Design and Optimization of a Seedling~~-Providing~~ Feeding Device ~~of~~ for the Automatic Transplanter ~~of~~ on a Maize Straw Seedling-~~growing~~ Sprouting ~~Bowl~~ Tray ~~Made of Maize straw~~

Abstract

This research aimed to solve ~~the~~ current problems in the process of maize transplanting ~~currently~~ in China such as large labor intensity, low working efficiency and poor quality. ~~Based~~ On the basis of the structure of a ~~maize~~ seedling-~~growing~~ sprouting ~~bowl~~ tray made of maize straw and the agronomic requirements of maize production, this ~~paper~~ study developed a new ~~seedling-providing~~ feeding device ~~of~~ for such a ~~seedling-growing~~ sprouting ~~bowl~~ tray ~~made of maize straw~~, determined the dimensions of the key components in ~~the~~ a virtual environment ~~through~~ via Solid Edge software and ~~got~~ obtained optimization of the working parameters in ~~combined~~ combination with Matlab, including the contribution degree and the rotational regression experimental analysis factor. Some tests on field validation and maize production were conducted as well. The test results showed ~~that~~ the importance of the working parameters on an upright degree in descending order (~~and~~ as well as the best working parameters) ~~was~~ to be the vertical angle of seedling ~~dropping~~ planting (13.14°), the forward speed of ~~locomotive~~ locomotion (0.57 m/s), and the horizontal angle of the seedling box (22.5°). The standard deviation of the field validation was 6.04%, which was within the allowable range to meet the requirements of maize transplanting. Compared with maize transplanting machines (and ~~compared with~~ manual transplanting operations) currently on the market, the labor inputs, as well as the rates of spacing ~~qualified rate~~ and upright degree ~~qualified rate~~ qualification, omitted planting ~~omission rate~~ and the yield of the ~~seedling-providing~~ new feeding device ~~of~~ for the automatic transplanter ~~of~~ on a maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize straw~~ increased 0 (6.9%), 0 (3.1%), 0 (4.5%) and 0 (-1.0%), respectively; ~~but~~ whereas, the manufacturing cost was reduced by 35.5%. The results can provide a technical basis and reference for ~~the~~ subsequent development of automatic transplanters ~~of~~ on-maize straw seedling-~~growing~~ sprouting ~~bowl~~ trays ~~made of maize straw~~.

Keywords: Maize, Seedling-~~growing bowl~~ sprouting tray, Automatic transplanter, Seedling-~~providing~~ feeding device, Optimization

1 Introduction

Maize was the first major crop cultivated in Heilongjiang Province, China. In 2014, its total planting area and the total yield were 6.37×107 ha and 28.139 million tons, respectively, accounting for 46.1%

of the total planting area and 51.7% of the total crop yield ~~of Heilongjiang Province~~. The maize production of ~~Heilongjiang~~ this province, the largest commodity grain production base, has played ~~the~~ a very important food-security role ~~of food security~~ in China [1].

Currently in Heilongjiang Province ~~of China~~, maize ~~production~~ is most commonly directly sowed in the spring [2], which ~~was~~ is more convenient and labor-~~saving~~ efficient. But the low ground temperature in ~~spring~~ this season ~~was~~ is a major bottleneck restricting the growth of maize ~~yield~~ crops [3].

A large number of field tests have proved that the transplanting technology of seedling-~~growing~~ sprouting ~~bowl~~ trays made of maize straw ~~was~~ is one of the most effective means to break through the aforementioned maize-production bottleneck ~~of maize production~~ ~~in Heilongjiang Province of China~~ [4]. *[English Editor's Note: It is unnecessary (and redundant) to repeatedly name the province--unless another one is introduced.]*

At the beginning of the 21st century, ~~some~~ certain areas of Heilongjiang Province, such as Nahe City, Hailun City, Qinggang County, Anda City and Mingshui County, tried manual transplanting of maize [5]. ~~It's~~ The yield obviously increased ~~obviously~~, but ~~the~~ problems still existed, including large labor-intense input ~~and intensity~~, low work~~ing~~ efficiency, and a low degree of work~~ing~~ standardization. ~~At the same time~~ Concurrently, with ~~the~~ annual increases ~~of~~ in rural labor ~~transferring~~ transfers, ~~amount of rural labor year by year~~ and ~~the continuous~~ continually ~~increase of~~ increasing labor costs [6], transplanting such ~~the~~ large areas of maize ~~transplanting~~ crops cannot be achieved by manual means alone. Therefore, the mechanization of maize seedling transplanting ~~was~~ is imperative.

At the beginning of 20th century, ~~the~~ international researchers and institutions started trying ~~the mechanization of~~ to mechanize maize seedling ~~transplanting~~ transplantation. In the 1920s, ~~some~~ researchers in certain developed countries such as France, Holland and ~~Italian~~ Italy ~~developed~~ devised the UT-2, MT and AUTOMA clamp types of maize transplanters, respectively [7]. In the former Soviet Union, ~~developed~~ the CKH-6A and CKB-4A disk-cramping types ~~of maize transplanter~~ were developed [8]. In ~~some developing countries such as~~ China, a developing country, Wu Wei and his group developed the 2YZ, 2ZT, and 2Z-2 clamp types ~~of maize transplanter~~ and the 2ZY-2, 2ZB-2, and 2ZQ chain-cramping types ~~of maize transplanter~~ [9]; Yu Xiugang and his group developed the 2YZ-4, 2ZB-6, and 2ZYB-2 hanging-cup types ~~of maize transplanter;~~[10] whereas, Feng Jun and his group ~~developed~~ designed the 2ZB-4, 2ZDF, 2ZY-200 and 2ZG-2 seedling conduction tube types ~~of maize transplanter~~ [11]. The transplanting and yield-improving effects of the ~~above~~ aforementioned maize transplanters were ~~obviously~~ obvious, but most of them were semi-automated ~~way of transplanting maize~~ methods that also required manual operations [12]. The existing problems, ~~existed~~ such as the low speed of manual transplanting, large labor intensity and low working efficiency, cannot meet the actual needs ~~of~~ in a large transplanting area ~~of transplanting~~.

~~Based on~~ In view of the ~~above~~ aforementioned problems, researchers at Heilongjiang BaYi Agricultural University used maize straw as the main ~~materials~~ material to ~~develop~~ devise ~~the~~ a seedling-~~growing~~ sprouting ~~bowl~~ tray for the first time by using certain physical methods which ~~could~~ can break through the restrictive bottleneck ~~restricting the growth of~~ in maize ~~yield~~ cultivation.

Taking ~~the~~ a ~~seedling-growing~~ sprouting ~~bowl~~ tray made of maize straw as the seedling carrier, ~~this~~

~~study~~ we developed a seedling~~-providing~~ feeding device ~~of~~ for an automatic transplanter ~~of~~ mounted on ~~seedling-growing bowl tray made of maize straw~~ this type of sprouting tray ~~It was the~~ as an effective solution ~~of~~ to a series of problems in ~~China~~ the traditional mechanical operations of maize ~~transplanting~~ transplantation in China.

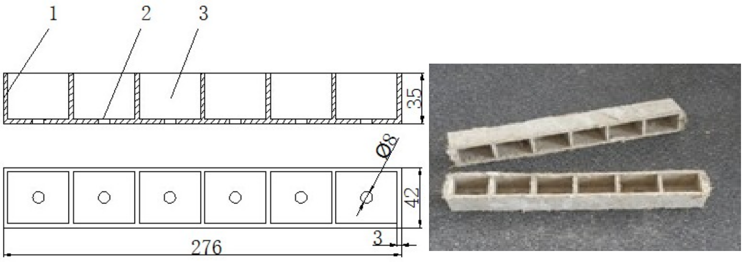
~~The~~ Tests have verified that ~~the~~ this device, which ~~had~~ has strong regional adaptability, a good working effect, and a high degree of automation, can ~~provide~~ serve as a good mechanical carrier for ~~maize~~ mechanical maize ~~transplanting~~ transplantation.

