Application of Molecular Biology Techniques in Plant Identification

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Abstract: In plant taxonomy research, traditional identification methods mainly rely on the observation and comparison of morphological and ecological characteristics. However, this method appears inadequate when faced with issues such as significant morphological variation and difficulty in distinguishing closely related species. Conducting plant molecular identification is necessary to improve identification accuracy, address issues related to closely related and hidden species, protect biodiversity, promote agricultural and forestry development, and advance scientific research. This article mainly discusses the application of molecular biology techniques in plant identification, covering the importance, challenges, and specific applications and advantages of various molecular biology techniques in plant identification. This article elaborates on the importance of plant identification, the advantages of molecular biology technology, PCR based plant species identification, the application of DNA barcode technology in plant species identification, and the advantages of DNA barcode technology in plant identification. It introduces the application of PCR technology, DNA barcode technology, and other technologies in plant identification, and looks forward to future technological development directions.

Keyword: Molecular Biology; DNA; RNA; Plant Recognition; Applications

1. Introduction

Plant identification is important in multiple fields, including agricultural production, biodiversity conservation, ecosystem management, and botanical research. Accurate plant identification is crucial for ensuring food safety, increasing agricultural yields, protecting genetic resources, and understanding biodiversity in ecosystems. However, there are a series of challenges in the process of plant identification, mainly stemming from plant diversity, ecological adaptability, environmental adaptability, and rapidly developing molecular biology techniques. There are a wide variety of plant species, with over 300000 known species worldwide, and there are also many undiscovered or undescribed species. This diversity means that when conducting plant identification, researchers must be able to distinguish a large number of species and varieties, even in their natural environments. In addition, many plants have high ecological adaptability, and different individuals of the same species may adapt to different environmental conditions, which requires identification work to be able to identify individuals of the same plant species in these different environments.[1] The growth environment of plants is complex and varied, and they can grow in soil, water, air, or other non-traditional habitats. These different habitat conditions may have an impact on the morphological, physiological, biochemical, and molecular characteristics of plants, thereby bringing additional complexity to plant identification[2].

The rapid development of molecular biology technology has provided new tools and methods for plant identification. For example, researchers can quickly and accurately identify plant species and varieties by using PCR technology with universal primers, RAPD, DNA barcoding, and whole genome sequencing[3]. The application of these technologies greatly improves the efficiency and accuracy of plant identification, but also brings new challenges such as the complexity of technical operations, the professionalism of data analysis, and the cost of equipment and reagents. In addition, with the popularization of molecular biology technology, the training and requirements for operators are also increasing. Laboratory technicians need to master the principles and techniques of molecular biology, while data analysts also need to have some knowledge of botany in order to better understand and interpret molecular data. Plant identification plays an important role in ensuring the protection of biodiversity, improving agricultural production efficiency, and ensuring food safety[4].

2. Plant Species Identification Based on PCR

2.1 Development and Application of Universal Primers and Specific Primers

The application of universal primers and specific primers in molecular biology technology is an important research direction in the field of molecular biology, especially in species identification, genetic diversity analysis, and the development and utilization of biological resources. Universal primers refer to primers that can bind to corresponding regions of multiple species in the target DNA sequence, while specific primers are designed for specific DNA sequences of specific species and can only bind to DNA sequences of these specific species. The development and application of universal primers can greatly improve the efficiency and accuracy of molecular biology techniques in species identification[5]. Due to the ability of universal primers to amplify characteristic DNA sequences of multiple species simultaneously, it reduces the tedious primer design and synthesis work in the traditional single species identification process, and also reduces errors in identification caused by improper primer selection. For example, in the quality identification of animal derived foods or medicinal materials, universal primers can quickly screen for the presence of a specific species in the target sample, providing basic data for further in-depth research[6,7].

