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Yields of Vegetables and Peanut in Rotation Plantings

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Abstract. **Crop rotations can reduce problems that occur in monoculture planting systems. In 1990, at Lane, Okla., 0.5 ha of Bernow fine-loamy soil was planted to peanut (*Arachis hypogaea* L.). In the following 5 years, bell pepper (*Capsicum annuum* var. *annuum* L.), cucumber (*Cucumis sativas* L.), navy bean (*Phaseolus vulgaris* L.), and cabbage (*Brassica oleracea* L. Capitata group) were planted in one of four rotations after 1, 2, or 3 years of peanut. The first vegetable planting in each annual rotation was followed by either vegetables or peanut in following years. In 3 of the 6 years, peanut or vegetables were planted in each rotation. Peanut yields in the first year averaged 6.6 Mg·ha^{-1}, but were <1.9 Mg·ha^{-1} thereafter. Yields of the first vegetable planting, which followed 1 or 2 years of peanut, were normal for this location, but were significantly lower after 3 years of peanut. For second or third plantings of vegetables in rotations, yields were reduced up to 50% compared to the first vegetable planting. For most crops, the rotation that had 3 years of peanut followed by 3 years of vegetables generally produced the least cumulative yield. Numbers of sclerotia produced by soilborne plant pathogenic fungi fluctuated over the years, but were the same in the spring of the second and sixth years. Rotating these crops appears to have limited applicability for maintaining high vegetable or peanut yields.**

Continuous production of peanut can lead to reduced yield (Akem et al., 1992; Bell and Sumner, 1984). Because of pest problems, and since peanut growing and marketing are subject to changes in the national farm support system (Hoover and Sumner, 1985), there has been increased interest in rotating peanut with other crops, and in diversifying production on peanut land.

In the southeastern United States, multiple cropping is possible, and crops can be planted before and/or after peanut (Sumner et al., 1978, 1979). Vegetables often have low yields following peanut as compared to following other vegetables (Sumner et al., 1983). In these cropping systems, vegetables were planted in the same growing season as peanut. It is not clear whether, in annual rotations of peanut and vegetables, problems would be carried over to subsequent years. This experiment was designed to determine how vegetable and peanut yields are affected by annual crop rotations.

Materials and Methods

The experiment was conducted on a Bernow fine-loamy, siliceous, thermic Glossic Paleudalf soil at Lane, Okla. In the 2 years previous, sweet corn (*Zea mays* L.) was grown on this ground. In 1990, a 0.5-ha area was plowed and disked and beds, on 0.9-m centers, were formed east to west with a rolling cultivator. In each year, sufficient fertilizer to support vegetables, ≈112N–180P–450K kg·ha^{-1}, actual, with a year-to-year variation of ±5 kg·ha^{-1} for each fertilizer component, was broadcast preplant (McCraw and Motes, 1987). This amount would also be sufficient to support peanuts (Sholar et al., 1996). Russo (1991) found that, at least for peppers, a split application of fertilizer did not improve yield over a single preplant application.

The 0.5 ha was planted with 'Spanco' peanut. The area was subdivided into 16 plots, each of which was assigned to one of four rotations (R) that were replicated four times. Each of the 16 plots was 9.1 m wide × 12.2 m long, with six treatment rows. From 1991 to 1995 there was a 4.5-m nonplanted strip between plots. A guard row of either peanut or vegetables was on the north and south sides of plots. Three of the treatment rows in each plot were treated with the soil fungicide pentachloronitrobenzene (PCNB). Tetrachloroisophthalonitrile (chlorothalonil) was applied weekly, and alternated in application to peanut with *N*-(2,6-dimethyl-phenyl)-*N*-(methoxyacetyl) alanine (metalaxyl) once symptoms of fungal colonization of foliage were observed. Plots were assigned to rotations so that peanut or vegetables were each planted in an individual plot in 3 of the 6 years of the experiment (Table 1). The rows treated with fungicides in 1990 were treated with PCNB, regardless of crop, in subsequent years. In each year plots were arranged in a split-plot design with rotation being the main plot and fungicide treatment being the subplot.

