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TESTING OF MULTIPURPOSE EQUIPMENT FOR SIMULTANEOUS PRIMARY AND SECONDARY SOIL TILLAGE PREPARATION

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Abstract: Soil resource conservation in crop establishment is a global issue that has gained much interest in a recent year, due to the growing demand for food in the agricultural sector. Despite the above, there is a current trend in the different production systems oriented to extensive and intensive use of the soil, which has increased not only its costs (mainly fossil fuel consumption), but also its physical, chemical and biological degradation to the detriment of its sustainability and sustainability. Faced with this problem and the lack of technically appropriate equipment, it is important to generate agricultural practices and technological innovations that, in addition to being efficient, can be quickly adopted by producers, given their competitive advantages. The objective of this research was to present an integral technological alternative to reduce fuel consumption and effective operation time, through a Multipurpose prototype that performs the simultaneous preparation of primary tillage (plowing) and secondary tillage (harrowing) of the soil, using medium power tractors. The Multipurpose is a mechanical equipment made up of three sections: (chisel plow + harrow + lump breaker), which are combined for the simultaneous preparation of primary and secondary tillage of the soil. The first section has a plow with three semi-straight chisels with narrow tips (two shallow and one deep with flap coupling), the second section has a harrow with 12 discs and finally, it uses a lump breaker. The working width of the equipment is 1.2 m and it is 3.2 m long. The equipment requires a minimum of an 80-horsepower tractor and is coupled to the tractor's three-point hitch. This technology performs soil conditioning for crop production in a single step.
Keywords: combined tillage equipment, soil preparation, multipurpose equipment.

INTRODUCTION

During the last decade in Mexico, the sowing area has decreased considerably due to low productivity caused by unfavorable soil and climatic conditions that are even more accentuated by climate change; this situation has caused substantial ecological and economic losses and a national deficit in the production of basic grains (maize, beans, rice, soybean and sorghum), which has aggravated the economic and social situation of agricultural producers (SIAP-SAGARPA, 2017).

Soil resource conservation is an issue that has gained much interest in recent years due to the growing demand for food in the agricultural sector; according to the Food and Agriculture Organization of the United Nations, demand in this sector is set to increase by 50% in 2050 and more than 80% of the increase in production by that year will come from land that is currently cultivated with certain levels of restrictions (FAO, 2011). Currently in Mexico, 93 million hectares, equivalent to 47% of the national soil, show some type of degradation caused mainly by agricultural and livestock activities and deforestation (SEMARNAT, 2012). Despite the importance of soil conservation and the environmental services it offers, there is a clear lack of technologies aimed at conserving the physical, chemical and biological fertility of the soil, which present a holistic approach to minimize soil degradation and favor the rapid adoption of sustainable conservation practices (P.D. INIFAP, 2018).

It should be noted that the current trend in the various production systems is to use the soil resource extensively and intensively, which has increased its physical, chemical and biological degradation, to the detriment of its productivity. Faced with this problem, it is important to generate new crop management practices that, in addition to being efficient, can be quickly adopted by producers, since the limited application of innovations for soil agricultural practices results in high production costs, limits the yield and quality of harvests and reduces the possibilities of making an agro-system sustainable. For the specific case of the "soil preparation" technology component, it is important to note that many of the implements and equipment were designed for conditions in other countries (Ortiz, 2002 and Reynolds 2015). It should also be considered that in Mexico 74% of national agricultural production is cultivated in rainfed agriculture, so it is certainly exposed to climate change and factors that threaten production, highlighting the impact on productivity and on water, soil and energy resources (information published in PND 2013-2018).

For the establishment of a crop, it is traditionally required to prepare the root bed and the seedbed, activities commonly known as primary and secondary tillage. These operations are carried out separately and sometimes, depending on the type of management, the availability of equipment and soil conditions, each operation is carried out one or more times, generating high costs (fuel consumption, excessive operation and transportation times) and low quality of work, which results in low profitability and a smaller sowing area. On the other hand, an operator or tractor driver, without diagnosis or technical support, generally carries out soil preparation, so the effect on soil structure is usually negative, making the sustainability and sustainability of agricultural production more vulnerable.

