# RESEARCH ON THE SPRAY CYLINDER INTERNAL FLOW FIELD AND ITS INFLUENCE ON SPRAYING QUALITY OF FORAGE SEED SPRAY SEEDING MACHINE

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# 牧草种子喷播机喷筒内流场及其对喷播质量影响研究

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## ABSTRACT

*The objective of ecological restoration and rehabilitation of grasslands is to recreate the original appearance of damaged or degraded vegetation. From previous research, the pneumatic spraying technology is now more commonly used in the world for vegetation restoration. Pneumatic spraying is relatively inexpensive and causes little damage to the original vegetation, making it one of the most effective techniques for restoring natural grassland vegetation under natural climatic conditions. In this paper, the effect of the spraying machine pipe working airflow on the quality of spraying was studied through simulation analysis and experimental tests. The seeding area of the spraying machine corresponding to different values of the pipe inlet airflow speed was determined. The conclusions show that: 1) the spray pipe inlet airflow velocity has a great influence on the uniformity of spraying. When the airflow velocity is higher than 55 m/s, the spraying is not uniform, while the airflow velocity is lower than 45 m/s, the spraying amplitude is smaller, the operational efficiency is low, which is not conducive to the restoration of degraded grasslands; 2) considering the uniformity of spraying and operational efficiency, the airflow velocity at the inlet of the spray pipe should be between 45 and 55 m/s when the spraying machine is in operation. The seed drop area is changed, by adjusting the airflow velocity of the spray pipe inlet, and the reseeding and leakage area of the seed drop area is reduced, so that the spraying performance of the spraying machine is optimized.*

## 摘 要

*草原生态恢复与重建目标是再现被破坏或已退化植被原貌。从前期研究情况看，气力喷播技术目前在世界上应用于植被修复比较普遍。气力喷播技术成本相对较低，对原有植被破坏较小，是在自然气候条件下恢复天然草原植被的有效技术手段之一。本文通过仿真分析和试验测试研究了气力喷播机喷筒工作气流对喷播质量的影响，确定了不同数值喷筒入口气流速度所对应的喷播机落种区域。结论表明：1）喷筒入口气流速度对喷播均匀性有很大影响，当气流速度高于 55 m/s 时，喷播不均匀，当气流速度低于 45 m/s 时，喷播幅度较小，作业效率低，不利于退化草原修复；2）考虑喷播均匀性和作业效率，喷播机工作时喷筒入口气流速度应在 45~55 m/s之间，且通过调节喷筒入口气流速度改变了种子的落种区域，减小了落种区域重播、漏播面积，实现了对喷播机喷播性能的优化。*

## INTRODUCTION

The goal of grassland ecological restoration and reconstruction is to reproduce the original vegetation that has been damaged or degraded, and to rebuild a healthy ecosystem (*Chen et al.,2007; Chen et al., 2022; Jiang et al., 2023*). The time and cost of ecological restoration depend on the size of the restoration area, degree of degradation, and restoration techniques employed *(Jiang et al., 2023; Long et al., 2002)*. Currently, the main techniques for grassland vegetation restoration include enclosure, artificial seeding, aerial seeding, and pneumatic seeding. Among them, pneumatic seeding is a widely used and effective technique, with relatively low cost and short restoration period *(Liang et al., 2015; Yue et al., 2022)*. It also causes minimal damage to the existing vegetation, making it one of the most effective means of restoring natural grassland vegetation under natural climatic conditions *(Mu et al., 2012)*.

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Pneumatic seeding operation for degraded grassland vegetation restoration involves spraying coated grass seeds onto the degraded land. The grass seeds and coating adhere to the soil surface, creating conditions for plant growth. With the help of rainwater, the grass seeds can take root and germinate, thereby completing the restoration of degraded grassland vegetation *(Fan et al., 2013)*.

