A DOUBLE SHANK SUBSOILER FOR SUGAR CANE CULTIVATION

J.S. Torres, L F. Villegas, F. Villegas & J.P. Raigosa
CENICANÁ, Colombian Sugar Cane Research Center, A.A. 9138, Cali Colombia.

ABSTRACT

There is a general tendency to emphasize deep cultivation practices such as subsoiling because this is thought to be an operation to guarantee high cane production. The conventional curved subsoiler disturbs the soil profile to a given depth, from which point downwards the soil is compressed to the sides leaving a compact groove where excess water accumulates.

A double shank subsoiler based on the critical depth concept was developed to increase the breakup area within the soil profile and to avoid leaving the groove. The shank in front tills the soil down to the critical depth and the rear shank breaks and loosens the soil to a greater depth resulting in an apparent displacement of the critical depth. The subsoiler performed according to the design concept, the breakup area is bigger and deeper than the one obtained with the conventional subsoiler. The subsoiler was attached to an instrumented category III quick-attaching coupler to measure side and vertical implement components of load. The new subsoiler requires 200 to 225 hp, which is used efficiently to break up the soil. The double shank subsoiler, called “Cenitandem,” is widely used for reduced tillage planting and ratooning of cane fields harvested mechanically.

Keywords: Sugarcane, subsoiler, cultivation, critical tillage depth.

INTRODUCTION

Cane harvesting and planting in Colombia is a year round activity. Harvesting in wet periods makes it difficult for infield traffic, even if equipment is mounted on tracks or on high flotation tires. Direct damage to the cane stool and soil compaction may be serious and it is often necessary to perform early renovation of the cane fields. The presence of water on the soil surface due to frequent rain or high water tables cause delays to the entry of machinery to the fields resulting in having idle land for several months which affects economic return.

Various machines and implements are used for mechanical eradication of the old stool and subsequently for the preparation of a good soil bed where the cane seed-sets are to be placed. Most of the time, the sequence, the type of implements and the number of passes of the machinery are established either by tradition or availability of some farm implements as well as by the good experience of the neighboring farmers with a given practice or implement. Each field at the time of cultivation presents conditions that may require the selection of a given sequence or number of passes of an implement, therefore it is not intended to standardize land preparation or cultivation methods to cope with all soil condition and compaction problems.

The effective use of agricultural machinery is of worldwide interest due to the high cost of machines, non-rational use of farming equipment and the need to compete in the world market with low production costs (De Beer et al., 1993). In the Cauca river valley, farmers usually talk about land preparation and cultivation
practices in terms of “standards” which are equivalent to hours per hectare required to execute a given practice sacrificing effectiveness of the task to increase cane yield.

Land preparation for planting involves different practices which may include mechanical stool eradication with a heavy disk harrow, chisel plowing, harrowing, cross subsoiling, light disk harrowing and furrow opening. The number of passes and the type of implement used for each practice vary according to the experience and criteria of the persons involved in land preparation, as well as the condition of the equipment.

During land preparation there is a natural tendency to emphasize deep cultivation as an unavoidable requirement to guarantee high production. It is necessary to recognize specific climate conditions, impeding soil layers or the need to incorporate chemical amendments to justify deep cultivation practices such as subsoiling. Yang and Quintero (1986) in the Cauca valley of Colombia, found a small response on cane production to deep cultivation practices on Vertisols and Inceptisols. The increases in cane yield associated with deep cultivation were, however, not enough to justify land preparation treatments that involved subsoiling.

Soil compaction effects on cane yield vary with cane variety, rainfall distribution and irrigation management. The presence of impeding layers in the subsoil limit root growth and subsequently reduce nutrient and water availability to plants. Compacted soils require frequent application of irrigation. Ibrahim and Miller (1989) working with cotton and potatoes found that subsoiled and irrigated fields presented less stress symptoms than non-subsoiled and irrigated fields.

Varieties with inhibited shallow root systems are seriously affected by compacted soil layers. Sandy layers of soil with low organic matter content are easily compacted in wet periods during the passage of agricultural machinery. Ricaud (1977) in Louisiana found 19 to 40% cane yield increase after deep subsoiling of a sandy soil. On the other hand, Moberly (1972) demonstrated in South Africa that deep subsoiling is not a practice to guarantee higher cane yields. In Hawaii subsoiling has been used as accompanying practice to facilitate disk plowing when there are compacted layers in the subsoil (Trouse and Humbert, 1959).

