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Research Article

Experimentation Research and Design of Circular Tube Slit Pneumatic Precise Wheat Seed-metering Device

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Abstract: In order to solve problems that traditional mechanical wheat seed-metering device has defects such as poor seeding uniformity and consistency, instability and high seed-injuring rate, a kind of pneumatic wheat precision seed-metering device is designed. The seed-metering device with internal and external circular tube grip seeds in vertical slit of the external circular tube by the negative pressure of the internal circular tube. We optimized slit width, rotating speed and negative pressure of the seed-metering device by the orthogonal experiment. In the field, we did contrast experiment through contrasting the existing mechanical seeder for wheat and measured and analyzed seeding uniformity, seedling emergence rate, consistency of each line seeding quantity, stability of total seeding quantity and rate of damaged seeds of the seed-metering device. The experiment data shows its each seed distance variation coefficient increases more 20% than current domestic mechanical wheat seed-metering device and its seeding uniformity gains obvious improvement.

Keywords: Field experiment, pneumatic, precision, seed-metering device, slit, wheat

INTRODUCTION

Wheat precision seeding technology promotes its output and quality, being significant to stable and high yield (Zheliang *et al*., 2012; Ruixue *et al*., 2009). It requires precise, quantitative and even seeding, so that each wheat plant obtains equal nutrient area and place, sufficient water and fertilizer for effective tiller (Feng and Liu, 2004). As for precision seeding, wheat dropping distance evenness is hardest controllable. Dropping distance evenness depends on uniform seed flow. Seed metering, seed charge and touchdown have effects on seeding evenness in the seed trench, of which seed metering of the seed-metering device uniformity plays a leading role (Junfeng *et al*., 2001; Liao *et al*., 2012; Liu and Zhao, 2008; Zhao *et al*., 2011).

Presently wheat field seeding mainly uses mechanical wheat seeder, having high rate of damaged seeds and unstable seeding quantity (Zhao *et al*., 2005; Hui, 2003; Liu *et al*., 2011, 2009). The new type pneumatic precision seed-metering device does not damage seeds and is tolerant to seeds geometry for precision seeding (He and Qiu, 2001; Huo *et al*., 2003; Wang, 2006). In USA, Australia, Canada and France it researched and applied pneumatic precision seeding machines, of which air flow first-order distributive central type seed metering system is mostly applied to grain drills, but is not applied in China due to high cost (Zheng, 2007; Sun, 2003). New type wheat precision seeding seed-metering device with combined suckers developed by China Agricultural University, small type pneumatic wheat precision seeding sample machine developed by Wheat Engineering Research Center in Shandong Province and twin-disk pneumatic precision seeding machine developed by Hui (2003) in Shandong Agricultural University, all of them have some defects and have no products in the market (Liang *et al*., 2001; Jun *et al*., 2000; Hui *et al*., 2002). Therefore it is necessary to develop new type wheat precision seeding machine.

Traditional mechanical wheat seed-metering device has poor seeding uniformity and consistency, instability and high seed-injuring rate, which cannot match the wheat precise seeding agronomic requirements. In this study, a type of circular tube slit pneumatic precise wheat seed-metering device is designed to solve the problem. In addition, it compares with present mechanical wheat seeder by field seeding test and seedling emergence rate to evaluate the effect of the pneumatic seed-metering device for sowing.

METHODOLOGY

Structure and operation principle seed-metering device:

Seed-metering device structure: This seed-metering device performs seed metering through straight slit based on suction principle, being composed of 13

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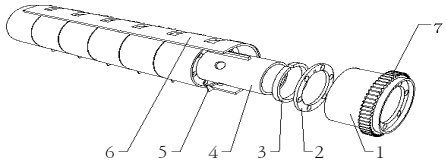


Fig. 1: The structure figure of slit-style pneumatic seed-metering device for wheat
1: External circle tube; 2: Joining disk; 3: Crack control circle; 4: Internal circle tube; 5: Seed falling plate; 6: Seed protection board; 7: Gear

