academicJournals

Vol. 10(10), pp. 1083-1090, 5 March, 2015
DOI: 10.5897/AJAR2013. 8394
Article Number: 83BC5CD51190
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

An agronomic and economic evaluation of lettuce cultivars intercropped with rocket over two cultivation seasons

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Received 17 December, 2013; Accepted 21 February, 2015

The objective of this study was to investigate the agronomic and economic viability of lettuce intercropped with rocket over two cultivation seasons. The experimental designs were in randomized blocks in 3 × 3 + 2 factorial arrangement with four repetitions. The treatments were made up of a combination of three lettuce cultivars (Elisa, Veronica and Lucy Brown) and three cultivation systems (monocrop, intercrop with transplanted rocket and intercrop with seeded rocket) plus two other treatments (monocrop of seeded rocket and monocrop of transplanted rocket). Measurements of plant height were taken for the lettuce, number of leaves per plant were taken for both and stand count for the rocket. Total fresh matter per hectare was evaluated for both cultures. To evaluate the efficiency of the intercrop systems, the land equivalent ratio, total operating cost, gross revenue and economic results were determined. The intercropped rocket produced higher values for leaf area, and productivity and revenues were higher for the transplanted rocket mono cropping in both cultures. The characteristics of the lettuce were affected by the different cultivation systems and the treatments with loose-leaf lettuce, mainly in the first cultivation cycle, demonstrated higher productivity, land equivalent ratio and economic results compared to the lettuce mono cropping.

Key words: *Lactuca sativa*, *Eruca sativa*, viability.

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is the leafy vegetable with the highest consumption in Brazil and is cultivated across practically the whole country. According to the Brazilian Seed and Seedling Association (ABCSEM, 2012), its production during the 2010/2011 season was 1.3 million tons, making it the fifth largest vegetable crop in terms of economic importance.

Rocket (*Eruca sativa* M.) belongs to the Brassicaceae family and is an annual herbaceous plant with a height of 15 to 25 cm and a growth cycle and management similar

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to those for lettuce and coriander crops. Its leaves are thick and divided with green leaf blades and light-green ridges, it has rapid vegetative growth and a short life cycle and its tender leaves are consumed as a salad (Grangeiro et al., 2011).

Leafy vegetables constitute a diverse group of plants made up of over one hundred species cultivated on a temporary basis, and in Brazil are predominantly produced using conventional cultivation systems and monocropping techniques. In recent years, however, the growth of different cultivation systems has been observed, in particular those using greenhouses and intercropping techniques, both being options used to increase productive yield (Purqueiro et al., 2007).

Intercropping systems constitute optimizing labor and exploiting the plant architecture, considering variations in cultural cycles, size and nutritional requirements, and facilitating the use of raw materials and irrigation, reducing the occurrence of weeds and increasing production through the use of easy-to-use technology (Rezende et al., 2005). According to Montezano and Peil (2006), the main advantage of intercropping in olericulture is that it leads to higher productive efficiency while reducing the impact on the environment.

However, it is recommended that the efficiency of intercropping be evaluated through economic analysis, as this helps in the interpretation of the results obtained from cultivation systems. Rezende et al. (2005) have demonstrated that the joint cultivation of carefully selected and managed vegetable crop species provides higher net revenues than those associated with monocrops.

Batalha (2010) claims that globalization has impacted the whole of Brazil's production chain, providing technological and structural improvements and exposing the obstacles that need to be overcome in order to increase competitiveness. In order to do this, the search for alternative production technologies, such as intercropping, is of great value to Brazil's horticultural production system.

Therefore, the objective of this study was to evaluate the use of lettuce intercropped with rocket as an alternative and sustainable cultivation system for use in vegetable crop production in the Northwest region of Paraná - Brazil.

MATERIALS AND METHODS

The experiments were carried out on the Umuarama-PR Regional Campus of the State University of Maringá (UEM), located at latitude 23°47'28.4"S and longitude 53°15'24.0"W and at an altitude of 379 m. The soil used was a typical sandy Dystrophic RED LATOSOL (EMBRAPA, 2013). During the experimental period, the minimum and maximum temperatures were 15.7 and 24.1°C and rainfall was 465 mm for the first cultivation cycle (April to June 2012) and 18.1 and 30.9°C with a rainfall of 43 mm for the second cultivation cycle (August to September 2012) (SEAB, 2013). The physical and chemical characteristic of the soil are shown in Table 1.

