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Technical evaluation of the fertilization of flue cured tobacco farming in Campoalegre and Garzon, Huila

Evaluación técnica de la fertilización en el cultivo de tabaco Virginia, en los municipios de Campoalegre y Garzón, Huila

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ABSTRACT

Agricultural production changes constantly and producers have to be able to use resources more efficiently to obtain a greater yield and improve quality at the lowest possible cost. Consequently, the objective of this paper was to carry out a technical evaluation of the fertilization programs for flue-cured tobacco farming in the municipalities of Campoalegre and Garzon, located in the department of Huila, Colombia. Seven treatments, corresponding to six fertilization alternatives (three dosages and two application sources) and the conventional treatment carried out by producers (the control) were evaluated. When the leaves reached ripeness for harvest, they were harvested, cured and later classified and weighed to measure the yield and the quality obtained from the treatments. For the technical and economic analysis, the yield, fertilization cost, net and gross income, and the purchase quality were taken into account. The municipality of Campoalegre showed a greater average yield (3,080 kg ha^{-1}) over Garzon (2,640 kg ha^{-1}). For both municipalities, the highest costs were experienced with the 150% fertilization treatment and the use of ammonium sulphate (AMS). For Campoalegre, the greatest yield was obtained without the use of ammonium sulphate at all three dosages. In Garzon, the greatest yield was obtained with the 100% dosage with or without the use of AMS and the conventional treatment carried out by the producers. The best cost-benefit ratio in Campoalegre was obtained with the 50% dosage of fertilization recommended without use of AMS and, in Garzon, it was obtained with the conventional treatment.

Key words: fertilization, economic analysis, cost benefit analysis, *Nicotiana tabacum* L.

RESUMEN

La producción agrícola es dinámica y competitiva, y los productores deben ser más eficientes en la utilización de los recursos para obtener mayor rendimiento y mejor calidad al menor costo posible. Por lo anterior, el objetivo del presente trabajo fue realizar una evaluación técnica de programas de fertilización en el cultivo de tabaco Virginia, en los municipios de Campoalegre y Garzón del departamento del Huila. Se evaluaron siete tratamientos correspondientes a seis alternativas de fertilización (tres dosis y dos fuentes de aplicación) y un testigo comercial. Cuando las hojas alcanzaban la madurez de recolección, se cosecharon, se curaron y posteriormente se clasificaron y pesaron para obtener el rendimiento y la calidad por tratamiento. Para el análisis técnico y económico se tuvo en cuenta el rendimiento, costo de la fertilización, ingreso bruto y neto, y calidad de compra. El municipio de Campoalegre presentó mayor rendimiento promedio (3.080 kg ha^{-1}) con respecto a Garzón (2.640 kg ha^{-1}). Para los dos municipios los costos más altos se presentaron en los tratamientos con dosis del 150% de la fertilización y la utilización de sulfato de amonio (SAM). Para Campoalegre, los mayores rendimientos se obtuvieron con la no utilización de SAM a las tres dosis. En Garzón, los mayores rendimientos se obtuvieron con la dosis al 100% con y sin aplicación de SAM y el testigo comercial. La mejor relación beneficio-costo en Campoalegre se obtuvo con la dosis al 50% de la fertilización recomendada sin aplicación de SAM y en Garzón se obtuvo con el testigo.

Palabras clave: fertilización, análisis económico, análisis beneficio costo, *Nicotiana tabucum* L.

Introduction

Among the short-term crops grown in Colombia, the cultivation of tobacco occupies eleventh place for importance by sown area (ENA, 2009). In 2009, there were 9,829 ha of Tobacco with 9,520 productive units in the country, showing an 11% increase in contrast to the year before. For the same year, the departments with the larger sown areas were: Santander (51%), Huila (17%), Bolivar (15%), Sucre (7%), with an average productive area of 1.0, 6.0, 4.0, 0.5, and 0.4 ha, respectively, and other departments such as Boyaca, Guajira, Tolima, Valle del Cauca, Cauca, Quindio, Risaralda and Magdalena (10%) (ENA, 2009).

