

Design and experiment of the notched disc ditching and fertilizing machine

W H Huang, X H Dong, M Li, L J Wei, C Ge and Z J Niu

Agri-Machinery Research Institute of Chinese Academy of Tropical Agricultural Sciences

271253449@qq.com

Abstract: In order to meet the fertilizer agronomic requirements of sugarcane in the hot areas of South China, using the method of notched disk ditching to design a notched disk ditching and fertilizing machine. The static equilibrium equation is established by having the force analysis that the notched disc plow cuts the sugarcane leaves, and the diameter and structural parameters of the notched disc plow are determined. The results of field test show that the working performance of each component of the notched disk ditching and fertilizing machine is stable, and it can primely cut the soil, ditch and prevent winding in the sugarcane fields with a lot of weeds or sugarcane leaves, it meets the fertilizer requirements of sugarcane in the hot areas of South China.

1. Introduction

In the hot areas of South China, sugarcane, sisal, rubber and other crops are planted, and they all need fertilizing, ridging and other management procedures, however, the main way is to use artificial ditching, fertilizing and ridging now, each person can only finish two mu per day, the labor intensity is large and the efficiency is low, and the fertilizer depth is 5-10cm, some even failed to broadcast into the ditch or failed to cover the fertilizer, it has poor quality of work and serious waste of fertilizer, and it is easy to burn crops to affect the growth of crops in high temperature^[1]. The existing sugarcane fertilizing machines for ditching are rotary knife or plow, when they work in the sugarcane fields covered with a lot of weeds or sugarcane leaves, it is easily entangled and clogged to be unable to operate normally. Therefore, it is of great significance to design the notched disk ditching and fertilizing machine for the sugarcane fertilization operation in the hot areas of South China^[2].

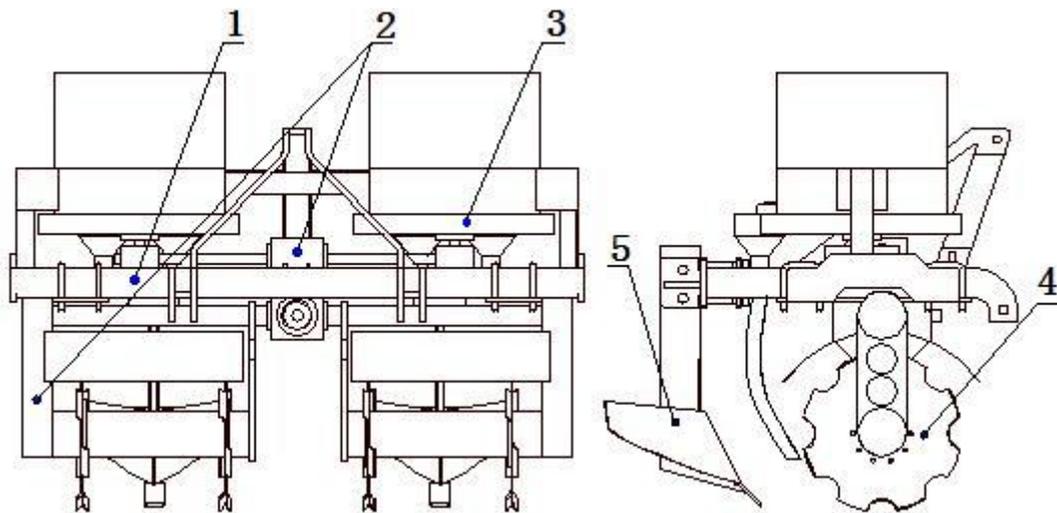
2. The structure and working principle of the whole machine

2.1 Whole machine structure

The notched disk ditching and fertilizing machine is mainly composed of a frame, a transmission mechanism, fertilizing device, a notched disk plow, ridging plough and other parts, the structure is shown in Figure 1.

The fertilizer applicator is connected to the tractor through the three-point mounted mechanism, and two notched disks are installed under the frame, two fertilizer boxes are installed on the left and right sides of the frame, each fertilizer box has two fertilizer scrapers and two fertilizing hopper, the upper end of the fertilizing hopper is a cylindrical cone and the lower end is cylindrical export. The guide tube is installed below the fertilizing hopper and the ridging plough is installed in the rear end of the machine frame.





1.Frame 2. Transmission mechanism 3.Fertilizing device 4. notched disc plow 5. Ridging plough
Figure 1. Schematic diagram of the notched disc ditching and fertilizing machine

2.2 Working principle

The machine carries out the process of ditching, fertilizing and earthing at the same time, the tractor suspends fertilizing machine to operate, at the same time, the power of the tractor is passed through the power output shaft and the universal joint to the intermediate transmission, and it through a pair of bevel gear decelerating and changing the direction to the four output axis. The two output axes above the intermediate gearbox will pass the power to the worm gear reducer to drive the turntable. Under the action of centrifugal force, the fertilizer comes across the scraper and moves laterally to the edge of the disk, then it falls to the ditch. At the same time, the power is transmitted through a pair of spur gears to the two output axes below the intermediate transmission, then it passes the universal joint to the two sides of gear reducer to drive the notched disk plow to turn the ditch, the ridging plough puts soil to both sides to turn cover fertilizer, while covering the root of sugarcane, thus it can complete furrowing, fertilizing, ridging and other operation processes.