2 ~~Seedling-growing bowl tray made of maize straw and working requirements~~ Structural and functional parameters of maize straw seedling-sprouting tray

2.1 Structure

In accordance with the ~~ideas~~ general concept of a ~~maize~~ seedling-~~growing~~ sprouting ~~bowl~~ tray ~~and combined~~ in combination with the specific agronomic requirements of maize production, the ~~seedling-growing bowl tray made of~~ maize straw sprouting tray used in this research (shown in Figure 1) ~~was composed~~ consisted of ~~the~~ pot holes, ~~the~~ vertical edges, a vent and ~~the~~ vertical seedling feeding holes ~~etc~~.

The pot holes were the growing spaces ~~of~~ for the maize seeds. The vertical edges were the coupling



1. vertical edges 2. vent and ~~the~~ vertical seedling feeding holes 3. pot hole

Figure 1 Maize straw seedling-~~growing~~ feeding ~~bowl~~ tray ~~made of maize straw~~

portion of an adjacent maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize straw~~ (the vertical edges ~~was~~ being shared by adjacent pot holes) and were mainly used to maintain the integrity of ~~seedling-growing bowl~~ the tray ~~made of maize straw~~. The vent and vertical seedling feeding holes were used to ensure ~~the~~ air circulation ~~of~~ from the bottom of ~~seedling-growing bowl~~ the tray ~~made of maize straw~~ and realize orderly vertical transplanting.

Combined with the agronomic requirements of maize production [13, 14 and 15], the main structural parameters of the ~~seedling-growing bowl~~ sprouting tray ~~made of maize straw were~~ are ~~shown~~ listed in Table 1.

Table 1 Main structural parameters

Items	Values
Total number of pot holes	6
Seeding quantity of single pot hole	1

Horizontal dimension / mm	276
Vertical dimension / mm	42
Depth of pot hole / mm	32
Thickness / mm	35

2.2 ~~Working~~ Functional requirements

In order to meet the requirements of the follow-up operations ~~and~~ in combination with ~~the combination of~~ the actual maize production ~~of~~ in Heilongjiang Province, the transplanting and seedling~~-providing~~ feeding work ~~of~~ maize needed to meet the following requirements [16 and 17]:

1) Emergence rate of maize before transplanting ~~was more~~ greater than 98%;

2) Row spacing ~~was~~ @ 60-70 cm with adjustable plant spacing ~~can be adjusted~~;

3) Upright degree of ~~the~~ maize seedlings after transplanting ~~was~~ not less than 85%;

4) Seedlings injury rate ~~was~~ less than 1.2%;

5) Omitted planting ~~omission~~ rate ~~was~~ less than 2.7%.

3 Design and function of seedling~~-providing~~ feeding device ~~and working process~~

3.1 Overall design

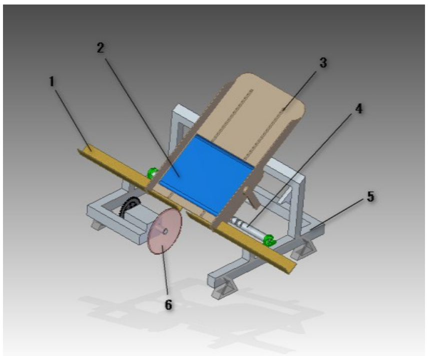
~~Combined with~~ In consideration of the transplanting requirements and structure of a ~~seedling-growing bowl~~ maize straw sprouting tray ~~made of maize straw~~, ~~the~~ a seedling~~-providing~~ feeding device ~~of seedling-growing bowl tray made of maize straw~~ was developed. Its structure ~~was shown~~ is illustrated in Figure 2, and the main technical parameters ~~were shown~~ listed in Table 2.

The ~~seedling-providing~~ feeding device ~~of~~ for the ~~seedling-growing bowl~~ sprouting tray ~~made of maize straw~~ was mainly composed of the rack, seeding boxes, feeding mechanisms and power transmission system ~~etc~~. A seeding box was used for storing ~~seedling-growing bowl~~ the sprouting tray ~~made of maize straw~~. The feeding ~~mechanism~~ device ~~was made up~~ consisted of horizontal ~~feeding mechanism~~ and vertical ~~feeding~~ mechanisms which ~~finishing~~ finished the horizontal and vertical feeding operations of ~~seedling-growing bowl~~ the sprouting tray ~~made of maize straw and~~ in ~~cooperating~~ tandem with the cutting operations of seedling needles [18 and 19]. The power transmission system was composed of a power shaft, a spiral shaft and a shifting fork, mainly used for ~~passing~~ transmitting the input power of the tractor to the various working parts [20 and 21].

Table 2 Main technical parameters

Items	Values
Dimensions (work) /mm	2312×1562×412
Number of operations	2
~~Rowing~~ Row spacing of transplanting /mm	65
~~Plant~~ Spacing of transplanting /mm	15-30
Seedling planting speed /min	$\geqslant$90

Operational efficiency /(km^{2}·h^{-1})	0.15-0.6
Supporting power /kW	42-70



1. rack 2. vertical feeding mechanism 3. seedling box 4. spiral shaft 5. rack 6. planting mechanism

(Note: AB- axial length of spiral groove, CD- inner distance of seedling box)

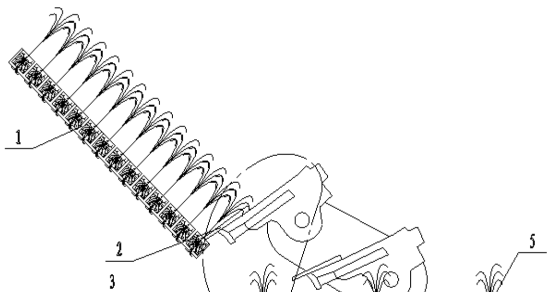
Figure 2 Schematic diagram of seedling-~~providing~~ feeding device

3.2 ~~Working~~ Operational process

In the ~~operation~~ process of maize ~~transplanting~~ transplantation, after a growth period of about 38 days, ~~firstly~~ we first ~~put~~ placed the maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize straw (growing period about 38 d~~ (~~shown~~ pictured in Figure 3)) into the seedling box, the furrow opener and the irrigation system, respectively, by digging holes ~~and~~ for irrigation (0.5 L/hole) in the soil ~~along the~~ in a forward direction [22, 23 and 24]. Under the ~~action~~ moving parts of the seedling-~~providing~~ feeding device and seedling needles, the ~~seedling-growing bowl~~ sprouting tray ~~made of maize straw~~ was cut into blocks and orderly transferred to the soil ~~holes~~ apertures.

Figure 3 Seedlings before transplanting

The ~~soil~~ blocks of ~~blocks~~ soil ~~was~~ were covered with ~~the~~ a ~~coverer~~ lid to complete ~~a~~ the transplantation process ~~of transplanting~~. ~~And~~ The ~~seedling-growing bowl~~ straw sprouting tray, ~~made of maize straw also~~ having completed a life cycle, ~~then being~~ was also degraded in the ~~role of~~ soil. The ~~working~~ entire process ~~was shown~~ is illustrated in Figure 4.



3.3 Motion simulation of seedling ~~providing~~ feeding device

~~In order~~ To facilitate the design and shorten the design cycle, ~~the~~ a motion simulation of a virtual sample device was ~~made~~ constructed in ~~the~~ a virtual environment with Solid Edge software. The ~~analysis~~ results of the analysis were ~~shown~~ as follows:

1) The axial distance L_{AB} (~~shown~~ depicted in Figure 5) played a decisive role in the size of the seedling door, ~~which meet the~~ as expressed in equation (1):

$$L_1 = L_{CD} - L_{AB} \tag{1}$$

where

L_1 is the width of the seedling door, mm;

L_{AB} , the axial length of the spiral groove, mm

L_{CD} , the inner distance ~~of~~ within the seedling box, mm. *[English Editor's Notes: (1) I suspected that Figure 5 was obstructing my view of the text; therefore, I temporarily cut-and-pasted onto the last page of this manuscript. Now, when I try to bring the figure back to this page, it refuses to paste in the proper position. Sorry! (2) There was also a problem with Figure 4: I struckthrough your last four words at the end of the caption (to show that they should be deleted); but three of those words disappeared, and I cannot retrieve them!]*

2) ~~Making sure~~ The dimensional precision when the spiral shaft was processing needed to be verified to avoid the phenomenon of "getting stuck" in the transplanting operation [25].