In Spring 1991, and for all other years, two of the six treatment rows in plots, in the appropriate rotations, were planted with either 6-week-old greenhouse-grown seedlings of 'Pip' bell pepper, seed of 'Fleetwood', an indeterminate Type II navy bean, or seed of 'Dasher II' cucumber. One row of each crop was planted in fungicide-treated soil and the other in nontreated soil. Cucumbers were grown on trellises made from woven nylon (TrellisPlus; Dalen Products, Knoxville, Tenn.), strung between metal posts spaced 3 m apart. In-row spacing of peppers and cucumbers was 0.46 m. Navy bean seeds were drilled and spaced 5 cm apart in the row. Occasionally, chlorothalonil was applied to cucumbers in rows that had been treated with PCNB. The insecticides (3-phenoxyphenyl) methyl (±)-*cis,trans*,-3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate (permethrin) and 1-naphthyl *N*-methylcarbamate (carbaryl) were applied to cucumbers as required.

Following the last harvest of spring-planted vegetables, plants were mowed and the beds reformed with the rolling cultivator. Four-week-old greenhouse-grown seedlings of 'Solid Blue 770' cabbage were transplanted in August of each year on the same beds that had vegetables. In-row spacing of cabbage was 0.3 m. No additional fungicide applications were made to cabbage. Occasionally, a *Bacillus thuringiensis*-containing insecticide was required. A vegetable transplanter (Holland Transplant Co., Holland, Mich.) was used for peppers and cabbage. Overhead irrigation was used when precipitation was <50 mm·week^{-1}.

Bell pepper, cucumber, and cabbage were harvested when they reached grade US #1 or better [U.S. Dept. of Agriculture (USDA), 1945, 1958, 1989]; navy bean and peanut were harvested at maturity. Bell pepper was harvested four times over 21 days. Cucumber was harvested until the marketable yield was <50% of total yield for any individual harvest. Cabbage was harvested three times over 14 days. Navy bean and peanut were harvested once, and peanut pods were evaluated by USDA graders. The marketable peanut yield was de-

Table 1. Sequence of peanut (P) and vegetables (V)^z in annual rotations from 1991 to 1995.

	Year					
Rotation	1990	1991	1992	1993	1994	1995
1	P	V	P	P	V	V
2	P	P	V	P	V	V
3	P	P	P	V	V	V
4	P	P	V	V	P	V

^{z}Spring-planted vegetables were bell pepper, cucumber, and navy bean; cabbage was planted in late summer of each year following the spring planted vegetables in each plot.

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termined by multiplying the total yield by the total sound marketable kernels (SMK) rating, which is recorded as a percentage. Cumulative marketable yield for all crops, and the average SMK rating, was determined across the rotations over the length of the experiment. In September of each year, annual Italian ryegrass (*Lolium multiflorum* Lam.) was planted at 30 kg•ha^{-1} in each plot. In plots with fall cabbage, annual Italian ryegrass was sown in alleys between rows.

Starting in 1991, sclerotia, which were likely in the genera *Sclerotium* and *Sclerotinia*, were counted before planting in the spring of each year. Soil samples were taken from three locations in each plot. Three 10-g subsamples from each homogenized sample were washed according to the method of Adams (1979). Washed samples were filtered through Whatman No. 4 filter paper (Whatman Intl., Maidstone, England), which were viewed with a binocular microscope (30× total magnification). The area of the field of view was determined. The average number of sclerotia from three randomly distributed fields on each disk was determined, converted to the total number of sclerotia on the disk, and recorded as the number of sclerotia in 10 g of soil. Sclerotia viability was not tested.

Data were analyzed by the general linear models procedure in SAS (ver. 6.1, SAS Inst., Cary, N.C.). Cumulative yield for each crop, and average SMK ratings, were determined and subjected to post hoc means separation analysis. Days to harvest for each crop was determined. Total precipitation and growing season high, low, and average minimum and maximum air temperatures for each crop were tabulated (Table 2). These data were correlated with these and marketable yields and SMK rating.

Results

Crop year and crop rotation affected yield and SMK rating (Table 3). Fungicide treatment affected yield only of navy bean, where nontreated plants produced 1.4 vs. 1.1 Mg•ha^{-1} for treated plants. Except for cabbage yield and SMK rating, there was an interaction between planting year and rotation.

The SMK rating ranged between 64%–76%, and the cumulative average rating was not affected by rotation (Table 4). In 1993, R2 produced a higher peanut yield than R1. Occasionally, within a year, there were differences in vegetable yields between rotations. In 1992, R4 had a better bell pepper yield and a worse navy bean yield than R2. In 1995, R4 had the best cucumber yield. Cumulative yields for peanut, bell pepper, and cucumber were least for R3. Cumulative yield for navy bean was not affected by rotation, and for cabbage cumulative yields for R1, R2, and R3 were similar.

