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Review

The Analysis of the Applications of Crop Seed Tape Sowing Technology and Equipment: A Review

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Abstract: Seed tape sowing technology is a kind of crop cultivation technology based on a carrier. This technology first wraps crop seeds in a kind of carrier materials and makes them into seed tape. The seed tape is then laid down in farmland with special equipment. Seed tape planting has the advantages of accurate control of hill spacing, simplification of field sowing process and helps to implement order agriculture. Seed tape manufacturing and laying equipment are the core equipment of the technology and their working reliability directly affects the advantages of seed tape planting technology. Based on the research status of seed tape planting technology and equipment, this article made comparisons between the key technologies which include the method for seed tape manufacturing, seed tape sowing, furrowing, seed tape guiding technology, etc. In this paper, the basic problems of seed tape technology that still need further study are put forward. The future development of tape sowing technology and equipment are predicted as follows: the intelligent high precision and high-speed seed tape manufacturing equipment, the large intelligent integrated seed tape planter of "land preparation-seeding tape making-sowing", the small and medium-sized mobile walk-behind planters, the application on the agricultural landscape and the crop transplanting. This study will be helpful to promote the further development of seed tape planting technology and provide a reference for the research of tape planting technology and equipment.

Keywords: seed tape; direct seeding; seed germination; crop sowing

Citation: Zhang, B.; Liu, D.; Xi, X.; Zhang, Y.; Chen, C.; Qu, J.; Dong, H.; Zhang, R. The Analysis of the Applications of Crop Seed Tape Sowing Technology and Equipment: A Review. *Appl. Sci.* **2021**, *11*, 11228. https://doi.org/10.3390/app112311228

Academic Editors: Claudio De Pasquale and Leo Sabatino

Received: 18 October 2021
Accepted: 21 November 2021
Published: 26 November 2021

1. Introduction

Sowing is one of the important links of agricultural production. At present, there are mainly two ways of planting crops; one is direct seeding and the other is transplanting [1–3]. With the continuous development of agricultural technology, sowing methods are gradually showing a trend of diversification and refinement and agricultural production is developing towards refinement and intelligentization. People have gradually paid attention to precision seeding since it can reduce seed consumption and improve economic efficiency [4]. Due to the different sizes of seeds of different crops, it is difficult to design a planter that meets both large-size seeds and small-size seeds. Therefore, it is necessary to design a variety of planters for specific seeds [5,6]. In addition, sowing stability (such as hole spacing, row spacing, number of seeds per hole, etc.) is a core issue and research showed that sowing speed has a great influence on sowing uniformity which mainly includes the hill space and the depth [7]. Seed tape sowing (also called seed rope), as a niche kind of precision seeding technique, can meet the requirements above because of its technological characteristics. Seed tape sowing can be independent of the seed size restrictions. It belongs to direct seeding and was first proposed by William Nelson McComb [8–10].

Seed tape seeding technology was more common in the United States and Europe in the early days and it was later introduced by Asian countries. The seed tape technique was originally proposed for precision seeding of small seeds and it is mainly divided into two parts. One is seed tape manufacture and the other one is seed tape laying [11]. Put seeds and fertilizers in a tape carrier made of suitable material at the same time, and therefore one planter can be used to sow multiple crops. Seed tape sowing can also prevent seed waste caused by manual seeding or seeding by planters [12,13]. In Tang's [14] research, the consumption of rapeseed sowed by seed tape was 60% less than ordinary sowing, and the production increased by 20%. Seed tape has been proven to have good economics and superiority in crop planting. In the experiment of green radish seed tape planting, compared with artificial sowing, it was obvious economic advantages which saved 490~530 CNY/667 m^2 [15]. Wu et al. [16] used seed tape technology to cultivate Chinese herbal medicine *Saposhnikovia*, which reduced production costs by 2000 CHN/667 m^2. Compared with conventional transplanting, rice seed tape sowing saves water 4500 m^3/hm^2 and reduces the amount of rice seed consumption by 17~33% [17,18].

At present, research on seed tape sowing technology mainly focuses on 3 aspects: the exploration of agronomic requirements for seed tape seeding, the research on seed tape manufacturing and the research on seed tape laying. The purpose of this review is to analyse and summarize the application research of crop seed tape sowing technology and equipment, including the agronomic technology, key technology and equipment of seed tape manufacturing and laying. The basic issues of seed tape which need further study were summarized and corresponding research suggestions were put forward. At the same time, the future development direction of rope planting technology was proposed.

2. Study on Agronomic Condition of Seed Tape Planting

Since the variety of seed types, whether the agronomic parameters (such as hill distance, sowing depth, seed numbers in one hill, etc.) of different seeds with seed tape are consistent still needs to be explored. To determine the effects of seed tape planting techniques on crop growth, researchers have been studying the agronomic parameters for seed tape sowing. Fischer [19] found that the optimal sowing depths for different types of seeds are various. While it is difficult for farmers who lack the experience to remember the most suitable sowing depths for various types of seeds. When using seed tape technology for sowing, seed tape would be buried in the soil. If seeds were buried too deep or too shallow, it would affect the growth of the seed root system. For this reason, Fischer improved the internal structure of the seed tape. A layer of soluble gum was sealed on the upper layer of the seed tape, and the inside of the gum was wrapped with seeds. To ensure that the side of the seed was facing upwards when sowing, Fischer marked the other side of the seed tape with a special colour. It can prevent seed damage from being buried too deep or too shallow. Wetzel and Batson [20] found that the radial growth of mycelium of *Rhizoctonia solani* and *Pythium aphanidermatum* was significantly reduced in media amended with polyethene oxide seed tape compared to tomato direct seeding. There was no significant difference in fresh or dry weights of seedlings, root-hypocotyl, or cotyledon fractions from tomato seed germinated in solutions containing various levels of polyethene oxide. To study the mulching of leaf and root crops with high planting density, Nakajima et al. [21] sowed the carrot seeds with seed tape and the results demonstrated the feasibility of the seed tape sowing technique.

Seed tape technology was originally used for sowing small crops such as vegetables and flowers. Meanwhile, researchers realized that the seed tape technique could still be used to produce other crops such as corn and rice. To reveal the effect of seed tape on crop growth, Ramarao's [22] research revealed that there was no significant difference in the emergence percentage, emergence time and emergence rate of corn seed. Ogava [23] conducted the rice seed tape direct seeding test and the results showed that the yield of rice was more than the ordinary direct seeding. Since the seed tape needs to be coated

with a certain amount of glue to assist positioning and to clarify the effect of seed tape with sticky rice glue as adhesive on the growth of rice seedlings, Han et al. [24] used chemical glue seed tape to carry out a comparative test with it. The results showed that under the same conditions, the seedling emergence rate and growth quality of seedlings were not significantly affected, but the sticky rice glue seed tape was more friendly to the environment. Since fertilizer, herbicide and seeds can be woven into the seed tape when making seed tape, the amount of herbicide and fertilizer used in the seed tape and their locations relative to the seed would affect the growth of seedlings [25]. Table 1 summarizes the specific results of research about the effect of seed tape sowing on different crops in different agronomic parameters conditions.

Table 1. Summarizes the specific effects of seed tape seeding on the growth of different crops.

Task	Seed Species	Treatment Method	Specific Results	Ref
Effect of perforated in seed tape on the emergence of seedlings	Lettuce	Heavy perforated in seed tape	Average germination: 87%	Chancellor (1969) [5]
		Unperforated soluble paper	(1) field trial average germination: 78% (2) laboratory average germination: 90%	
Polyox tape on the growth of tomato	Tomato	thiram-treated seed in polyox tape	reductions of 53.7 and 49.9% in mycelial growth of *R. solani* and *P. aphanidermatum*	Wetzel and Batson (1980) [20]
Germination study of seed tape planting	Komatsuna (*Brassica Campestris* L.)	Plant with paper mulch and seed tape	Germination rate: more than 90%	Nakajima (2003) [21]
	radishes and carrot		Germination rate: more than 80%	
Yield of rice by seed tape	Rice	Direct seeding with seed tape in paddy fields	The yield of rice: 58.1–59.2 kg/hm^2 which is 14~16 kg more than ordinary direct seeding	Ogava (1970) [23]
Yield of rice by seed tape	Rice	Direct seeding with seed tape in dry fields	The yield of rice: 8241.8 kg/hm^2	Ren and Li et al. (2005, 2006) [17,18]
		Direct seeding with seed tape in paddy fields	The yield of rice: 8322.0 kg/hm^2	
Effects of glue used in seed band production on rice growth	Rice	Sticky rice glue	Germination rate: 98.7%	Han et al. (2015) [24]
		PVA chemical glue	Germination rate: 95.4%	
The influence of herbicide and fertilizer in seed tape to the crops	Rice	Fertilizer + seeds	Increase the seedling height by 19.8%	Cui et al. (2011) [25]
		Herbicide + seeds	Inhibit if the herbicide was too close to the seeds	
Effect of seed tape on corn growth	Corn	Corn sowing with seed tape in sandy field	No significant difference with common sowing	Sato et al. (2003) [26]
Effect of hill distance on rice growth	Rice	25~35 mm	qualified rate: 84.4%	Cui (2012) [27]
			leakage rate: 3.85%	

Crop growth is affected when the roots domain environment is changed [28,29]. The effect of seed tape sowing method on crop growth index is mainly due to its influence on the crop root environment. The temperature and humidity in the root zone of crops planted with seed tape had better stability than direct seeding [30]. However, the mechanism of seed tape sowing on the root zone environment is not clear.