Table 1. Main soil characteristics of Dystrophic RED Latosol (Umuarama, PR. 2012).

Soil characteristics	Soil layer (cm)
	0-20
Clay (%)	10.75
Silt (%)	2.95
Sand (%)	86.3
pH ($CaCl_2$)	4.49
Organic matter (g dm^{-3})	24.17
P (mg dm^{-3})	41.41
K ($cmol_c$ dm^{-3})	0.61
Ca^{2+} ($cmol_c$ dm^{-3})	5.26
Mg^{2+} ($cmol_c$ dm^{-3})	1.75
Al^{+3} ($cmol_c$ dm^{-3})	0.10
H + Al ($cmol_c$ dm^{-3})	5.62
CEC- cation exchange capacity ($cmol_c$ dm^{-3})	13.23
Base saturation index (%)	57.52

The experimental designs were in randomized blocks in 3 × 3 + 2 factorial arrangement with eleven treatments, combining three lettuce cultivars (Veronica - loose-leaf, Elisa - crisp-leaf, and Lucy Brown - American) and three cultivation systems (monocrop, intercrop with transplanted rocket and intercrop with seeded rocket), as well as transplanted and seeded rocket monocrops, with four replications.

The experimental plots covered 1.5 × 1.5 m, totaling 2.25 m², with a useful area of 0.5 × 0.5 m or 0.25 m² being used for the evaluations. The lettuce seedlings were formed in styrofoam trays with 128 cells and transplanted with a spacing of 0.35 × 0.35 m.

For the plots containing transplanted rocket, the seedlings were formed by depositing eight seeds into each cell, and each cell was transplanted at 0.05 m intervals in rows according to the treatment. The plots containing seeded rocket were thinned to maintain a uniform population across all of the treatments, the arrangement of which is shown in Figure 1.

The plots were maintained using crop treatments and the required agrotechnological management during the experimental period. Thiamethoxam WG (16 g 100 L^{-1}) and Azoxystrobin WG (20 g 100 L^{-1}) were applied to control insects and fungus. Irrigation was carried out via sprinkling. Fertilization and correction of soil acidity were carried out via soil analysis and using recommendations for the crops used as described by CQFS (2004). Fertilization was carried out in the two cultivation systems using 100 kg ha^{-1} of P, 87 kg ha^{-1} of Ca and 53 kg ha^{-1} of S as simple superphosphate (20.6% P, 18% Ca and 11% S) and a top dressing of 150 kg ha^{-1} nitrogen (N) from urea and 200 kg ha^{-1} potassium (K_2O) in the form of potassium chloride, divided into three applications. These fertilizers were mixed, homogenized and applied 160, 390 and 550 growing degree days (GDD).

The variables used to evaluate the effect of the treatments on the development of the crops were: fresh mass production (rocket + lettuce), number of leaves of the plant (rocket), final stand count (rocket), as well as plant growth characteristics (number of leaves and height of the plant) for lettuce.

Fresh mass production was determined for the lettuce and rocket by collecting and weighing the plants from the useful plot area (0.25 m²). The stand count of rocket was determined directly by counting (0.25 m²) of plants in the plots.

Direct measurement was used to determine the growth characteristics of the lettuce, using a 30 cm graduated rule to measure heart height and directly counting the number of leaves, discarding leaves with characteristics undesirable to the consumer.

