

DESIGN AND EXPERIMENT OF KEY PART OF 2ZXS-2 CANTALOUPE TRANSPLANTER

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2ZXS-2 哈密瓜移栽机的关键部件设计与试验

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ABSTRACT

Aiming at the trouble of low survival rate of cantaloupe seedling in hyperthermia, drought and dry land in Turpan region of China, the existing transplanting machine is the key to mechanized and non-destructive transportation and planting of large plants of young tender melon seedlings, root water injection, and precise soil piling in planting holes, and other technical difficulties. The design of mulch film planting cantaloupe transplanter for laying pipes belts and membranes, watering and transplanting, which can complete rotary tillage, spreading drip irrigation belts, laying mulch and covering the soil around the membrane, transplanting pot seedlings on the membrane, and water injection at the bottom. This machine puts the water injection pipeline under the inner side of the transplanter, and through the multi-point linkage electric control, the seedling preservation water is injected into the bottom of the seedlings pot while the seedlings are transferred, which not only ensures the survival rate of the melon seedlings, but also an accurate piling of the planting hole is realized. The technology of transplanting with water and piled soil for planting holes effectively solved the technical problems of mechanized transplanting of cantaloupe under high temperature and arid climate conditions in Turpan. After the cantaloupe seedlings were transplanted in dry land, the probability of survival was more than 96.9% after seven point five hours of drip irrigation. Operating efficiency can reach 0.067 hectares per hour, eight times as much as manual transplanting. The speed of transplanting machine is about 1.1 m/s, the quality of transplanting rate was 93.26 percent. The operating standards of these transplanters meet the agronomic requirements for transplanting cantaloupe.

摘要

针对现有新疆吐鲁番地区高温干旱，瓜苗旱地移栽成活率低等问题，现有移栽机对于大株型幼嫩瓜苗的机械化无损输送及栽植、根底注水、种植穴精准堆土等关键技术难题，设计哈密瓜铺管铺膜坐水移栽机，实现了一个作业流程即可完成旋耕、铺滴灌带、铺地膜及膜边覆土、钵苗膜上移栽、根底注水、种植穴堆土及镇压的机械化复式作业。该机具创新设计的坐水系统将注水管路置于鸭嘴栽植器的内侧下方，通过多点位联动机电控制，在移苗的同时将保苗水注入钵苗根底，不仅确保了瓜苗成活率，并且大幅提高了水分利用率；通过覆土滚筒与鸭嘴栽植器的运动耦合设计，实现了种植穴的精准堆土。坐水移栽技术与种植穴堆土技术有效解决了吐鲁番等地高温干旱气候条件下进行哈密瓜机械化移栽的技术难题，旱地移栽后 7.5 小时进行滴灌的瓜苗成活率超过 96.9%。田间试验表明，机械化作业效率可达 0.067 公顷/人/小时，较人工作业提高 8 倍以上。机具作业速度为 1~1.1m/s 左右，移栽合格率为 93.26%，满足哈密瓜移栽农艺要求。

INTRODUCTION

In these years, with the change of China's agricultural structure layout, the planting scale of cantaloupe has been expanding and there is a lack of matching mechanized special equipment. Then, many transplanting machines are used for pepper, tomato, cabbage and other vegetables (Bao, 2020; Chen Jianneng, 2015). Because the characteristics of different regions in China vary greatly, the cantaloupe planting areas have strict requirements on planting conditions, especially in the light, soil, rain and other environments. The agronomic requirements for growing cantaloupe in the eastern and western parts of China are quite different. In order to reduce the obstacle and harm of continuous cropping of cantaloupe, it is necessary to spray the roots of cantaloupe seedlings.

In the arid areas of western China, cantaloupe is planted with agricultural film covering technology. Generally, pipe is first laid, film is laid and then transplanted. These processes are usually carried out manually with a large amount of labour. In actual planting, in order to avoid dehydration of seedlings due to high temperature, a certain amount of water is often injected into the root of seedlings when transplanting, and finally the survival rate of transplanting can be guaranteed.

