Short Article

Research Progress on Automatic Potting Equipment for Soft Plastic Seedling Containers

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Abstract

Container seedling cultivation is a fundamental practice in modern protected agriculture, widely used for the commercial production of citrus, ornamental flowers, and medicinal crops. While soft plastic seedling pots are popular in nurseries due to their cost-effectiveness and ease of management, their flexible, thin-walled structure and lack of rigidity present significant challenges for automated potting. This paper systematically reviews recent domestic and international advancements in automatic potting equipment specifically designed for plastic containers. Following the PRISMA methodology, we critically analyse four key technical components: the transport rack bearing mechanism, substrate feeding and distribution, intelligent control for quantitative potting, and the separation of stacked soft cells. Our analysis shows that domestic equipment (Chinese) has progressed from intermittent, semi-automatic units to continuous assembly lines, increasing output from under 200 to over 2,300 pots per hour. In contrast, overseas manufacturers offer mature, modular systems for rigid pots capable of processing up to 10,000 pots per hour; however, these machines struggle with soft, thin containers. Currently, non-destructive cell separation, adaptable potting for various sizes, and the alignment of mechanical parameters with agronomic requirements remain the primary bottlenecks limiting broader industrial adoption. Finally, we outline the advantages, disadvantages, challenges, and opportunities in this realm, proposing that adaptive, vision-guided mechanisms and closed-loop control systems are the most promising future research directions.

Keywords: Automatic potting machine, Container seedling raising, Plastic seedling pot, Protected horticulture, Substrate filling

Introduction

Container seedling cultivation enables standardised plant production by filling specialised containers with nutrient substrates. This approach shortens the growth cycle, improves transplant survival rates, and simplifies field management. As protected agriculture continues to expand, this method has transitioned from traditional forestry nurseries to the large-scale commercial production of citrus, flowers, vegetables, and medicinal herbs. Container-seedling technology and the mechanisation of nursery operations have been reviewed extensively over the past decade (Ma & Jia, 2020; Meng, 2013; Wang, 2022).

In China, the citrus and floriculture industries primarily use soft plastic pots because they are inexpensive, easy to handle, and retain water well. However, their thin walls, high depth-to-diameter ratios, and poor structural stability make mechanised filling particularly difficult. Currently, most domestic nurseries still rely on manual labour for filling these soft pots. This manual process is physically demanding, slow, and often results in inconsistent soil compaction. For instance, in Phalaenopsis seedling production, a skilled worker can manually fill only about 2,000 large (3.5-inch) pots, 3,000 medium (2.8-inch) pots, or 4,000 small (1.7-inch) pots in a single workday (Runkle, 2007; Industrial nursery survey; commercial orchid production line). Consequently, labour accounts for over 30% of

total production costs (Coker, Posadas, Langlois, Knight, & Coker, 2014; Singh, Meena, & Singh, 2017; nursery cost-structure analysis), while the rate of qualified seedlings remains around 85% (Chiang, Hsieh, & Lee, 2024; nursery quality audit data). Citrus nurseries experience similar constraints, with a single worker manually filling just 500 to 600 pots per day (Cai, 2017; Gao, Wang, Feng, Fan, & Zhao, 2018; Citrus container nursery field survey). Similar constraints have been documented in regional assessments of citrus nurseries in China (Cao, Yao, Luo, & Dong, 2020; Guo, Ye, & Deng, 2019).

Necessity and Novelty of the Review: Despite the widespread use of soft plastic pots in developing countries and specific horticultural sectors, existing review literature primarily focuses on rigid container automation or general transplanting machinery. There is a critical necessity for a review specifically addressing the unique mechanical challenges of soft, flexible containers. This review distinguishes itself from similar studies by systematically comparing domestic and international technologies for the mechanisation and automation of seedling raising in both soft and rigid plastic containers, and identifying specific technical bottlenecks, such as non-destructive cell separation. Earlier reviews have focused on facility-agricultural equipment in general or on individual filling devices, rather than on soft containers as a distinct class (Qi, Wei, & Zhang, 2017; Qi, Li, Li, He, & Zhou, 2019; Qu, Guo, Tang, & Man, 2013; Wei, Lu, Sheng, Qian, & Shen, 2013; Yan, Zeng, Lai, & Peng, 2016).