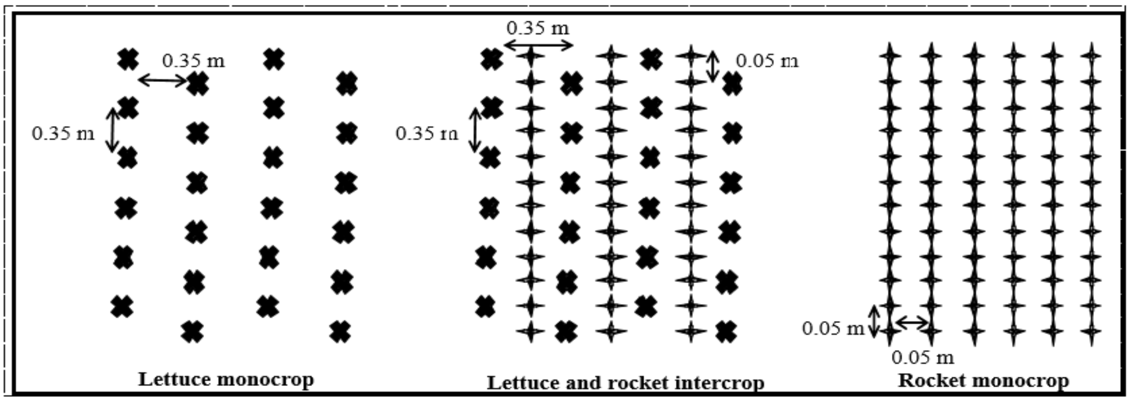

Figure 1. Arrangement and configuration of the monocrop and intercrop fields (Umuarama, PR. 2012).

Table 2. Quantity and cost of inputs used, according to crop arrangement (Umuarama, PR. 2012).

Quantity of inputs	L+TR	L+SR	L	TR	SR
Dolomitic limestone (kg ha^{-1})	3.500	3.500	3.500	3.500	3.500
Simple Superphosphate (kg ha^{-1})	555	555	555	555	555
Urea (kg ha^{-1})	307	307	307	307	307
Potassium chloride (kg ha^{-1})	455	455	455	455	455
Pelleted seeds (g ha^{-1})	330 + 1.360	330 + 2.040	330	1.360	2.040
Trays (units ha^{-1})	612	204	204	408	0
Substrate (kg ha^{-1})	663	221	221	442	0
Insecticide AKTARA 250 WG® (g ha^{-1})	200	200	200	200	200
Fungicide AMISTAR WG® (g ha^{-1})	100	100	100	100	100
Leaf fertilizer (L ha^{-1})	0.3	0.3	0.3	0.3	0.3

L+TR, Lettuce + transplanted rocket; L+ SR, lettuce + seeded rocket; L, lettuce; TR, transplanted rocket; SR, seeded rocket.

Economic evaluation of the crops was carried out by calculating production costs for lettuce and rocket in both a monocrop and an intercrop. The production cost structure used by the Agricultural Economy Institute (IEA) (Matsunaga et al., 1976) was used to determine the Total Operating Cost (TOC), taking into account the all of the producer's outlays during the production cycle, such as expenses associated with workforce, repair and maintenance of machinery, implements and specific improvements, machine and implement operation, inputs and the depreciation in value of the machinery, implements and specific improvements used in the production process.

Technical coefficients related to operations associated with soil preparation (plowing and harrowing) and the application of herbicides and other technical coefficients were obtained during the experiment. The inputs used during the study were quantified for each treatment as shown in Table 2.

From this data, the following information on production technology was determined: type and time in use for the machinery and equipment used in each operation, the types and quantities of inputs and workforce requirements from the preparation of the soil up to harvest, with the per unit values of each item being calculated according to the description provided below.

Workforce salaries were obtained from the Umuarama Rural Worker's Union, considering a monthly salary based on 25 working days and a working day of eight hours. The information required for the implantation and management of the crops was determined using technical coefficients and monitoring during the experiment. The average prices quoted by the Central Supply Center for Paraná (CEASA-PR) and the São Paulo General Warehousing and Centers Company (CEAGESP) for June and September 2012 were used to calculate gross revenues. Net revenues were obtained from the difference between gross revenues and TOC for each crop.

Activities to develop the seedlings included the washing of trays, preparation of the substrate (humidifying followed by homogenization), filling of trays and manual sowing. The terrain was cleared using herbicide to remove weeds.

The marking of transplant locations involved determining the planting arrangement of the lettuce and rocket seedlings using the spacing determined for each treatment. Manual weeding was carried out within the plots and in the spaces between them. Spray irrigation was used for both of the crops. The estimated production cost did not take into account any expenses associated with the commercialization of the products.

