Research Article

Multipurpose technology for simultaneous preparation of primary and secondary tillage of the soil (second phase: construction and evaluation of the prototype)

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Abstract

In Mexico, the continuous increase in the prices of fossil fuels and agricultural fertilizers has led to a reduction in the area planted with crops, specifically basic grains. This situation has caused substantial ecological and economic losses and a national deficit in the production of basic grains, which has aggravated the economic and social situation of agricultural producers. Faced with these production growth limitations, it is important to generate new practices and innovations that contribute to reducing these factors. In soil preparation, which is considered one of the most costly activities in food production, there is an enormous technological lag. At present, the discs plow is still by far the most widely used implement for primary soil preparation in food production, causing high rates of soil loss due to erosion, hard layers, minimal use of moisture and, consequently, low productivity. Likewise, it requires high power requirements, excessive operation times and high fuel consumption. The purpose of this research was the construction and evaluation of a prototype for simultaneous preparation of primary and secondary tillage of the soil for crop establishment to reduce operation times and fuel consumption, without detriment to the quality of work and increase yields. The results show a mechanical equipment integrated by three sections (chisel plow + harrow + lump breaker), which are combined for the simultaneous preparation of primary and secondary tillage of the soil. This technology is responsible for performing in a single step, the soil conditioning for crop production, significantly surpassing the conventional system.

Keywords: multipurpose equipment, soil preparation, combined tillage

Introduction

The demand for food, fuel and energy resources continues to increase worldwide and the achievements in crop yields are not enough when compared to the high cost of energy applied to production.[1] Future projections towards the year 2050 in global food production ensure that it will increase up to one third of current consumption.[2] During the last decade in Mexico, the sowing area has decreased considerably due to low productivity caused by unfavorable edaphic and climatic conditions; that are even more accentuated with climate change. This situation has caused substantial ecological and economic losses and a national deficit in the production of basic grains (corn, beans, rice, soybeans and sorghum) which has aggravated the economic and social situation of agricultural producers.[3] In addition to this environmental problem, there is a technological lag in soil preparation, caused by the lack of technological innovations and agricultural practices that contribute to reduce technical factors, which leads to low profitability and less sowing area and, consequently, the precarious economic and social situation of the Mexican countryside.

In the intensive production of basic grains, soil preparation is the agricultural practice that represents the highest unit costs in food production and the one that consumes the greatest amount of energy in the form of "fossil fuel" in the world.[4,5] Therefore, it is necessary to optimize the resources used in activities that require higher costs in agricultural production, such as soil tillage. Soil tillage operations require high-energy consumption; this can limit agricultural activities by reducing the profitability of the production system;[6] however, if technological changes are implemented in appropriate food production systems, including conservation agriculture, it is estimated that 50% of fossil energy could be saved.[7] Reduced tillage or zero tillage not only saves time and energy, but also reduces the cost of cultivation, improves the soil environment for better crop yields, and increases water availability for plant growth.[8,9,10]

In this respect, vertical tillage could be a better alternative as a conservation system. On the other hand, energy savings are considerable.[11] Energy savings using vertical tillage compared to the conventional system have been documented in several studies.[12,13,14] The required draft force for implements and the quality of tillage depends on the specific soil strength, working depth, soil density and moisture at the time of operation; chisel spacing in combination with working at critical depth could result in different force requirements even for the same soil condition.[15,16,17] Therefore, it is important to analyze the different tillage parameters and their effect on tillage quality.[14a] The draft force demand for a given tillage operation will also be affected by soil conditions and implement geometry.[18,19,20]

Most of the research on draft force demand concerns the performance of narrow tips.[15a] Chisel geometry has a useful working depth, below this depth, also called critical depth (CD), compaction rather than soil loosening may occur and soil specific strength values may increase.[21] The critical depth depends on tip geometry and soil conditions,[22] described that there is a critical depth for chisel performance, at which lateral soil removal occurs, and it depends on implement width, angle of attack, as well as soil density and soil moisture content. Plowing depth depends on the crop to be cultivated, soil characteristics and on the available energy source.[23] In addition, fuel consumption increases proportionally with plowing depth.[24,25] The effect of chisel angle of attack, evaluated by[26,21a] clearly shows how both horizontal and vertical forces increase with increasing angle of attack. The angle of attack at 25 degrees showed a lower specific soil resistance.[27,28,29,30] In one tool configuration, integrating the shallow chisels ahead of the deep chisels significantly reduced the tensile force, indicating that soil spoiling by a separate operation, prior to deep spoiling, provides an effective way to reduce the tensile force demand on the deep chisel.[31] Described how the spacing between chisels can affect the pattern of soil disturbance or spoiling produced by a pair of chisels operating at the same depth.

