetables and dairy remain the two top-selling organic food categories, followed by packaged foods and beverages (Dettmann and Dimitri, 2007; Greene, 2013; Gelski, 2015)

Interest in organic and locally produced food in the Southeast United States has increased demand for regionally grown organic produce. Increased demand has sparked an interest among conventional vegetable growers about organic production techniques and put increasing demand on existing organic growers.

The challenge in this region is to increase organic production in the face of higher incidence of disease, insect, and weed pressures typically experienced due to long growing seasons under hot, humid conditions. Almost all organic vegetables in the Southeast are produced on small farms. As a consequence, production and economic models that encompass profitability of entire rotations are not available. Crop rotations are needed to help growers increase profits and reduce risk, but relatively little research-based information is available on optimal production systems in the Southeast. Providing production and economic information on well-planned crop rotations, crop budgets, and profitability to small and medium-sized growers interested in organic production will make agriculture more sustainable and profitable. This information will also be a useful tool for conventional growers interested in transitioning to organic production (Fonsah et al., 2007b; Ahmadiani et al., 2016).

Continuous monoculture cropping does not contribute to soil fertility and productivity but rather encourages pests and diseases and increases environmental degradation. Adopting a crop rotation system—which has major agronomic, environmental, and economic benefits compared to monoculture cropping (Fonsah et al., 2010; Christensen et al., 2012)—is one solution to these issues (Dogan et al., 2008; Christensen et al., 2012; Kinyau et al., 2013).

Crop rotation increases soil fertility and productivity; reduces diseases, pests, and weeds; and increases farmer profitability (van Bniggen and Termorskuizen, 2003; Fonsah et al., 2007b; Neves et al., 2007; Dogan et al., 2008; Nielsen et al., 2011; Ahmadiani et al., 2016). Studies on factors related to the use of crop rotations and cover crops have shown beneficial effects on diminishing disease severity (percentage of host tissue infected) and incidence (number of plants infected) (van Bniggen and Termorskuizen, 2003).

A well-planned and appropriate crop rotation can improve soil physical properties by increasing organic matter and soil fertility and controlling soil erosion (Gianello and Bremner, 1986; Thomas, 1996; Lu, Teasdale, and Huang, 2003; Halloran, Griffin, and Honeycutt, 2005). Crop rotation may also help farmers reduce income variability and the likelihood of economic loss (Baldwin, 2006). Rotations can also help farmers protect the value of their assets. According to

Hennessy (2006), a rotation can be used to better manage labor supply through the year in regions with a small labor market.

This study evaluates crop rotation systems for high-value, cool-season vegetables and develops an economic methodology and framework to determine the rotation with the highest return at the lowest risk in the Southeast United States (Fonsah et al., 2007a; Fonsah et al., 2008; Flanders et al., 2009).

Materials and Methods

The research was conducted on certified organic land at the Horticulture Farm in Watkinsville, Georgia, over 3 years (September 2010–September 2013). The Durham Horticulture Farm is a University research and education center located on the Piedmont soils of Georgia. The land has been in organic production since 2010. The experiments were designed in a randomized complete block, with three replications for each rotation. Plot size was 2 m × 15 m.

The experiment consisted of two main rotations each of which had three treatments or sub-rotations of high-value, cool-season crops (A_1, A_2, and A_3 for rotation A, and B_1, B_2 and B_3 for rotation B). Different treatments or sub-rotations indicate the sequence of crops in each rotation. These rotations were discussed and modified based on experience and inputs from the organic grower advisory team. The goal was to improve soil quality through cover crop biomass addition, to rotate and use cover crop families to break pest cycles, and to use crops to supply nitrogen and suppress weeds.

In rotation A, strawberry was planted in September, grown through the winter, and harvested in May. Following the strawberry harvest, bush beans were planted as a summer crop. This was followed in late summer/early fall by oats/Austrian winter pea, then followed in late winter with potatoes, harvested in May. After potatoes, sunhemp was planted as a summer cover crop, followed by onions planted in September and harvested in April and May, followed in early fall by southern pea.

The second rotation, rotation B began with broccoli transplanted in September and harvested in November/December. Broccoli was followed by lettuce in January and sudax/iron clay pea mix in April to over summer. This was followed by carrots sown in September/October and harvested in January/February and followed by sugar snap peas. Sunhemp was planted in May to over summer at which time onions were planted in September and harvested the following April/May. Onions were followed by millet to over summer. Table 1 summarizes the different sub-rotations and crop sequences.

An enterprise budget was developed for each crop to perform the economic analysis. The budget included crop total variable costs (costs related to plants or seed, fertilizer, labor, plastic, machinery, interest on capital, irrigation, harvest, and marketing), total fixed costs (costs associated with machinery, irrigation, land, and overhead management), total gross revenue or return, and crop net return (Fonsah and Hudgins, 2007; Fonsah and Torrence, 2008). Total costs are the sum of total variable costs and fixed costs. Total gross revenue represents total sales from each crop. Mean gross revenue represents average sales or average gross revenue.

Table 1. Crop Rotations for High-Value, Cool-Season Vegetables in the Southeast United States, 2011–2013

Rotation A Treatments		
A_1	**A_2**	**A_3**
Strawberry	Oats/Austrian winter pea	Onion
Bush bean	Potato	Southern pea
Oats/Austrian winter pea	Sunhemp	Strawberry
Potato	Onion	Bush bean
Sunhemp	Southern pea	Oats/Austrian winter pea
Onion	Strawberry	Potato
Southern pea	Bush bean	Sunhemp

Rotation B Treatments		
B_1	**B_2**	**B_3**
Broccoli	Carrot	Onion
Lettuce	Sugar snap pea	Millet
Sudax	Onion	Broccoli
Carrot	Millet	Lettuce
Sugar snap pea	Broccoli	Sudax
Onion	Lettuce	Sugar snap pea
Millet	Sudax	Sunhemp

Results

Table 2 shows that it costs more over 3 years to produce lettuce, onion, and strawberry than the other crops under study.