Both bright leaf and dark leaf tobacco are cultivated in Colombia; they differ from each other by their chemical

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composition and organoleptic properties. Among the bright leaf variety, three types are cultivated: flue-cured (*Virginia*), Burley, and air-cured Virginia (Espinal *et al*., 2005). Flue-cured tobacco has a soft flavor and aroma, medium nicotine level and high sugar content; its combustion fumes are sweet and acidic. It is harvested leaf by leaf and cured in barns with flues conveying heat into the barns; the cured leaves acquire a yellow tone (Rojo, 2008). Burley tobacco has a neutral flavor, good combustibility and stuffing capacity; the entire plant is harvested and dried or air-cured and the cured leaves acquire a reddish coloration (Rojo, 2008). The production of bright leaf tobacco takes place in two regions that make up 81.3% of the production: The first region is composed of Santanter, Norte de Santander and Boyaca with 47.7% and the second is composed of Huila and Tolima with 37.0%. Tobacco farming is also being implemented in Quindio, Risaralda, Magdalena, Guajira and Valle del Cauca with 18.7% of the production (Espinal *et al*., 2005; Zambrano and Tovar, 2007).

Two types of dark leaf tobacco are cultivated: 'Garcia' and 'Cubita' (Espinal *et al*., 2005; León and Coronado, 2006). Dark leaf tobacco usually has a strong flavor and aroma, high nicotine content and alkaline smoke; it is air cured under natural conditions and, after a fermentation process, it acquires tonalities which range from light to dark brown (Rojo, 2008). Dark leaf tobacco of the García variety has big, thick, broad leaves while 'Cubita' has elongated narrow leaves; additionally, the tar and nicotine content is low compared to other Colombian tobaccos (Espinal *et al*., 2005; León and Coronado, 2006). The production of 'Cubita' dark leaf tobacco is done mainly in the departments of Sucre (62%), Bolivar (21%) and Magdalena (17%) due to their proximity to seaports. The production of 'Garcia' dark leaf tobacco is carried out mainly in Santander (84.5%) and Boyaca (15.5%) (Espinal *et al*., 2005; Zambrano and Tovar, 2007).

The socioeconomic importance of tobacco farming in Colombia is based on the generation of employment due to the use of manual labor and the generation of extra income for the producing families. This crop adapts to poor soils with scarcity of water, providing reasonable economic income. It also has the advantage of a guaranteed sale and financing from purchasing companies; even though this may not often be enough to satisfy the families basic needs (CCI, 2001; Agrocadenas, 2004, 2005).

The department of Huila has been specializing in the production of flue-cured tobacco, which is cultivated mainly in the municipalities of Campoalegre, Garzon, Rivera, Altamira, Agrado, Algeciras, Palermo, Hobo, Gigante, Tesalia, Villavieja, Guadalupe, Neiva, Yaguara, Baraya, and Suaza, where Campoalegre and Garzon represent 49% of the cultivated area. This crop has played an important role in the regional economy because of the generation of direct employment and rural income, with approximately 260 daily wages/ha per crop, without taking into account indirect employment such as oil production, inputs, marketing, transport, among other. Similarly, the department receives income tax revenues and foreign exchange currency through raw tobacco exports and/or from processed products. Tobacco manufacturing generates technological advancements, employment and contributes to income generation in rural areas to the extent that it supports the production of raw material (Zambrano and Tovar, 2007).

