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ECONOMIC EFFECT OF THE JACK BEAN-CORN ROTATION AND THE PARTIAL SUBSTITUTION OF MINERAL FERTILIZERS

Efecto económico de la rotación canavalia-maíz y de la sustitución parcial de fertilizantes minerales

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ABSTRACT. The green manures are a practice that is used to substitute total or partially the nitrogen fertilization in agricultural systems. However, few works guided to evaluate their economic effect. The present work was carried out to quantify the costs and benefits of the employment of Jack Bean and the mycorrhizical inoculation like nutritional alternatives next to the nitrogen fertilization in corn and to evaluate the profitability of the system. It was demonstrated that to bigger contribution of the N from Jack Bean, it is higher the quantity of the fertilizer substitution. Also, the mycorrhizical inoculation promotes a bigger use of the N coming from the fertilizer or the Jack Bean, reflected in an increment of the agricultural yields, with the rising decrease of the production costs and increase the value of the production and the relationship benefits/cost. Bigger economic benefits were obtained if the canavalia was used in the rainy period in comparison to the one sowed in the dry period, due to the increment of their benefits like green manure in the rainy season.

Key words: green manures, agricultural economics, maize, jack bean

RESUMEN. Los abonos verdes son una práctica que se emplea para sustituir total o parcialmente la fertilización nitrogenada en los sistemas agrícolas. Sin embargo, existen pocos trabajos encaminados a evaluar su efecto desde el punto de vista económico. Es por ello que el presente trabajo se realizó para cuantificar los costos y beneficios del empleo de canavalia y la inoculación micorrízica como alternativas nutricionales junto a la fertilización nitrogenada en el cultivo del maíz y evaluar la rentabilidad del sistema. Se demostró que a mayor aporte del N de la canavalia, es más alta la cuantía de la sustitución de fertilizante. Además, la inoculación micorrízica promueve un mayor aprovechamiento del N proveniente del fertilizante o de la canavalia, reflejado en un incremento de los rendimientos agrícolas, con la consiguiente disminución de los costos de producción y aumento del valor de la producción y de la relación beneficio/costo. Se obtuvieron mayores beneficios económicos si la canavalia se empleó en el período lluvioso, en comparación con la sembrada en el período poco lluvioso, debido al incremento de sus beneficios como abono verde en la temporada de lluvias.

Palabras clave: abonos verdes, economía agrícola, maíz, canavalia

INTRODUCTION

The application of green fertilizers is an old cultural practice and incorporation of plants to preserve and/or restore the organic matter and nutrient levels in soils. This technique follows the principle of covering the soil and preserves the re-establishment of the productivity in crop areas and the environment making an adequate use of the land, machinery and inputs (1; 2).

However, its adoption was abandoned under the conditions of intensive agriculture, particularly from the beginning of the so called Green Revolution due to the development of the mineral fertilizer industry. At present, it gets into the world trend to produce more healthy foods from organic agriculture or those produced with a minimum use of chemical and without degradation of the environment (2).

Agriculture faces the loss of self-sufficiency and the deterioration of natural resources. Hence, the need of developing profitable and friendly management alternatives with the environment that provides a better

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life quality to farmers (3). Thus, there is a great outlook of using green manures to guarantee agricultural productivity; environmental preservation, input saving –nitrogen fertilizers mainly in recovering soil fertility and controlling erosion (4).

One of the issues less dealt with by the scientific literature is the impact derived from the use of green manure in agricultural systems. In Mexico, long-term studies have been made that show how agricultural systems, with the inclusion of leguminous plants like *Canavalia ensiformis* D.C and corn, it is more profitable than corn (*Zea mays* L.) itself in single-crop systems due to fertilizers and herbicides saving and also for its forage uses (5).

However, in Cuba there are a few research on this issue, dealing mainly with the effect of totally replacing mineral fertilizers for green manures, (6), nevertheless, the quoted research did not break down production costs by the introduction of green manures, nor compared its combined use with complementary rates of nitrogen mineral fertilizer.

Therefore, this research targeted the quantification of costs and benefits of using canavalia as a partial substitute of nitrogen fertilizer in corn, and also evaluates the profitability of the system.

