Advance Journal of Food Science and Technology 10(11): 865-869, 2016
DOI: 10.19026/ajfst.10.2277
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: July 2, 2015 Accepted: August 5, 2015 Published: April 15, 2016

Research Article

Pneumatic Cyperus Esculentus Filming Seeder

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Abstract: In order to realize large-scale cultivation of the cyperus esculentus, reduce its labor input and meet precision sowing requirement, a precision pneumatic cyperus esculentus filming seeder was to be developed. Physical characteristics of the cyperus esculentus seeds was to be calculated and analyed for optimization design seeder structure. Through field test, the variation coefficient of each row and space between the plants of seeder meets agronomic requirements. Qualified rate of sowing depth is 90%.

Keywords: Cyperus esculentus, filming, pneumatic, seeder, seed-metering device

INTRODUCTION

Cyperus esculentus is an economic crop with fine quality, high yield and comprehensive utilization combining grain, oil, herding and feeding (Zhang, 2004). This widely applied plant has well developed root system, strong tillering and regeneration capacity. Each cyperus esculentus has 50-250 tubers averagely and each of them weighs about 2-2.6 g. There are about 1000-1300 tubers/kg. Average per mu yield of fresh fruits is above 800 kg and the maximum 2000 kg in top production areas. Dry cyperus esculentus yield is about 600-800 kg, which can produce cooking oil 200-300 kg. Its yield per mu is far above that of soybean, rapeseed and peanut. To plant one mu cyperus esculentus is equal to plant 3-5 mu peanuts and 7-10 mu rape. The cyperus esculentus oil yield is 32-39%, four times as large as that of rapeseed, twice as large as that of peanut. Cyperus esculentus ranks the top output in present economic oil crops, which deserves the title "King of Oil Plants". As the new type of nutrition and health care cooking oil, clean tawny and mellow, it rivals olive oil. It contains rich linoleic acid and protein, amino acid of high nutritional value, minerals especially kalium and phosphorus. Cyperus esculentus oil has low sodium and zero copeningsterol, being capable to prevent from cardiovascular cerebrovascular diseases and hyperlipidemia. It has fine quality, being far better than rap oil and soybean oil (Chen *et al*., 2008). Cyperus esculentus may realize large-scale, intensive and mechanized planting. It has bright development prospect, excellent economic, social and ecological benefits.

Although it is largely demanded in the market, cyperus esculentus has not realized industrialized production and there are seldom seeding devices. People constantly pay attention to the seeder and other mechanical problems. Currently cyperus esculentus generally adopts improved mechanical peanut seeder, which takes mechanical external force seed-metering device. It has great seeding pulsation, poor evenness and high seeds breakage rate. Consequently it is difficult for precision and semi-precision sowing.

In this study it designs a pneumatic precision filming seeder for cyperus esculentus planting.

ANALYSIS AND CALCULATION OF PHYSICAL CHARACTERISTICS OF THE CYPERUS ESCULENTUS SEEDS

Seeds physical characteristics are basic to design the seed-metering device. Before the design, firstly it shall determine geometric dimensioning and shape, thousand-seed weight and friction angle of cyperus esculentus seeds.

Geometric dimensioning and shape: Geometric dimensioning and shape refer to seeds length, breadth and depth, being prominent to determine the seed suction opening diameter of the air suction seed-metering device.

Determination method: It randomly chooses 100 seeds, getting length, breadth and depth of each seed by vernier caliper. According to the statistics, the average length l is 16.52 mm, average breadth b is 9.80 mm and average depth d is13.56 mm.

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Table 1: Measurement weight record

Groups number	1	2	3	4	5	6	7	8
Weight (g)	85	89	80	86	84	86	81	82

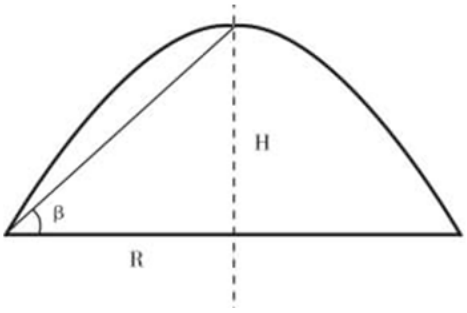

Fig. 1: Schematic diagram of measuring natural angle of repose

Thousand-seed weight: Thousand-seed weight refers to the weight of 1000 seeds according to the specified moisture. It plays a remarkable role in the calculation of wind pressure in the air suction seed-metering device.

