BIOMETRY, MODELLING AND STATISTIC

Modeling and simulation of liquid fertilizer devices for nitrogen top dressing in maize fields

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ABSTRACT. Nitrogen top dressing is essential to supplement maize needs in crop fields. In Brazilian agriculture, a spreader is the most popular equipment used to apply nitrogen fertilizer to growing maize. However, spreaders present at least three problems: non-uniform fertilizer placement, granular fertilizer placement on the top of maize leaves, and granular fertilizer scattering without a precise target. As an alternative, liquid nitrogen fertilizer applied in side bands of maize rows can improve nutrient placement and dosage precision. The objective was to design a liquid fertilizer application device for assembly on a boom sprayer. For this, a programming model was simulated in Matlab. The liquid fertilizer source, fertilizer rate, maize row width, and boom sprayer speed were considered as input parameters. The simulation assisted in the design of the liquid fertilizer device. The device was constructed and evaluated on a laboratory bench. As a result, pressure, nozzle outlet flow, and forward speed were compatible with a self-propelled sprayer. The proposed process showed the potential to improve the outlet flow quality (coefficient of variation less than 10%). In addition, the liquid fertilizer device was considered simple to assemble in the sprayer's boom. These characteristics could represent some attractive aspects for the farmers.

Keywords: agricultural machinery; boom sprayer; liquid fertilizer nozzle; nutrient placement method.

Introduction

Brazil is the third largest maize producer in the world (104 million Mg in 2020), accounting for approximately 7.3% of global production (Food and Agriculture Organization of the United Nations [FAO], 2022). The Brazilian maize area expanded from 12.6 to 18.2 million hectares in the last ten years (2010 to 2020), an increase of 44% FAO (2022). In the same period, the FAO (statistics division) registered an expansion of production quantity (90%) and yield (30%) in Brazil. Maize expansion in Brazilian fields is mainly explained by the spread of "the second crop", a growing agricultural practice during the fall and winter seasons (Mattos & Franco da Silveira, 2018). In this model, maize fields are usually introduced after the soybean harvest, which is considered as "the first crop" and cultivated in the spring and summer seasons. The production and yield increase are also related to technological improvements, such as new hybrid varieties, no-tillage production, precision planting, and soil fertility management. Nevertheless, maize yield is lower in Brazil (5.6 Mg ha^{-1}) than in the other two significant producing countries, the United States (10.8 Mg ha^{-1}) and China (6.3 Mg ha^{-1}), according to the FAO (2022).

Nitrogen fertilizers can contribute to yield growth in an intensive farming model. The fertilizers in agriculture can supplement natural soil nutrient availability, supplying crop needs, especially for high yield potential (e.g., maize varieties). Additionally, fertilizer application compensates for nutrient losses to the environment. In maize, nitrogen top dressing is performed during initial growth, when there are 4–8 fully expanded leaves (Panison et al., 2019). In Brazil, nitrogen top dressing is usually carried out using a spreader (self-propelled, trailed, or mounted) for granular fertilizers.

The broadcast method places nitrogen fertilizer on the soil surface, which may be associated with nitrogen losses, such as surface runoff and ammonia volatilization (NH$_3$ emission), especially for urea (Santos et al., 2020), the most common nitrogen source in Brazilian agriculture (60%). In addition, some fertilizer granules can fall on top of the plant canopy, causing punctual phytotoxicity in the leaves (Vargas et al., 2015). Furthermore, fertilizer placement throughout the total area does not concentrate on nutrient availability for

root uptake (near crop rows). Spreader popularity in Brazilian agriculture may be related to some advantages for the farmers, such as the operational capacity (hectares per hour), low cost to carry out infield operation, and minor complexity of the mechanisms.

In general, nitrogen fertilizer incorporated into the soil, in addition to crop rows, increases mineral availability (nitrate and ammonium) for nutrient uptake by roots (Silva et al., 2017; Nkebiwe et al., 2016; Prasertsak et al., 2002). Additionally, nitrogen fertilizers incorporated into the soil subsurface are less susceptible to losses (Nkebiwe et al., 2016). However, opening furrows (often 5–10 cm deep) under the growing crop can break and cut the maize roots, even when it is carried out in the middle of the maize inter-row space. The working tool can also damage the aerial parts of maize plants. Nevertheless, nitrogen top dressing in maize can be more efficient, even when nitrogen fertilizer is placed on the surface. The ammonium nitrate losses due to ammonia emission are less than 3%, even when applied on the surface (Nascimento et al., 2013). In addition, the nitrogen fertilizer applied on the side bands of the crop row can increase mineral availability. For example, in previous research in Brazil, Vargas et al. (2015) reported that liquid urea ammonium nitrate (UAN, 42 kg N m^{-3}) increased grain yield by 18.5% when side banded on growing maize compared to the broadcast method.