MATERIALS AND METHODS

This research was done based on the results of two other research works that included the use of green manure in corn.

Experiment 1. Effect of *Canavalia ensiformis*, mineral fertilizer rate and vesicular mycorrhizae in corn (7).

This experiment was done twice during 2003 and 2006. Fallow-rotation and corn-canavalia relationships were evaluated with and without mycorrhizal inoculation of the grass. Increasing rates of mineral fertilizers were added to the corn (NH_4NO_3). Yields were estimated and from the discontinuous model of response to mineral fertilizer, optimum rates were estimated to reach maximum stable yields in each rotation (Table I). The agronomical results of this experiment are detailed in volume 43, number 2, of the Cuban Journal of Agricultural Science (7).

Experiment 2. Response of *Canavalia ensiformis* to mycorrhizal inoculation with *Glomus cubense* (isolate INCAM-4), its effect in time in corn growing (8).

This experiment was conducted in three agricultural farms for two seasons, spring (rainy period) and winter (dry period). In each farm, rotations canavalia-corn with the mycorrhizal inoculation of green manure and/or main crop were studied. Table II shows recommended treatments according to the conditions in each farm and yields, both from the recommended treatment and the production control (fallow with no mycorrhizal inoculation). The agronomical results of this experiment are detailed in volume 33, number 2, of the Journal Cultivos Tropicales (8).

Economic assessment of corn yields

The economic assessment of yields was done based on the recommended treatments for both experiments, the following indicators were evaluated:

- Production value (total production value in \$ ha^{-1}): corn yield multiplied by the sale price of 1 ton of product.
- Production cost per hectare (total cost in \$ ha^{-1}): sum of expenses for the application of mineral fertilizers and/or biofertilizers used and green manure plus the cost of soil preparation, crop and manpower cost. To calculate this value, a breakdown of all expenses was done.
- Profit (\$ ha^{-1}): difference between the production value and production costs.
- Economic benefit (\$ ha^{-1}): difference between treatment profit and control's.

Table I. Studied rotations in Experiment 1, optimum recommended rate in each of them and maximum stable yields of corn

Rotation	Year	Optimum recommended rate (kg N.ha^{-1})	Maximum stable yield (t.ha^{-1})
fallow – corn	2003	0,00	3,20 [M]
fallow – corn		129,03	4,47
canavalia – corn			4,59 [C]
canavalia – inoculated corn with AMF			4,53 [C]
fallow – corn	2006	0,00	2,87 [M]
fallow – corn		69,07	4,02
canavalia – inoculated corn with AMF		70,07	4,67
canavalia – corn		50,31	4,61
canavalia – inoculated corn with AMF		50,00	4,85

AMF: with *Glomus cubense*. Fallow: soil under resting conditions for three months. Mineral fertilizer NH_4NO_3. M Corn yields in the treatment without canavalia and without nitrogen fertilizer. [C] in rotations with canavalia from 2003, the maximum stable yield was recorded without applying complementary rates of mineral fertilizer.

- Relative treatment costs ($ ha^{-1}): difference between treatment costs and control's.
- Cost/Benefit relationship: Quotient of dividing the economic benefit between the relative costs.

Cost/Benefit values higher than 1 indicate the profit and a value of 2, a benefit of 100 %. Value of 3 or more than 3 means very significant profits.

Manpower costs were distributed according to the time used in cultural practices of each treatment based on the hour payment ($ hour^{-1}), and taking into account the amount of persons and hours of work. For the estimation of these indicators, the basic information offered in Table III was used.

Table II. Control and recommended rotations in each studied farm, corn yields

Farm	Season	Rotations	Yield (t ha^{-1})
La Asunción	Spring 07	fallow–corn	3,33
		canavalia–corn[N]	4,73
La Asunción	Winter 07	fallow–corn	2,16
		canavalia–corn[N]	2,68
Santa Teresa	Spring 07	fallow–corn	3,72
		canavalia inoculada – inoculated corn with AMF	4,70
Zacarías	Spring 07	fallow – corn	3,57
		Inoculated canavalia – inoculated corn with AMF	4,75
Zacarías-1	Winter 07	fallow – corn	1,54
		Inoculated canavalia – inoculated corn with AMF	2,60
Zacarías-2	Winter 07	fallow – corn	1,33
		Inoculated canavalia – inoculated corn with AMF	2,44

AMF: with *Glomus cubense*. Fallow: soil under resting conditions for three months. [N] For the recommended treatments in "La Asunción" farm (both evaluated seasons), it was not necessary to inoculate AMF.