4. Design of ~~the~~ key components

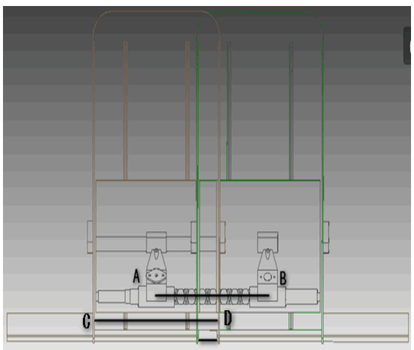


Figure 5 Motion simulation of working process

4.1 Horizontal seedling-~~providing~~ feeding device

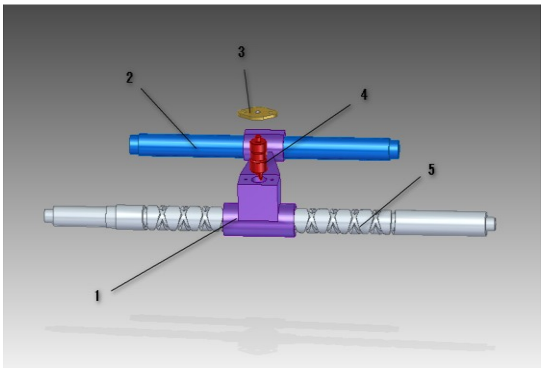
4.1.1 Feeder requirements ~~of horizontal seedling providing~~

1) ~~According to~~ In accordance with the size of the maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize straw~~, the horizontal spacing ~~needed~~ should be 45.5 mm when transplanting. The ~~allowed~~ maximum allowable ~~transplanting~~ displacement amount ~~was~~ is 4 mm when cutting the seedlings.

2) The next transplanting operation ~~needed to~~ should be ~~conducted~~ run after finishing ~~6 times~~ six horizontal operations.

4.1.2 Structure

The horizontal ~~seedling providing~~ feeding device ~~was~~ is one of the key components of the ~~seedling providing device of~~ automatic transplanter, ~~of seedling-growing bowl tray made of maize straw Its~~ the bearing ~~part~~ of which ~~was~~ is ~~the~~ a spiral shaft, ~~Therefore~~ of which the diameter ~~of spiral shaft~~, ~~it's~~ the pitch and the helix angle ~~were~~ are the key parameters. The modeling of the ~~Spiral~~ shaft mechanism ~~modeling was~~ is ~~shown~~ illustrated in Figure 6.



1. sliding sleeve 2. seedling box connecting rod 3. slide plate 4. slider 5. spiral shaft

Figure 6 Modeling of spiral shaft mechanism ~~modeling~~

1) Shaft diameter ~~of spiral shaft~~

The ~~spiral~~ shaft of the ~~horizontal seedling providing~~ feeding device ~~was~~ is mainly exposed to shear stress during the working process, as ~~shown~~ expressed in equation (2):

$$\tau_T = \frac{T}{W_T} = \frac{9.55\times10^6 P}{0.2d^3 n} \leq [\tau_T] \tag{2}$$

Derivation:

$$d \geq \sqrt[3]{\frac{9.55\times10^6 P}{0.2n[\tau_T]}} = \sqrt[3]{\frac{9.55\times10^6}{0.2[\tau_T]}} \cdot \sqrt[3]{\frac{P}{n}} = C\sqrt[3]{\frac{P}{n}}$$

where τ_T is the shearing force; MP_a. $[\tau_T]$, the allowable shearing force; MP_a. T, the torque; $N \cdot mm$. W_T, the anti-torsional section modulus, mm^3; P, the power, kW; n, the shaft speed ~~of spiral shaft~~; $r/\min$. d, the cross-section radius of the ~~spiral~~ shaft, mm; and C, the safety factor.

~~Based~~ On the basis of the operating conditions, the spiral shaft selection was 40Cr, the ~~spiral shaft~~ diameter after ~~check~~ inspection ~~was~~ being $d \geq 10.53$ mm.

In practical application, we set the groove to make the radius increase by 3%; ~~so~~ therefore, $d \geq 10.875$ mm and the shaft diameter, ~~of spiral shaft~~ $R_1 = 22$ mm.

2) Pitch and helix angle of ~~spiral~~ shaft

(1) Pitch

The horizontal ~~planting~~ plant spacing ~~was~~ required is 45.5 mm during the cutting operation; ~~so~~ hence, the pitch ~~of spiral shaft of device of horizontal seedling providing~~ was ~~determined~~ set at $D = 23$ mm.

(2) Helix angle ~~of spiral shaft~~

~~It~~ This value ~~can be~~ is calculated by equation (3):

$$\gamma = \arctan\left(\frac{D}{\pi R}\right) \tag{3}$$

where γ is the helix angle ~~of spiral shaft~~; °. D, the pitch, mm; R, the diameter ~~of spiral shaft~~, mm.

After ~~calculated~~ calculation γ =18.4° .

4.1.3 Slider

The seedling box ~~of~~ on the ~~seedling-growing bowl~~ sprouting tray ~~made of maize straw~~ ~~needed~~ needs a horizontally reciprocating movement during ~~transplanting~~ transplantation; ~~So~~ therefore, we designed ~~the~~ a slider to drive the ~~seedling~~ box ~~doing~~ during this ~~reciprocating movement~~ reciprocation along the ~~spiral~~ shaft.

Because of this reciprocating movement, the slider ~~needed reciprocating movement when transplanting the seedling-growing bowl tray made of maize straw, which needed to have~~ requires strong wear resistance. ~~So~~ Therefore, we used a double-circular slider, ~~and it's~~ the structure of which ~~was shown~~ is diagrammed in Figure 7.

~~To~~ The double-circular structure ~~guarantee~~ ensures that the slider ~~was~~ is able to move in the ~~right~~ proper direction when it ~~moved~~ is transiting through ~~the~~

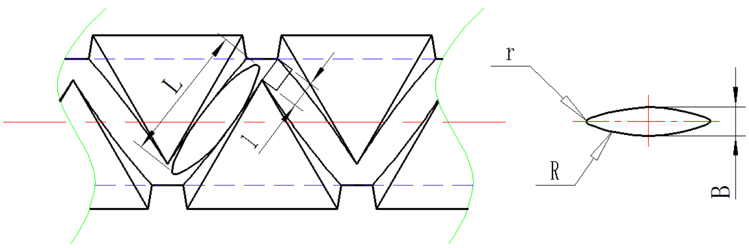


Figure 7 Schematic diagram of double circular arc slider mechanism

~~transition part of~~ both ends of the shaft and the cross-section of the spiral groove. The relationship ~~was~~ is ~~shown~~ expressed in equation (4):

$$\begin{cases} L > 2l \\ l = \dfrac{B}{\sin 2\gamma} \end{cases} \tag{4}$$

where B is the width of the gullets, mm; γ , the spiral-lead angle; ° . L , the tangent contact surface length of the slider and spiral groove, mm; and l , the width of the spiral groove, mm.

Taking B =5 mm and ~~put~~ inserting γ =18.4° into the equation, we ~~had~~ obtained l =8.347 mm; ~~so~~ thus, L ~~was~~ = 17 mm.

4.2 Vertical seedling-~~providing~~ feeding device

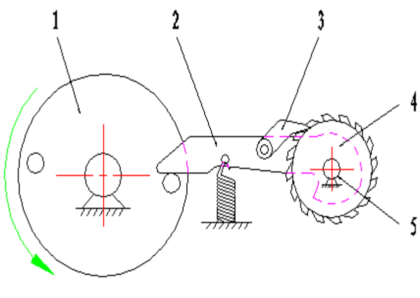
4.2.1 Feeder requirements ~~of vertical seedling providing~~

1) Intermittent ~~providing~~ feeding, ~~providing spacing was~~ spaced at 35 mm intervals.