Nitrogen use efficiency improves under the International Plant Nutrition Institute (IPNI) guidelines: 1) nitrogen fertilizer product (the right source); 2) application rate (the right dosage); 3) application period (the right time); and 4) fertilizer placement (the right place). These aspects assist in the adoption of better management practices. Such principles can help in the development and optimization of technologies for nitrogen top dressing in maize. From a precision agriculture perspective, agricultural machines are essential to make these management practices a viable alternative for farmers. Precision agriculture technologies can maximize crop yield and minimize input resource losses (Cisternas et al., 2020). However, technology adoption relies on factors such as relative advantage, compatibility, and low complexity (Pathak et al., 2019).

Although it is less frequent in Brazil, technology for liquid fertilizer application represents an alternative for improving nitrogen top dressing application in maize fields. At present, the liquid fertilizer matter is insufficiently studied; as a result, only a few options for liquid fertilizer technology are available. For example, liquid fertilizers are less frequent than dry fertilizers in Brazilian crop fields (Silva & Magalhães, 2019). However, liquid fertilizers have some advantages, such as high application quality (Sharda et al., 2016) and dosage control (Xiuyun et al., 2019; Yamin et al., 2016). In addition, the fertilizer (e.g., UAN) could be carried out using a boom sprayer, which is common equipment. However, a specific application nozzle is needed to apply the liquid fertilizer to the soil surface.

Today, the spreader used for nitrogen top dressing presents at least three problems: non-uniform fertilizer placement, granular fertilizer placement on the top of maize leaves, and granular fertilizer scattering without a precise target. Therefore, considering that fertilizer placement in the side bands of maize rows (near of roots zone) and precise dosage (quality) improve nitrogen top dressing, the objective was to design a liquid fertilizer application device for assembly on a boom sprayer. For this, programming modeling, simulation, and bench tests were used for analyses.

Material and methods

Proposed technology for nitrogen top dressing in maize fields

The alternative for improving nitrogen fertilizer application in Brazilian maize fields involved a liquid fertilizer apparatus. These nozzle sets were coupled with common equipment used for spraying agricultural pesticides. Thus, two processes were combined on the same machine. The processes were carried out in distinct stages (spraying and fertilizer application). For this, a self-propelled sprayer was used to perform the application. As an advantage, the hydraulic system was the same (reservoir, pump, valves, pipelines, and boom sections). The extension rods with a liquid fertilizer nozzle represented a significant change in relation to the conventional structure mode (Figure 1). For example, the pesticide spray targeted the plant canopy, while the liquid fertilizer jet pointed to the side band at the plant base.

This technology applied a direct liquid fertilizer jet on both sides of the crop row (maize, rice, wheat, sugarcane, and cotton plants). The extension rod enabled liquid fertilizer to reach the nearest plant base, an advantage for nutrient availability. The extension rod consisted of a rubber pipe, rubber seat gaskets, a steel wire coil, a nozzle holder, a nozzle quick cap, a nozzle body adapter, and a liquid fertilizer nozzle (Figure 2).

The steel wire coil covered the rubber pipe to make it straight for operation. The rubber pipe connected to the boom sprayer using a nozzle holder. The barb adapter (made from polyvinyl chloride) and universal quick cap, sealed with a seat gasket, completed these assembly parts. Rubber pipes connected to the nozzle body adapter on the other side of the extension rod. In sequence, the nozzle tip coupled to the apparatus using a universal quick cap and seat gasket (a seal against leaks). This technology is protected by a patent application submitted to the National Institute of Industrial Property of Brazil[1] (number BR 10 2021 011618 8).

Figure 1. Alternative for nitrogen top dressing in maize fields using a self-propelled sprayer for liquid fertilizer application. Adapted from the Jacto website.
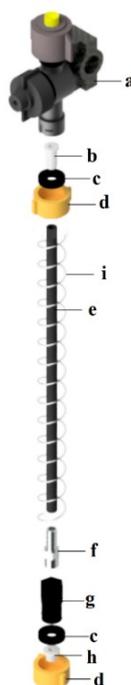
Figure 2. Extension rod for liquid fertilizer application. a - Nozzle holder. b - Plastic barb adapter. c - Rubber seat gasket. d - Nozzle quick cap. e - Rubber pipe. f - Stainless steel barb adapter. g - Nozzle body adapter. h - Liquid fertilizer nozzle tip. i - Steel wire coil.

Modeling and simulation applied for liquid fertilizer application

Input and output parameters were considered to model liquid fertilizer application. The main parameters are shown in Table 1. The liquid fertilizer flow (Q [l min^{-1}]) was calculated as follows:

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[1] Brazilian National Institute of Industrial Property - INPI. Patent number BR 10 2021 011618 8. Available at https://www.gov.br/inpi/pt-br

$$Q = \frac{Fr \times N \times w \times s \times 60}{c \times 10000} \tag{1}$$

where: Fr - fertilizer rate (kg ha^{-1} of N); N - liquid fertilizer nozzles per boom section (unit); w - crop row width (m); s - forward speed (m s^{-1}); c - nitrogen fertilizer concentration (kg L^{-1}).

