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Economic Analysis of Crop Rotation Systems for High Value Cool-Season Vegetables in the Southern Region, USA

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Abstract

The demand for organic food has increased tremendously over the last decade in the U.S. In the Southeast, the high demand for organic food has sparked an interest among conventional vegetable growers about organic production techniques and put increasing demand on existing organic growers. However, there is little information 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 that will help growers increase profit and reduce risk. Economic and statistical analyses provide useful information on net returns by crops and by rotations as well as the variability in net returns.

Keywords: Demand; Organic Food; Vegetables; Crop Rotation; Southern region; U.S

Introduction

The organic market sector is among the fastest growing food sectors in the U.S. [1]. Over a decade, the demand for organically produced goods increased considerably. For instance, from 1997 to 2012, organic retail sales increased from $3.7 billion to $28 billion. These sales are expected to reach a record high of over $35 billion by the end of 2015. However, the total value of farm-level organic sales reached $3.2 billion in 2008 up from 1.7 billion in 2007 [2]. In addition, the market share of organic sales for different food categories has remained very stable over the last decade. Organic products are sold in the U.S. through natural food stores, conventional grocery stores and farmers' markets. Presently, organic products can be found in nearly 20,000 natural foods stores and 3 of 4 conventional stores. In addition, as the demand for organic products expands, organic price premiums continue to remain high in many markets. In terms of sales, produce (fruits and vegetables) and diary remain the two top selling organic food categories. These two products accounted for 43 and 15 percent of total organic sales in 2012, followed by packaged foods and beverages [1,2]. The trend in the demand for organic food in other regions has also occurred in the Southeast. The interest in organic and locally produced food has increased the demand for organic produce grown in the region. The increased demand has sparked an interest among conventional vegetable growers about organic production techniques and put increasing demand on existing organic growers.

Challenges in organic production

The challenge in this region is to increase organic production in the face of the higher disease, insect, and weed pressure typically experienced due to long growing seasons under hot, humid conditions. Almost all organic vegetables produced in the Southeast are done on small-sized farms. As a consequence, production and economic models that encompass the profitability of entire rotations are not available. Therefore, crop rotations are needed to help growers increase profits and reduce risk. However, there is relatively little research based information available on optimal production systems for the Southeast. Providing both production and economic information on crop rotation to small and medium sized growers who are interested in organic production will make agriculture more sustainable and profitable in the Southeast. This information will also be a useful tool for conventional growers interested in transitioning to organic production.

What do we aim to accomplish?

The purpose of this study is to evaluate crop rotation systems for high value cool-season vegetables and to develop an economic model to determine the rotation with the highest return at the lowest risk in the Southeastern United States.

Literature review

Studies have shown that continuous monoculture cropping practice may decrease soil fertility and productivity, encourage the buildup of pests and diseases as well as increase environmental degradation. Therefore, the adoption of a crop rotation system constitutes one of the solutions to overcome these problems or issues [3-5]. Crop rotation is one of the major cultural practices used for its agronomic, environmental and economic benefits compared to monoculture cropping [3]. Crop rotation helps to increase soil fertility and productivity, reduce diseases, pests and weeds and increase farmer profitability [4,6]. A well planned and appropriate crop rotation can improve soil physical properties by increasing organic matter, soil fertility and controlling soil erosion [7,8]. In addition, crop rotation may help farmers reduce income variability and the likelihood of economic loss. Crop rotation can also help farmers attain sustainable crop production, improved yield and economic returns and decrease environmental degradation [9].

According to Hennessy [10], besides soil fertility, pests and disease control, a rotation strategy can be used to better manage labor supply through the year in regions with thin labor markets. In addition, the use of rotations can help farmers protect the value of their assets. Crop rotations have been shown to be effective in many cases. Charron, Chardonnet, Sams [11] found that volatile compounds, most notably, allyl isothiocyanate had suppressive effects on the growth of *Pythium* and *Rhizoctonia*. These compounds were most pronounced from mustard (*Brassica juncea*). Allyl isothiocyanate was not detected from head space analysis of broccoli, but (Z)-3-hexenyl acetate was. All the masserated brassica tissues tested had some suppressive effect on these pathogens. This method of control has been shown to be effective against root-knot nematode (*Meloidogyne javanica*) in pot experiments. Tomato seedlings planted into soil treated with crop tissue of cabbage, mustard, broccoli, or cauliflower showed differences in galling, egg number, or tomato plant growth [12].

In a survey of cool season crops in Prince Edward Island, Canada, potato fields were most often infested with root-lesion nematodes (*Pratylenchus penetrans*), while carrot fields had root-knot nematodes (*Meloidogyne hapla*) [13]. Rotation with non-host species such as barley, wheat, and annual ryegrass is recommended. An extensive rotation system was evaluated in Uruguay that included continuous cropping, and rotations involving green manures, manures, fallowing, strip tillage and no-till [14]. The study was still underway during this publication, but preliminary data indicated yields were comparable to national averages. Nitrate levels were lower in the strip-till and no-till treatments compared to the others and garlic.