3. Research on Key Technology and Equipment for Seed Tape Manufacture

The process of making a seed tape usually involves placing seeds into the seed tape material with a metering device. Therefore, the process of making seed tape involves two areas of technology. One is the material for seed tape and the other one is the process of seed tape production.

3.1. Materials Used for Seed Tape

The material of seed tape is one of the important factors affecting crop growth. Originally, people used paper or common plastic as a carrier to make seed tapes [31]. People gradually preferred a kind of soluble paper to make seed tape according to Chancellor's research [5]. With the continuous breakthrough of material technology, the selection of seed tape materials presents a trend of diversification. Researchers have done a lot of work to explore the suitable materials for seed tape. Scientists realized that seed tapes should have good toughness without affecting seed germination. Therefore, the material used to make the agricultural plastic film is a good choice to produce seed tape. However, the extensive use of agricultural plastic film causes great pollution to the environment [32–35]. To reduce the pollution caused by agricultural plastic films to farmland, Serrano et al. [36] recycles agricultural plastic by catalytic cracking. While recovering seed tape materials is a complex and tedious process. Therefore, the seed tape material should also be biodegradable.

The degradation of agricultural plastic film could be accelerated by adding starch-containing biodegradable plasticizers to it [37]. The biodegradable materials used for seed tape production mainly include two types; one is biodegradable cellulose fibre material and the other is biodegradable synthetic cellulose material [38]. Polylactic acid fibre (PLA) which belongs to biodegradable synthetic cellulose material is widely used in agricultural film production as an environmentally friendly material [39]. Its final degradation products are carbon dioxide and water. This is consistent with the water-soluble membrane proposed by some researchers [40]. In order to improve the properties of seed tape materials and select suitable seed tape materials, researchers have done a lot of work. Table 2 summarized the basic research on improving the property of seed tape material. To determine suitable seed tape material, Cui [27] selected four materials (absorbent cotton non-woven fabric, kraft paper, PP non-woven fabric and PLA non-woven fabric) for a series of tests which includes composition analysis, spectral analysis, tensile strength analysis, degradation rate and seedling emergence rate analysis. The results showed that the degradation rate of absorbent cotton non-woven fabric was the fastest but the tensile strength was lower. The emergence rate of kraft seed tape was the lowest. The degradation rate of PP non-woven fabric was the slowest. After a comprehensive comparison, Cui believes that PLA non-woven fabric was more suitable as seed tape material. Due to the wide variety of crop seeds, the effects of seed tape materials, production techniques and other factors on the growth of different crops are unclear. Millington [41] studied 12 species and batches of seeds with a total of 6200 seeds under different seed tape treatments through a series of experiments which were divided into 3 phases (Figure 1). The results showed that a tissue paper material used by Seed Developments Limited produces maximum seedling penetration rates and the penetration rates of seedlings were greater in 2 ply format seed tapes than 4 ply format seed tapes of the same material. Denia and Heny [42] used sea pandan leaves as the main material for seed tape making, and then carried out the experiment of seed tape cultivation for the choy sum planting, which provided a theoretical basis for the selection of seed tape materials.

3.2. Key Technology of Seed Tape Manufacture

The manufacture of seed tape mainly includes two key technologies; one is seed wrapping technology and the other one is seed metering technology.

Table 2. Summarizes the research of seed tape materials.

Task	Material	Method	Results	Ref
To develop the environmentally friendly biodegradable composites	PLA non-woven fabric	Non-woven stacking method	The sample reached about 115 MPa in bending strength	Katayama et al. (2006) [43]
To improve the ductility of PLA film	PLA	Adding epoxidize Karanja oil (EKO) to PLA	Showed an optimal balance between the improvement of the fragility of the material and improving the elongation with 5 wt%	Garcia-Garcia et al. (2020) [44]
To apply free-of-chemicals pre-treatments to maximise the environmental benefit of flax technical fibres	Flax-PLA non-woven fibre	Ultrasound and gamma ray irradiation	The hygroscopic behaviour: decreased; Stress at break for the case of ultrasound pre-treatment: increased	Gautreau (2021) [45]
To investigate the influence of environmental factors such as water and UV irradiation on degradation of PLA/NR fibre.	The polymer solutions for electrospinning	Differential scanning calorimetry + UV irradiation	(1) The addition of NR to the PLA matrix leads to a slight increase in the melting temperature; (2) After 100 h of UV exposure melting and crystallization temperature decreased	Tertyshnaya (2021) [35]

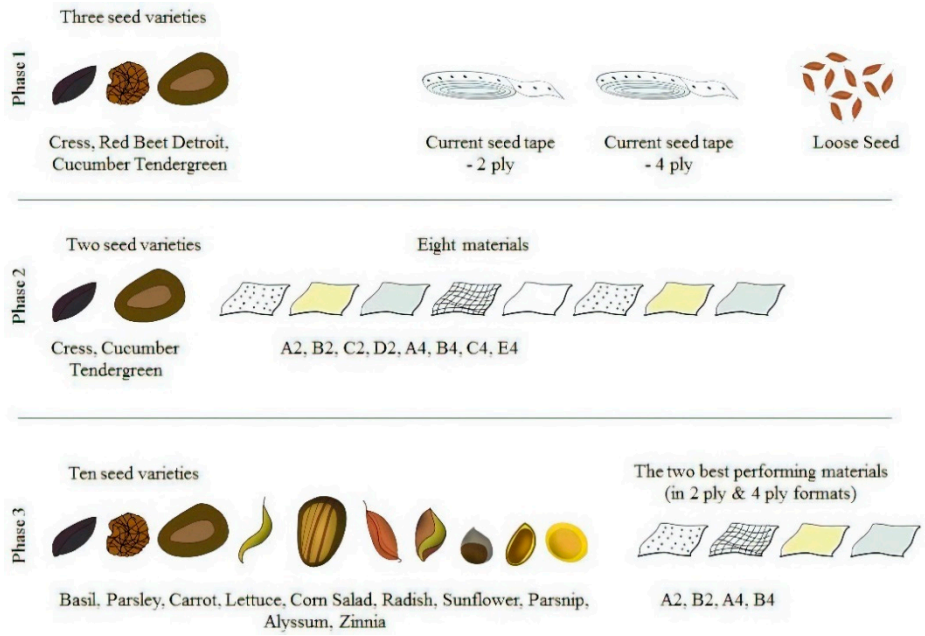
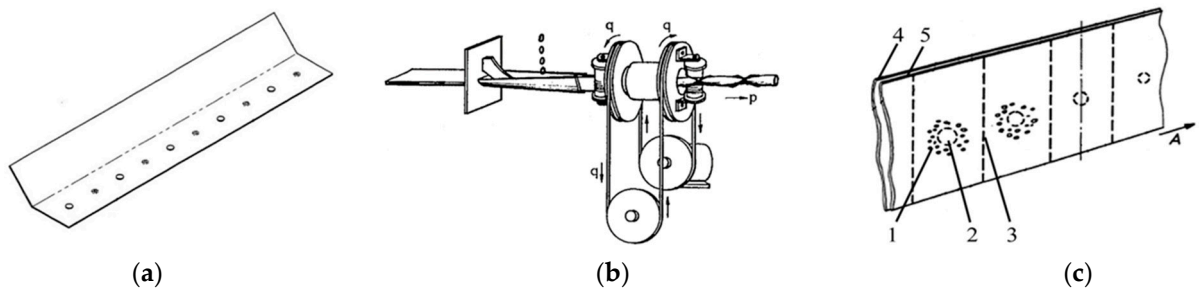


Figure 1. The experimental scheme in Millington's research [41].

3.2.1. The Seed Wrapping Technology and Equipment

In general, seed wrapping technology mainly includes 3 types which are paper tape folding, multi-layer paper tape wrapping, and rope twisting. Folding type refers to wrapping seeds in a seed rope by folding one layer of tape, such as the seed tape designed by Benjamen (Figure 2a). The twisting type refers to the use of only one paper tape to make seed tape by twisting the tape (Figure 2b). The multi-layer paper tape wrapping type refers to the use of two layers or more sandwiches of the seeds to form a seed tape (Figure 2c).



(**a**) (**b**) (**c**)

Figure 2. Three different types of seed tapes. (**a**) Folding type seed tape (https://patentimages.storage.googleapis.com/3d/48/6b/a92c63f9077c3f/US20110271888A1.pdf (accessed on 21 November 2021)) [46] (**b**) Device for making water-soluble seed tapes [47]; (**c**) Seed tape designed by Ahm (https://patentimages.storage.googleapis.com/6c/5b/13/f2be258f5ff65f/WO2007065436A1.pdf (accessed on 21 November 2021)) [48]. 1. Binder 2. Seed 3. Dividing line 4. Rear containment material 5. Front containment material.