Table 1. Essential dimensions and parameters applied to simulate liquid fertilizer application.

Maize field	
Crop row width	0.45 m
Simulation scenarios	
Forward speed	1.5 a 4 km h^{-1}
Pump input velocity	540 rev min^{-1}
Pump output flow	100 L m^{-1}
Fertilizer rate	40–180 kg ha^{-1} of N
Liquid urea–ammonium nitrate	
Concentration	0.416 kg L^{-1} of N
Injection tip characteristics	
Orifice diameter	1.5, 2.0, 3.0, and 4.0 mm
Discharge coefficient	0.7, 0.6, 0.5, and 0.4
Drop tubes per section	7–12

Modeling, simulation, and analysis were used to support the design and comprehension of the hydraulic system for liquid fertilizer application. Simulation was also used to understand the dynamic and static characteristics of the application process. The programming model considered the mechanical and hydraulic parameters. Thus, the operating scenarios were related to the sprayer forward speed, fertilization rate, liquid fertilizer characteristics (density and kinematic viscosity), crop row width, and sprayer boom width. The hydraulic dimension was considered for the reservoir, tubes, filter, piston pump, valves (drawer, retention, three-way, servo valve, three-way valve, relief valve, and servo valve), extension rod pipe, liquid fertilizer nozzle tip, and measure instruments (flowmeter and gauge pressure).

Modeling and simulation of the liquid fertilizer system were performed using Simulink, which was linked to Matlab (MathWorks, R2012a, Natick, MA, USA). Simulink has customizable libraries for programming block diagrams. Here, the main library was Simscape, in which the programmable blocks represented valves, pipelines, hydraulic pumps and motors, hydraulic cylinders, and instruments for measuring speed, force, and pressure. Figure 3 shows the Simulink block assembly of the hydraulic system, with elements represented as speed control block (I), centrifugal pump (II), check valve in suction line (III), a subsystem used to measure pressure (IV), an output signal converter (V), three-way valve used for flow control (VI), a measurement flow block (VII), pressure data output (VIII), set point of liquid fertilizer flow (IX), math block used to add or subtract (X), proportional–integral–derivative controller (XI), check valve in return line (XII), return orifice (XIII), reservoir (XIV), input of fluid characteristics (XV), boom section with connection between pipes (XVI), extension rod with drop tube arranged for application at both sides of crop rows (XVII), liquid fertilizer nozzle represented by a fixed orifice (XVIII), a pressure measurement in the end of the boom section (XIX), math block used to calculate the drop pressure across the boom section (XX), math block used to calculate the hydraulic power based on flow and pressure measurements (XXI), and numerical solution block (XXII).

A variable liquid fertilizer rate was also implemented in the Simulink model, using a classic closed-loop control (proportional integral derivative). The principle of liquid fertilizer rate control was output flow returning to the reservoir through a three-way valve. For that, a servo valve was applied to actuate on the opening and closing level. At the same time, the liquid flow carried out to the boom section was measured using a flowmeter. In this model, the set point was indicated as the required fertilizer flow rate, the value of which was compared to the parameter measured by the flowmeter. Simultaneously, the deviation (error) processed by the controller sends an electrical signal to the servo valve to reduce the application error.

