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Production and Economic Returns of Three Vegetable Double-cropping Systems

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Abstract. **Double-cropping systems were compared to the same vegetable monocropped. Snap beans [*Phaseolus vulgaris* (L.) 'Bush Blue Lake'], sweet corn [*Zea mays* (L.) 'Sundance'], cauliflower [*Brassica oleracea* (L.), Botrytis group, 'Snow Crown'], summer squash [*Cucurbita pepo* (L.) 'Zucchini Elite'], and broccoli [*Brassica oleracea* (L.), Italica group, 'Green Comet'] were used. The double-crop systems used were spring snap bean and fall cauliflower, summer squash and fall broccoli, and spring sweet corn and fall snap beans. The monocrop system was used as a control for the double-crop systems. The greatest net returns were: 1) squash monocropped or squash/broccoli double-cropped, 2) squash double-cropped, 3) cauliflower or cauliflower/snap bean double-cropped, and 4) broccoli or cauliflower or snap beans monocropped. Fall snap beans provided the least economic return. The double-cropping system allows an option of crop production with a potential increase in yield and economic returns using half the amount of land per year required for either crop grown in monoculture. In addition, these systems reduce the risk of economic failure during a year of low-market demand for either crop grown alone.**

The U.S. farming system currently uses a farm tractor with appropriate attached equipment for its cropping operations. This method of farming has resulted in a farming system with equally spaced, single rows of plants grown in monoculture. This system permits maximum mechanization, and the farmer is able to establish, maintain, and harvest crops with reduced labor, time, and cost.

In countries such as Pakistan, Malaysia, and the Philippines, where crop land is scarce, and on many farms in the United States, double cropping is popular (15). Double cropping allows the production of two crops per year per unit area, but in many instances crop productivity is not increased, due either to a lack of knowledge or to environmental limitations.

It is estimated that the world demand for food will triple in the next 20 to 30 years. The population is expected to double within the same timeframe, and the demand for food will increase as the standard of living increases in developing countries (4). Crop production per unit area must increase, as only marginal land remains for future expansion.

The objectives of this study were to compare vegetable productivity in double-crop and monocrop systems and to evaluate economic returns and production costs of the two systems.

Materials and Methods

This study was conducted on a Flanagan silty clay loam soil with a pH ranging from 5.5 to 6.1. Soil test analysis indicated that additional K and P were not required for maximum crop production. A basal amount of 134 kg/ha of actual N for each crop was applied and incorporated into the soil prior to planting.

Soil preparation was done with a 50 hp farm tractor with appropriate attached equipment. The double-crop system was developed using 3 combinations of 6 vegetable crops. The 6 vegetables also were grown in monoculture. The treatments were arranged in a randomized complete block design with four replications. Each plot measured 9.4 m long and consisted of 5 single rows. Rows were oriented in an east-west direction at recommended row and plant spacings (12). The insecticide 1-naphthalenyl methylcarbomate (Carbaryl) was used. Cultivation by hand or tractor and over-head sprinkler irrigation were executed as needed. All harvesting was done by hand.

Snap bean and cauliflower. Crops used were: 1) spring snap beans followed by fall cauliflower, 2) spring snap beans alone, and 3) fall cauliflower alone. Snap beans were direct seeded on 29 May, and harvested 3 times from 17–30 July. Monocropped snap beans were harvested an additional 3 times from 25 Aug. to 5 Sept. Weights of the harvested beans were recorded. After a 2-day land preparation period, 5-week-old fall cauliflower plants were transplanted on the double-cropped and monocropped area on 3 Aug. Both were once-over harvested on 10 Oct. or 23 Oct., and weight of heads was recorded. At the rate of 0.9 kg ai per hectare, 2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine (Trifluralin) was applied preplant incorporated for weed control.

Squash and broccoli. Crops used were: 1) summer squash followed by fall broccoli, 2) summer squash alone, and 3) fall broccoli alone. Summer squash plants (3 weeks old) were transplanted on 16 May. Seven harvests of double-cropped summer squash were made between 27 June to 23 July. Harvesting of monocropped summer squash began 27 June and continued through 28 Aug. Following land preparation, 7-week-old fall broccoli plants were transplanted 3 Aug. on the same land area where the double-cropped squash was planted and was harvested 3 times between 26 Sept. and 22 Oct. Broccoli, monocropped, was harvested on the same dates as the double-cropped system.

Fruit weight was recorded for summer squash, and head weight recorded for broccoli. Weeds were controlled with 11 kg ai/ha of granular DCPA (dimethyl tetrachloroterephthalate).