Table III. Value of the different inputs and cost of agricultural activities in the use of green manure and corn production[A, B, C, D, E, F]

	Unit of measure	Value	Reference
1) Prices of mineral fertilizers			
Ammonium nitrate	$ t^{-1} (CUP)	257,36	(9)
2) Selling prices of biofertilizers			
EcoMic® (AMF)	$ kg^{-1} (CUP)	2,50	(10)
3)) Cost of green manures			
Soil preparation	$ ha^{-1} (CUP)	20,00	(11)
Planting		5,00	
Incorporation		20,00	
Total		45,00	
4) Prices of acquired seeds			
Canavalia	$ kg^{-1} (CUP)	6,30	(12)
Corn	$ kg^{-1} (CUP)	4,93	(13)
5) Rates of soil preparation and cultural practices for corn			
Plowing	$ ha^{-1} (CUP)	31,60	(11)
Crossing		17,28	
Harrow 965 kg		4,80	
Plough through		17,28	
Corn planting		56,21	
Cultural practices		14,75	
Total		141,92	
6) Hour rate of manpower			
	$ hora^{-1} (CUP)	2,4147	(14)
7) Prices of the collected product			
Corn	$ kg^{-1} (CUP)	3,74	(15)

CUP = Cuban bill

[A] Ministerio de la agricultura. *Listado Oficial de Precios de Servicios Agropecuarios*, La Habana, Cuba, 1999, p. 4.

[B] Instituto de Pastos y Forrajes. *Precio oficial de las semillas de pastos y forrajes*, 2002, p. 1.

[C] Instituto Nacional de Ciencias Agrícolas. *Ficha de costo EcoMic®*, Mayabeque, Cuba, 2005, p. 1.

[D] Ministerio del Trabajo y Seguridad Social. *Resolución de salario de los Auxiliares de Investigaciones Agropecuarias*, La Habana, Cuba, 2005, p. 2.

[E] Ministerio de la agricultura. *Precios de los fertilizantes y de la papa reconsumo*, La Habana, Cuba, 2007, p. 1.

[F] Ministerio de la agricultura. *Listado Oficial de Precios*, La Habana, Cuba, 2008, p. 2.

RESULTS AND DISCUSSION

Table IV shows the economic analysis made to treatments with optimum recommended mineral fertilizer rates in each of the three variants studied in experiment 1, when compared to the treatment of corn with no mycorrhizal inoculation and without nitrogen sources.

For the two studied years, there was a cost/benefit relationship higher than 1, which implied economic returns from the harvests. In 2003, the treatment that only included the recommended mineral fertilizer rate, in spite of the benefit, was lower than that recorded from using canavalia and mycorrhizal inoculation, that was significant in series with values above 3 (9).

It was due to high yields in the presence of canavalia and without the application of mineral fertilizer rates, since this manure incorporated 290 kg ha^{-1} of N to the system and multiplied mycorrhizal propagules in the soil (7), which favored an adequate functioning of the mycorrhizae by replacing the necessary fertilizer to guarantee high yields. On the other hand, the value of chemical fertilizer was very high and it brought about total increased crop costs.

During 2006, the treatment that only received the optimum mineral fertilizer rate showed an increased cost/benefit relationship as compared to the first year and it corresponded to reduced optimum rates of mineral fertilizer reached in the second year; however, these indicators were lower to those of the treatments that received canavalia and the AMF inoculation in the presence of complementary fertilizer rates.

Similar results have been reached in Brazil upon the economic analysis of corn production in agricultural systems that included rotations with different species of green manures due to the reduction of external inputs that implied the use of cover crops as N source (10).

