OPEN ACCESS

ORIGINAL ARTICLE

Revista Ciencias Técnicas Agropecuarias 35
January-December 2026
ISSN 1010-2760, eISSN 2071-0054
Cu-ID: https://cu-id.com/2177/v35e04

Modification of a granular chemical fertilizer spreader for the application of organo-mineral fertilizers

Modificación de una fertilizadora de abonos químicos granulados para la aplicación de fertilizantes órgano-minerales

Elvis López Bravo[1*], Omar González Cueto[1], Maykel Cruz Díaz[1], Pedro Paneque Rondón[2] and Miguel Herrera Suárez[3]

[1] *Universidad Central "Marta Abreu" de las Villas, Facultad de Ciencias Agrícolas, Departamento de Ingeniería Agrícola, Villa Clara, Cuba. E-mail: omar@uclv.edu.cu, maykelcd@uclv.edu.cu*
[2] *Universidad Agraria de La Habana, UNAH. Centro de Mecanización Agropecuaria (CEMA), San José de las Lajas, Mayabeque, Cuba, E-mail: paneque@unah.edu.cu*
[3] *Universidad Técnica de Manabí Facultad de Ingeniería Mecánica, Portoviejo, Manabí, Ecuador. E-mail: miguelhs2000@yahoo.com*

[*] Author for correspondence: Elvis López Bravo, e-mail: elvislb@uclv.edu.cu

ABSTRACT: The use of organo-mineral fertilizers in sugarcane cultivation is primarily limited by the high application rates required due to the low delivery capacity of chemical fertilizer spreaders. This study aims to modify the dosing system of TATU fertilizer spreaders to achieve the appropriate application rates of 2 and 4 t/ha of Nerea and Agromena fertilizers. To this end, a study of the spreader's components and general characteristics, the dosing system, and the hopper capacity was conducted. The main results included the determination of the transmission system's kinematic chain and the calculation of the gears and their position within the chain. The hopper capacity was increased to meet the machine's field capacity, and the calculation of the screw conveyor was automated. It was concluded that by swapping the drive and driven wheels of the hydraulic motor and increasing the transmission ratio, it is possible to obtain the appropriate fertilizer application rates. Similarly, the hopper capacity must be increased to 1.1 m³ to ensure adequate field capacity.
Keywords: Fertilizer, Conveyor, Soil, Dosage.

RESUMEN: El empleo de fertilizantes órgano-minerales en el cultivo de la caña de azúcar tiene como principal limitante las altas normas necesarias para aplicar al suelo, debido a la baja capacidad de entrega de las máquinas para fertilizantes químicos. El presente trabajo tiene como objetivo modificar el sistema de dosificación de las fertilizadoras TATU para lograr la dosificación adecuada de 2 y 4 t/ha de los fertilizantes de Nerea y Agromena. Para ello se realizó un estudio de sus partes y características generales, el sistema dosificador y la capacidad de la tolva. Como principales resultados se obtuvo la cadena cinemática del sistema de transmisión y se realizó el cálculo de las ruedas dentadas y su posición en la cadena cinemática. Se realizó el aumento de las dimensiones de la capacidad de la tolva para satisfacer la capacidad de campo de la máquina y se automatizó el cálculo del transportador sinfín. Se llegó a la conclusión de que con el intercambio de las ruedas conductora y conducida del hidromotor y el aumento de la relación de transmisión es posible obtener las dosis adecuadas de fertilizante. De igual modo debe aumentar la capacidad de la tolva a 1,1m³ para garantizar la capacidad de campo de la misma.
Palabras clave: propiedades del suelo, órgano-mineral, transportador sinfín, sistema de dosificación., maquinaria agrícola, caña de azúcar.

INTRODUCTION

Fertilizing sugarcane with organic and mineral fertilizers contributes to improving soil properties and increasing crop yields. Organic fertilizers promote natural fertility and soil health, while mineral fertilizers meet the crop's immediate and specific nutritional needs. Their use ensures long-term production sustainability by creating an environment conducive to optimal nutrient uptake by the roots. This approach also contributes to improved soil aggregate structure stability, increased water and gas permeability, and enhanced water retention capacity. Formulating these fertilizers from local raw materials and byproducts of various industrial processes allows for reduced production costs, the activation of local supply chains, and improved access for producers (Ortiz, 2019; García-Ramos et al., 2022; Wang *et al.*, 2025).