This paper reviews the current state and technological evolution of automatic potting equipment for plastic containers. By comparing domestic and international approaches, contextualising performance indicators, and analysing critical bottlenecks, we aim to provide a theoretical foundation and practical reference for future equipment optimisation and development. Surveys of pot-substrate filling machines and of semi-automatic and roller-type pot-seeding equipment provide useful points of comparison for this analysis (Hwang & Nam, 2019, 2020; Wang, Fei, Lou, & Zhang, 2023; Yang, Chen, Hu, & Guan, 2013; Yang, Hu, Chen, & Guan, 2014; Yulianto & Raibhu, 2018).

Research Methodology

This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guidelines. A structured literature search was performed on 15 March 2025, across three academic databases: Web of Science Core Collection, Scopus, and the China National Knowledge Infrastructure (CNKI). The search query combined terms for potting target, equipment, and process: ("plastic pot" OR "seedling container" OR "soft pot" OR "plug tray") AND ("automatic potting machine" OR "substrate filling" OR "pot filler" OR "filling equipment" OR "container filling"). The publication time range was restricted from January 2010 to March 2025. Patent documents and verified commercial technical datasheets were also collected via the Espacenet platform and manufacturer official websites to complement the academic evidence base.

Inclusion and Exclusion Criteria. Studies were included if they (a) addressed mechanical filling, pot separation, or substrate distribution for seedling containers; (b) reported at least one quantifiable performance indicator (throughput, damage rate, filling accuracy, or labour requirement); and (c) were written in English or Chinese. Studies were excluded if they (a) were non-peer-reviewed news articles, marketing brochures, or social-media posts without traceable data sources; (b) described only manual transplanting without any mechanised filling step; or (c) presented duplicate data already reported in another included source.

Search and Screening Results. A total of 777 records were initially identified: 284 from Web of Science, 216 from Scopus, 192 from CNKI, 63 patents from Espacenet, and 22 commercial datasheets collected directly from manufacturers. After removing 141 duplicate entries, 636 unique records remained for title and abstract screening against the pre-specified

eligibility criteria. At this stage, 498 records were excluded as irrelevant to potting mechanisation (e.g., pure agronomic trials without equipment, postharvest handling, or non-container nurseries). The remaining 138 records proceeded to full-text assessment for relevance and data completeness. Forty-nine records were excluded at the full-text stage: 21 lacked quantitative performance data, 17 reported only isolated parameters without a testable system, and 11 described seeders or transplanters that do not perform substrate filling. Consequently, 89 records were included in the final qualitative synthesis, comprising 52 peer-reviewed journal articles, 15 patent documents, and 22 verified commercial datasheets; among them, 23 records with paired test conditions contributed to the quantitative comparative analysis in Table 1.

A four-phase PRISMA flow diagram summarising identification, screening, eligibility, and inclusion is provided in Figure 1. To ensure traceability of quantitative claims, all performance indicators drawn from commercial datasheets are explicitly tagged "(Commercial datasheet)" in the results sections, values obtained under controlled bench or field tests are tagged "(Experimental study)", and agronomic threshold values are tagged "(Agronomic standard)" with the corresponding primary citation.