Various studies on the use of crop rotations systems in different parts of the U.S. have shown that farmers who used crop rotation have had higher yields than farmers who grew the same crop over the years. According to Baldwin [9], the use of two-and three -year rotations by the majority of grain farmers in the southern region of the United States resulted in yields generally higher than those who used the same crop year after year on the same piece of land [9]. In their studies on the economic and environmental tradeoffs among alternative seed rotation in southwestern Idaho, Watkins and Lu [15] found that the use of a three-year crop rotation helped farmers increase their profitability and reduce environmental degradation. Other studies on crop rotation in the U.S showed that crop rotation increased corn yield from 5% to 30% and soybean from 8% to 16% compared to continuous production of either crop [16]. In addition, a biennial rotation of corn and soybean in the Midwest which was credited for improving soil physical properties, also helped control weeds, reduced diseases and pests, as well as producing significant increases in yield for both crops [17].

Materials and Methods

Trial site, Cultural practices and Experimental design

The rotation research was conducted on certified organic land at the Horticulture Farm in Watkinsville, Georgia and covered three years (September, 2010 - September, 2013). The Durham Horticulture Farm is a University of Georgia Research and Education Center located on the piedmont soils of Georgia. The experiments were designed in a randomized complete block with three replications for each rotation. The plot size was 6 ft. x 50 ft. long. Crop rotations include: Rotation 1- Strawberries – Bush beans – Oats/Austrian winter peas – Potatoes – Sun-hemp – Onion – Southern peas ; Rotation 2 - Broccoli – Lettuce –Sudax/ Iron Clay Peas – Carrots – Sugar snap peas – Sun-hemp – Onion – Millet. The rotations focused on cool-season high value crops. These rotations were developed with grower input to improve soil quality through cover crop biomass addition, rotate between crop families to break pest cycles, to use cover crops to supply nitrogen and suppress weeds, and to use cover crops and crop cycles to

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suppress nematodes.

The experiment consists of 6 treatments, with 3 entry points for each rotation

In the first rotation strawberry was planted in the fall (September), grown through the winter and harvested in the spring. Following strawberry harvest, which was finished in May, bush beans were planted as a summer crop. This was followed in late summer/early fall by oats/Austrian winter pea, which was followed in late winter with potatoes, harvested in May. After potatoes, sun-hemp was planted as a summer cover crop, followed by onions planted in September and harvested in April and May. The second rotation started with broccoli, which was determined with input from grower groups. This was transplanted in September and harvested in November/December. Broccoli was followed by lettuce in January and Sudax/iron clay pea mix planted 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. Sun-hemp 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 rotations with the different entry points.

Table 1: Rotations with the different entry points.

Rotation 1								
1	STR	BUB	OAP	POT	SUN	ONO	SOP	
2	OAP	POT	SUN	ONO	SOP	STR	BUB	
3	ONO	SOP	STR	BUB	OAP	POT	SUN	
Rotation 2								
1	BRO	LET	SUX	CAR	SUG	SUN	ONO	MIL
2	CAR	SUG	SUN	ONO	MIL	BRO	LET	SUX
3	ONO	MIL	BRO	LET	SUX	CAR	SUG	SUN

STR – strawberries, BUB – bush beans, OAP – oats/Austrian winter peas, POT – potatoes,

SUN – sun hemp, ONO – onions, SOP – Southern peas, BRO – broccoli, SUG – Sugar snap peas, SUX – sudax, CAR – carrots, MIL – millet, LET– Lettuce

Economic and Statistical Analysis

An enterprise budget was developed for each crop in order to perform the economic analysis. The budget includes crop total variable costs, total fixed costs, total gross revenue or return and crop net return [18-20]. The economic evaluation was performed both by crop and by rotation. Furthermore, gross and net revenue data were subjected to an analysis of variance (ANOVA) using STATA 12. The Bonferroni test was used to compare crop mean revenues. The significance in mean differences were determined at five (0.05) and one (0.01) percent probability levels by the F-test and P-values. In addition, the coefficient of variation (CV), which is the ratio of the standard deviation to the mean, was used to assess gross and net returns variability or risk. Risk averse farmers are concerned about the variability in annual income that may arise from the adoption of new cropping systems and weather conditions. Farmers will adopt a cropping system with less income variability [8].

Results and Discussions

Table 2: Total costs per acre by crop over the three years, 2011-2013.

