

## Design and Experiment of Precision Rice Hill-drop Drilling Planter for Dry Land Based on Adjustable Speed Scoop-wheel Seedmeter

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**Abstract.** At present, the rice direct seeding equipments in China are difficult to achieve precise hill-drop and can not meet the agronomic requirements, so we put forward a rice direct seeding technique with synchronous open furrows and design a suspension type of precision rice hill-drop drilling planter for dry land based on adjustable speed scoop-wheel seedmeter. This paper describes the overall structure and performance parameters of the equipment, introduce the design of adjustable speed spoon-wheeled seedmeter and transmission system in detail, and obtain the key parameters. The field performance tests show that under the adjustable range, say, 8 rows, spaced 250mm, 100-240mm hole space, the consistency deviation of the holes is less than 3%, the hole space deviation is less than 3%, the empty hole rate is less than 5% and the overall performance is excellent. This design provides a new method and reference for design and application of rice direct seeding.

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### 1 Introduction

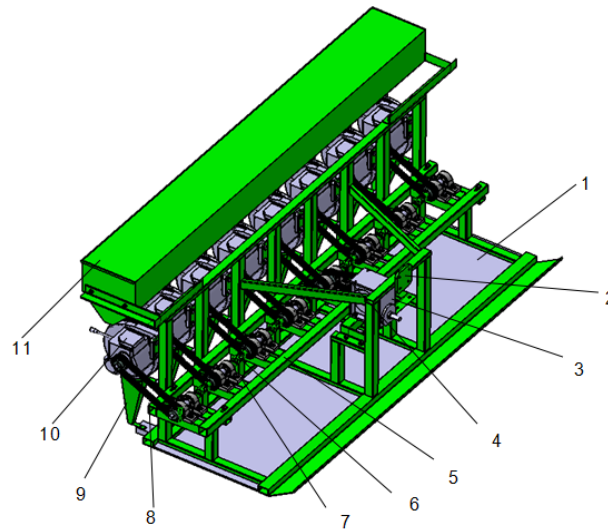
Rice direct seeding is a simple cultivation method which sows the seeds directly in the field instead of artificial seedling and transplanting<sup>[1-3]</sup>. The foreign researches on rice direct seeding began in the last century and have developed many machine models which are suitable for various working conditions. Most of them are based on models designed by engineer Class and Kubota. In China, precision rice hill-drop drilling machine for dry land with synchronous fertilizing and rice pneumatic seedmeter-oriented stir equipment are conducted by Zeng Shan<sup>[4]</sup> and Zhang Guozhong<sup>[7]</sup> respectively. This kind of machine is mainly to analyze the control of planting seeds.

The rice direct seeding equipments in China are difficult to achieve precise hill-drop and can not meet the agronomic requirements, so we put forward a precision rice hill-drop drilling planter for dry land based on adjustable speed scoop-wheel seedmeter. It has advantages of strong adaptability, adjustable speed, stable sowing which meet the requirements of rice seeding precisely and provides equipment and technical support to accelerate the rice planting mechanization.

### 2 Overall structure and performance parameters

The overall structure of precision rice hill-drop drilling planter for dry land based on adjustable speed scoop-wheel seedmeter is shown in figure 1. It is mainly composed of floating plate and bracket, total suspension, reducer, total input chain, transmission bracket, universal transmission shaft, transmission shaft, power output chain, seed spout, seeder unit, seed box and so on. The working process including power output machine sends power to power input shaft of reducer of planter through total output universal joint, then reducer, the output power to the total transmission shaft, then sends power to both sides through universal shaft in order to make the transmission

shafts rotate with the same speed. Each transmission shaft drives its own corresponding seedmeter to rotate. The seeds in seedmeter fall into seed spout through opening and come to the holes in the field. Thus, the whole process is completed. The performance parameters of equipment are shown in Table 1.



