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Study of a Combined Subsoil Chiseler and Rotary Furrower and its Application in Agricultural Production In Vietnam

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1 Introduction

Sugar cane is an industrial cash crop and is able to be grown on various types of soil. For a long time, the preparation of land and furrow making has been done by farmers, and in sugar cane growing areas this has been achieved by the use of hand tools, implements, and also common machinery like the moldboard plow, disc plow, harrows and ridgers. In order to meet agronomic requirements, multi-pass tilling methods are often used which results in a prolonged time for preparing the land. On the other hand, the effect of the tractor and other implements in a sequence of multi- pass tillage operations may cause soil compaction, destruction of the soil structure, an increase in soil erosion, higher costs for land preparation and, thus, little benefit for cane growers.

In developed countries, based upon a high technical standard in cane cultivation, the tilling operation for cane planting has been almost totally mechanized, with deep plowing and furrowing up to 40-50 cm deep.

Presently, based upon the tilling procedures being commonly applied in cane growing areas of the Viet nam, the tilling depth for cane planting is generally of 25-30 cm while the cane roots may reach up to 60 cm deep. Higher cane and yield would be obtained if deep chiselling could be performed. Experimental studies conducted by the Lam son Sugar cane Company in Thanh Hoa province on a 400 ha area under cane showed that if an increased investment (principally in deeper tilling) of VND 500,000 per ha, a cane yield of 80-100 tons per ha was obtained, which is 20% higher than that obtained prom conventional tilling.

Recently, together with the mechanization development and application of technical and scientific progresses, the cane production technology has been correspondingly improved. Deeper plowing has been performed, therefore, the production of cane has increased gradually from 40 tons/ha in 1980 up to 50-60 tons/ha in 1996. However, in view of the Vietnamese cane growers and scientists, the current tilling implements for cane planting in favour of its growth do still not meet the desired soil depth and the cost for land preparation remains too high within the total investment cost for cane growing.

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According to the study results obtained from agronomists, deep subsoil chiselling is not required over the whole surface of the field but it is useful where cane is to be planted to facilitate its root growth into subsoil. Deep chiselling only at the place where cane will be planted helps reduce the cost of tillage, and also, reduces soil erosion problems.

The current implements for use in soil furrowing for cane planting in Vietnam are of pull-type ones that provide a depth up to only 25-30 cm when they are mounted on the tractors as is commonly used in Vietnam. Implements for deep chiselling on the field are still not available. Therefore, the question is, whether a machine which combines a rotary furrowing and a subsoil chiselling machine could be developed, then the cost for tillage would be reduced while maintaining the agronomic requirements of intensive cane cultivation for increased cane yield.

2 Objectives of the study

The study on the design development of the machine as envisaged above is aimed to obtain the following:

- Minimize the number of trips over the field.
- Obtain appropriate soil depth as required.
- Increase the pulverization of the soil for cane planting.

The machine should be adapted to the practical conditions in terms of the available power sources and soil types in agriculture.

3 Selection of the working principle and development of a prototype

Based upon the results from the study on the physical and mechanical characteristics and agronomic requirements of the soil for cane growing and the analysis of the advantages and disadvantages of the possible working principles and components of the furrowing machines currently used in cane growing regions, a working model of furrow making for cane planting has been developed by combining the pull-type and power rotary-type working parts into one unit. The passive or pull-type component is actually a chisel type subsoiler which is attached to the front and is used to break through and shatter the soil. The active part is a powered rotary tiller with reverse rotation and a narrow width of 30-35 cm. Two discs of 320 mm diameter are mounted on the horizontal shaft of this tiller on which 12 L shaped blades are attached. During operation the blade cuts a segment of soil, pulverizes it and throws the pulverized soil to both sides thus forming a furrow for cane planting. The soil segments being thrown from the blade ends will hit against a fender, further pulverizing the cut soil. Those soil pieces that are still left in or which fallen down the furrow bottom will be moved again to the tiller by a sweeping device and therefore will be thrown up from the bottom of the furrow.