The tobacco production system in the department of Huila is characterized by an average planting area of 7 ha in Campoalegre and 8 ha in Garzon, using mainly hired manual labor for cultivation work (temporary workers) and primarily leased plots for cultivation, having water available for irrigation, using surface irrigation, tillage practices, herbicides regularly, rotating crops such as corn, kidney beans, rice and/or sorghum and obtaining two crops a year; the first one in June-July and the second one between August-October (Plaza *et al.,* 2011b). Within the cost structure of tobacco farming in the department of Huila, the preharvest stage is responsible for 73.5% of the costs, followed by postharvest at 20.5% and the seedbed only takes up 6.0%. Among the activities performed during the preharvest stage, fertilization is the most expensive with 26% of the costs, followed by crop set up which includes soil preparation and transplanting (Plaza *et al*., 2011a).

Agricultural production changes constantly and producers have to be able to use resources more efficiently to obtain a greater yield and improve quality at the lowest possible cost (Rojo, 2008). The profitability of the tobacco production system comes from the production (yield and quality) and from the costs paid by the producers related to the investment (Chouteau and Fauconier, 1993). An important task to accomplish the goal of better production and quality comes from a balanced and suitable management of the nutrients, as this will result in a healthier plant, capable of manifesting all of its genetic potential (Rojo, 2008). For the establishment of an optimal fertilization program, one that provides the amount of nutrients plants need in a timely manner to reach the production potential, one must take into account the nutritional status of the soil, the maximum nutritional absorption, the rate of absorption of nutrients during the plant's lifecycle and their distribution (leaves, stems, roots) (Moustakas and Ntzanis, 2005; Rojo, 2008).

Fertilization accounts for between 15 and 26% of tobacco production costs for the department of Huila (Garay, 2008; Plaza *et al.*, 2011a); this percentage highlights the importance of reducing or at least maintaining said costs and improving the profitability of the crop, which is fundamental to the sustainability of the production system (Marín *et al.*, 2008). As fertilization represents a high percentage of production costs, it is important to know the factors that influence the plant response to fertilizer applications in order to determine the proper amounts that should be applied to obtain the greatest technical and economic benefit (Flórez *et al.*, 1978). Therefore, the objective of this paper was to provide a technical assessment of fertilization programs in the cultivation of flue-cured tobacco, in the municipalities of Campoalegre and Garzon in the department of Huila, Colombia.

Materials and methods

The study was conducted on two tobacco farms located in the department of Huila (Colombia), in the municipalities of Campoalegre (2°37.5'10'' N and 75°21.7'73'' W), located at 525 m a.s.l., with an average temperature of 28°C, relative humidity of 68% and average solar radiation of 32 MJ m^{-2}; and Garzon (2°13.7'76'' N and 75°36.1'66'' W), located at 790 m a.s.l., with an average temperature of 25°C, relative humidity of 74% and average solar radiation of 28 MJ m^{-2}. These municipalities exhibited sandy loam soils with slight and moderate acidic pHs respectively; P, K, Mg, S and Cl contents unsuitable for cultivation and an ideal texture, pH and N percentage (Tab. 1). The material used was tobacco (*Nicotiana tabacum* L.), Virginia variety, NC297, and the seedbed was prepared and, when the plants had 5 true leaves, they were transplanted with a planting density of 20,833 plants/ha, distributed in rows 1.2 m wide and 0.4 m between plants. Each experimental unit had an area of 57.6 m^2. Crop management was performed in accordance with the production practices of each study area.

Experiment design

The trials were established under a completely randomized design with a 3 x 2 factorial arrangement. Seven treatments and three replications per treatment were used; they corresponded to six fertilization alternatives and the conventional treatment. The conventional treatment (control) corresponded to the current treatment recommended by the Protabaco Company (Plaza *et al.*, 2011a) and used by the producers. The alternatives (Tab. 2) corresponded to combining three fertilization doses (recommended dose, 50% of the recommended dose and 150% of the recommended dose) and two application source groups. A correct balance of nutrients when using the different fertilizer sources available for the tobacco producers was obtained by using or not using ammonium sulphate as a nitrogen source and by seeking to maintain the nitrogen ratio (NO_3 and NH_4) at 50:50. The recommendations of fertility according to soil analysis following the methodology of ICA (1992) and Gómez (2005) were considered for selecting the dosage, which correspond to 100% or recommended dose (Tab. 3). To make a recommendation on the amount of fertilizer, the levels of extraction for each mineral element were applied as reported by Ballari (2005) and an expected production of 3,200 kg ha^{-1} was used.