Land Equivalent Ratios (LERs) were calculated according to the method used by Willey (1979), using the formula: UET = (Yab/Yaa) + (Yba/Ybb), where Yab is the production of crop "a" intercropped with crop "b", Yba is the production of crop "b" intercropped with crop "a", Yaa is the production of crop "a" in a monocrop and Ybb is the production of crop "b" in a monocrop.

The data obtained was submitted to analysis of variance and averages were compared using the Scott-Knott test with a 5% level of probability.

Table 3. Analysis of variance of variables analyzed, total fresh mass production for lettuce and rocket in kg/m^2 (TFM), number of leaves per plant for rocket (NLPP) and final stand count in plants m^{-1} for rocket (SC) and number of leaves per plant (NLPP) and heart height in cm for lettuce (HH) (Umuarama/PR, 2012).

SV	Variables analyzed									
	TFM		NLPP (rocket)		SC (rocket)		NLPP (lettuce)		HH (lettuce)	
	1st cycle	2nd cycle	1st cycle	2nd cycle	1st cycle	2nd cycle	1st cycle	2nd cycle	1st cycle	2nd cycle
GL	10	10	7	7	7	7	8	8	8	8
SQ	2.78	2.68	4.66	0.26	735.22	762.47	721.38	2023.25	5.35	118.50
MS	278391235	268371788	0.67	0.04	105.03	108.92	90.17	252.91	0.67	14.81
Fc	136.40**	54.62**	0.88^{ns}	0.04^{ns}	3.78**	2.51*	15.41**	48.56**	2.64*	4.61**
CV (%)	6.50	13.54	20.62	19.47	15.84	20.35	10.16	11.33	10.90	15.16

SV, Source of variation (treatments); GL, grau de liberdade; SQ, Soma de Quadrados; MS, Mean squares; Fc, F calculado; CV, coefficient of variation. *Significant (5%); ** Significant (1%); ^{ns}Non - significant.

Table 4. Total fresh mass production for lettuce and rocket in kg/m^2, number of leaves per plant for rocket and final stand count (plants/m) for rocket and number of leaves per plant and heart height (cm) for lettuce (Umuarama/PR, 2012).

Treatment	Fresh mass (kg/m^2)		Number of leaves per plant (rocket)		Stand count (plants m^{-1})		Number of leaves per plant (lettuce)		Heart height (cm)	
	1st cycle	2nd cycle	1st cycle	2nd cycle	1st cycle	2nd cycle	1st cycle	2nd cycle	1st cycle	2nd cycle
ELL+TR	2.460^{c}	1.793^{b}	3.67^{a}	4.96^{a}	67.50^{b}	57.50^{b}	29.13^{a}	36.50^{a}	4.15^{b}	6.17^{b}
ELL+SR	2.400^{c}	1.781^{b}	4.99^{a}	4.91^{a}	59.50^{b}	69.50^{a}	30.56^{a}	21.94^{b}	4.17^{b}	3.18^{d}
ELL	1.133f	1.755^{b}	-	-	-	-	30.25^{a}	23.44^{b}	4.22^{b}	7.27^{a}
VCL+TR	2.191^{c}	1.452^{c}	3.84^{a}	4.81^{a}	59.46^{b}	53.50^{b}	20.69^{b}	24.44^{b}	4.82^{a}	4.92^{c}
VCL+SR	1.870^{d}	1.428^{c}	4.32^{a}	4.64^{a}	71.54^{a}	73.00^{a}	20.56^{b}	13.06^{c}	4.37^{b}	5.22^{c}
VCL	1.174f	1.561^{c}	-	-	-	-	23.13^{b}	13.25^{c}	4.72^{a}	2.87^{d}
LBAL+TR	2.269^{c}	1.485^{c}	4.33^{a}	4.87^{a}	64.50^{b}	62.50^{b}	19.38^{b}	22.38^{b}	4.75^{a}	3.80^{d}
LBAL+SR	2.358^{c}	1.580^{c}	4.29^{a}	4.80^{a}	72.50^{a}	77.00^{a}	20.06^{b}	14.81^{c}	5.04^{a}	2.86^{d}
LBAL	1.417^{e}	1.488^{c}	-	-	-	-	20.56^{b}	11.50^{c}	5.29^{a}	3.15^{d}
TR	3.742^{a}	1.903^{a}	4.36^{a}	4.87^{a}	52.00^{b}	49.50^{b}	-	-	-	-
SR	3.160^{b}	1.781^{b}	3.93^{a}	4.87^{a}	85.50^{a}	75.00^{a}	-	-	-	-
CV %	6.5	13.54	20.62	19.47	15.84	20.35	10.16	11.33	10.9	15.16