The simulated scenarios were used to determine the output flow and hydraulic pressure. The program answers were critically analyzed and applied for design and selection (e.g., pipelines, hydraulic pumps, and valves). Furthermore, the simulation extracted valuable information about the estimated power demand (kW).
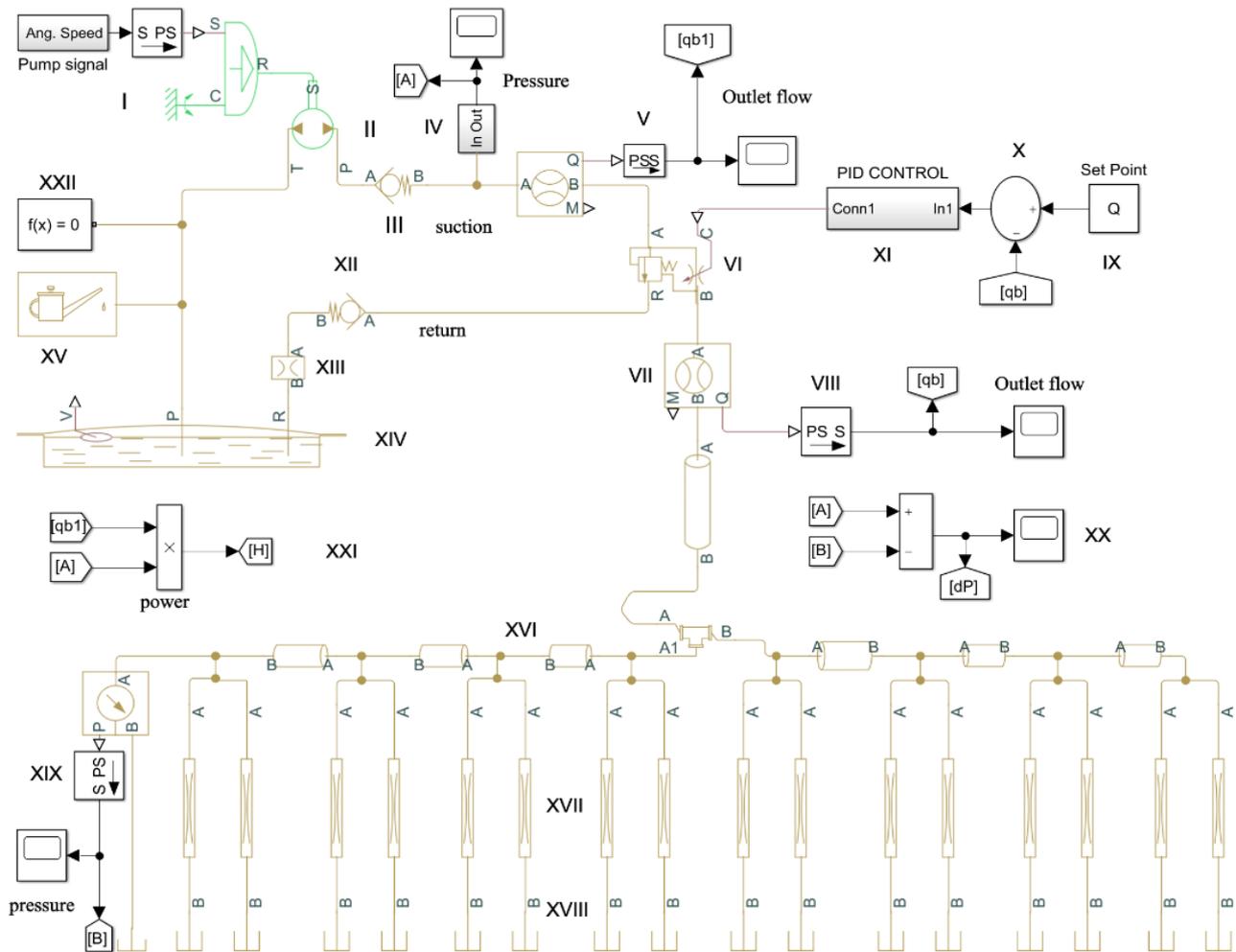
Figure 3. Block diagram of the liquid fertilizer system in the Simulink environment.

The proposed liquid fertilizer application system for laboratory bench tests

An experimental bench was assembled to evaluate the proposed liquid fertilizer application model. The hydraulic system was designed with nine extension rods (one boom section). A bench hydraulic circuit was developed as common equipment for spraying. The assembly was carried out using the following: reservoir (0.2 m³); two in-line filters; an electric diaphragm pump (input of 12 V and 17 A) with a maximum flow rate of 19 L min.⁻¹ (maximum pressure of 4 bar), model DW 1194 made by Kawashima; two switching holder power supplies used to convert alternate current for the direct current; two manometers applied to measure the drop pressure across the boom section; a manual relief valve; an electric on−off valve; a flowmeter; an electrical servo valve; a controller panel (model Basic 2000, made by DRS); an angular rotation sensor; a boom section with nine nozzle holders; and nine extension rods with liquid fertilizer nozzles.

The extension rod and application nozzle tip were designed to link to the standard nozzle holder, in which it has a universal dimension. The nozzle holders are mounted on the sprayer's boom. In addition, the liquid fertilizer nozzle tip was designed using an inlet hole of 6.35 mm. At the outlet, the nozzle tip divides the liquid fertilizer into two jets for the placement of liquid fertilizer near crop rows. Here, the two outlet orifices were 1.5 mm for the bench tests. The opposite orifices were drawn using an angle of 30° from vertical. The angle was applied for the placement of a liquid fertilizer jet on parallel sides of the crop rows. More details about the extension rod for liquid fertilizer are shown in Figure 4.