According to the cantaloupe transplanting order, the newly transplanted cantaloupe seedlings until the transplanting completed, then unified irrigation water. Take the planting area of 5 ha as an example, each machine and tool operate at 1.67 ha/day, a 5 hectares transplant takes 2.9 days to complete. If it is waited for 5 hectares of transplanting to be completed before watering the transplanted seedlings, it is inevitable that the first transplanted seedlings will not survive due to dehydration. If you want to solve this problem, you can first fill the soil with water before transplanting, but it will lead to excessive soil moisture, resulting in heavy soil viscosity, which makes it difficult for the transplanting machine to enter the operation. Therefore, the root irrigation of cantaloupe seedlings at the same time of transplanting can effectively improve the survival probability of cantaloupe seedlings.

Early in the 1960s, dry land transplanting machinery has begun to be researched in China, but did not develop quickly (Jin Liyu, 2021; Jin Xin, 2018). Since the 1970s, China has begun to develop bare seedling transplanting machine, originally used for beet transplanting; used in the vegetable transplanters. After the 1980s, semi-automatic transplanting machinery structure gradually improved, functional adaptability was stronger, but developed foreign transplanting machine, having a cost that is too high, is not suitable for China's transplanting technology agronomic requirements. China's transplanting machine development started late, the effective combination of agricultural machinery and agronomy is not high, the structure and function are relatively simple. In the early 21st century, China's semi-automatic transplanting machinery began to be widely used, but the cantaloupe water transplanting machinery is rarely studied. (Liu Cunxiang, 2013; Lu Yongtao, 2011).

Therefore, this paper designed a water cantaloupe seedlings transplanter with water injection function can realize transplanting at the same time with soil table irrigation. The machine's operation process can complete soil rotary tillage, drip belt, mulching film, film and soil, bowl seedling film transplanting, root water injection (water), planting hole soil and ballast mechanized double operation.

MATERIALS AND METHODS

Whole structure and working principle - Whole structure

ZZXS-2 type cantaloupe seedlings water transplanting machine with water injection function mainly consists of duck beak transplanting device, transmission system, film covering mechanism, water injection mechanism, CAM mechanism, frame and other components. The 3D assembly drawing is shown in Figure 1 below. The working principle of the transplanting machine is as follows: the seedlings are fed into the duckbill transplanting device by the seedling tray. The transplanting device is driven by the multi-rod mechanism to complete the work of opening, planting and rotating, and then the suppression wheel is overlaid to complete the transplanting operation. Main working parts: duck-head planter, multi-rod drive mechanism and seedling feeding plate. The two-dimensional final assembly drawing is shown in Figure 1, and its appearance is shown in Fig. 2.

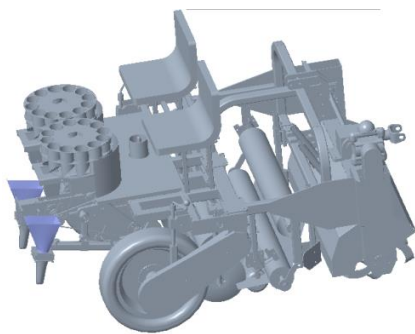


Fig. 1 – Overall cantaloupe transplanter



Fig. 2 – Appearance

The transplanter and the tractor are connected by three-point suspension system, relying on the driving wheel and the ground to roll power, and then the power is transmitted through the transmission system to each key component.

The duckbill transplanter puts the cantaloupe seedlings into the seedling tray, and then keeps the duckbill mouth of the duckbill transplanter upward through the linkage mechanism. The transplanter has two duckbill funnels, and the cam mechanism drives and controls the opening and closing of the duckbill funnels. When working, the operator on the machine will put the transplanted seedlings into the seedling tray, and the seedling dispenser will feed the distributed seedlings into the rotator of the transplanting device. After the transplanting rotator is turned to the lower part of the dispenser and inserted into the soil, the duck-billed funnel will be opened, and a certain amount of water will be injected at the same time. After the melon seedlings fall, the duck-billed funnel will be kept open and will be pulled out of the soil through the rotation of the dispenser and then closed, waiting for the seedlings to be cast again. The opening and closing of the duck-billed funnel are controlled by the CAM mechanism. The soil covering wheel located at the back of the dispenser compresses the soil on both sides of the root of the melon seedlings, which plays the role of burying soil and compacting. (Li Hua, 2017; Li Ge, 2003; Lu Zhijun, 2017; JB / T 10291, 2013).

Transplanting agronomic qualification

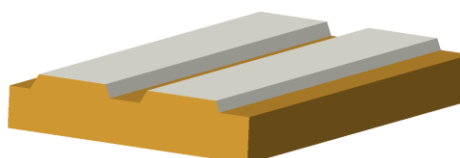


Fig. 3 - Ridging Cantaloupe double membrane cultivation agronomy

The technical data of transplanting machine for Hami melon in northwest arid areas are shown in table1.

