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Operational and logistics costs of nitrogen fertilization systems in sugarcane production in Tucumán, Argentina

Costos operacionales y logísticos de los sistemas de fertilización nitrogenada en la producción de caña de azúcar en Tucumán, Argentina

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RESUMEN

La fertilización nitrogenada en el cultivo de caña de azúcar es una práctica cultural de gran importancia dentro de una gestión orientada al logro de plantaciones de alto rendimiento. Su alto costo requiere un uso oportuno y efectivo de fertilizantes para lograr los máximos beneficios. El objetivo de este trabajo fue comparar los costos operativos de diferentes alternativas de aplicación de fertilizantes, dos tipos de fuentes de nitrógeno y encontrar la combinación más efectiva en términos de sostenibilidad económica y ambiental. Se determinaron parámetros productivos, operativos y económicos para dos fertilizadoras, una neumática de 9 surcos que aplica el fertilizante en superficie, y un fertilizador cultivador con la capacidad para aplicar 2 surcos simultáneamente en la superficie e incorporando el fertilizante al suelo. El costo con una fertilizadora neumática varió entre 12 USD/ha y 13 USD/ha, mientras que el fertilizador-cultivador fue entre 33 USD/ha y 59 USD/ha. En Tucumán el momento óptimo para realizar la fertilización comprende aproximadamente 40 día; con la fertilizadora neumática se podría llegar a fertilizar una mayor cantidad de surcos dentro del período oportuno (1.660 ha). Se concluye que la fertilizadora neumática requiere una inversión y un costo de aplicación de tres a cinco veces menor, también, menor consumo de combustible y tiempo operativo. Otro beneficio es la mayor eficiencia en la logística de carga y distribución del producto. La fertilizadora neumática es una alternativa interesante para fertilizar la caña de azúcar en el marco de la sostenibilidad, especialmente en grandes extensiones.

Palabras clave: fertilizadora neumática, fertilizante, sostenibilidad, tiempo operativo, logística.

ABSTRACT

Fertilization is a cultural practice of maximum importance in management to achieve a high-yield sugarcane crop. Its high cost requires timely and effective use of fertilizer to achieve maximum efficiency. The objective of this work was to compare the operating costs of different fertilizer application alternatives, two types of nitrogen sources and to find the most effective combination in terms of economic and environmental sustainability. Productive, operative and economic parameters were determined for two fertilizer applicator machines, a 9-furrow pneumatic machine that applied the fertilizer on the surface, and a cultivator and fertilizer applicator with the capacity to apply two furrows simultaneously both on the surface and incorporating the fertilizer into the soil. The cost of fertilizing with the pneumatic machine varied between 12 USD/ha and 13 USD/ha, while for the fertilization-cultivator machine it was between 33 USD/ha and 59 USD/ha. In Tucumán, the optimal time to fertilize is about 40 days; with the pneumatic applicator more rows could be fertilized during this period (1,660ha). In addition, the pneumatic fertilizer machine requires an investment and application cost 3-5 times lower, a lower fuel consumption, shorter operating time and greater efficiency in the logistics of loading and distribution of the product than the fertilizer cultivator machine. The pneumatic fertilizer machine is an important alternative to fertilize sugarcane within the framework of sustainability, especially in large areas.

Key words: Pneumatic fertilizer, fertilizer, sustainability, operating time, logistics.

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INTRODUCTION

In Argentina, sugarcane is grown on approximately 430,000 ha, distributed mainly in the region of northwest Argentina. The province of Tucumán represents approximately 63% of this area, followed by the provinces of Jujuy (23%) and Salta (14%).

Application of nitrogen (N) fertilizer is a fundamental requirement in on-farm management that is aimed at achieving fields with high-yielding cane (Romero et al. 2009).In Tucumán, average yield increases of 23 t/ha, ranging from 10 and 55 t/ha (according to soil type and cane age), have been recorded where adequate amounts of N are applied at the recommended time. This means an expectation of production increase of 10% to 40% above unfertilized plots (Leggio *et al.* 2018; Romero *et al.* 2009).

