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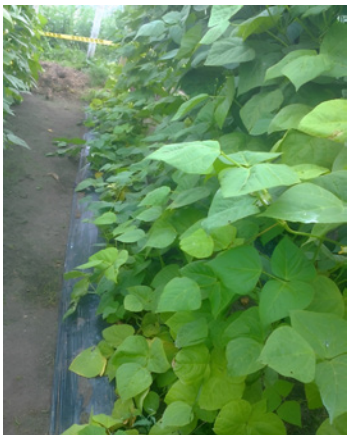
Technical and economic study of commercial varieties of green beans with plastic mulch

Estudio técnico y económico de variedades comerciales de habichuela con cobertura plástica



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Green beans with plastic mulch.

Photo: A.M. Ospina-Ruiz

ABSTRACT

Green beans are consumed worldwide due to their healthy nutritional properties. These are an important part of the modern "Grab-and-Go" diet, along with the traditional diet. Green beans are rich in protein, vitamins, fiber, folic acid and numerous minerals. In Colombia, the production of green beans is concentrated in the eastern mountain range, where there are currently low yields due to the phytosanitary problems associated with the traditional Blue Lake variety, added to the little implementation of production strategies such as plastic mulches. Thus, four varieties of green beans with plastic mulch were technically and economically evaluated. The experimental design used was complete randomized blocks with eight treatments, resulted of factors combination of the varieties (UNAPAL Milenio, Blue Lake Pole, Blue Lake National and Blue Lake S-7) and with and without plastic mulch, with four repetitions and an experimental unit of 25 plants. Planting distances were 0.25 m between plants and 1.2 m between rows for a population density of 33,333 plants/ha. The variables evaluated were: yield components, production per plant (g) and crop yield (t ha^{-1}). The plastic mulch (black-black) had no differential effect on the agronomic behavior of the green bean varieties in the study area. The UNAPAL Milenio variety, with 9,134 kg ha^{-1}, reached an agronomic behavior similar to the conventional Blue Lake variety with 9,717 kg ha^{-1}. The Blue Lake variety presented the best economic behavior with a cost-benefit ratio of 1.15 and a rate of return of 14.85%.

Additional key words: *Phaseolus vulgaris* L.; plasticulture; productivity; profitability; yield components.

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RESUMEN

Las habichuelas se consumen en todo el mundo debido a sus propiedades nutricionales saludables. Estas hacen parte importante de la dieta moderna "Grab-and-Go", junto con la dieta tradicional. Las habichuelas son ricas en proteínas, vitaminas, fibra, ácido fólico y numerosos minerales. En Colombia, la producción de habichuela se concentra en la cordillera Oriental donde actualmente se presentan bajos rendimientos por los problemas fitosanitarios asociados a la variedad tradicional Blue Lake, sumado a la poca implementación de estrategias de producción como lo son los acolchados plásticos. Así, se evaluó técnica y económicamente cuatro variedades de habichuela con acolchado plástico. El diseño experimental utilizado fue bloques completos al azar con ocho tratamientos, resultado de la combinación de los factores, variedad (UNAPAL Milenio, Blue Lake Pole, Blue Lake Nacional y Bue Lake S-7) y con y sin acolchado plástico, con cuatro repeticiones y una unidad experimental de 25 plantas. Las distancias de siembra fueron a 0,25 m entre plantas y 1,2 m entre surcos para una densidad de población de 33.333 plantas/ha. Las variables evaluadas fueron: componentes de rendimiento, producción por planta (g) y rendimiento del cultivo (t ha^{-1}). El acolchado plástico (negro-negro) no tuvo efecto diferencial en el comportamiento agronómico de las variedades de habichuela en la zona de estudio. La variedad UNAPAL Milenio con 9.134 kg ha^{-1}, alcanzó un comportamiento agronómico similar a la variedad convencional Blue Lake con 9.717 kg ha^{-1}. La variedad Blue Lake presentó el mejor comportamiento económico con una relación beneficio-costo de 1,15 y una tasa de rentabilidad de 14,85%.

Palabras clave adicionales: *Phaseolus vulgaris* L.; plasticultura; productividad; rentabilidad; componentes del rendimiento.