Measurement method: It adopts 100-seed method.

Sampling: It fully mixes all pure seeds after the purity analysis and puts them on the clean desktop. It randomly selects 100 seeds as one group by quartering (to avoid artificial discard). As counting, it puts each five seeds in one pile, combining two piles to get a pile of ten seeds, taking ten piles to get 100 seeds, eight groups in total.

Weighting: It weighs counted samples and enters them in Table 1, the measurement record of thousand-seed weight.

Calculation: According to eight repeating weight readings, it calculates the average weight of eight groups ($\bar{X}$) by the following formula, then calculates standard deviation (S) and coefficient of variation (C).
Standard deviation:

$$S = \sqrt{\frac{n(\sum X^2) - (\sum X)^2}{n(n-1)}} \quad (1)$$

In the formula: X refers to the weight (g) of each repeating group. n refers to numbers of repetition.
Coefficient of variation:

$$C = \frac{S}{\bar{X}} \times 100\% \quad (2)$$

In the formula: $\bar{X}$ is the average weight of 100 seeds (g).

According to the data in Table 1, $\bar{X} = 84.13$, $\Sigma X^2 = 56679$, $(\Sigma X^2) = 452929$.

According to formula (1), standard deviation:

$$S = \sqrt{\frac{8 \times 56679 - 452929}{8 \times (8-1)}} = 2.99$$

According to formula (2), coefficient of variation:

$$C = \frac{2.99}{84.13} \times 100\% = 3.55\%$$

If coefficient of variation is not exceeding 4.0%, the calculation of thousand-seed weight may be in accordance with the measurement results. $10 \times \bar{X}$ refers to seeds thousand-seed weight, namely, 841.3 g.

The natural angle of repose: The natural angle of repose, also called the angle of rest, refers to the included angle formed between the cone slope and its bottom margin. The cone is formed when seeds are freely dropping on a plane from height.

It adopts the traditional straightness measurement (Fig. 1), using the fixed basal diameter. It only needs to measure the cone height of cyperus esculentus. So the angle of repose:

$$\beta = \arctan \frac{H}{R}$$

Of which H refers to the cone height and R refers to the cone basal radius. According to the abovementioned method, the seed angle of repose is 37°.

OVERALL STRUCTURE DESIGN OF THE SEEDER

Overall structure design: The cyperus esculentus seeder is composed of the framework, ridger, air suction seed-metering device, sowing opener, soil coverer, filming structure and land wheel. The brief structure is shown in Fig. 2.

Working principles of air suction precision filming seeder: It installs the ridger on the front beam of the framework and sowing assembly on the back beam. Wind pressure in the suction chamber is provided by the fan through air duct. The centrifugal fan is installed in the tractor's front bumper. When the fan is in operation, its rotational speed is around 4500 r/min. When the seeder is in operation, the discharge plate rotates through land wheel driving and rotating structure. The seed suction openings contact cyperus esculentus seeds. Due to pressure difference inside and outside the air chamber, it generates the suction to suck seeds in the seeds chamber. To promote seeds flowability and suction performance, there are 0.2 mm-0.7 mm chamfers on the suction side. Also it installs dashers that are evenly distributed in peripheral

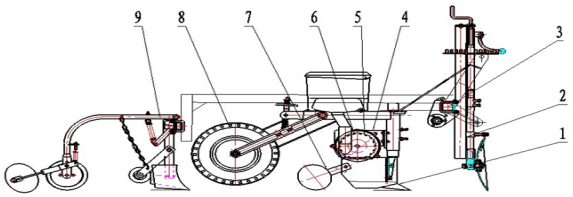

Fig. 2: Structure diagram cyperus esculentus filming seeder; 1: Sowing opener; 2: Soil moisture; 3: Machine frame; 4: Seed-metering device; 5: Seeding plate; 6: Mixing device; 7: Soil coverer; 8: Land wheel; 9: Filming structure

direction on the discharge plate. Each dasher is located between two adjacent suction openings respectively. So that seeds can be sucked in a better way after being dashed.

The seeder adopts the shovel opener that locates in front of the air suction seed-metering device. Seeds fall into the seed channel that is ditched by the opener and are covered by the double disk soil coverer. The land wheel, not only as the driving wheel but the rolling wheel also, is installed at the back of the opener. It rolls the sowing rows under self weight and spring pressure. At the back of the land wheel there installs dismountable filming mechanism or shaping wheel that can be selected according to the farmer's requirements.