2) The next vertical ~~seedling providing~~ feeding ~~needed to~~ should be ~~conducted~~ run after finishing ~~6 times~~ six horizontal operations.

4.2.2 ~~Design of structure~~ Structural design

According to ~~the~~ vertical seedling-feeding requirements ~~of vertical seedling providing~~, the ~~vertical seedling providing device~~ feeder ~~of~~ on a maize straw ~~seedling-growing bowl~~ sprouting tray ~~made of maize straw was shown in Figure 8 and was~~ is mainly composed of a shifting fork, a rocker, and a ratchet, as illustrated in Figure 8.



1. shifting fork, 2. rocker, 3. ratchet, 4. ratchet, wheel, 5. ~~transmitting~~ transmission shaft

Figure 8 ~~Structure principle~~ Structural design of longitudinal replanter

During the transplanting, the power of the shifting fork ~~was~~ is transmitted by the spiral shaft through the gear structure, ~~making~~ causing the fork to continuously ~~rotating~~ rotate counterclockwise when the transplanter ~~was at work~~ is operating. When the seedling box is moved to ~~both ends~~ each end, a plate of ~~6~~ six ~~seedling-growing bowl~~ sprouting trays ~~just needed~~ then needs vertical replenishment. The second rocker ~~2 moved~~ moves into the effective working area of the two arms of the shifting fork, the spiral shaft ~~drove~~ drives the shifting fork ~~rotating~~ rotation one lap, the shifting arms ~~shifted~~ move the rocker twice, and the ratchet pawl ~~pushed~~ pushes the ratchet clockwise, thereby rotating two ratchets. ~~Every time~~ At each iteration, the spring ~~drove~~ drives the rocker, causing it to ~~returning~~ return to the initial position; and the coaxial belt ~~completed~~ completes the vertical replenishment with a 42-mm vertical displacement. At this time the slider ~~just moved~~ merely moves into the return ~~sliderway~~ track through the buffer area at both ends of the spiral groove, thereby driving the seedling box to horizontal-~~seedling providing~~ feeding mode.

1) ~~The~~ Number of ratchets

The diameter of a ratchet ~~can be~~ is calculated by equation (5):

$$\frac{1}{c}\times 2\pi R_1=\frac{42}{2} \tag{5}$$

where c is the number of ratchets; R_1, the diameter of a ratchet, mm.

The vertical distance ~~that~~ in which the seedling box can hold back ~~was~~ is 55 mm; ~~so~~ hence, $R_1\leq 55$ mm. The number of ratchets should be 15; ~~so~~ thus, $R_1=50.4$ mm, as amended.

2) Ratchet rotation angle

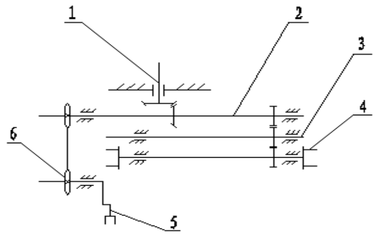
Therefore, ratchet rotation angle $\theta=\frac{360^{\circ}}{15}=24^{\circ}$.

~~Above~~ The aforementioned conditions can meet the needs when the seedling box is moved to ~~both ends~~ each end and the shifting fork ~~shifted~~ moves the ratchet twice to ~~realize~~ achieve vertical seedling feeding at 42-mm displacement. Thus, ~~achieving replenishing a~~ the ~~seedling-grow bowl~~ sprouting tray is replenished.

4.3 Power transmission system

The power transmission system ~~was shown~~ is diagrammed in Figure 9. The tractor supplies power ~~of~~ to the ~~seedling-providing~~ feeding device, ~~came from tractor. The device was~~ which is articulated by a three-point suspension structure~~. It connected~~ that connects the power by a cardan joint and a power-input shaft, then ~~transmitted~~ transmits the power to the horizontal-~~seedling providing~~ feeding spiral shaft, the vertical-~~seedling providing~~ feeding shifting fork and the planting device via the power transmission shaft (shown in Figure 4). The rotary spiral shaft ~~rotary~~ ~~drove~~ drives the hyperboloid slider ~~to do~~ in a collision movement in the spiral groove when transplanting and also ~~drove~~ drives the seedling box ~~to do~~ in a straight reciprocating movement by connecting the sleeve in the shaft direction. ~~At the same time~~ Concurrently, the planting mechanism at the seedling door, driven by the chain drive mechanism, ~~was working on~~ works at picking ~~seedlings~~ and ~~dropping~~ planting the seedlings in ~~cooperating~~ tandem with the ~~seedling~~ feeder box ~~feed~~. The seedling box ~~would just~~ then moves to ~~both ends~~ each end when a row of seedlings ~~were~~ has been picked. Then the shifting fork ~~shifted~~ shifts the ratchet at the back of the seedling box and ~~drove~~ drives the coaxial ~~seedling~~ feeding belt to ~~work~~ operate on the vertical ~~seedling providing~~ feeder. ~~In this way~~ Thus, the ~~seedling providing~~ feeding cycle circularly ~~cooperated~~ cooperates with the ~~seedling~~ picking cycle to complete ~~seedling~~ the transplanting.

To ensure that the seedling needle can effectively cut the maize ~~seedling-growing bowl~~ sprouting tray ~~made of maize~~, the power transmission ratio should meet the ~~requirement~~ conditions ~~of~~ in equation (6):



1. power input shaft 2. power transmission shaft 3.spiral shaft 4.vertical ~~seedling providing~~ feeding fork 5. planting mechanism 6.sprocket

Figure 9 Diagram of transmission system

$$\begin{cases} i_{63} = \dfrac{i_6}{i_3} = \dfrac{1}{2} \\ i_{23} = \dfrac{i_2}{i_3} = \dfrac{1}{1} \end{cases} \quad (6)$$

5. Optimization of working parameters

5.1 Testing conditions

This testing was conducted in the soil bin laboratory in the College of Engineering ~~of~~ at Heilongjiang Bayi Agricultural University. ~~It~~ This trial was ~~a~~ to test ~~bed for~~ a seedling-~~providing~~ feeding device ~~of~~ on a maize straw ~~seedling-growing bowl~~ sprouting tray, powered by a TCC-3 soil-bin automated vehicle, ~~made of maize straw~~ as established and reformed by the university. ~~It was powered by TCC-3 soil bin automated test car.~~

5.2 Test design

A large number of tests ~~showed~~ indicated that the horizontal angle of the seedling box (Z_1), the vertical angle of seedling-~~dropping~~ planting (Z_2), and the forward speed of ~~locomotive~~ locomotion (Z_3) ~~and~~ were the main ~~influence~~ factors ~~of~~ influencing the ~~seedling providing~~ feeding device. To optimize the working parameters, the tests used the rotational regression method ~~of rotational regression~~ for experimentation. The coding levels of the factors ~~level were shown~~ are listed in Table 3.

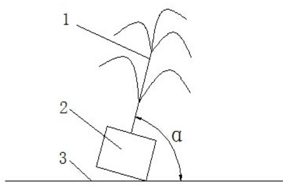
Table 3 Coding levels of factors ~~level~~

Coding	Z_1 /°	Z_2 /°	Z_3/(m·s^{-1})
~~Above higher~~ Highest ~~level~~（+1.682）	45	20	0.6
~~Higher~~ High ~~level~~ （+1）	40	18	0.5
~~Zero~~ Neutral ~~level~~ （0）	33.5	16.5	0.4
~~Lower~~ Low ~~level~~ （-1）	27	15	0.3
~~Under lower~~ Lowest ~~level~~（-1.682）	22	13	0.2
Change interval	6.75	2	0.1

5.3 Evaluation indicator

The evaluation indicator ~~of~~ for the testing was the upright degree. In the evaluation criteria of previous research, the operational quality of a rapeseed transplanting machine specified the percentage of the number of plantings ~~that~~ for which the angle of a seedling stem with the ground was not less than 30° , thereby accounting for the number of actual ~~transplanting~~ transplanted seedlings, excluding the number of ~~omission~~ omitted ~~seedlings~~, buried ~~seedlings~~, injured ~~seedlings~~ and lodging seedlings [26, 27, 28 and 29].