Based on the early spraying experiments, spraying operations are a fast and efficient technique for restoring grassland vegetation under natural climatic conditions (*Wang et al., 2013; Xu et al., 2006; Zhang et al., 2013*). Significant research achievements have been made regarding the use of pneumatic seeders for restoring grassland vegetation. However, during the process of using pneumatic seeders to restore degraded grassland, factors such as the working airflow of the spray pipe have not been considered in relation to the uniformity of spraying.

To improve the spraying quality of the sprayer, this study focused on the 4BQD-40C pneumatic sprayer and investigated the flow field inside the spray pipe, determining its distribution and variation pattern, and analyzed its impact on the seeding area *(Zhang et al., 1997; Cao et al., 2023)*. Based on this, the study analyzed the effects of changing the inlet airflow velocity of the spray pipe on the spraying quality of the sprayer, with the aim of minimizing the area of missed or re-sprayed seeds in the seeding area.

## MATERIALS AND METHODS

### *Principle analysis*

4BQD-40C type pneumatic seeder has been improved over many years, and its basic functions are already complete. It is mainly composed of a spray pipe, a seed tube, a seed storage box, a seed dispenser, a fan, and a rotating part, as shown in Fig. 1.

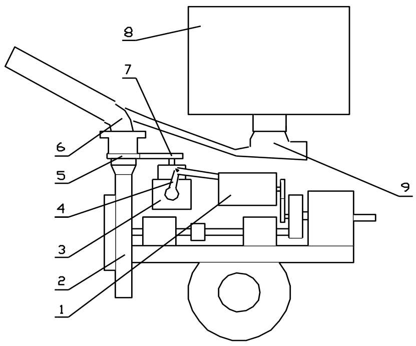


**Fig. 1 – Structure diagram of the spraying machine**
*1 – Worm gear reducer; 2 – Air-blower ;3 – Amplifier; 4 – Rocker 5 – Spray cylinder's gear wheel; 6 – Spray cylinder's Swing mechanism; 7 – Amplifier's output gear; 8 – Material box; 9 – Stuff feeding mechanism*

During the spraying process of the sprayer, the coated ice grass seeds are subjected to the action of their own weight and the air flow in the conveying pipe. They enter the seeding device through the metering device and are then transported into the falling seed device. At the outlet of the fan, a throat pipe is installed to generate negative pressure. Due to the negative pressure of the main air duct throat pipe, the ice grass seeds in the falling seed device are sucked in, suspended and accelerated in the main air duct, and then sprayed out with the high-speed air flow of the spray pipe, as shown in Fig. 2. While the sprayer is moving forward under traction, its spray pipe oscillates back and forth within the horizontal plane at an angle of 0° to 180° (*Zhang et al., 1997; Zhao et al., 1997*).

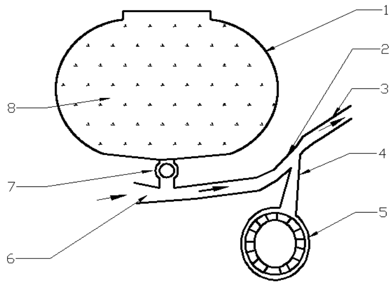


**Fig. 2 – Diagram of Sprayer working principle**
*1 – Material box; 2 – Seed Tube;3 – Spray-duct; 4 – Pipe; 5 – Air-blower; 6 – Air inlet duct; 7 – Seeding Apparatus; 8 – Seed*

***Spraying quality analysis***

The seed is sprayed at high speed through the spray pipe of the sprayer based on the principle of pneumatic conveying. The movement of the seed at the outlet is a combination of the oscillation of the spray pipe and the linear movement of the sprayer. The trajectory of the seed in half a cycle is a trochoid, while the trajectory in the other half of the cycle is another trochoid with the same shape but opposite direction. By magnifying the trajectory of the seed sprayed by the sprayer, it can be seen that the sowing area is enclosed by four curves, as shown in Fig. 3. The sowing area of one cycle of spray pipe oscillation consists of eight curves. When the spray pipe oscillates from counter-clockwise to clockwise, the end curve of the first half cycle is the same as the start curve of the second half cycle, and they are actually the same curve (*Zhang et al., 1997; Zhao et al., 1997*). Therefore, the sowing area is composed of seven different curves. Based on the above analysis, a GUI program is designed in MATLAB software to draw the sowing area of the sprayer, as shown in Fig. 4.

