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A crop trait information acquisition system with multitag-based identification technologies for breeding precision management

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ABSTRACT

This paper aims to establish a crop trait information acquisition system by combining barcode and radio frequency-based electronic identification (RFID) and near-field communication (NFC) technology applications. The system was devised to ensure (a) correct identification of each crop material and plot, (b) quick query and positioning for information collection, (c) correct combination of crop phenotypic data and images, and (d) reliable recording of periodic crop trait data with dependable transmission to the main server. This system, with multitag-based identification technology, was developed on an Android platform using the Java language. A type of RFID/NFC tag with a high-frequency chip was applied in the core, and a quick response (QR) code was used on the surface for material identification. A smartphone with NFC function can be used as an RFID reader, and its built-in camera can be used to decode QR codes. The system was used in some seed industries' commercial breeding and in national crop variety regional trial, with its functions including reading/writing of RFID/NFC tags, decoding QR codes, acquiring crop trait information, creating field maps, and uploading data. This system provided a low-cost and highly efficient solution for crop trait information collection.

1. Introduction

While it is the most time-consuming key link in breeding, observation of plants' field performance is indispensable in the breeding process. Moreover, the accuracy and completeness of all data are considerable challenges. Currently, data acquisition makes use of field log sheets in Chinese breeding work (Huang and Li, 2014). However, traditional field data acquisition made use of manual recording, which easily introduced human errors and required reorganization. In addition, the labor cost of such a practice is high. The breeders record the crop trait information and presence of plant diseases and input this information on a spreadsheet software (such as Microsoft Excel). Furthermore, manual collection led to delays in data summary, which restricts data analysis, use, and the establishment of subsequent breeding plans (Chen and Li, 2010). Furthermore, a large amount of crop condition images and phenotypes should be collected. However, manual data collection cannot integrate data and images (Meng et al., 2005).

Many advanced foreign seed enterprises, such as Pioneer, Syngenta, and Monsanto, have handheld data collection equipment and high-level breeding information management systems. Field observation information, such as data and images, is recorded and transmitted quickly through the handheld breeding data collection system. Thus, the data need not be reorganized manually after collection. Breeders can input plants' growth information, including photos, into the database while in the field, thereby improving the efficiency of data collection.

Portable devices (mobile phones, personal digital assistants (PDAs), and pocket PCs)) are widely used in intelligent agriculture. For example, Fang and He (2008) developed a fast pocket PC-based field information collection system to acquire and analyze field information. Cunha et al. (2010) used mobile devices and identification tags to render contextualized information and services to support in-field precision viticulture management practices. Li et al. (2010) developed a farming information acquisition and decision support system in a PDA for cucumber traceability. Qian et al. (2015) established a farm and environment information bidirectional acquisition system with individual tree identification using smartphones. Rafoss et al. (2010) developed an application to track down and eradicate disease outbreaks and susceptible host plants

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using a GPS-enabled mobile phone. Mesas-Carrascosa et al. (2012) developed and implemented a smartphone application to inspect agricultural plots. Moreover, identification technologies, such as barcodes and radio-frequency-based electronic identification (RFID), are widely used in such integrated systems. These systems can offer advantages, such as decreased recording errors, automation of farm implements, reduction of labor costs, and overall productivity optimization (Samad et al., 2010). RFID applications are applied in agro-food, livestock, cold-chain monitoring, or farm machinery (Ruiz-Garcia and Lunadei, 2011), but rarely in crop breeding. For example, Qian et al. (2012) developed a wheat flour traceability system for wheat flour mills by combining 2D barcode and RFID technology applications. Barge et al. (2010) described an RFID-based traceability system for single-potted plant tracking from nursery to distribution in commercial greenhouses. Reiners et al. (2009) also developed an RFID technology application for the individual identification of weaned piglets.

Mobile communication technology can provide significant assistance in improving field data collection efficiency. Information collection and uploading using portable devices have become effective means for collecting farming operation information. The present study developed a highly credible crop trait information acquisition system with multitag-based identification technologies using a smartphone for breeding precision management. This crop trait information acquisition system was used in combination with the electronic label and crop breeding information management system ("Golden Seed" Breeding Platform, GSBP). Such a system facilitates efficient data collection; integrates mobile devices, RFID/near-field communication (NFC), and barcode technology; and promotes the timely uploading of collected data.

