Vol. 11(1), pp. 10-17, January-June 2021
DOI: 10.5897/JCBBR2020.0126
Article Number: 7CC9BAC67158
ISSN 2141-2227

http://www.academicjournals.org/JCBBR

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Journal of Computational Biology and Bioinformatics Research

Full Length Research Paper

Development of information system for tracking breeding traits of improved crops

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Received 7 February, 2020; Accepted 27 May, 2021

Plant breeding involves application of a group of systems targeted at transporting collected decent parents' traits to produce an improved crop in the offspring. Cross-breeding and selection in plant breeding has been able to considerably improve yields as well as pest and disease resistance of crops. Efficiency in crop breeding research programs is contingent upon the aptitude of breeders making it possible to successfully produce, classify, store, track and choose recombinant genetic constitution with a determined number of required traits. It is not easily done with the manual system to store and manage large volumes of data generated in all research institutions. Locating files among tons of data is a tedious and time-consuming process for researchers. The importance of keeping track of research data is becoming vital in agricultural research institutions. A study was conceived in response to the need to improve the storage, tracking and dissemination of research data collected during the breeding of improved crops. It was conducted to develop a system for tracking breeding records, at the National Agricultural Research Laboratories (NARL) in Uganda. This was motivated by the increasing need to develop high yielding yet resilient crop varieties due to the constantly changing climate amid other socio-economic changes like population pressure and loss of soil fertility. Different methods were used to design such systems which included data-flow diagrams (DFDs) and entity relationship diagrams (ERDs). An ERD was used to recognize the data to be apprehended and deposited, and regained in order to accomplish the process of storing and tracking files. As a result, a breeding tracking system was developed as an application tool that can manage the creation and tracking of records. The advanced system supports information sharing between scientists and easy access to the trait information in improved crops.

Key words: Data, tracking, plant, breeding.

INTRODUCTION

Plant breeding is recognized as genomic enhancement within plants' presentation to collectively regulate required genetic factor and decrease the incidence of the unwanted genes in plants (Lance et al., 2020). This conserves the veracity of the parental genotype, inserting only a minor supplementary section of evidence that

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pedals a precise trait. A gene is a classification of deoxyribonucleic acid (DNA) that comprises evidence that determines a particular characteristic (Sarkar and Plutynski, 2010). Genes are located in chromosomes and are units of legacy that are accepted from one generation to the next and provide directions for expansion and function of the organism. Crops with genetic improvement are referred to as genetically enhanced crops. A better plant comprises a gene or genes, which has been artificially inserted in the process of conventional breeding.

Agriculture and biotechnology are critical contributors to solving the global problems of hunger, poverty and environmental degradation (Tonukari and Omotor, 2010). Although major scientific breakthroughs have been realized in engineering, electronics, information technology and medical research, advances in agricultural technologies, particularly agricultural biotechnology, hold a great potential for economic growth, crop productivity, nutritional quality necessary for reducing poverty and associated challenges in developing countries (Ivar et al., 2007). In Uganda, the land area under agriculture has been steadily declining due to population growth that was 40.0 million in 2019 (UBOS, 2019). At the global level, the world population was 7.7 billion in 2019 and is predictable to range almost to 9 billion in the year 2045 (UNDP, 2012). Therefore, a wide assortment of agricultural hereditary variety requirements to be taken, availed and used in order to feedstuff this rising population. Climate alteration is an additional risk to biodiversity that will meaningfully influence genetic resources for food manufacture (Lidder and Sonnino, 2012). Crop production must double by 2050 to encounter the foretold production stresses of the worldwide population. However, attaining this goal will be an important challenge for plant breeders for the reason that crop yields would consume to upsurge at a rate of 2.4% per year, yet the regular rate of increase is only 1.3%, with yields festering in up to 40% of land below cereal construction.