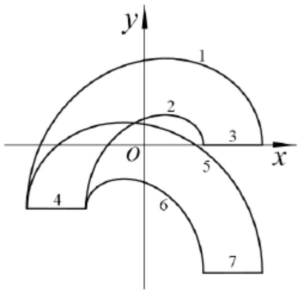


**Fig. 3 – Diagram of the falling region**

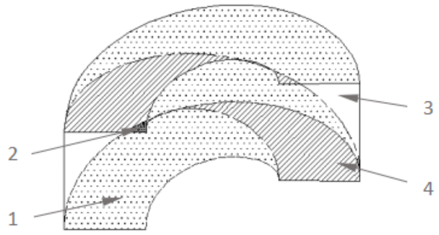


**Fig. 4 – Sketch map of missing and broadcast area in seeding area**
*1 – Normal spraying area; 2 – Secondary spraying area; 3 – Missed spraying area; 4 – One spraying area*

According to Fig. 4, the 4BQD-40C pneumatic seed drill shows uneven spraying areas such as reseeding and missed seeding in the seeding area (*Zhang et al., 2013*). The factors affecting this area include the swing frequency of the spray pipe, the air flow velocity of the spray pipe, and the internal flow characteristics of the spray pipe. Among them, the air flow velocity and internal flow characteristics of the spray pipe have a greater impact on spraying quality indicators such as seeding area, spraying bandwidth, seed spraying interval, and spraying uniformity. Therefore, this paper mainly studies the internal flow characteristics of the spray pipe of the seed drill, explores the distribution and variation of the flow field, and reveals the influence of the internal flow field of the spray pipe on the seeding area of the seed drill.

Based on the design principle of the sprayer, the spray pipe area is divided according to Fig. 5. At the same time, ProE software is used to create a 3D model of the spray pipe and seeding tube as shown in Fig.6, and Fluent software is used to conduct numerical simulation research (*Zuo et al., 2020; Xu et al., 2017*).

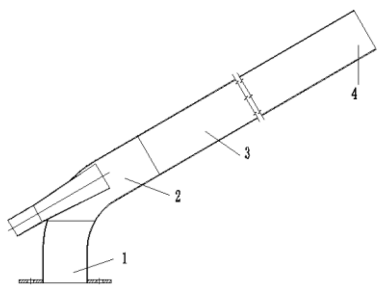


**Fig. 5 – Area division of spray cylinder**
*1 – Spray pipe inlet; 2 – Seed pipe insertion section; 3 – Front section of spraying pipe; 4 – Spraying pipe outlet*

**Fig. 6 – Simplified three-dimensional model of the seeds convey pipe and spray pipe**

Using Pro/E to create a 3D model and import it into Ansys Workbench for model conversion. Then, use Meshing software to perform meshing, as shown in Fig. 7. Finally, use Ansys Fluent 17.0 for flow field simulation analysis (*Chen et al., 2018; Ma et al., 2022; Shen et al., 2022*).