2. Framework for breeding management services

The crop breeding service-oriented framework (CBSOF) is a framework that supports common crop breeding practices. An overview of the proposed CBSOF architecture is depicted in Fig. 1, which illustrates the mechanism of interaction between the crop trait information acquisition system and the remote crop breeding information management platform (GSBP) and between the crop trait information acquisition system and the label printing system.

As shown in Fig. 1, four parts are included in the CBSOF architecture. Tags are the basis for breeding material identification. In the entire life cycle of the crop material, breeding electronic labels are used for their identification. Thus, a QR code is attached to the electronic tag surface for the identification of breeding materials. The label printing system writes the RFID/NFC tag and prints the QR code. This label printing system can replace traditional label making and significantly improve efficiency. The crop trait information acquisition system in smartphones is key in barcode scanning, RFID/NFC tag reading, information collection, and data access from a remote server. This system also supports the collection of trait information for various crops, such as maize, paddy, wheat, soybean, cotton, and oilseed rape. The proposed system was developed on an Android platform using the Java language with the following functions: QR decoding, electronic tag reading/writing, quick reading of test and material information, crop trait information collection, and data uploading. The breeding information management system (GSBP) deployed on the remote server supports the storage and management of information. The interaction between GSBP and the crop trait information acquisition system was obtained through the HTTP protocol. The functional framework of CBSOF is shown in Fig. 2. In the whole breeding process (from seed to new seed), the CBSOF helps breeders accomplish planning, field lay-out, data collection, field pedigree trace-back, initial selection, data processing, data analysis and evaluation, pedigree generation trace-back, and selection. The CBSOF also contains the germplasm resource module, breeding material module, cultivar selection module, cultivar evaluation module, pedigree management module, data analysis module, collect and trace back terminal, breeding electronic labels, and labeling device.

The steps in crop trait information collection in the field can be described as follows: (1) the QR code on the electronic card is scanned or the electronic tag of material is read by the acquisition system with smartphone; (2) the QR code or RFID/NFC tag is decoded to obtain the plot number; (3) the plot record list is quickly positioned based on the plot number; (4) crop trait (such as plot yield, plant height, and leaf color) information is collected manually by the breeder in the field and displayed on the screen;

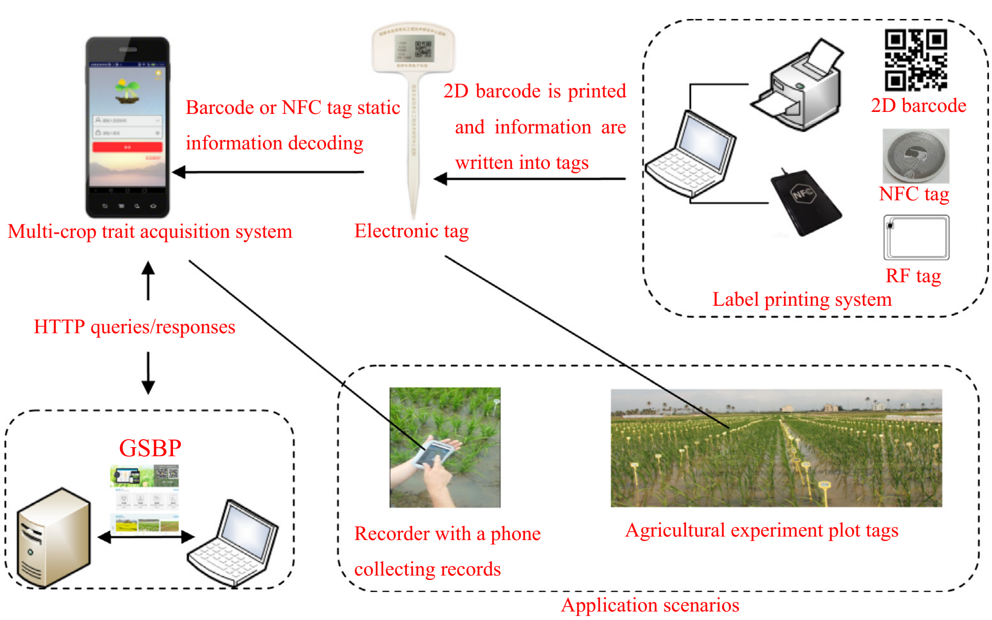

Fig. 1. CBSOF architecture overview.