The development and application of specific primers not only ensure high accuracy, but also improve the specificity and specificity of research. In species identification, when universal primers cannot distinguish certain closely related species or specific species in mixed samples, specific primers demonstrate their unique advantages. By designing primers for specific genes or DNA sequences, target species can be accurately identified and distinguished, which is of great significance for biodiversity research, protection and utilization of genetic resources, as well as safety evaluation of genetically modified and genetically engineered products. In practical applications, universal primers are often combined with specific primers to achieve higher identification accuracy and coverage[8]. For example, in the quality identification of traditional Chinese medicine, universal primers can quickly screen for the presence of target species in the medicine, while specific primers can further identify specific species types, even the same species from different geographical sources or growth stages. This combination application not only improves the efficiency and accuracy of identification, but also reduces the cost and complexity of experiments to a certain extent.

The development and application of universal primers and specific primers are important components of molecular biology technology in plant identification. Their effective combination provides a fast, accurate, and cost-effective method for species identification, which plays an important role in protecting biodiversity, promoting sustainable utilization of biological resources, and promoting the healthy development of related industries.

2.2 Application of PCR-RFLP and PCR-SCP in Species Identification

PCR-RFLP (polymerase chain reaction restriction fragment length polymorphism) and PCR-SCP (polymerase chain reaction single strand conformation polymorphism) are important tools for species identification in molecular biology techniques. These two technologies provide reliable species identification methods for biological research through different principles and methods.[9]

The PCR-SCP technique involves amplifying specific DNA fragments through PCR and performing single strand conformation electrophoresis analysis on them. The process is shown in Figure 1.

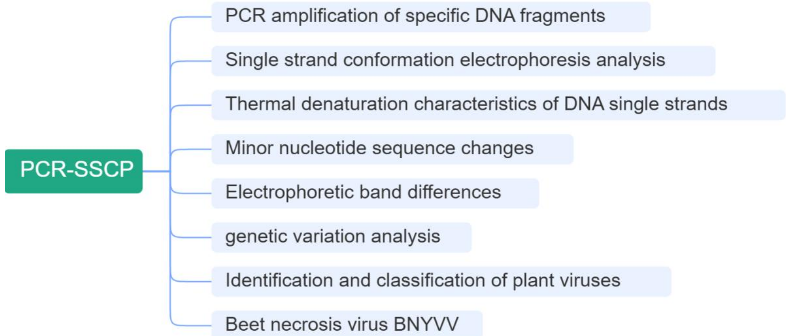

Figure 1. PCR PCR/SNP Technique

The PCR-RFLP technique involves preparing multiple restriction fragments of different lengths of the target DNA, amplifying these fragments using PCR, and finally analyzing the length polymorphism of these fragments through electrophoresis for species identification. The advantage of this technology is that it can not only be used for intra species diversity research, but also for inter species and population level polymorphism classification research. For example, in the field of traditional Chinese medicine identification, PCR-RFLP technology is used for variety identification and adulteration monitoring of Fritillaria thunbergii. By extracting DNA and using restriction endonucleases to process PCR amplification products for electrophoretic analysis, the adulteration ratio in the medicinal material can be effectively detected[9].

In practical applications, both PCR-RFLP and PCR-SCP techniques have their unique advantages and limitations, as shown in Figure 2.

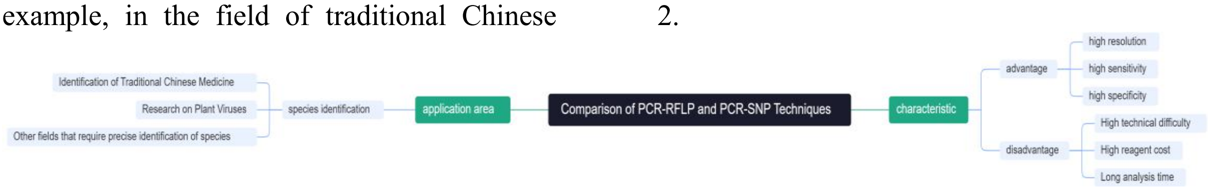

Figure 2. Advantages and Limitations of PCR-RFLP and PCR-SNP

3. Application of DNA Barcode Technology in Plant Species Identification

DNA barcoding technology is a DNA based molecular biology method that allows scientists to quickly and accurately identify and identify biological species through relatively short, standardized DNA fragments. Since its first proposal by Paul Hebert in 2003, this technology has shown broad application prospects in the field of species identification. The core principle of DNA barcode technology is to use standardized, sufficiently variable, easily amplified, and relatively short DNA fragments that can represent the species within the organism. These fragments exhibit high species specificity within species, while differences exist between different species, making them a 'barcode' for species identification.[10]