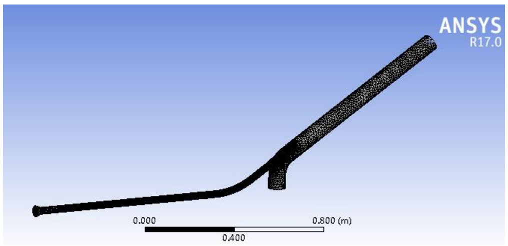


**Fig. 7 – Meshing of the seeds convey pipe and spray pipe**

In previous research on the 4BQD-40C pneumatic spraying machine, it was found that the maximum airflow velocity at the spray pipe inlet can reach 60 m/s, but when the airflow velocity at the spray pipe inlet is around 47 m/s, the spraying is more uniform and the spraying efficiency is higher (*Zhao et al., 2010*). Based on this, spray pipe inlet airflow velocities of 60 m/s, 55 m/s, 47 m/s, 35 m/s, and 25 m/s were selected for study. When the spray pipe inlet airflow velocity is 60 m/s, the velocity distribution inside the seeding tube and spray pipe is shown in Fig. 8.

As shown in Fig. 8, the velocity distribution of the airflow is relatively uniform in the later stage of the seed tube and the spray pipe. The velocity along the axial direction in the seed tube remains at around 58 m/s, while it remains at around 53 m/s near the tube wall. However, there is a region with higher airflow velocity and an airflow vortex next to the insertion section where the seed tube is connected to the spray pipe, as shown in the enlarged local view in Fig. 9.

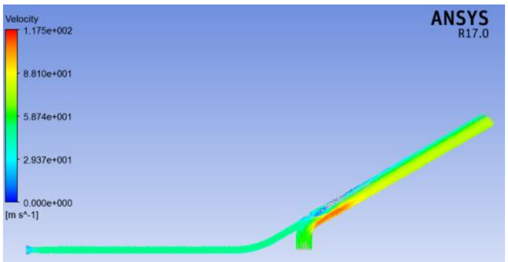


**Fig. 8 – Velocity vector diagram in conveying seeds pipe and spray pipe**

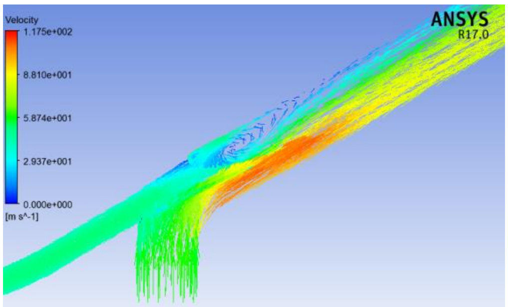


**Fig. 9 – Partial enlargement of velocity vector in insertion section of seed conveying pipe**

The local airflow in the insertion section of the feeding tube hinders the entry of seeds into the interior of the spray pipe. However, at this point, the seeds already have a certain initial velocity under the action of the airflow, which can overcome the hindrance and enter the spray pipe smoothly. At the same time, according to the velocity distribution vector diagram, it can be seen that after the seeds enter the spray pipe, they are transferred to the area of higher airflow velocity under the action of the airflow vortex and obtain greater energy in this section. By changing the inlet airflow velocity of the spray pipe, the velocity distribution of the airflow in the feeding tube and spray pipe can be obtained. The average values of the velocity of the airflow in the feeding tube and spray pipe are taken on a circular cross-section and the relationship is shown in Table 1.

**Table 1**

**Relationship between inlet airflow velocity of spray cylinder and velocity of inlet of conveying pipe and outlet of spray tube**

| | | | | | |
|---|---|---|---|---|---|
| **Inlet airflow velocity of spray cylinder [m/s]** | 60 | 55 | 47 | 35 | 25 |
| **Inlet airflow velocity of conveying pipe [m/s]** | 56.5 | 48.9 | 39.2 | 29.6 | 22.3 |
| **Outlet airflow velocity of spray tube [m/s]** | 78.3 | 67.9 | 56.8 | 42.5 | 30.6 |

According to the data fitting in Table 1, the relationship between the inlet airflow velocity of the spray tube and the inlet airflow velocity of the seed delivery tube is as follows:

$$v_s = 0.96v_{pr} - 3.15 \quad (1)$$

where:

$v_s$ represents the airflow velocity in the seed delivery pipe, [m/s]; $v_{pr}$ represents the airflow velocity at the spray pipe inlet, [m/s]. Based on the experiment, it is found that the minimum velocity required for seed suspension is 9.58 m/s. Therefore, according to equation (1), the minimum velocity at the spray pipe inlet should be 13.3 m/s. To ensure smooth seeding, a safety factor of 2.5 is taken, so the minimum spray pipe inlet velocity to be used for the seeder is 35 m/s.