~~According~~ In accordance with the growth features of a maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize straw~~, the angle of ~~bowl~~ the tray with the ground was set ~~with the ground to~~ at α. As ~~shown~~ illustrated in Figure10, $\alpha \in \left[80^\circ, 90^\circ\right]$ was excellent, $\alpha \in \left[65^\circ, 80^\circ\right]$ was good, $\alpha \in \left[45^\circ, 65^\circ\right]$ was qualified, and $\alpha < 45^\circ$ was ~~unqualified~~ disqualified [30].



1. maize seedling 2. block of straw ~~seedling-growing bowl~~ sprouting tray ~~made of maize straw~~ 3. ground

Figure 10 Upright degree

The trials tested each sample for the angle of its stem with the ground ~~of each sample,~~ and calculated the upright degree by the ratio of the number of qualified ~~planting~~ seedlings with the total number of samples, ~~which can be~~ as calculated by equation (7):

$$Z_L = \frac{Z_H}{Z_Q} \times 100\% \quad (7)$$

where Z_L is the upright degree, %; Z_H , the number of qualified ~~planting~~ seedlings; and Z_Q, the total number of samples ~~of planting~~.

5.4 Data processing

The tests used the the rotational regression program ~~of rotational regression~~ for experimentation, analyzed the ~~test~~ results by ~~SPSS~~ stepwise regression using SPSS Statistics software, and established the mathematical model. Then we ~~conducted analysis~~ analyzed the interaction between ~~of~~ a single factor and ~~two~~ various pairs of factors ~~interaction~~ to determine the contribution of their respective degrees of ~~various factors~~ influence on the target, and solved the equation ~~of~~ for the optimal value by using the optimization toolbox in Matlab software ~~optimization toolbox~~. Finally, we verified the ~~correctness~~ accuracy of the theoretical ~~analysis~~ analytical results through field testing.

5.5 Analysis of results

5.5.1 Function construction

~~The~~ A stepwise regression analysis of the experimental results was ~~taken~~ implemented ~~through~~ via SPSS, setting the evaluation indicator upright degree (y) ~~to~~ as a variable, setting the vertical angle of seedling droppings as well as the forward speed of ~~locomotive~~ locomotion and the horizontal angle of the seedling box ~~to~~ as arguments. Then the significant coefficient was selected and the non-significant coefficient (Table 4) ~~was~~ eliminated to establish the regression equation (8):

Table 4 Factor analysis

Model		Non-standardized coefficients		t	*Sig*
		B_C	Standard deviation		
1	（Constant）	76.218	1.621	47.030	.000
	Z_1	-10.277	2.103	-4.887	.000
2	（Constant）	76.794	1.312	58.517	.000
	Z_1	-10.277	1.690	-6.081	.000
	Z_3	-5.588	1.579	-3.539	.000
3	（Constant）	77.005	1.085	71.003	.000
	Z_1	-10.816	1.404	-7.704	.000
	Z_3	-5.783	1.304	-4.435	.000
	Z_2	-4.380	1.359	-3.224	.004

$$y = 77.005 - 10.816Z_1 - 4.38Z_2 - 5.78Z_3 \quad (8)$$

5.5.2 Dimension-reduction analysis

To analyze the effect between ~~two~~ pairs of factors and the evaluation index, we ~~took~~ conducted a two-factor ~~interactions~~ interactive analysis of the test results by the dimension-reduction method, fixing $N-2$ factors in the quadratic regression model with N factors to ~~get~~ obtain the regression model ~~between two factors and evaluation index~~. ~~The~~ Following ~~discussed~~ is a discussion of the influence of ~~two~~ those different factors on the upright degree.

1) Horizontal angle of seedling box and vertical angle of seedling ~~dropping~~ planting

When analyzing the influence of ~~two factors~~ the interaction between the horizontal angle of the seedling box Z_1 and the vertical angle of seedling ~~dropping~~ planting Z_2 on the upright degree y, we ~~can~~ set the forward speed of ~~the locomotive~~ locomotion Z_3 ~~on~~ at the fixed value 0; ~~so~~ hence, the regression equation was expressed as (9):

$$y = 77.005 - 10.816Z_1 - 4.38Z_2 \quad (9)$$

Revise graphic:

Vertical angle of seedling ~~dropping~~ planting

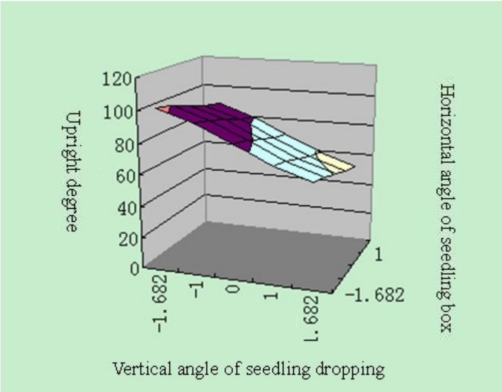


Figure 11 Effects of horizontal angle of seedling box and vertical angle of seedling ~~dropping~~ planting on ~~the~~ upright degree

The influence of the interaction between the horizontal angle of the seedling box and the vertical angle of seedling ~~dropping~~ planting on the upright degree ~~was shown~~ is graphed in Figure 11.The areas of relatively high upright degree appeared when both of these ~~horizontal angle of seedling box~~ and ~~vertical~~ angles ~~of seedling dropping~~ were below ~~level~~ the 0 level. When the vertical angle ~~of seedling dropping was~~ is fixed, the upright degree will gradually increase with the decrease ~~of~~ in the horizontal angle ~~of seedling box~~. When the horizontal angle ~~of seedling box~~ was fixed, the upright degree gradually increased with the decrease ~~of~~ in the vertical angle ~~of seedling dropping~~. This phenomenon ~~was~~ occurred mainly because ~~that when the angle of~~ a seedling-box angle that was too large ~~it~~ could ~~lead to large~~ cause the vertical angle of ~~seedling dropping~~ planting to be too large and ~~Then the seedlings would~~ consequently fall over easily. Both the ~~angle of seedling box~~ horizontal and the vertical angles ~~of seedling dropping~~ needed to match reasonably to increase the upright degree. Therefore, the vertical angle of seedling ~~dropping~~ planting was the major factor influencing the upright degree [31].

2) Horizontal angle of seedling box and forward speed of ~~the locomotive~~ locomotion

When analyzing the influence of ~~two factors~~ the interaction between the horizontal angle of the seedling box Z_1 and the forward speed of ~~the locomotive~~ locomotion Z_3 on the upright degree y, we ~~can~~ set the vertical angle of seedling ~~dropping~~ planting at $Z_2 = 0$; ~~and then~~ hence, the regression equation was expressed as (10):

$$y = 77.005 - 10.816Z_1 - 5.73Z_3 \qquad (10)$$

The influence of the interaction between the horizontal angle of the seedling box and the forward speed of ~~the locomotive~~ locomotion on the upright degree ~~was shown~~ is graphed in Figure 12.When the forward speed of ~~the locomotive~~ locomotion was at the ~~level of~~ -0.594 level and the horizontal angle of the seedling box was below ~~level~~ 0, the upright degree was the highest. When the forward speed ~~of the locomotive~~ was fixed, the upright degree changed little with ~~the~~ a change ~~of~~ in the horizontal angle ~~of seedling box~~. When the horizontal angle ~~of seedling box~~ was fixed, the upright degree changed significantly with ~~the~~ a change ~~of~~ in the forward speed ~~of the locomotive~~. Too large or too small a change in the forward speed ~~of the locomotive would~~ caused a decrease ~~of~~ in the upright degree. These ~~reason was that,~~ changes occurred when the forward speed of ~~locomotive~~ locomotion was the same ~~with~~ as that of the horizontal component velocity of the seedlings knife [Is "knife" the correct word here? This is the 1st occurrence.] but in the opposite direction [32 and 33], when both were approaching ~~seedling dropping~~ planting at zero speed and the seedlings' landing was most stable. Therefore, the horizontal angle of the seedling box was the major factor influencing the upright degree.