When the seed tape planting technology was first proposed, Edward E. Grey and David E. Grey [49] designed a seed tape winding machine whose transmission system of this mechanism was more complicated, and the rope wrapping system, the gluing system was driven by a multi-stage gear structure. Its seed–metering type was pneumatic and the seed was wrapped in the seed rope in a three-fold way. On certain occasions, some groups still have a demand for micro seed tapes, such as university researchers and experimental farms. To satisfy the requirement, Cochran et al. [50] designed a small pneumatic seeding type rope winding machine. This machine can be used for seed tapes and seeds of different widths. The machine was also equipped with a speed adjustment device and a counting device to better record the parameters of the seed reel. Henrik and Kiklas et al. [48,51–53] surrounded seeds with special additives and binders and sandwiched them between two layers of water-soluble material. Therefore, the seeds can be kept in an adequate water environment during germination which controls the germination process. Benjamen [46] proposed that pesticides should also be implanted into seed tape, and the seeds and fertilizer should be placed at intervals that would improve crop disease resistance. Foster [54] has designed a dispensing package for the roll of seed tape machine which consisted of a plasticized cardboard. It could lock the reel in a predetermined position and ensure the quality of seed tape. Johnson [55] suggested that the two layers that wrap seeds should be heat sealed together. In order to achieve the production of corn seed tape with high efficiency and high quality, Xu et al. [56] has designed a corn directional seed tape production technology. The helical winding of the seed tape can be realized by the winding motor driven by a sensor signal from the height sensor. A perforated seed rope winding machine (Figure 3) was developed by the German engineer Scholl [57]. The seed tape made by this mechanism was composed of three layers of paper tape. When it was working, the puncher first punches the middle layer of paper tape with even small holes, and the other paper tape is tightly attached to the bottom of the paper tape through the conveying and pressing mechanism. The small hole forms a concave small hole, and the seeding mechanism puts the seeds into the opened small hole. The third paper tape was tightly covered on the hole paper tape through another set of conveying and pressing mechanisms. The nail piercing device of the book implement fixes the three layers of paper tape.

In terms of seed tape twisting production, Zhang et al. [58] developed a seed rope twisting machine, which can weave rice seeds, fertilizers, and herbicides into seed ropes according to agronomic requirements. The linear velocity and the number of twisting per unit length of the rope were analysed for the winding mechanism of the seed tape twisting machine. Field trials show that the institution the seed rope produced can meet the production requirements [59]. However, there are still problems such as poor hill spacing control, low production efficiency and seed rope winding forming. For this reason, Zhou and Ji [60,61] of Nanjing Agricultural University developed a new generation of seed rope

winding machine. The test results show that it can meet the agronomic needs, and there is no significant difference compared with the local traditional machine transplanting or manual transplanting. In 2011, Hu [62] from Hunan Agricultural University designed a kind of seed rope winding machine with straw rope as the carrier. This machine can reuse the straw harvested by mechanical or manual harvesting. It can prepare 10 seed ropes at the same time each time. It can produce 10 km of seed tape per hour, while the uniformity of chemical fertilizers and herbicides is 95%. The seed loss rate is only 3%. However, due to the large number of working parts and the complicated structure, the machine is equipped with five motors, which has high energy consumption. The size of the seed rope is relatively large, and the seed rope may float off the soil when sowing. Therefore, this technology has certain limitations. In 2012, Wang and Shang [63] of Qingdao Agricultural University designed a set of precision seeding equipment based on the seed tape mode that can be applied to a variety of crops. The equipment includes a seed rope weaving machine and a seed rope planter. Taking carrot as the experimental object, the operation indexes are as follows: the missed seeding rate 2.7%, the qualified rate of plant spacing 96.3%, the qualified rate of seeding depth 92.3% and the germination rate 95.7%. Field experiments indicated that this set of equipment can meet agricultural requirements. Zhang and Cui et al. [27,64–68] designed a new type of rice seed tape machine with an optimized automatic control system (Figure 4), which greatly produced the production efficiency of seed tape. Cui also concluded that the most appropriate twisting number was 47 per meter.

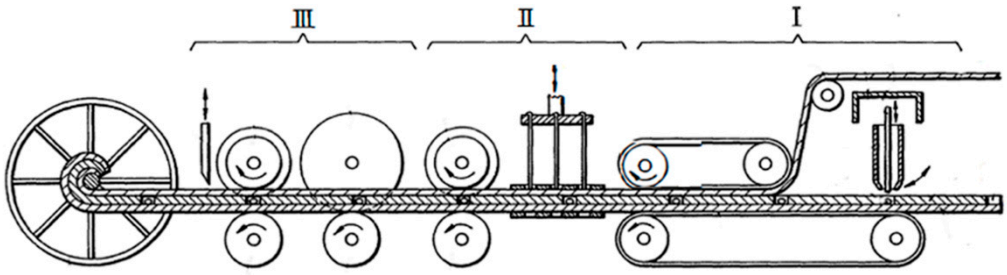


Figure 3. Machine for forming seed tape designed by Scholl [57]. Part I is the drilling seed supply system; part II is the rope reinforcement system and part III is the seed rope compaction system.

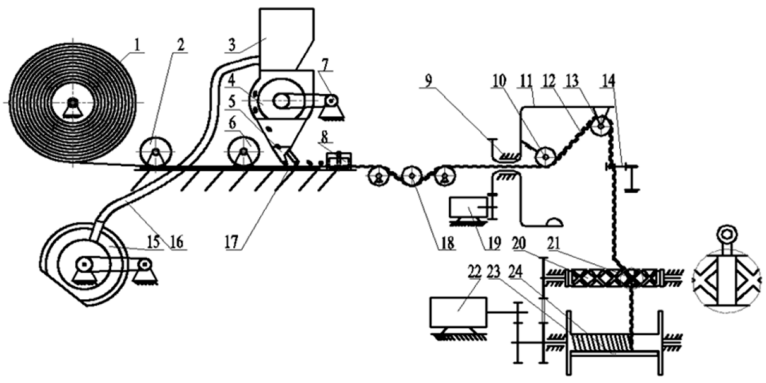


Figure 4. Working principle diagram of the rice seed tape twisting machine [27].

In order to overcome the shortcomings of the previous technology, Xu and Wang [69] invented a seed band sowing method suitable for precise sowing of small-particle seeds and designed a seed tape production device, which is equipped with a loose seed drop mechanism. The loose seeds scattered outside the seed point are blown into the collector. Compared with the previous device, it solves the problem of decoupling of fine seed and good method, which is beneficial to the integration of fine seed breeding and promotion,

seeds and cost-saving. Seed production, processing and circulation are all standardized, and it is convenient to calculate the total output by the number of seeds sown per unit area. Shi [70] designed a kind of tape making machine controlled by a programmable logic controller (PLC). The control system of this machine was composed of several motors and frequency converters, which can feedback the tension signal of seed rope and ensure the production quality of seed tape. Li et al. [71] designed a precision seed tape wrapping machine for small seeds. A vacuum seeding disk was used which can realize zero-speed seeding of seed tape, and it improved the precision of seeding. To improve the safety of the seed tape twisting machine, Luo et al. [72] designed an electric leakage safety detection device. Seed tape technology also has a good application in landscape agriculture. Huang et al. [73] developed a seed tape weaving technology of mixed rapeseed and wheat, which provides a reference for landscape planting of field crops.

3.2.2. The Seed Metering Technology in Seed Tape Manufacture

Theoretically, any seed metering device could be used for seed tape production. However, the common method of seed tape arrangement is mainly pneumatic seeding type or external force feed. The seed tape producing machine design by Cui and Ren used the external force feed. Although the hill spacing requirement can be theoretically guaranteed through the automatic control system, the collision between seed and seed tape could easily lead to inaccurate positioning. Therefore, some kind of seed tape wrapping machines will also include a gluing system.

To improve the positioning accuracy of seeds in the seed tape, researchers have conducted detailed studies on both pneumatic seed metering devices and external force feed. Craig [74] designed a rotary pneumatic seed rope winding machine, which has faster speed and efficiency, and a better seed positioning effect than previous generations of seed rope winding machines. The metering device designed by Depperman et al. [75] could extract the single seed from a specific tray and pinpoint them using an accumulator. In order to improve the accuracy and stability of the pneumatic seed metering device, a cylindrical stirring device was designed which realized accurate seeding of 1~3 seeds/hill [76]. Han [77] optimized the shape of the seed guiding tube and designed a supporter on the rice seed tape twisting machine. As a result, the two core devices greatly improve the performance of the seed tape twisting machine. Crop seed metering device usually uses multiple rice seeds for sowing, which is difficult to form a hill. If the seeds in the seed tape were wrapped in an irregular position, it would affect the emergence effect of seed tape [78].

The rice seed metering device usually uses multiple rice seeds for sowing, which is difficult to form a hill, especially sowing on the seed tap. To improve the performance of rice seeding in one hill, Xing et al. [79] based on the study of the trajectory of seed throwing optimized sucking holes on the sucking plate of the rice pneumatic seed metering device with an adjustable seeding rate. It was 10–17% higher than the original qualification rates of seed throwing, which greatly improved the qualification rate of seed throwing. Peng [80] used a stepper motor controlled by a PLC to drive seed metering devices, which can accurately control plant spacing and improve seed quality. A kind of spiral lifting seed arrangement device designed by Ahm [81] was used in the seed rope winding machine. In the seedbox, a vertical spiral conveyor was used to transport the seeds from the bottom to the top. The top end of the spiral conveyor was connected with the outlet of the seedbox, and the seeds reach the outlet vertical chamber and then fall free on the tape to complete the seeding operation. Besides, some companies are providing various kinds of rope reels, such as SEDOS in Slovak. The seeds are placed on the seed tape by an air suction seed metering device (Figure 5).

Figure 5. Air suction seed metering device (https://www.sedos.sk/Data/1049/UserFiles/SEDOS%20Catalogue%202012%20ENG.pdf (accessed on 8 October 2021)).