The fertilizers used were:

- 17-9-18-3, containing the following elements in the proportion of N:P_2O_5:K_2O:MgO:S as 17:9:18:3:6. Ratio of ammonium and nitrate, N-NH_4:N-$N0_3$ = 60:40.
- 13:3:43, containing the following elements in the proportion of N:P_2O_5:K_2O. Ratio of N-NH_4:N-$N0_3$ = 5:95.
- 21:11:7.5, containing the following elements in the proportion of N:CaO:MgO. Ratio of N-NH_4:N-$N0_3$ = 50:50.
- Ammonium sulphate (AMS), containing the following elements in the proportion of N:S as 21:24. Ratio of N-NH_4:N-$N0_3$ = 100:0).

TABLE 1. Physicochemical properties of the soil before planting in Campoalegre and Garzon.

pH	N-NO_3	N-NH_4	N-total	P	S	CE	Ca	K	Mg	Na	Al	CICe
Campoalegre												
			(mg kg^{-1})			(dS m^{-1})			(cmol kg^{-1})			
6.3	3.49	4.51	8	44.1	5.52	0.74	5.52	0.19	1.54	0.08	0.00	7.33
Garzon												
pH	N-NO_3	N-NH_4	N-total	P	S	CE	Ca	K	Mg	Na	Al	CICe
			(mg kg^{-1})			(dS m^{-1})			(cmol kg^{-1})			
5.6	7.86	6.55	14.41	53.5	9.94	0.34	10.3	0.44	3.24	0.08	0.00	14.1

TABLE 2. Treatments for each study area in terms of amount applied per product.

Treatments	Doses (%)*	Products (kg ha^{-1}) 17-9-18-3	13:3:43	21:11:7.5	AMS	Sulfato K	DAP
Campoalegre							
a50	50	275	288	175	50		
a100	100	550	575	350	100		
a150	150	825	863	525	150		
b50	50	550	163	75			
b100	100	1100	325	150			
b150	150	1650	488	225			
Control	Control	750	50		50	100	50
Garzon							
a50	50	250	288	63	25		
a100	100	500	575	125	50		
a150	150	750	863	188	75		
b50	50	475	125	150			
b100	100	950	250	300			
b150	150	1425	375	450			
Control	Control	790	105		155	155	

* recommended dose.

TABLE 3. Fertilizer recommendation to tobacco Virginia for an expected production of 3,200 kg ha^{-1} in Campoalegre and Garzon.

Element	N	P_2O_5	K_2O	CaO	MgO	S
Campoalegre						
Requirement	181	23	250	141	31	31
Soil analysis	8	44.09	0.19	5.52	1.54	5.52
Application (kg ha^{-1})	256.1	52.7	347.5	90.7	25.7	47.39
Garzon						
Requirement	181	23	250	141	31	31
Soil analysis	14.41	53.45	0.44	10.33	3.24	9.94
Application (kg ha^{-1})	254.3	52.7	279.42	90.7	25.7	44.27

- Sulfato K, containing the following elements in the proportion of K_2O:S as 50:17.
- DAP, containing the following elements in the proportion of N:P_2O_5 as a 18:46. Ratio of N-NH_4:N-$N0_3$ = 100:0.

Fertilizer applications were conducted according to the different mineral absorption curves for the plant (Rojo, 2008), split into two applications. The first application occurred 8 days after transplantation (DAT) and the second 35 DAT for both municipalities.