Averages followed by the same letters down the column did not differ according to the Scott-Knott test (P>0.05). CV = Coefficient of variation. Treatments: Elisa loose-leaf lettuce + transplanted rocket (ELL+TR), Elisa loose-leaf lettuce + seeded rocket (ELL+SR); Elisa loose-leaf lettuce (ELL); Veronica crisp-leaf lettuce + transplanted rocket (VCL+TR); Veronica crisp-leaf lettuce + seeded rocket (VCL+SR); Veronica crisp-leaf lettuce (VCL); Lucy Brown American lettuce + transplanted rocket (LBAL+TR); Lucy Brown American lettuce + seeded rocket (LBAL+SR); Lucy Brown American lettuce (LBAL); transplanted rocket (TR); seeded rocket (SR)

RESULTS AND DISCUSSION

According to Table 3, it can be inferred that there was a higher production of fresh mass in the first crop cycle (April - June) for the rocket monocrops due to a significant influence on the total production of fresh mass, since the plots containing only rocket presented the highest averages compared to the lettuce monocrop and intercrop, independent of the type of implantation used (Table 4).

These results agrees with the results obtained by Oliveira et al. (2010), who verified a higher production of fresh mass in rocket monocrops when studying rocket and lettuce intercrops. In this study, the higher production associated with the rocket monocrop was probably due to the arrangement of the rocket plants allowing for more efficient use of space and to the absence of lettuce, permitting higher vegetative growth. These factors led to two harvests being reaped. The highest production among the monocrops was observed for transplanted rocket.

When analyzing the production of the intercrops in relation to the lettuce monocrops, it was observed that there was a significantly higher production for the intercrops (Table 4), as has already been observed by Costa et al. (2007), who obtained a higher production of fresh mass when studying intercrops of lettuce and rocket.

Table 5. Production of fresh mass of lettuce and rocket crops as a function of intercrop system and land equivalent ratio (LER) in the two cultivation cycles. (Umuarama/PR, 2012).

Treatments	Cycle	Lettuce (kg/m^2)	Rocket (kg/m^2)	LER
ELL+TR	1st	1.048	1.398	1.30
	2nd	0.234	1.560	0.95
ELL+SR	1st	1.153	1.248	1.41
	2nd	0.517	1.264	1.00
VCL+ TR	1st	1.025	1.166	1.18
	2nd	0.269	1.183	0.81
VCL+TR	1st	0.817	1.053	1.03
	2nd	0.214	1.214	0.87
LBAL+TR	1st	1.152	1.117	1.11
	2nd	0.396	1.088	0.72
LBAL+SR	1st	1.474	0.884	1.32
	2nd	0.326	1.254	0.92

Treatments: Elisa loose-leaf lettuce + transplanted rocket (ELL+TR), Elisa loose-leaf lettuce + seeded rocket (ELL+SR); Elisa loose-leaf lettuce (ELL); Veronica crisp-leaf lettuce + transplanted rocket (VCL+TR); Veronica crisp-leaf lettuce + seeded rocket (VCL+SR); Veronica crisp-leaf lettuce (VCL); Lucy Brown American lettuce + transplanted rocket (LBAL+TR); Lucy Brown American lettuce + seeded rocket (LBAL+SR); Lucy Brown American lettuce (LBAL); transplanted rocket (TR); seeded rocket (SR)

For the second cultivation season (July - September) higher production was observed for the transplanted rocket monocrop again, however high temperatures (28 - 32°C) during cultivation negatively influenced lettuce and rocket production, and higher competition within the intercrops reduced production. This lower production for the rocket monocrops in the second cycle was due to there being only one harvest, as higher temperatures reduce the lettuce growth cycle by up to 20 days.