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INTRODUCTION

The green bean (*Phaseolus vulgaris* L.) is a crop of great global economic importance due to its nutritional properties and industrial uses. Allowing the use of both the pod and the grain, as well as its use for animal consumption, due to its high protein value (Hernández *et al*., 2010). In Central America and the Caribbean, green beans represent the main source of protein in the diet of a large part of the population (Hernández *et al*., 2010).

In Colombia, in the year 2019, there was a decrease in yields in green bean crops in relation to past years, going from 9.28 t ha^{-1} in 2006 to 8.08 t ha^{-1} in 2019 (Agronet, 2023). Production is concentrated in the eastern mountain range, in the departments of Cundinamarca, Santander, Huila, Tolima and Boyaca, with 45.09 t, representing 80% of the national production. For its part, the department of Valle del Cauca contributes 10% of the national production (5.44 t). Caldas ranks 15th in production, reporting the lowest green bean yields in the last 10 years, with 6.00 t ha^{-1} (Agronet, 2023).

In the tropics, green beans are produced mostly by small farmers (areas smaller than 0.5 ha) and, in the case of Colombia, pole beans are the most widely used, which demands more labor than bush beans. These varieties allow the farmer to harvest green beans for a longer period of time throughout the year and adapt their offer to the market conditions. This generally requires few volume of high-quality production. On the other hand, in developed countries, the crops are larger and the bush growth varieties are the most used due to their ease for mechanized harvesting; big part of the production is destined for industrial purposes (Vallejo and Estrada, 2004).

The varieties and genotypes of green beans present in the Colombia's national market have been produced mostly in the United States, as is the case of the variety traditionally used Blue Lake (90% of the planted area, until the year 2000), which was produced by the company Ferry Morse through closed pedigree. At the time of its market launch, the Blue Lake variety presented field tolerance to bacteriosis, angular spot, oidium and was moderately susceptible to rust (Petropoulos *et al*., 2020). A short time later, the variety became highly susceptible to these and many more pathogens, due to the use of only this variety, the indiscriminate use of agrochemicals and the production of their own seed by farmers, thus favoring the spread of pathogens (Hernández *et al*., 2010).

Currently, a good number of improved materials are available on the market, among which there are national materials developed in our agroecological conditions, such as the UNAPAL Milenio variety (Blair *et al*., 2010); however, the potential of these materials in various areas remains unknown given that, in many cases, it is the farmers themselves who must assume the risk if they want to incorporate any change in their productive system.

Plastic mulch is a technology that has been used in various crops and that, in most cases, has increased yields by controlling factors that negatively affect productivity such as weeds, pests, and diseases. In addition, it exerts important and favorable modifications in the physical environment (soil) where the plants are grown, affecting fertility, humidity, temperature and physical structure (Zribi *et al*., 2011; Fischer *et al*., 2022).

Some studies have shown that black-black plastic mulch generates beneficial effects and increases yields in various crops (Gao *et al*., 2019). However, its effects on the green bean crop are unknown. Indications of the effect of this practice in the cultivation of green beans are the studies in the cultivation of beans that show a beneficial effect on the productive characteristics and the severity of diseases (Tofanelli and Wortman, 2020). The aim of this study was to evaluate economically four varieties of green beans under plastic mulch in the Colombian Andean region.

MATERIALS AND METHODS

The study was carried out at the Tesorito Farm of the Universidad de Caldas, located in the municipality of Manizales, department of Caldas (Colombia), between August and December of the year 2020. With an altitude of 2,340 m, mean annual temperature of 17.5°C, relative humidity of 78%, annual precipitation of 2,000 mm, solar brightness of 1,473 h $year^{-1}$ (Cenicafé, 2022) and Andisol soils derived of volcanic ash with sandy loam texture rich in organic matter (Obando *et al*., 2006).

The evaluated materials were four commercial varieties of indeterminate growth green beans: UNAPAL Milenio, Blue Lake S-7, Blue Lake Pole and Blue Lake National with and without plastic mulch.

After the preparation of the land, the 1.2 gauge black-black plastic (PQA, 2023) mulch was installed and 10 cm diameter holes were later made in the mulch for direct sowing of the seeds.