4. Research on Key Technologies and Equipment of Seed Tape Laying

Laying the seed tape in the seed groove is the mission of the seed tape planter. The operation requirements of laying the seed rope are that the depth of the seed rope in the soil meets the agronomic requirements, and the seed rope is not broken. Therefore, seed tape laying machine is the other important equipment of seed tape sowing technology. Seed tape buried in the soil too shallow or too deep would affect the emergence of seeds. Seed tape laying includes three core technologies which are guiding of seed tape, driving mode of seed tape planter, and covering technology of seed tape planter.

4.1. Guiding of Seed Tape

Whether the tape guiding device is reasonable or not will determine the seed tape strength received during the seeding process. If the design is unreasonable, the local tension of the seed rope will be too large and the rope will break. When seed ropes are being laid, the ditch depth needs to be determined according to the agronomic requirements of different crops. The seed tape guiding system mainly includes a seed tape disc and tape guiding wheels. Zhang [82] experimentally studied the relationship between the rotational inertia of the seed tape reel and the friction moment of the bearing and proved the feasibility of driving the seed rope tray to release the rope through the seed rope friction force. According to the number of tape guiding wheels, it can be divided into one-level tape guiding system, two-level tape guiding system and multistage-level tape guiding system.

In order to improve the quality of tape laying, Zhang et al. [83] studied the dynamic response characteristics of the tape laying system and optimized the rope angle of tape laying (Figure 6). Based on the stress analysis of the tape guiding wheel, Lv et al. [84,85] designed a seed tape guiding device that belongs to two-level tape guiding system. It combined the guiding device with the ditching device to further simplify the structure of the seeder. When the soil has been opened the seeds groove, the seed tape was laid into the bottom of the groove immediately (Figure 7a). To improve the performance of the seed tape planter, Lv et al. [86] carried out finite element analysis on the frame of the tape guiding mechanism and optimized the structural parameters. The most common problem in the process of rope laying is broken and disorderly tape. Liu et al. [87] based on the discrete element method (DEM) optimized the seed tape guiding opener which reduced the resistance of ditching. Figure 7 also showed another 3 kinds of tape guiding devices. Figure 7b is a knife guide tape opener produced by SEDOS. Figure 7c is a press-in tape guiding mechanism developed by Ren et al. [88] which uses the ground wheel to press the seed tape into the soil. Figure 7d shows the core-drawing tape guiding opener developed by Zhang [82].

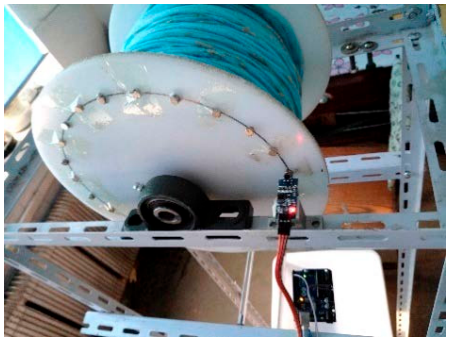


Figure 6. The tape guiding system [83].

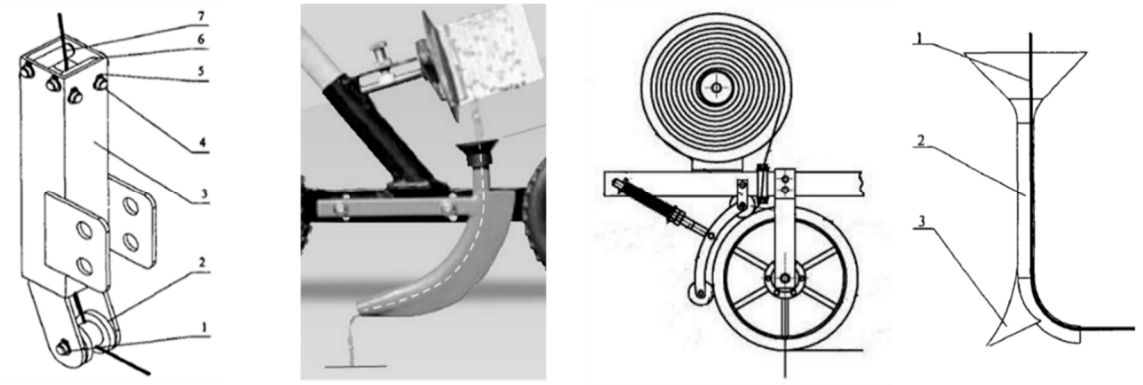


Figure 7. Kinds of tape guiding system. (**a**) Tape guiding system designed by Lv, 1. Axle of tape guiding wheel 2. tape guiding wheel 3. Shell 4. Axle of tape guiding pipe 5. Gasket 6. tape guiding pipe 7. Seed tape [84]; (**b**) Knife guide tape opener (https://www.sedos.sk/Data/1049/UserFiles/SEDOS%20Catalogue%202012%20ENG.pdf (accessed on 8 October 2021)); (**c**) Press-in tape guiding mechanism [88]; (**d**) Core-drawing tape guiding opener, 1. Seed tape 2. Tape guiding pipe 3. Furrower [82].

4.2. Walking Mode of Seed Tape Planter

Seed tape planters can be divided into traction type and hand-guided types according to walking mode. A hand-guided seed tape planter is mainly applied for a small field or family garden, while the traction type can be used for a large-scale field.

When the seed tape sowing technology was first put forward, Sanford [89] designed a hand-pushed rope planter (Figure 8). The mechanism was equipped with small teeth inside the rope pulley groove to ensure that there is no slippage between the seed rope and the wheel. The ditch depth can be adjusted through the positioning holes set on its frame. The mechanism added a soil covering mechanism, which was composed of a long bolt and pressure constrained by springs, the number of seeding rows was single. Motohashi and Yuri [90], Japanese scholars, invented a hand-held single-row rope planter in 2012 (Figure 9a). The machine was driven by a battery, and the working speed can be adjusted by a gearbox, which has good manoeuvrability. Since the front-end travelling wheels cannot swerve, the mechanism had certain drawbacks when turning the ground. Zhang [82] improved and manufactured the second generation of manually seed tape direct seeding machines, which proved that manpower can drive the rice direct seeding machine in the field. The operation of the tape-seeder is always stimulated by soil. In order to clarify the interaction characteristics between soil and tape-seeder, Zhang et al. [91] designed a small manually seed tape planter and established a soil-tape planter system model. The influencing factors of operation quality are clarified. However, if the soil conditions or soil preparation conditions are not ideal, the working performance of the machine would be affected. To improve the adaptability of the seed tape planter to the soil, Lv [92] designed a

hand-guided seed tape planter combined with a rotary cultivator. It can complete rotary tillage and seed laying seed tape in one operation (Figure 9b).

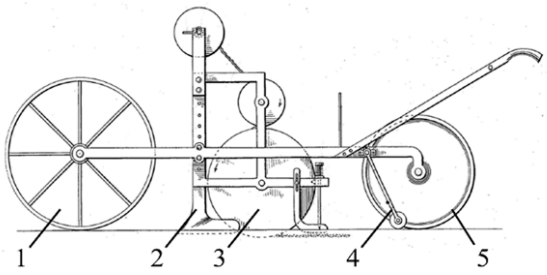
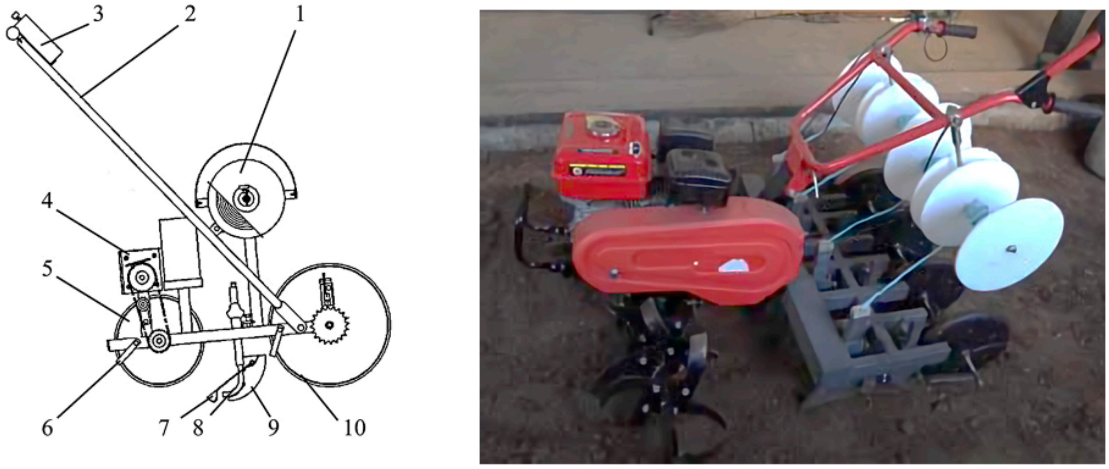


Figure 8. Seeder tape planter designed by Sanford [89]. 1, front-wheel 2, furrow opener 3, rope guiding wheel 4, scribing wheel 5, pressing wheel.