Globally, in intensive basic grain production, soil preparation is the agricultural practice that represents the highest unit costs in food production and consumes the most energy in the form of "fossil fuel" in the world (IDAE, 2006; Adeyowin and Ajav, 2013). Between 2010 and 2017, due to the rising cost of fuels almost 100% of agricultural projects have reduced their profitability. In addition, there is no technological response or innovations to replace or optimize the cost of soil tillage management. Another factor is the degree of mechanization of the Mexican countryside; an analysis of the national scenario carried out by Negrete (2006) leads to the conclusion that: based on an agricultural frontier of 24 million hectares, with a merchandisable area of 18.6 million hectares, 360,000 tractors of 50 to 80 horsepower would be required. If the assumptions of the scenario were valid, the current stock would have 217,300 active tractors, which represents 60% of the mechanization needs. This means that the modernization of the Mexican countryside is going in slow motion and/or in reverse given the deficit of tractors specifically and in addition to the lack of technological development and innovations for agricultural activities in crop establishment. Of the 238,830 tractors in Mexico, 54% have exceeded their useful life, as maintenance and operation is costly, according to the National Agricultural Survey (ENA, 2014).

This means that only low-powered machinery is available for soil preparation and cultivation operations, which are limited to small pieces of equipment.

The purpose of this research work was the technological validation under field conditions of a multipurpose tillage prototype for integrated soil preparation, capable of simultaneously performing three operations in one (plowing, harrowing and weeding) with the use of 80 horsepower tractors (predominant in Mexico) and optimizing fuel consumption and effective operation time by up to 50%, improving soil quality and crop productivity compared to conventional systems currently in use.

This technological validation process

performed with producers, defines the technical and economic feasibility in terms of supporting the transformation of technological innovations into demonstrable concepts and has to be simultaneous in the times of innovation (Yepes, 2018).

Validation is a process of INIFAP's research results, particularly of its products or services, and these institutional processes confirm that the necessary and relevant standards demanded by the producer are reached and, on the other hand, guarantee their adoption.

MATERIALS AND METHODS

DESCRIPTION OF THE VALIDATION SITE

The present validation work was carried out with a cooperating producer in the locality of Canta Ranas in the municipality of Cotaxtla, Veracruz. It is located at coordinates 18°54'7" N and 96° 22 '16" W, at an altitude of 61 masl. It has a warm sub-humid climate with late summer rains; the average annual temperature is in the range of 24 to 28 °C and an average annual rainfall of 1,000 to 1,200 mm. The soil type determined was a sandy clay loam and at the time of tillage, a moisture content of 14.62, 20.55 and 22 % was registered for the depth of 0.10, 0.20 and 0.30 meters, respectively. The validation was performed in the spring/summer 2023 rainy season cycle. The corn material used was the INIFAP hybrid H-520 with a density of 62500 seeds per hectare and the fertilizer dose used was the INIFAP technological package.

TEST CONDITIONS

Two technologies were used for testing: 1) Multipurpose prototype or proposed technology and 2) Use of the three-disc plough plus the use of a cross-passage harrow as with the control technology (this being the most widely used technology at present in our country). The testing agricultural activity for both technologies is primary tillage (root bed) and secondary tillage (seed bed).

DESCRIPTION OF THE PROPOSED TECHNOLOGY

1) Multipurpose Prototype Technology:

It is a mechanical equipment composed of three sections: chisel plough + harrow + lump breaker, which are combined for the simultaneous preparation of primary and secondary tillage of the soil. This technology performs soil conditioning in a single step. In the first section, it has a plough with three semi-straight chisels with narrow tips (two shallow and one deep with flap coupling); the second section has a 12-disc harrow and finally, it uses a spike harrower. See Figure 1 and Table 1.

Figure 1. Multipurpose prototype

It also has the capacity to be used in individual sections per tillage Figure 2 and 3.