Results and discussion

Nozzle outlet flow for liquid fertilizer application

Maize fields require a significant amount of nitrogen fertilizer (Faria et al., 2019; Panison et al., 2019; Simão et al., 2020; Vargas et al., 2015). Between 40 and 180 kg ha⁻¹ of nitrogen were considered in the

simulations. UAN was considered the nitrogen fertilizer input, a solution with 0.416 kg L^{-1} available mineral nitrogen (30 ± 2% total nitrogen, (Cahill et al., 2007)). Thus, a fundamental result for the application nozzle was presented (Figure 5). The simulation showed a linear relationship between the fertilization rate and outlet flow. Additionally, the forward speed scaling required proportional compensation at outlet flow. This application nozzle outlet flow estimate could be useful for the selection of hydraulic elements (e.g., valves, pump, pipe lines, filters, and reservoir).
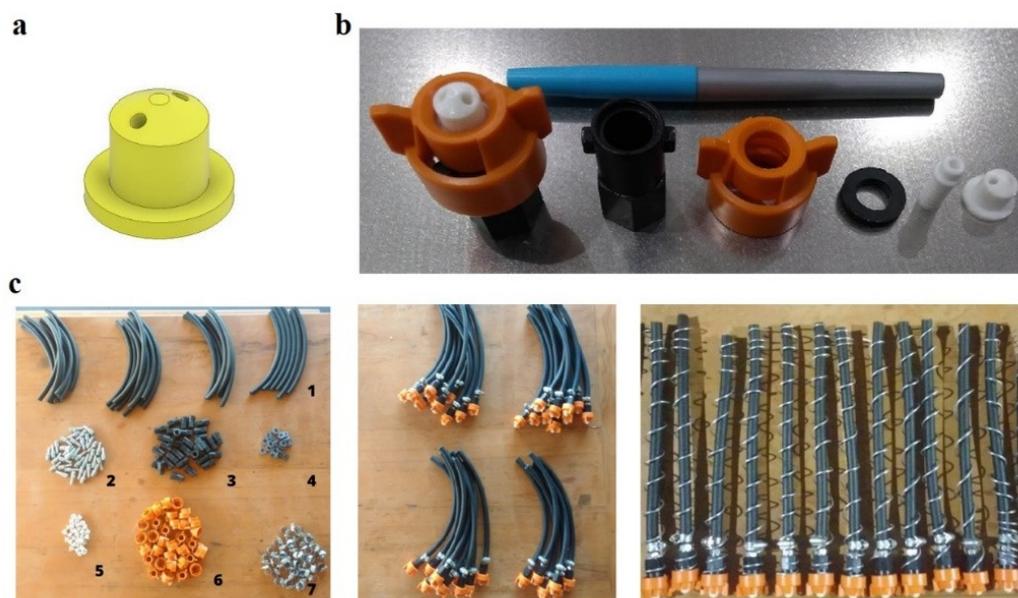

Figure 4. Extension rods for liquid fertilizer application tests. a Liquid fertilizer nozzle tip. b Components of the nozzle body end. c Extension rods at different stages of manufacturing.
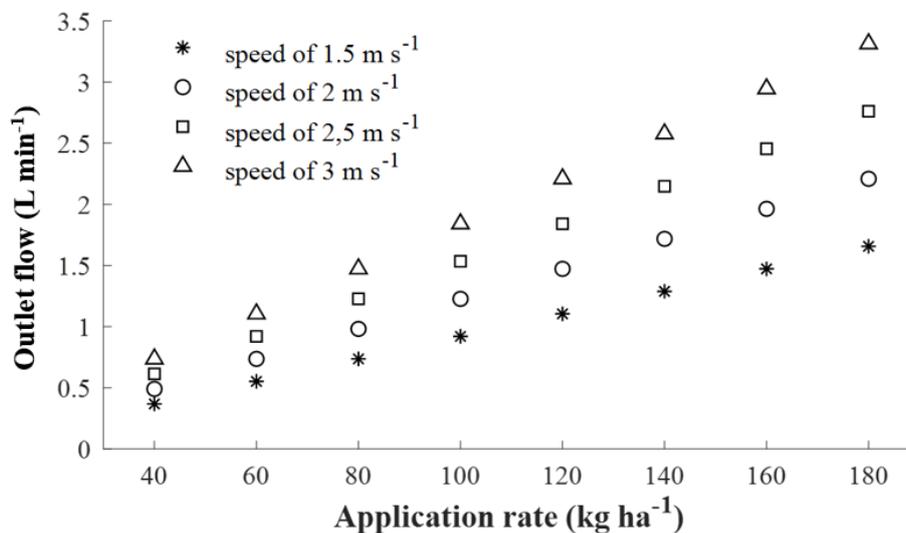

Figure 5. Simulation of nozzle outlet flow considering liquid urea–ammonium nitrate.

The desired nozzle outlet flow (set point) is normally applied through a variable control system, which converts the application rate and forward speed into an actuation signal. Traditional variable rate systems generally use a servo valve that controls the dosage through the application line, while a three-way valve receives the dosage that returns to the reservoir. The sprayer hydraulic circuits are also frequently made with electronic on–off valves for each boom section. In general, the wet boom sprayer is divided into sections for each electronic servo valve in this equipment (e.g., eight or nine application lines per section). In addition, the variable rate can be performed directly at the application nozzle (variable–orifice nozzle) using pulse–width modulation, varying the frequency and duty cycle of a solenoid valve installed in the nozzle body (Sharda et al., 2016).