The optimum period for applying fertilizer in ratoon crops is from October to mid-November. The availability of soil N is important near, or after, crop closure. It is associated with increasing temperatures and rainfall and contributes markedly during the growth period (Romero *et al.* 2009).

Urea, the most widely used N fertilizer commercially, is subject to volatilization that reduces its efficiency and contributes to it becoming a contaminant (Romero *et al.* 2016). Such losses can be minimized when urea is incorporated into the soil and placed near the roots of the crops. However, this practice is costly, as the machinery needed for its incorporation requires use of high-powered tractors. In addition, the high cost of the operation means timely and effective execution is needed to ensure maximum utilization of the equipment (Romero *et al.* 2009).

It is important to find strategies to integrate greater efficiency of available technologies with maintenance or increases in yield, reduced costs and lower environmental impacts (Leggio *et al.* 2018). Surface-applied fertilizers that require lighter machinery are of fundamental importance to achieve sustainable management of sugarcane. Such is the case with calcium ammonium nitrate (CAN), a fertilizer that can be applied to the soil surface with low potential N volatilization losses. This fertilizer obviously provides two chemical forms of N, nitrate and ammonium, that are almost immediately availability for crop uptake and with apparent lower risk of losses. If CAN is applied on the surface the losses are 1.7%. In the case of urea, the losses can be from 30 to 40% of N in surface, according (INTA Pergamino).

The aim of our study was to compare the operating costs of different fertilizer application alternatives (a pneumatic multi-row fertilizer applicator and a mechanical fertilizer-cultivator) and two types of N sources (urea and CAN) and find the most effective combination in terms of economic and environmental sustainability.

MATERIAL AND METHODS

The investigation entailed three case studies (CS A, CS B and CS C) that included various machinery options and sources of N fertilizer.

Machinery

Two alternatives were available: a pneumatic applicator capable of fertilizing nine rows, and a mechanical fertilizer-cultivator with a capacity to apply fertilizer to two furrows simultaneously.

In CS A1 and CS A2, the fertilizer was surface-applied to nine rows with the pneumatic applicator. In CS B the fertilizer was simultaneously surface-applied to two rows with the mechanical fertilizer-cultivator. In CS C the mechanical fertilizer-cultivator incorporated the fertilizer into the soil.

Time and labor

The following assumptions were made: surface application using the pneumatic applicator: fertilizer applied to 42 ha per day (equivalent to 2500 furrow/day) with 10 hours of allocated labor(Case A1 and A2); surface application using the fertilizer-cultivator: fertilizer applied to 21 ha/day (equivalent to 1250 rows/day);if the fertilizer is incorporated into the soil, the unit can fertilize 14 ha or 833 rows per labor day; two fertilizer cultivator teams working simultaneously (two tractors with one implement each in CS B); and in CS C, three tractors were used with one implement each).This information was provided by farmers, researchers and service providers, who were considered qualified informants of these data.

Fertilizer

Nitrogen was in the form of CAN in CS A and CS B sourced from 1000 kg bags and 50 kg bags, respectively. In CS C bags of 50 kg of urea were used. In Case A1 it was necessary to add a crane-plume for the handling of the bags.

Costs

To determine the operating cost of the work with each implement, the analysis was carried out in two stages, one for loading the fertilizer into the equipment and the other for applying the fertilizer. Operating costs per hectare for the different case studies were determined by the methodology described by Pérez *et al.* (2009): fuel costs (USD/ha) = Oil price (USD/L) x 0.16 (L/h/HP (coefficient of fuel hourly expense x tractor power (HP); repairs and maintenance costs (USD/ha) = Purchase price (VN) x operating time (h/ha) x coefficient of repairs and maintenance of machinery (CGR) (Frank coefficient); and labor cost (USD/ha) = (tractor driver wage (USD)/10 h) x operating time (h/ha).

Capital investment

In order to determine the investment required in each case, the following items of machinery/implements were taken into account for the different case studies – CS A (pneumatic machine): one 92 HP tractor, the pneumatic fertilizer machine and a crane-plume; CS B (fertilizer and cultivator on surface): two 120 HP tractors and two fertilizers applicators; and CS C (fertilizer and cultivator for deep-row cultivation): three 163 HP tractors and three fertilizers applicators. In all cases, a tractor was added to transport the fertilizer to the implement. The costs are shown in Table 1.