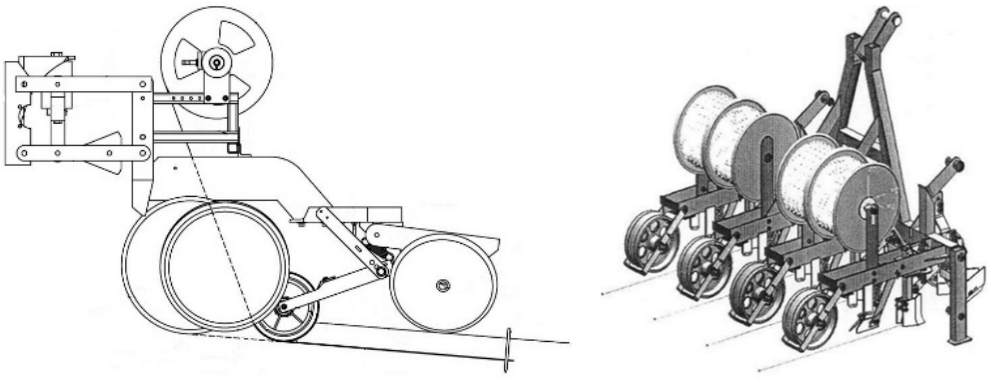


(**a**) (**b**)

Figure 9. Two kinds of hand-guided types of tape planter. (**a**) Seed tape planter designed by Ryosumi (https://patentimages.storage.googleapis.com/7b/82/a3/adb74f12120c19/JP2012235727A.pdf (accessed on 20 November 2021)) [90]; (**b**) Seed tape planter designed by Lv [92]. 1. Seed tape disc 2. Pushrod 3. Switch 4. Motor 5. Pressing wheel 6. Scraper plate 7. Scriber 8. Seed tape guiding pipe 9. Furrow opener 10. Walking wheel.

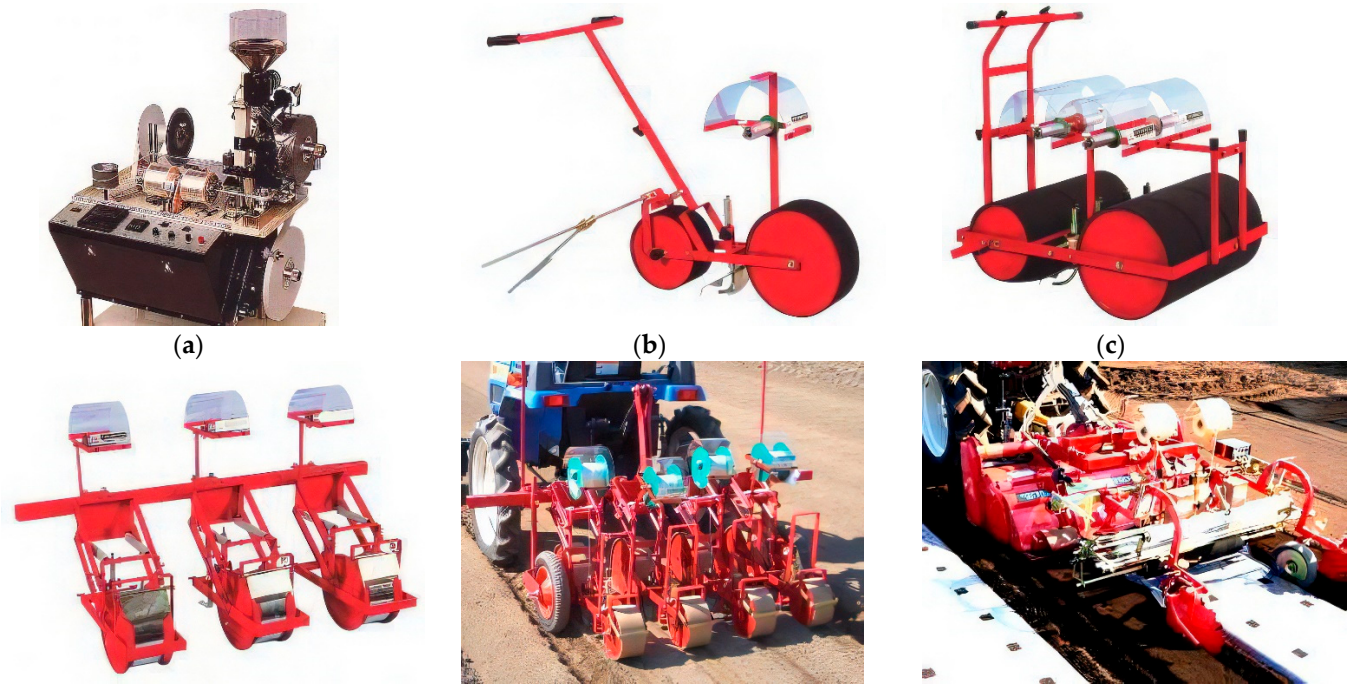
The traction seed tape planter is mainly pulled by a tractor. Figure 10a shows a tractor-towed seed tape planter connected to the tractor by its parallel four-bar coping mechanism. The seed tape reel was connected to the frame through the mounting arm and was laid down to the seed groove through the guide rope device, which has a good operation effect [93]. Griffin et al. [94] designed a tractor-traction type two-row rope planter. The planter was characterized by a collection of fertilizer discharge systems, rope laying system, rope burying system and film coating system. This machine was mainly used for tobacco, tomato, corn and other crop seedings. In order to improve the adaptability of rope seeding machine to the soil, Lv [95] proposed an anti-blocking device when improving the design of the new generation of prototypes and developed a four-row rice seeding rope direct seeding machine and the tractor traction work to improve the work efficiency, as shown in Figure 10b. In 2013, Ren et al. developed a traction four-row rice seed tape planter. The mechanism used a pressing wheel instead of the traditional ditching method to lay down the seed tape into the soil. This mechanism also adds a rope cutting system driven by a four-bar mechanism. Tests have revealed that the mechanism has shown good workability for plots with suitable soil moisture content and ideal soil softness [88]. However, the working performance of this machine would easily be affected by the soil conditions. In addition, Dou [96] invented a paper carrier garlic planter driven by a tractor,

which includes a cultivation device and a packaging device, which realizes the integration of garlic and garlic seed packaging and seeding. There is a riding platform on the planter, which can manually adjust the position and posture of garlic. Two rows of tape paper respectively take four rows of garlic cloves, which are then cut into four rows of seed tapes by the end blades and seeded through their respective seeding systems. The machine has a high degree of automation and high seeding efficiency. Besides, there are currently several international companies offering seed tape seeding services and equipment, such as Nippon Plant Seeder in Japan. Figure 11 lists some seed tape equipment produced by Nippon which contained traction type and hand-guided types.



(**a**) (**b**)

Figure 10. Two kinds of hand-guided types of tape planter. (**a**) Seed tape planter designed by Deppermann (https://patentimages.storage.googleapis.com/71/f7/53/666419465f4e7e/US20130152836A1.pdf (accessed on 20 November 2021)) [93]; (**b**) Seed tape planter designed by Lv [95].



(**a**) (**b**) (**c**)

(**d**) (**e**) (**f**)

Figure 11. Seeder machine and tape seeders of Nippon. (**a**) SMV-1J type rope twisting machine; (**b**) TSA-7 seeder; (**c**) TSD-7 seeder; (**d**) TRA-7x seeder; (**e**) TRA-8st; (**f**) SDM-T354F. (http://www.plantseeder.co.jp/en.html (accessed on 8 October 2021)).

4.3. Soil Covering Device of Seed Tape Planter

During the operation of the seed tape planter, the embedding depth of seed tape will affect the crop emergence rate and other indicators. Seed tape sowing requires that the tape covered by the soil should be even, without naked leakage, and the thickness of the soil is generally 2~3 cm.

In 2000, Tadashi [97] designed a direct seeding machine with two rows for paddy fields, which is mainly used for direct seeding of rice. The seed tape was first led to the surface of the paddy field. Then the planter pressed seed tape into the paddy field by a pressing wheel fixed on the back of the planter. Later in 2002, Tadashi [98] optimized the original design. The vertical type of the original rotating blade was optimized for bending, which improved the pressure damage to seed rope during sowing. When the planter works in a dry field, seed tape is usually covered by a soil covering device and suppression device. However, in loose soil conditions, the covering and suppression devices can be omitted because of the fallback properties of the soil [99]. Lv et al. [100] designed a dynamic testing system for the depth of the rope seeding machine to improve the performance of soil covering. The soil covering system was tested under the simulated field conditions. The mathematical model of soil covering depth was established and the soil covering structure parameters were optimized. The thickness of the soil cover of the rope seeder is easily affected by the speed of the machine, the depth of the ditch and the angle of the soil cover plate. Ren et al. [101] determined the primary and secondary relationship of its influencing factors by orthogonal test. Zhang [30] made a mechanical analysis of the interaction between soil particles and soil covering plate (Figure 12). The soil covering device was designed and optimized to improve the operation quality of the rope seeding machine.

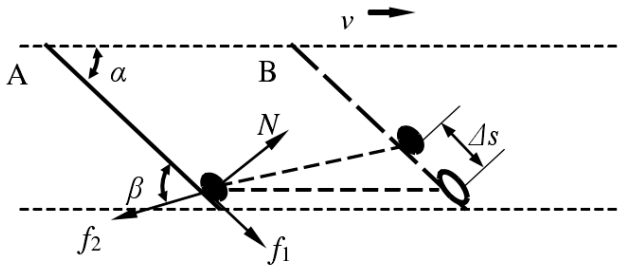


Figure 12. Stress analysis of soil particles [30].

5. Discussions and Prospection of Seed Tape Sowing

5.1. Fundamental Issues in Seed Tape Sowing That Still Need Further Discussion

Based on the analysis and comparison of the research status of seed tape, seed tape sowing certainly has many benefits. However, it is not widely used in agricultural production currently. There are still some basic issues that need to be further studied.