Deep subsoiling is a general practice for land preparation and ratooning of cane fields in the Cauca valley. It is done without taking into consideration soil conditions with regard to degree of compaction and moisture content. Soil profiles have been dug in experimental and commercial plots along the Cauca river valley and it is common to observe lose soil down to a given depth. From this point downwards the soil is compressed by the passage of subsoiler shanks creating a cavity where excess water accumulates. Baver (1956) indicates that part of the energy transferred by the tractor to the subsoiler is used to overcome cohesion forces between soil particles and as friction between the soil particles and the subsoiler shank. A large percentage of the power is used by the shank of the subsoiler to push the particles aside leaving a groove. Compaction of soil around the grooves left by the subsoiler takes place under both dry and moist conditions.

The aim of the present work was to evaluate the performance of a double shank subsoiler designed to create a displacement to the critical tillage depth in such a way that deeper soil would not be compacted.

DESIGN PRINCIPLES

Single curved shank subsoiler is in common use in the Cauca river valley for both land preparation and ratooning cultivation. The conventional subsoiler implement involves the use of two curved shanks of 60 to 80 cm in length with a sweptback blade and the spacing between is set according to the furrow spacing. Subsoiling is a practice that requires the use of tractors with 150 hp.

Studies on soil mechanics conducted in the former Soviet Union by Zelenin and Kostritsyn cited by Gill and Vanden Berg, 1968, Mckyes (1985), Godwin and Spoor (1977) recognized that a narrow and vertical soil
cutting tool might not be able to lift soil up over its entire length. A critical tillage depth was defined as that depth below which soil is not ruptured or lifted toward the soil surface, but rather is compressed to the sides of the tool without causing breakup. The critical depth depends on the tool geometry and hardness of the soil; below this depth less energy is required to compress and move the soil particles horizontally around the tool than is required to slide the soil towards the surface.

Based on the concept of critical tillage depth developed by Zelenin and Kostritsyn a double shank or tandem subsoiler was developed for land preparation and ratooning of sugarcane. The present implement has two aligned curved shanks arranged as a tandem (Figure 1). The Shank in front is supposed to till the soil up to the critical depth and the rear shank is supposed to break up and loosen the soil to a greater depth forcing an apparent displacement of the initial critical depth in such a way that the ruptured area is deeper and wider. The implement thus works in layers, a first layer of 25 to 30 cm of soil is ruptured by the front shank and the rear shank works on a second layer from 30 to 60 cm creating a bigger ruptured area within the soil profile.

![Figure 1. Schematic of the double shank subsoiler](image)

FIELD EVALUATION

The double shank subsoiler was first evaluated at the Riopaila sugar estate on a heavy clay soil (Vertisol). The field appeared quite dry on the surface but a few centimeters down the soil was quite wet. The degree

![Graph showing the area covered by the double shank subsoiler](image)
of soil breakup obtained after the passage of the double shank subsoiler was compared with the conventional single curved subsoiler. Both implements were attached to a Caterpillar AG-6 steel track tractor with 240 HP at the draw bar. After the passage of the implements soil profiles were dug (1.5 × 1.0 m²) a metallic grid 10 cm × 10 cm was used to identify the soil disturbance boundaries and therefore the area of the soil profile affected by each implement (Figure 2).

![CONVENTIONAL SUBSOILER: 1400 cm²](image1)

**Figure 2.** Area of the soil profile disturbed by the double shank and conventional subsoilers on a Vertisol.

The soil breakup area obtained by the passage of the tandem subsoiler was 2500 cm² which is 78% larger than the disturbed area of the conventional subsoiler (1400 cm²); both implements had the same type of sweepback blades at 20°. Besides the differences in soil disturbance areas, the tandem subsoiler produced a smaller clod size while the conventional subsoiler produced some big cracked surfaces within the soil mass; the soil appeared fractured with clod sizes larger than 10 cm. The design hypothesis of the double shank subsoiler was proved acceptable in this wet and heavy soil.

The tandem subsoiler was also tested on a Mollisol of the Manuelita sugar estate. The soil was friable and the moisture content was adequate for subsoiling. In this case the tandem subsoiler was compared with a Paratill, an implement that is very popular in USA for land preparation and cultivation. The Paratill consists of two angled shanks that run parallel to each other; the angled shank design offers the possibility to orient them towards the inside (convergent) or divergent as was the case in the present evaluation. The shanks were set 50 cm apart and a ripper was placed in the middle to break the clods. Both implements were coupled to

**DOUBLE SHANK SUBSOILER: 3000 cm²**
a Caterpillar Challenger 65 tractor with 280 HP. The area disturbed by the tandem subsoiler was 3000 cm$^2$ which is larger than the 1800 cm$^2$ disturbed of the Paratill (Figure 3). The ruptured area of the Paratill clearly identifies the geometry of the implement and the passage groove of the divergent shanks. The average clod size obtained with the tandem subsoiler was smaller than the average size of the Paratill.