Operational costs

Operating costs for all cases include fuel cost, repairs and maintenance costs (CGR), depreciation and labor cost are shown in Table 2.

Loading and logistics of the fertilizer to the implement

Tables 3 and 4 show the parameters that were used to determine the cost of loading and transport fertilizer to the implement.

Amortization

The amortization of the machinery and implements represented compensation for the loss of value of the goods. This loss can occur due to the passage of time (obsolescence), or due to wear and tear when the use of the machinery exceeds the annual hours of use established by the manufacturer. In this analysis the loss of value due to attrition of each case was considered as:

Amortization (USD/hours) = [Purchase price (USD) - Residual value (USD)] / hours of use.

The residual value was calculated as 30% of the purchase price of the tractor (Table 5).

Table 1. Investment required (USD).

Machinery	Quantity	Case studies		
		CS A	CS B	CS C
Tractor (92 HP)	1	62,200		
Tractor (120 HP)	2		226,200	
Tractor (163 HP)	3			414,300
Pneumatic machine	1	17,411		
Fertilizer and cultivator	2(B), 3(C)		30,898	46,347
Crane –plume	1	3862		
Tractor for transport (85 HP)	1	55,218	55,218	55,218
Total (USD)		**138,691**	**312,316**	**515,865**

Note: Purchase price of the machinery expressed in USD, excluding value added tax (VAT), average July-August 2018.

Table 2. Cost of application: operating time, fuel consumption, purchase price of machinery, theoretical repairs and maintenance coefficients (CGR), value of labor.

Case study	Operating time (h/ha)	Oil consumption (L/h)	Purchase price tractors (USD)	CGR tractors	Purchase price fertilizer machine (USD)	CGR fertilizer applicators	Number of tractor operators	Cost of tractor operator (USD/h)*
CS A1 and A2	0.24	1.47	62,200	0.00007	17,411	0.00002	1	2.18
CS B	0.24	3.84	226,200	0.00007	30,899	0.00002	2	4.36
CS C	0.24	7.82	414,300	0.00007	46,348	0.00002	3	6.54

Note: *Law 26,727. Minimum remuneration and without supplementary annual salary (SAC), July 2018.

Table 3. Cost of loading and logistics: operating times, purchase price of machinery and theoretical coefficient of conservation and maintenance.

Case study	Number of tractor operators	Number of operators	Operating time (h/day)	Purchase price tractors (USD)	CGR Tractors	Purchase price crane-plume (USD)	CCR crane-plume
CS A1	1	1	0.25	55,218	0.00007	3862	0.00002
CS A2	1	1	10	55,218	0.00007	-	-
CS B	1	1	8	55,218	0.00007	-	-
CS C	1	1	8	55,218	0.00007	-	-

Table 4. Parameters for the calculation of fertilizer logistics according to package and machinery used.

em	Fertilizer-cultivator	Pneumatic applicator	
Number of rows/day	2500		
Nitrogen source	Urea / CAN	CAN	
Fertilizer package (kg)	50	50	1,000
Fertilizer hopper (kg)	600	3,000	
Quantity of fertilizer (kg/day)	9,600	10,000	
Number of operators	2	2	
Operating time logistic labour (h/day)	8	10	0.25
Other implements	Tractor 85 HP and trailer	Tractor 85 HP, trailer and crane	
Operating time fertilizer loading (h/ha)	0.08	0.08	

Table 5. Amortization of the machinery required per hectare (USD/ha).

Case study	Amortization (USD/ha)		
	Applicators	Loading and transport machinery	Total
CS A1	5.66	0.29	5.95
CS A2	5.66	0.26	5.92
CS B	17.52	0.26	17.78
CS C	30.66	0.26	30.91

RESULTS AND DISCUSSION

The application costs to apply the fertilizer with the two types of implements are provided on Table 6 and the cost of loading and transport according to the fertilizer application practices are shown in Table 7.