For the preparation of the land, a cleaning area was done by means of a scythe in the entire lot; subsequently, a layout and chopping was carried out in furrows at a depth of 20 cm and at a distance of 1.20 m.

As amendments, 2 t ha^{-1} of agricultural lime (dolomite lime - Caldessa®) and 5 t ha^{-1} of organic matter (Kikes®-Abonissa) were applied. The amendments were incorporated into the soil by chopping into furrows.

Staking was done 28 days after sowing (DAS). Bamboo stakes, polypropylene fiber and wire were used for the staking. Each stake was placed 6 m apart in the furrow and buried 50 cm deep. The wire was fixed with staples at the upper end of the bamboo and another at 10 cm from the ground, holding it at the ends of the grooves in order to maintain the tension of the system. Wire was used as support to install the "V" shaped staking with polypropylene fiber for each plant.

Sowing was done directly to the ground, making a reseeding at 10 DAS. Distances of 1.20 m between rows and 0.25 m between plants were used, for a planting density of 33,333 plants/ha. At the time of sowing, a N-P-K fertilizer (10-20-20) was added 10 cm below the seed.

Three edaphic fertilizations and a foliar one were performed. The first fertilization was done at the time of sowing with a compound N-P-K fertilizer (10-20-20) at a rate of 20 g/site, incorporating the fertilizer 10 cm below the seed. The second and third fertilization was done at 40 DAS and 50 DAS respectively, by means of liquid fertilization in the form of a "drench" with a mixture composed of calcium nitrate, potassium nitrate and calcium hydroxide at a rate of 2, 5 and 5 g per site, respectively.

Foliar fertilization was carried out with two fertilizers 12-30-10 and 4-4-3 enriched with free amino acids and polysaccharides, both with minor elements in a dose of 0.25 g L^{-1} and 2 cm^3 L^{-1}, respectively.

Weed control was mechanical and manual twice in the crop, at 29 DAS and 62 DAS. Mechanical weeding with a hoe and machete was done in the lines and furrows of the crop. Manual weeding was done

around the stem plant. In the furrows with plastic mulch, cleaning was done in the hole where the green bean plants were sown.

Phytosanitary management was carried out in accordance with the protocols established for the cultivation of green beans at the Tesorito farm, according to good agricultural practices (GAP) (Colombia DANE, 2016). During the crop cycle, six phytosanitary applications were made (Tab. 1).

The treatments evaluated were Blue Lake Pole + plastic mulch (BLP+PP), Blue Lake Pole - without plastic mulch (BLP-PP), Blue Lake S-7 + plastic mulch (BLS7+PP), Blue Lake S-7 - without plastic mulch (BLS7-PP), UNAPAL Milenio + plastic mulch (UNM+PP), UNAPAL Milenio - without plastic mulch (UNM-PP), Blue Lake National + plastic mulch (LA+PP), and Blue Lake National - without plastic mulch (LA-PP). The trial corresponded to a randomized complete block (RCB) experimental design, with a 4×2 arrangement, with eight treatments and four repetitions per treatment. The eight treatments were made up of four varieties (UNAPAL Milenio, Blue Lake Pole, Blue Lake S-7 and Blue Lake National) under two productive systems (plastic mulch and bare soil). The effective size of the experimental unit was 25 plants at 0.25 m between plants and 1.20 m between rows, for a density of 33,333 plants/ha.

For the analysis of production costs, a record of the agronomic tasks was kept and the efficiency was evaluated, taking into account the time executed for each task. All the values in the calculation of the cost of production were quoted in Manizales, Caldas, in the fourth quarter of 2022. As reference for the costing, market prices in Manizales for the fourth quarter of 2022 were used. The reference price for the calculation of the cost/benefit ratio (R C/B) was carried out with the average price per kg in the markets of the region over the last 3 years (2020, 2021 and 2022).

For the definition of production costs, the concept of operational cost was used by Herrera *et al*. (2015), which includes all production costs, without taking into account the interests of the invested capital. Thus, it was possible to obtain production costs and cash flows, on the basis of which the profitability of the crop was estimated, directing the product to the local market.

For the characterization of production costs, records were kept in a cost calculation sheet adopted from the *Corporación Colombia Internacional* (Colombia International Corporation) model (Colombia DANE, 2023). All values were calculated in US dollars per hectare (US$/ha) with the exchange rate reported in the fourth quarter of 2022, according to the Bank of the Republic of Colombia.