Higher values for the rocket number of leaves per plant were obtained in general for the intercrop in both cultivation cycles, independent of the method of implantation (Table 3), when compared to the monocrops, possibly due to the larger amount of space available for the plants to develop and the lower population density, different than demonstrated by Nascimento et al. (2013). However, this differs to the results obtained by Oliveira et al*.* (2010), who found no difference in rocket number of leaves per plant, independent of the spatial arrangements used.

The intercrop of lettuce with seeded rocket and the mono cropping of seeded rocket demonstrated significantly higher stand counts, the plots containing seeded rocket presenting higher averages than the transplanted rocket monocrop and the intercrops containing transplanted rocket. This is due to the increased difficulty in controlling the number of seeds used during sowing compared to that possible through the development of the seedlings in trays (Table 5).

Looking at the lettuce growth characteristics, it can be verified that the number of leaves in the first cultivation cycle was higher for loose-leaf lettuce (Table 4), which may be attributed to the morphological characteristics of the material, in agreement with the results obtained by Costa et al*.* (2007). In the second cycle, the plots containing the intercrop with transplanted rocket had the highest number of leaves, and again the loose-leaf lettuce demonstrated the highest numbers due to the morphological characteristics of the material and reduced competition with rocket at the end of the cycle, providing better conditions for vegetative growth and a higher number of leaves.

For heart height (Table 4), loose-leaf lettuce presented the lowest values in the first cycle due to the precocity of the material. In the second cycle, this material presented the largest values for height due to the climatic characteristics of the period and the competition with the rocket at the end of the cycle, which caused the crop to surpass the vegetative stage more rapidly, as demonstrated in a study by Silva et al*.* (2000), in which plant height was influenced by increased plant density.

Therefore, it was verified that LER (Table 4) was higher for the intercrops in the first cycle, which was also observed by Rezende et al*.* (2005) and Costa et al*.* (2007), especially for the intercrop of Elisa lettuce with seeded rocket, which presented a LER 41% higher than that for the monocrop due to the fact that two harvests were reaped, agreeing with the results obtained by Oliveira et al*.* (2010), who observed higher efficiency in the intercrop due to the regrowth of the rocket.

During the second cycle, in which temperatures in the region are higher, it was observed that values for LER

Table 6. Total hours, costs of operations and inputs, total operating cost, revenues and economic result. CAU-UEM, (Umuarama-PR, 2012).

Treatment	Cycle	Total hours (h/ha)	Cost of operations (R$/ha)	Total cost of inputs (R$/ha)	Total operating cost (R$/ha)	Revenues (R$/ha)	Result (R$/ha)
ELL+TR	1st	817.93	4.282.03	4.277.79	8.559.82	31.483.13	22.923.31
	2nd	788.40	4.142.61	4.143.49	8.286.10	28.166.76	19.880.66
ELL+SR	1st	634.75	3.554.95	3.481.42	7.036.37	29.488.95	22.452.58
	2nd	605.32	3.415.53	3.347.12	6.762.65	25.190.54	18.427.89
ELL	1st	498.09	2.771.09	3.318.12	6.089.21	8.156.95	2.067.74
	2nd	468.66	2.631.67	3.183.82	5.815.49	12.640.47	6.824.98
VCL+TR	1st	817.93	4.282.03	4.277.79	8.559.82	29.147.20	20.587.38
	2nd	788.40	4.142.61	4.143.49	8.286.10	22.354.92	14.248.82
VCL+SR	1st	634.75	3.554.95	3.481.42	7.036.37	25.340.36	18.303.99
	2nd	605.32	3.415.53	3.347.12	6.762.65	22.558.07	15.795.42
VCL	1st	498.09	2.771.09	3.318.12	6.089.21	10.711.80	4.662.59
	2nd	468.66	2.631.67	3.183.82	5.815.49	14.235.23	8.419.74
LBAL+TR	1st	817.93	4.282.03	4.277.79	8.559.82	26.915.57	18.355.75
	2nd	788.40	4.142.61	4.143.49	8.286.10	21.214.23	12.928.13
LBAL+SR	1st	634.75	3.554.95	3.481.42	7.036.37	25.180.73	18.144.36
	2nd	605.32	3.415.53	3.347.12	6.762.65	23.542.06	16.779.41
LBAL	1st	498.09	2.771.09	3.318.12	6.089.21	9.777.48	3.688.27
	2nd	468.66	2.631.67	3.183.82	5.815.49	10.267.23	4.451.74
TR	1st	543.53	3.253.05	3.091.58	6.344.63	63.540.52	57.195.89
	2nd	514.10	3.113.63	2.957.28	6.070.91	32.315.91	26.245.00
SR	1st	360.45	2.250.24	2.376.86	4.627.10	53.660.23	49.033.13
	2nd	331.02	2.110.82	2.242.56	4.353.38	30.239.92	25.886.54