After coating, the equivalent diameter of the ice grass seed was set to 2.5 mm. Numerical analysis was carried out for airflow inlet velocities of 35 m/s, 40 m/s, 47 m/s, 50 m/s, 52 m/s, 55 m/s, and 60 m/s, with a seed dispenser rotating at 18 rpm. The corresponding relationships between the airflow inlet velocity and the seed velocity at the spray pipe outlet are shown in Table 2.

**Table 2**

**Relationship between airflow velocity at sprayer inlet and coated seeds velocity at the outlet of spray cylinder**

| **Inlet airflow velocity of spray cylinder [m/s]** | 60 | 55 | 52 | 50 | 47 | 40 | 35 |
|---|---|---|---|---|---|---|---|
| **Maximum speed of seeds at the outlet of spray pipe [m/s]** | 16.4~22.5 | 20.8 | 19.8 | 18.5 | 17.8 | 14.5 | 12.5 |
| **Minimum seed speed at the outlet of the spray pipe [m/s]** | 12.8~16.3 | 14.9 | 14.3 | 13.6 | 12.9 | 10.3 | 9.3 |

From table 2, it can be seen that when the inlet airflow velocity of the spray pipe is 60 m/s, the maximum velocity of seed ejection at the outlet of the spray pipe varies between 16.4 and 22.5 m/s, and the seed ejection velocity is unstable. When the inlet airflow velocity of the spray pipe decreases to 55 m/s, the seed ejection velocity becomes more stable. When the inlet velocity of the spray pipe is between 35 and 55 m/s, the relationship between the maximum seed velocity at the spray pipe outlet and the inlet airflow velocity of the spray pipe is given by the formula:

$$v_{rmax} = 0.42v_{pr}\text{-}2.21 \quad (2)$$

The relationship between the minimum seed velocity at the spray pipe outlet and the airflow velocity at the spray pipe inlet is:

$$v_{rmin} = 0.28v_{pr} - 0.45 \quad (3)$$

According to the above analysis, after seed coating, the maximum seed velocity at the spray pipe outlet is linearly related to the inlet airflow velocity of the spray pipe. Therefore, adjusting the inlet airflow velocity of the spray pipe in the range of 35~55 m/s can change the seed velocity at the spray pipe outlet and adjust the seed sowing area, which lays a foundation for improving the uniformity of the seed sowing machine in the future.

***Test conditions***

The test site is a relatively flat soil area in the campus of the school, with a temperature range of 17~23°C, and the test was conducted when the wind speed was less than 1.0 m/s. The testing equipment includes one stopwatch, one measuring tape, one electronic scale, one TSI 9565-P multifunctional anemometer, and one hot-wire velocity probe as shown in Fig. 0, with main parameters listed in Table 3.

**Table 3**

**Performance parameters of wind speed probe**

| Item | Range of measurement [m/s] | Accuracy of measurement [m/s] | Resolution ratio [m/s] | Operating temperature [℃] |
|---|---|---|---|---|
| **Parameter** | 0~50 | ±0.015 | 0.01 | -20~50 |

**Fig. 10 – 9565 P multifunction wind meter**

***Airflow velocity test***

This test used an air speed probe to test the airflow velocity at the outlet of the spray pipe and the inlet of the seed delivery tube. Ensure that the seed box, seed delivery tube and spray pipe are clear and free of seed before conducting the test. The frequency converter was adjusted so that the airflow velocity at the inlet of the spray pipe was 40 m/s.