Table 1. Phytosanitary applications during the crop cycle of 4 varieties of green beans.

Application	Days after sowing (DAS)	Type	Dose	Active ingredient
1	10	Insecticide	1 g L^{-1}	Thiocyclam-hydrogenoxalate
2	28	Insecticide	2 cm^3 L^{-1}	Dimethoate
3	50	Fungicide	3 cm^3 L^{-1}	Tetracloroisoftalonitrile
		Fungicide	2 cm^3 L^{-1}	Pyrimethanil
4	58	Insecticide	1 g L^{-1}	Thiocyclam-hydrogenoxalate
		Fungicide	2.5 g L^{-1}	Prochloraz
		Fungicide	1.5 g L^{-1}	Benomyl
5	63	Insecticide	1 g L^{-1}	Thiocyclam-hydrogenoxalate
		Fungicide	5 g L^{-1}	Propineb
6	70	Insecticide	1 g L^{-1}	Clothianidin
		Fungicide	5 g L^{-1}	Propineb
		Fungicide	1 g L^{-1}	Azoxystrobin - Difenoconazole
7	93	Insecticide	1 cm^3 L^{-1}	Spinetoram

In the estimates of production costs, the same technological level was considered, maintaining the proportionality of hours spent with manual labor and the amount of agricultural inputs. The technical coefficients (man-day hours and the amount of agricultural inputs) were based on the efficiencies of the workers of the Tesorito Farm. The costs were divided into two parts as follows:

Manual operations: the average value of US$8.85 per day of service (man-day) was considered, equivalent to the remuneration paid to rural workers in the region, not including social security contributions, since, in general, the activity is carried out by family or hired labor in specific seasons.

Agricultural inputs: the average price among the main distributors in the region was used.

After the production costs were defined (Tab. 2), the cash flow was estimated, considering an investment of 8 months. Values are expressed in US dollars per hectare at the time of investment.

To analyze the profitability of the crop, the following financial indicators were calculated: gross income, net income, production costs and economic indicators for each variety such as the unit production margin, cost benefit ratio and rate of return (UPM, R C/B and the RR).

Table 2. Structure of production costs in US$/ha of four varieties of green beans with plastic mulch.

Concept	BLP+PP		BLP-PP		BLS7+PP		BLS7-PP	
	Value ($USD)	% Part	Value ($USD)	% Part	Value ($USD)	% Part	Value ($USD)	% Part
Manpower	734.52	15.41	716.82	16.79	734.52	15.00	716.82	16.12
Fertilizers	1,065.56	22.35	1,065.56	24.95	1,065.56	21.76	1,065.56	23.96
Fungicides	106.33	2.23	106.33	2.49	106.33	2.17	106.33	2.39
Insecticides	43.26	0.91	43.26	1.01	43.26	0.88	43.26	0.97
Materials	2,071.79	43.46	1,636.69	38.33	2,079.17	42.45	1,646.52	37.02
Other	278.60	5.84	278.60	6.52	278.60	5.69	278.60	6.26
Subtotal	4,300.06		3,847.26		4,307.44		3,857.09	
Harvest	309.74	6.50	265.49	6.22	442.48	9.03	442.48	9.95
Seed	157.33	3.30	157.33	3.68	147.49	3.01	147.49	3.32
Total	4,767.12	100	4,270.07	100	4,897.41	100	4,447.06	100
Concept	UNM+PP		UNM-PP		LA+PP		LA-PP	
	Value ($USD)	% Part	Value ($USD)	% Part	Value ($USD)	% Part	Value ($USD)	% Part
Manpower	734.52	15.06	716.82	16.20	734.52	15.23	716.82	16.57
Fertilizers	1,065.56	21.85	1,065.56	24.08	1,065.56	22.10	1,065.56	24.64
Fungicides	106.33	2.18	106.33	2.40	106.33	2.21	106.33	2.46
Insecticides	43.26	0.89	43.26	0.98	43.26	0.90	43.26	1.00
Materials	2,078.68	42.62	1,645.05	37.17	2,075.73	43.05	1,641.11	37.95
Other	278.60	5.71	278.60	6.29	278.60	5.78	278.60	6.44
Subtotal	4,306.94		3,855.61		4,303.99		3,851.68	
Harvest	442.48	9.07	442.48	10.00	398.23	8.26	353.98	8.18
Seed	127.83	2.62	127.83	2.89	119.31	2.47	119.31	2.76
Total	4,877.25	100	4,425.92	100	4,821.53	100	4,324.97	100