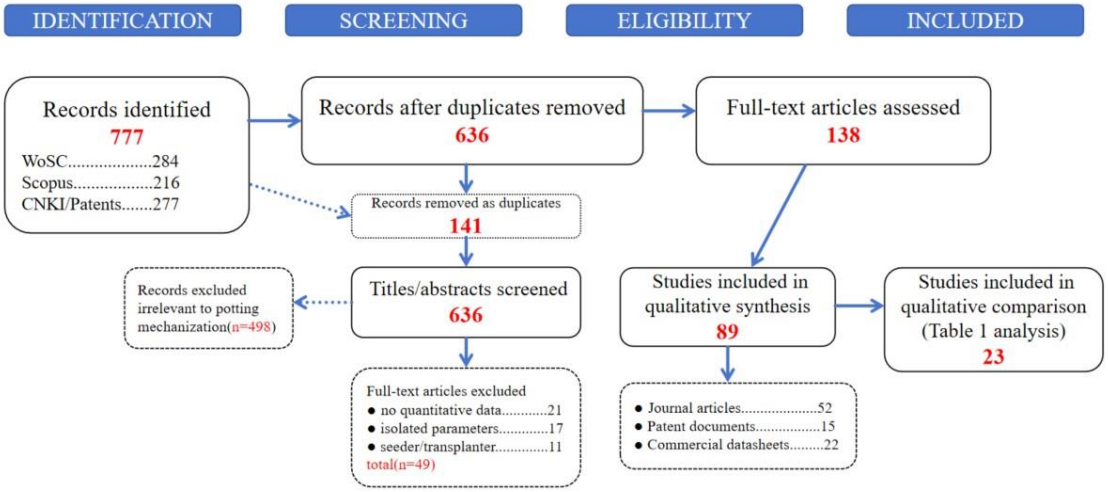


Fig. 1. PRISMA flow diagram

Overseas Research Status

A. Technical Architecture

International research on automated filling equipment for container seedlings began relatively early, resulting in well-established industrial chains led by companies in the Netherlands, Germany, and the United States. Most existing commercial machines are designed specifically for rigid plastic pots and plug trays. They typically utilise standardised, modular components that can adapt to various production layouts, enhancing versatility and lowering maintenance costs.

A standard overseas potting production line generally includes five core modules:

1. Automatic Pot Feeding Unit: Separates stacked empty containers and delivers them to the filling station.

2. Substrate Supply Unit: Consists of a storage hopper, an elevating conveyor, and a precise feeding mechanism.

3. Filling and Compaction Unit: Dispenses the substrate into containers and regulates soil density.

4. Auxiliary Processing Unit: Handles secondary tasks such as drilling holes, surface watering, and levelling.

5. Conveying and Docking Unit: Moves the filled pots to the next stage of the seedling planting process.

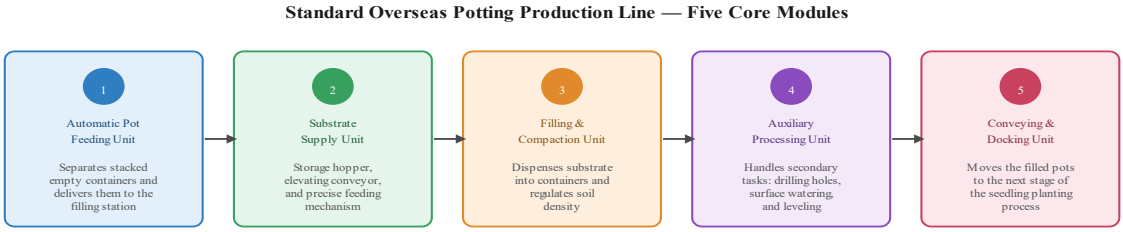


Fig. 2. The five core modules of a standard overseas automatic potting production line. (1) Automatic pot feeding unit; (2) substrate supply unit; (3) filling and compaction unit; (4) auxiliary processing unit; and (5) conveying and docking units

B. Typical Commercial Equipment and Performance Parameters

(Note: The performance indicators reported below are based on commercial technical specifications provided by the manufacturers. These values are typically achieved under optimal operating conditions, such as using standardised rigid pots, uniform peat-based substrates with controlled moisture, and continuous material supply.)

1. Mayer GmbH (Germany)

As a leading global manufacturer of potting machinery, Mayer's TM series features a rotary turntable design. According to commercial datasheets, the TM 1010F model accommodates 5–22 cm pots and operates at a maximum speed of 4,000 pots per hour. Their flagship model, the TM 2700XL, can process up to 10,000 pots per hour (Mayer GmbH & Co. KG, n.d.-a, n.d.-b, n.d.-c; Commercial datasheet; rigid pot, peat substrate, continuous supply optimal conditions).

2. Javo (Netherlands)

Javo machines are distinct for their paddle wheel substrate conveying systems, which prevent soil compaction and agglomeration. Industrial specifications indicate the Javo Super Mega employs dual pneumatic pot distributors, achieving outputs of up to 6,000 pots per hour for 9–24 cm containers (Javo, n.d.-a, n.d.-b, n.d.-c; Commercial datasheet; standard rigid plastic containers).