This could be especially useful in circumstances where the available tensile force is a limiting factor. The addition of shallow chisels placed ahead of deep chisels can reduce the total draft force by approximately 10%. Increased soil disturbance, with lower specific soil resistance, can be achieved by placing wings or sweepers on the chisels, combined with the use of shallow chisels working ahead of the deep chisels. This significantly increases the efficiency of the operation by reducing the specific soil resistance (draft force/disturbed area) by almost 30%.[21b] Soil failure planes developed from wing tips tend to approach the vertical direction rather than developing at approximately 45 degrees to the horizontal. However, the wing width selected will depend on soil strength; impact risk and overall draft force considerations, as well as specific soil strength. Wing widths of 0.7-0.8 of the working depth have been used satisfactorily in many low impact risk soils at working depths between 0.3 and 0.45 m. From a rigorous documented review of the most representative scientific papers on vertical tillage,[32] determined that, for the most efficient use of energy, four operating parameters should be considered before applying primary tillage development. These parameters were 1) working depth based on the critical depth theory. 2) Position and spacing of the chisel bodies. 3) Number of bodies and 4) Use of wings or sweepers. Each of these parameters evaluated individually represented a significant savings in energy demand, which when added together were expected to be more significant.

The purpose of this research was the construction and evaluation of a multipurpose prototype for the simultaneous preparation of primary and secondary soil tillage for crop establishment based on a previously elaborated design, with the objective of reducing operation times and fuel consumption, but without detracting from the quality of the work and increasing yields.

Materials and methods

Location of the test site

The present research work was conducted in the agricultural mechanization department of the Cotaxtla Experimental Station (INIFAP), which is located at km 34.5 of the federal highway Veracruz-Córdoba, Municipality of Medellin de Bravo, and Z.C. 94270, Veracruz, Mexico. The site destined for the realization of the field tests of the prototype will be the lot (D4) with coordinates (18°56'20"N, 96°11'30.3"WO), belonging to the C.E. Cotaxtla, INIFAP. The experimental site is located in a sub-humid tropical climate (AW0) with rainfall in summer AW, a mean annual rainfall of 1200 mm and average temperatures of 24.5°C. The soil is a deep vertisol, flat (slope less than 3%), and rich in exchangeable bases, organic matter, slightly acid pH, heavy texture and dark black color.

The development of this technology for soil preparation was consisted in two phases

Phase one: conceptual design of the prototype (design completed in 2020)

Second phase: construction and evaluation of the prototype (2021-2022)

In this document, the second phase take place.

Second phase: first action: construction of the prototype (chisel plow)

The following considerations applied to the construction and selection of materials:

Tillage factors: working depth, type and degree of soil disturbance are the main factors when selecting tillage implements, but should be consider along with draft and penetration force requirements for effective operation.

Two main variables were consider in the design and selection of geometry for specific tillage implements, according to equation (1) and equation (2):

I. Depth/Width (D/W) ratio (equation 1).
II. Angle of attack of the chisel (α) (equation 2).

It is necessary to distinguish three categories of these tips according to their depth/width ratio (D/W),[33] according to equation (3), equation (4) and equation (5).

I. Depth of teeth (blades) with $D/W < 0.5$ (equation 3).
II. Narrow tips with $1 < D/W < 6$ (equation 4)
III. Very narrow tips with $D/W > 6$ (equation 5)
IV. The chisel angle is indicating by the angle at which the opener creates a horizontal line in the direction of travel.

The positions considered as a function of the working depth of the deep chisel for shallow chisels[33a] were gave by equation (6), equation (7) and equation (8).

I. Depth= 2/3 times the depth of the deep chisel (equation 6)
II. Lateral spacing = 2.5 times the depth of the deep chisel (equation 7)
III. Front spacing = ≥ 1.5 times the depth of the deep chisel (equation 8).

The recommended deep and shallow tooth spacing for good soil loosening was gave by equation (9) and equation (10):

I. 1.5 times the working depth for the single tines (equation 9)
II. 2.0times the working depth for the winged teeth (equation 10).

Second phase: second action: prototype construction (disc harrow)

The following engineering parameters and technical characteristics that define the construction of the harrow were estimated: effective capacity, efficiency, disc types, number of discs, disc size, weight of the harrow, type of hitch, type of wipers, operating speed, theoretical working width, working depth, and draft and power requirements.