Yield and quality

When the leaves had ripened, they were harvested and cured in barns heated by flues from coal furnaces. The cured leaves were then classified, taking into account parameters of physical quality such as leaf level (bottom-B, middle-M, superior-S, and Top-C), the degree of ripeness of the leaf, its color (lemon-L, orange -N, red-brown-RC, green-SG), health, body or thickness of the leaf lamina, size (length), elasticity, shine and aroma, which were then grouped into four grades (1-first, 2-second, 3-third and others) (Tab. 4); these parameters were evaluated from the Protabaco Company. Subsequently, the leaves were weighed having been grouped by quality: first (B1L + M1L + S1L), second (B2L + M2L + S2L), third (B3L + M3L) and others (all other remaining qualities); and, afterwards, the total yield for all of the grades were tallied. Since the production of the first grade quality was very low, the first and second grades were combined and analyzed as one.

Gross and net income

Gross income is the amount earned by calculating the yield (obtained per hectare) and the selling price for each grade according to leaf quality. Net income is the difference between gross income and the total of production costs per treatment. The sale price was determined according to the grades obtained for each treatment at the time of sale of the cured leaves and is given by company buyers. Protabaco Company handles up to five grades and, within each grade, there are different prices depending on class. The average percentage difference in prices between classes of the same quality varies as follows: 15% in the 1st grade, 38% in the 2nd and 3rd and 46% to 51% in the 4th grade. The 1st grade has eight classes, the 2nd has 11, the 3rd has 11, and the 4th and 5th have 7 classes (Plaza *et al.*, 2011a).

TABLE 4. International criteria of the classifier or buyer to assign grades to flue-cured tobacco leaves by Protabaco Company.

Grade*	Leaf level	Level of maturity	Color	% damage to the lamina	Uniformity	Size (cm)	Classification
B1L	Lower part of the plant	Ripe	Distinctively lemon	<5%	95% minimum	50 minimum	First
B2L	Lower part of the plant	Ripe	Distinctively lemon	<10%	90% minimum	40 minimum	Second
B3L	Lower part of the plant	Ripe	Distinctively lemon	<15%	85% minimum	30 minimum	Third
M1L	Middle part of the plant	Ripe	Distinctively lemon	<5%	95% minimum	50 minimum	First
M2L	Middle part of the plant	Ripe	Distinctively lemon	<10%	90% minimum	40 minimum	Second
M3L	Middle part of the plant	Ripe	Distinctively lemon	<15%	85% minimum	30 minimum	Third
BMG	Lower and middle part of the plant	Mixed	Lemon and dark orange	<15%	85% minimum	30 minimum	Other
BR	Lower and middle part of the plant	Ripe or slightly over-ripe	Dark	<25%	90% minimum	30 minimum	Other
S1L	Superior part of the plant	Ripe	Distinctively lemon	<5%	95% minimum	50 minimum	First
S2L	Superior part of the plant	Ripe	Distinctively lemon	<10%	90% minimum	40 minimum	Second
S3L	Superior part of the plant	Ripe	Distinctively lemon	<15%	85% minimum	30 minimum	Third
C2L	Crown leaves	Slightly ripe	Distinctively lemon	<10%	90% minimum	40 minimum	Second
C3L	Crown leaves	Slightly ripe	Distinctively lemon	<15%	85% minimum	30 minimum	Third
SR	Superior part of the plant	Ripe or slightly over-ripe	Dark	<25%	90% minimum	30 minimum	Other
K4	Leaves any level	Ripe or over-ripe	Dark orange	<30%	70% minimum	30 minimum	Other

*Only the description of the grades obtained in the development of this research were included.

Technical and economic analysis

The criteria taken into account when choosing the optimal dose and combination of fertilizers for flue-cured tobacco were: yield, fertilization cost, gross income, net income and sale quality characteristics. Similarly, an economic analysis was conducted with the cost-benefit ratio for all treatments, which resulted from dividing gross income by total production costs.

