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RESEARCH ARTICLE

Field Book – Mobile App for Plant Genetic Resources Management

M Elangovan
Principal Scientist, ICAR-Indian Institute of Millets Research (IIMR), Hyderabad–500030, India.

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Digitalization is the process of converting information into a digital format. Digital India, launched in 2015, aims towards the promotion of digital literacy and creation of digital infrastructure for empowering rural communities. Considering the need of digitalization and handling of huge data, a mobile based application technology for data collection named Field book has been developed by Kansas State University (KSU), United States of America and International Maize and Wheat Improvement Centre (CIMMYT), Mexico. Such app could be very useful to collect data related to plant genetic resources (PGR). Efforts have been made by ICAR-Indian Institute of Millets Research (IIMR), Hyderabad to customize the field book to use as one stop solution for plant genetic resource management. We have customized the app for collection of characterization data of eight crops namely sorghum, pearl millet, finger millet, foxtail millet, barnyard millet, proso millet, kodo millet and little millet. The app is customized for DUS characterization of sorghum and collecting passport data for PGR exploration. Twenty-seven agro-morphological traits are created as SOR GERM file for sorghum characterization. The trait screen has several advantages including saving of note book data collection. The off-line data collection reduces threat of sharing the data without owner knowledge. ICAR-IIMR-Hyderabad has initiated the training on field book to the researchers in the country with a target of 5000 researchers by 2020. This mobile app has potential to reduce paper usage, cutting of large number of trees and thus saving carbon foot prints and also facilitating more efficient data collection, analysis and storage.

Key Words: Characterization, Digitalization, Exploration, Field book, PGR

Introduction

Digitalization is the integration of digital technologies into everyday life (Ochs and Riemann, 2018). Digital Information and Media are excellent tools to upsurge knowledge which is an important production factor in agriculture (Afroz *et al.*, 2015). In 2017, the number of mobile phone users in India is expected to rise to 730.7 million. In this same year the number of smartphone users in India is predicted to reach 340 million and could reach almost 468 million by 2021 (Tableau, Statistica, 2019). Digital India, launched in 2015 aims towards the promotion of digital literacy and creation of digital infrastructure for empowering rural communities. Considering that 58% of rural households depend on agriculture as a major source of livelihood, the role of Digital Agriculture needs to be considered within Digital India.

Advances in digital technologies offer the potential for transformational change in agriculture such as being observed in providing new ways to improve productivity and profitability in Australia. Rapid developments in computing power, robotics, big data, and cloud computing are creating opportunities for more data-driven approaches into farm management, referred to as 'smart farming' (Zhang *et al.*, 2017).

Conventional approach of data collection on paper has several disadvantages including the delay in data availability for analysis, errors during the transcription, vulnerability to loss or damage (Johnston, 2017). Collecting data using mobile technology, especially when the data is uploaded to a properly administered campus server, makes the data much more secure and is immediately available for review and analysis. The use of mobile technology also introduces additional functionality. This includes more reliable data through the use of authority controls and validity checks. It also enables use of GPS coordinates, photographs, audio, and video in addition to textual and numeric data. An increased use of digitalization, remote sensing, and ICT would improve efficiency, quality, and timeliness of controls and audits (Karner, 2017).

**Author for Correspondence: Email- elangovan@millets.res.in*

The use of mobile application for collecting the field or lab data is very limited in research institutes in India and other developing countries. Recently, a mobile based application technology for data collection named Field book was developed by KSU and CIMMYT. This mobile app can be used to collect any kind of field or lab data and reduces manpower and papers; increases accuracy and authenticity. Field book is an open-source Android app that is used to collect data on field which is very useful for the field functionaries for collection of geographical information, information with geo-tagged photos and audio records. This app is developed as an open source tool that can be used to collect data on all kinds of experiments. Hence has potential to replace paper field books and is projected to increase the speed of collection and analysis that will enable the rate of genetic gain. The ability to keep data organized in digital form allows technicians and breeders to focus on other tasks, leading to further innovation and growth of plant breeding programs (Rife and Poland, 2014).

The improvising of the field book applications has added many new data collection formats, quality and requirements on the increasing and improving demand in the digital technology arena. The three new data formats such as barcode scanning, field mapping and survey developed and upgraded by Courtney (2017) opens a new open-source domain for acquisition of data on farmlands to accompany the research of plant breeders.