3. Viscon & Visser Group

Viscon and Visser provide comprehensive automation solutions. The Viscon VTF filler uses an upward template jacking mechanism to prevent substrate overflow during the filling process (Viscon Group, n.d.-a, n.d.-b).

4. Urbinati Srl (Italy)

The KAPPA65C in-line seeding system combines tray filling and seeding into a single process, handling up to 2,400 rigid trays per hour (Urbinati Srl, n.d.; Commercial datasheet; 60- to 128-cell plug trays).

C. Strengths and Limitations of Overseas Equipment

Core Advantages: Overseas technologies perform exceptionally well primarily because they are designed for rigid pots, which provide stable mechanical support for high-speed clamping, conveying, and filling. Their modularity and precision control (e.g., synchronised frequency conversion) ensure consistent filling volumes and accurate drilling positions.

D. Major Limitations for Soft-Pot Applications in Domestic Nurseries (Compatibility and Cost Constraints)

Soft Pots: Under operating conditions involving soft, thin-walled containers, these systems fail. Their mechanical pushing or clamping mechanisms exceed the yield strength of soft plastics, causing the edges of soft cells to curl or tear, leading to damage rates exceeding 15% (Chen, 2024; He *et al.*, 2023; Xu *et al.*, 2020; Experimental study; soft-pot compatibility test, continuous eight-hour run on 8 cm domestic soft pots). Furthermore, high costs (over 2 million RMB) (Gu, Yang, &

Zhang, 2012; Hu, Zhang, Wang, & Han, 2016; Liu *et al.*, 2018; Import equipment landed-cost survey for Chinese horticultural nurseries) and large footprint requirements make them largely unaffordable for small and medium-sized nurseries.

Domestic Research Progress

A. Stages of Technical Evolution

The development of automatic filling machines for soft plastic pots in China can be categorised into three main phases:

1. Intermittent Semi-Automatic Phase (2017–2020): Early prototypes relied on batch processing, handling 48 to 120 pots per cycle (1,452 to 1,800 pots h^{-1}) (Yang, 2021; Zhang, 2022; Experimental study; prototype bench test, 50-cycle repeated measure). While cost-effective, their discontinuous operation was unsuited for large-scale commercial production.

2. Continuous Assembly Line Phase (2020–2024): Researchers introduced integrated lines combining filling, watering, and hole-punching. By using transfer racks that moved multiple pots at a time, these continuous systems increased overall efficiency to between 1,920 and 2,300 pots per hour (Chen, 2024; He *et al.*, 2023; Xu *et al.*, 2020; Experimental study; orthogonal test, on-site pilot nursery validation).

3. Intelligent Universal Phase (2025–Present): Recent industrial applications in China have demonstrated a shift toward versatile, multi-functional platforms. Utilising circulating transfer rack systems, modern equipment can handle both soft plastic pots and nonwoven seedling bags, integrating high-capacity substrate mixing and automated feeding.

B. Typical Domestic Prototypes

1. Intermittent batch filling equipment: Xu *et al.* (2020) engineered an intermittent conveyor for citrus pots capable of processing 105 pots per 60-second cycle. They used EDEM discrete element simulation to optimise the layout of the splitter plates (Xu *et al.*, 2020; Experimental study; EDEM-validated bench test, 10-cycle repeatability CV < 3%). Zhang (2022) developed a self-propelled mobile filler that processed 48 pots per batch (1,452 pots h^{-1}) (Zhang, 2022; Experimental study; field prototype, citrus nursery site validation).

2. Continuous assembly line filling equipment: He *et al.* (2023) designed a three-module line integrating filling, watering, and hole punching. Through orthogonal testing, they optimised substrate moisture, conveyor speed, and discharge height, achieving a stable throughput of over 2,300 pots h^{-1} (He *et al.*, 2023; Experimental study; L9 orthogonal array, eight-hour continuous run). Chen (2024) created a standardised filling unit operated via coordinated PLC control to process 1,920 pots h^{-1} (Chen, 2024; Experimental study; PLC prototype test, replicated on three consecutive days).