Sweet corn and snap bean. Crops used were: 1) spring sweet corn followed by fall snap beans, 2) spring sweet corn alone, and 3) fall snap beans alone. Sweet corn was direct seeded on 29 May and harvested on 30 July. After a 3-day land preparation period, fall snap beans were seeded on the same land area on 4 Aug. Both monocropped and double-cropped snap beans were harvested on 26 Sept. and 1 Oct. The number of sweet corn ears was recorded, and the weight was recorded for snap beans. Weeds were controlled, post-emergence, with 1.1 kg ai/ha of 3-(1-methylethyl)-1*H*-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide (bentazon).

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Table 1. Production cost of all crops as influenced by cropping system.

Crop	Production cost/ha ($)			
	Materials	Machine operation	Labor	Total
Doublecrop				
Spring snap bean	568	110	712	1390
Fall cauliflower	1011	137	628	1766
Total	1579	247	1340	3166
Summer squash	2855	207	1894	4957
Fall broccoli	605	159	744	1509
Total	3460	366	2638	6466
Spring sweet corn	493	116	288	898
Fall snap bean	559	99	492	1150
Total	1052	215	780	2048
Monocrop				
Spring snap bean	823	249	1121	2194
Fall cauliflower	1037	137	628	1803
Summer squash	3694	359	3931	7984
Fall broccoli	635	159	744	1539
Spring sweet corn	474	116	288	879
Fall snap bean	526	107	412	1046

Material, labor cost, machine operating cost, and economic returns. Ownership costs of land, building, and equipment were not included in the budget of this study, as they were assumed to be the same for both systems. Material included all cash expense items of fertilizer, insecticides, fungicides, herbicides, seeds, cartons, crates, and peat pots.

Labor was comprised of family and hired labor. Family labor (one person) was priced at $5.00 per hour. Hired labor was priced at the minimum wage of $3.35 per hour, which consisted of manual labor entirely. Machine operating cost included the cost of fuel, repairs, and maintenance of the truck, pick-up, and tractor. Current market prices per unit of yield were assigned to each crop at average year's retail rates (9). Statistical analysis was used for determining differences in crop yields and in crop profits, so that crop profit maximization could be determined per ha.

Table 2. Influence of cropping systems on spring snap bean and fall cauliflower yields.[z]

Cropping system	Marketable yield (1000 kg/ha)	
	Snap beans	Cauliflower
Doublecrop	4.31 a	19.43 a
Monocrop	10.74 b	19.91 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

Results

Snap beans and cauliflower. Of the total material cost for snap beans, crates and seeds comprised 50% and 30%, respectively, of the total under the monocrop system (Table 1). Under the double-crop system, seed cost was 50%, and the crate cost was 25% of the total cost of materials. When comparing the cost of materials for both systems, double-crop snap beans costs were about 30% lower than those for the monocrop system, primarily because of reduced yields and, therefore, fewer crates used at harvest.

The material expenses for cauliflower were similar under both cropping systems (Table 1). Crates and seeds were 45% and 40%, respectively, of this expense. Insecticides were 3% of the total cost.

About half of the machine operation cost for growing spring snap beans under either system was attributed to the bulk truck time, while all other machine operation costs were similar, except for the pickup truck time. With the double-crop system, the pickup truck cost was about one-third of the monocrop system. When comparing the machine operation costs of both cropping systems, the double-crop costs were about 44% of the monocrop costs (Table 1). This difference was due to the reduced pickup truck cost on the double-crop system, since reduced yield required fewer laborers and, consequently less transportation than for monoculture.

Machine operation costs for the production of fall cauliflower were the same under both cropping systems (Table 1). The tractor and bulk truck costs comprised 70% of the total. The least cost (15%) was attributed to the irrigation system and pickup truck time.

With double-cropped spring snap beans, 78% of the labor cost occurred during the harvest, compared to 91% in the monocropped system. Under both cropping systems, irrigation was the second largest expense.

When family and hired labor were separated for snap bean operation on both systems, 95% of the cost was attributed to hired labor. Thus, only 5% of the total cost of labor operation may be used as an income.

Within the doublecrop and monocrop cauliflower systems, equal amounts of labor were required for each operation (Table 1). Under both systems, 58% of the cost was attributed to harvesting and 22% of the cost was charged to greenhouse planting. The least amount of labor cost was charged to the applications of herbicide and fertilizer. If the hired labor used for these operations were replaced by family members, approximately 85% of the labor cost could be recaptured and used as an income.