Tracking and tracing of improved crops

According to the new guideline (applicable since 2015) in the European Union, traceability is mandatory in all phases of the supply chain, cover all food and feedstuff as fit as commercial operators without preconception to current lawmaking on exact segments such as grains (European Union, 2015). A plant research institute must record and have information such as name, location, status, nature of plant consignment number and a more comprehensive explanation of the crop (Luca et al., 2013). Unless detailed requirements for additional traceability exist, the obligation for traceability is incomplete to safeguarding that researchers are at least able to classify the immediate source of the crop as well as immediate subsequent receiver. Handling the enormous quantity of data and processing them is a challenge that needs to be answered by emerging data management and tracking system for managing upgraded crops (Adetunji and Izang, 2018).

METHODOLOGY

System design is the process of turning the abstract solution into a practical specification suitable for implementation. The system was designed based on the functional and nonfunctional requirements obtained during requirements collection which described the parameters and the data to be incorporated into the system. Different methods were used to design the system which included data flow diagrams (DFDs) and entity relationship diagrams (ERDs).

To release the purpose of this paper, we begin with modelling the projected tracking system using the data flow diagram and context diagram. A data flow diagram (DFD) is a graphical illustration of the flow of data and modelling its procedural aspects. A DFD is often used as an initial stage to generate a summary of the system without going into details. Data flow illustrations show the purposes to be accomplished by a system and the data flow in the system, what alterations are made on the data. They similarly give graphic representations of the system's mechanisms, procedures and the boundaries. The excellent data flow diagram is based on the detailed information to be comprehended by practical and non-technical spectators. It can deliver a high-level system overview with limitations and influences to other systems, and lastly, it can deliver a comprehensive representation of the system mechanism. It uses diagram to document an object-based rottenness of systems and to show the communication amongst these objects and the dynamic forces of these objects. The information tracking system was developed as a web request with three tier construction. Hypertext Pro-processor (PHP) handles data transmission from the user boundary to the database and query demand to the database from the user interface Entity Relationship Diagrams (ERDs) were used to perfect together with the rational and physical database construction projects. The entity relationship data model shows the relations among the objects complicated in the system composed of their qualities and designates the number of incidences an entity can exist for a single incidence of the related entity. ERDs aid the imprisonment of additional details such as data about entities (attributes and constraints on entities) and their relations. An ERD was used to classify the data to be taken, stored and retrieved in order to provide the activities completed in the procedure of filing and paying taxes. ERDs are comparatively humble, user friendly and can provide a unified view of data which is independent of any data model (Tiberiu and Liviu, 2010)

The reason for choosing PHP is that it is not only a broadly used open-source scripting language but also PHP is free software and turns on numerous platforms making it platform independent. PHP is companionable with almost all web servers in use today. PHP supports an extensive variety of databases. It can open, read, write, remove and close files on the server. It can gather the form information and can send and obtain cookies. PHP can add, remove, modify data in a database and can limit users from retrieving some pages on your website. PHP can encode data with PHP varied output users produced.

The database management system used is MySQL. It is one of the world's greatest popular open databases, allowing the cost-effective distribution of reliable, high-performance, and climbable web-based and entrenched database application. It is perfect for both small and big applications. MySQL is very fast, dependable and easy to use. It chains standard SQL.MySQL accumulates on a number of platforms. It is free to transfer and use and is established, distributed, and supported by Oracles Corporation.

Cascading style sheets (CSS) come in handy for styling the user interfaces, creating them appealingly pleasing to users of the system.

Germplasm tracking

Information technology (IT) benefits crop growth by helping data management and operation across corrections and software systems. Efforts to advance new crops must grow from individual, inaccessible data sets to a realm where information flows easily from field and laboratory trainings to a systematic tracking system.

Some systems accomplished linking crop-specific data to crop development information (Seelye et al., 2016). This ranges from possession of source germplasm to misuse of indigenous knowledge about potential uses (Subramanian and Pisupati, 2010). Careful documentation of the crop growth procedure will deliver shareholders the information needed to achieve and track the information about enhanced crops.