Revise graphic:

Forward speed of ~~the locomotive~~ locomotion

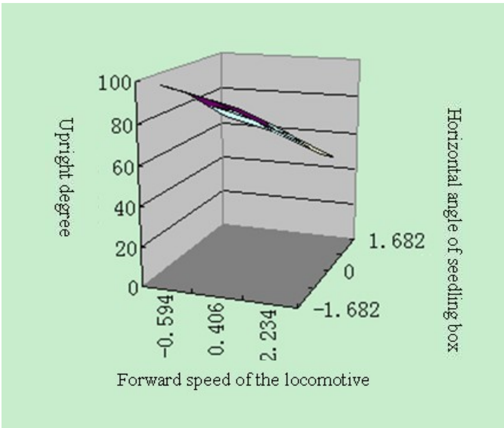


Figure 12 Effects of horizontal angle of seedling box and forward speed of ~~the locomotive~~ locomotion on upright degree

3) Vertical angle of seedling ~~dropping~~ planting and forward speed of ~~the locomotive~~ locomotion

When analyzing the influence of ~~two factors~~ the interaction between the vertical angle of seedling ~~dropping~~ planting Z_2 and the forward speed of ~~the locomotive~~ locomotion Z_3 on the upright degree, we ~~can~~ set the horizontal angle of the seedling box at $Z_1 = 0$; ~~and then~~ thus, the regression equation was expressed as (11):

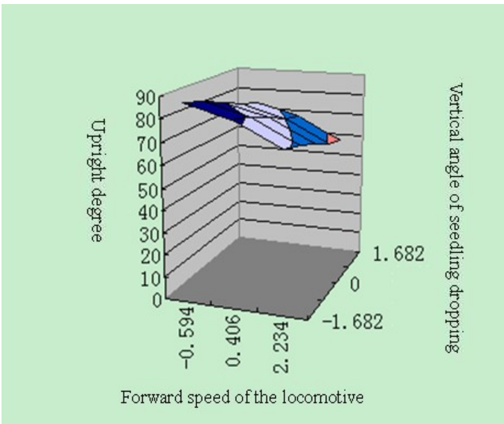
$$y = 77.005 - 4.38Z_2 - 5.783Z_3 \quad (11)$$

Revise graphic:

Forward speed of ~~the locomotive~~ locomotion

and

Vertical angle of seedling ~~dropping~~ planting



The influence of seedling ~~dropping~~ planting and the

Figure 13 Effect of forward speed of ~~the locomotive~~ locomotion and vertical angle of seedling ~~dropping~~ planting on upright degree forward speed of ~~the locomotive~~ locomotion on the upright degree ~~was shown~~ is graphed in Figure 13.When the forward speed ~~of the locomotive~~ was at the ~~level of~~ -0.594 level and the vertical angle ~~of seedling dropping~~ was below ~~level~~ 0, the upright degree was relatively higher. When the forward speed ~~of the locomotive~~ was fixed, the upright degree changed little with the change ~~of~~ in the vertical angle ~~of seedling dropping~~. When the forward speed ~~of locomotive~~ was ~~fluctuate~~ fluctuating ~~on~~ at the critical point of ~~seedling dropping~~ planting at zero speed, the upright degree was relatively stable. The upright degree changed more significantly when the forward speed ~~of the locomotive~~ was above the level of 0.406 than it was below that level ~~0.406~~. Therefore, the forward speed of ~~the locomotive~~ locomotion was the major factor influencing the upright degree.

5.6 Analysis of ~~the~~ importance of factors

The contribution-rate method was usually used to determine the primary ~~&~~ and secondary [Insert a noun?] ~~and~~ as well as the importance of the influence of various factors on the target. For the quadratic regression equation [34], we ~~got~~ obtained the variance ratio of regression coefficients $F(j)$, $F(ij)$, $F(jj)$ and ~~set~~ formulated the equation ~~was~~ as (12):

$$\delta = \begin{cases} 0(F \leq 1) \\ 1 - \dfrac{1}{F}(F > 1) \end{cases} \tag{12}$$

We ~~got~~ obtained the contribution rate of each factor of the regression equation ~~to~~ for the evaluation index y.

The formula of the contribution rate of factor j ~~to evaluation~~ for that index ~~y~~ was (13): [Delete this *y*]

$$\triangle_j = \delta_j + \frac{1}{2}\sum_{\substack{i=1 \\ i \neq j}}^{m} \delta_{ij} + \delta_{jj} \tag{13}$$

where

δ_j ~~was~~ is the contribution of factor j as a coefficient; δ_{ij}, ~~was~~ the contribution of interaction terms; δ_{jj}, ~~was~~ the contribution of the quadratic term. Through comparing the value of the contribution rate [35], we can intuitively determine the primary and secondary [Insert a noun?] ~~and~~ as well as the importance of the influence of each factor on evaluation y.

Table 5 Regression coefficients and contribution rates

Regression ~~coefficients~~ coefficient	Contribution rate
$F_{(1)} = 23.879$	$\Delta_1 = 0.958$
$F_{(2)} = 27.716$	$\Delta_2 = 0.963$

$F_{(3)} = 24.755$	$\Delta_3 = 0.959$

~~Therefore~~ Thus, the variance ratio of regression coefficients and the contribution rates in this test ~~were shown~~ are listed in Table 5.

~~So~~ Therefore, the descending order of importance of the factors ~~was~~ is as follows: vertical angle of seedling ~~dropping~~ planting, forward speed of ~~locomotive~~ locomotion, and horizontal angle of the seedling box.

5.7 Optimization of working parameters

The optimization of working parameters with Matlab by solving the regression equation ~~was that~~ is as follows: ~~when~~ horizontal angle of seedling box, ~~was~~ 22.5° and ~~horizontal angle of seedling box was~~ 13.14° ; ~~and the~~ forward speed of ~~the locomotive~~ locomotion, ~~was~~ 0.57 m/s; ~~the~~ upright degree of ~~seedling-growing bowl~~ sprouting tray, ~~made of maize straw reached~~ 89.64%. [Better: List this data in a Table.]

5.8 Verification test

To adjust the testing ~~bed~~ plot for the seedling-~~providing~~ feeding device to the optimum parameters and measure the differences ~~of~~ in the upright degrees of several experiments and the fit of the results by theoretical analysis [36 and 37], the upright degree of the maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize straw~~ (shown in Figure 14) was determined ~~as~~ to be 83.6%. The relative error was no more than 6.04% when compared with the optimal results, which was within the allowable range; ~~so~~ therefore, the optimal results were reliable.

Table 6 Results of experimental verification

No.	Z_1 /°	Z_2 /°	Z_3/(m·s^{-1})	Z_L /%	Average
1	13.14°	22.5°	0.57m/s	82.32	
2	13.14°	22.5°	0.57m/s	85.08	83.6%
3	13.14°	22.5°	0.57m/s	83.42	

Figure 14 Verification test

6 Production test

6.1 Test conditions

The production test was conducted in Shengping Township, ~~in~~ Anda City, Heilongjiang Province from May to October ~~in~~ 2014. The testing ground was flat ~~without covering with~~ and free of both weeds and crop residues[38, 39 and 40]. The ridge distance was 65 cm in ~~The soil was~~ black soil ~~And the~~ having a firmness ~~was~~ of 236.7$\times$10^4 Pa.

6.2 Test design

To verify the reliability and ~~yield~~ increase ~~of~~ in yield from a transplanting machine ~~of~~ equipped with a maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize straw~~ (T), we set two conditions. ~~One~~ The first was to compare the seedling-~~providing~~ feeding device ~~of~~ on an automatic transplanter ~~of seedling-growing bowl tray made of maize~~ having the aforementioned type of sprouting tray (T$_1$), as developed by the Agricultural Machinery Engineering Science Research Institute of Heilongjiang Province, with transplantation in traditional maize production. The ~~other one~~ second was to compare ~~with~~ manual transplanting (T$_2$) with traditional maize production. Therefore, we set 4 [Delete Arabic numeral] four 1.2 ha testing areas, ~~with~~ each ~~area of 1.2 ha and~~ under the same management.