Phenotypical data acquisition has been completed by hand or accompanied by expensive software, which may be unavailable to most developing countries (Rife and Poland, 2014). Nielsen and Gangadhara (2016) opined that field book is useful with the explosion of genomic data and need for increased speed of data collection. Karner (2017) stated that digital society is not just a technology, but a comprehensive social organization, where the information and its exchange play a major role. Digitalization of farming sector would contribute to its competitiveness, help to raise farmers' income, and attract young people to join the traditional activity, which is vital for the whole society.

Customization of App for PGR Management

Though the field book was initially used for collecting the field related experimental data, an effort has been made by ICAR-Indian Institute of Millets Research (IIMR), Hyderabad to customize the field book to use as one stop solution for PGR management.

Downloading and Installing

Field book can be downloaded from Google Play Store on your mobile phones and tablets. Upon installation, the app will ask the user if they wish to load sample data and turn on the tutorial. The source code for Field book is available on GitHub.

Data Storage and Folders

Once field book has been installed and opened. It will create nine different folders in the devices memory with specific purpose to handle and store the data. The folders are as below:

1. **Field export:** This folder stores exported data files after collecting the data
2. **Field import:** The field book file are created in MS-Excel with information about the field or lab experiments and imported in .csv format (comma delimited)
3. **Plot data:** The data associated with plots (audio and photos) are organized into this folder based on the name of the imported field or lab experimental file individually
4. **Resources:** This folder can hold pictures and files that can be helpful when out in the field and are accessible from the main data collection screen
5. **Database:** This folder contains files that are exported when backing up the database
6. **Trait:** This folder contains backed up trait files which you can create by add, delete, and edit traits from the sample file available. For example, each crop germplasm will have separate descriptor trait file for characterization
7. **Archives:** This folder contains archive files
8. **Error:** This folder contains error files
9. **Updated:** This folder contains update files

Settings Menu

This is the first menu to be seen while installing the Field book. A user cannot collect the data until two steps are taken – importing the field file and loading/create the trait file. The settings menu is the main location for configuring field book. The options in this menu are used to import files, load traits, change profile information, export data, change the language, and toggle different advanced settings.

Creating Field Files for PGR Characterization

Field files can be created in MS-Excel and can load both CSV and XLS files. File names and column headers should exclude the following characters: / ? < > \ * | ” . Field book import files should, at the least, include three columns: a unique ID, a primary order, and a secondary order. To create field file for PGR characterization, each accession number should be assigned a unique identifier. This unique ID is used internally to associate data with a specific accession and should be globally unique. The unique ID for the experiment on characterization of sorghum germplasm can be created viz., crop code (three letters), season (K for Kharif, LK for Late Kharif, R for Rabi and S for Summer) and year of characterization (two digit number). For example, the Sorghum-Kharif-2018 and the first genotype can be read as SORK18001. When importing files, field book will check to see if the unique ID is unique within the file being imported. In addition, two columns must be included as a basic navigation ordering. These are referred to as the Primary and Secondary Order. The user can select these columns based on how they traditionally walk through the field. The related information on crop name, accession number, IC/EC number, type of material, received from, category and bed number can be used as primary or secondary order. Similar way field file for different crop germplasm characterization can be created. Once a field file has been designed, it can be transferred to the Android device via apps like shareit, drop box or manually with a USB cable.

Creation of Trait Files for PGR Characterization

There are 12 different data formats available to create the trait file. They are numeric, categorical, date, percent, rust rating, text, boolean, multi-category, location, counter, photo and audio. Each trait formats utilize different layouts and features to streamline how the data is collected. Data is collected in field book by creating traits. The different data formats and its input style is presented in Fig. 1.