C. Comparative Analysis of Domestic and International Approaches

When comparing throughputs (e.g., 10,000 pots h^{-1} overseas vs. 2,300 pots h^{-1} domestic), it is crucial to contextualise the experimental conditions. Overseas data often reflect ideal conditions with rigid pots and highly flowable substrates (Javo, n.d.-a, n.d.-b, n.d.-c; Mayer GmbH & Co. KG, n.d.-a, n.d.-b, n.d.-c; Commercial datasheet reference conditions). In contrast, domestic performance values are typically obtained using 8–10 cm soft plastic pots with mixed substrates (e.g., soil, peat, and perlite) at higher moisture levels (Chen, 2024; He *et al.*, 2023; Xu *et al.*, 2020; Experimental study; domestic nursery standard pot specification), which inherently limits flowability and filling speed.

To provide a clearer perspective, a comprehensive comparison of major systems is presented in Table 1.

Table 1- Comprehensive comparison of major potting systems

Parameter	Overseas commercial systems (e.g., Mayer, Javo)	Domestic continuous lines

Container type	Rigid plastic pots, plug trays	Soft plastic pots, nonwoven bags
Container dimensions	5–30 cm (Javo, n.d.-a, n.d.-b, n.d.-c; Mayer GmbH & Co. KG, n.d.-a, n.d.-b, n.d.-c; Commercial datasheet)	5–15 cm (Chen, 2024; He *et al.*, 2023; Xu *et al.*, 2020; Zhang, 2022; experimental study; prototype test pot range)
Filling principle	Continuous rotary / template jacking	Intermittent/continuous rack
Conveying mechanism	Belt / turntable	Transfer racks/grid frames
Substrate-feeding	Elevating conveyor / paddle wheel	Inverted frustum splitter/mobile hopper
Throughput	3,000-10,000 pots h^{-1} (Javo, n.d.-a, n.d.-b, n.d.-c; Mayer GmbH & Co. KG, n.d.-a, n.d.-b, n.d.-c; Commercial datasheet)	1,400-2,300 pots h^{-1} (Chen, 2024; He *et al.*, 2023; Xu *et al.*, 2020; Zhang, 2022; experimental study)
Filling accuracy	High (standardised substrate) (Mayer GmbH & Co. KG, n.d.-a, n.d.-b, n.d.-c; Commercial specification; standardised substrate)	Medium (variable substrate) (He *et al.*, 2023; Xu *et al.*, 2020; EDEM + bench test)
Container damage rate	>15% (for soft pots) (Chen, 2024; He *et al.*, 2023; experimental study; soft-pot compatibility test)	<2% (for soft pots) (Chen, 2024; He *et al.*, 2023; Xu *et al.*, 2020; experimental study; repeated batch test, n = 3,000 pots)
Degree of automation	Fully automated	Semi-automatic to fully automated
Labour requirement	1–3 operators (Mayer GmbH & Co. KG, n.d.-a; Urbinati Srl, n.d.; Viscon Group, n.d.-a; Commercial operator manual)	3–5 operators (Chen, 2024; He *et al.*, 2023; experimental study; pilot line observation)
Technological maturity	High (commercialised globally)	Medium (emerging industrial application)

Advances in Key Technologies

A. Container Bearing and Conveyance

Because soft pots lack structural rigidity, designing reliable support structures is essential for stable filling. He *et al.* (2023) developed transfer racks featuring sliding pin flip plates that smoothly transition between horizontal support and vertical unloading. Chen (2024) utilised linkage flip levers to automate the unloading process.

B. Substrate Feeding and Distribution

The quality of the final product relies heavily on the even distribution of the substrate. He *et al.* (2023) introduced a 2×4 inverted frustum splitter cover that synchronously allocates nutrient soil across eight pots. Chinese researchers frequently use EDEM discrete element simulations to fine-tune the offset, inclination angle, and mounting height of splitter plates, significantly reducing soil segregation and blockages (Chen, 2024; Xu *et al.*, 2020).