The costs per hectare calculated to fertilize the sugarcane crop with different alternatives (machinery and presentation of the fertilizer) are given in Table 8. This does not include the cost of the fertilizer used. The average price of N in 2018 was 482 USD/t for urea and 490 USD/t for CAN.

Table 9 shows the fuel expense (energy) required to fertilize 42 ha with a pneumatic machine and a mechanical fertilizer-cultivator (applying on the surface or incorporating the soil). This shows energy and economic savings in the use of a pneumatic fertilizer applicator compared to a fertilizer-cultivator.

The recommended timing for application of fertilizer in Tucumán is between October 15 and November 30 (Romero *et al.* 2009). However, due to the climatic conditions in Tucumán, the optimum time to apply fertilizer to sugarcane in Tucumán is reduced to 40 days. During this 1,667 ha can be fertilized with a single pneumatic fertilizer applicator. However, operating time has been reduced since this practice was introduced, with some companies reporting rates of 67 ha/day). In this way, 2,666 ha were fertilized using the pneumatic applicator during the 40-day period. In that same period, the fertilizer- cultivator was able to surface-apply fertilizer to 833 ha and incorporate fertilizer to 555 ha.

Table 6. Application cost (USD/ha) to fertilize with two types of machinery.

Case study	Application costs (USD/ha)				
	Fuel	Repairs and maintenance	Amortization	Labour	Total application cost
CS A1	3.06	1.13	5.66	0.65	10.50
CS A2	3.06	1.13	5.66	0.65	10.50
CS B	7.98	3.95	17.52	1.31	30.75
CS C	16.25	7.18	30.66	1.96	56.05

Table 7. Cost of loading and transport (USD/ha) of fertilizer according to the fertilizer application practice.

Case study	Fertilizer bags (kg)	Costs of loading and handling (USD/ha)				
		Fuel	Repairs and maintenance	Amortization	Labour	Cost of loading and logistics
CS A1	1000	0.94	0.32	0.29	0.03	1.58
CS A2	50	0.94	0.31	0.26	1.24	2.75
CS B	50	0.94	0.31	0.26	1.03	2.54
CS C	50	0.94	0.31	0.26	1.03	2.54

Table 8. Application and logistics cost (machinery+labour) (USD/ha) for applying fertilizer.

Case study	Fertilizer bags (kg)	Application and logistics (USD/ha)				
		Application		Loading and transport		Total
		Machinery	Labour	Machinery	Labour	
CS A1	1000	9.85	0.65	1.55	0.03	12
CS A2	50	9.85	0.65	1.51	1.24	13
CS B	50	29.45	1.31	1.51	1.03	33
CS C	50	54.09	1.96	1.51	1.03	59

Table 9. Expense in liters of fuel for a pneumatic fertilizer applicator and a fertilizer-cultivator.

Case study	Fuel	
	Quantity of diesel (L)	USD
CS A	193	167
CS B	429	372
CS C	828	716

CONCLUSIONS

Our economic analysis indicated that the use of the pneumatic applicator provided an investment and energy three to five times lower with the pneumatic applicator than that of the fertilizer- cultivator. In addition, the use of less powerful equipment has other benefits, such as the lower environmental impacts on soil compaction and greenhouse gas emissions.

The use of a pneumatic fertilizer machinery with bags of 1000 kg resulted in a lower cost and was the most efficient alternative. Improving the handling and logistics of the product presented the lowest total expenditure, energy consumption and operating time.

In addition, with a single pneumatic fertilizer machine approximately 1660 ha can be fertilized within the time available for fertilization (40 days), while with only one fertilizer-cultivator, only 550 ha can be fertilized.

The pneumatic fertilizer machinery continues to be evaluated to improve its efficiency.

As each situation is specific to a particular set of circumstances, the outputs of the tool will depend on the variables provided and analyzed. The tool will allow fertilizer and machinery to be used more efficiently to optimize crop yield and quality whilst avoiding over-fertilization and, therefore protecting the environment. It will enable improved decision-making on methods of applying fertilizer for each field.

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