Figure 2. Vertical chisel plough (Primary tillage)

Prototype set-up	Number/dimensions	Components
Sections	Three	Plough + harrow + lump-breaker
Multipurpose	3.20 x 1.20 x 1.10 m	Length, width and height
Plough	3	Semi-straight chisels: two front chisels + one rear chisel with wings
Limiting wheels	2	For depth adjustment
Chasis	Trapezoidal platform with double frame: front and rear	Double platform frame for the attachment of two shallow chisels at the front and one deep chisel at the rear
Harrow	12	discs
Chasis	1.4 x 0.70 x 1.1 meters in length, width and height	Main frame for disc coupling
Mechanical cleaners	10	Between discs
Lump breaker	Sectioned in 7 rows with spikes distributed every 0.10 m, for a total of 14 spikes per row and 98 total spikes.	Trailed circular lump breaker with spouts
Chasis	0.46 x 1.63 m with 0.22 m diameter tube	Lump breaker frame
Coupling 1	Category II	Third point of the tractor
Coupling 2	Category II	At the third point between sections
Power requirement	Mínimum 80 Hp	Power source
Prototype weight	645kg	Total weight

Table 1. The technical configuration of the multipurpose prototype is presented, as a result of the construction using the described methodological parameters and includes the components of each section.

Figure 3. Harrow + lump breaker

(Secondary tillage)

This equipment shown in figures 2 y 3 in integrated setting requires at least an 80 HP tractor and is coupled to a category two, three-point hitch on the tractor. It also has the ability to be used in individual sections per tillage Figure 3 and 4.

DESCRIPTION OF CONVENTIONAL TECHNOLOGY

2) Conventional disc plough + harrow technology

Disc plow: It is a mechanical implement composed of three discs, each with a support attached to the frame to which the disc is fixed on bearings that allow it to rotate. The disc is attached by means of four or five screws, which allows replacement in case of breakage or wear. A wiper, or scraper, is placed on top of each disc to remove the band of soil that rises up the disc. The angle of inclination of the disc with respect to the ground (penetration) and the angle it forms with the direction of advance (attack) can be adjusted. The disc marking includes diameter and thickness equivalent to 26 inches in diameter (660 mm) and 3/16 inch thick (4.8 mm)]. The concavity for this blade can be between 87 and 120 mm. To facilitate the cutting of the soil, the discs are sharpened at the edge. Penetration angle: 20 to 25º; angle of attack: 40 to 45º. Mass: reversible plows 250 to 400 kg/body; fixed plows 150 to 300 kg/body. Distance between bodies: 70 - 115 cm; frame clearance: 70 - 95 cm. See Figure 4. Auxiliary equipment operating elements: Reversibility, mechanics, hydraulics.

Figure 4. Conventional disk plow for primary soil tillage

Disc harrow: It is a mechanical implement with an integral hitch category two of the three points of the tractor and is equipped with two sections of mixed discs, ten discs for each session. The front discs are serrated with 1 ½" round center and ten smooth rear discs of equal center. See Figure 5. This equipment is designed to work in soil preparation, weed control and residue incorporation in a simple and safe way. It is equipped with angle adjustment in both the front and rear sections, a feature that makes it more versatile in different soil and moisture conditions.

Figure 5. Conventional disc harrow for secondary soil tillage

Validation conditions

For this validation, we focused on homogeneous operating conditions in the following conditions:

- Same plot size (5000 square meters)
- A single soil type (sandy clay loam)
- One tractor (80 HP)
- The same tractor operator from the beginning to the end of the test
- One speed (dual power third speed at 1800 rpm)
- One technician for the variables to be measured: fuel consumption and effective operating time
- Same soil depth when tillage is applied (0.30 m of working depth)

Validation design:

A completely randomized block design with a single repetition was used, but of continuous type for soil tillage in a plot of 5000 square meters; giving a greater degree of certainty to the two comparative variables and evaluated as dependent. It is important to mention that the Renam code was validated for the fuel consumption test, which states that "The evaluation for fuel consumption must be continuous, performed in an area greater than or equal to 2000 square meters in at least one test and must be of continuous type, that is, it must be evaluated from the beginning to the end of the operation", thus completely eliminating the error caused by the fluid compensator caused by the global fuel system.