![Figure 3. Area of the soil profile disturbed by the double shank and the paratill subsoilers on a Mollisol.](image)

**FIELD USE**

The good results obtained during the field test of the double shank subsoiler encouraged us to use this implement as a primary tool for renovation of sugar cane fields following the reduced tillage system for planting.

Soils of the Cauca river valley are fine textured belonging mainly to Mollisols, Vertisols and Inceptisols. The general topography is flat with slopes less than 1.5%, where the risk of wind or soil erosion is small and therefore the main interest to opt for minimum tillage practices is to reduce production costs. Conventional land preparation includes mechanical stool eradication of the old crop. This is done by three or four passes of a heavy disk harrow, disk or moldboard plow operating 20 to 25 cm deep. Most of the time mechanical stool eradication is not an effective practice to destroy the previous crop because the whole stool or part of it can be partially buried or transplanted requiring more passes which increase the cost of land preparation (SASA, 1978-1979).

Mechanical stool eradication in the Cauca valley could represent up to 40% of the total land renovation costs. Chemical stool eradication with a cane killing herbicide is thus an attractive alternative to reduce cost. Roundup at a rate of 8 to 10 l/ha (Iggo and Moberly, 1975; Hadlow and Millard, 1977; Chedzey and Findlay, 1985) is the most effective and common herbicide used for eradicating old sugar cane stools. Fusilade is also being used in the Cauca valley as an effective cane killer at a rate of 3 to 4 l/ha.

After harvesting the crop that is to be eradicated, it is necessary to wait for three to four weeks until the new regrowth has reached a height of 20 to 25 cm before applying Roundup (4 to 6 l/ha) or Fusilade (3 to 4 L/ha). Due to the tropical weather conditions that prevail in the Cauca valley, the cane is actively growing the whole year round; this allows for the application of reduced rates of herbicides to kill the cane stool. A few days after spraying the herbicide, a first pass of the double shank subsoiler is executed to loosen the soil within
the old inter-row. Right after subsoiling with the double shank subsoiler, a fertilizer applicator incorporates the fertilizer and loosens the soil to open a furrow where the seed sets of the new crop will be placed. In order to incorporate the old stool into the soil and to prepare the soil profile within the new inter-row space, a second pass of the double shank subsoiler is conducted as soon as most of the old stools have died.

MECHANICAL PERFORMANCE

The double shank and conventional curved subsoiler were attached up to a category III quick-attaching coupler for tractors equipped with a three-point linkage hitch system. A transducer consisting of precision strain gauges was placed between the coupler and the subsoiler for each of the three points, acting as a dynamometer (Figure 4) to measure side and vertical load components. Axial loads on the rear shank were measured by means of an instrumented bar.

![Figure 4. Schematic of three-point hitch with instrumented transitions](image)

Axial forces were registered with four active strain gauges (Micromerasurements type CEA-06-250UN-350) placed at 45°, 90°, 225° and 270° around the circumference of the extensions legs. Two strain gauges (EA-06-250MQ-350) placed at 0° and 180° were used to register vertical forces. Strain gauges were wired for maximum sensitivity and temperature compensation following a Wheatstone bridge arrangement. The data acquisition system was integrated by a 21-XL Campbell Scientific Micrologger which provided a constant 2500 mV excitation voltage to each strain gauge. Deformation of the strain gauges causes a voltage reading (output) that is converted into force by means of the following calibration equations for the extensions and transducer bar.

\[
\text{Tension force (Kgf)}: \quad F_t = 166667 X - 83333
\]

\[
\text{Compression force (Kgf)}: \quad F_c = 33333 X - 16667
\]

\[
\text{Compression force on the transducer bar (Kgf)}: \quad F_{ct} = 2000 X - 1000
\]
Recorded force readings were stored in the micrologger memory and transferred to a computer for analysis. The power required by the implements was obtained by multiplying the average working velocity and the summation of forces in the horizontal direction recorded at the three point hitch. Vertical and side forces were taken as a reference as part of the performance evaluation to find the draft required by the double and single shank subsoilers.