Source: Data for the region of Umuarama – PR, AGRIANUAL (2012), CEASA – PR and CEAGESP (2012). Treatments: Elisa loose-leaf lettuce + transplanted rocket (ELL+TR), Elisa loose-leaf lettuce + seeded rocket (ELL+SR); Elisa loose-leaf lettuce (ELL); Veronica crisp-leaf lettuce + transplanted rocket (VCL+TR); Veronica crisp-leaf lettuce + seeded rocket (VCL+SR); Veronica crisp-leaf lettuce (VCL); Lucy Brown American lettuce + transplanted rocket (LBAL+TR); Lucy Brown American lettuce + seeded rocket (LBAL+SR); Lucy Brown American lettuce (LBAL); transplanted rocket (TR); seeded rocket (SR).

were generally lower for the intercrops when compared to the lettuce monocrops due to higher competition between the crops and the fact that the second cycle was around 20 days shorter and did not allow for a second rocket harvest. This affected LER for the intercropped treatments.

Analyzing Table 6, TOC was higher in both cycles for the intercrops with seeded and transplanted rocket when compared to the monocrops of lettuce. When comparing the two cycles, the first has higher values of TOC. Previously, Cecílio Filho et al*.* (2008), studying chicory and rocket, observed TOC values 33 and 42% higher for the intercrop compared to monocrops of chicory and rocket respectively. However, Rezende et al*.* (2009) obtained higher values for lettuce and rocket compared to intercrops of these with pepper.

Increased labor requirements were observed for the development, thinning and transplant of the seedlings, which supports data presented by Rezende et al*.* (2005) studying a range of intercropped vegetable crops.

For the treatments containing transplanted rocket, TOC was higher compared to the values obtained for seeded rocket, lettuce monocrops and transplanted and seeded rocket monocrops for both cultivation cycles (Table 6), and this is due to the need to develop rocket seedlings, requiring more hours of work per hectare compared to these three other systems. These results are supported by the findings of Barros Junior et al*.* (2008), who observed a large influence of TOC for lettuce seedlings. This study differs from the present study, as they acquired seedlings and did not develop them themselves. However, author did demonstrate that the seedlings had a significant influence on TOC, explaining the results obtained in this study for transplanted rocket.

Use of transplanted rocket also affects input costs and the total cost for the intercrop, considering that this cost represented 50 to 55% of TOC for the treatments. This was also observed by Rezende et al. (2005), who observed that 55 to 62% of total cost was due to inputs. Therefore, the higher TOC observed for the treatments with transplanted rocket was due to the development of the seedlings, the marking of the field and the transplant of the rocket, supporting the results obtained by Rezende et al. (2011) on the impact of labor on TOC when studying a lettuce and cucumber intercrop.

In addition, the intercrop with transplanted rocket involved higher input costs for seedling development (trays and substrate), representing 9 and 10% of TOC for the first and second cultivations cycle respectively, assuming that the cost of the trays is spread over five yearly crop cycles.

Analyzing Table 6, higher gross revenues were observed for the rocket monocrops in both cycles. In the first cycle, this measurement was 59, 60 and 84% higher for American lettuce compared to the intercrop with transplanted rocket, seeded rocket and the monocrop respectively. For the second cycle these values were 34, 25 and 69% higher.

The higher production observed for the rocket monocrops (Table 3) affected the gross revenues obtained for the crops, which were higher for the lettuce intercrops and monocrops. Similar results were obtained by Rezende et al. (2009), who observed gross revenues for a rocket monocrop that were 8 and 5% higher compared to a lettuce monocrop and an intercrop with pepper respectively. Similar results were obtained by Silva et al. (2008) when studying lettuce and cucumber, where the lettuce monocrop provided higher gross revenues.