BLP+PP = 'Blue Lake Pole' + plastic mulch, BLP-PP = 'Blue Lake Pole' - without plastic mulch, BLS7+PP = 'Blue Lake S-7' + plastic mulch, BLS7-PP = 'Blue Lake S-7' - without plastic mulch, UNM+PP = 'UNAPAL Milenio' + plastic mulch, UNM-PP = 'UNAPAL Milenio' - without plastic mulch, LA+PP = 'Blue Lake National' + plastic mulch, LA-PP = 'Blue Lake National' - without plastic mulch.

Yield components were evaluated as number of pods/plant, green pod/plant weight, production per plant (g) and yield (kg ha^{-1}). The data obtained were evaluated by analysis of variance using the SAS statistical program, version 9.0 (SAS Institute Inc., Cary, NC); additionally, tests of comparative averages were performed using the Duncan test at the 5% significance level.

RESULTS AND DISCUSSION

The production costs for one hectare of each of the varieties with and without plastic mulch were similar until the beginning of the harvest, because both the cultural work and the agricultural inputs used present similar costs. The main variation occurred in the material items due to the use of plastic mulch and labor, specifically associated with the installation of plastic mulch, weed management and harvesting, due to the fluctuation of productivity that each of the materials evaluated are shown in table 2.

The highest cost of production is for the varieties with mulch with values between US$4,767.12 and US$4,897.41 per ha. The participation of materials for the construction of stakes and fertilizers in the total costs was high on average, 42.90% and 23.21%, respectively (Tab. 2). The varieties without plastic mulch were the ones with the lowest percentage of participation in materials in the total costs with 37.62% (Tab. 2). Martínez-Reina *et al*. (2019) obtained a mean production cost of green beans in the humid Caribbean of Colombia of US$ 1,177.74.

These same authors, in order to obtain basic information on the production and economic returns of long green beans in the Humid Caribbean of Colombia, highlight that the green bean production systems are under a family and subsistence farming system, where the use of family labor predominates by 75%; 100% of the farmers use uncertified seed, 90% perform manual weed control and 70% do chemical control of insects. 86% of production is destined for the local market, and 14% for family consumption. The average production is 4,950 kg ha^{-1}; the average sale price was US$0.26 per kg for the year 2019, which generated a cost-benefit ratio of 1.09 in 4 months of the production cycle and a profitability of 8.9%. Since the investments are low, it is considered an efficient production, which guarantees sustainability over time.

From the evaluation of the yield components, significant differences were observed according to table 3. For the behavior of the variable number of pods per plant, the varieties Blue Lake S-7 with and without plastic mulch stand out together with the variety UNAPAL Milenio and Blue Lake National with mulch, with 28.25, 31.75, 28.00 and 27.75 pods per plant, respectively. In contrast, the Blue Lake Pole variety with and without plastic mulch had the worst performance with a difference close to 50% of 16 pods per plant on average for the ones with best performance (Tab. 3). For the variable pod/plant weight, there were no statistical differences in all varieties in interaction with and without mulch with values between 10.53 and 8.51 g/plant.

Table 3. Average of yield components of 4 varieties green beans with plastic mulch.