Test spray pipe outlet airflow velocity:

(a) The wind speed probe is placed at the exit position of the spray pipe, perpendicular to the center line of the pipe, with the probe facing the direction of the incoming flow.

(b) Once the data displayed by the wind speed probe has stabilized, the airflow velocity at the outlet of the spray pipe is measured.

(c) The measurement points were selected from the center of the pipe, 10 mm from the center, 20 mm from the center, 30 mm from the center and at the edge of the pipe, and 10 instantaneous values were recorded for each area as the pipe exit airflow velocity.

(d) Calculate the average of each measurement point for the airflow velocity at the spray pipe outlet.

Testing the spray pipe velocity at the inlet of the seed delivery tube:

(a) The wind speed probe is placed at the inlet of the seed tube, perpendicular to the center line of the tube, with the probe facing the direction of incoming flow.

(b) Once the data displayed by the wind speed probe has stabilized, the airflow velocity at the inlet of the seed delivery pipe is measured.

(c) The measurement points were selected at the center of the seed tube, 5 mm from the center, 10 mm from the center and at the edge of the seed tube. 10 instantaneous values were recorded in each area as the airflow velocity at the inlet of the seed tube.

(d) Calculate the average value of each measurement point for the inlet airflow velocity of the seed tube.

***Spraying seed range test***

A relatively flat soil site was chosen as the test site to give a true picture of the seed drop from the spray pipe. The seed drop in the seed drop area reflects the exit velocity of the seeds from the spray pipe, so the distribution of seeds in the seed drop area was used to verify the velocity of the seeds at the spray pipe exit in the test.

(a) Before starting the test, the test site was gridded as shown in Figure 11. This was done to facilitate the subsequent counting of seeds in the drop zone. The grid size was: 2m x 2m and the grid size of the total seed drop area was: 40m x 40m.

(b) The center line of the total seed drop area is chosen as the location of the spreader, while the edges of the grid are numbered to facilitate subsequent statistics.

(c) For the test, the seed dispenser speed was set to 18 rpm, while the fan was started and the frequency converter operating frequency was changed. The spraying test was carried out at inlet air velocities of 40 m/s, 45 m/s, 47 m/s, 50 m/s and 55 m/s respectively.

(d) After the spraying is completed, four locations in the sprayed seed drop area are selected for measurement at 30º, 60º, 120º and 150º of the canister swing, and the amount of seed dropped at each measurement point is counted separately, and the seed dropped is cleaned up after the count is completed.

**Fig. 11 – Grid partition map of experimental area**

During the experiment, the seeding rate was fixed at 18 rpm, and the airflow velocity at the spray pipe inlet was adjusted by changing the frequency of the variable frequency drive to 40 m/s, 45 m/s, 47 m/s, 50 m/s, and 55 m/s for seeding tests. After seeding, four locations were selected in the seeding area where the spray pipe swung 30º, 60º, 120º, and 150º, respectively. The seeding amount at each location was counted, and the seeds on the ground were cleaned up after the counting was completed.

During the swing of the spray pipe, the seed distribution range in the seeding area is shown in Fig. 12, $R$ represents the distance from the outer edge of the seeding area to the center of the spray pipe swing, $r$ represents the distance from the inner edge of the seeding area to the center of the spray pipe swing, and the seeding belt is $R$-$r$.