Following 1 or 2 years of peanut, vegetable yields were normal for this area. All vegetables had lower yields, sometimes up to 50%, if they followed 3 years of peanut (Table 4). In each rotation, vegetable production in the second and third years was almost always lower than in the first year. The exception was for bell pepper in R3 in 1994. Except for bell pepper, vegetable yields in 1995 appeared to be increasing.

Sclerotia counts fluctuated between 1300–2000/10 g of soil. In all rotations, sclerotia counts in Spring 1991 were almost identical to those in Spring 1995, and there were no differences between fungicide-treated and nontreated plots.

Some abiotic factors were correlated with yield or SMK rating (Table 5). For bell pepper, the lowest minimum air temperature was positively correlated, but the highest minimum air temperature was negatively correlated with yield. Average minimum air temperature was negatively correlated with cabbage yield. For cucumber lowest and highest minimum, average maximum, and lowest and highest maximum air temperatures were negatively correlated, but precipitation was positively correlated with yield. Highest minimum air temperature, and average, lowest, and highest maximum air temperature were negatively correlated with navy bean yield. Precipitation was positively correlated with navy bean yield. Lowest minimum and maximum air temperatures were negatively correlated with peanut yield. Lowest minimum air temperature was negatively correlated with SMK rating.

Discussion

Monoculture brings about changes in soil pH and tilth, residual nutrients, and in populations of disease and beneficial organisms (Shippers et al., 1987; Shipton, 1977). These changes can lead to reduced yields. In some cases rotations with other crops can be used to improve yields of all crops in a rotation (Curl, 1963; Sumner, 1984).

In this research there were trends suggesting vegetables should not be planted in the same soil after more than 2 years of peanut monoculture. Also, for unknown reasons, yields from the second or third vegetable plantings were less than from the first, regardless of rotation. Conditions resulting from these rotations may alone, or in concert, influence vegetable yields.

There was no evidence that sclerotia-producing fungi were responsible for the decline in vegetable yields. If there had been pressure

Table 2. Planting and last harvest dates, days to harvest, air temperatures, and precipitation for all crops, 1990–1995.

		Date			Temp (°C) between planting and harvest				
					Minimum		Maximum		
Crop	Year	Planting	Last harvest	Days to harvest	Avg	Range	Avg	Range	Precipitation (mm)
Peanut	1990	18 June	12 Oct.	116	19.0	5.0–24.0	28.2	11.1–37.8	49
	1991	28 May	17 Sept.	112	20.5	7.2–25.6	30.9	22.2–31.1	39
	1992	7 May	24 Sept.	140	16.3	4.4–25.6	27.3	11.1–34.4	85
	1993	14 May	22 Sept.	131	18.0	6.1–25.6	31.4	15.6–40.0	58
	1994	16 May	8 Aug.	114	19.1	10.6–25.0	29.5	22.8–35.6	42
Bell pepper	1991	17 Apr.	19 July	93	17.3	4.4–23.3	28.3	15.0–36.1	40
	1992	16 Apr.	30 July	94	15.2	4.4–24.4	26.2	14.4–33.9	76
	1993	28 Apr.	16 July	79	17.4	5.6–24.4	28.4	20.0–35.6	34
	1994	14 Apr.	5 July	83	16.9	3.3–25.0	28.7	11.7–35.0	32
	1995	18 Apr.	6 July	79	15.8	2.8–25.6	27.5	14.4–34.4	39
Cabbage	1991	23 Aug.	11 Dec.	81	11.3	–6.7–23.3	24.5	–3.9–36.7	35
	1992	15 Aug.	6 Nov.	83	10.6	–4.4–25.6	25.5	6.1–24.4	23
	1993	28 Aug.	22 Nov.	86	11.1	–7.8–25.0	25.4	3.3–35.6	49
	1994	25 Aug.	29 Nov.	96	20.8	–2.8–33.9	22.1	5.0–33.3	49
	1995	21 Aug.	27 Nov.	98	12.7	3.9–24.4	27.6	16.1–40.0	20
Cucumber	1991	7 May	26 June	80	20.2	4.4–25.6	31.4	22.2–35.0	31
	1992	17 Apr.	14 Aug.	119	15.6	4.4–24.4	26.5	14.4–34.4	90
	1993	21 May	28 July	68	18.8	9.4–25.6	30.4	20.6–37.8	19
	1994	16 May	29 July	74	18.9	10.6–25.0	30.2	24.4–35.6	22
	1995	9 May	6 July	77	18.8	9.4–25.6	31.0	23.9–37.2	24
Navy bean	1991	13 May	15 Aug.	94	20.6	16.7–25.6	32.1	24.4–36.7	35
	1992	13 Apr.	23 July	101	16.4	4.4–23.3	26.9	15.0–36.1	59
	1993	27 Apr.	3 Aug.	98	18.4	5.6–25.6	30.6	3.3–40.0	35
	1994	16 May	13 July	58	14.4	19.1–25.0	30.0	24.4–35.0	20
	1995	9 May	31 July	83	18.8	9.4–25.6	31.0	23.9–37.8	27