Treatment	Number of pod/plant	Weight pod/plant	Production plant (g)	Yield (kg ha^{-1})
BLP+PP	16.75 bc	10.53 a	176.37 c	5,879 c
BLP-PP	15.00 c	9.54 a	143.05 d	4,768 d
BLS7+PP	28.25 a	10.30 a	290.87 a	9,696 a
BLS7-PP	31.75 a	9.20 a	292.14 a	9,738 a
UNM+PP	28.00 a	10.14 a	283.79 a	9,459 a
UNM-PP	26.25 ab	10.07 a	264.26 ab	8,809 ab
LA+PP	27.75 a	8.51 a	236.31 b	7,877 b
LA-PP	23.75 b	8.79 a	208.66 c	6,955 c

BLP+PP = 'Blue Lake Pole' + plastic mulch, BLP-PP = 'Blue Lake Pole' - without plastic mulch, BLS7+PP = 'Blue Lake S-7' + plastic mulch, BLS7-PP = 'Blue Lake S-7' - without plastic mulch, UNM+PP = 'UNAPAL Milenio' + plastic mulch, UNM-PP = 'UNAPAL Milenio' - without plastic mulch, LA+PP = 'Blue Lake National' + plastic mulch, LA-PP = 'Blue Lake National' - without plastic mulch. Means with different letters indicate a significant difference according to Duncan's test ($P \leq 0.05$).

The yield behavior was higher for the varieties Blue Lake S-7 with and without mulch and the 'UNAPAL Milenio' with plastic mulch, with yields of 9,696, 9,738 and 9,459 kg ha^{-1}, respectively. A study by San-Miguel *et al*. (2021), with the variety Cuba-98, obtained yields with the use of biostimulants between 5,900 and 9,700 kg ha^{-1}. According to Agronet (2023), for the year 2019 the average yield for Colombia was 8,080 kg ha^{-1}. Varieties Blue Lake S-7 and UNAPAL Milenio performed better than the national average with and without plastic mulch.

According to Villota *et al*. (1993), the variety Blue Lake National obtained a yield of 7,416.2 kg ha^{-1}, lower than the yield of this variety with plastic mulch with 7,877 kg ha^{-1}. In this same study, the efficiency of conventional fertilization was evaluated *versus* complete fertilization with boron in 'Blue Lake Pole' green beans, carried out in the department of Valle del Cauca, reporting 8,067 kg ha^{-1}. According to Arbeláez *et al*. (2016), the boron element plays an important role in the fertility of the plant at the time of leaf growth, flowering, fruit set and the seed formation process; in addition, it affects many physiological processes of the plant such as transport of sugars, synthesis and structure of the cell wall, lignification, metabolism of carbohydrates, metabolism of RNA, IAA, phenols and ascorbates, respiration and integrity of the plasmatic membrane (Kabir *et al*., 2015). Meanwhile, Calero *et al*. (2020) doubled the production of the variety Blue Lake with 17,974 kg ha^{-1} with 3 t ha^{-1} of chicken manure and 1 t ha^{-1} of vermicompost and 16,132 kg ha^{-1} with 1.5 t ha^{-1} of chicken manure and 1 t ha^{-1} of vermicompost.

Petropoulos *et al*. (2020) reported a higher yield for the varieties Blue Lake and UNAPAL Milenio of 10.33 and 13.10 t ha^{-1}, respectively; possibly, the differences in yields can be attributed to the geographical location of each study area, in which the different environmental conditions can make sowing materials express differently.

Regarding the variety Blue Lake Pole, its worst behavior and performance obtained in this study could be due to the fact that this variety was evaluated at an altitude of 2,150 m, being outside the optimal altitudinal range of 600 and 1,800 m a.s.l., for the variety.

Economic viability of the investment

The average commercial value in the chain markets in the city of Manizales was US$0.52 per kg. According to Colombia DANE (2013), in Colombia, in general terms, the determination of the green bean price is free, taking into account the supply and demand of the product. This is how Martínez-Reina *et al*. (2019) report that the National Administrative Department of Statistics Colombia (DANE in Spanish) is in charge of reporting on the behavior of the prices of this product at the level of the various supply centers of the country. The purchase-sale relationship and the determination of the prices of the green beans produced in the region is given by the supply and demand of the product. Prices change from day to day and the purchase price from the producer depends on the day the crop is sold.

Table 4. Economic analysis of four green beans varieties with plastic mulch.