Pressure and power demand for liquid fertilizer application

The hydraulic power was directly influenced by the forward speed (Figure 6). The discharge coefficient and fertilizer nozzle size (orifice diameter, e.g.) are other aspects that also affect power demand. Based on the results, smaller orifices demand higher hydraulic power under similar conditions. This inverse relationship between orifice diameter and power demand was associated with inlet pressure. Here, the pressure measurements also indicated an effect of the discharge coefficient (simulated values at 0.4 and 0.7). A dimensionless value of around 0.6 could be assumed as enough for the nozzle orifices (NBR-ISO-5167 1994). In general, smaller discharge coefficient values brought about a pressure increase. This behavior may be associated with the decrease in the discharge flow efficiency of fluid through the orifice (Knutson & Van de Ven, 2016).

The hydraulic power estimate (Figure 6) considered one boom section with nine application lines (a common section size in self-propelled sprayers). The number of sections depends on the full wet boom sprayer width. Equipment with 24 m (operational width) could be designed using six boom section, for example. This hydraulic power demand analysis is essential for design, especially on the specification of the primary power source. For example, a tractor's power take-off can be used to transmit energy to the drawbar sprayer's pump (e.g., pistons or diaphragm). However, self-propelled machines normally apply a centrifugal pump carried out by an oil-hydraulic motor. In both cases, an internal combustion engine is the primary source of energy.

The hydraulic pressure was also analyzed as a function of the forward speed, discharge coefficient, and orifice diameter of the application nozzle (Figure 6). From the results, forward speed had a significant impact on hydraulic pressure. The orifice diameter and discharge coefficient were also relevant. An application nozzle with a small orifice diameter could be more prone to clogging besides the pressure elevation. Partial or complete clogging can reduce the uniformity of liquid fertilizer dosage through the lines in the boom section. The hydraulic pressure elevation can induce some failures, such as broken connections and leaks. The hydraulic pressure during liquid fertilizer application generally achieves a significant range based on the operating conditions (1.0–9.0 bar, as measured by Sharda et al., 2016).
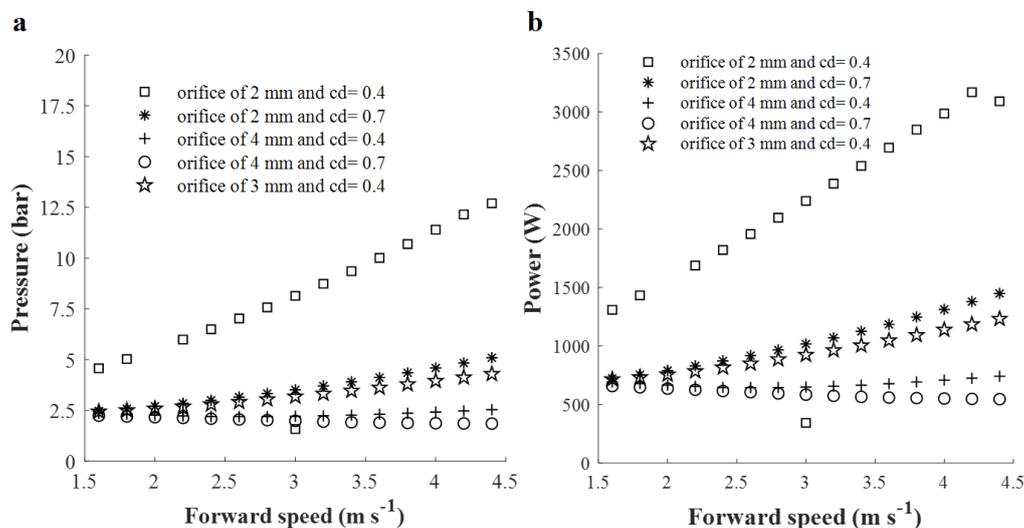

Figure 6. Operational aspects on liquid fertilizer application, considering 150 kg ha⁻¹ of N, liquid urea–ammonium nitrate, and a boom section with nine application lines. a - Hydraulic power demand. b - Inlet pressure.

Number of application lines per boom section

A certain dosage uniformity among the application lines across the boom section is fundamental to sustaining the quality control of liquid fertilizer application. In this sense, the boom section size (6, 7, 8, or 9 application lines) was simulated. As a primary result, the coefficient of variation was used to measure precision. Here, the simulation indicated how many more application lines were present in the boom section, showing a decrease in hydraulic pressure (Figure 7b), which causes an increase in the coefficient of variation. This pressure drop increment across the boom section was mainly associated with pipelines (length, diameter, and material), the number of components (valves, connections, and application nozzle), and nozzle orifice diameter. The pressure drop across the boom section had a direct effect at the outlet flow of nozzles. In this

