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Research on the Integration and Practice Path of Marker-Assisted Selection Technology in Higher Vocational Agricultural Education

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Abstract: With the rapid development of modern biotechnology, marker-assisted selection (MAS) technology has become a core tool in the field of crop genetic breeding, driving the seed industry towards precision and efficiency. As the main position for cultivating technical and skilled talents, higher vocational education must actively adapt to industrial technological changes and integrate such cutting-edge technologies into the teaching system. Focusing on the teaching integration of marker-assisted selection technology in higher vocational agricultural majors, this paper analyzes the current application status and challenges of the technology in higher vocational agricultural education, expounds its important value in improving students' technical application capabilities and aligning with the needs of the modern seed industry, and proposes a systematic integration practice path from aspects such as curriculum system reconstruction, teaching resource development, teacher capability improvement, industry-university-research collaboration, and teaching method innovation, aiming to provide reference for the teaching reform of higher vocational agricultural majors.

Keywords: Marker-assisted selection; Higher vocational agricultural education; Curriculum integration; Teaching reform; Teaching system innovation

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1. Introduction

In today's rapidly developing biotechnology era, modern breeding technologies represented by marker-assisted selection (MAS) are profoundly changing the production methods and innovation models of traditional agriculture. By directly identifying DNA markers associated with target traits for early and precise selection, this technology significantly shortens the breeding cycle and improves breeding efficiency, and has become one of the core competitiveness of the modern seed industry [1–3]. Facing the trend of agricultural industrial transformation towards technology and precision, higher vocational agricultural majors shoulder the important mission of cultivating high-quality technical and skilled talents who understand technology, can operate, and are proficient in application [4]. Therefore, how to effectively integrate cutting-edge technologies such as marker-assisted selection into the higher vocational curriculum system and realize the synchronous update of teaching content and industrial technological development has become a key issue in the current teaching reform of agricultural vocational education. This paper aims to explore the integration value, current problems, and systematic implementation paths of MAS technology in higher vocational agricultural courses, so as to promote professional teaching to keep up with technological development and cultivate practical talents suitable for modern agriculture.

2. Current status of the integration of marker-assisted selection technology in higher vocational agricultural education

2.1. Overview of domestic and foreign integration status

In developed regions of agricultural vocational education at home and abroad, integrating molecular biotechnology into the curriculum system has become a trend [5]. For example, agricultural universities of applied sciences in the Netherlands, Germany, and other countries generally offer modules such as "Fundamentals of Molecular Breeding" and "Agricultural Biotechnology Training" in majors such as crop production and horticulture, focusing on the application of technology in variety breeding, seed quality testing, and other areas. Some leading agricultural higher vocational colleges in China, such as Jiangsu Agri-animal Husbandry Vocational College and Xinjiang Agricultural Vocational Technical College, have attempted to introduce molecular marker-related teaching content in majors such as Biotechnology and Application, Seed Production and Management, with the content focusing on the introduction of technical principles and simple process demonstration [6].

2.2. Main problems and challenges in the integration process

First, the disconnection between teaching content and post capabilities. The existing content is mostly biased towards a theoretical overview, and is not closely connected with specific work tasks such as marker development, genotyping, and data analysis actually adopted by seed companies and breeding enterprises. Second, the lack of teaching resources and training conditions. This technology involves precision instruments and expensive reagents, and many higher vocational colleges lack supporting standardized laboratories and simulation teaching platforms. Third, the insufficient technical practice ability of the teaching staff. Most teachers lack practical experience in applying this technology in front-line breeding work. Fourth, the lack of a systematic design of the curriculum system. Technical content is often scattered across multiple courses, failing to form a progressive skill training chain from basic cognition to comprehensive application.

3. Integration value of marker-assisted selection technology in higher vocational agricultural education

3.1. Empowering precision breeding and improving the industrial adaptability of talent cultivation

Systematically integrating MAS technology into curriculum teaching enables students to master the core skills of the modern seed industry, thereby being competent for front-line technical positions such as variety purity and authenticity testing, assisted selection, and fingerprint map construction, directly aligning with the needs of seed enterprises for emerging positions such as "breeding technicians" and "gene testers" [7].