3. Design of key parts

3.1 Design of the notched disc plow

3.1.1 Determination of the diameter of the notched disc plow.

To ensure good permeability of the notched disc plow on the surface covered with sugarcane leaves, we need to ensure that sugarcane leaves can be cut off by notched disc plow but not driven by displacement. By static equilibrium analysis, it is known that the displacement of the sugarcane leaves are not driven by the notched disc plow, which needs to be satisfied^[3].

$$f_1 + f_2 \geq N \quad (1)$$

Type f_1 —Friction between the ground and the sugarcane leaves

f_2 —Friction between the notched disc plow and the sugarcane leaves

N —Horizontal thrust imposed on sugarcane leaves by the notched disc plow

The diameter D of notched disc plow, the penetration depth h of the notched disc plow, the diameter D of sugarcane leaf (sugarcane leaf is regarded as cylindrical friction), friction angle of sugarcane leaves and ground and the friction angle of the sugarcane leaf and the notched disc plow are introduced. Decomposition of the type (1) can be obtained, the condition of sugarcane leaves is not driven by the notched disc plow when cutting is.

$$\arccos\left(1 - \frac{2h + d}{D}\right) \leq \alpha_1 + \alpha_2 \quad (2)$$

For the sugarcane in the southern hot area, the average diameter of the leaves of sugarcane is 15 millimeters^[4], the penetration depth h of the notched disc plow is about 140 millimeters, the friction angle between sugarcane leaf and steel plate is calculated at 28° ^[5], the friction angle of the sugarcane leaves and the ground is calculated at 20° , then the diameter of the notched disc D is 440 millimeters. Because the diameter of the notched disc plow directly affects the height of the whole machine, if the height of the whole machine is too high, it will cause the high labor intensity of the fertilizer, the diameter of the notched disc plow is 440 millimeters.

3.1.2 Structural design of the notched disc plow.

In order to improve the cutting ability that notched disc plough cuts sugarcane leaves, we need improve the properties of soil, cutting and anti winding, it has the advantages of comprehensive standard notch disc cutter and runner boot. Through theoretical analysis and comparison test, and referencing to the existing opening mechanism of the existing no tillage narrow row seeder, it is concluded that the notched disc opening plow of the notched disc ditching and fertilizing machine adopts the two sides bending structure of the slider notch.

In order to ensure that the length of the notch arc is greater than the maximum cutting arc and ensure the performance of cutting and embedding. It is calculated by data of the penetration depth h of the notched disc plow is about 140 mm, the diameter of the notched disc plow is 440 millimeters and the speed of the unit is 1 m/s, the notched disc plow sets 8 gaps.

To sum up, the structure of the notched disc plow is shown in Figure 2.