5.1.1. Economic Factors

Seeds should be made into seed tape first in the application of seed tape technology to crop production compared with traditional sowing. The additional process means more input in crop cultivation which include more equipment, more manpower and resources. Therefore, the upfront costs will increase. In the Xinjiang province of China, seed tape was originally introduced for cotton cultivation and the cost in the experiment was higher than conventional planting [102]. In addition, the production of seed tapes requires special equipment. People think that the production of wrapping seeds into seed tape is more cumbersome and not as convenient as direct seeding. With the continuous maturity of precision seeding technology, people are more and more inclined to precision direct seeding than seed tape sowing which is the main reason that seed tape is not widely used.

To break this dilemma, we should give full play to the advantages of seed tape technology. Ensure that the seed tape is of high quality and high seedling emergence rate.

Factors such as increased inputs and seed savings, labour costs and crop economic benefits due to the production of seed tape should be considered. Determine the crops and suitable seed tape material that could bring higher economic benefits to use seed tape sowing.

5.1.2. The Interaction of Soil-Machinery

The stability of soil cover depth is one of the key factors affecting the seed emergence rate. The quality of soil preparation before sowing would directly affect the soil covering effect of seed tape. The results showed that the soil thickness and stability of seed tape were more ideal when soil preparation was higher. On the contrary, the stability of soil depth is poor, and even the seed tape is exposed to the surface. These problems greatly limited the development of the technological advantages of seed tape.

In order to improve the adaptability of the rope-seeder to soil conditions and improve the quality of soil covering the seed tape, we can start from the following aspects.

(1) Strengthening basic theoretical research on soil-mechanical interaction.
(2) Optimize the structure of the rope seeding machine, such as ditching, guide rope and other links.
(3) Before laying the seed tape, install the earth breaking device and the rope seeding machine for the composite operation.

5.1.3. Crop-Seed Tape-Soil Coupling Interaction

Theoretically, any crop can be seeded by seed tape. However, some researches showed that the emergence rate of the same crop was inhibited and uninhibited in the seed tape sowing experiment and people may believe that it is risky to sow with seed tape. Therefore, the agronomic requirements (such as hill distance, sowing depth and other parameters) of different crops when seeding with seed tape are not clear. The effects of seed tape sowing on the root zone environment are not clear. The most suitable seed tape materials and technological parameters for different crops need to be further explored. As a result, we should strengthen the agronomic basic research of seed tape sowing technology. Reveal the suitable agronomic parameters for different crops sowed with seed tape such as hill distance, row spacing, temperature and humidity of the soil.

5.1.4. Intelligent Issues of Seed Tape Equipment

With the development of science and technology, agricultural machinery equipment has gradually become more intelligent. However, due to the low proportion of application of seed tape technology, seed tape seeding equipment has not been well developed, especially the seed tape laying machine. In addition, intelligent seed tape equipment is helpful to improve the seed tape quality of making and sowing. The technological advantages of seed tape would be fully exploited and people would pay more attention to seed tape seeding technology which would be a virtuous circle. Therefore, we can study the intellectualization of seed tape equipment from the following aspects.

(1) Precise control of seed hill distance in seed tape manufacture.
(2) An unmanned seed tape planter based on the GNSS system.
(3) Seed tape intelligent synchronous release and disconnection system.
(4) Sowing depth control and monitoring system.

5.2. Development Prospection Trend of Seed Rope Sowing Technology

With the continuous progress of agricultural science and technology, combined with the direction of agricultural development, the development trend of seed rope planting technology is summarized as the following points:

(1) The intelligent high precision and high-speed seed tape manufacturing equipment. Agricultural production is gradually developing towards factorization, such as the SEDOS and Nippon company. Farmers who sow with seed tape could buy seeds from the factory, and the factory needs to provide farmers with seed tape reels on

time. Therefore, the working efficiency of the seed tape manufacture will be greatly improved in the future.

(2) The emergence of large intelligent integrated seed tape planter of "land preparation-seeding rope system-seeding". It would include the soil preparation system, seed tape production system, seed tape laying system, autopilot system, the GNSS system and some other intelligent control system. The soil preparation system directly ploughs the soil into the most suitable conditions. Then the seeds are formed into the seed tape reel in the integrated seed tape planter and lay down into the soil. Integrated seed tape planter integrates the seed tape making and laying which reduces the manpower input in the process of making the seed tape.

(3) Development of small and medium-sized mobile (manpower) walk-behind planters. For farmers with small areas of arable land, small and medium-sized mobile walk-behind planters will be popular. This type of rope planter has the advantages of good manoeuvrability, flexibility in and out of small fields, easy transportation, and low cost.

(4) Seed tape planting technology can be used for agricultural landscape planting. With the improvement of people's living quality, the agricultural landscape is more and more sought after by people, such as rice field painting and lawn painting. Most paddy fields are planted by hand, which makes them expensive to produce. If the seed tape seeding technique is used for paddy field painting seeding, the corresponding seeds can be wrapped into the seed tape in seed tape manufacture. As Huang et al. proposed, the seed tape mixed weaving of rapeseed and wheat seeds could realize landscape planting in the field [73].

(5) Seed tape planting technology can be used for transplanting crops. Usually, we use the seed tape technology for crop cultivation is to pull the seeds into the seed tape, and then lay down the seed tape by the laying device which belongs to crop direct seeding. Many crops such as rice and rape are mainly produced by transplanting. Transplanting with seed tape begins by germinating the seed in the seed tape. When the seedlings grow to a certain extent, the seed tape with the seedlings is laid down in the groove by special transplanting equipment. It is consistent with the idea of seed zone transplanting proposed by Ahm [103].

6. Conclusions

Seed tape sowing technology has significant advantages, such as saving seeds, simplifying the sowing process, reducing labour costs and so on. However, seed tape technology also has certain disadvantages. Only by exploiting the strengths and circumventing the weaknesses can seed tape technology benefits human. This article studied and analyzed the development status of seed tape sowing technology and its core technology which involved two aspects: seed tape manufacture and seed tape laying technology. According to the existing research, the bottleneck problems of rope seeding technology are analyzed. Finally, based on the above comparative analysis, this article suggests the future development trend of seed tape sowing technology.