1-floating plate and bracket,2-total suspension,3-reducer,4-total input chain,5-transmission bracket  
6-universal transmission shaft,7-transmission shaft,8-power output chain,9-seed spout,10-seeder  
unit,11-seed box

Fig.1 The overall structure diagram of rice planter

Tab. 1 Technical parameters of rice planter

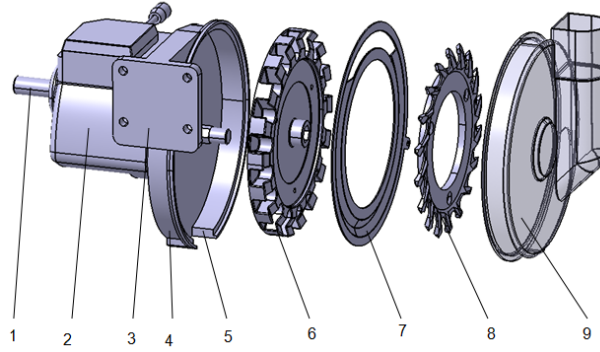
Contents	Type of parameters
Structure	suspension
Power/ <i>kW</i>	15.4
Speed/ ( $r \cdot \min^{-1}$ )	3000
Size ( $L \times W \times H$ ) / ( $mm \times mm \times mm$ )	2896×724×936
Operational efficiency/ ( $m^2 \cdot h^{-1}$ )	3000□9000
Mass/ <i>Kg</i>	780
The number of rows	8
Row space/ <i>mm</i>	250

### 3 Design of Key Components

#### 3.1 Adjustable Speed Scoop-wheel Seedmeter

##### 3.1.1 Transmission Structure Design of Seedmeter

Adjustable Speed Scoop-wheel Seedmeter is composed of shell, speed regulating device, guide impeller, clapboard, seed spoon wheel and end cover. Seeds can be sent to the seed meter by seed inlet mouth which is in the outer end of the end cover. Dig holes for seeds, rotate with spoon-wheel and transport seeds to the upper level along the scoop-wheel. The seeds drop to the guide groove in the surrounding of guide impeller. The guide impeller rotates against the wall of it. When the seeds are rotated to the opening, they will fall into the seed tube [8], as shown in Figure 2.

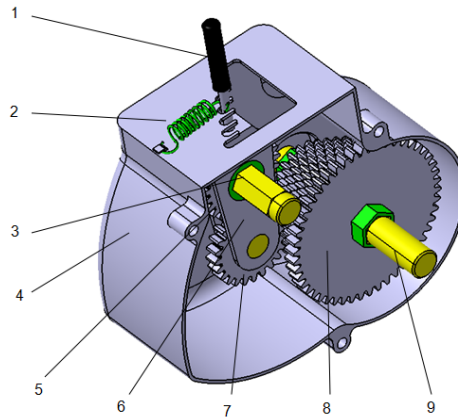


1-power input shaft, 2-speed regulating device,3-Hanging fixing holes,4-shell,5-seed opening  
6-Guide impeller,7-Clapboard,8-scoop-wheel,9-end cover

Fig.2 Structure diagram of spoon-wheel seedmeter

### 3.1.2 Speed Control Structure Design of Seedmeter

Scoop-wheel seedmeter has its own speed regulating device and could adjust the spaces between seeds, so it is very convenient and practical. Speed regulating device of spoon-wheel seedmeter is composed of shell, speed regulating handle, tension spring, power input shaft, power output shaft, driving gear, cage, inertial wheel and driven gears and other parts. By toggling the handle, driving gear could change position on power input shaft in order to control and regulate different numbers of teeth between inert wheel and driven gear in terms of gear meshing. By changing the gear ratio to adjust the speed of the output shaft of seedmeter, thus adjusting the range of seeds, as shown in figure 3.



1-speed regulating handle, 2-power input shaft,3-tension spring,4-shell,5-driving gear  
6-cage,7-inertial wheel,8-driven gears,9-power output shaft

Fig.3 Structure diagram of speed regulating device of spoon-wheel seedmeter

When planter is working, output power is transmitted to the seedmeter via power input shaft of spoon-wheel seedmeter. The rotation of power input shaft of seedmeter drives the rotation of driving gear, the driving gear transmits the power to the power output shaft through the transmission between inertial wheel and driven gear.

### 3.1.3 Speed Control Parameter Design of Seedmeter

When the rice planter is working, the engine of machine drives the driving wheel forward in the field and the speed can be controlled. The space between holes of planter is a constant, does not change with the machine's forward speed. The transmission ratio  $i_{PK}$  of rear drive shaft (driving wheel) to the power output shaft (swivel caster) of prime motor is a constant. Set K for rear wheel driving shaft, P for power output swivel caster shaft, the transmission ratio  $i_{PK}$  is:

$$i_{PK} = \frac{n_p}{n_k} \quad (1)$$

Rice planter has its own speed regulating device and could adjust the spaces between seeds, the transmission principle diagram of regulating device is shown in figure 4. As can be seen from the figure, the principle of speed regulation lies in gear set on the output shaft T of seedmeter, the different gear mesh between power input shaft E and output shaft T leads to different speed ratios, so as to control the speed of output shaft of seedmeter. According to the number of gear teeth in the figure 4, we could calculate the maximal and minimal transmission ratio  $i_{ET}$  between power input shaft E and output shaft T of seedmeter, thus obtaining the range of  $i_{ET}$ . Define the maximal value of  $i_{ET}$  is  $i_{ET \max}$  and the minimal is  $i_{ET \min}$ , then

$$i_{ET \max} = \frac{n_{E \max}}{n_T} \quad (2)$$

$$i_{ET \min} = \frac{n_{E \min}}{n_T} \quad (3)$$

From equation (2) and (3), we could obtain the range of transmission ratio  $i_{ET}$  between power input shaft E and output shaft T. In order to get the total transmission ratio  $i_x$  of transmission system, we could choose the transmission ratio (set as  $\overline{i_{ET}}$ ) corresponding to the median seed space to compute and design the total transmission ratio  $i_x$  at the first step when design the movement parameters.

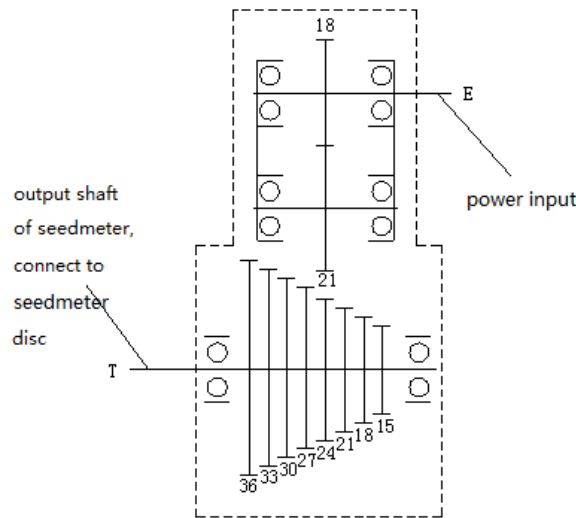


Fig.4 Transmission principle diagram of regulating device

The distance of driving wheel per unit time is equal to the maximal distance between seeds, whereas the distance between seeds is a constant when rice planter is working in the field according to the specific agronomic requirements. Therefore, the transmission ratio  $i_{TK}$  of rear drive shaft (driving wheel) K of prime motor to output shaft of seedmeter T is a certain. The distance between two adjacent holes should be calculated on the basis of agronomic requirement of average distance. According to the requirement that the distance of driving wheel per unit time is equal to the maximal distance between seeds, we have

$$\Delta x \times n_T \times N = n_K \times \pi \times d \quad (4)$$

Where  $\Delta x$  ---- the distance between the adjacent seeds (hole space);

$n_T$  ----the speed of seedmeter disc;

$n_K$  ----the speed of rear drive shaft (driving wheel) of prime motor;

$N$  ----the number of holes in seedmeter disc;

d---the walking diameter of rear drive shaft (driving wheel) of prime motor.

According to the above equation, we have

$$i_{TK} = \frac{n_T}{n_K} = \frac{\pi \times d}{\Delta x \times N} \quad (5)$$

The ratio of power output swivel caster shaft P of prime motor to output shaft T of seedmeter is transmission ratio  $i_{PT}$ . According to the analytic result, the total transmission ratio  $i_x$  is

$$i_x = i_{PE} = \frac{i_{PT}}{i_{ET}} = \frac{\frac{n_{PK}}{n_{TK}}}{\frac{n_{Emid}}{n_T}} \quad (6)$$

In this design, the prime motor of rice planter is the Kubota ride-speed planter, according to technical parameters provided by the manufacturer, the walking diameter of driving wheel of it is 900mm. From the equation (1),

$$i_{PK} = 9.792$$

Rice planter adopts the 18 spoons, 8 adjustable speeds seedmeter. In the teeth gear set of speed control device, the maximum number of teeth, the middle number of teeth and the minimum number of teeth are  $z_{\max} = 36$ ,  $z_{mid} = 24$ ,  $z_{\min} = 15$ . From the equation (2) and (3),

$$i_{ET \max} = 2 \quad i_{ET \min} = 0.833$$

Given that the number of holes in seedmeter disc  $N = 18$ , the walking diameter of rear drive shaft (driving wheel) of prime motor  $d = 0.9$  mm, the distance between rice seeds normally ranges from 120mm, 140mm, 160mm, 180mm, to 210mm and the average value is 160mm. i.e., use  $\Delta x = 160$  mm in the calculation, from the equation (5),

$$i_{TK} = 0.982$$

From the equation (6),

$$i_x = 7.48$$

We could obtain the parameters of governor, as shown in the table 2.