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Second phase: third action: construction of the prototype (lump breaker).

It was designed as a circular section placed on an axle, which allows it to roll when dragged over the field, usually by means of a simple hitch at one point. The roller is formed by a single element mounted on a common axle, although with a certain mobility that adjusts to the irregularities of the terrain. The outer diameters of the spiked elements forming the roller are equal, as well as the roughness and profile of its surface, which, together with the weight of the roller, conditions the degree of settlement.

Working width: 1 to 1.10 m, Frame: rigid or by independent elements.

Auxiliary elements: folding: manual or hydraulic; transport wheels.

Hitch: semi-mounted or trailed.

Second phase: fourth action: evaluation of the multipurpose prototype

In this action, the technical evaluation consisted of real operating conditions of the three components (plow + harrow + harrower) in an integral way in comparison with conventional tillage used with three-disc plow + 20-disc lifting harrow applied in a cross pass.

Experimental design for the evaluations

For each evaluation, a useful plot of 115 meters long by 18 meters wide was used for a total area of 2070 m^2 for each of the treatments. The variables quantified were:

I. Power required (W) and draft force (N).
II. Fuel consumption l ha^{-1}
III. Effective working time h ha^{-1}
IV. Disturbed soil area in m^2
V. Aggregate size in mm
VI. Grain yield (corn)

The following equation was used to measure the power required for the implements:

(Equation 11)

$$P = v(F_{ti} - F_t)$$

P = Power required by the implement (W);

Fti = Force required by the tractor plus implement (N);

Ft= Force required only by the tractor (N),

v = travel speed (m/s).

The distance covered in the tests was 115 m and was traveled in an average time, so the average working speed was settled in 4.7 km h^{-1}.

Fuel consumption variable. - A continuous non-stop test will be consisted of, where the intervention of the fuel compensator is limited and a real test can be performed (determined by the international RENAMM code for fuel tests), it will not be repeated given the requirements and nature of the test. For this activity, the full tank method was used, endorsed by the,[34] which consists of filling the fuel tank at the beginning of the test and refilling at the end of the test.

Effective operating time

It is the time necessary to determine the work to be consisted of with the equipment, without taking into account the time to turn around at the headlands and the time of suspension due to failures.

$Teo=Tt\text{-}Tc\text{-}Tf60$ (Equation 12)

Where:

Teo: effective operation time (hours)

Tt: total operating time (minutes)

Tc: time to turn around at headlands (minutes)

Tf: time of suspension due to failures (minutes)

For the remaining variables, a randomized block design with three replications will be used, where the only variant is the tillage applied. Each repetition was represented by the working width of the implement in a complete path along the length of the plot. The statistical program R-language-12 modified, 2012, analyzed the data.

Disturbed soil area

To determine the tillage profiles, three profilometries were done for each repetition, using a rod profilometer according to the methodology described by [21c]. Replacing the graduated rods with a graduated bar. The sampling points selected for each of the replications were measured 30, 60 and 90 m from the starting point of each test, then the rods were inserted one by one, until touching the soil not removed, taking care not to damage the tillage profile. Each rod is at 0.10 m so you have a complete reading of the working depth, previously set on the implement.

Ad= Area disturbed (m^2)

Wd= working depth (m)

Ww=Working width (m)

Draft Force

One of the tests is the determination of draft force; currently the approved method in Mexico (Plow Standard NMX-O-182-SCFI-2003) requires a draft dynamometer, which is placed between two tractors, one tractor with the implement to be evaluated in working position and the other as a power source (Figure 1).

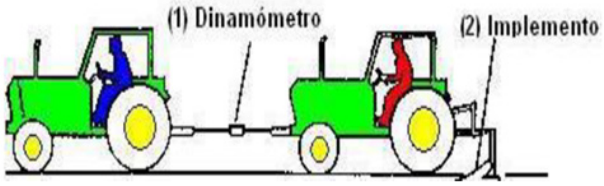

Figure 1 Pulling force of an implement coupled to the tractor.

For data analysis, first, the Excel files are opened and the channels are plotted to observe the behavior of the data. To know the value of the deformation in Volts of the field tests, the Fast Fourier Transform algorithm included in the Matlab program is selected; this algorithm calculates the frequency spectrum of the data obtained, and from here the greatest magnitude occurred and its corresponding frequency can be located.[35] The technical parameter of the Specific Resistance of the soil was given by the total draft force measured on the implement over the working area applied by the width of the implement.