The double shank and the curved conventional subsoilers were attached to a Caterpillar 45 Challenger tractor and used on Mollisols, Inceptisols and Vertisols. The double shank subsoiler had a power draft requirement that varied between 200 and 225 HP while the conventional curved subsoiler had a lower power draft requirement (120 to 150 HP). The main justification of the higher power requirement of the tandem subsoiler is the superior tillage conditions, improved soil loosening and ruptured area achieved by this implement.

CONCLUSIONS AND RECOMMENDATIONS

The double shank subsoiler was designed following the concept of critical depth developed by Zelenin and Kostritsyn in the former Soviet Union. The soil area disturbed by the present subsoiler was 60 to 70 % bigger than the area disturbed by the conventional curved subsoiler and the Paratill subsoiler when used in Mollisols, Inceptisols and Vertisols. The new subsoiler requires a power draft that varied between 200 and 225 HP which is 50 to 60 % higher than the power required by the conventional subsoiler (120 to 150 HP). The extra power required by the new subsoiler is used efficiently to break up the soil creating a good till with small size clods; on the other hand there is a new critical depth which results in a deeper and wider ruptured area within the soil profile. The compacted groove left below the critical depth by the passage of a single shank subsoiler was not observed with the double shank subsoiler which implies a better use of the energy transferred by the tractor to the implement.

The double shank subsoiler known locally as “the Cenitandem” is a very efficient implement that has been widely accepted in the Cauca river valley for reduced tillage planting. Sugar mills that just started mechanical harvesting are using this subsoiler as a standard ratooning practice to ameliorate compaction created by the intense traffic of infield equipment. For ratooning purposes a shorter shank should be used which results in reduced power requirements.

REFERENCES


Torres, J.S., S.J. Yang, F. Villegas 1990. Soil compaction and cane stool damage by semi-mechanized harvesting systems in the wet Season. Sugar Cane N° 5: 12-16


RESUMEN

La subsolación es una práctica que se realiza como una condición indispensable para obtener buenas producciones. El subsuelo curvo convencional usado en el Valle del Cauca distura el perfil del suelo hasta cierta profundidad a partir de la cual el suelo es comprimido hacia los lados dejando una cavidad donde se acumulan los excesos de agua.

Se desarrolló un subsolador con doble vástago, basado en el concepto de la profundidad crítica, para aumentar el área roturada y evitar la formación de una cavidad compacta. El vástago delantero rotura el suelo hasta la profundidad crítica y el vástago trasero rompe y rotura el suelo a mayor profundidad lo cual resulta en un desplazamiento aparente de la profundidad crítica de laboreo. El subsolador se desempeñó de acuerdo a la hipótesis de diseño. Para medir las fuerzas verticales y horizontales se instrumentó un enganche rápido. El nuevo subsolador requirió entre 200 y 225 HP, los cuales son usados eficientemente para roturar el suelo. Se usa el subsolador de doble vástago denominado "Cenitandem" es usado ampliamente para labranza reducida y para el subsuelo de socas cosechadas mecánicamente.

SOUSS-SOLEUR DOUBLE POUR LA CANNE À SUCRE

RÉSUMÉ

Il y a une tendance générale à l'utilisation des techniques de travail du sol profond, telles que le sous-solage, car elles sont considérées comme favorisant une production de canne élevée. Le sous-soleur conventionnel à dents incurvées modifie le profil du sol jusqu'à une profondeur donnée à partir de laquelle le sol est tassé et laisse une semelle de labour où s'accumule l'excès d'eau.

Le sous-soleur double basé sur cette observation a été développé pour augmenter le volume de sol travaillé. La première dent de sous-solage travaille le sol jusqu'à la profondeur critique et la seconde dent fissure le sol et l'ameublit à une profondeur plus importante.

Avec ce modèle de sous-soleur, la zone travaillée est plus large et plus profonde que celle obtenue avec le sous-soleur classique.

Le sous-soleur a été monté sur un releveur catégorie 3, des mesures d'efforts vertical et latéral ont été effectuées.

Pour réaliser un travail efficace de sous-solage, cet outil nécessite une cellule motrice d'une puissance de 200 à 225 hp. Le sous-soleur double appelé "Cenitandem" est largement utilisé pour diminuer les travaux du sol à la plantation, ainsi que les travaux d'entretien après la récolte mécanique.

MC: canne à sucre, sous-soleur, travail du sol, profondeur de travail critique