Tab. 2 Transmission ratio parameters of Governor

Transmission Ratio	$i_{PK}$	$\overline{i_{ET}}$	$i_{TK}$	$i_{PT}$	$i_x$
Value	9.792	1.333	0.982	9.974	7.48

### 3.2 Overall Design of Transmission

Design the overall scheme of transmission according to transmission roadmap of rice planter, as shown in figure 5, where K is the rear drive shaft (driving wheel) of prime motor, P is the power output shaft (swivel caster) of prime motor, E is input shaft of seedmeter, T is output shaft of seedmeter.  $i_x$  is total transmission ratio of transmission system,  $i_{ET}$  is transmission ratio of seed space adjustment device of seedmeter.

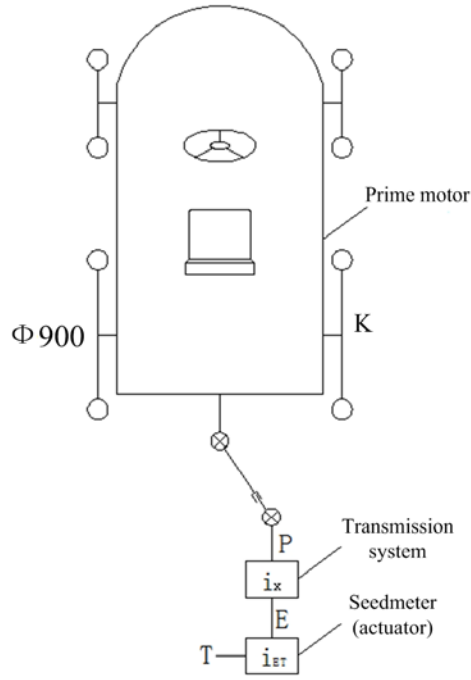


Fig.5 Overall scheme of transmission diagram of rice planter

According to the transmission roadmap of rice planter, as shown in figure 6, the entire transmission system contains three stage transmissions. The first stage is from power input shaft of reducer (P) to power output shaft (Q), the second stage is from power output shaft of reducer (Q) to transmission shaft (V), the third stage is from transmission shaft (V) to power input shaft of seedmeter (E). Therefore, we obtain the following relations:

$$i_x = i_{PE} = i_{PQ} \cdot i_{QV} \cdot i_{VE} \quad (7)$$

Where  $i_{PQ}$  ----the transmission ratio of reducer;

$i_{QV}$  ----the transmission ratio of power output shaft of reducer to transmission shaft;

$i_{EV}$  ----the transmission ratio of transmission shaft to power input shaft of seedmeter.

In order to make the power transmission in transmission systems more efficient and reliable, when distribute the transmission ratio for all levels, the transmission ratio of reducer in the first stage is designed as the same value as transmission ratio of total transmission system, the transmission ratios of second and third stage are all 1: 1, i.e.,  $i_{PQ} = 7.5$ ,  $i_{QV} = i_{VE} = 1$ . According to this method, the relations between power output shaft of reducer and transmission shaft and between transmission shaft and power input shaft of seedmeter are all 1: 1. So, we could choose the chain-type transmission and the sprocket which has same number of gear teeth as the power input/output shafts for power transmission.

According to the above analysis and computation, we could obtain the detail transmission system diagram of rice planter, as shown in figure 6. As can be seen from the figure, the first stage of transmission system(P-Q) is chosen the worm reducer which speed ratio is 7.5, the choices of second stage (Q-V) and third stage (V-E) are 1:1 chain transmissions and the number of sprocket teeth are all 15.