sense, the simulation reveals that a boom section carried out with nine application lines can result in values above 10% for the coefficient of variation when pressure drops under the bottom of the working range (below 2 bars, Figure 7).
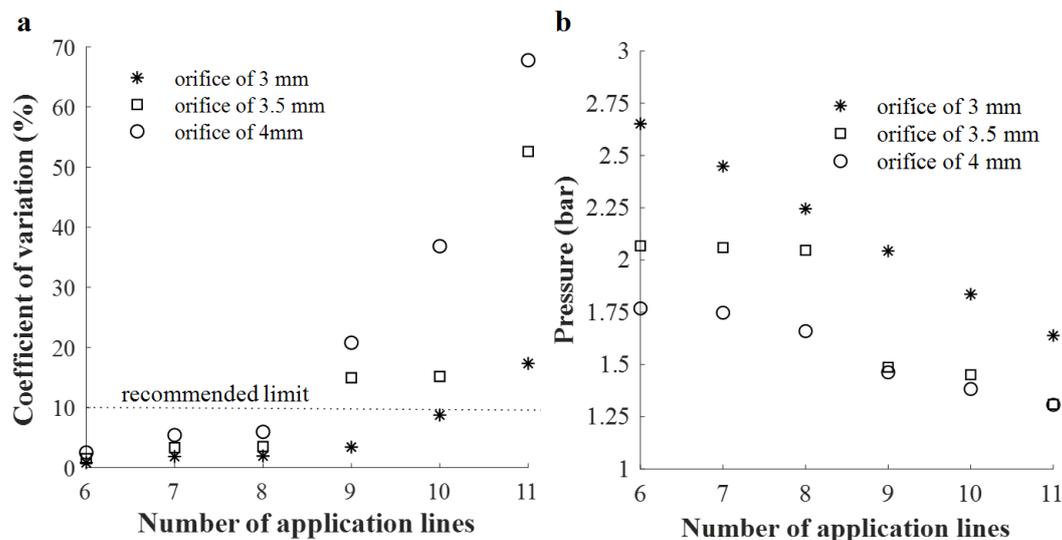

Figure 7. Simulation of the boom section size (forward speed of 3.5 m s^{-1} and discharge coefficient of 0.4). a – Coefficient of variation. b - Hydraulic pressure.

A precise liquid fertilizer application, in addition to better quality control, reflects the benefits to the field. The precise dosage, around agronomic fertilizer prescription, can positively contribute to crop development. In common fertilizer broadcast application as top dressing, the high dosage variation (20–35%, Campbell et al., 2015; Fulton et al., 2001; Virk et al., 2013) can cause unevenness across the crop, especially when using mechanized application without steer guidance but with a satellite signal (errors on the overlap bands). Here, the proposed system showed the potential to achieve small coefficients of variation on liquid fertilizer application (below 10%, Figure 7a). The results showed a tendency for quality control improvement. In general, equipment for site-specific management achieves a low coefficient of variation (~10%, Reyes et al., 2015).

The scenarios that consider different boom section sizes (6, 7, 8, 9, or 10 application lines) showed a lower coefficient of variation (below 10%) for 9 application lines per section when considering orifice nozzles with a diameter of 3 mm. The better results (when compared to the nozzles with orifices of 4 mm) were associated with the working pressure level. The simulation revealed a pressure decay across the boom section for two situations: a larger orifice diameter and more application lines. The pressure decay was linked to the worst quality control (coefficient of variation increase), especially when a drop occurred below the working pressure level (approximately at 2.0 bar in the simulated scenario, Figure 7).