When analyzing other series, though the cost/benefit relationship of the green manure was not so high like in 2003, because of the application of complementary rates of mineral fertilizers, economic indicators were very advantageous. During this year, high economic returns from the inoculated treatment with optimum fertilizer rates were recorded, without the use of canavalia.

Nevertheless, the best cost/benefit relationships were reached in the treatments of canavalia and mycorrhizal inoculation. Moreover, these treatments led in two years to saving money for the reduced rates of nitrogen mineral fertilizer which is an important additional indicator to consider for the economic analysis of the treatments.

Similar results were recorded in Mexico where cost/benefit relationships were above 1 in all the treatments with corn as single crop and corn plus canavalia, however, in the latter one, economic indicators were higher due to fertilizer saving and increased production in the system including green manure (5).

Table V, like the previous one, shows the economic analysis performed to the results of experiment 2, when series canavalia-corn and its inoculation, recommended for each farm and season were compared with the series fallow-corn without inoculation (8).

Table IV. Economic analysis of recommended treatments in the sequences studied in Experiment 1

Rotation	Year	Optimum doses (kg N ha^{-1})	Production value ($ ha^{-1})	Production costs ($ ha^{-1})	Profit ($ ha^{-1})	Benefit ($ ha^{-1})	Relative cost ($ ha^{-1})	B/C
B-M	2003	0,00	11968,00	2746,15	9221,85			
B-M		129,03	16717,80	5124,23	11593,57	2371,72	2378,08	1,00
C-M			17166,60	3490,45	13676,15	4454,30	744,30	5,98
C-M+AMF			16942,20	3493,20	13449,00	4227,15	747,05	5,66
B-M	2006	0,00	10733,80	2746,15	7987,65			
B-M		69,07	15034,80	4019,14	11015,66	3028,01	1272,99	2,38
B-M+AMF		70,07	17465,80	4040,32	13425,48	5437,83	1294,17	4,20
C-M		50,31	17241,40	4417,69	12823,71	4836,06	1671,54	2,89
C-M+AMF		50,00	18139,00	4414,72	13724,28	5736,63	1668,57	3,44

Rel B/C: Cost/Benefit relationship. AMF: with Glomus cubense. B – M: fallow – corn; C – M: canavalia – corn; C – M + HMA: canavalia – inoculated corn. Fallow: soil under resting conditions for three months. Mineral fertilizer NH_4NO_3. $ = CUP (Cuban peso)

Table V. Economic analysis of the recommended sequences in farms. Experiment 2

Farm	Season	Treatment	Production value ($ ha^{-1})	Production costs ($ ha^{-1})	Profit ($ ha^{-1})	Benefit ($ ha^{-1})	Relative cost ($ ha^{-1})	B/C
La Asunción	Spring 07	B-M	12441,73	2746,15	9695,58			
		C-M	17702,67	3490,45	14212,22	4516,63	744,30	6,07
La Asunción	Winter 07	B-M	8078,40	2746,15	5332,25			
		C-M	10023,20	3490,45	6532,75	1200,50	744,30	1,61
Santa Teresa	Spring 07	B-M	13912,80	2746,15	11166,65			
		C+AMF-M	17578,00	3520,70	14057,30	2890,65	774,55	3,73
Zacarías	Spring 07	B-M	13364,27	2746,15	10618,12			
		C+AMF-M	17752,53	3520,70	14231,83	3613,72	774,55	4,67
Zacarías - 1	Winter 07	B-M	5759,60	2746,15	3013,45			
		C+AMF-M	9724,00	3520,70	6203,30	3189,85	774,55	4,12
Zacarías - 2	Winter 07	B-M	4961,73	2746,15	2215,58			
		C+AMF-M	9125,60	3520,70	5604,90	3389,32	774,55	4,38

Rel B/C: Cost/Benefit relationship. HMA: with Glomus cubense. B – M: fallow – corn; C – M: canavalia – corn; C + AMF – M + AMF: inoculated canavalia – inoculated corn. Fallow: soil under resting conditions for three months. $ = CUP (Cuban Peso).