For example, 27 agro-morphological traits are created as SOR GERM file for sorghum characterization. The trait screen allows the user to create new traits or modify existing traits. The new traits can be created by pressing the add trait button (+) at the bottom of the screen. Each trait has a custom creation menu where the user can mention the name of the trait and other related states of

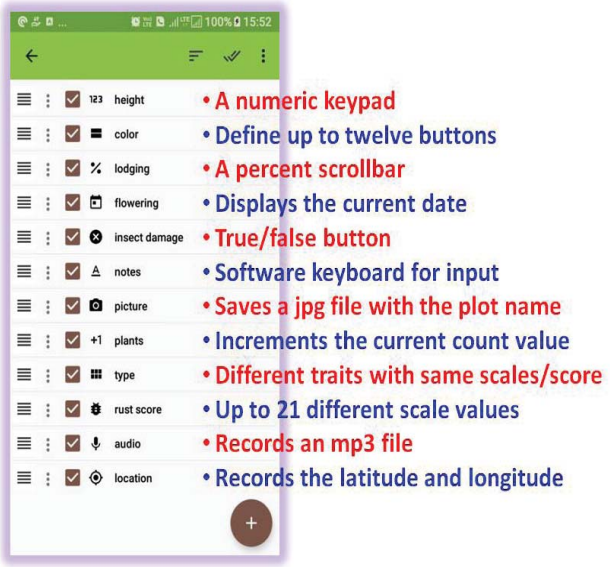


Fig. 1. Twelve different data formats and its input style

the trait. Traits name are unique and cannot share the same name. Each trait has options to make data collection easier. The menu icon on each line allows each trait to be delete, copy or edit. The checkbox allows traits to be active or hidden on the main layout screen. Traits can be reordered by dragging and dropping the icon on the right of each trait line. Lists of traits can be created and transferred between different devices using the import/ export option on the toolbar. The newly created trait files are stored in the trait folder. The example traits and its format to be selected while creating trait file for plant genetic resources characterization and plant genetic resources exploration in general are presented in Table 1 and Table 2 respectively.

The different trait files customized for different crop germplasm descriptors for characterization is presented in Fig 2. a. Sorghum, b. Finger millet, c. Pearl millet, d. Lentil, e. Wheat and f. Barley. The trait files customized for collecting exploration data / passport data is presented in Fig. 3.

Exporting Data

Collected data can be exported to as CSV files. The export dialog allows the user to customize how collected data is exported. Two different formats can be selected viz., database or table. The export file can include only the unique identifier or all field columns that were imported. The export file can contain all traits currently active or all traits for which data has been collected. The filename is automatically generated by the app

Table 1. Common traits used for PGR characterization and its data type for creation of trait file

S.No.	Type of data	Traits
1	Numeric	Number of tillers, Flag leaf blade length (cm), Flag leaf blade width (cm), Peduncle length (cm), Lower raceme length (cm), Culm branching, Panicle length (cm), Panicle width (cm), Plant height (cm), Grain yield per plant (g), 1000- seed weight (g), Pod length (cm), fruit length (cm) etc.
2	Categorical	Growth habit, Plant pigmentation, Inflorescence shape, Inflorescence colour, Panicle compactness, Spikelet arrangement on the rachis, Lowest raceme shape, Lowest raceme thickness, Lower raceme branching, Lodging, Grain colour, Grain shape
3	Percent	Staygreen, Lodging, resistance to pest / disease
4	Date	Days to flowering, Harvesting date
5	Boolean	Insect / Pest damage
6	Text	Remarks
7	Photo	Panicle, seed, other variable traits
8	Counter	No. of plants in a row/plot
9	Multicat	Multiple trait selection
10	Rust rating	Screening for leafy diseases, pest damage
11	Audio	Describe the accession other than the available traits
12	Position	Displays latitude and longitude of the data location

Table 2. Common traits used for PGR exploration and its data type for creation of trait file

S.No.	Type of data	Traits
1	Numeric	Latitude, Longitude, Altitude
2	Categorical	Status, Frequency, Material, Sample type, Sample method, Habitat, Disease symptoms, IPN infection, Cultural practices, Season, Associated crop, Soil colour, Soil texture, Stoniness, Land aspect, Slope, Topography, Agronomic score, Ethno useful parts, Kind, Informants
3	Percent	Drought/Flood/Natural calamity
4	Date	Date of collection
5	Boolean	Logical scores on availability of traits
6	Text	Common name, Botanical name, Vernacular name, Village, Taluk , District, State
7	Photo	Field view, Panicle, Seed, Other variable traits
8	Counter	Minimum available trees
9	Multicat	Multi-traits with same scale/score
10	Rust rating	Pest/Disease rating
11	Audio	Farmers interview , additional description of germplasm
12	Position	GPS data

based on the current date (YYYY-MM-DD), current time (HH-MM-SS) and the name of the field file that was imported into the app.