Results and discussion

Figure 1, Table 1 Shows the first plan of the conceptual design of the Multipurpose prototype, with the methodological considerations implemented in the design such as number of components, space between components, number of racks, shape of the racks in each of

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the sections. Likewise, the technical information of the materials to be used for the construction is already available and defined as follows:

I. The frame materials for the chisel plow, harrow and lump breaker were selected with robust profile characteristics, but seeking to reduce the weight with the calculation of efforts in the critical points.

II. The discs and components selected were of commercial type.

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

Technical configuration of the prototype	Quantity/dimensions	Components
Sections	Three	Plow + harrow + Lump breaker
Multi-purpose	3.20 x 1.10 x 1.10 m	Length, width and height
Plow	Three	Semi-straight chisels: two front + one rear with wings
Limiting wheels	2	For depth adjustment
Chassis	Trapezoidal platform with double frame: front and rear	Double platform frame for coupling two shallow chisels at the front and one deep chisel at the back
Disc harrow	12	discs
Chassis	1.4 x 0.70 x 1.1 meters in length, width and height.	Main frame for the coupling of the discs
Cleaners	10	between discs
Lump breaker	7-row sectioned lump breaker with spikes distributed every 0.10 m, for a total of 14 spikes per row and 98 total spikes.	Towed circular lump breaker with power source transmission.
Chassis	0.46 x 1.63 m chassis with 0.22 m diameter tube	Lump breaker frame
Coupling 1	Category II	To tractor third point
Coupling 2	Category II	To third point between sections
Power required	Mínimum 80 hp	Power source
Prototype weight	400 kg	Total weight

Some technical aspects of the prototype were not made public since this equipment is in the process of intellectual property registration

Figure 2,3 Integral Multipurpose Prototype for the integral preparation of primary and secondary soil tillage. Drawings provided by the author, August 2021.

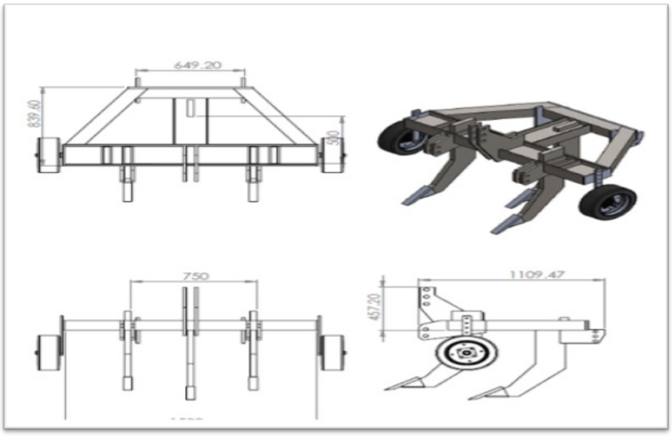

Figure 2 Three chisel plow used individually as a component used for primary soil tillage. Drawings provided by the author, August 2021.

Figure 3 12-disc harrow plus lump breaker, used integrally as components used for secondary soil tillage. Drawings provided by the author, August 2021.

The Multipurpose in Figure 4, is a mechanical equipment integrated by three sections (Chisel plow + Harrow + Lump breaker), which are combined for the simultaneous preparation of primary and secondary tillage of the soil. This technology consists of a single step of soil conditioning (minimum tillage) for crop production, specifically basic grains. The first section has a plow with three semi-straight chisels with narrow tips (two shallow and one deep with fin coupling), the second section has a 12-disc harrow and finally, it

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uses a spike harrower. The working width of the equipment is 1.2 m and it is 3.2 m long. This equipment requires a minimum of an 80-horsepower tractor and was coupled to the tractor's three-point hitch. It also has the capacity to be used by individual sections since it has a hitch coupling on each section.

Table 2 Shows that the data obtained in the performance variables of the multipurpose prototype show a reduction of up to 50% when compared to conventional tillage using a disk plow plus the use of a harrow cross pass. [1a] when using the five-chisel plow compared to the disk plow, found similar results in labor soil tillage [32a]. On the other hand, a higher yield of up to 30 % was obtained from the first crop cycle in grain corn under irrigation condition in a spring/summer production cycle in 2021 year. On the other hand, the specific resistance of the soil identifies the quality of the work performed in a given area and the required draft force, which improves the capacity of the prepared soil. This parameter determined that the multipurpose requires 25% more power, but prepares more soil surface up to 43% more than conventional technology, which reduces the cost of soil preparation with machinery.