Table 2. Total Costs per Acre for High-Value, Cool-Season Vegetable Crop Rotations in the Southeast United States, 2011–2013

Crop	**Year 1 (2011)**	**Year 2 (2012)**	**Year 3 (2013)**
Broccoli	$4,759	$5,343	$7,014
Carrot	$4,957	$5,297	$5,526
Lettuce	$7,497	$11,182	$10,452
Onion Rotation A	$8,523	$10,108	$10,700
Onion Rotation B	$8,508	$9,455	$10,539
Potato	$6,015	$6,036	$6,609
Strawberry	$10,028	$9,429	$11,417
Bush beans	$2,173	$4,340	$5,453
Southern peas	$1,966	$3,379	N/A

Notes: 1 acre = 0.405 hectares.

In terms of total gross revenue, onions have the highest mean gross return, followed by lettuce and strawberry, over the 3 years under study (Table 3).

Table 3. Gross Revenue per Acre for High-Value, Cool-Season Vegetable Crop Rotations in the Southeast United States, 2011–2013

Crop	Year 1 (2011)	Year 2 (2012)	Year 3 (2013)	Mean Gross Revenue	Coefficient of Variation
Broccoli	$2,762	$6,205	$10,248	$6,405	0.585012
Carrot	$4,756	$5,596	$6,130	$5,494	0.126075
Lettuce	$12,064	$22,971	$22,418	$19,151	0.320806
Onion Rotation A	$9,760	$28,514	$23,347	$23,874	0.184333
Onion Rotation B	$19,664	$28,343	$23,779	$23,929	0.181432
Potato	$6,655	$7,844	$10,116	$8,205	0.214322
Strawberry	$21,023	$12,970	$11,265	$15,086	0.345472
Bush beans	$0	$4,238	$7,111	$3,783	0.945394
Southern peas	$0	$4,323	N/A		

Notes: 1 acre = 0.405 hectares**.**

Though Table 3 indicates that average revenues for onions are higher than those for lettuce, Table 4 shows that there was an increase in crop net returns or net revenue—the difference between gross revenue and total costs—from year 1 to year 3 for all crops except strawberry, which had a decreasing trend. Onions had the highest net return, followed by lettuce and strawberry.

Table 4: Net Returns per Acre for High-Value, Cool-Season Vegetable Crop Rotations in the Southeast United States, 2011–2013

Crop	Year 1 (2011)	Year 2 (2012)	Year 3 (2013)	Mean Net Returns	Coefficient of Variation
Broccoli	($1,997)	$862	$3,234	$699.67	3.743605
Carrot	($201)	$300	$604	$234.33	1.734698
Lettuce	$4,567	$11,790	$11,967	$9,441.33	0.447206
Onion Rotation A	$11,237	$18,406	$12,646	$14,096.33	0.269445
Onion Rotation B	$11,156	$18,887	$13,240	$14,427.67	0.277245
Potato	$640	$1,807	$3,508	$1,985.00	0.726580
Strawberry	$10,995	$3,541	($152)	$4,794.67	1.184287
Bush beans	($2,173)	($101)	$1,658		
Southern peas	($1,966)	$944	N/A		

Notes: 1 acre = 0.405 hectares. Numbers in parentheses represent a negative return or a loss.

In rotation A, treatment A_1 had the highest net return, followed by A_2 and A_3 (Table 5). In rotation B, treatment B_2 produced the highest net return, followed by B_3 and B_1.

Table: 5: Net Returns per Acre for High-Value, Cool-Season Vegetable Crop Rotations in the Southeast United States, 2011–2013

Rotation	Net Return
A_1	$21,063
A_2	$17,339
A_3	$14,317
B_1	$11,765
B_2	$30,957
B_3	$20,168

	Rotation A			Rotation B		
	A_1	A_2	A_3	B_1	B_2	B_3
	Strawberry	Oats/Aust. W Pea	Onion	Broccoli	Carrot	Onion
	Bush bean	Potato	Cowpea	Lettuce	Sun Hemp	Millet
	Oats/ Aust. W Peas	Sun Hemp	Strawberry	Su/C. pea	Onion	Broccoli
	Potato	Onion	Bush bean	Carrot	Millet	Lettuce
	Sun hemp	Cowpea	Oats/Aust W Peas	Sunhemp	Broccoli	Su/C. pea
	Onion	Strawberry	Potato	Onion	Lettuce	Carrot
		Bush bean				
Net return	$21,063	$17,339	$14,317	$11,765	$30,957	$20,168

Notes: 1 acre = 0.405 hectares**.**

Conclusion and Discussion

This study analyzed the profitability and economic viability of organic crop rotations for high-value, cool-season vegetables in order to identify high-profit, low-risk crops and rotations. Economic analysis of data collected over a 3-year experimental crop rotation shows that lettuce, onion, and strawberry cost more to produce, but onion has the highest net returns over those 3 years, followed by lettuce and strawberry. However, the means test comparison indicated no difference in net returns between lettuce and onion, implying that a farmer would be indifferent between planting onion and lettuce.

This study can serve as a source of information on organic vegetable crop production in the Southeast United States. Researchers and farmers interested in organic production can learn how to develop and set up a profitable organic vegetable crop production system. The information can help small- and medium-sized growers move from monoculture cropping systems to crop rotation systems, increase profits, reduce risks, and respond effectively to increasing demand for organic food.

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