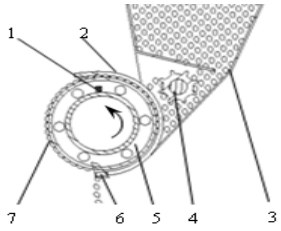


Fig. 2: The work principle figure of the seed-metering device for wheat
1: Joining bond; 2: Seed protection board; 3: Seed box; 4: Mixing wheel; 5: External circle tube; 6: Seed falling plate; 7: Seed sucked

external circle tubes, joining disk, crack control circle, internal circle tube, seed falling plate, seed protection board and gear, as illustrated in Fig. 1. The seed-metering device has applied practical new-type patent. Internal circle tube connects with chain wheel as main axle of the seed metering device to drive the seed-metering device. Thirteen external circle tubes of the same outer diameter set around inner tubes to control straight slit between two adjacent external circle tubes through crack control circle, totally twelve slits, namely, twelve rows. Moreover it can adjust slit size by changing crack control circle. Vacuum air suction negative pressure sucks wheat seeds through air hole in the wall of internal circle tube and that in the wall of joining disk from the slit in external circle tube. One side of the seed charge plate is fixed into the slit of the external circle tube to make seeds fall into the seeding box and into the seed trench.

Seed-metering device operation principle: As the wheat seeder operating in the field, driven by land wheel, it rotates seed-metering device through chain drive. Negative pressure airflow of the blower passing gas tube and air hole in internal circle tube generates negative pressure in external circle tube and generates vacuum suction at the slit. Each slit sucks one circle of wheat seed. Rotating to seed falling plate, seeds fall into seed receiver box blocked by seed falling plate and accomplish seed metering. Seed protection board may ensure no leakage sowing except for the slit. Mixing wheel at the bottom of the seed box constantly stirs bottom wheat seeds, being in favor of uniform suction of wheat seeds. The operation principle is illustrated in Fig. 2.

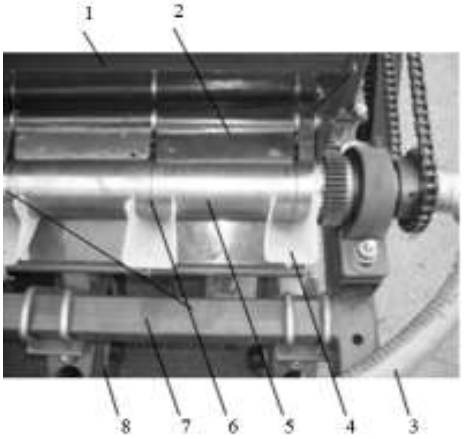


Fig. 3: The part object picture of the overall seeder
1: Seed box; 2: Seed protection board; 3: Air tube; 4: Guiding seed box; 5: Seed-metering device; 6: Seed sucking slit; 7: Machine frame

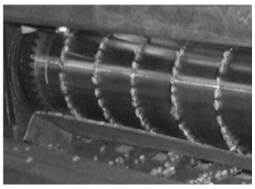


Fig. 4: Reality suction seed picture of the seed-metering device

Seed-metering device installation and seed suction performance: Figure 3 is an illustrated part picture of whole structure installation, showing detailed installation position and actual structure shape of the seed-metering device.
Seed suction performance is illustrated in Fig. 4.

SEEDER FIELD TEST AND ANALYSIS

Taking straight slit pneumatic wheat seed-metering device as the key part, twelve-row equidistant wheat precision seeding machine is manufactured. It performed field seeding test in national project for food production test area in Shenzhou City of Hebei Province. The test selects two adjacent lands with commonly equal soil features, equal fore-rotating crops and the same seeding period, uniform field management. It makes seeding contrast test by commonly used mechanical wheat seeder (2BXF-12 disc type wheat seeder) installing mechanical external Geneva wheel seed-metering device and straight pneumatic wheat seeder. It seeds in two adjacent plots by the same seeding quantity (180 kg/ha) with the operation speed 3.5-3.7 km/h and checks seedlings within fifteen days after the seeding.