Received: 20/08/2025
Accepted: 30/01/2026
Conflict of interests: The authors of this work declare no conflict of interests.
Author Contributions: Conceptualization, Methodology: Elvis López Bravo. **Data curation, Writing, original draft:** Elvis López Bravo, Omar González Cueto. **Formal analysis:** Elvis López Bravo, Maykel Cruz Díaz. **Investigation:** Elvis López Bravo, Maykel Cruz Díaz, Omar González Cueto. **Supervision, Validation:** Elvis López Bravo, Omar González Cueto, Pedro Paneque Rondón, Miguel Herrera Suárez. Suárez. **Writing, review & editing:** Elvis López Bravo, Pedro Paneque Rondón, Miguel Herrera Suárez.
The mention of trademarks of specific equipment, instruments or materials is for identification purposes, there being no promotional commitment in relation to them, neither by the authors nor by the publisher.

Fertilizer spreaders are machines designed for the accurate distribution of fertilizer to crops. The quality of their work depends on technical aspects such as precise dosing and uniform distribution. However, many of these machines have limitations in terms of efficiency and accuracy. This situation highlights the need to develop and evaluate new technologies that optimize both fertilizer use and the sustainability of agricultural systems (Sánchez y González, 2018; Ortiz, 2019; Chen *et al.*, 2023).

To increase sugarcane yields, it is necessary to adopt technologies that enhance soil productivity, optimize resource use, and introduce precision mechanisms at every stage of the agricultural process. In this regard, innovation in agricultural machinery plays a crucial role, representing one of the most effective ways to achieve more efficient and profitable agriculture (Palacios *et al.*, 2011; Torres-Sandoval et al., 2023).

The use of organo-mineral fertilizers such as Nerea and Agromena has been studied to achieve their efficient incorporation into the soil using fertilizer spreaders (González-Cueto *et al.*, 2025a; González-Cueto *et al.*, 2025b). These fertilizers have gained particular importance due to their agronomic benefits, as they combine organic and inorganic components, achieving the gradual release of nutrients and improving the soil's biological properties. However, their efficient application requires equipment with technical characteristics that guarantee a high delivery rate, which is not possible with fertilizer spreaders designed for chemical fertilizers. This study aims to modify the fertilizer delivery system parameters of the TATU-M spreader, based on the need for its use in applying Agromena and Nerea fertilizers.

MATERIALS AND METHODS

To characterize the TATU-M fertilizer spreader, the machine belonging to the "George Washington" Agro-Sugar Company in the municipality of Santo Domingo was used (Figure 1). The dimensions of each of its components were measured using a ruler, measuring tape, and vernier caliper. During the process, the hoppers, gearbox guards, working parts, and outlet pipes were disassembled.

To determine the transmission ratio at each speed step, the kinematic chain from the hydraulic motor to the conveyor was analyzed. This involved counting the teeth of each gear in the gearbox and developing the kinematic equation based on the general formulation:

$$i = \frac{Z\ driving}{Z\ driven} \qquad (1)$$

Where:
Z driving: Number of teeth of the driving wheel;
Z driven: Number of teeth of the driven wheel.

The calculation of the hopper capacity to meet the delivery was carried out under the criterion of maintaining the relationship between the fertilizer delivery and the volume of the hopper, thus guaranteeing the original design parameters of the machine, for which the methodologies for the design and evaluation of fertilizer machines were used (Cañavate *et al.*, 1989; FAO, 1994). Measurements were taken of the existing hopper and its relative position with respect to the other components. The following equation was used to calculate the forward speed:

$$v = \frac{600 \cdot Q}{D \cdot B} \qquad (2)$$

Where:
v: forward speed (km/h);
Q: fertilizer spreader delivery rate (kg/min);
D: delivery rate (kg/ha);
B: working width (m).