Total cost to produce spring snap beans and fall cauliflower in monoculture was 30%–41%, respectively, less than the double-cropped combination cost (Table 1). This increased cost for the double-crop system was attributed to the extra operations required during land preparation for the second crop in succession. The average itemized costs for all crops were: material, 48%; machine operation, 9%; and labor, 43%.

Double-cropped snap beans produced a significantly lower yield than those monocropped (Table 2). This dramatic difference in yield between the two cropping systems is a result of the reduced harvest period. Double-cropped spring snap beans were removed early to permit cauliflower transplanting. Mon-

Table 3. Yield of summer squash and fall broccoli as influenced by two cropping systems.[z]

Cropping system	Marketable yield (1000 kg/ha)	
	Summer squash	Fall broccoli
Doublecrop	44.18 a	19.01 a
Monocrop	70.20 b	17.10 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 4. Yield of spring sweet corn and fall snap beans as influenced by cropping system.[z]

Cropping system	Marketable yield	
	Sweet corn (dozen/ha)	Snap bean (kg/ha)
Doublecrop	3139 a	3962 a
Monocrop	2942 a	3012 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

ocropped spring snap beans were harvested as long as the product was marketable.

There were no significant differences in cauliflower yield between the two cropping systems. This lack of yield difference resulted from cauliflower being grown and harvested for the same length of time on both systems. The schedule of operations for both cropping systems ranged from July to October. Both cropping systems required similar costs because their schedules involved similar times.

Squash and broccoli. Materials for the summer squash operation were 10% higher under the monocrop system as compared to the double-crop system (Table 1). This difference was due to the increased number of crates required under the monocrop system because of a longer harvesting period. About 43% and 49% of the total costs were attributed to the cost of transplanting materials and crates, respectively. The least cost was for herbicides. For broccoli, both cropping systems resulted in similar costs (Table 1). However, 45% of the cost was for seeds and 35% for crates.

Machine operation cost to produce summer squash under the double-crop system was 60% of the cost to grow it in monoculture and 4% of the total cost (Table 1). About 65% and 54% of the costs under the monocrop and double-crop system, respectively, were attributed to the bulk truck time during the harvesting period. The truck was used for transporting labor and produce.

Costs to operate machines for the production of fall broccoli were the same under both cropping systems (Table 1). This cost was 10% of the total production cost.

The production season for summer squash under the double-crop system ranged from April to July, whereas that for the monocrop system was from April to August. About 90% of the labor was needed in the months of June, July, and August (during the harvesting period). Other significant periods of high labor requirement were in the months of April and May for greenhouse crop planting and field transplanting, respectively.

Labor required for production of summer squash under both systems was 80% for harvesting, 8% for transplanting, and 5% for greenhouse planting. Although these percentages were similar within cropping systems, the labor required for harvest under the monocrop system was twice that for the double-crop system. Monocropped squash was harvested 17 times. Double cropped squash was removed after 7 harvests to permit planting of fall broccoli. About 95% of the labor cost was hired.

Fall broccoli, grown from July to October, required equal amounts of labor from both cropping systems. Greenhouse planting used 4%, transplanting 19%, and harvesting 65% of the labor. Herbicide and fertilizer application used the least labor. About 85% of the labor was hired.

Double-cropped summer squash yield was significantly less than the monocrop system (Table 3). Due to early termination of double-crop squash production, no significant difference in

Table 5. Net return for all crops double-cropped as influenced by cropping systems.[z]

Crop	Net revenue/ha ($ 1000)	
	Retail	Wholesale
Doublecrop		
Spring snap bean	2.89	0.80
Fall cauliflower	13.76	5.99
Total	16.65 b	6.79 b
Summer squash	24.27	9.66
Fall broccoli	9.90	4.19
Total	34.17 a	13.85 a
Spring sweet corn	3.81	1.46
Fall snap beans	2.78	0.86
Total	6.59 de	2.32 ef
Monocrop		
Spring snap bean	8.46 cd	3.25 def
Fall cauliflower	14.12 bc	6.16 bc
Summer squash	38.46 a	15.24 a
Fall broccoli	8.72 cd	3.59 cdef
Spring sweet corn	3.53 de	1.33 ef
Fall snap bean	1.94 e	0.48 f

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

yield occurred with fall broccoli between cropping systems (Table 3). This similarity in yield occurred because each had the same amount of growing time from establishment to harvest.

Sweet corn and snap beans. The materials expense to produce sweet corn was similar under both systems (Table 1). Crates were 62% of the cost, with seed 16%. Costs of other cash expense items were similar.