Seeding uniformity measurement and contrast test: It selects three areas per filed, six rows wheat per area, continuous forty sections per row, 5 cm/section. It

Table 1: Comparative analysis of seeding uniformity

	Testing pneumatic precise wheat seeder			2BXF-12 disc type wheat seeder		
Test plot number	1	2	3	1	2	3
Average number of grains per section $\bar{X}$	3.8	3.9	3.8	3.9	3.9	4.0
Standard deviation S	1.6	1.5	1.4	2.6	2.2	2.4
Variation coefficent V/%	42.7%	38.3%	37.7%	65.1%	56.8%	60.2%
Ratio of empty segment/%	5.0	1.6	3.3	10.0	2.5	4.2
Standard deviation of plot sample	1.5			2.4		
Uniformity variation coefficent of plot/%	39.6			60.7		

Table 2: Comparison of seedling emergence rate of two kinds of wheat seeder

	Testing pneumatic precise wheat seeder (%)					2BXF-12 disc type wheat seeder (%)				
Test plot number	1	2	3	4	5	1	2	3	4	5
Seedling emergence rate/%	90.8	84.5	92.3	89.9	88.2	74.4	73.5	66.7	70.4	72.5
Average seedling emergence rate/%	89.1					71.5				

measures total wheat seeds in each section per row, calculating average seed numbers $\bar{X}$ per section, standard deviation S, variation coefficient V and the percentage of dead section numbers occupied total sections, respectively reckons uniformity variation coefficient and appraises seeding uniformity of the wheat seeder. Table 1 shows that in equal seeding quantity, area sample standard deviation (1.5), uniformity variation coefficient (39.6%) and the area percentage of dead section numbers occupied total sections of straight pneumatic seeder are all smaller than present mechanical seeder. It has obvious promotion in seeding uniformity.

Field seedling emergence rate measurement and comparison: It selects five operation areas of equal area in each plot according to equal conditions. Each area width is equal to one working width and the length is one meter. It measures seedling numbers in each row and calculates seedling emergence rate by Eq. (1). The results are shown in Table 2. The seedling emergence in operation plots by two kinds of seeders is shown in Fig. 5:

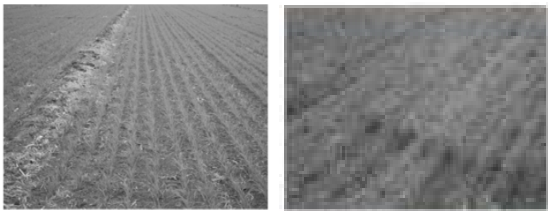
$$c = \frac{Q_\varepsilon}{Q_c} \quad (1)$$

$$Q_c = \frac{Q}{q_k} \times 10^6 \quad (2)$$

of which:

c = Field seedling emergence rate, %
Q_ε = Measured actual seedling emergence rate, plants/ha
Q_c = Seeding numbers, seeds/ha
Q = Seeding quantity, kg/ha
q_k = 1000 seeds quality, g/1000 seeds

Results of other performance tests: Comparing each performance parameter in the test with normal data shown in GB-9478-88 Grain Drills Test Method, it finds that variation coefficient qualified standard of seed metering amount per row uniformity is less than or equal 6.0%, test result of this machine is 3.0%;



(a) (b)

Fig. 5: Seedling emergence contrast picture of two kinds of seeder (a) slit pneumatic precise wheat seeder, (b) 2BXF-12 disc type wheat seeder

variation coefficient qualified standard of total seed metering quantity stability is less than or equal 1.3%, test result of this machine is 0.8%; variation coefficient qualified standard of seeding uniformity is less than or equal 45%, test result of this machine is 25.3%; qualified standard of rate of damaged seeds is less than or equal 0.5%, test result of this machine is 0.25%. It shows that all performance indexes satisfy the national standard.

CONCLUSION

Compared with present mechanical wheat seeder, straight pneumatic wheat seeder in this research topic has high seeding uniformity, low rate of damaged seeds, seldom seedling missing and seedling-less ridges. It proves that straight pneumatic wheat seed-metering device satisfies precise less seeding technology.

The wheat individual tiller by this precision seeding machine seeding is doubled, averagely four to seven tillers (presently seeder's wheat individual having one to three tillers), with evenly seeds distribution, less basic seedling and more individual tillers. Therefore the individual has sufficient nutrition, large area of illumination, strong wheat seedling and developed roots, as well as high capacity of lodging resistance, all of which ensure high and stable yield of wheat.

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