The field capacity of the fertilizer spreaders was determined at the forward speed at which they apply the standard delivery rate, considering a field efficiency of 70%, using the following equation:

$$Wh = 0{,}1 \cdot v \cdot B \cdot 0{,}7 = 0{,}07v \cdot B \qquad (3)$$

Where:
Wh: field capacity (ha/h);
v: forward speed (km/h);
B: working width (m).

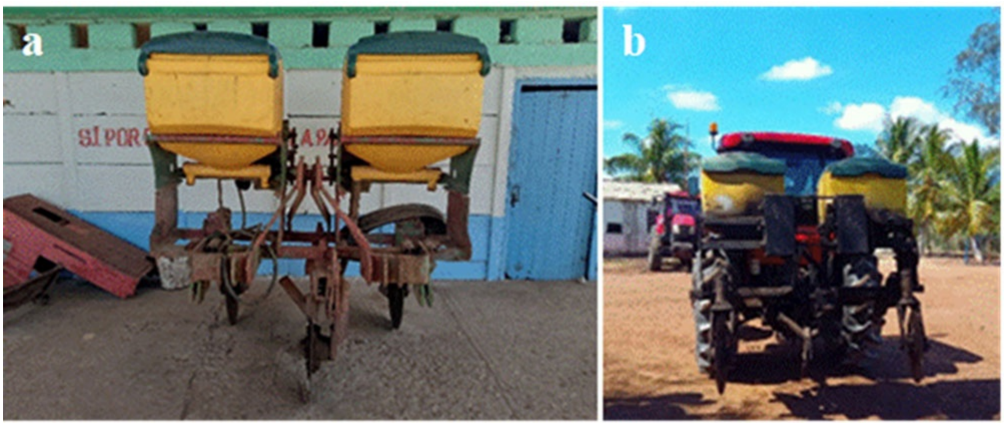

Figure 1. TATU-M Fertilizer (a), Tractor Mounting (b).

RESULTS AND DISCUSSION

Characterization of the TATU-M Fertilizer Spreader

The TATU-M fertilizer spreader (Figure 1a) is a modified version of the original Brazilian-made DCA-1200 fertilizer spreader, manufactured by TATA Marchesan S.A., which was mounted on the frame of the F-350 fertilizer machine. It is used for applying NPK fertilizer to sugarcane crops. The machine transports the fertilizer from the hopper to the bottom of the furrow using an auger conveyor system. The delivery rate is adjusted by changing the conveyor speed. The fertilizer is incorporated into the soil by a chisel plow buried at a depth of 15 cm. The MTZ-80 tractor (Figure 1b) provides the traction. Despite their technological and design differences, the performance of this machine is comparable to the ID-David fertilizer spreader used for foliar applications on various crops. (González-Cueto et al., 2023). Table 1 shows the different construction parameters of the machine, resulting from the measurements taken.

Table 1. TATU-M Parameters

Parameter	Value
Hopper volume	0,35 m^3
Number of hoppers	2
Working parts	2
Straw cutting discs	2
Working width	Furrows between 60 and 2.10 m
Fertilization method	Bottom of furrow
Hitch	Three-point hitch
Drive system	Hydraulic system
Length	1,30 m
Width	2,11 m
Height	1,30 m
Weight	380 kg
Power required	30 cv

The different components of the screw conveyor speed switching system that ensure the variation of the delivery standard are shown in Figure 2. The transmission between the hydraulic motor shaft and the input to the gearbox (Figure 2b) is achieved by 25.4 mm double-pitch chains with sprockets Z1=10 and Z2=18, resulting in a reduction gear ratio of i = 0.55. For the hydraulic motor's nominal speed of 500 min^{-1}, 275 min^{-1} is obtained at the gearbox input. Finally, the rotational motion of the screw conveyor (Figure 2c) is delivered by chain sprockets with a slight reduction of i = 0.94.

The kinematic chain (Figure 3a) shows the transmission scheme of the hydraulic motor's rotational motion to the screw conveyor. The hydraulic motor's output shaft connects to the gearbox, which switches the screw conveyor's rotational speed. Using the kinematic equation (Figure 3b), it is possible to calculate different chain wheel combinations based on the fertilizer delivery demand.