Database

The database can be backed up and transferred between tablets. When exporting the database, two different files are exported: one containing the database, and one containing the user settings when the database was exported. To re-import the database, both files need to be present in the database folder.

Need for Digitalization of Data Collection

Many electronic versions of information dissemination has happened in the near past such as e-book, e-journal, e-thesis, e-mail etc. The modern day electronic information like lengthy e-mails has become short message SMS, whatsapp, twitter etc. The mobiles have taken over the cameras for photo capturing. The atlas book has become google maps. The cassettes/CDs have become mp3 audio files. The video coverage has become video clips. The hard discs have become SD cards. There is need to change our paper note books to smart phone for collecting data. The digitalization of data can be done using the field book mobile app as ICT (Information and Communication Technology) tool for any form of data collection.

Challenges in Implementing Digitalization of PGR Management

The main challenges for implementation of digitalization are shifting from field note book to mobile field book due to several reasons including faith in the older technology. A study by Hirose *et al.* (2017) revealed that the mobile users i) perceived ease of use positively influences perceived usefulness ii) perceived ease of use

a) Sorghum b) Finger millet c) Pearl millet

d) Lentil e) Wheat f) Barley

Fig. 2. Crop descriptors customized using the field book mobile app

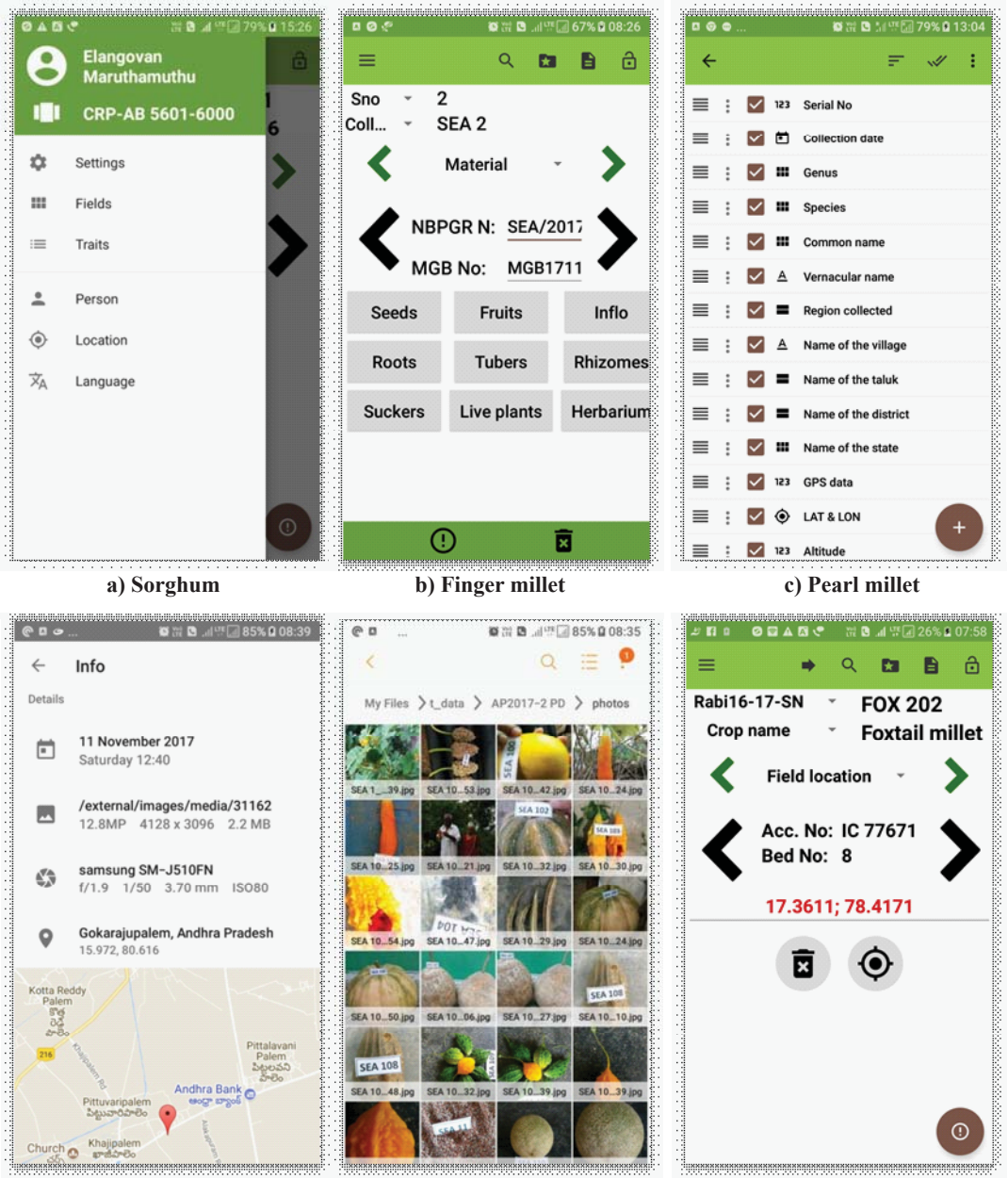
positively influences attitudes toward mobile apps usage, iii) perceived usefulness positively influences attitudes toward mobile apps usage iv) attitudes toward apps positively influence intentions to use mobile apps. It's really high time to for the user researchers to change their attitude towards the field book mobile app in place of the paper field book.