Table 1

Transplanting machine technical parameter table

No.	Project	Technical parameters
1	Version	ZZXS-2
2	Form of power	by tractor
3	Horse power of tractor	≥40
4	Membrane width	350-450 (mm)
5	Adjustable planting width	85, 90, 95 (cm)
6	Adjustable water injection	60-100 (ml/hole)
7	Outline dimensions L × W × H	2250 x 1500 x 1800 (mm)
8	Machine weight/kg	700~ 750 kg

Design analysis of key mechanisms - Chain drive design of the planting mechanism

The duck-bill transplanting mechanism is a key part of the whole transplanter. The transplanter mechanism is a crank-link - CAM mechanism. The assembly drawing of the transplanting machine is shown in Figure 1, and the duck-bill transplanting mechanism is shown in Figure 4. Before the cantaloupe transplanter operation, which should match well transplanting speed and forward speed and seeding speed match, avoid injured cantaloupe seedlings, seedling clip and seedling belt phenomenon (Shao Yuanyuan, 2019; Tang Qing, 2016; Wu Jun, 2016; Wu Jun, 2012).

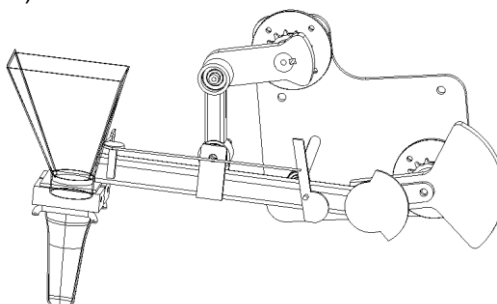


Fig. 4 - 3D image of transplanter

The “duck mouth” actuated by the CAM drives the crank connecting rod mechanism to move, and the cam-to-connecting rod power transmission ratio is calculated as follows:

$$i = i_{\omega} \frac{z_2}{z_1} = \frac{n_1}{n_2} \tag{1}$$

where: i - Transmission box reducer reduction ratio;

Z_1, Z_2 - Number of teeth of the sprockets in the planter drive system;

n_1, n_2 -Power speed of the seedling mechanism and crank speed , [r/min].

The crank angle speed depends on the transplanting operation speed of 4.8 rad/s, take the delivery agency for cantaloupe seedlings speed is 0.59 rad/s, and the transmission ratio i_{ω} , choose 10 speed reduction gear. According to the above selection data and transmission ratio 0.12, the number of gears driven by two cams is calculated: $z_2=15, z_1=18$.

Field testing - Test site and test method

The test site was selected in Turpan, China, and the test time was March 2022. The main measuring instruments were clocks, tape measures, soil moisture content tester, etc. According to the transplanting conditions of Hami melon planted in the arid areas of northwest China, the relevant parameters of the machine and tools were set in advance to match the operation speed, seeding speed and transplanting row spacing and plant spacing. In this experiment, the row spacing of planting cantaloupe is 45 cm, while the plant spacing is 40 cm. The field debugging test diagram is shown in Figure 5.



Fig. 5 - Transplanting machine operation test site

Test methods

Dry cantaloupe transplanting machine belongs to the technology and method of transplanting machine in dry area, so, we take reference to the standard “transplanter in dry land” and manufacturer's standard Q/HY·J0324—2019 “Melon transplanter” including the relevant provisions of the test method for conducting the transplanting operation (Wang Yongwei, 2018; Wu Wei, 2013; Xue Dangqin, 2013; Xu Gaowei, 2019; Yu Xiaoxu, 2014). The cantaloupe transplanting effect test was carried out in the planting season of Turpan Cantaloupe, China. This experiment analysed the influence of operation speed on evaluation index of transplanting effect under different moisture content soil (Zhao Xiaowei, 2014; Zhang Xiaolong, 2017).

The corresponding index detection methods are shown as follows in Table 2.