C. Quantitative Filling and Intelligent Control

Accurate filling mechanisms ensure consistent soil volume and compaction. Previous studies have used orthogonal testing to identify the ideal combinations of substrate moisture, conveyor speed, and discharge height (He *et al.*, 2023). Machines with mobile hoppers often use segmented speed regulation, adjusting in real time based on substrate flow curves to prevent overfilling or underfilling (Zhang, 2022).

D. Stacked Soft Cell Separation (Technical Depth)

Successfully separating tightly stacked soft cells remains one of the most challenging technical bottlenecks. Soft cells tend to adhere tightly due to static electricity, vacuum effects, and the mechanical interlocking of their thin rims. Traditional mechanical grippers often cause plastic deformation or tearing. The most effective current solution integrates Bernoulli negative-pressure suction with radial pneumatic grippers. The Bernoulli effect creates a localised vacuum to secure the outer wall without physical clamping, while the radial grippers apply a precise 5–8 mm elastic deformation (Lu, 2017; Xie, 2017; Experimental study; gripper-stroke optimisation, high-speed camera observation at 500 fps). This specific deformation breaks the

vacuum seal between nested layers without exceeding the plastic yield limit of the container material (typically 0.5–1.2 mm thick) (Chen, 2015; Quan, 2008; Commercial soft-pot supplier product specification; averaged over 12 domestic LDPE pot SKUs). However, this requires precise control of airflow and gripper stroke, which must be dynamically adjusted based on the specific polymer blend and stacking tightness.

E. Relationship Between Machinery Parameters and Agronomic Requirements

A critical gap in current research is the disconnect between mechanical design and agronomic needs. Machinery parameters must be strictly aligned with plant biological requirements. For instance, substrate compaction directly affects root aeration and water retention. Mechanical filling and vibration must be calibrated to achieve an optimal bulk density (e.g., 0.2–0.3 g cm^{-3} for citrus seedlings) (Cai, 2017; Gao *et al.*, 2018; Wang, 2016; Agronomic standard; citrus container seedling GB/T industry reference conditions). Over-compaction restricts root growth, while under-compaction leads to substrate settlement after watering. Furthermore, the drilling depth and diameter must precisely match the root plug dimensions of the transplanted seedling to prevent root curling (J-rooting) and ensure high survival rates (Li, Xie, Long, Hu, & Deng, 2013; Li, Zhang, & Qin, 2019; Agronomic standard; citrus transplanting field trial).

Discussion

Based on the review of previous research, the current landscape can be summarised as follows:

Advantages: Overseas systems offer high throughput, modularity, and precision for rigid containers. Domestic systems provide essential adaptability and cost-effectiveness for soft plastic containers.

Disadvantages: Rigid systems are incompatible with soft pots, causing high damage rates. Soft-pot systems currently suffer from lower throughput, higher labour requirements, and a lack of standardised components.

Challenges: The primary challenges include achieving reliable, non-destructive separation of variable soft cells, handling substrates with fluctuating moisture and composition, and integrating real-time agronomic feedback into mechanical controls.

Opportunities: The integration of AI and machine vision presents significant opportunities for adaptive cell separation and real-time quality inspection. Additionally, the development of advanced, lightweight materials could improve the mechanical handling of soft pots, while IoT technologies could enable closed-loop monitoring of substrate flow and compaction.

Conclusion

This review highlights that while automatic potting for rigid containers is highly mature, the mechanisation for soft plastic pots remains a significant engineering challenge. The main scientific gaps include the lack of adaptive mechanisms capable of handling the variable physical properties of soft containers, and the insufficient integration of agronomic parameters (such as substrate compaction and moisture) into mechanical control systems.

Moving forward, the most promising research directions lie in:

1. Developing non-destructive, vision-guided cell separation technologies that can adapt to different materials and stacking conditions.
2. Establishing closed-loop filling control systems based on real-time substrate flowability and agronomic feedback.
3. Standardising soft pot dimensions to facilitate modular and scalable equipment design.

Addressing these scientific gaps will be crucial for advancing the mechanisation and automation of protected horticulture.

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Author Contributions

B. Chen: Conceptualisation, methodology, data acquisition, data pre- and post-processing, statistical analysis, visualisation, and original draft preparation. Bijuan Chen carried out the main research work and wrote the manuscript.