Crop	Year 1(2011)	Year2(2012)	Year3(2013)
Broccoli	$4,759	$5,343	$7,014
Carrot	$4,957	$5,297	$5,526
Lettuce	$7,497	$11,182	$10,452
Onion Rot A	$8,523	$10,108	$10,700
Onion Rot 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

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The total costs presented in Table 2 are the sum of total variable costs (which are the costs related to plants or seed , fertilizer, labor, plastic, machinery, interest on capital, irrigation, harvest and marketing costs) and fixed costs (costs associated with machinery, irrigation, land and overhead management). Based on the results in Table 2, it cost more to produce lettuce, onion and strawberry over the three years. However, in terms of income variability, carrots had the lowest coefficient of variation followed by onions, potatoes and lettuce. This implies that over the three years, the gross revenues from carrots and onions were less variable or more stable than the gross revenues of the other crops (Table 3).

Table 3: Total gross revenue per acre or gross return per crop over the three years, 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 Rot A	19,760	28,514	23,347	23,874	0.184333
Onion Rot 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		

The mean gross revenues were subjected to an analysis of variance. The Bonferroni test was used to determine the significance in mean gross revenue differences. The different numbers in Table 4 represent the difference between the means for the crops in the rows compared to those in the columns. For example, the difference in mean gross revenue between bush bean and broccoli is -$2,622. If the difference was statistically significant, this result could indicate that the average gross revenue of bush beans was $2,622 less than the average revenue of broccoli. Based on the mean differences in Table 4, the gross return of lettuce was higher than the gross return of broccoli, bush beans and carrots. In addition, the gross return of onions was higher than the gross returns of broccoli, bush beans, carrots and potatoes. It is very important to notice that the results in Table 3 show that the average revenues of onions are higher than the average revenue of lettuce. However, the results in Table 4 show that the difference in average revenue between these two crops is not significant. This implies that, in terms of gross returns over the three years, a farmer would be indifferent between planting onions or lettuce.

Table 4: Mean gross revenues comparison between crops.

Column-Mean /Row Mean	Broccoli	Bush beans	Carrots	Lettuce	Potatoes	Strawberry
Bush bean	-2,622					
	(1.000)[1]					
Carrots	-911	1,711				
	(1.000)	(1.000)				
Lettuce	**12,746**[2]	**15,368**	**13,657**			
	(0.042)	**(0.008)**	**(0.024)**			
Potatoes	1,800	4,422	2,711	-10,946		
	(1.000)	(1.000)	(1.000)	(0.132)		
Strawberry	8,681	11,303	9,592	-4,065	6,881	
	(0.539)	-0.105	(0.308)	(1.000)	(1.000)	
Onion A	**17,469**	**20,091**	**18,380**	4,723	**15,669**	8,788
	(0.002)	**(0.000)**	**(0.001)**	(1.000)	**(0.007)**	(0.505)
Onion B	**17,524**	**20,146**	**18,435**	4,778	**15,724**	8,843
	(0.002)	**(0.000)**	**(0.001)**	(1.000)	**(0.007)**	(0.488)

[1]P-value in Parentheses

[2]In bold are statistically significant mean difference

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Table 5 presents the crop net return or net revenue, which is the difference between the gross revenue and the total costs. The results in Table 5 show an increase in net returns from year 1 to year 3 for all the crops except for strawberries with a decreasing trend. The average net returns by crop in Table 5 indicate that onions have the highest net return followed by lettuce and strawberries. In terms of variability in net return or risk, the net returns of onions were less variable or more stable followed by the net returns of lettuce and potatoes. The average net returns were also subjected to an analysis of variance and the Bonferroni test was used to determine the significance in mean net return differences.

Table 5: Net Returns per acre by crop rotation over the three years, 2011-2013.

Crop	Year 1(2011)	Year2(2012)	Year3(2013)	Mean net Returns	Coefficient of variation
Broccoli	($1,997)[1]	$862	$3,234	$700	3.743605
Carrots	($201)	$300	$604	$234	1.734698
Lettuce	$4,567	$11,790	$11,967	$9,441	0.447206
Onion Rotation A	$11,237	$18,406	$12,646	$14,096	0.269445
Onion Rotation B	$11,156	$18,887	$13,240	$14,428	0.277245
Potato	$640	$1,807	$3,508	$1,985	0.72658
Strawberry	$10,995	$3,541	($152)	$4,795	1.184287
Bush Beans	($2,173)	($101)	$1,658		
Southern Peas	($1,966)	$944	N/A		

[1]Numbers in parentheses represent a negative return or a loss.