At the farm La Asunción, where a satisfactory functioning of the mycorrhizae in canavalia and in corn was found without the need of inoculation, the cost/benefit relationships depended on the season. The economic returns were very significant in spring, which made clear the importance of canavalia; they were acceptable in winter due to reduced agricultural yields at this time, nontheless, high yields were recorded in corn when green manure was added to the treatment as compared to the traditional treatment in corn preceded by a fallow (Table II).

On the other hand, in the two farms with a low initial number of AMF spores, in which there was a response to mycorrhizal inoculation, reflected on increased yields, the use of canavalia provided economic returns to growers. There was a higher economic impact by inoculating canavalia and the promotion an efficient mycorrhizal symbiosis in both crops, regardless the season in which plants were planted, due to productive improvements that permitted the combined use of canavalia and AMF.

Similar results have been reported in coffee seedling production where different leguminous species as N source and organic matter in the substrate, were used with the consequent considerable saving of external inputs and the multiplication of mycorrhizal propagules on the soil that contributed to an efficient symbiosis of the crop (11).

Results indicated that the combined use of canavalia and mycorrhizal biofertilizers provided economic benefits higher than those from mineral fertilization, since they favored the reduced use of mineral fertilizers[G, H] increased yields and improved the efficiency of mineral fertilizers with a lower financial investment in corn growing.

Likwise, in areas where no fertilizers were applied, canavalia contributed and/or recycled a considerable quantity of N, from 130 to 147 kg ha^{-1} of N (7), that is, when considering the contribution of biological fixation, the negative balance of nutrients in the soil–plant system[I], is lower

As to mycorrhizal inoculation, increased nutrient uptake led to a higher efficiency in the use of the mineral fertilizer and in the case these were not applied the efficiency in the use of green manure[J] increased .

Relative to the above, the use of green manure species, can be very efficient from the economic point of view in those sustainable corn production systems with low inputs, even without the incorporation of the mycrorrhizal inoculation management (6).

[G] Torres, N.C.L. y Vallejo, R.A. *Efecto de tres abonaduras orgánicas en el cultivo de apio (apium graveolens) en la zona de la Libertad Cantón Espejo, Provincia del Carchi* [Tesis de Ingeniero], Universidad Técnica de Babahoyo, Ecuador, 2013, p. 62.

[H] Rosero, R.R. *Respuesta del cultivo de cebolla roja (Allium cepa L.) a la aplicación de tres tipos de abonos orgánicos en la parroquia Imantag, provincia de Imbabura* [Tesis en opción al título de ingeniero], Universidad Técnica de Babahoyo, Ecuador, 2012, p. 62.

[I] Domínguez, A. *Manejo de las cubiertas vegetales en cítricos ecológicos valencianos. Jornadas de Fertilización en Citricultura Ecológica*, edit. Estación Experimental Agraria de Carcaixent. Instituto Valenciano de Investigaciones Agrarias (IVIA), 2010, p. 22.

[J] Martín, G.M. *Manejo de la inoculación micorrízica arbuscular, la Canavalia ensiformis y la fertilización nitrogenada en plantas de maíz (Zea mays) cultivadas sobre suelos Ferralíticos Rojos de La Habana* [en línea] [Tesis de Doctorado], Instituto Nacional de Ciencias Agrícolas, Mayabeque, Cuba, 2009, [Consultado: 14 marzo 2015], Disponible en: <http://agris.fao.org/agris-search/search.do?recordID=CU2010400099>.

Research from other authors have determined that though green manure studied by them increased costs from the seed side, they also reduced the costs of fertilizers and increased yields, which turns them into an alternative that allows inputs saving (12), benefits that are promoted when they are jointly used with domestically produced mycorrhizal biofertilizers.

Moreover, another advantage of green manure is they produce direct benefits to soil fertility by recycling nutrients, they also promote soil and natural biology as species introduced through biofertilization.

On the other hand, the increase in yields permitted to widely cover production costs by using biofertilizers and green manure (13). On the contrary, corn growing without nutrients supply damages soils, reduces yields and the productive potential of the crop (14).

Another economic advantage of green manure is that once it is introduced in the farms, small areas for seed production can be allocated which reduces costs, and the surplus can even be sold and be a source of income for farmers.

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