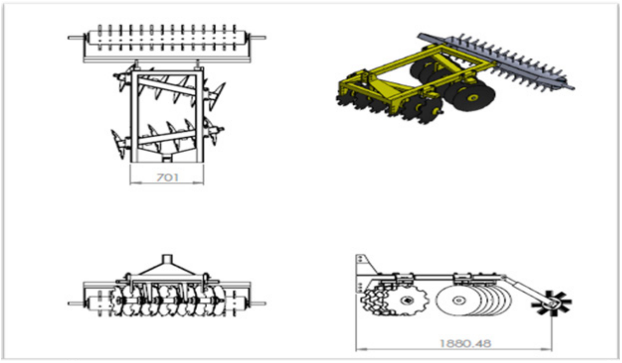

Figure 4 Integral Multipurpose Prototype in evaluation of primary and secondary soil tillage under real operating conditions. Photograph provided by the author, April 2022.

Table 2 Results of variables obtained under field conditions in primary and secondary soil preparation

Test Primary Tillage + Secondary Tillage	Draft Force (N)	Disturbed Área (m^2)	Specific Resistance of soil (N/m^2)	Power demand (W)	Fuel Consumption (l ha-1)	Effective operating time (hrha-1)	Grain yield with irrigation (kgha-1)
Multipourpose*	18082	0.353	51153	23547	33	4.44	8083
Conventional **	14420	0.2	71888	18778	16.75	1.5	5550

*Integrated prototype with three components: three chisel plow + 12-disc harrow and harrower (one pass of the equipment). ** Use of three-disc plow (one pass) + 20-disc harrow (two passes).

Conclusion

The development of a multipurpose technology for the application of primary and secondary soil tillage in a single pass was obtained, capable of obtaining greater efficiency and effectiveness than the conventional system of disk plowing plus the use of a harrow cross pass. The use of this technology is required to eliminate the use of horizontal or disk tillage and to improve the efficiency and improve the profitability and sustainability of staple crops, especially in developing countries.

Acknowledgements

None.

Conflicts of interest

The author declares there is no conflict of interest.

References

1. Reynolds CMA, Capetillo BA, Zapata CM, et al. Vertical Tillage Technology for Primary Soil Preparation. *Global Journal of Agricultural Innovation, Research & Development*. 2022;9:10–19.
2. García I. "Aplicaciones de la robótica en la agricultura, desarrolladas en Holanda", *Vida Rural*, núm. 2013;366:16–19.
3. SIAP-SAGARPA. *Anuario estadístico de la producción agrícola*. 2017.
4. (IDAE). *Ahorro, eficiencia energética y sistemas de laboreo agrícola.* Instituto para la Diversificación y Ahorro de Energía. Madrid, España. Segunda edición corregida. 2006. p. 1–44.
5. Adewoying AO, EA Ajav. Fuel consumption of some tractors models for ploughing operations in the sandy-loam soil of Nigeria at various speeds and ploughing depth. *Agric Eng Int: CIGR journal*. 2013;15(3):67–74.
6. Kichler CMJP, Fulton RL, Raper WC. *Spatially Monitoring Tractor Performance to Evaluate Energy Requirements of Variable Depth Tillage and Implement Selection ASABE annual meeting 2007 paper 071028*. 2007.
7. Pimentel D, Marklein A, Toth MA, et al. Biofuel Impacts on World Food Supply: Use of Fossil Fuel, Land and Water Resources. *Energies*. 2008;1:41–78.
8. Shrivastava AK, Satyendra JHA. Modification and performance evaluation of tractor drawn improved till plant machine under vertisol. *Agric Eng Int: CIGR Journal*. 2011;13(2).
9. Dutzi S. The effects of various tillage and sowing systems on energy input and crop production parameters. *Agricultural Engineering Landtechnik*. 2008;63(6):338–340.
10. Brunotte J, C Sommer. Konservierende Bodenbearbeitung aus Sicht der Wissenschaft. In: Intelligenter Pflanzenbau. S. 110 –144, 3. Auflage. Amazone-Werke. 2009.
11. Cavalaris CK, TA Gemtos. Evaluation of four conservation tillage methods in the sugar beet crop.The CIGR E-Journal.Volume 4. The Internet-First UniversityPress. Cornell University Library. Ithaca, NY, USA. 2002.
12. Hoogmoed WB, R Derpsch. Chisel Ploughing as an alternative tillage system in Parana Brazil. *Soil Tillage Research*. 1985;6(1):53–67.
13. Cadena ZM, T Gaytán M, A Zermeño G. Desempeño de implementos de labranza en términos de consumo de energía y calidad de trabajo. *Revista Agraria Nueva Época*. 2004;1(3):12–17.
14. Camacho-Tamayo JH, GA Rodríguez. Evaluación de implementos de labranza a diferentes velocidades de operación y contenidos de agua del suelo. *Agricultura Técnica*. 2007;67(1):60–67.
15. Arvidsson J, T Keller, K Gustafsson. Specific draught for mouldboard plough, chisel plough and disc harrow at different water contents. *Soil and Tillage Research*. 2004;79(2):221–231.