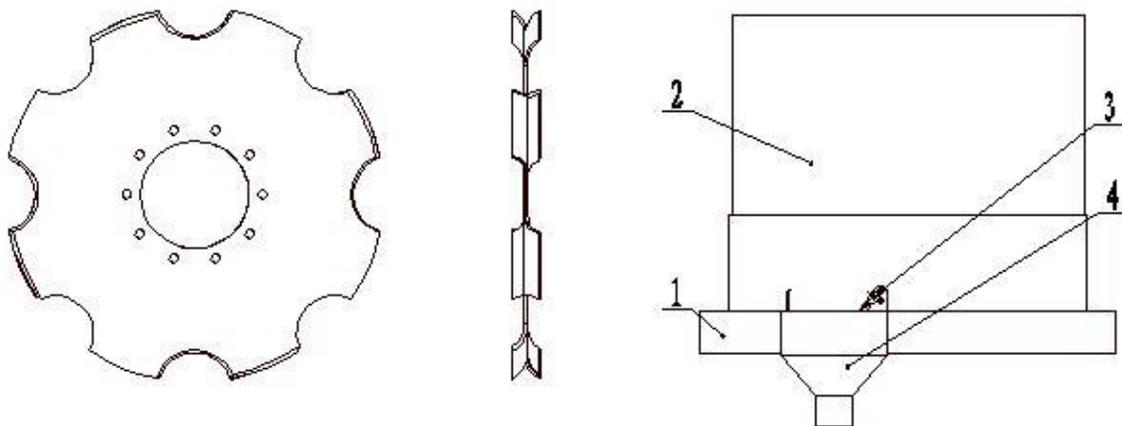


Figure 2. Schematic diagram of notched disc plow

1. Turntable 2. Fertilizer box 3. Scraper 4. Fertilizer hopper

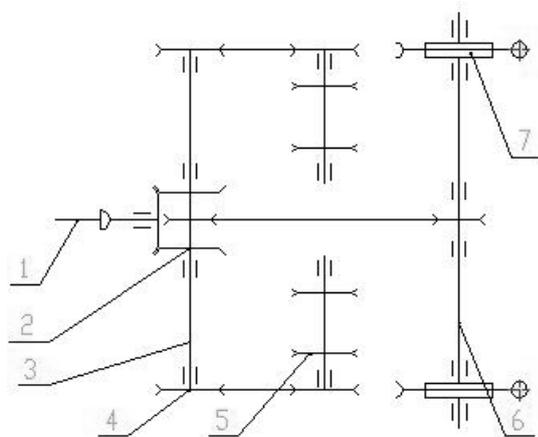
Figure 3. Schematic diagram of fertilizing device
Design of the fertilizer plant

The fertilizing device is composed of fertilizer box, turntable, scraper and fertilizer bucket (Figure 3), it's a very important component in the fertilizing machine and driven by the output power on the tractor. The fertilizer box is made of cylindrical plastic bucket, fixed on the frame with the mounting frame, and it is simple, low cost and corrosion resistant. The turntable is a component part of the fertilizer box, it is made of stainless steel, the turntable is installed on the output shaft of the worm and worm reducer, the tractor's output power drives it to turn. The fertilizer is placed in the fertilizer box and pressed on the turntable, Due to the rotation of the turntable, the fertilizer rises and shifts laterally to the fertilizer row under the action of centrifugal force, finally the fertilizer falls into the ditch. The scraping angle of the scraper is 45° and the size of the scraper can be adjusted up and down to adjust

the amount of fertilizer. The machine adopts disc scraper type fertilization mode. The mechanism is simple, which realizes uniform fertilizer distribution and high efficiency.

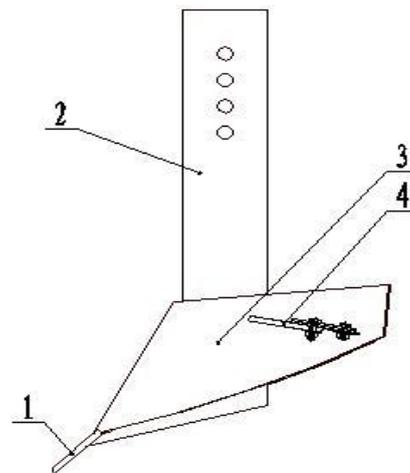
3.2 Design of transmission mechanism

The intermediate gear box adopts a structure into four. The above two output shafts transmit power to turbine worm reducer by universal joint. The worm gear decelerator converts horizontal rotation to vertical rotation to drive the turntable to rotate. The follow two output axes are passed through the universal joint to transfer the power to both sides of the gear reducer, and drive the notched disk to rotate. The intermediate gearbox is installed in the middle of the frame and the two turbines worm reducers are also installed on the frame. Design two sets of ditching gearboxes, which are located on the left and right sides of the machine, to balance the weight of the machine, to reduce the vibration of the whole machine during the working^[6]. The power transfer structure is shown in Figure 4.



1. Tractor power output shaft
2. Intermediate transmission
3. furrow drive shaft
4. ditch gear transmission box
5. Notched disc
6. Row fertilizer transmission shaft
7. Turbine worm transmission box

Figure 4. Schematic diagram of power transmission system



1. Plow tips
2. Plough column
3. Earth board
4. Adjusting board

Figure 5. Schematic diagram of the banking structure

3.3 Design of the frame

The frame is made of A3 materials. The manufacturing cycle is short, the cost is low, and the structure is reasonable. It is easy to manufacture, and the installation, adjustment, repair and replacement of components are all convenient, it also has good manufacturability and good seismic performance. The ditching device is mounted on the frame with U bolts, and it can be adjusted to the left and right sides. The fertilizer bucket is fixed on the frame by welding.

3.4 Design of the ridging plough

The ridging plough is designed to be adjustable and detachable double plane, which is composed of ploughing columns, left and right earth boards, plow tips and adjusting boards (Figure 5). The plough tip is made of 65Mn material and welded to the front end of the plow post. Plow body surface plough column and the left and right hilling plate composed of an adjustable angle. The front end face of the plow column is welded by the pin shaft and the shaft sleeve, by adjusting plate angle bolted around Earth plate. The soil ploughing is cut into the soil when working, and the soil is broken up and crushed. The left and right soil boards are followed by turning the soil to the sides, to complete the work of earth up^[7].