The power is driven by the land wheel, consequently delivered to the intermediate propeller shaft by chains and then delivered to seed-metering device shaft. It is simple and reliable. Changing different chains it may adjust the seed spacing. The device is fitted with 20-horse power tractor by three-point hitch connection.

SEED-METERING DEVICE STRUCTURES AND WORDING PRINCIPLES

Suction components of the air suction seed-metering device are composed of vacuum chamber housing, discharge plate, friction-reducing seal ring, vacuum linking pipe and fan. When the air suction seed-metering device is in operation, the negative pressure produced by the high speed fan is transferred to seeding individual vacuum chamber. When the discharge plate is rotating, subjected to negative pressure of the vacuum chamber, it sucks seeds and rotates with the discharge plate. When seeds are rotated out of the vacuum chamber, they are no longer under the negative pressure and dropped into the furrow under the action of gravity or under the seed scraping device (Fig. 3).

The general diameter of the discharge plate is 140 mm-260 mm (Zhang, 1997), which is made of 1.2 mm thin stainless steel plate, diameter 200 mm. The seed suction opening has 0.2 mm-0.7 mm chamfers in the sidewall. It selects 18 suction openings on the discharge plate. The average breadth (b) of cyperus esculentus is 9.8 mm, so seed suction opening diameter (d) is 6.5 mm.

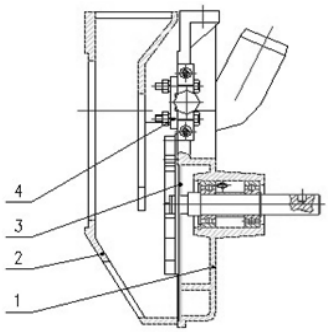

Fig. 3: Structure diagram of seed-metering device; 1: Cylinder assembly; 2: Seeds chamber; 3: Seeding plate; 4: Seeds cleaning device

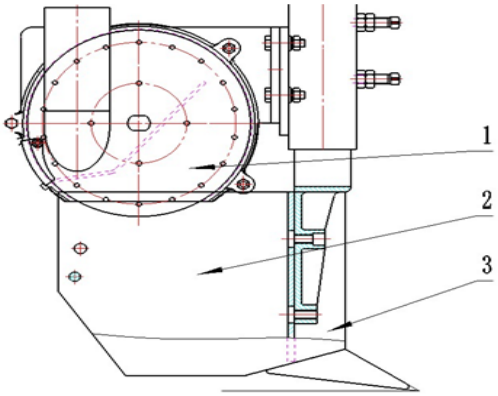

Fig. 4: Structure diagram of opener and its fender; 1: Seed-metering device; 2: Opener fender; 3: Opener

Table 2: Cyperus esculentus number of each rows of seeder

Test No.	X_1	X_2	X_3	X_4	X_5
1	348	350	347	344	351
2	342	346	343	346	349
3	346	348	346	342	348

The opener: According to agricultural requirements and land preparation before planting, when the fitting shovel opener is in operation, being subjected to the traction, there is a general tendency that the opener will be embedded to the ground by self weight and additional pressure. Therefore the seed-metering device has good performance to be embedded to the ground. The tip and anterior ridge of the shovel raises part of the soil, so that the bottom soil is in the surface. Both sides of the shovel squeeze the soil. It forms barrow and furrow. Cyperus esculentus is planted in the sand land that has little resistance coefficient, consequently it has excellent performance in soil self-backfill. Considering the required sowing depth, it installs fenders in both sides of the opener, whose length is longer than the distance between the seeds dropping place and the end of the opener. The fender can prevent from soil self-backfill before seeding and guarantee plant depth requirements. The structure is shown in Fig. 4.