Table 2 shows the gearbox output speeds for each wheel combination, which are changed by a cantilever wheel selector mechanism. Of the seven speeds, three function as reduction gears, three as multiplication gears, and one is neutral or direct drive.

Dosing System Modification

With the maximum auger speed of 481.2 min^{-1}selected, a delivery rate of 19.3 kg/min of Agromena and 13.9 kg/min of Nerea was achieved, according to measurements taken under static conditions. However, the delivery rates for Agromena and Nerea fertilizers are 74.6 and 37.3 kg/min, respectively, to meet the application rates of 4 t/ha and 2 t/ha.

The modifications to increase the fertilizer delivery rate are based on increasing the auger speed according to the application rate for each fertilizer (Table 3). With this objective, the first modification to the input min^{-1} of gearbox M-1 is carried out, which consists of swapping the gears, resulting in Z1=18 and Z2=10, thus achieving a multiplication ratio of i = 1.8 and an input rotation speed of 900 min^{-1}, which increases the maximum speed to 1575 min^{-1}. As can be seen in Table 3, the desired delivery rate for Nerea fertilizer is achieved for gear change number six; however, the delivery rate for Agromena is not met at any speed setting.

Figure 2. Hydromotor (a), Gearbox (b) and transmission to the screw conveyor (c).

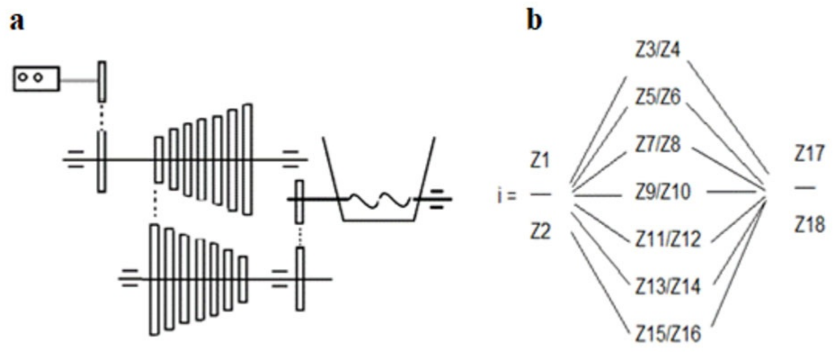

Figure 3. Kinematic chain (a) and kinematic equation (b).

Table 2. Gearbox speed steps

	1ra	2da	3ra	4ta	5ta	6ta	7ma
Driving, Z	16	18	20	22	24	26	28
Driven, Z	28	26	24	22	20	18	16
Gear ratio, i	0.57	0.69	0.83	1	1.2	1.4	1.75
Output min^{-1}	156.7	189.7	228.2	275	330	385	481.2

Table 3. Modification of the transmission ratio

	Fertilizer (kg/min)	1ra	2da	3ra	4ta	5ta	6ta	7ma
Actual	Agromena	6.32	7.66	9.22	11.07	13.28	15.99	19.37
	Nerea	4.56	5.53	6.65	7.98	9.58	11.53	13.97
M-1	Agromena	20.50	24.83	29.89	35.87	43.05	51.82	62.78
	Nerea	14.78	17.91	21.56	25.87	31.05	37.37	45.28
M-2	Agromena	29.60	35.86	43.17	51.80	62.16	74.82	90.65
	Nerea	21.35	25.86	31.13	37.36	44.83	53.96	65.38

To increase the output revolutions that meet the requirements for both fertilizers, a further modification of the M-2 transmission ratio is made, aimed at increasing the Rotation Frequency (min^{-1}) at the gearbox input. This is achieved by recalculating the transmission using the kinematic equation, increasing the number of teeth on the drive gear until the values that satisfy the delivery standards for both fertilizers are obtained. This is achieved with Z1 = 26 and Z2 = 10 and a transmission ratio of i = 2.6. The fertilizer delivery results for M-2 are shown in Table 3. The sixth speed step delivers the standard for Agromena, and the fourth step delivers the standard for Nerea with adequate accuracy. This also ensures the possibility of increasing or decreasing the delivered fertilizer volume in both cases using the remaining speed steps, thus meeting the demands of this type of fertilizer according to results from various authors (González-Cueto *et al.*, 2025b; Hamed *et al.*, 2025).

