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Soil Descompactor Equipment for Deep Tillage

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Abstract: Soil preparation is definitely one of the most critical and costly agricultural activities for the establishment and subsequent development of crops in any production system. The importance is based on preserving the planting site in conditions that are favourable for crop yields. At present in our country, conventional tillage with disc plows is mostly used for primary or deep tillage of the soil, which shows the urgent need for the development of technologies to reduce the loss and degradation of this invaluable resource. The search for solutions to this problem in soil preparation has led to the study and adoption of conservation tillage practices, including vertical tillage (VT), in order to reduce the impact on the environment and especially on soil resources. It is convenient to point out that the VT is a conservation tillage alternative that promotes energy saving and improves physical properties compared to conventional tillage. The objective of the present work was to develop a prototype of a mechanical implement to remove hard soil layers, using the parameters of vertical tillage and the critical depth theory; capable of reducing fuel consumption and effective tillage time by up to 50%, in addition to improving the quality of tillage and some physical parameters of the soil compared to conventional tillage applied with disc plow. The results show the development of a prototype for deep tillage that removes hard soil layers. This equipment uses a plow with five rigid chisels with narrow tips and the combined effect of design and operating parameters. This deep tillage implement does not invert the soil and subsequently requires a harrow cross pass. Likewise, this technology represents savings in fuel consumption and effective operating time of up to 50% per hectare depending on site conditions.

Key words: soil compaction, tined tillage, narrow vertical tillage

1. Introduction

Soil preparation is definitely one of the most critical and costly agricultural activities for the establishment and subsequent development of crops in any production system. The importance is based on preserving the planting site in conditions that are favourable for crop yields. No one in the agricultural sector is unaware of the lack of mechanized technological innovations in Mexico and developing countries around the world, mainly in soil management and preparation. At present in our country, conventional tillage with disc plows is mostly used for primary or deep tillage of the soil, which shows the urgent need for the development of technologies to reduce the loss and degradation of this invaluable resource. According to INEGI (2013) [1], 66% of soils in Mexico present some type of damage. It is also important to point out that 74% of national agricultural production is cultivated in rainfed conditions, exposed to climate change and with factors that directly affect its productivity. The search for solutions to this problem in soil preparation has led to the study and adoption of conservation tillage practices, including vertical tillage (VT), with the purpose of reducing the impact on the environment and especially on the soil resource. For the above mentioned, it is important to know different technical and operative parameters of tillage implements and their effect on the soil. It is convenient to point out that the VT is a conservation tillage alternative that promotes energy

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saving and improves physical properties compared to conventional tillage. The VT is performed with chisels and corresponds to the operation of bursting or breaking the soil and fragmentation up to 0.40 meters deep without inverting the horizons, due to this, there is less decomposition of organic matter and greater conservation of soil moisture. Raper and Berthold (2007) [2] documented and concluded that, in soil tillage, much can be done to decrease the economic and environmental cost with vertical tillage, via reduction of energy use, selecting the appropriate implement geometry, adequate working depth and moisture in the soil profile. On the other hand, after a rigorous documentary review of published articles and evaluation of field conditions, (Reynolds et al. (2015) [3] determined the influence of four operating parameters that should be considered as working adjustments before applying deep soil tillage and making energy use more efficient. These integrated parameters were 1) working depth based on the critical depth theory 2) position and spacing between chisels 3) number of bodies 4) use of wings or sweepers.

The objective of the present work was to develop a prototype of a mechanical implement to remove hard soil layers, using the parameters of vertical tillage and the critical depth theory; capable of reducing fuel consumption and effective tillage time by up to 50%, in addition to improving the quality of tillage and some physical parameters of the soil compared to conventional tillage applied with disc plow.

2. Material and Methods

2.1 Methods

2.1.1 Location of the Test Site

The prototype was developed and evaluated in the engineering and mechanization unit of the Cotaxtla Experimental field station, belonging to the National Institute of Forestry, Agricultural and Livestock Research (INIFAP), located in the municipality of Medellin de Bravo, Veracruz, at 18°56' north latitude and 96°11' west longitude and an altitude of 15 meters above sea level.

2.1.2 Design Method

Conceptual design exemplified by (Reynolds et al; 2022 in the use of the seven stages of design):

1) Clarification of objectives
2) Establishment of functions
3) Setting requirements
4) Determination of characteristics
5) Generation of alternatives
6) Evaluation of alternatives
7) Improvement of details

2.1.3 Technical parameters of vertical tillage in the prototype design

Working depth, type and degree of soil disturbance was the primary factor in selecting tillage implements, but must be considered along with draft and penetration force requirements for efficient operation. There are two main variables in the design and selection of appropriate tillage implement geometry: Equation (1) and Equation (2):

Depth to width ratio (d/w) (1)

Chisel angle (α) (2)

It is necessary to distinguish three categories of these blades or tips based on their depth/width (d/w) ratio [4] as Eq. (3), Eq. (4) and Eq. (5).

Width of tips (blades) with $d/w < 0.5$ (3)

Narrow tips with $1 < d/w < 6$ (4)

Very, narrow tips with $d/w > 6$ (5)

The working angle is indicated by the angle at which the groove opener or tip creates a horizontal line in the direction of travel. The optimum angle for a chisel is considered 25 degrees due to the increased soil mobilization; while increasing the angle increases the pulling force proportionally.