Fertilization costs were calculated from the commercial value of the fertilizer sources (Tab. 5), the doses used and the manual labor for the treatments evaluated in each of the studied municipalities. All other factors involved in the production cost structure remained constant in each of the study areas as they shared the same crop management.

TABLE 5. Commercial value of fertilizers for the year 2013.

Source	Value (US$)
17-9-18-3	37.6
13:3:43	67.5
21:11:7.5	24.6
AMS	21.4
Sulfato K	55.3
DAP	30.5

All fertilizer are sold in amounts of 50 kg.

Statistical analysis

An analysis of variance (ANOVA) was conducted with the SAS statistical software v. 8.1e (SAS Institute, Cary, NC) and, when significance was found, an LSD (least significant difference) mean comparison test was conducted with a reliability of 95%.

Results and discussion

Yield

The yield did not exhibit significant statistical differences for the factors evaluated ($P\leq0.05$). The better results in the municipality of Campoalegre were achieved without the use of ammonium sulphate (AMS) at the three application doses of b50, b100 and b150, which presented yields of 39, 32 and 33%, respectively, higher than the conventional treatment (Tab. 6). In Garzon, the treatments that reported the higher yields were achieved through the use of AMS at 100% of the dose (a100) (a dose 5% higher than the conventional treatment), at 100% of the dose without the use of AMS (b100) (a dose 6% higher than the conventional treatment) and the conventional treatment (the fertilization performed by the producers) (Tab. 6).

On the other hand, it can be appreciated that the municipality of Campoalegre showed a higher average yield of cured tobacco leaves (3,080 kg ha^{-1}) with regard to Garzon (2,640 kg ha^{-1}). These results coincide with those reported by Plaza *et al*. (2011a), who made a collection of yield and quality reports from raw material producers and suppliers for Protabaco in the municipalities of Campoalegre and Garzon from 2005 to 2008; finding that Campoalegre had an average yield of 2,545 kg ha^{-1}, 2.3% higher than the departmental average (2,486 kg ha^{-1}) and 6.2% higher than the Garzon average which showed a yield of 2,396 kg ha^{-1}, lower than the departmental average.

The reasons for the higher yield of Campoalegre include that this municipality has increased net photosynthesis, stomatal conductance and transpiration of the tobacco crop, because it has more solar radiation, a higher average temperature and lower relative humidity, as compared to Garzon (Hoyos, 2013). The growth and development of plants depends on various environmental variables, such as temperature, relative humidity, light intensity and availability of water and essential minerals (Azcón-Bieto *et al*., 2004; Hermans *et al*., 2006). These environmental factors also modify the photosynthetic capacity of the plants.

TABLE 6. Yields for the cultivation of flue-cured tobacco in Campoalegre and Garzon (Colombia).

Treatment	Yield (kg ha^{-1})	
	Campoalegre	Garzon
a50	2,714 a	2,665 a
a100	3,292 a	2,873 a
a150	2,687 a	2,585 a
b50	3,540 a	2,115 a
b100	3,371 a	2,914 a
b150	3,402 a	2,573 a
Control	2,556 a	2,749 a

a, utilization of AMS; b, no utilization of AMS. Means with different letters indicate significant differences according to the least significant difference (LSD) test ($P \leq 0.05$).

Purchase quality

Tables 7 and 8 show the production of cured leaves according to purchase quality for both municipalities studied. As for the grades that represented the highest production for each of the treatments, in Campoalegre, it was observed that the S2L grade (see characteristics in Tab. 4) showed the greatest production outcomes for the treatments with a dosage of 150% of the recommended dose (a150 and b150) with values of 26 and 33%, respectively. The S3L grade (Tab. 4) showed the highest percentages for the treatments with fertilization doses at 50% (a50 and b50), with the dose at 100% without using ammonium sulphate (b100) and with the conventional treatment with values of 45, 38, 44 and 29%, respectively (Tab. 7).