Analysis of the liquid fertilizer application device

The bench results were essential for confirming some working aspects (Figure 8), which were observed during modeling and simulation of the liquid fertilizer application. From the nozzle outlet flow average (nozzle orifice diameter of 1.5 mm), an approximately linear scaling was achieved at a forward speed between 2 and 4 m s^{-1}. In sequence, an increase in forward speed tests (above 4 m s^{-1}) resulted in outlet flow saturation; this result was mainly associated with the physical limitation, such as the application nozzle dimensions (e.g., outlet orifice diameter), internal pipeline diameter, pump capacity (e.g., absorption volume, efficiency, and angular velocity), and valve size. In summary, the liquid fertilizer application system must have an operating range for the outlet flow. The operating range can be specified using a quality limit. Here, the bench tests obtained a better result to the nozzle outlet flow (coefficient of variation at ~10%) at a forward speed equal to or greater than 4 m s^{-1}. The hydraulic pressure was maintained at approximately 1 bar at this speed level. In contrast, a lower level (approximately 0.8 bar) was significantly negative to the nozzle outlet flow uniformity (coefficient of variation from 40 to 100%) across the lines of the boom section. Thus, outlet flow regularity through the application nozzles essentially depended on the working pressure maintenance. Such behavior was also observed in the simulation that considered the boom section size (6, 7, 8, 9, or 10 application lines, Figure 7).
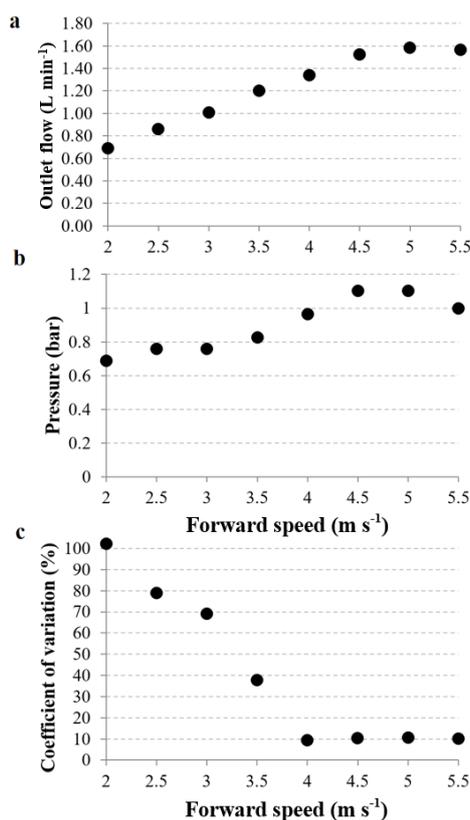
Figure 8. Bench tests were carried out in a boom section with nine application lines. a - Nozzle outlet flow average (nozzle orifice diameter of 1.5 mm). b - Inlet pressure. c - Coefficient of variation.

In general, the liquid fertilizer application quality followed the same principles as pesticide application technology. Thus, the fertilizer nozzle has an operating range (outlet flow and pressure). In this sense, the liquid fertilizer flow at a certain forward speed determines the application rate level (liters per hectare). This application takes place on the soil surface, in parallel side bands of crop rows. As one of the advantages, the liquid fertilizer jet must infiltrate into the soil, at the place closest to the root bulb. In another similar method, solid nitrogen fertilizer (granular urea) can be applied in the side bands of crop rows on the surface (general description in Steusloff et al., 2019). However, this application quality can be impaired by frequent problems, such as recurrent clogs in the dosage system (Zha et al., 2021). Here, the sprayer system for liquid fertilizers was effective for quality control (coefficient of variation less than 10%).

The raised characteristics of forward speed (4 m s^{-1}), operating pressure (1 bar), and nozzle outlet flow (1.4 L min.$^{-1}$) are compatible with the self-propelled operating range. Self-propelled sprayers can achieve up to 6.5 m s^{-1} (Chen et al., 2020), applying 0.5–3.5 L min.$^{-1}$ under a pressure range from 1 to 6 bar (Sharda et al., 2016). Such characteristics are consistent with equipment fully dedicated to liquid fertilizer application (Sun et al., 2018). Here, the proposal differs by the structural process, which makes the dual mode of the sprayer hydraulic system possible. The fertilizer device (fertilizer nozzle body + extension rod) also has a relative simplicity for assembling the sprayer boom; this feature will contribute to its adoption by Brazilian farmers. The technology primarily proposed for nitrogen fertilization on maize fields can also be extended to other crops relevant in Brazil that require nitrogen top dressing, such as sugarcane, wheat, sorghum, and cotton.

Conclusion

Liquid fertilizer is a viable technology for nitrogen top dressing in maize fields. Here, the boom sprayer was considered as an alternative for liquid fertilizer application. For this, an extension rod with a liquid fertilizer nozzle was developed for the placement of jets in the side bands of crop rows. The simulation and laboratory bench tests showed that liquid fertilizer application was compatible with the operational capacity of the self-propelled sprayer (pressure, nozzle outlet flow, and forward speed). In addition, the liquid fertilizer nozzles (characterized by the outlet orifice diameter) performed better under specific pressure and outlet flow ranges. The application quality was better under these operating ranges (lower coefficients of variation). A

boom sprayer with liquid fertilizer operation has some advantages for farmers, such as: sprayer equipment will remain in the field for a longer time, and the spreader will be less necessary in maize fields. In addition, the proposed extension rod with liquid fertilizer nozzle was considered relatively simple to assemble and integrate into the sprayer's hydraulic system without major modifications. Such characteristics can ease farmers' adoption of the proposed process by farmers. In Brazil, where the nitrogen top dressing is normally carried out using a broadcast method (granular fertilizer scattered in the full area). Furthermore, the proposed process showed potential to improve the application quality through nozzle outlet flow values that presented a coefficient of variation less than 10%.

Data availability

The data used in the search were made available publicly, and can be accessed through the link: https://ufprbr0-my.sharepoint.com/:f:/g/personal/marcelo_jose_ufpr_br/IgD-fEchAZ3sRaOteI-7XFgvAYWuZLVtrXFcA33Ymbw4g30?e=JGAY3Z

Acknowledgements

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