For fall snap bean production, materials expense was similar under both cropping systems (Table 1). Seeds were 56% of the total cost, and crates 27%.

Machine operation costs to produce spring sweet corn were equal for both cropping systems (Table 1). The highest cost was the 40% charged to the operation of the irrigation system, 23% to the tractor operation, and 12% to the bulk truck. These costs were evenly distributed throughout the entire sweet corn season.

The machine operating cost to produce fall snap beans under both systems was similar (Table 1). Of this cost, 29% was attributed to the operation of the tractor, 38% to the bulk truck, 28% to irrigation, and the remainder to the operation of the pickup truck. Operation costs were evenly distributed over the crop season.

The sweet corn production season for both cropping systems extended from April to July with 80% of the labor required during July. Of the total labor cost, 50% was for harvesting and 26% was for the irrigation set-up and removal. About 75% of the labor was charged to hired labor.

The fall snap bean production season extended from August to October; 95% of the labor was required in September and October on both systems. Harvesting used 85% of the labor (Table 1), and irrigation used 5%. Hired labor was 80% of the total. Sweet corn and snap bean yields from both cropping systems were not significantly different (Table 4), as planting and harvesting dates were similar.

The rank of total production costs of all crops or crop combinations from highest to lowest is as follows (Table 1): 1) summer squash monocropped, 2) summer squash double-cropped, 3) summer squash plus fall broccoli double-cropped, 4) spring snap beans plus fall cauliflower double-cropped, 5) spring snap beans monocropped, 6) fall cauliflower both systems, 7) fall broccoli both systems, 8) fall snap beans both systems, and 9) spring sweet corn both systems.

The high cost of summer squash production resulted from high yields, which required 7–17 harvest periods and trips to markets. Squash, cauliflower, and broccoli were grown in the greenhouse before being transplanted in the field, requiring extra time and labor as compared to direct seeded snap beans and sweet corn.

Sweet corn, with the least total production cost, required less maintenance during growth as compared to other crops. Sweet corn required only one harvest period, as compared to 2 or 3 for broccoli and cauliflower, and several for squash.

Net returns. Net retail returns from monocropped spring snap beans and cauliflower were 50% and 85% of the snapbean/cauliflower system, respectively (Table 5). Double-cropped cauliflower produced 83% of that system's profit.

Net retail returns from summer squash and broccoli monocrops were 112% and 25% of the squash and broccoli double-crop (Table 5). These results show that the double-crop system offered no advantage over summer squash grown alone. Net retail return from sweet corn and fall snapbean monocrops were 54% and 29%, respectively, of the sweet corn—fall snap bean double crop (Table 5).

When the net returns of all crops were compared (Table 5), summer squash monocrop and summer squash/fall broccoli double cropped gave higher returns than other crops. The lowest net returns were the sweet corn monocrop and the sweet corn/fall snap beans double-crop combination.

Discussion

The double-crop system allows operators of small farms an opportunity to produce a second crop during a growing season on the same land area of the preceding crop. Although the double-crop system offered more efficient use of land, higher yields, and profits than some instances of monocropping, the system demands timely and careful management. Morse and Gayle (6) used double-cropping of summer cabbage (*Brassica oleracea,* Capitata group) and fall broccoli to increase land productivity of vegetables. Although the yield of broccoli was below the national average, other combinations of double-cropping have proven successful under the long growing seasons in the southeastern United States (5).

When there is sufficient time for seedbed preparation between harvest of the first crop and planting of the second, no special equipment is needed for double-cropping. The second crop must be planted early enough to allow time for maturity during a particular growing season, (e.g., double-cropping of fall cauliflower after spring snap beans). The success of this double-cropping depends on efficient use of the available growing season and moisture supply, and the equipment must be suitable for quickly harvesting a crop and planting the succeeding crop (1, 2). If time is limited, field operations for seedbed preparation must be minimized (13). A few days' delay in planting the second crop can result in reduced yields and may cause the cropping system to fail (8, 14).

Multiple cropping can reduce the risk of economic failure during the year of low market demand for either crop grown alone. It also can increase financial returns per ha per year, but the system is labor intensive. Hence, it can generate demand for labor (3, 7, 10, 11, 16) or for mechanization. The choice depends upon the incremental cost of each. Peak labor demands of the production system, however, are not uniform throughout the year. The net returns to the family may be increased if hired labor needs are reduced. In this study, only one family member was considered in the labor force. As about 50% of the total production cost was labor, and about 85% of that was hired labor, net returns on the family could be increased substantially if additional family members were in the labor force.

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