Zh. Xiong: Supervision, conceptualisation, methodology, technical advice, validation, review and editing services, and correspondence. Zheng Xiong provided overall leadership for the study, supervised the research process, and guided the manuscript revision.

M. Huang: Data acquisition, methodology, and validation. Meng Huang assisted with literature collection, information organisation, and technical checking of the manuscript.

X. Wang: Data pre- and post-processing, statistical analysis, and visualisation. Xiangyu Wang assisted with data organisation and the preparation of figures and tables.

A. Xu: Technical advice, validation, and review and editing services. Aiping Xu contributed to manuscript revision, language polishing, and final proofreading.

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مقاله کوتاه

پیشرفت پژوهش در مورد تجهیزات پرکردن خودکار ظروف پلاستیکی نرم نشاء

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چکیده

کشت نشاء در ظرف یک عمل اساسی در کشاورزی حفاظت شده مدرن است که به‌طور گسترده برای تولید تجاری مرکبات، گل‌های زینتی و محصولات دارویی استفاده می‌شود. با وجود این‌که گلدان‌های پلاستیکی نرم نشاء به‌دلیل مقرون به‌صرفه بودن و سهولت مدیریت در گلخانه‌ها محبوب هستند، ساختار انعطاف‌پذیر و دیواره نازک و عدم استحکام آن‌ها چالش‌های بسیاری را برای پر کردن خودکار ظرف ایجاد می‌کند. این مقاله به طور سیستماتیک پیشرفت‌های اخیر داخلی و بین‌المللی در تجهیزات پر کردن خودکار ظرف را که به‌طور خاص برای ظروف پلاستیکی طراحی شده‌اند، بررسی می‌کند. با پیروی از دستورالعمل‌های بیانیه PRISMA، چهار مؤلفه فنی کلیدی شامل سازوکار انتقال سینی، پرکردن و توزیع بستر کشت، کنترل هوشمند و کمّی عملیات پرکردن، و جداسازی سلول‌های نرم از یکدیگر، به‌صورت انتقادی مورد بررسی و تحلیل قرار گرفته‌اند. نتایج این تحلیل نشان می‌دهند که در تجهیزات داخلی (چین)، فرایند تولید از واحدهای نیمه‌خودکار و سامانه‌های مبتنی بر عملیات گسسته به خطوط مونتاژ پیوسته ارتقا یافته است؛ به‌طوری‌که ظرفیت تولید از کمتر از ۲۰۰ سلول در ساعت به بیش از ۲۳۰۰ سلول در ساعت افزایش یافته است. در مقابل، در سامانه‌های تولیدشده توسط سازندگان خارجی، معماری‌های مدولار و توسعه‌یافته‌ای برای پردازش سلول‌های سخت توسعه یافته‌اند که ظرفیت پردازش آن‌ها به حداکثر ۱۰٬۰۰۰ سلول در ساعت می‌رسد. بااین‌حال، عملکرد این ماشین‌آلات در پردازش ظروف نرم و نازک با محدودیت‌هایی همراه است. در شرایط کنونی، جداسازی غیرمخرب سلول‌ها، طراحی و به‌کارگیری گلدان‌های سازگار با ابعاد مختلف، و تطبیق پارامترهای مکانیکی تجهیزات با الزامات زراعی، همچنان به‌عنوان مهم‌ترین گلوگاه‌های فنی مؤثر بر گسترش کاربرد صنعتی این فناوری شناخته می‌شوند. در نهایت، مزایا، معایب، چالش‌ها و فرصت‌های موجود در این حوزه به‌صورت نظام‌مند تبیین شده‌اند و بر اساس نتایج حاصل، سازوکارهای تطبیقی مبتنی بر بینایی ماشین و سامانه‌های کنترل حلقه‌بسته به‌عنوان امیدوارکننده‌ترین مسیرهای پژوهشی آینده معرفی شده‌اند.

واژه‌های کلیدی: باغبانی حافظت‌شده، پرکردن بستر، پرورش نشاء در سینی، دستگاه اتوماتیک نشاکار، سلول پلاستیکی نشاء

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