Determining Hopper Capacity

Figure 4 shows the original design of the TATU fertilizer spreader's hopper. Each hopper has a loading volume of 0.35 m^3. As a result of the increased delivery rate, fertilizer availability decreases, consequently requiring more frequent refills during application. The hopper capacity is calculated to meet the delivery rate based on maintaining the relationship between delivery rate and hopper volume, thus ensuring the machine's original design parameters, as recommended by authors (Cañavate et al., 1989; Ortiz, 2019).

With the current hopper dimensions, up to 350 kg can be loaded to apply fertilizer with an average density of 1 kg/cm^3. Therefore, with the current maximum standard rate of 18 kg/min, the hopper unloading time is 19.4 min. Maintaining an application speed of 7 km/h, a distance of 2250.4 m is covered, representing 22.5 rows in typical 1-hectare fields with a 1.60 m bed spacing. Each hopper fertilizes an area of 0.36 ha, for a total of 0.72 ha per machine.

With the delivery rate increased to 74.6 kg/min for Agromena fertilizer, which also has a density of 1.3 kg/cm^3, the hopper can be filled with only 270 kg, which is unloaded in 3.6 min. Achieving a travel distance of 417.6 m, this represents a total area of 0.14 ha. This working capacity affects the machine's main operating parameters, increasing preparation, transport, loading, and field time.

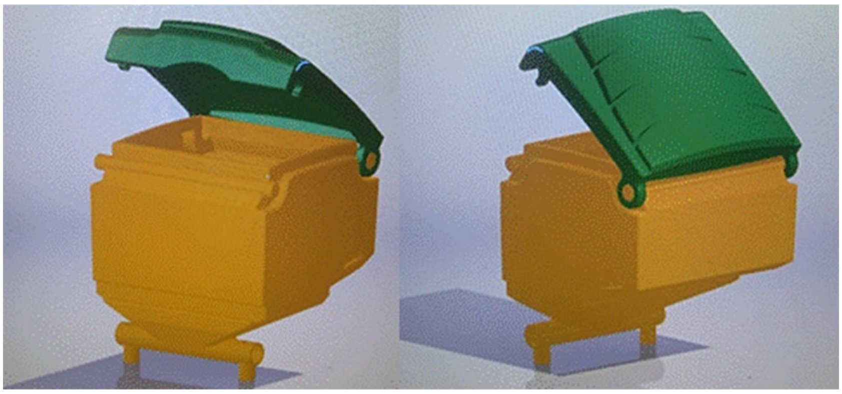

Figure 4. TATU-M fertilizer spreader hopper.

To achieve operational indicators consistent with the machine's original parameters, it is proposed to increase the hopper's load capacity while maintaining a 20-minute unloading time. This represents loading the hopper with 1.5 tons, which implies increasing its volume to 1.1 m³.

However, as a consequence of increasing the total volume to 3 tons, the power required for operation and the pressure exerted on the tractor's rear axle will increase. Similarly, it would be necessary to evaluate the performance of the auger conveyor and the capacity of the chutes to deposit the volume onto the soil, considering an increase in the outlet flow rate, which could increase the pressure inside the chutes.

CONCLUSIONS

The chain wheel exchange dosing mechanism in the TATU-M fertilizer has a transmission ratio between 0.57 and 1.75, which is insufficient to deliver the necessary dose of organo-mineral fertilizers Nerea and Agromena.

The appropriate dosage to apply the delivery standards of Nerea or Agromena fertilizers is achieved by modifying the number of teeth on the hydromotor wheel and their exchange with that of the input shaft of the speed box.

The increase in the loading capacity of the hopper from 0.35 m³ to 1.1 m³ enables adequate field capacity of the machine and maintenance of its operating parameters.

ACKNOWLEDGMENTS

The research presented in this publication was funded by the Office of International Funds Projects Management of the Ministry of Science, Technology and Environment of the Republic of Cuba under code PN3602LH002-087.

REFERENCES

CAÑAVATE, J. O.; MARTOS, J. L. H.; ALTISENT, M. R.: *Las máquinas agrícolas y su aplicación,* 488pp., Mundi-Prensa, ISBN: 9788-4711-40852, 1989.