Table 2

The corresponding index detection methods

No.	Index	Computational formula	Terms explanation
1	Seedling lodging rate	$T = \frac{N_{DF}}{N}$	T - Seedling lodging rate, [%]; N _{DF} - Lodging point number, [-]; N - The total number of points determined, [-].
2	Repeat planting rate	$D = \frac{N_{CZ}}{N}$	D - Heavy planting rate, [%]; N _{CZ} - Heavy planting point number, [-].
3	Missing planting rate	$M = \frac{N_{LZ}}{N}$	M - Missing planting rate, [%]; N _{LZ} - The number of missing holes, [-].
4	Injury seedling rate	$W = \frac{N_{SM}}{N}$	W - Injury seedling rate, [%]; N _{SM} - number of injury seedling, [-].
5	Transplanting qualified rate	$Q = \frac{N_{HG}}{N}$	N _{HG} =N-(2N _{CZ} +N _{DF} +N _{LZ} +N _{SM}) Q-Transplanting qualified rate, [%].

RESULTS

Land plots with different moisture content were selected for the test (22.5%, 20.3%, 18.1%, 16.2%), at the beginning of the transplanting test, the seedlings being transplanted at a 0.8 m/s, 1 m/s, 1.2 m/s, 1.4 m/s operation speed; the repeat planting rate, lodging rate, missing planting rate and seedling damage rate were determined respectively, and the transplant quality rate was calculated. The specific test data is shown in Table 3.

Transplanting operation quality indices at different operating speeds

Table 3

Soil rate of water content [%]	Machine speed [m/s]	Transplant quality evaluation parameters				
		Repeat planting rate [%]	Lodging rate [%]	Missing planting rate [%]	Seedling damage rate [%]	Transplanting quality rate [%]
22.5	0.8	1.21	1.61	1.23	2.23	93.72
	1.0	1.68	1.26	1.17	2.63	93.26
	1.2	1.13	2.23	1.16	3.11	92.37
	1.4	1.92	1.95	1.75	3.05	91.33
20.3	0.8	1.77	1.71	3.77	2.23	90.52
	1.0	1.53	1.32	1.65	2.61	92.89
	1.2	1.66	2.21	2.32	2.94	90.87
	1.4	2.28	2.36	3.61	2.81	88.94
18.1	0.8	2.30	2.13	4.37	2.15	89.05
	1.0	1.92	1.96	2.65	1.92	91.55
	1.2	1.78	2.75	2.25	2.96	90.26
	1.4	3.21	3.46	3.69	2.55	87.09
16.2	0.8	3.41	4.23	5.17	2.03	85.16
	1.0	3.95	2.86	3.44	1.44	88.31
	1.2	3.86	3.71	3.16	2.88	86.39
	1.4	4.12	4.43	4.52	2.61	84.32

According to the experimental data, recorded in the above table 3, the data in the table was analysed. Test data shows that, it can be seen significantly that when the dry land transplanter operation with different moisture content, the machine speed increased, the damage rate and lodging rate of the transplanting seedlings became larger, the repeated transplanting rate and the leakage rate became smaller and then increased, the transplanting qualified index showed a weak trend, when the machine speed was 1 m/s. The evaluation index of transplanting effect is the best, the damage rate is the lowest, and the qualified rate of transplanting is the highest at this time, 93.26. Therefore, the matching speed was set as the best agronomic parameter of the machine.

CONCLUSIONS

(1) According to the Xinjiang Turpan melon planting mode and agronomic requirements, based on the existing transplanting methods for the mechanized non-destructive transportation and planting of large young melon seedlings, root water injection, planting hole accurate soil piling and other key technical problems, the innovative water injection system places the water injection pipe, which put in the inside of the transplanter, through multi-point linkage electromechanical control, the water for the seedling is injected into the bottom of the pot while removing seedlings, not only to ensure the survival rate of the melon seedlings, but also to greatly improve the water utilization rate; the design of the cover roller achieves the accurate soil accumulation of planting holes.

(2) In this paper, a cantaloupe transplanting machine with water injection is designed, which can complete rotary tillage, pipe and film laying, transplanting, water injection, soil covering and other processes at one time to meet the agronomic requirements of cantaloupe planting in arid areas. Through the adaptability test study in Turpan, China, it can effectively solve the phenomenon that cantaloupe seedlings wither and die due to delayed water injection after transplantation. After transplanting, the survival probability can be up to 98%, and the transplanting efficiency can also reach 0.067 ha/h/person. When the transplanting speed is 1 m/s, the best transplanting qualified rate is 93.26%, which meets the agronomic requirements of transplanting cantaloupe in arid areas and can improve the theoretical data support for transplanting cantaloupe in arid areas.

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