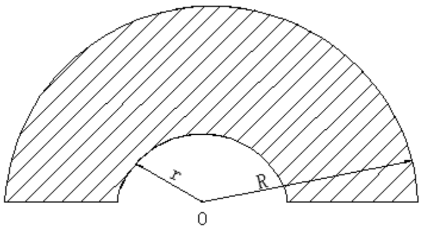


**Fig. 12 – Schematic diagram of spraying seed range**

## RESULTS

### *Airflow velocity test results*

According to Table 4, the airflow velocity near the edge of the spray pipe is the lowest, and gradually increases towards the center of the spray pipe, reaching its maximum value at the center. When the inlet airflow velocity of the spray pipe is 40 m/s, the airflow at the outlet does not change much, except for the low airflow velocity near the edge of the spray pipe. The rest of the velocities are close to, and all greater than, 47 m/s. This is consistent with the simulation results, which indicate that the airflow velocity at the spray pipe outlet is mainly distributed in the range of 47.0-47.8 m/s. Therefore, the numerical simulation results can be considered reliable. However, at the edge of the spray pipe, the simulated airflow velocity is 45.6 m/s, while the experimental measurement is 47.6 m/s, and the difference is relatively large. This may be due to differences in testing methods and measurement errors.

**Table 4**

**The distribution of airflow velocity at the spray pipe outlet when the airflow velocity at inlet is 40 m/s**

| Location of measuring points | Test value 1 [m/s] | Test value 2 [m/s] | Test value 3 [m/s] | Test value 4 [m/s] | Test value 5 [m/s] | Average value[m/s] |
|---|---|---|---|---|---|---|
| **Spraying pipe center** | 47.83 | 47.81 | 47.88 | 47.91 | 47.83 | 47.85 |
| **10 mm from the center** | 47.74 | 47.77 | 47.74 | 47.68 | 47.69 | 47.72 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **20 mm from the center** | 47.55 | 47.54 | 47.61 | 47.54 | 47.61 | 47.57 |
| **30 mm from the center** | 47.33 | 47.29 | 47.37 | 47.30 | 47.32 | 47.32 |
| **Edge of inner wall of spraying pipe** | 47.56 | 47.93 | 48.02 | 47.95 | 47.57 | 47.81 |

From Table 5, a similar pattern can be obtained as in Table 4. The airflow velocity at the inlet of the delivery tube gradually decreases from the center to the edge of the tube, with a greater decrease near the wall of the tube. The simulation analysis shows that the airflow velocity at the center of the delivery tube is 34.8 m/s, while the experimental measurement shows 32.5 m/s, indicating a close agreement between the simulation and experimental results. These experimental results demonstrate the correctness of the simulation analysis, and the model and analysis method can be used for further theoretical analysis.

**Table 5**

**The distribution of airflow velocity at the inlet seeds convey pipe when the airflow velocity at inlet is 40 m/s**

| Location of measuring points | Test value 1 [m/s] | Test value 2 [m/s] | Test value 3 [m/s] | Test value 4 [m/s] | Test value 5 [m/s] | Average value [m/s] |
|---|---|---|---|---|---|---|
| **Seed pipe center** | 32.54 | 32.47 | 32.53 | 32.46 | 32.51 | 32.50 |
| **5 mm from the center** | 32.43 | 32.49 | 32.51 | 32.45 | 32.47 | 32.47 |
| **10 mm from the center** | 32.31 | 32.27 | 32.28 | 32.32 | 32.29 | 32.29 |
| **Edge of inner wall of seed delivery pipe** | 30.98 | 30.18 | 30.34 | 30.91 | 30.68 | 30.62 |

***Spraying seed range test results***

Put the coated grass seeds into the seeding box, and set the rotary speed of the seeder to 18 rpm. By changing the inlet airflow velocity of the spray pipe, the sowing area of the seeds was tested, and the results are shown in Table 6. When the inlet airflow rate of the spray pipe is high, the outer edge R of the sowing area is also large, indicating that the speed of the seeds at the spray pipe outlet increases with the increase of the inlet airflow rate. When the airflow rate decreases from 55 m/s to 45 m/s, although both the farthest and closest distances of the sowing area decrease, the sowing width remains basically unchanged at 10.7 m and 10.2 m. Therefore, when the inlet airflow rate of the spray pipe is in the range of 45-55 m/s, the sowing area can be adjusted by adjusting the inlet airflow rate of the spray pipe. However, when the airflow rate further decreases, the seed cannot form a stable velocity flow when ejected, causing uneven distribution of the sowing points, ultimately affecting the sowing uniformity, and reducing the sowing range and efficiency.