CHEN, J.; YANG, J.; LI, X.; WANG, C.; ZHAO, L.; ZHANG, P.;.C. LI: "The Effects of Biochar-Based Organic Fertilizer and Mineral Fertilizer on Soil Quality, Beet Yield, and Sugar Yield", *Agronomy*, vol. 13 (9), 2023. ISSN: 2073-4395.

FAO: *Principios y Prácticas de Prueba Y Evaluación de Máquinas Y Equipos Agrícolas (Boletines de Servicios Agrícolas de la FAO),* 279pp., Food and Agriculture Organization of the United Nations, ISBN: 9789-2530-34581, 1994.

GARCÍA-RAMOS, C. M.; QUIRÓS-ROQUE, V. A.; ROSALES-MENDOZA, L. E.: "Los residuos generados en la producción de la industria azucarera en los últimos 25 años", *Revista iberoamericana de bioeconomía y cambio climático*, vol. 8 (16): 79-91, 2022. ISSN: 2410-7980.

GONZÁLEZ-CUETO, O.; GARCÍA-VALERA, M.; LÓPEZ-BRAVO, E.; AGUILA-ALCANTARA, E.; PINEDA-RUIZ, E.; ÁLVAREZ-HERNÁNDEZ, U.: "Physical properties of AGROMENAS-G and NEREA fertilizers produced at the Empresa Geominera del Centro", *Revista Ciencias Técnicas Agropecuarias*, vol. 34, 2025a. ISSN: 2071-0054.

GONZÁLEZ-CUETO, O.; HERNÁNDEZ-SOLARES, A.; LÓPEZ-BRAVO, E.; GONZÁLEZ-NUÑEZ, J. C.; GATO-MARTÍNEZ, I.; CRUZ-DIAZ, M.; GARCÍA-PEDRAZA, L.: "Calibration of fertilizers for application of AGROMENAS-G and NEREA to sugarcane", *Revista Ciencias Técnicas Agropecuarias*, vol. 34, 2025b. ISSN: 2071-0054.

GONZÁLEZ-CUETO, O.; SALCERIO-SALABERRY, R. A.; SORIANO-ALONSO, E. Y.; MERLÁN-MESA, G.; LÓPEZ-BRAVO, E.; HERRERA-SUÁREZ, M.: "Caracterización de la fertilizadora ID-David para la aplicación mecanizada del abono órgano mineral Agromena-G", *Revista Ciencias Técnicas Agropecuarias*, vol. 32 (1), 2023. ISSN: 2071-0074.

HAMED, L.; ELGEZERY, M.; ABOU HUSSIEN, E.; FAIYAD, M. N.; EMARA, E.; ABDEL-HAKIM, S.: "Role of nano-mineral fertilizers in sugar beet growth and environmental sustainability in sandy soils", *Pedosphere*, vol., 2025. ISSN: 1002-0160.

ORTIZ, R.: *Fertilización Sostenible en Cañaverales Cubanos,* Editorial Agroecológica, ISBN: 2019.

PALACIOS, O.; MEJÍA, E.; SÁNCHEZ, H.: "La frescura de la caña de azucar", *Agrociencia*, vol. 45 (17), 2011. ISSN: 2521-9766.

SÁNCHEZ, J. L.; GONZÁLEZ, R.: *Tecnología de Aplicación de Fertilizantes en Agricultura,* Ediciones Agro-Técnicas, ISBN: 2018.

TORRES-SANDOVAL, J.; ROMANTCHIK-KRIUCHKOVA, E.; LÓPEZ-CRUZ, I. L.; LÓPEZ CANTEÑS, G. D. J.: "Sistema mecatrónico para controlar el dosificador de semilla y presión de vacío de una sembradora-fertilizadora", *Revista fitotecnia mexicana*, vol. 46 (4): 439-449, 2023. ISSN: 0187-7380.

WANG, J.; LUO, Z.; LI, J.; LI, J.; XU, M.: "Fertilization decreases microbial CUE via enhancing soil properties and microbial respiration in coal mine reclamation area", *Applied Soil Ecology*, vol. 211: 106145, 2025. ISSN: 0929-1393.