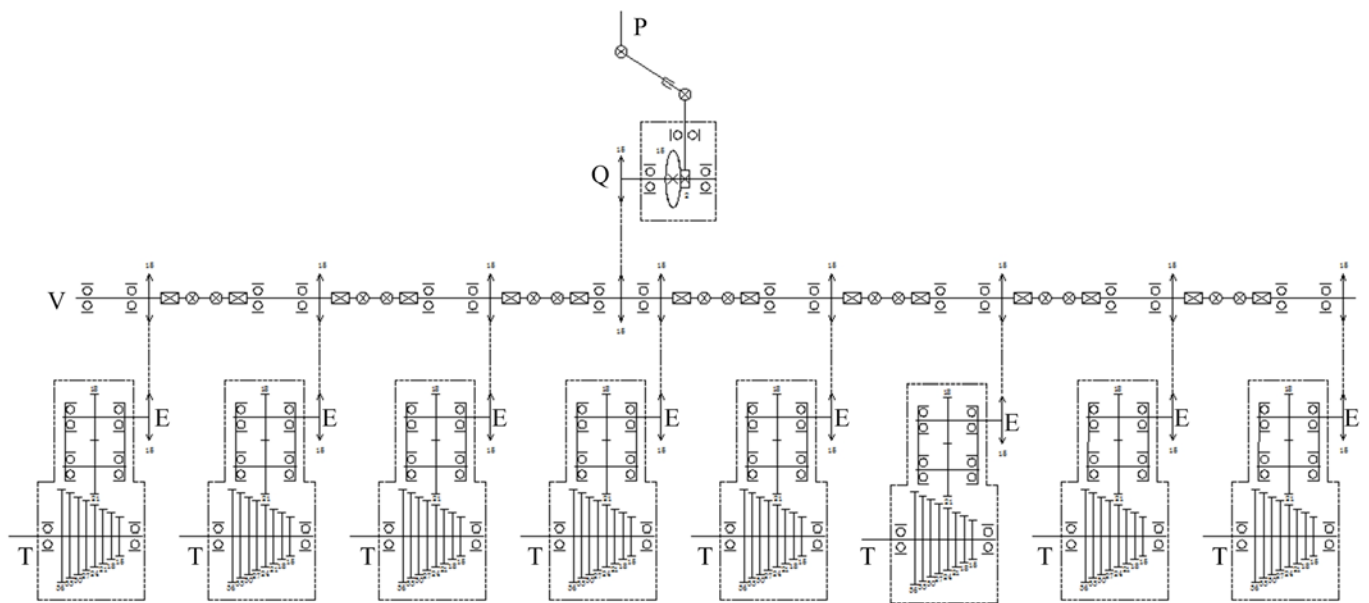


Fig.6 Transmission system diagram of rice planter

## 4 Field Test

### 4.1 Test Condition

The prototype machine is mainly composed of planter body and prime motor. Prime motor of planter is a Kubota ride-speed, four-wheel rice planter (Model NSPU-68C), it is able to adapt to the paddy field operation and reliable, stable and efficient when working.

Test materials are Peiliangyou 98 (Wandao 129) hybrid rice. The average length of rice is 8mm, the ratio of length to width is 3.2. According to agronomic requirements of rice cultivation, soak the seeds for specific process and dry them before sowing. Test time is early May 2014 and the location is Nongcui Park in Anhui Agricultural University.

Before the test, load a certain amount of rice seeds to the eight seedmeters of planter, then drive the prototype of planter to the testing field. Adjust each speed control handle to an unified position and do the congruent experiment of hole spaces; set the eight seedmeters to eight different positions and do the accuracy test of adjusting hole spaces; carry out the uniformity test of sowing in the test bench. The results are shown in figure 7.



Fig.7 The field test of Rice prototype planter

## 4.2 Test Results

### 4.2.1 Congruency of Hole Spaces

During the test, speed handle of seedmeter is placed at "4-speed" position (hole space is 160mm), in order to verify whether there is a difference between hole space of prototype and the designed value 160mm. We measured the total distance of every six holes of prototype, calculated the

average value of hole space between each two adjacent holes, then computed the deviation between test and theoretical value of hole space. Figure 7 shows rice seeds distribution and field measurements, test results are shown in table 3.

Tab.3 Information about congruent experiment of hole paces

Group number	Total distance between 6 holes (mm)	Average hole space (mm)	deviation (%)
1	817	163.4	2.125
2	809	161.8	1.125
3	794	158.8	0.750
4	815	163.0	1.875
5	796	159.2	0.500

As can be seen from the analysis results in table 3, when the speed handle of seedmeter is placed at "4-speed" position, there is a very little deviation between the hole space of prototype and the designed value 160mm (including measurement error and darting error of seeds), the average hole space is about 160mm which is consistent with the designed value. The test results show that the transmission of prototype is reliable, design parameters are accurate and correct. Verify the accuracy and reliability of design parameters, and the transmission feasibility of the whole machine.