4. Field experiment

The field experiment was carried out in Guangdong Province, Zhanjiang City Lake farm in October 2017, the soil type is red soil and the test area is 20 acres. The calculation of leaf coverage rate of sugarcane in experimentation area was carried out before the test, and the results were shown as shown in Table 1.

Table 1. Leaf coverage rate of sugarcane in experimental plots

Number	1	2	3	4	5	Average value
Coverage rate/%	52.36	46.54	51.47	46.28	39.78	47.29

At the same time, soil moisture content and firmness were tested by TZS soil moisture meter and soil compactness tester. The results were shown in Table 2 and 3.

Table 2. Soil moisture content of the test block (%)

Depth /mm	Number					Average value
	1	2	3	4	5	
0-7	16.12	15.24	12.30	11.26	14.56	13.90
7-14	16.53	16.02	17.56	13.84	13.95	15.58

Table 3. Soil firmness of test block(MPa)

Depth /mm	Number					Average value
	1	2	3	4	5	
0-7	1.52	15.24	12.30	11.26	14.56	13.90
7-14	16.53	16.02	17.56	13.84	13.95	15.58

The speed of the tractor was set to 1m/s during the test. There are 10 points for the position of the notched disc plow in the test area, the vertical distance between the bottom of the ditch and the ground surface is measured by the ploughing depth gauge, that is the ditching depth of the notched disc plow. We choose 10 large areas, each of which is divided into 10 communities, to measure the amount of fertilizer and calculate the evenness of fertilization. The measurement results are shown in Table 4 and 5. According to the data in the table, in actual operation process, the average ditching depth of notched disc is 140.1 mm, and the average fertilization uniformity is 92.60% and the depth of ditching and the uniformity of fertilization are relatively stable.

Table 4. Ditching depth test data

Number	1	2	3	4	5	6	7	8	9	10	Average value
Depth /mm	143.3	139.5	141.7	137.4	139.5	139.7	137.3	140.6	140.2	141.8	140.1

Table 5. Fertilization evenness

Number	1	2	3	4	5	6	7	8	9	10	Average value
Uniformity /%	92.14	92.82	93.02	92.73	92.20	92.36	92.88	93.06	92.78	92.02	92.60

The effect of field test is shown in Figure 6. The notched disc ditching and fertilizing machine works well in the plots covered with sugarcane leaves, and there is no obvious phenomenon of sugarcane leaves and weeds blocking. The results showed that the notched disc ditching and fertilizing machine had good passing ability when the sugarcane leaves were covered with ground surface.



Figure 6. Working effect diagram of a notched disks with the ditching and fertilizing machine

5. Conclusion

(1) A notched disc ditching and fertilizing machine was designed, which can complete the broken ridge or ditching, fertilizing and hilling and some comprehensive projects.

(2) The machine is simple in structure, reasonable in design, simple in adjustment and operation. Through analyzing the stress in the process of cutting sugarcane leaves with notched disc, the diameter of the notched disc plow is determined to be 440 millimeter, and 8 slippers notch two sides bending structures are adopted.

(3) The experimental results show that the notched disc ditching and fertilizing machine has good soil, ditching and anti winding performance in in the plots covered with sugarcane leaves , the average trenching depth is 140.1 millimeter, the average fertilization uniformity is 92.60%, and the planting depth and fertilization uniformity is relatively stable, it meets the fertilizer agronomic requirements of sugarcane of the hot areas of South China.

Acknowledgements

This work was financially supported by the Hainan Natural Science Foundation Project (317252). The basic scientific research service fee of the Central Public Welfare Research Institute of the Chinese Academy of Tropical Agriculture (1630132017001). The Science and Technology Planning Project of Guangxi (Department of Guangxi AB16380166). The Science and Technology Planning Project of Zhanjiang (2017A02017).

Reference

- [1] Li M,Huang H and Deng G R 2008 *J. China Tropical Agriculture*.**3** 35-36
- [2] Wei G J,Jian S C,Jiang W,Di Z F and Zhou J L 2014 *J. Journal of Agricultural Mechanization Research*.**9** 190-2
- [3] Zhuang J,Jia H L,Ma Y H,Li Y and Di Y K 2013 *J. Transactions of the Chinese Society for Agricultural Machinery*.**44** 83-88
- [4] Bai X H 2012 *Study on the key parts of no tillage planter and its parameterized design method* (Shen Yang: Shenyang Agricultural University)
- [5] Liu Y and Hou Z M 1987 *J. Transactions of the Chinese Society for Agricultural Machinery*.**3** 20-28
- [6] Huang W H,Yan X L,Dong X H,Li M and Wei L J 2018 *J. Journal of Agricultural Mechanization Research*.**40** 140-4
- [7] Dong X H,Lu J M,Li M,Zhang J M,Li R H,Huang C,Wei L J and Deng Y G 2013 *J. Guangdong Agricultural Sciences*.**40** 180-2