Author Contributions: Conceptualization: B.Z., D.L., X.X., Y.Z., H.D. and B.Z. reviewed the literature and wrote the initial draft of the paper with assistance from D.L., X.X., Y.Z., H.D., C.C., J.Q. and R.Z. contributed to revising the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the grant of the Interdisciplinary Project of Yangzhou University Crop Science Special Zone (yzuxk202007), the grant of the Natural Science Foundation of the Jiangsu Higher Education Institutions of China (20KJD210003), the grant of the Key Research and Development Program of Jiangsu Province (BE2020319), the Jiangsu Graduate Scientific Research Innovation Program (JSCX21-1623).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Gómez De Barreda, D.; Pardo, G.; Osca, J.M.; Catala-Forner, M.; Consola, S.; Garnica, I.; López-Martínez, N.; Palmerín, J.A.; Osuna, M.D. An Overview of Rice Cultivation in Spain and the Management of Herbicide-Resistant Weeds. *Agronomy* **2021**, *11*, 1095. [CrossRef]
2. Farooq, M.; Siddique, K.H.; Rehman, H.; Aziz, T.; Lee, D.; Wahid, A. Rice direct seeding: Experiences, challenges and opportunities. *Soil Tillage Res.* **2011**, *111*, 87–98. [CrossRef]
3. Pandey, S.; Velasco, L. Economics of Direct Seeding in Asia: Patterns of Adoption and Research Priorities. In *Direct Seeding: Research Issues & Opportunities International Workshop on Direct Seeding in Asia Rice Systems: Strategic Research Issues & Opportunities*; International Rice Research Institute: Los Baños, Philippines, 2002; pp. 3–14.
4. Cloete, S. Precision planting technology: Designed to maximise farm ouput. *Farmer's Weekly*, 12 August 2019; 50–51.
5. Chancellor, W.J. Seed Tape System for Precision Selection and Planting of Small Vegetable Seeds. *Trans. ASAE* **1969**, *12*, 876–879. [CrossRef]
6. Li, C. Research on development of seed tape technology. *J. Xiaogan Univ.* **2008**, *28*, 91–94.
7. Valentina, N.; Ionel, O.; Ion, S.; Alexandru, S. The speed influence working on sowed accuracy and precision seeding. *Ann. Univ. Craiova-Agric. Mont. Cadas. Ser.* **2021**, *50*, 408–411.
8. Willan, N.M. Seed Tape. U.S. Patent 1143980, 22 July 1915.
9. Obara, H.; Ono, K.; Takahashi, K. Labor-saving techniques on seeding and thinning of vegetables by use of seed tape. *Agric. Hortic.* **1973**, 69–73.
10. Redenbaugh, K.; Fujii, J.; Slade, D.; Viss, P.; Kossler, M. Artificial seeds—Encapsulated somatic embryos. In *High-Tech and Micropropagation I*; Springer: Berlin/Heidelberg, Germany, 1991; pp. 395–416.
11. Fan, Z.; Gao, K.; Mi, X. Preliminary study on carrier tape sowing method of maize seeds. *J. Shanxi Agric. Univ.* **1995**, *15*, 241–243. (In Chinese)
12. Nobuta, M.; Ogaya, O.; Yamada, M. Studies on the Direct Sowing Culture System of Seed Tape. *Jpn. J. F. W. Res.* **1968**, *1968*, 40–44. [CrossRef]
13. Lin, J.; Shao, Y.; Li, H.; Wang, R.; Feng, L.; Yang, G. Discussion on precision planting technology of vegetable seeds. *Sci. Technol. Tianjin Agric. For.* **2020**, 33–34. (In Chinese)
14. Tang, X.; Sun, Z.; Zhao, P. SYS-A Type Seed Tape Braiding Machine and Seed Tape. *Farm Prod. Process.* **2016**, 63–64. [CrossRef]
15. Feng, L. Facility green radish seed tape seeding mechanization technology and equipment analysis. *Agric. Eng. Technol.* **2020**, *40*, 46–48. (In Chinese)
16. Wu, J.; Li, X.; Tu, Y.; Zhang, Y.; Ren, P. Mechanized cultivation technology of Chinese herbal medicine windbreak planting rope sowing. *Agric. Eng. Technol.* **2019**, *39*, 73–74. (In Chinese)
17. Ren, W.; Li, X. Experimental Study on the Yield for the Technology of Rice Direct Sowing with Seed Rope. *J. Agric. Mech. Res.* **2006**, 162–166. [CrossRef]
18. Ren, W.; Li, X.; Cui, H.; Liu, W. Effect of the technique of rice direct sowing with seeds twisted in paper rope on rice yield character. *J. Shenyang Agric. Univ.* **2005**, *36*, 265–270.
19. Fischer, A.C. Seed Tape. U.S. Patent 2281927, 6 January 1937.
20. Wetzel, M.; Batson, W.E. Influence of Polyethylene Oxide Seed Tape on Growth of Rhizoctonia solani and Pythium aphanidermatum and on Damping-off of Tomato. *Phytopathology* **1980**, *70*, 558–559. [CrossRef]
21. Nakajima, Y.; Morita, T.; Kataoka, K.; Fudano, T.; Kawase, K. The trial of leaf and root crops cultivation using paper mulch combined with seed tape. *Hortic. Res.* **2003**, *2*, 293–296. [CrossRef]
22. Ramarao, V.; Thomison, P.R.; Gabriel, C.K.; Bennett, M.A.; Grassbaugh, E.M.; Kleinhenz, M.D.; Shearer, S.A.; Pitla, S.K. Seed Tape Effects on Corn Emergence under Greenhouse Conditions. *Crop. Manag.* **2014**, *13*, 2014–2051.
23. Ogawa, O. Direct Seeding of Rice by Seed Tape. *Jpn. Agric. Res. Quart.* **1970**, *5*, 12–15.
24. Han, B.; Liang, L.; Meng, F.; Ge, Y.; Zhang, S. Research on the Factors Affecting Seeding Quality of Seed Nursery Strip for Rice. *J. Agric. Mech. Res.* **2015**, 170–173. (In Chinese with English abstract) [CrossRef]
25. Cui, H.; Ren, W.; Dai, L. Effect of fertilizer and herbicides in seed tape on rice growth characteristics. *J. Shenyang Agric. Univ.* **2011**, *42*, 335–339.
26. Sato, H.; Sato, J.; Saito, T. Direct sowing method by using seed tape for Eustoma retarding culture in sand dune area. *Bull. Hortic. Res. Yamagata Prefect. Jpn.* **2003**, 63–76.
27. Cui, H. Development and Experimental Study on Rice Seed Tape Twisting Machine. Ph.D. Thesis, Shenyang Agricultural University, Shenyang, Liaoning, China, 2012.
28. Zhu, L.; Tang, X.; Lu, C.; Shen, A.; Wang, S. Effects of root restriction on growth, fruit quality and nutrient element contents of Vinifera. *South China Fruits* **2004**, *33*, 80–82. (In Chinese with English abstract)
29. Wang, C.; Sun, L.; Leng, P.; Xu, X.; Cui, M.; Liu, S. Root zone temperature, plant growth and fruit quality of watermelon affected by nonwoven-fabric-root-restrict ion-cultivation. *J. China Agric. Univ.* **2011**, *16*, 81–86. (In Chinese with English abstract)

30. Zhang, B. Design and Experimental Study of a Small Roped Type Rice Direct Seeding Machine. Ph.D. Thesis, Shenyang Agricultural University, Shenyang, Liaoning, China, 2018.
31. Craig, B.M. Seed-Tape Manufacture. U.S. Patent 3511016A, 12 May 1970.
32. Yan, C.; He, W.; Turner, N. Plastic-film mulch In Chinese agriculture: Importance and problems. *World Agric.* **2014**, *4*, 32–36.
33. Yan, C.; He, W.; Xue, Y.; Liu, E.; Liu, Q. Application of biodegradable plastic film to reduce plastic film residual pollution in Chinese agriculture. *Chin. J. Biotechnol.* **2016**, *32*, 748–760. (In Chinese with English abstract)
34. Liu, E.; Zhang, L.; Dong, W.; Yan, C. Biodegradable plastic mulch films in agriculture: Feasibility and challenges. *Environ. Res. Lett.* **2021**, *16*, 11004. [CrossRef]
35. Tertyshnaya, Y.; Zakharov, M.; Ivanitskikh, A.; Popov, A. Impact of environmental agents on non-woven polylactide/natural rubber agrofiber. *E3S Web Conf.* **2021**, *285*, 7034. [CrossRef]
36. Serrano, D.P.; Aguado, J.; Escola, J.M.; Garagorri, E.; Rodrı, X.; Guez, J.M.; Morselli, L.; Palazzi, G.; Orsi, R. Feedstock recycling of agriculture plastic film wastes by catalytic cracking. *Appl. Catal. B* **2004**, *49*, 257–265. [CrossRef]
37. Šerá, J.; Stloukal, P.; Jančová, P.; Verney, V.; Pekařová, S.; Koutný, M. Accelerated Biodegradation of Agriculture Film Based on Aromatic–Aliphatic Copolyester in Soil under Mesophilic Conditions. *J. Agric. Food Chem.* **2016**, *64*, 5653–5661. [CrossRef]
38. Zhang, J.; Ma, J.; Guo, X. Fiber materials for the production of seed tapes. *Beijing Tex. J.* **2003**, 16–18.
39. Fambri, L.; Pegoretti, A.; Mazzurana, M.; Migliaresi, C. Biodegradable fibres. *J. Mater. Sci. Mater. Med.* **1994**, *5*, 679–683. [CrossRef]
40. Hao, N.; Xiong, C.; Zhang, Y. The Utility Model Relates to a Water-Soluble Seed Tape for Seedling Raising. CN Patent Application No. 211090565U, 28 July 2020.
41. Millington, S.M. Research for Alternative Material and Its Effect on Seed Germination in Seed Tapes Products. Master's Thesis, The University of the West of England, Bristol, UK, 2018.
42. Denia, F.S.; Heny, A. Effectivity of Seed Tape of Pandan leaves Sea (Pandanus tectorius) against the vigor of Pakcoy and Caisim. *J. Agric. Sci.* **2019**, *17*, 52–62.
43. Katayama, T.; Tanaka, K.; Murakami, T.; Uno, K. Compression moulding of jute fabric reinforced thermoplastic composites based on PLA non-woven fabric. *High Perform. Struct. Mater. III* **2006**, *85*, 159–167.
44. Garcia-Garcia, D.; Carbonell-Verdu, A.; Arrieta, M.P.; López-Martínez, J.; Samper, M.D. Improvement of PLA film ductility by plasticization with epoxidized karanja oil. *Polym. Degrad. Stab.* **2020**, *179*, 109259. [CrossRef]
45. Gautreau, M.; Kervoelen, A.; Barteau, G.; Delattre, F.; Colinart, T.; Pierre, F.; Hauguel, M.; Le Moigne, N.; Guillon, F.; Bourmaud, A.; et al. Fibre Individualisation and Mechanical Properties of a Flax-PLA Non-Woven Composite Following Physical Pre-Treatments. *Coatings* **2021**, *11*, 846. [CrossRef]
46. Benjamen, S. Seed Tape. U.S. Patent 20110271888A1, 10 November 2011.
47. Masakazu, N. Seed Tape for Seeding. U.S. Patent 3623266, 30 November 1971.
48. Ahm, P.H.; Carsten, A. Machine for Bedding out Seed or Plant Tapes. U.S. Patent 20070137871A1, 21 June 2007.
49. Gray, E.E.; Gray, D.E. Machine for Forming Seed Tape. U.S. Patent 1160278, 16 November 1915.
50. Carlton, D.; Tobin, J.R. Seed-Tape Manufacturing Machine. U.S. Patent 3772849, 20 November 1973.
51. Henrik, A.P. A Germinating Unit as Well as a Seed Tape Including Several of Such Germinating Units Successively Arranged. WO Patent Application No. WO/2007/065436A1, 14 June 2007.
52. Niklas, W.; Annaberg, B. Seed Tape, Seed Tape System and Greening or Planting System. U.S. Patent 2016/0249522A1, 1 September 2016.
53. Ahm, P.H. Germinating Unit as Well as a Seed Tape Including Several of Such Germinating Units Successively Arranged. U.S. Patent 20090173001A1, 9 July 2009.
54. Foster, R.G. Seed Tape Dispenser. U.S. Patent 3752303, 14 August 1973.
55. Johnson, C.W. Method of and Appartus for Making Seed Tape. U.S. Patent 3846956, 12 November 1974.
56. Xu, L.; Zhao, X.; Lu, X.; Li, Y.; Li, S.; He, S. A Production Method and Device for Maize Oriented Seed Tape. CN Patent Application No. 103609227A, 5 March 2014.
57. Scholl. The Invention Relates to a Method and Device for Making Sowing Belt. DE Patent Application No. 19503971A1, 14 August 1996.
58. Zhang, T.; Ren, W.; Ma, Y.; Wang, C. Parameter analysis on twisting rope machine of rice seed rope twisting machine. *J. Agric. Mech. Res.* **2006**, *12*, 78–79.
59. Ren, W.T.; Li, X.; Zhang, Y. Development and experiment on a rice seed rope twisting machine. *J. Agric. Mech. Res.* **2005**, 169–172.
60. Zhou, J.; Ji, C. Development of machine for producing precision seeding rope with paper for rice direct sowing. *Trans. Chin. Soc. Agric. Eng.* **2009**, *25*, 79–83.
61. Zhou, J.; Ji, C. Machine for Producing Rice Seed Rope and Field Experiment. *J. China Agric. Univ.* **2009**, *14*, 98–102.
62. Hu, Y. Developing of Direct Sowing Straw Machine with Seeds. Master's Thesis, Hunan Agricurtual University, Changsha, Hunan, China, 2009.
63. Wang, J.; Shang, S. Development of plot precision planter based on seed tape planting method. *Trans. CSAE* **2012**, *28*, 65–71.
64. Zhang, Y. Developing of the New Twisting Rope Mechanism of the Rice Seed Rope Twisting Machine. *Agric. Sci. Technol. Equip.* **2011**, 52–53. [CrossRef]
65. Cui, H.; Ren, W.T. In Proceedings of the 2nd International Conference on Applied Robotics for the Power Industry (CARPI), Zurich, Switzerland, 11–13 September 2012.