In Garzon, it was observed that the S2L grade (see characteristics in Tab. 4) showed the highest production values for the treatments with use of ammonium sulphate at 50% and 150% of the recommended dose (a50 and a150), with the dose at 100% without the use of AMS and with a 150% dose (b100 and b150) with values of 21, 37, and 31% respectively. The M3L grade (see characteristics in Tab. 4) showed the highest production outcome for the treatments without the use of AMS at 50% of the dose (b100) and the conventional treatment with values of 25 and 18%, respectively. Finally, M2L (see characteristics in Tab. 4) had the highest production results for the treatment at 100% of the recommended dose with AMS (a100) with an outcome of 22% (Tab. 8)

Technical and economic analysis

Considering yield, fertilization cost, gross income, net income and the production quality for sale, it was observed that, for the municipality of Campoalegre, the best results were achieved with the treatments: b50, b100 and b150, which corresponded to the recommended fertilization treatment with 17-9-18-3, 13:3:43 and 21:11:7.5 for the

TABLE 7. Cured leaf production (kg ha^{-1}) according to sale quality in Campoalegre.

Treatment	B1L	M1L	B2L	M2L	S2L	B3L	M3L	S3L	BR	K4	SR
a50	23		98		260	29	112	1208	251	273	460
a100			92	48	282	73	131	788	224	288	1365
a150		53		35	711	42	24	496	224	393	710
b50		62		146	373		32	1339	414	392	783
b100			50	270	110	57	131	1491	405	340	517
b150		16	76	48	1139		92	428	171	609	823
Control			70	48	680	13	31	733	155	228	596

a, utilization of AMS; b, no utilization of AMS. See abbreviations in Tab. 4.

TABLE 8. Cured leaf production (kg ha^{-1}) according to sale quality in Garzon.

Treatment	B1L	S1L	B2L	M2L	S2L	C2L	B3L	M3L	S3L	C3L	BGM	BR	K4	SR
a50		82		393	549			336	146			453	235	472
a100		80	20	631	605	68	21	159	65	22		437	161	603
a150					945	55	16	340	54			293	159	723
b50		83	42	244	221	15	39	535	142		10	288	271	225
b100		86		438	665			316	65	36		428	346	532
b150		181		72	793	73		227		18		435	151	624
Control	156	86	324	435	392		112	492		37		262	197	256

a, utilization of AMS; b, no utilization of AMS. See abbreviations in Tab. 4.

TABLE 9. Technical and economic results for the fertilization alternatives of the trials in Campoalegre.

Treatment	Yield (kg ha^{-1})	Fertilization costs (COL$ ha $^{-1}$)	Gross income (COL$)	Net income (COL$)	Purchase quality (%)			
					1st	2nd	3rd	Other
a50	2,714	1,738,214	12,968,685	1,255,597	0.8	13.2	49.7	36.3
a100	3,292	3,076,429	15,107,903	2,056,600	0	12.8	30.2	57.0
a150	2,687	4,414,643	12,894,922	1,494,595	2.0	27.8	20.9	49.4
b50	3,540	1,712,367	16,849,832	5,162,591	1.8	14.6	38.7	44.9
b100	3,371	3,024,735	16,059,435	3,059,826	0	12.8	49.8	37.4
b150	3,402	4,337,102	16,493,125	2,181,149	0.5	37.1	15.3	47.1
Control	2,556	1,717,802	12,581,965	889,289	0	31.2	30.4	38.3

a, utilization of AMS; b, no utilization of AMS, con: conventional

TABLE 10. Technical and economic results for the fertilization alternatives from the trials in Garzon.