Mobile App for Seed Genebank Management

Angala and Diaego (2015) reported that the adoption and implementation of mobile computing as a tool to improve efficiency in data collection and information management for the genebank operations. On the other hand Hernández and Gonzalez (2015) suggested following challenges for collecting data by mobile i) No full coverage of wireless points in the work areas of Genetic Resources Program ii) No connectivity with experimental stations (Popayan, Santander de Quilichao, and Tenerife).

Action Plan to Implement Mobilization in PGR Management

The field book mobile app can also be used as a platform to manage the accession conserved in the seed genebank. A working model is being customized for this purpose at ICAR-IIMR Hyderabad.



a) Sorghum **b) Finger millet** **c) Pearl millet**

d) Lentil **e) Wheat** **f) Barley**

Fig. 3. Trait files customized for plant genetic resources exploration

The action plans includes, organizing learning workshop for the PGR workers especially young researchers, identifying their ongoing experimental problems and converting them to mobile field book, build a confidence on data security related doubts, monitoring the progress on implementation and make them the trainer.

More Apps Available for Researchers for Characterization of Plant Genotypes

There are more and more mobile apps being developed for strengthening the data collection in field related experiments – NDVI images to judge the vigour rating, leaf area index (LAI) and leaf biomass around flowering and to very late senescence rating (Liebisch *et al.*, 2017).

Cresente *et al.* (2017) developed novel open source software called Phenobook, which consists of web-based software for experiment design, data input and visualization, and exportation, combined with a mobile application for remote data collecting. Phenobook

is a software tool that can be easily implemented in collaborative research and development projects involving data collecting and forward analyses.

Roxanne *et al.* (2017) developed a smart phone application to integrate a low-cost Bluetooth colour sensor with a GPS-enabled smart phone.

Pengcheng *et al.* (2017) reported that the colours of soil and proofread cards can be acquired by the smartphone, converted into RGB signals and then after simple processing can help in-rapid soil classification.

Conclusion

The hard copy recording of data in the field consumes lot of paper. Replacing the paper field book can only be possible by increase use of field book mobile app. ICAR-IIMR Hyderabad has initiated the training on field book to the researchers in the country. We have trained 2,632 researchers so far from 5 State Agricultural Universities (SAUs), 6 ICAR institutes, 3 AICRP's on Sorghum, Small millets and Pearl millet, 4 Agricultural Colleges, 2 Private Seed Industries and 30 lectures/practical's on Digital Field Book in various training programmes. A target of 5000 trained researchers by 2020 has been aimed. In continuance of efforts many scientists at ICAR institutes (IIMR-Hyderabad, IISR-Indore, NBPGR-New Delhi, IIHR-Baengaluru, NRCP-Solapur, DOGR-Pune) and SAUs (PJTSAU-Hyderabad, Dr PDKV-Akola, PAU-Ludhiana, CCSHAU-Hisar, TNAU-Coimbatore and NAU-Navsari) have started using the field book. With the average use of 10,000 paper sheets per year by a scientist, all the 5000 researchers' uses field book mobile app, it has potential to save 5.0 crore paper sheets per year which is equal to saving of 6,000 trees annually. All institutions should take advantage of the latest technologies like tablets, computers and smart phones to record and maintain digital files and notes.

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