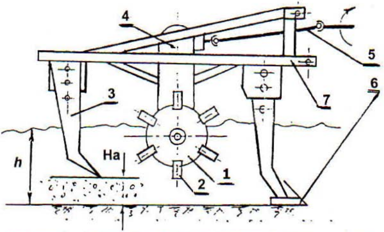

Fig. 1: Diagram showing the working principle of the combined deep subsoil chiseler and rotary furrower

1 - Rotary drum disc 2- Blade of L shape 3- Device for sweeping soil from the furrow bottom 4- speed reducer 5- cardan shaft 6- chisel 7- Frame

The active working components are disc 1, on which blade 2 is attached. The rotary drum rotates at a direction that is opposite to the movement direction of the tractor. Torque is transmitted from the PTO shaft of the tractor to the cardan shaft 5 and the speed reducer 4.

Study results on the developed prototype as mentioned above shows that: the power requirement and working quality of the machine during operation depends largely on the number of blades (Z) being attached on the disc, the diameter of rotary drum (D), the rotation speed of the drum (n) and the forward speed of the tractor aggregate (V_m). Apart from these factors, the physical and-mechanical soil properties and soil type and condition are also factors which greatly affect power consumption and the quality of making furrow (as indicated by the amount of soil which falls down to the bottom of the furrow, the degree of soil surface level, the desired dimensions of the furrow). The working width of the blade has much influence on the process of throwing soil segments away from the bottom. Also, the inclination angle of the main blade against the auxiliary blade is a parameter which affects the process of soil cutting and throwing.

The interrelationship between the above parameters is quite complicated during the operation of the machine and is difficult to determine by mathematical analysis. Therefore, it is necessary to carry out experimental studies to determine the optimal parameters of the working devices for use in the calculation, design and manufacture of the combined subsoil chiseller and rotary furrower for cane planting.

4 Experimental results

In order to evaluate the working quality of the machine, the results of interest where selected as the Power consumption (y_1) and the amount of soil being fallen back to the bottom (y_2).

Power consumption is measured through measuring torque on the rotary drum shaft. Draft is measured by using strain gages which employ the principle of a bridge tensor circuit.

4.1 Results obtained from the single factor experiment

Based upon previous studies on the rotary tiller and theoretical studies, it was observed that the rotary drum size and speed of rotation are the two parameters which greatly affect the working of the machine.

In order to study the effect of the diameter and the rotary drum speed on the output indexes, relevant experiments have been conducted on the soil bin at the Vietnam Institute of Agricultural Engineering- Ha Noi, which is an old alluvium soil layer with the soil hardness of 18-25 kg/cm^2 and moisture content of 17-24%.

Through the experiments the dependence of power consumption of the machine (y_1) and the amount of soil which fell back to the furrow bottom (y_2) on the variable diameter of the rotary drum (X_5) are indicated by the equations below:

$$y_1 = 17.31 + 0.0362\ X_5 + 7.657\ 10\text{-}5\ X_5^{\ 2}$$

$$y_2 = -\ 641.9 + 0.503\ X_5 + 238{,}545.33\ / x_5$$

The power consumption (y_1) and the amount of soil which fell back (y_2) obtained from experiments with variable rotation speed of rotary drum (X_3) are indicated below:

$$y_1^{\ *} = 13.22 + 0.03\ X_3 + 10.99.10\text{-}5\ X_{32}$$

$$y_2^{\ *} = -584.03 + 0.65\ X_3 + 153{,}419.65/X_3$$

From the above experimental results, it is seen that the suitable range of the variation of the rotary drum and rotation speed of the rotary drum are:

D =500-600 mm, n =320-440 RPM.