6.3 Evaluation indicator

1) ~~Qualified~~ Qualification rate of ~~planting~~ plant spacing

We set the distance between each two adjacent ~~2~~ seedlings ~~to~~ at X_i (mm) and the theoretical transplanting spacing ~~to~~ at X_r (mm) to determine the qualification rate of plant spacing according to the relationship between X_i and X_r [41], for which the actual distance between adjacent ~~2~~ seedlings was $X_i \in (0.5X_r, 1.5X_r]$.

~~So~~ Thus, the ~~qualified~~ qualification rate ~~of planting spacing can be~~ is calculated with equation (14):

$$Z_G = \frac{Z_{GH}}{Z_{HT}} \times 100\% \tag{14}$$

where Z_G is the ~~qualified~~ qualification rate ~~of planting spacing~~; %. Z_{GH}, the number of spacing-qualified seedlings; and Z_{HT}, the total number of seedling samples ~~of seedlings~~.

2) Omitted planting ~~omission~~ rate

The evaluation criteria ~~of~~ for quality operation ~~quality~~ of a rapeseed transplanting machine ~~specified~~ specifies the measurement of distance between two adjacent ~~2~~ seedlings. We set ~~it~~ this measurement ~~to~~ at X_i (mm) and ~~set~~ the theoretical transplanting spacing ~~to~~ at X_r (mm) to determine the number of ~~omission~~ omitted plantings according to the relationship between X_i and X_r. When the actual distance between two adjacent ~~2~~ seedlings was $X_i \in (0.5X_r, 1.5X_r]$, the number of ~~omission~~ omitted plantings was one; when the actual distance was $X_i \in (2.5X_r, 3.5X_r]$ [41], the number of ~~omission~~ omitted plantings was two. ~~And so forth.~~

~~So~~ Thus, the omitted planting ~~omission~~ rate ~~can be~~ is calculated with equation (15):

$$Z_O = \frac{Z_{OH}}{Z_{OT}} \times 100\% \tag{15}$$

where Z_O is the omitted planting ~~omission~~ rate, %; Z_{OH}, the number of ~~omission~~ omitted plantings; Z_{OT}, the total number of samples ~~of planting~~.

6.4 Test results

The test results ~~were shown~~ are listed in Table 7.

Table 7 Production test results

Indicators	T	T_1	T_2
Manual input/(yuan·ha^{-1})	1233	1300	1672
Manufacturing cost /yuan	43200	67000	0
Spacing ~~qualified~~ qualification rate/%	94.1	93.9	92.7
Upright-degree ~~qualified~~ qualification rate/%	83.2	83.1	80.1
Omitted planting ~~omission~~ rate/%	2.2	2.3	3.2
Yield increase/%	10.2	10.0	5.7

As ~~shown~~ indicated in Table 7, T was closer to T_1 in ~~aspects~~ terms of manual input, spacing ~~qualified~~ qualification rate, upright-degree ~~qualified~~ qualification rate, and yield increase; ~~but~~ however, the manufacturing costs were reduced by 35.5%. When compared with T_2, the manual input was reduced 26.26%; the spacing ~~qualified~~ qualification rate increased 1.4%; the upright-degree ~~qualified~~ qualification rate ~~of upright degree~~ increased 3.1%; the omitted planting ~~omission~~ rate was reduced 1.0%; and the yield increased 4.5%. ~~Above~~ These results ~~proved~~ demonstrate that the design, theoretical analysis and parameter selection were ~~rational of~~ reasonable for the seedling-~~providing~~ feeding device ~~of~~ on the automatic transplanter ~~of~~ on the maize seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize~~ used in this ~~paper~~ research [42, 43and 44].

7. Conclusion

In this ~~paper~~ study, ~~took~~ a stepwise regression analysis of multi-~~factors~~ factor experimental results was implemented ~~through~~ via SPSS, ~~established the~~ a mathematical model of the main parameters of a seedling-~~providing~~ feeding device ~~of~~ on the automatic transplanter ~~of~~ on a maize seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize~~ formulated, and a field test conducted. The conclusions were as follows:

1) The ~~influence degree of~~ working parameters ~~on~~ influencing the upright degree were ranked in descending order (and best working parameters) ~~was~~ as follows: vertical angle of seedling ~~dropping~~ planting, forward speed of ~~locomotive~~ locomotion, and horizontal angle of seedling box.

2) The optimization of working parameters was ~~that~~ achieved when the horizontal angle of the

seedling box was 22.5° ; the ~~horizontal~~ vertical angle of the seedling box, ~~was~~ 13.14° ; ~~and~~ the forward speed of ~~the locomotive~~ locomotion, ~~was~~ 0.57m/s; and the upright degree of the maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray, ~~made of maize straw reached~~ 89.64%.

3) Compared with maize transplanting machines currently on the market, the labor inputs, as well as the rates of spacing ~~qualified rate~~ and upright degree ~~qualified rate~~ qualification, omitted planting ~~omission rate~~ and the yield of our ~~seedling providing~~ new feeding device ~~of~~ for the automatic transplanter ~~of~~ on a maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize straw~~ were ~~basically~~ essentially the same; ~~but~~ however, the manufacturing cost was reduced by 35.5%. Compared with manual transplanting operations, the rates of spacing ~~qualified rate~~ and upright degree ~~qualified rate~~ qualification ~~and~~ as well as the yield increased 6.9%, 3.1% and 4.5%, respectively; whereas, the planting omission rate was reduced by 1.0%.

Acknowledgments ["XXXX" indicates redaction for anonymity.]

This study was funded by Scientific and Technological Project Number: XXXX and Universities Science and Technology Innovation Team Project Number: XXXX in XXXX Province. [CJR stopped editing at this point.]

References

[1] Wu W X, Luo X W, Yang W Y. Review on mechanization of strip compound planting system of wheat-maize-soybean. Transactions of the CSAE, 2015; 31(Supp.1): 1—7. (In Chinese with English abstract)

[2] He P. Introduction to maize seedling transplanting mechanization technology in our country. Chinese Agricultural Mechanization, 1999; (2): 37—40. (in Chinese with English abstract)

[3] Ma S Q, Wang Q, Luo X L. Effect of climate change on maize growth and yield based on stage sowing . Acta Ecologica Sinica, 2008; 28(5): 2131—2139 (In Chinese with English abstract)

[4] Chen Z, Hao F P, Wang D F. Development of technology and equipment of corn harvester in China. Transactions of CSAM. 2012; 43(12):45—50. (In Chinese with English abstract)

[5] Ma S Q, Wang Q, Chen F T. Impact of spring maize seeding growth on yield and assessment models of production cut under background of spring drought. Transactions of the CSAE, 2015; 31(Supp.1): 171—179. (In Chinese with English abstract)

[6] Zhang S J, Zhang Y S, Sun L B..Analysis of distributional characteristics and primary causes of maize drought in northeast china. Chinese Joural Agrometeorology, 2013;34(3)：350—357. (In Chinese with English abstract)

[7] Dong Q T, Li M S, Liu J. Spatio—temporal evolution characteristics of drought of spring maize in

northeast china in recent 50 years. Journal of Natural Disasters, 2011; 20(4)： 52－59. (In Chinese with English abstract)

[8] Zhou F J, Lu J, Du J X. Parameters optimization and experiment of corn-paper transplanting machine with seedling disk. Transactions of the CSAE, 2014; 30(1): 18－24. (In Chinese with English abstract)

[9] Wu W, Sun S L, Xiao M T. Optimization design for planter of 2ZY-1 tobacco transplanting machine. Chinese Journal of Construction Machinery,2012; 10(2): 166－170. (In Chinese with English abstract)

[10] Yu X G, Yuan W S, Wu C Y. Research and development status of the oilseed rape transplanter in China and improvement of clip-chain transplanter. Journal of Agricultural Mechanization Research, 2011; (1): 232－234. (In Chinese with English abstract)

[11] Feng J, Qin G, Song W T. The kinematic analysis and design criteria of the dibble-type transplanters. Transactions of the CSAM, 2002; 33(5): 48－50. (In Chinese with English abstract)