66. Cui, H.; Ren, W. Performance test of rice seed tape twisting mechanism. *Int. Agric. Eng. J.* **2012**, *21*, 59–64.
67. Cui, H.; Ren, W.; Zhang, B.; Yang, Y.; Dai, L.; Xiang, Q. Design and implementation of automatic control system for rice seed tape winding units. In *Computer and Computing Technologies in Agriculture IV—4th IFIP TC 12 Conference, CCTA 2010, Nanchang, China, 22–25 October 2010*; Springer: New York, NY, USA, 2010; pp. 428–436.
68. Tian, J. Research on the Design of Rice of the Seed Rope Twisting Machine. *Agric. Sci. Technol. Equip.* **2015**, 43–44. [CrossRef]
69. Xu, H.; Wang, N. Seed Paper Tape Seeding Method. CN Patent Application No. 103548452A, 5 February 2014.
70. Shi, Y. Electrical Controller of Seed-Rope Weaving Machine. CN Patent Application No. 203206158U, 18 September 2013.
71. Li, X.; Wang, J.; Zhao, S.; Zhang, F.; Duan, Y.; Liu, Z. Design and Experimental Research on the Seed Tape Knitting Machine. *J Agric. Mech. Res.* **2018**, 174–178.
72. Luo, Z.; Liu, H.; Dong, J.; Xu, M.; Zhang, W. Design of leakage safety detector in laboratory and its application in seed tape knitting machine. *J. Tianj. Agric. Univ.* **2021**, *28*, 45–48.
73. Huang, X.; Lan, C.; Ma, L.; Zhu, H.; Zhao, Z. Development of landscape seed tape mixed weaving machine for rape and wheat. *Trans. CSAE* **2021**, *37*, 9–18.
74. Craig, B.M. Feeding, Propelling and Tensioning System for Tape in a Seed-Tape Manufacturing Machine. U.S. Patent 3555774, 19 July 1971.
75. Deppermann, K.L.; Frey, T.; McNabnay, M.; Forinash, B.J.; Badino, C.L. Systems and Method for Selection of Seed and Placement on Seed Tape. U.S. Patent 20130192134A1, 1 August 2013.
76. Xing, H.; Zang, Y.; Wang, M.Z.; Luo, W.X.; Zhang, H.M.; Ma, X.Y.; Fang, Y.L. Design and Experimental Analysis of a Stirring Device for a Pneumatic Precision Rice Seed Metering Device. *Trans. ASABE* **2020**, *63*, 799–808. [CrossRef]
77. Han, D. Improvement Design and Experimental Study on Key Parts of Rice Rope Twisting Machine. Master's Thesis, Shenyang Agricultural University, Shenyang, China, 2016.
78. Bai, H.; Shuai, L.; Wang, D.; Wang, G.; Teng, L. Design of Seeding System for Rice Seed Rope Twisting Machine. In Proceedings of the ASABE 2017 Annual International Meeting, Spokane, WA, USA, 16–19 July 2017.
79. Xing, H.; Wang, Z.; Luo, X.; He, S.; Zang, Y. Mechanism modeling and experimental analysis of seed throwing with rice pneumatic seed metering device with adjustable seeding rate. *Comput. Electron. Agric.* **2020**, *178*, 105697. [CrossRef]
80. Peng, L.; Peng, J.; Meng, P. Design of Control System with Stepper Motor Driving Seed-metering Device Based on PLC. *J. Agric. Mech. Res.* **2020**, *42*, 183–188. (In Chinese with English abstract)
81. Ahm, P.H. Machine for Producing Seed Tapes. WO Patent Application No. 01/84908, 15 November 2001.
82. Zhang, Y. Study on Development Principle and Testing for Seed Rope Direct Sowing Machine of Rice. Master's Thesis, Shenyang Agricultural University, Shenyang, Liaoning, China, 2006. (In Chinese with English abstract).
83. Zhang, B.; Song, Y.; Wu, L.; Xin, M.; Ren, W. Design and dynamic response analysis of rope laying system of roped type rice direct seeding machine. *Int. Agric. Eng. J.* **2017**, *26*, 120–129.
84. Lv, X. Design and Study on Rice Rope Direct Seeding Machine. Ph.D. Thesis, Shenyang Agricultural University, Shenyang, China, 2008.
85. Lv, X.; Lv, X.; Wentao, R. Experimental Study on Working Performance of Rice Rope Direct Seeding Machine. *Agric. Sci. China* **2010**, *9*, 275–279.
86. Lv, X.; Lv, X.; Ren, W. Finite Element Modeling and Modal Analysis on Suspension Equipment of Rice Rope Direct Seeding Machine. In Proceedings of the International Conference on Intelligent Computation Technology & Automation, Shenzhen, China, 15 April 2011; IEEE: Piscataway, NJ, USA; pp. 81–85.
87. Liu, D.; Dong, H.; Zhang, B.; You, J.; Yu, X. Design of Seed Rope Guiding Opener Based on DEM. In Proceedings of the International Conference on Mechanical Automation and Computer Engineering, MACE 2020—Mechanical Automation, Computer Technology, Xi'an, Virtual, China, 28–30 October 2020; IOP science: Bristol, UK; pp. 117–122.
88. Ren, W.; Song, Y.; Xin, M.; Wu, L.; Cui, H. Crop Seed Rope Direct Seeder. CN Patent Application No. 103858566A, 18 June 2014.
89. Sanford, P.T. Seed Tape Planter. U.S. Patent 1292082, 21 January 1919.
90. Motohashi, Y.; Yuri, S. Seed Tape Laying Machine. JP Patent Application No. 2012235727A, 6 December 2012.
91. Zhang, B.; Xin, M.; Song, Y.; Wu, L.; Ren, W. Design of a manually operated rice seed rope planter. *Int. Agric. Eng. J.* **2017**, *26*, 104–111.
92. Lv, P. Design and Study on Walking Rice Rope Direct Seeding Machine. Master's Thesis, Shenyang Agricultural University, Shenyang, China, 2017.
93. Deppermann, K.L.; Forinash, B.J.; Frey, T.; Mcnabnay, M. Seed Tape Planter. U.S. Patent 2013152836(A1), 19 June 2013.
94. Curtis, G.J.; Griffin, C.C. Method and Apparatus for Seed Tape Plating. U.S. Patent 4092936, 6 June 1978.
95. Lv, X.L.; Lv, X.R.; Ma, R.C. Design of a Rice Rope Laying Machine for Direct Sowing. *Eng. Trans.* **2017**, *65*, 447–460.
96. Dou, L. Garlic Seed Tape Sower. CN Patent Application No. 104782283, 22 July 2015.
97. Tadashi, O. Laying of Seed Tape and Device for Laying Seed Tape. JP Patent Application No. 2000041420A, 15 February 2000.
98. Tadashi, O. Seed Tape-Laying Device for Paddy Rice. JP Patent Application No. 2002238313A, 27 August 2002.
99. Lerink, P.; Wondergen, J. Device for Planting Seed(ling) Tape. WO Patent Application No. WO/2005/072508, 11 August 2005.
100. Lv, X.; Cheng, X.P.; Lv, X. Design and study of soil cover depth testing system of rope direct seeding machine. *Acta Agric. Univ. Jiangxiensis* **2010**, *32*, 383–387. (In Chinese with English abstract)

101. Ren, W.; Han, S.; Shi, P.; Liu, C.; Lv, C.; Hu, Y. Study on the Effects of Soil Covering Thickness on Working Parameter of Rice Rope Direct Seeding Machine. *J. Agric. Mech. Res.* **2013**, 167–169.
102. Song, Q. Experiment on seed tape sowing technology. *Xinjiang Agric. Mech.* **2003**, 19. (In Chinese) [CrossRef]
103. Ahm, P.H. A Seed Tape Including Successively Arranged Germinating Units as Well as a Method of Germinating Said tape. WO Patent Application No. 2004028237A1, 14 September 2011.