from these fungi, sclerotia counts would probably have increased, which was not the case. Dow et al. (1988) reported that high humidity and temperatures between 20 and 25 °C were optimal for infection of plants by some soilborne organisms. They also indicated that young plants were more susceptible than older ones. Temperature and moisture conditions at this location may not have been optimal for disease development.

Relatively constant sclerotia counts do not rule out other disease-causing organisms as being responsible for vegetable yield declines. There were few indications of fungal-induced disease, which would explain why fungicides did not improve yields. Application of fungicides reduced navy bean yield. It may be that fungicides interfered with soil organisms that are beneficial to navy bean.

Abiotic factors not associated with crop culture can also affect yield. Fluctuations in air temperature and precipitation may explain some of the year-to-year differences in yields. Vegetable (Pierce, 1987) and peanut flower production and retention (Bagnall and King, 1991) are affected by air temperature. During the 1992 growing season of the spring-planted crops, temperatures were lower and precipitation was higher than in other years. However, in that year yields of spring-planted crop yields resembled those of 1991. It was not until 1993, a year in which temperature and precipitation were more near the average, that vegetable crop yields dramatically declined, even though peanut yields were closer to the normal yield for the area, not like that for 1990, which was extraordinarily high. Before 1990, the land was in grass and sweet corn. These conditions are ideal for peanut (Henning et al., 1982). The peanut cultivar Spanco has the capability, under excellent conditions, to commercially produce at the 1990 level, a generally good year for Oklahoma peanut yields (R. Sholar, personal communication). From 1990 to 1994, average marketable yields of peanut were within those expected for this variety (Kirby et al., 1989).

Table 3. Effect of crop year, rotation, and fungicide application on yield of vegetables and peanut and total sound marketable kernel (SMK) rating.

					Peanut	
Treatment	Bell pepper	Cabbage	Cucumber	Navy bean	Mkt. yield	SMK[z] rating
Year (Y)	**	**	**	**	**	**
Rotation (R)	**	**	**	**	**	**
Fungicide (F)	NS	NS	NS	*	NS	NS
Interactions						
Y × R	*	NS	*	*	**	NS
F × R	NS	NS	NS	NS	NS	NS
F × Y	NS	NS	NS	NS	NS	NS
F × Y × R	NS	NS	NS	NS	NS	NS

[z] Percentile data transformed to radians prior to analysis.

[NS,*,**] Nonsignificant or significant at $P < 0.05$ or 0.01, respectively, analysis of variance.

Table 4. Interactive effects of rotation and planting year on yield and total sound marketablekernel (SMK) rating of peanut and yield of vegetables.

	Peanut SMK rating (%)						Cumulative
Rotation	1990	1991	1992	1993	1994	1995	avg
1	75	V	64	67	V	V	69 a
2	76^{NS}	70	V	68^{NS}	V	V	71 a
3	73^{NS}	70^{NS}	66^{NS}	V	V	V	70 a
4	76^{NS}	69^{NS}	V	V	71	V	72 a
			Peanut marketable yield (Mg•ha^{-1})				
1	7.08	V[z]	0.96	1.64	V	V	9.68 a
2	6.36^{NS}	0.86	V	2.09**	V	V	9.31 a
3	6.23^{NS}	0.86^{NS}	0.87^{NS}	V	V	V	7.96 b
4	6.81^{NS}	0.80^{NS}	V	V	1.10	V	8.71 a
			Bell pepper marketable yield (Mg•ha^{-1})				
1	P	9.75	P	P	4.02	2.97	16.74 a
2	P	P	10.56	P	4.73^{NS}	3.01^{NS}	18.30 a
3	P	P	P	4.13	5.17^{NS}	2.77^{NS}	12.07 b
4	P	P	13.84*	4.18^{NS}	P	3.83^{NS}	21.85 a
			Cucumber marketable yield (Mg•ha^{-1})				
1	P	41.38	P	P	6.43	21.44	69.70 b
2	P	P	43.49	P	7.71^{NS}	16.12^{NS}	67.32 b
3	P	P	P	19.69	5.94^{NS}	17.79^{NS}	43.42 c
4	P	P	41.57^{NS}	13.64^{NS}	P	24.25*	79.46 a
			Cabbage marketable yield (Mg•ha^{-1})				
1	P	20.75	P	P	4.13	13.53	38.41 b
2	P	P	24.55	P	5.43^{NS}	16.69^{NS}	46.67 ab
3	P	P	P	17.24	9.36^{NS}	14.42^{NS}	41.02 b
4	P	P	24.84^{NS}	17.27^{NS}	P	12.35^{NS}	58.46 a
			Navy bean marketable yield (Mg•ha^{-1})				
1	P	1.71	P	P	0.37	1.31	3.39 a
2	P	P	1.84	P	0.41^{NS}	1.41^{NS}	3.66 a
3	P	P	P	1.46	0.56^{NS}	1.27^{NS}	3.29 a
4	P	P	1.67*	1.45^{NS}	P	1.41^{NS}	4.53 a