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16. Raper RL, JS Bergtold. In row subsoiling: A review and suggestions for reducing cost of this conservation tillage operation. *Applied Engineering in Agriculture*. 2007;23(4):463–471.
17. Manuwa SI. Performance evaluation of tillage tines operating under different depths in a sandy clay loam soil. *Soil Tillage Research*. 2009;103(2):399–405.
18. Taniguchi T, JT Makanga, K Ohitomo, et al. Draft and soil manipulation by a moldboard plow under different forward speed and body attachments. *Transactions of the ASAE*. 1999;42(6):1517–1521.
19. Naderloo L, R Alimadani, A Akram, et al. Tillage depth and forward speed effects on draft of three primary tillage implements in clay loam soil. *Journal of Food, Agriculture and Environment*. 2009;76(3):382–385.
20. Olatunji OM, WI Burubai, RM Davies. Effect of weight and draught on the performance of disc plough on sandy loam soil. *Journal of Applied Science, Engineering and Technology*. 2009;1(1):22–26.
21. Spoor G, RJ Godwin. An experimental investigation into deep loosening soil by rigid tines. *Journal Agriculture Engineering Research*. 1978;23(3):243–258.
22. McKyes E. *Soil Cutting and Tillage. Developments in Agricultural Engineering*. vol. 7. Elsevier, Amsterdam. 1985.
23. Pandey MM. *Present status and future requirements of farm equipment for crop production*. Central Institute of Agricultural Engineering, Bhopal. 2004. p. 67.
24. Moitzi G, H Weingartmann, J Boxberger. *Effects of tillage systems and wheel slip on fuel consumption*. In: The Union of Scientists -Rousse: Energy Efficiency and Agricultural Engineering, 7. -9. June 2006, Rousse, Bulgaria. 2006. p. 237–242.
25. Kalk WD, KJ Hülsbergen. Diesel fuel input in plant production. Agricultural Engineering. *Landtechnik*. 1999;54(6):332–333.
26. Payne PCJ, DW Tanner. The relationship between rake angle and the performance of simple cultivation implements. *Journal Agriculture Engineering Research*. 1959;4(4):312–325.
27. Wildman WE, CA Reaves, WR Gill. Effect of slip plow design on draft forces and soil loosening. *Transaction of ASAE*. 1978;21(3):422–426.
28. Magalhães PSG, WR Souza. *Subsolador: Influência de parâmetros geométricos no mecanismo de forças*. 2:1033. XIX Congresso Brasileiro de Engenharia Agrícola, Piracicaba, Sao Paulo, Brasil, 1990.
29. Mathur SM, KP Pandey. Influence of system parameters on performance of reversible hoe type furrow opener for animal drawn seed and fertilizer drills. *In: Proceedings of International Agricultural Engineering Conference*. 1992;1:143–150.
30. Chauduri D. Performance evaluation of various types of furrow openers on seed drills. *A review Agric Eng Res*. 2001;79:125–137.
31. Godwin RJ, Spoor G, Soomro MS. The effect of tine arrangement on soil forces and disturbance. *Journal of Agricultural Engineering Research*. 1984;30(1):47–56.
32. Reynolds CMA, Magaña SCG, Zapata MC, et al. Vertical Tillage Parameters to optimize energy consumption. *Agric Eng Int: CIGR J*. 2015;17(4):130–140.
33. Godwin R, O´Dogherty M. Integrated soil tillage force to prediction models. *Journal of Terramechanics*. 2007;44(1):3–14.
34. OECD. *Fuel consumptions models for Tractor Test Report*. University of Nebraska at Lincoln, 2016. p. 1–10.
35. Mojica LED. *Evaluación de discos cortadores de residuos y abresurcos para labranza de conservación empleando equipos multiusos de tracción animal*. Tesis de licenciatura, Instituto Tecnológico de Veracruz, México. 2000.

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