3.2. Innovating teaching carriers and promoting the in-depth realization of the integration of theory and practice

MAS technology is essentially a standardized and detachable complete workflow, covering multiple links from sample preparation, DNA extraction, PCR amplification, electrophoresis detection to data interpretation and breeding decision-making. Driven by modular training projects, it can integrate knowledge from multiple disciplines such as genetics, biochemistry, and bioinformatics into the process of solving practical breeding problems, deepening students' ability to apply comprehensive knowledge [8].

3.3. Connecting scientific research and teaching and stimulating students' innovative potential

Feeding teaching with scientific research is a key path to promote the connotative development of higher vocational education and cultivate technical and skilled talents with innovative spirit [9]. Teachers can simplify their own or cooperative units' scientific research projects into teaching cases or students' innovative topics, guiding students to participate in the micro-research process from marker screening to result analysis, thereby constructing a virtuous cycle of "teaching inspires scientific research inspiration, and scientific research nourishes teaching depth" [10].

4. Integration practice path of marker-assisted selection technology in higher vocational agricultural education

4.1. Construct an "Industry-Oriented, Ability-Progressive" modular curriculum system

(1) Clarify Post Capability Objectives

The starting point of curriculum system reconstruction is to accurately align with the actual talent needs of the regional industry. A systematic investigation should be conducted on local modern seed industry groups, biotechnology service enterprises, and high-tech agricultural parks. In-depth analysis of the daily work content, typical work tasks, and technical development requirements of target positions such as "molecular detection laboratory technicians" and "breeding assistants" should be carried out. Through analysis, the demand for MAS technology from enterprises is decomposed into specific, measurable, and trainable core skill points.

(2) Develop a Modular Curriculum Group

Break disciplinary barriers to form a three-dimensional curriculum system of "theoretical modules + practical modules + comprehensive training". Design progressive curriculum modules such as "Fundamentals of Modern Agricultural Biotechnology" → "Marker-Assisted Selection Technology Training" → "Comprehensive Practice of Crop Precision Breeding", with MAS technology as the core main line running through them.

(3) Align with the "1+X" Certificate System

To enhance the standardization and social recognition of talent cultivation, the curriculum system needs to strategically align with the "1+X" certificate system [11][12]. Active cooperation with authoritative training and evaluation organizations should be pursued to jointly develop or deeply integrate the assessment standards and content of X certificates, realizing the organic unity of curriculum standards and vocational standards, and teaching processes and assessment processes.

4.2. Develop "Virtual-Real Integration, Cost-Controllable" three-dimensional teaching resources

(1) Build a Virtual Simulation Training Platform

In view of the practical teaching bottlenecks such as high cost of reagents and consumables, strong professionalism in equipment maintenance, and long experimental cycle involved in key links of MAS technology such as DNA extraction, PCR amplification, gel electrophoresis, and data interpretation, it is necessary to systematically develop or introduce high-fidelity and highly interactive virtual simulation training software and platforms [13]. Enable students to internalize muscle memory and standard operating procedures through repeated practice in a "zero-consumable, zero-risk" environment, laying a solid skill and confidence foundation for entering real laboratories.

(2) Establish a Teaching Case Library

To visualize abstract technical principles and contextualize complex breeding processes, it is necessary to systematically build a teaching case library with clear themes, clear structures, and dynamic updates. Its core sources should focus on two levels: one is the iconic MAS technology breeding achievements worldwide; the other is to deeply tap local industrial practices, collecting real project cases from provincial and municipal agricultural scientific research institutes to leading seed companies that use MAS technology to solve local practical breeding problems. Each case should systematically sort out the entire process from breeding goal setting, marker development and selection, technical route formulation, experimental process, data judgment to variety approval.

4.3. Build a "Dual-Qualified, Research-Teaching Integration" teachers' teaching innovation team

(1) Implement a Teacher Enterprise Rotation Plan

To completely solve the bottleneck of the teaching staff's "strong theory but weak practice", it is necessary to establish an institutionalized, regular, and task-driven teacher enterprise rotation practice mechanism. During the practice, teachers need to complete a "practice task list" jointly formulated by both schools and enterprises. By assuming specific job responsibilities, teachers will personally experience the requirements of the industry for technical accuracy, efficiency, and cost control, understand the key transformation links from scientific research to application, and accumulate valuable "front-line engineering experience."