4.2 Results obtained from the multi-factor experiment

Based upon the results from the preliminary experimental study and the single factor experiment, the multi-factor experiment was based upon variation of the following parameters: working width of rotary blade (X_1) from 60-80 mm, cutting angle of rotary blade (X_2) from 110-120°, rotation speed of rotary drum (X_3) from 320-440 RPM, forward velocity of the machine aggregate (X_4) from 0.31-0.75 m/s and the rotary drum diameter (X_5) from 500 -600 mm.

The experiment was carried out following Hartly's second order experimental design with the selected objectives being: the power requirement value is among the range of farm tractor output being commonly used in agriculture; the amount of soil falling back to the furrow bottom should be within the limitation of agronomic requirement (H< 5 cm) with fastest speed of operation possible.

The solving of the mathematical model for the negotiable optimal results in the optimal parameters as follows:

X_1=72mm; X_2=108°; X_3=410 RPM; X_4=0.41 m/s and X_5=586 mm.

4.3 Results obtained from field operation

Based upon the experimental study of the model on the soil bin, the method of similitude and dimension analysis has been applied in an attempt to define a series of the machines with different outputs for use with different tractors in agriculture of Vietnam.

A machine prototype has been manufactured for use with the tractor MTZ-50 with the following technical specifications: rotary drum diameter D = 600 mm, forward velocity: V_m =0.5-1.05 m/s, rotation of rotary drum n = 380 - 400 RPM, number of rotary blades on the disc Z = 4, working width of the blade b_d =75 mm, the angle between the principal and the auxiliary blade a = 120°, setting angle of the rotary blade g = 45° and the angle of blade grinding i =18°.

The results from field tests at several locations in Thanh Hoa province under the conditions of soil hardness : H_{av} =18-25 kg/ cm^2, and the soil moisture content W = 18-22% indicate that the machine works well. The working quality of the tested furrow meets the agronomic requirements i.e. the depth of furrow > 30 cm, width of the furrow varying from 25-30 cm, the soil which fell down into the furrow 5-7 cm, the depth of chiselling relative to the field surface is 40-45 cm. After operation, the proportion of the soil which is broken down to lumps within 3-5 cm in size accounts for 80% of the total without leaving any soil segments bigger than 10 cm - assuring the quality of land preparation for cane planting. The soil is thrown up to both sides of the furrow thus facilitating the next operation of covering the seed pieces with shattered soil after planting.

The machine has been transferred to several cane growing zones for production in the provinces of Thanh Hoa and Hoa Binh. The machine is stable during operation and its working quality when furrowing for cane planting meets the requirements as given by agronomists.

Fig 2: Combination of subsoil chiseler and rotary furrower

5 Conclusions

The use of a new type of subsoil chiseller and rotary furrower will help to lower the cost of land preparation for cane planting, increase cane yield by 20% when compared to existing methods, reduce the time for land preparation for cane planting and increase the protection capacity against soil erosion. Through the results obtained from the study and field operation, the working principle combining passive and active devices for a subsoil chiseller and rotary furrower proved to be suitable. The machine has promising potential for applications in intensive sugar cane cultivation for increased cane yield in Vietnam.

6 Summary

In the mechanization of cane production, it is possible to separately mechanize the land preparation for cane planting. However, in order to increase cane yield and the quality of sugar cane, it is better to carry out integrated mechanization.

From the analysis of the advantages and disadvantages of the conventional machinery of land preparation for cane planting like moldboard plow, disc plow, subsoil chiseler etc., a simple model has been established. It is composed of an active component (rotary furrower) and a passive component (subsoil chiseler), both are installed on one unit. The prototype can work at a depth of over 40 cm. Initial test results show that the machine developed could help overcome the disadvantages generally encountered with current machinery for preparing soil and making furrow for cane planting. Optimum parameters of the rotary furrower have been determined: the rotary speed 380-400 RPM, rotary drum diameter from 550-600 mm, forward velocity of the tractor from 0.75-1.05 m/s.

7 References

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