3.1 Species Identification and Classification

DNA barcode technology can extract DNA from plant samples and perform PCR amplification and sequencing on specific barcode sequences. For example, rbcL and matK in chloroplast DNA, as well as the ITS region of ribosomal DNA, are commonly used barcodes for plant species identification. By comparing with known barcode databases, the species identity of the sample can be quickly determined.

3.2 Species Diversity Assessment

DNA barcode technology can be applied to assess species diversity in plant communities or ecosystems. Compared with traditional morphological methods, DNA barcode technology has the advantages of low cost and high efficiency, which can quickly identify species in a large number of samples and accurately evaluate biodiversity.[11]

3.3 Rapid Identification of Species

In some specific application scenarios, such as plant quarantine, customs inspection, pest management, etc., DNA barcode technology can provide the ability to quickly identify plant species, which is of great significance for preventing invasive alien species and protecting local ecosystems[12].

3.4 Paleobotanical Research

DNA barcode technology can also be applied to paleobotanical research, helping scientists reconstruct the structure and evolutionary history of ancient plant communities by analyzing DNA sequences in fossilized plants[13].

3.5 Identification of Traditional Chinese Medicine Materials

In the field of traditional Chinese medicine, DNA barcode technology is used to accurately identify the species of Chinese medicinal materials to ensure the source quality and medication safety of the materials[13]. For example, ITS2 sequence is often used as a DNA barcode for medicinal plants, and combined with psbA trnH sequence as a supplement, it can effectively identify the original species of Chinese medicinal materials and their mixed products. The application of DNA barcode technology in rapid identification of plant species not only improves the efficiency and accuracy of species identification, but also plays an important role in multiple fields such as biodiversity monitoring, environmental protection, agricultural production, and quality control of traditional Chinese medicine. With the continuous development of technology and the continuous improvement of databases, DNA barcode technology has broad prospects for application in plant species identification, and is expected to further promote scientific research and application practices in related fields.

4. Conclusion

4.1 Advantages and Challenges of Molecular Biology Techniques in Plant Identification

The advantages and challenges of molecular biology technology in the field of plant identification. The application of molecular biology technology in plant identification has become an important means of modern botanical research. This technology provides a powerful tool for plant taxonomy, systematics, and evolutionary biology by analyzing the genetic material of plants, such as DNA, to determine their species identity, population genetic diversity, and phylogenetic relationships. In terms of advantages, molecular biology technology has the characteristics of high accuracy, high efficiency, and low cost. Traditional plant identification methods, such as morphological classification, rely on the morphological characteristics of plants, which have significant limitations when facing closely related or morphologically similar species. In contrast, molecular biology techniques can provide an identification method that is not limited by morphology, especially in the analysis of inter species relationships, discovery of new species, and identification of genetically modified plants, demonstrating their unique advantages. For example, molecular biology methods such as polymorphism analysis based on PCR technology and phylogenetic analysis based on nucleic acid sequences can quickly and accurately identify plant species, especially for plants with unclear morphological characteristics. Molecular biology technology provides an unbiased identification method.

4.2 Future Development Direction

With the rapid development of molecular biology technology, the field of plant identification is undergoing a revolutionary change. Traditional morphological identification methods are gradually being replaced by molecular biology techniques due to their long processing time and limited accuracy. These technologies provide new solutions for plant identification with their high specificity, sensitivity, and speed. The future development direction is that the application of DNA barcode technology will be further expanded, the development of high-throughput sequencing technology (Next Generation Sequencing, NGS) will provide more possibilities for plant identification, individual level molecular marker technology will also be further developed, and with the rapid development of bioinformatics technology, data analysis methods are constantly improving.

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