#### 4.2.2 Accuracy of Adjusting Hole Spaces

The adjustment range of hole space of rice planter is 100mm ~ 240mm, it can be manually adjusted by speed handle. To judge the accuracy of adjusting hole space, we need relevant tests for verification. Set eight speed handles of seedmeter to eight different positions, in this way, one line represents one sowing situation. Measure the falling information of seeds in each line and hole space per line for five times and then get the average value, the results are shown in table 4.

Tab.4 Information about accuracy of adjusting hole spaces

position	Theoretical hole space (mm)	Measurements of hole space					Average value of hole space (mm)	deviation (%)
		1	2	3	4	5		
1	100	96	103	101	103	105	101.6	1.06
2	120	126	122	118	121	127	122.8	2.33
3	140	137	142	143	146	140	141.6	1.14
4	160	165	158	160	157	166	161.2	0.75
5	180	178	181	186	181	184	182.0	1.11
6	200	201	197	207	204	203	202.4	1.20
7	220	220	227	216	224	221	221.6	0.73
8	240	242	243	248	245	239	243.4	1.42

As can be seen from the analysis results in table 4, the average and theoretical values of hole space are matched, the deviations of it are all less than 3%. The results show that the range of adjusting hole space of this specific rice planter is 100 ~ 240mm which verify the accuracy of adjusting hole space.

#### 4.2.3 Uniformity of Sowing

Uniformity of sowing can be seen from the performance indicators such as variation coefficients from the hole spaces, pass rate of holes, the rate of empty holes, etc. Due to the limitation of test conditions, uniformity indicators cannot be measured in the reality. Scoop-wheel seedmeter is a popular fine sowing seedmeter in China at present and it is stable and reliable, so the performance parameters obtained from the test bench could indicate the performance in the field to some extents. Therefore, uniformity of sowing in the test bench is conducted by image method. Measurements at



each time are not less than 100 holes, obtain two kinds of seedmeters' performance indicators including standard deviation of hole spaces, variation coefficients from the hole spaces, pass rate of holes, the rate of empty holes under condition that hole spaces range from 100mm, 120mm, 140mm, 160mm, 180mm, 200mm, 220mm to 240mm (speeds of two conveyors are all 0.4 m/s) and measure the data for five times in each certain hole space, then calculate average value. According to the requirements of sowing rice, pass rate of holes requires each hole contains 2 ~ 6 seeds and the diameter of hole is not greater than 50mm, the rate of empty holes has to be less than 5%. Compare the performances of two seedmeters using the qualified index which includes the previous two indicators. The test results are shown in table 5.

Tab.5 Performance indicators of seedmeter prototype

position	Average value of hole space (mm)	Standard deviation of hole space (mm)	Variation coefficients from hole space (%)	Pass rate of hole (%)	Rate of empty hole (%)
1	99.12	31.64	31.92	92.78	1.60
2	120.34	40.29	33.48	93.42	1.54
3	141.06	41.39	29.34	93.45	1.51
4	159.89	56.20	35.15	94.19	1.33
5	180.53	60.86	33.71	94.57	1.17
6	202.17	65.56	32.43	95.73	1.02
7	221.94	75.84	34.17	95.86	1.13
8	240.67	79.97	33.23	95.97	0.96

As can be seen from performance indicators in table 5, each hole space corresponding to each position of scoop-wheel seedmeter is consistent with the designed value, the error of hole space is also within a reasonable range. Seedmeter's variation coefficients from hole spaces, pass rate of holes and rate of empty holes all satisfy performance indicators.

## 5 Conclusions

In view of the present domestic rice direct seeding machines do not have various models, it is difficult to achieve precise hill-drop drilling and can not meet the agronomic requirements. This paper designs a kind of adjustable speed rice direct seeding machine and emphasizes on the seedmeter and whole transmission structure of machine.

(1) The characteristics of equipments are they can synchronize furrow ridging through small planting holes, operation rows are 8, spaced 250 mm, hole distances ranging from 100mm to 240mm are adjustable. Operation efficiency could be 4.5 ~ 12.5 acres per hour.

(2) Obtain the actual sowing effect, verify the accuracy of parameters and feasibility of transmission by testing the prototype in the field. the consistency deviation of the holes is less than 3%, the hole space deviation is less than 3%, the empty hole rate is less than 5% The transmission of this kind of rice planter is accurate, reliable and sowing performance could meet the agronomic requirements of rice direct seeding.

This research provides a new idea for the design and manufacture of rice planter, and offers equipment and technical support to accelerate the rice planting mechanization.

## Acknowledgements

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