Treatment	Yield (kg ha^{-1})	Fertilization costs (COL$ ha^{-1})	Gross income (COL$)	Net income (COL$)	Purchase quality (%)			
					1st	2nd	3rd	Other
a50	2,665	1,480,795	13,178,271	1,465,668	3.1	35.3	18.1	43.5
a100	2,873	2,661,590	14,476,347	1,582,949	2.8	46.1	9.3	41.8
a150	2,585	3,842,385	12,669,267	1,404,926	0.0	38.7	15.9	45.4
b50	2,115	1,449,492	10,236,369	1,444,931	3.9	24.7	33.8	37.6
b100	2,914	2,598,983	14,364,607	1,533,816	3.0	37.9	14.3	44.8
b150	2,573	3,748,475	12,810,088	1,170,195	7.0	36.4	9.5	47.0
Control	2,749	1,996,881	14,017,041	1,788,352	8.8	41.9	23.3	26.0

a, utilization of AMS; b, no utilization of AMS.

three application doses (50, 100 and 150%). Among the previous alternatives, b50 showed the highest yield, lowest fertilization cost, a high percentage of third quality leaves and the highest gross and net income; the alternative b100 showed a high yield, the highest percentage of third quality leaves, intermediate costs and income. The alternative b150 showed a high yield, the highest cost, the highest percentage of second quality leaves and an intermediate income. The other alternatives showed lower yield and income and greater variations in the sale quality (Tab. 9).

In Garzon, the treatments a100 and b100 and the control achieved the better results with individual differences in cost, yield and sale quality percentage. The a100 treatment, which corresponded to the application of 17-9-18-3, 13:3:43, AMS and 21:11:7.5 at 100% of the dose, showed a high yield, the highest cost, the highest percentage of second grade leaves, the highest gross income and an intermediate net income. The b100 treatment corresponded to the application of 17-9-18-3, 13:3:43 and 21:11:7.5 (100% of the dose); this alternative presented the highest yield, a high percentage of second grade leaves, and an intermediate cost and income. The control treatment, where fertilization was implemented by the tobacco producer, applying 17-9-18-3, 13:3:43, AMS and potassium sulphate, had a high yield, lower costs, a high percentage of second grade leaves, an intermediate gross income and the highest net income. The other alternatives had lower yields and showed income variations at the time of sale (Tab. 10).

The analysis of the cost-benefit ratio is useful as an economic criterion for producers as it allows them to estimate the income received for each monetary unit spent on fertilizer (Flórez *et al*., 1978; López, 1997). The cost-benefit ratio did not exhibit significant statistical differences for the evaluated factors ($P \leq 0.05$). The best treatment in financial terms is the one with the highest ratio of benefits to costs, which can be seen in Tab. 11. For the municipality of Campoalegre, the best treatment was without the application of ammonium sulphate, at 50% of the dose (b50), because for every monetary unit invested, a profit of 1.44 monetary

TABLE 11. Cost-benefit ratio for the fertilization alternatives in Campoalegre and Garzon.

Treatment	Cost/Benefit	
	Campoalegre	Garzon
a50	1.11	1.13
a100	1.16	1.12
a150	0.90	0.90
b50	1.44	0.88
b100	1.24	1.12
b150	1.15	0.92
Control	1.08	1.15

a, utilization of AMS; b, no utilization of AMS.

units was obtained. For Garzon, the best treatment was the control, because 1.15 monetary units were obtained per each unit invested.

Conclusions

The findings of this study show that the municipality of Campoalegre produced a better average yield of cured tobacco leaves (3,080 kg ha^{-1}) than Garzon (2,640 kg ha^{-1}). The higher percentages among the quality grades in production for the municipality of Campoalegre were in S2L, S3L and SR; for Garzon, they were in S2L, M3L and M2L. For the municipality of Campoalegre, the higher yields were obtained without the use of ammonium sulphate for the three application doses. For Garzon, the higher yields were obtained with the dose at 100%, with and without ammonium sulphate and simultaneously with the control (conventional treatment). The best cost-benefit ratio in the municipality of Campoalegre was obtained with the b50 treatment, in which there was no application of ammonium sulphate, at 50% of the dose. In Garzon, this was obtained with the control.

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