Analyzing the lettuce monocrops and intercrops, the loose-leaf lettuce intercropped with transplanted rocket obtained 6 and 11% higher gross revenues than the intercrop with seeded rocket in the first and second cycles respectively.

It is worth highlighting that among the different types of lettuce, loose-leaf lettuce provided the highest gross revenues, which was expected due to its higher fresh mass production. Similar data was obtained by Mota et al. (2012), who obtained higher gross revenues for the majority of their loose-leaf lettuce and carrot intercrops compared with the carrot monocrops, confirming the potential of intercropped loose-leaf lettuce in high-temperature regions such as those observed for the second cultivation cycle in this study.

Analyzing Table 6, it can be observed that in the first cycle loose-leaf lettuce intercropped with transplanted rocket obtained an economic result around 91% higher than the monocrop and 2% higher than the treatment intercropped with seeded rocket, and in the second cycle the treatment with transplanted rocket obtained a result 7% higher than the intercrop with seeded rocket and 66% higher than the lettuce monocrop.

Crisp-leaf lettuce intercropped with transplanted rocket had a higher economic result in the first cycle compared to the monocrop and the intercrop with seeded rocket. American lettuce intercropped with transplanted rocket also obtained a higher result than the monocrop. Comparing the rocket monocrops, transplanted rocket had a result 14% higher in the first cycle and 1% higher in the second cycle.

The transplanted rocket monocrop obtained the highest economic result, which were 14 and 1% higher than seeded rocket for the first and second cycles respectively. Compared to the treatments with loose-leaf lettuce (loose-leaf + transplanted rocket, loose-leaf + seeded rocket and loose-leaf), the results for this treatment were 60, 61 and 96% higher for the first cycle and 24, 30 and 74% higher for the second cycle respectively. For the treatments with crisp-leaf lettuce (crisp-leaf + transplanted rocket, crisp-leaf + seeded rocket and crisp-leaf) results were 64, 68 and 92% higher for the first cycle and 46, 40 and 68% for the second cycle respectively.

When analyzing the lettuce monocrops and intercrops, economic results for the loose-leaf intercrops were higher than those obtained for the monocrops, supporting data obtained by Rezende et al. (2005) and Catelan et al. (2002), who observed higher net revenues for intercrops compared to monocrops. Analyzing just the intercrops, results for loose-leaf lettuce were higher than those obtained for crisp-leaf and American lettuce by 14 and 20% in the first cycle and 22 and 23% in the second cycle. Considering the above, the best intercrop in terms of economic results was loose-leaf lettuce with transplanted rocket.

Barros Junior et al. (2008) obtained higher net revenues for the same cultivars of crisp-leaf and American lettuce intercropped with rocket, especially for the American lettuce intercrop. Therefore, different types of lettuce present different economic results when cultivated in an intercrop system, as was observed in the present study where crisp-leaf outperformed America lettuce and where both were outperformed by loose-leaf lettuce when intercropped with rocket.

The rocket monocrop obtained a higher production than the other treatments, with results for transplanted rocket higher than those for seeded rocket. This was reflected in the economic results for this crop, which were consistently higher for the transplanted rocket, generating higher net revenues. Considering lettuce to be the main crop, the higher results obtained for production and revenues through the use of intercrops demonstrate the importance of the use of intercropping as an alternative cultivation system. This is supported by various studies, such as those by Rezende et al. (2005), Barros Junior et al. (2008) and Catelan et al. (2002), who also observed higher results for intercrops, confirming the viability of their use.

The viability of a cultivation system involving lettuce intercropped with rocket has been confirmed, with the best results being obtained for treatments involving transplanted rocket, even if it may be inferred that the intercrop in this study was representative only during the first crop cycle and demonstrated restrictions during the second cycle due to the region’s climatic conditions during this period, this information is supported by Porto et al. (2011), were both lettuce and rocket crops had better productive performance in the second cycle.

Conclusion

Intercropping has been proven to be a viable, productive and economic alternative for use in the Northwest Region of Paraná. The higher results for intercrops, confirming the viability of their use for lettuce and rocket. There was interference on meteorological conditions within the crop cycles.

Conflict of Interest

The authors have not declared any conflict of interest.

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