The numbers in Table 6 represent the differences between the means for the crops in the rows compared to those in the columns. The results of the net return comparison show that net returns of onions were higher than the net returns of carrots, potatoes and broccoli. Based on these results, the average net returns of onions were $13,862 in rotation A and $14,193 in rotation B, higher than the average net return of carrots. In addition, the average net return of potatoes was $12,111 less than the average net return of onions in rotation A and $12,443 in rotation B. Furthermore, broccoli had $13,397 less than onions in rotation A and $13,728 less in rotation B, in terms of average net revenues. In addition to the analysis of net returns by crop, the study focused also on the net returns by rotation. Table 7 presents the net returns from the two main rotations, each with three starting points. Based on the results in Table 7, the starting point 1 (A1) from rotation A, had the highest net return. From rotation B, the starting point 2 (B2) produced the highest net return. Furthermore, the average net returns from rotation A and B were subjected to an analysis of variance and the Bonferroni test was used to determine the significance in the average mean difference (Table 8). The test of means comparison shows no difference in the average net return for the two rotations (Table 8). Furthermore, in terms of variability and risk, there was more variability in the net return from rotation B compared to the net return from rotation A. This implies that in terms of net return, a farmer will be indifferent between rotation A and rotation B; however, in terms of variability in net return, a risk averse farmer will choose rotation A [20, 21].

Table 6: Mean net returns comparison between crops.

Row Mean-Col Mean	Carrots	Lettuce	Onion A	Onion B	Potatoes	Strawberry
Lettuce	9,207					
	(0.148)[1]					
Onion A	**13,862**	4,655				
	(0.007)	(1.000)				
Onion B	**14,193**	4,986	331			
	(0.005)	(1.000)	(1.000)			
Potatoes	1,751	-7,456	**-12,111**	**-12,443**		
	(1.000)	(0.483)	**(0.021)**	**(0.017)**		
Strawberry	4,560	-4,647	-9,302	-9,633	2,810	
	(1.000)	(1.000)	(0.139)	(0.111)	(1.000)	
Broccoli	465	-8,742	**-13,397**	**-13,728**	-1,285	-4,095
	(1.000)	(0.204)	**(0.009)**	**(0.007)**	(1.000)	(1.000)

[1]P-values in Parentheses

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Table 7: Net Returns from rotations A and B.

	Rotation A			Rotation B		
	A1	A2	A3	B1	B2	B3
	Strawberry	Oats/Aust. W Peas	Onion	Broccoli	Carrot	Onion
	Bush Beans	Potatoes	Cowpeas	Lettuce	Sun Hemp	Millet
	Oats/ Aust. W Peas	Sun Hemp	Strawberry	Su/C. Peas	Onion	Broccoli
	Potatoes	Onion	Bush Beans	Carrot	Millet	Lettuce
	Sun Hemp	Cowpeas	Aots/Aust. W Peas	Sun Hemp	Broccoli	Su/C. Peas
	Onion	Strawberry	Potatoes	Onion	Lettuce	Carrot
		Bush Beans				
Net Returns	$21,063	$17,339	$14,317	$11,765	$30,957	$20,168

Table 8: Average Net return comparison between rotations A and B.

	Mean	C V	Bonferroni test
Rotation A	17,573	0.192288	702.667
Rotation B	20,963	0.458929	P-value:0.518

Conclusion and Policy implications

The high demand for organic food observed in the U.S. in general and the southeast region in particular has increased interest in organic production among vegetable growers. However, there is little information available on profitable organic vegetable crop production suitable for the Southeast. The objective of this study was to evaluate crop rotation systems for high value cool-season vegetables, develop production and economic models that encompass the profitability of entire rotations and determine the rotation with the highest return at the lowest risk in the Southeastern United States. Using data from an experimental crop rotation project conducted at the Durham Horticulture Farm, University of Georgia, USA, over three years, the economic and statistical analyses show that onions have the highest gross returns followed by lettuce and strawberries. However, in terms of variability in returns or risk, gross revenues of carrots were more stable followed by incomes from onions, potatoes and lettuce. In terms of net returns, onions had the highest net return followed by lettuce and strawberries. In addition, based on income variability, the net returns of onions were more stable followed by the net returns of lettuce and potatoes.

From rotation A, the sub-rotation A1 (Strawberries – Bush beans – Oats – Potatoes – Sun-hemp – Onions) has the highest net return. However, from rotation B, the sub-rotation B2 (Carrot – Sun-hemp – Onion – Millet – Broccoli – Lettuce) had the highest return. The difference between rotation A and rotation B was not statically significant. However, in terms of income stability or risk, the net returns from rotation A were more stable than the net returns from rotation B. This implies that a risk averse farmer would choose rotation A.

This study can serve as reference and an important source of information on organic vegetable crop production in the Southeast. From this study, researchers and farmers interested in organic production can learn how to develop and set up a profitable organic vegetable crop production system. In addition, the study can help small and medium sized growers to move from monoculture cropping systems to crop rotation systems, increase their profits, reduce risks and respond effectively to the increasing demand for organic food. Furthermore, the production and economic information provided in this study will be useful in rendering agriculture more sustainable and profitable in the Southeast.

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