(2) Build a Research-teaching Transformation Platform

To break the barrier between scientific research and teaching, efforts should be made to build an institutionalized, regular, and organizationally supported research-teaching transformation platform. Teachers are encouraged to identify and separate links from ongoing research projects that are suitable for teaching, reflect key technical logic, and are safe and controllable, and transform them into comprehensive teaching projects. The platform will provide methodological guidance, technical support, and even necessary funding for such a transformation. This process not only keeps the teaching content cutting-edge and authentic but also, more importantly, constructs a virtuous closed loop of "scientific research feeds teaching, and teaching inspires scientific research".

4.4. Deepen the "Project-Led, School-Enterprise Collaborative" Practical Teaching Model

(1) Carry Out Enterprise Real Project Teaching

To completely solve the mismatch between practical teaching and production reality, it is necessary to take the initiative to establish in-depth cooperative relations with local relevant enterprises and systematically transform the actual productive tasks of enterprises into high-level comprehensive training projects. Specifically, through signing cooperation agreements, the periodic, basic but technically standardized business of enterprises can be packaged into the core tasks of students' "semester comprehensive training projects" or "special skill practice weeks" after strict teaching design and safety assessment [14].

(2) Co-build on-campus Productive Training Bases

To effectively connect the teaching process with the production process, schools and leading enterprises in the industry with in-depth cooperation should jointly invest in, design, and operate to build a highly simulated and functionally composite "Marker-Assisted Breeding Training Center", whose planning, layout, equipment configuration, and management and operation fully refer to the real scenarios and standards of molecular laboratories of modern seed enterprises. By co-building this physical platform, enterprises will pre-position their technical standards and culture on campus, and schools will obtain continuously updated practical teaching resources.

4.5. Innovate the "Data-Driven, Intelligent Evaluation" teaching methods and evaluation system

(1) Utilize Bioinformatics Public Platforms

To adapt to the increasingly data-intensive characteristics of modern breeding work, it is necessary to actively introduce and make full use of bioinformatics public databases and online analysis tools in teaching as key support for cultivating students' "data thinking" and "information literacy". Guide students to use free databases such as NCBI and Gramene and online analysis tools for basic bioinformatics training, such as marker query and sequence alignment. Through this training module, students can grow into composite technical and skilled talents who are proficient in experimental operations and have preliminary bioinformatics analysis capabilities.

(2) Establish a Multi-dimensional Process Evaluation System

To change the traditional evaluation model that relies solely on the final written exam, it is necessary to establish a comprehensive and process-oriented evaluation system oriented towards the cultivation of core vocational capabilities. The multi-dimensional data generated by this system is not only used to assess students' performance levels but also enables teachers to accurately locate weak links in teaching, continuously optimize teaching strategies and resources, and ultimately achieve "promoting learning through evaluation, promoting teaching through evaluation, and promoting reform through evaluation", making evaluation itself a core driving mechanism to ensure and improve the quality of talent cultivation [15].

5. Conclusion

Integrating MAS technology into higher vocational modern agricultural technology education is an inevitable requirement to respond to the technological changes in the seed industry and improve the quality of talent cultivation. This integration process is not a simple addition of content, but a systematic reform involving the curriculum system, teaching resources, teaching staff, teaching models, and evaluation systems. Higher vocational colleges should base themselves on regional industrial needs, rely on in-depth school-enterprise cooperation, and explore a cost-controllable and effective technology integration path by constructing modular courses, developing virtual-real integrated resources, building a "dual-qualified" team, and deepening project-based teaching. Ultimately, they will cultivate outstanding technical and skilled talents who can proficiently use modern biotechnology tools to solve practical agricultural production problems, providing solid human support for the development of China's modern agriculture and the revitalization of the seed industry.

Disclosure statement

The author declares no conflict of interest.

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