**Table 6**

**Relationship between coated seeds falling area and airflow velocity of spray tube inlet when seeding speed is 18 rpm**

| Airflow velocity [m/s] | Inner edge of seed falling area's test value 1 [m/s] | Inner edge of seed falling area's test value 2 [m/s] | Inner edge of seed falling area's test value 3 [m/s] | Inner edge of seed falling area's test value 4 [m/s] | Average value of inner edge of seed falling area [m/s] | Outer edge of seed falling area's test value 1 [m/s] | Outer edge of seed falling area's test value 2 [m/s] | Outer edge of seed falling area's test value 3 [m/s] | Outer edge of seed falling area's test value 4 [m/s] | Average value of outer edge of seed falling area [m/s] |
|---|---|---|---|---|---|---|---|---|---|---|
| 55 | 11.1 | 11.3 | 11.2 | 10.8 | 11.1 | 21.6 | 21.9 | 21.8 | 21.7 | 21.8 |
| 50 | 9.1 | 9.3 | 9.2 | 8.8 | 9.1 | 19.3 | 19.7 | 19.5 | 19.4 | 19.5 |
| 47 | 8.5 | 8.6 | 8.5 | 8.4 | 8.5 | 18.9 | 18.7 | 18.8 | 19.0 | 18.8 |
| 45 | 7.4 | 7.8 | 7.7 | 7.5 | 7.6 | 17.5 | 18.0 | 17.9 | 17.6 | 17.8 |
| 40 | 6.5 | 5.7 | 6.2 | 6.1 | 6.1 | 17.0 | 15.9 | 16.5 | 16.4 | 16.4 |

## CONCLUSIONS

Theoretical analysis was conducted on the impact of the spray pipe inlet airflow velocity on the spray performance of the sprayer, and spray experiments were carried out on coated Timothy grass seeds at different spray pipe inlet airflow velocities, leading to the following conclusions:

(1) When the sprayer is in a no-seed state, numerical simulation and experimental verification were conducted on the spray pipe inlet airflow velocity, revealing the relationship between the spray pipe inlet airflow velocity and the airflow velocities at the spray pipe outlet and the seed delivery tube inlet, laying a theoretical foundation for subsequent research.

(2) Theoretical analysis was conducted on the effect of the inlet airflow velocity of the spraying spray pipe on the spraying performance of the sprayer. Spray tests were also carried out on coated bermudagrass seeds at different inlet airflow velocities of the sprayer. The following conclusions were drawn: It was found from the analysis of the inlet airflow velocity of the spraying spray pipe that with the increase of the inlet airflow velocity, the outer edge R and inner edge r of the seed dropping range increased. However, when the inlet airflow velocity was between 45-55 m/s, the spraying bandwidth remained basically unchanged. When the inlet airflow velocity was lower than 45 m/s, the seed could not form a stable velocity flow upon spraying. Moreover, when the inlet airflow velocity of the spraying spray pipe was 60 m/s, the seed velocity at the outlet of the spray pipe varied greatly, making it unsuitable for spraying operations.

Based on the above analysis, the relationship between the seed distribution area and the spray pipe inlet airflow velocity during spraying has been obtained. Both theoretical analysis and experimental verification show that uneven spraying occurs when the airflow velocity is higher than 55 m/s, and the spraying range is small with low efficiency when the airflow velocity is lower than 45 m/s, which is not conducive to degraded grassland restoration. Considering the spraying uniformity and operation efficiency, the spray pipe inlet airflow velocity should be set between 45-55 m/s during operation, and the seed distribution area can be adjusted by adjusting the airflow velocity to reduce the area of seed re-sowing and seed leakage, and optimize the spraying performance of the sprayer.

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