[z] V = vegetables planted in that rotation in that year; P = peanut planted in that rotation in that year.

[NS,*,**] Nonsignificant or significant at $P < 0.05$ or 0.01, respectively, LSD. Mean separation in a column within crop and criterion by Duncan's multiple range test ($P < 0.05$).

Cover crops have been incorporated into rotations to protect and change the soil environment. However, cover crops may produce metabolites that affect the biology of soil-inhabiting organisms or of cash crops. Ryegrass as a winter cover followed spring-planted crops, and in the alleys between rows of fall-planted cabbage. Perennial Italian ryegrass (*L. perenne* L.) is known to interfere, principally through density, with yield of some vegetables (Bell, 1995). Whether this is true for annual ryegrass, *L. multiflorum*, in general, and for the crops evaluated here requires further research.

If there were allelopathic effects from the cover crop they likely would have been evident after two seasons, which was not the case since vegetable yields did not decline until the fourth growing season. If allelopathic effects had been present, they presumably would be evident across all rotations. However, for most crops, cumulative yields were affected by rotation. For most vegetables, R3, which had 3 years of peanut followed by 3 years of vegetables, produced the smallest cumulative yield. This result suggests that several years of peanut culture may cause changes in the soil environment that more adversely affect vegetables than if peanut was rotated with vegetables.

These data exposed limitations in rotating vegetables with peanut, at least at this location. Factors other than those measured likely affected and, in some cases, reduced yields up to 50%. It would be incorrect to ascribe all blame for reduced vegetable yields to their following 3 years of peanut. Vegetable yields also declined after following vegetables. In addition, there appeared to be limited rebounds in some vegetable yields in 1995, the last year of the rotation scheme; however, these were generally well below those of the first vegetable planting.

Summer (1994) stated that desirable rotation crops may not be profitable due to disease or climatic or economic conditions. More research is needed to determine the reason for reduced yields and how to best rotate vegetables with peanut. Additional work is also needed to determine if other vegetable crops can be successfully incorporated into a rotation with peanut. Brenneman et al. (1995) found that rotating peanuts with Pensacola bahiagrass (*Paspalum notatum* Flüggé) improved the yield of both. Sweet corn, also a monocot, which presumably has some of the qualities that make other monocots a good component of rotations with peanut, may be a viable addition to a rotation that will allow the production of peanut and vegetables.

Table 5. Correlations between cultural and environmental variables and crop yields and peanut sound marketable kernel (SMK) rating.

					Peanut	
Variable	Bell pepper	Cabbage	Cucumber	Navy bean	Mkt. yield	SMK rating
			Pearson Correlation Coefficients *(Prob > |R| under Ho:Rho = 0)*			
Precipitation			0.2104 (0.0396)	0.2049 (0.0453)		
Temperature						
Average min.		–0.2209 (0.0305)				
Lowest min.	0.2422 (0.0174)		–0.2284 (0.0252)		–0.3023 (0.0028)	–0.2104 (0.0397)
Highest min.	–0.3058 (0.0024)		–0.2339 (0.0218)	–0.2803 (0.0057)		
Average max.			–0.2106 (0.0394)	–0.2672 (0.0085)		
Lowest max.			–0.2278 (0.0256)	–0.2178 (0.0374)	–0.2697 (0.0079)	
Highest max.			–0.2667 (0.0086)	–0.2411 (0.0180)		

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