[12] Song H B, An F P, Shi Y. Study on eccentric transplanter. Transactions of the CSAM, 1997; 28(Suppl): 41－45. (In Chinese with English abstract)

[13] Liu L, Chen Y C, B X. Reserch on the transplanting machine with the nacelle. Journal of Shihezi University: Natural Science, 2008; 26(4): 504－506. (In Chinese with English abstract)

[14] Hu H L, Gu S K, Zeng A J. The design and experiment on planting apparatus with seeding-guiding tube. Transactions of the CSAM,1995;11(2)：59－64. (In Chinese with English abstract)

[15] Wang J W, Tang H, Zhou W Q. Improved design and experiment on pickup finger precision seed metering device. Transactions of CAME. 2015; 46(9): 68－76. (In Chinese with English abstract)

[16] Ma S Q, Wang Q, Luo X L. Effect of climate change on maize growth and yield based on stage sowing . Acta Ecologica Sinica, 2008; 28(5): 2131－2139 (In Chinese with English abstract)

[17] Dong Q T, Li M S, Liu J. Spatio－temporal evolution characteristics of drought of spring maize in northeast china in recent 50 years. Journal of Natural Disasters, 2011; 20(4)： 52－59. (In Chinese with English abstract)

[18] Hsiao T C. Plant responses to water stress . Annual Reviews in Plant Physiology, 1973; 24(1): 519－570.

[19] Lebreton C, Lazić-Jančić V, Steed A, etal. Indentification of QTL for drought responses in maize and their use in testing causal relationships between traits . Journal of Experimental

Botany,1995;46(7): 853－865.

[20] Seregin I V, Kozehevnikova A D. Strontium transport, distribution, and toxic effects on maize seedling growth .Russian Journal of Plant Physiology; 2004; 51(2): 215－221.

[21] Gao X, Gong D Z, Gu F X. Inhibiting soil respiration and improving yield of spring maize in fields with plastic film mulching. Transactions of the CSAE, 2014; 30(6): 62－70. (In Chinese with English abstract)

[22] Li R, Hou X Q, Jia Z K. Effects on soil temperature, moisture, and maize yield of cultivation with ridge and furrow mulching in the rainfed area of the Loess Plateau, China. Agricultural Water Management, 2013;(116):101－109.

[23] Ding R S, Kang S Z, Li F S. Evapotranspiration measurement and estimation using modified Priestley-Taylor model in an irrigated maize field with mulching. Agricultural and Forest Meteorology, 2013;(168): 140－148.

[24] Wang Y J, Xie Z K, Malhi S S. Effects of rainfall harvesting and mulching technologies on water use efficiency and crop yield in the semi-arid Loess Plateau,China. Agricultural Water Management, 2009; 96(3):374－382.

[25] Chu J, Lu H D, Xue J Q. Field experiment and effect of precise mechanical sowing of maize based on wide-narrow row deep rotation and no-tillage technology. Transactions of the CSAE, 2014; 30(14): 34－41. (In Chinese with English abstract)

[26] Zhou L M, Li F M, Jin S L. How two ridges and the furrow mulched with plastic film affect soil water, soil temperature and yield of maize on the semiarid Loess Plateau of China . Field Crops Research, 2009; 113(1):41－47.

[27] Li Z G, Zhang R H, Wang X J, et al. Carbon dioxide fluxes and concentrations in a cotton field in northwestern china: Effects of plastic mulching and drip irrigation. Pedosphere, 2011; 21(2): 178－185.

[28] Song C C, Sun L, Huang Y. Carbon exchange in a freshwater marsh in the Sanjiang Plain, northeastern China. Agricultural and Forest Meteorology, 2011; 151(8): 1131－1138.

[29] Hao Y B, Wang Y F, Mei X R. The sensitivity of temperate steppe CO2 exchange to the quantity and timing of natural interannual rainfall. Ecological Informatics, 2010; 5(3): 222－228.

[30] Song Z W, Guo J R, Deng A X. Effects of surface tillage regimes on soil moisture and temperature of spring corn farmland in Northeast China. Transactions of the CSAE, 2012, 28(16): 108－114. (In

Chinese with English abstract)

[31] Kang S Z, Liang Z S, Pan Y H. Alternate furrow irrigation for maize production in an arid area. Agricultural Water Management, 2000; 45(3): 267－274.

[32] Alvarez R, Steinbach H S A. Review of the effects of tillage systems on some soil physical properties, water content, nitrate availability and crops yield in the Argentine Pampas. Soil and Tillage Research, 2009; 104(1): 1－15.

[33] Soegaard H, Jensen N O, Boegh E. Carbon dioxide exchange over agricultural landscape using eddy correlation and footprint modeling. Agricultural and Forest Meteorology, 2003; 114(3): 153－173.

[34] Suyker A E, Verma S B, Burba G G, et al. Growing season carbon dioxide exchange in irrigated and rainfed maize. Agricultural and Forest Meteorology, 2004; 124(1): 1－13.

[35] Okuda H, Noda K, Sawamoto T, et al. Emission of N2Oand CO2 and uptake of CH4 in soil from a Satsuma mandarin orchard under mulching cultivation in central Japan. Journal of the Japanese Society for Horticultural Science, 2007; 76(4): 279－287.

[36] Wang C Y, Cai J J, Zhang J Q. Risk assessment of drought and chilling injury of maize in Northeast China. Transactions of the CSAE, 2015; 31(6): 238－245. (In Chinese with English abstract)

[37] Davidson R A, Lamber K B. Comparing the hurricanee disaster risk of U.S.coastal counties. Natural Hazards Review, 2001; 2(3): 132－142.

[38] Liu Y, Yang X G, Zhao J. Effects of climate change and variety alternative on potential yield of spring maize in Northeast China. Transactions of the CSAE ,2013; 29(18): 179－190. (In Chinese with English abstract)

[39] Andrighetto, Mosca G, Cozzi G. Maize-Soybean intercropping effect of different variety and sowing density of the Legume on forage yield and silage quality. Agronomy & Crop Science, 1992; (168): 354－360.

[40] Liu K S, Wiatrak Pawel.Corn production response to tillage and nitrogen application in dry-land environment. Soil and Tillage Research, 2012; (124):138－14

[41] Licht M A, Al-Kaisi M. Strip tillage effect on seedbed soil temperature and other soil physical properties. Soil and Tillage Research, 2005; (80): 233－249.

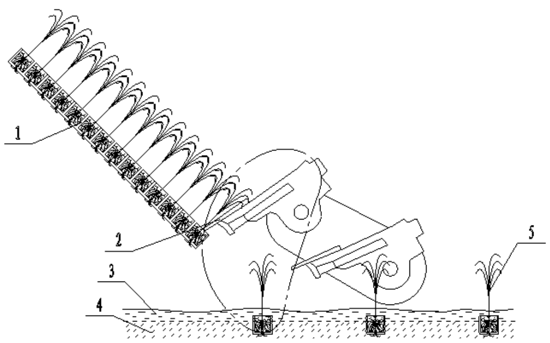
[42] Chen Z H, Chen X W, Qi X. Effect of chemical regulayion on maize in different cultivation

densities. Agricultural Science and Technology, 2011; 12(5): 691－694.

[43] Pirasteh-Anosheh H, Emam Y, Ashraf M. Impact of cycocel on seed germination and growth in some commercial crops under osmotic stress conditions. Archives of Agronomy and Soil Science, 2014; 60(9):1277－1284.

[44] Sulewska H, Smiatacz K, Szymanska G, et al. Seed sizeeffect on yield quantity and quality of maize (Zea mays L.)cultivated in South East Baltic region. Zemdirbyste-Agriculture, 2014; 101(1): 35－40.

Biographies: XXXX



1. maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of maize straw~~ 2. planting mechanism 3. water layer 4. soil 5. ~~seedling-growing bowl~~ sprouting tray ~~made of maize straw~~ in block after ~~transplanting~~ transplantation

Figure 4 ~~The transplanting~~ Transplantation process ~~of~~ with maize straw seedling-~~growing~~ sprouting ~~bowl~~ tray ~~made of~~