The variables quantified were:

- Fuel consumption l ha-1
- Effective working time h ha-1

Fuel consumption (l ha_1)

In the measurement of fuel consumption (Fc) for the work performed by the evaluated implements, the full tank method was used. This methodology consists of moving the implement coupled to the tractor to the place where the operation test is to be started, filling the tank with fuel up to the registration level or reference mark, recording on the field sheet, the mark at the moment the tank is full. This test is continuous (meaning that it does not stop from start to finish). This continuity of the test limits the intervention of the fuel compensator and allows to have a real (determined) test; it will not have repetition given the requirements and nature of the test. This same action was repeated for each test of each of the equipment to be evaluated.

At the end of the operation test, the fuel necessary to recover the level marked before the test is measured, it is very important to make sure to eliminate the air bubbles inside the tank before and after the fuel supply; for which the tractor must be rocked enough to remove the air from the tank. For the remaining variables, a randomized block design with a single repetition will be used, where the only variant is the tillage applied. The data will be analyzed by the statistical program R-language-12 modified, 2012.

The fuel consumption per surface area is obtained in liters per hectare and the calculation is made with the following equations:

Fuel consumption per hour

CCH = cc/St… ……………………….equation (1)

Where:

CCH: hourly fuel consumption l/ha-1

Cc: fuel consumption (l)

St: total area (m2)

In this test, only the fuel consumption for each agricultural operation was quantified in liters per hectare, the measurement was performed by the full tank method, which is supported as a valid and accepted test by the NTTL (Nebraska Tractor Test Lab) and referred to the (OECD, 2016). It is important to note that soil preparation is the agricultural activity that records the highest consumption of fossil fuels in the world (IDEA, 2006).

Effective operating time. - It is the time necessary to determine the work that was performed with the equipment, considering the total travel time without subtracting the time to turn around at the headlands and the time of suspension due to failures.

$Teo=Tt+Tc+Tf60$………………… (equation 2)

Where:

Teo: effective operation time (hours).

Tt: total operating time (minutes)

Tc: time to turn around at headlands (minutes)

Tf: failure hang time (minutes)

RESULTS AND DISCUSSION

Validation under real operating conditions in the field with producers is a process that is part of the research phases at INIFAP and allows technological insertion for its adoption. Table 2 shows the results obtained from the evaluations of the validation with producers in the two technical performance variables (fuel consumption and effective operating time), as well as the determination of the yield variable obtained by the producers themselves.

In the results of Table 2, we can observe that there is a highly significant differential in the two quantified variables, where the Cc presents a saving of 58.18 % and the Teo a 55.52 % in comparison with the use of conventional technology. Likewise, a benefit-cost ratio of 1:2 in the cost of maquila. The trend technology was very similar to that determined in other soil conditions. For the determination of the variable corn grain yield, the proposed multipurpose technology was superior from the first establishment. There is no documented and published information on

	Primary tillage + Secondary tillage	Fuel Consumption (l ha^{-1})	Effective Time of Operation (h ha^{-1})	Labor cost ($ ha^{-1})	Corn grain yield (Kg)
Technology validation	Plough	10.56	3.00	1800	NA
	Harrow (crossing step)	8.00	0.62	1800	NA
	Conventional	18.56	3.62	3600	4600
	Multipourpose	7.76	1.61	1800	4720

Table 2. Comparison of multipurpose vs. conventional technology for primary and secondary soil preparation.

the use of integrated equipment for primary and secondary soil preparation in Mexico.

Figure 6, shows the Multipourpose equipment used in the technological validation performed with grain corn producers in rainfed production for the spring-summer cycle of 2023.

Figure 6. Technological validation of the Multipourpose Prototype

CONCLUSIONS

1. We can dispose of a small-scale multipurpose technology that allows performing soil preparation (primary and secondary tillage of the soil simultaneously and in a single step) for crop establishment with the use of medium power tractors.

2. Reduce fuel consumption and effective operating time by up to 50% compared to conventional technology, which is the most widely used in Mexico.

3. Maintain at least the same crop yield results from the first production cycle.

4. Progressively improve soil conditions, given the change to vertical tillage instead of disc plowing.

5. Reduce the labor costs.

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