Treatment	Production cost (US$)	Yield (kg ha^{-1})	Sale price (US$/kg)	Net profit (US$)	UPM	RC/B	RR
BLP+PP	4,767.12	5,879	0.52	3,057.08	$ 0.81	0.64	-35.87
BLP-PP	4,270.07	4,768	0.52	2,479.36	$ 0.90	0.58	-41.93
BLS7+PP	4,897.41	9,696	0.52	5,041.92	$ 0.51	1.03	2.95
BLS7-PP	4,447.06	9,738	0.52	5,063.76	$ 0.46	1.14	13.86
UNM+PP	4,877.25	9,459	0.52	4,918.68	$ 0.52	1.01	0.84
UNM-PP	4,425.92	8,809	0.52	4,580.68	$ 0.50	1.03	3.49
LA+PP	4,821.53	7,877	0.52	4,096.04	$ 0.61	0.85	-15.05
LA-PP	4,324.97	6,955	0.52	3,616.60	$ 0.62	0.84	-16.38

UPM = unit production margin; R C/B = cost/benefit ratio; RR = rate of return. BLP+PP = 'Blue Lake Pole' + plastic mulch, BLP-PP = 'Blue Lake Pole' - without plastic mulch, BLS7+PP = 'Blue Lake S-7' + plastic mulch, BLS7-PP = 'Blue Lake S-7' - without plastic mulch, UNM+PP = 'UNAPAL Milenio' + plastic mulch, UNM-PP = 'UNAPAL Milenio' - without plastic mulch, LA+PP = 'Blue Lake National' + plastic mulch, LA-PP = 'Blue Lake National' - without plastic mulch.

The variety Blue Lake S-7 with and without mulch yielded the best net income with US$5,041.92 and US$5,063.76 per ha, respectively, followed by the UNAPAL Milenio variety, also with and without plastic mulch, with US$4,918.68 and US$4,580.68, respectively, reflecting a high potential for its production. The behavior of the remaining varieties with negative net income is financially unattractive (Tab. 4).

The unit production margin (UPM) values, which are up to the maximum point of US$0.52, present a suitable equilibrium point for an adequate profit margin in the productive system; within this range is the variety Blue Lake S-7 with and without padding. The varieties Blue Lake Pole and Blue Lake National and their interaction with plastic mulch presented values above US$0.53, which was the value perceived in the market, making these varieties financially unfeasible (Tab. 4).

According to the cost-benefit ratio shown by the analysis adopted (Tab. 4), the variety Blue Lake S-7 without plastic mulch presented the highest profitability, and this same variety with plastic mulch stood out as financially attractive for an investor in this type of production system; therefore, for the remaining varieties, the prospects of investors are not exceeded, making the profitability of the crop unfeasible.

Martínez-Reina *et al*. (2019) obtained a R C/B of 1.09 in four productive months with the variety Negra Criolla (regional material traditionally used by farmers in the Colombian humid Caribbean). Since the investments are low, it is considered an efficient production, which guarantees sustainability over time. This is how the economic analysis demonstrates the fragility in the economic sustainability of the sowing of green beans with and without cover, both due to the variation in the prices of the product and in relation to the incidence of unpredictable increases in the costs of agricultural inputs.

In general, the results indicate that the effect of plastic mulch does not yield the best economic results, however, it facilitates the integrated management of weeds and soil conservation (Gao *et al*., 2019). At the same time, an alternative to the traditional Blue Lake variety is presented with the UNAPAL Milenio variety that does not present statistical differences in production, in such a way that the market does not depend on a single commercial variety as nowadays that depends on 90% of a single variety. One of the criticisms found with the study is that the final disposal of plastic mulches at the end of the production cycle can generate soil contamination. However, the current regulations of plastic producing companies recycle them in order to give new uses and reduce possible contamination.

CONCLUSION

The variety UNAPAL Milenio with yield of 9,134 kg ha^{-1} reached an agronomic behavior similar to the variety Blue Lake with 9,717 kg ha^{-1} for the study area, becoming a sustainable alternative proposal for growers in the region.

The plastic mulch (black-black) had no differential effect on the agronomic behavior of the green bean varieties in the study area.

In relation to yield and profitability, the variety UNAPAL Milenio presented the best response together with the variety Blue Lake (control) for the study area, with a cost-benefit ratio (R C/B) of 1.04 and 1.15 and with rates of return of 4.37 and 14.85%, respectively.

Conflict of interests: The manuscript was prepared and reviewed with the participation of the authors, who declare that exist no conflict of interest that puts at risk the validity of the presented results.

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