The use of shallow chisels ahead of deep chisels significantly reduces the force on the deep chisel, indicating that loosening the ground surface by a separate operation prior to deep loosening offers an effective way to reduce the pulling force on the deep chisel. For this arrangement to work successfully, the position and spacing of the shallow chisel must be close enough to the deep chisel. The positions considered as a function of the working depth of the deep tip for shallow chisels [4] are given by Eqs. (6), (7) and (8):

Depth = 2/3 times the depth of the deep tip (6)

Lateral distance = 2.5 times the depth of the deep tip (7)

Distance forward = ⩾ 1.5 times the depth of the deep point (8)

Chisel spacing can affect the pattern of soil disturbance produced by a pair of tips operating at the same depth. Godwin and Doguerty (2007) [4] and Reynolds et al. (2015) [3] described the effect of chisel spacing on the resulting pull force, disturbance area and specific soil strength. The recommended deep and shallow chisel tip spacing for good soil loosening is given by Eq. (9) and Eq. (10):

1.5 times the working depth for single tips (9)

2.0 times the working depth for finned tips (10)

2.1.4 Proposed Prototype

- Primary soil tillage with the use of five chisels.
- Double platform.
- Three shallow front chisels.
- Two deep rear chisels and coupled with flippers using narrow tips for each of the chisels.

2.1.5 Test Methods

The variables measured in the subjected treatments used the test methodology for plows and harrows, developed and endorsed by INIFAP/OCIMA of the National Center for Standardization of Agricultural Machinery (CENEMA).

The test site was selected according to the following criteria (diagnostics).

The field should be a representative terrain as far as possible, the resistance to penetration will be evaluated in soils that have compacted layers or in which the soil rests for a longer period during the dry season.

The slopes of the soils should vary in a range of 1-4%. The test area should be at least 100 meters long by 20 meters wide.

It should have an arable layer of at least 30 centimeters.

Soil moisture should fluctuate between 11 and 16%

Bulk density should be between 1.2 and 1.4 g/cm^3.

2.1.6 Study and Measurements Variables

1. Fuel consumption "Fc" in (L/ha).
2. Effective operation time "Eot" in (Hr/ha).
3. Disturbed soil area "Ds" in (m^2).

2.1.7 Experimental design and data analysis

The test site consisted of two 50 m wide by 100 m long plots with a total area of one hectare. Only two treatments were used: T1 Control technology.

Chisel plowing with three discs (most commonly used implement in primary soil preparation in Mexico). T2 Technology proposed by INIFAP

Soil decompactor with five chisels (implement proposed as a technological alternative).

The experimental design was a completely randomized block with six replications for the for the two remaining variables:

Fuel consumption and Effective operating time, it was performed in a single continuous type test in the total area of 5000 m^2 per treatment this is supported as a valid test and accepted by the laboratory fuel consumption volume test on tractors at the University of Nebraska (2022) [5].

3. Results and Discussion

3.1 Results

Table 1 shows the specifications and main parameters of the hard soil layers descompactor prototype.

The descompactor (Figs. 1-3) is a mechanical agricultural implement used for deep soil preparation, its main function is to remove hard soil layers and perform primary tillage.

Its operation is based on vertical tillage parameters and critical depth theory. It uses a double platform chassis with five rigid chisels with narrow tips and the combined effect of the operating parameters: 1) working depth 2) position and spacing between chisels 3) number of tillage bodies and 4) use of sweepers. This deep tillage prototype has an adjustable working width from 1.80 m to 2.40 m depending on the working depth used 0.30 and 0.40 m, respectively. It is used as a plow or subsoiler and after its application, a harrow cross pass is required for crop establishment.

Table 1 Prototype specifications and use of the technical design parameters.

Technical design parameters of the component: descompactor	
Effective working width setting	1.60 m for 0.30 m working depth
	1.80 m for 0.40 m working depth
Front sections components	One front sections with 3 chisels
Rear sections components	One rear section with 2 chisels with wings
Working depth setting	0.30 and 0.40 m
Overall length descompactor	1.50 m
Overall width descompactor	750 kg
Descompactor weight	2.60 m
Coupling type	Third point hitch category II

Fig. 1 Descompactor side view.

Fig. 2 Descompactor front view.

Fig. 3 Prototype Descompactor for deep soil tillage panoramic view of the prototype under real operating conditions.

3.2 Test Results Under Field Conditions

For the evaluation of the implement in the field, a loam soil with the following content was used: sand 43.20%, clay 19.80% and silt 37.00%, with a moisture content of 16%.

Table 2 Response of performance variables in the application of primary vertical deep soil tillage.

Implement	Fuel Consumption	Effective operating time	Disturbed area of soil	Working depth
3 disk plow	26 liters	3.4 h ha-1	0.2116 m2	0.22 m
Descompactor	16.5 liters	1.5 h ha-1	0.4722 m2	0.34 m

4. Conclusions

The developed technology represents a saving in fuel consumption and effective operation time of up to 36.5% and 55%, respectively, compared to the most used technology in soil preparation (disc plow).

Primary or deep vertical tillage with the use of chisels represents a technological replacement to eliminate the use of disk plowing in our country.

The descompactor is an implement that does not invert the soil, so it improves the quality of work for secondary preparation, the depth of work improves the use of moisture which could register an increase in crop yields.

References

[1] INEGI. Carta de Uso del Suelo y Vegetación, Serie V (2011), escala 1: 250 000. INEGI. México. 2013.

[2] Raper R. L. and J. S. Bergtold, In row subsoling. A review and suggestion for reducing cost of this conservation tillage operation, *Applied Engineering in Agriculture* 23 (2007) (4) 463-471.

[3] Reynolds Chávez M. A.; S. G. Campos Magaña; M. Cadena Zapata; J. A López López and N. Cuervo Piña, Vertical tillage parameters to optimize energy consumption, *Agric Eng Int: CIGR Journal* 17 (2015) (4): 130-140.

[4] Godwin R. O. Dogherty M., Integrated soil tillage forcéto prediction models, *Journal of Terramechanics* 44 (2007) (1): 3-14.

[5] Nebraska University, Laboratory fuel consumption test NTTL, *last edition* (2022).