Table 3: Measurement data of sowing depth

Number/Death/Row number	1	2	3	4	5	6	7	8	9	10
1	5.1	5.3	4.8	5.9	5.8	7.2	5.4	5.6	5.8	5.3
2	4.8	4.5	3.9	4.7	5.1	5.5	4.7	4.2	5.1	5.4
3	5.4	5.2	5.6	5.8	6.5	5.2	4.8	4.7	4.8	5.3
4	4.6	4.8	4.7	5.2	5.6	6.2	6.4	5.8	5.5	5.1
5	5.1	4.9	4.6	5.3	5.4	4.9	4.7	4.6	5.3	5.2

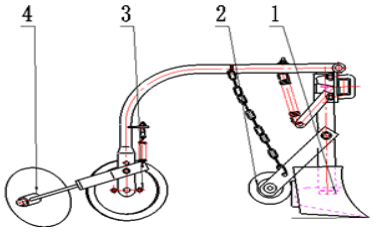

Fig. 5: Structure diagram filming mechanism; 1: Plowshare; 2: Filming wheel; 3: Rubber wheel; 4: Soil-covering plate

Filming mechanism: When it is planting cyperus esculentus it selects the sand land, on which moisture are quickly lost. So it is proper to preserve soil moisture by filming. Moreover, before the sowing, it uses organic fertilizer. To cover the mulching film has the advantage for decomposition of organic matter in organic fertilizer to boost the production of cyperus esculentus (Yang *et al*., 1996; Zheng, 1999). The brief structure of the filming mechanism is shown in Fig. 5.

Before filming, the filming mechanism hangs the mulching film rolls on the filming wheel, stretches one meter and compacts it by soil. As in operation, a couple of outward ploughshare ploughs the ridge and furrow. The rubber wheel aims at the ridge and furrow and presses two sides of the filming. Finally it performs earthing by two disks.

Measurement of seeding quantity identity in each row: The tractor lifter supports the overall machine, suspending the land wheel. It adds seeds in seeder box and rotates the land wheel to make each suction opening suck seeds.

It puts seed container under each grain tube and rotates the land wheel 20 rounds by 30 r/min rotational speed uniformly. It accounts seeds numbers in each container and records them in Table 2.

It repeats the test for three times to calculate coefficient of variation of each row in accordance with results:

$$\bar{x} = \frac{\sum x}{n} \tag{3}$$

$$V = \frac{S}{\bar{x}} \times 100\% \tag{4}$$

$$S = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}} \tag{5}$$

Table 4: Data statistics of space between the plants

Row number	Theoretical spacing/cm	Average spacing/cm	Spacing variation coefficients/%
1	10	13.5	32.9
2	10	14.4	26.8
3	10	12.4	35.6

In the formula, x refers to seeds numbers (average value of three times) in each row:

$\bar{x}$ = To average seeds numbers.
S = To standard deviation.
V = To coefficient of variation.
n = To numbers of rows:

$$\bar{x} = \frac{\sum x}{n} = \frac{345.3 + 348 + 345.3 + 344 + 346}{5} = 345.7$$

$$S = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}} = 1.47$$

$$V = \frac{S}{\bar{x}} \times 100\% = \frac{1.47}{345.7} \times 100\% = 0.42\%$$

After the calculation, the coefficient of variation in each row satisfies the seeder requirements.

Measuring the qualified rate of sowing depth: The sowing depth qualified rate refers to the percentage of points that the earthing depth is ranging from (h±1) mm accounting for total measured points:

$$\beta = \frac{d_1}{d_0} \times 100\% \tag{6}$$

where,
d_1 = To sowing depth qualified points
d_0 = To total measured points

The sowing depth refers to the distance between seeds and the ground surface. In each row it randomly selects 10 measuring points and the data are shown in Table 3.
Therefore the sowing depth qualified rate:

$$\beta = \frac{d_1}{d_0} \times 100\% = \frac{45}{40} \times 100\% = 90\%$$

Measurement of planting distance and coefficient of variation: It inspected the seedling of cyperus esculentus on May 14, 2012. In each row the seedlings are in good conditions. It randomly selects 3 rows to

measure the planting distance value. The statistics of planting distance value of 3 rows are shown in Table 4.

The results show that the seeder meets agricultural requirements about the planting distance of cyperus esculentus.

CONCLUSION

It determines geometric dimensioning and shape, thousand-seed weight and friction angle of cyperus esculentus seeds.

It designs a type of cyperus esculentus seeder that may accomplish ditching, precision sowing, rolling and filming in one time by analyzing advantages and disadvantages of current mechanical seeder. After the field test, the seeder meets agricultural requirements about the planting distance of cyperus esculentus.

ACKNOWLEDGMENT

The authors thank 2015 Science and Engineering Fund Projects of Hebei Agricultural University (ZD201501) for support.

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