The documentation of the complete plant breeding procedure and tracking information in breeding segment, emphasizes mostly on crossing, selection, increase, embryo rescue, micro-propagation and field testing. Each genetic entity, whether a single cell, seed packet, and tissue culture, is uniquely recognized, and the identifies can be associated with alternative names as needed. Sequences of generations are flawlessly linked, letting historic pedigrees to be traced as far back as archives allow. Genetic entities may be considered using user-specified attributes ranging from origin of germplasm, to plant signifiers (White et al., 2007).

Benefits of information systems for tracking information about improved crops

The role of Management Information System (MIS) in an organization can be compared to the role of a heart in the body. The data is to the blood and Management Data System (MIS) is to the heart. In the body, the heart acts the role of providing blood to all the essentials of the body together with the brain. It regulates and controls the inward impure blood, processes it and sends it to the end point in the quantity needed. It accomplishes the needs of blood supply to human body.

An MIS plays exactly the same role in the association. The system safeguards suitable data that is collected from the various sources, administered, and sent to the required last stop. The system is expected to fulfill the data needs of an individual, a group of individuals, the organization functions- the managers and the top supervisors. Hence, an MIS satisfies the diverse needs through a variety of systems such as Query Systems, Analysis Systems, Modelling Systems and Decision Support Systems. Therefore, MIS helps in Tactical Preparation, Management Control, Operational Controller and Transaction Processing. By contrast with labor-intensive systems, MIS have a variety of benefits to an organization specifically.

Extensive breeding and agronomic efforts over the past 50 years have been accountable for tripling cereal yields. Ongoing advances in the techniques available to breeders offer the possible to increase the rate of genetic improvement.

Plant genetic engineers often need to trace traits in improved crops to their original plant. This is done to track the source of a good trait using the breeding collections in order to get the traits for producing other improved crops. This process requires access to data from the field. The starting materials are taken to the laboratory where they are subjected to a number of experiments, before they are released back to the field as improved plants. Currently at Uganda's National Agricultural Research Organization (NARO), this data is manually collected, entered and stored in personal laboratory books and paper files. As a result, there are a lot of challenges regarding utilization of this data notably: data duplication, difficulty in locating data about specific samples, misinterpretation and wastage of time in locating data. The aim of this project was to develop an information system for tracking information about improved crops. It is hoped that such a system will make it easier to trace some of the good traits found in the improved crops in the process of breeding.

Plant breeding can be measured as an evolutionary procedure between humans and palatable plants. People produced variations in the plants that were used for agriculture and innovative plant. Plants yielding more substantial harvests freed some of the people's time for emerging art, handcrafting, and science, eventually leading to modern human life as recognized. Evolution could not exist deprived of agriculture and agriculture could not sustain the civilized world lacking contemporary crop varieties. From this opinion of view, it grows into making clear that plant breeding is one of the foremost fundamentals of development.

RESULTS AND DISCUSSION

Context diagram (data flow diagrams)

A setting diagram is a data flow diagram that precises all dispensation actions within the system in single process symbol. It defines the maximum level view of the system, shows a system as a whole with inputs and outputs from/to external factors. It was used to describe in general context of the system by identifying all the external entities or users interacting with the improved crop system. The information they feed into the system and the feedback from the system.

Data flow diagrams are a network symbol of a system. They are the keystone for controlled systems analysis and design. The diagrams use four symbols to characterize any system at any level of feature. The four entities that must be signified are the following.

System context diagram

The context-level DFD at Level 0 DFD shows some of the aspect of the system being demonstrated. The Level 0 DFD shows how the system is divided into sub-systems (processes), respectively of which contracts with one or additional of the data flows to or from an outside agent, and which collected offer all of the functionality of the system as an entire. It also classifies interior data stores that must be present in order for the system to do its job, and shows the flow of data between the numerous parts of the system. A context diagram is a data flow diagram that precises all dispensation happenings within the system in single process symbol (Figure 1).

Entity relationship diagram (ERD)/ER model

An entity-relationship diagram is a data modeling technique that creates a graphical representation of the entities, and the relationships between entities within an

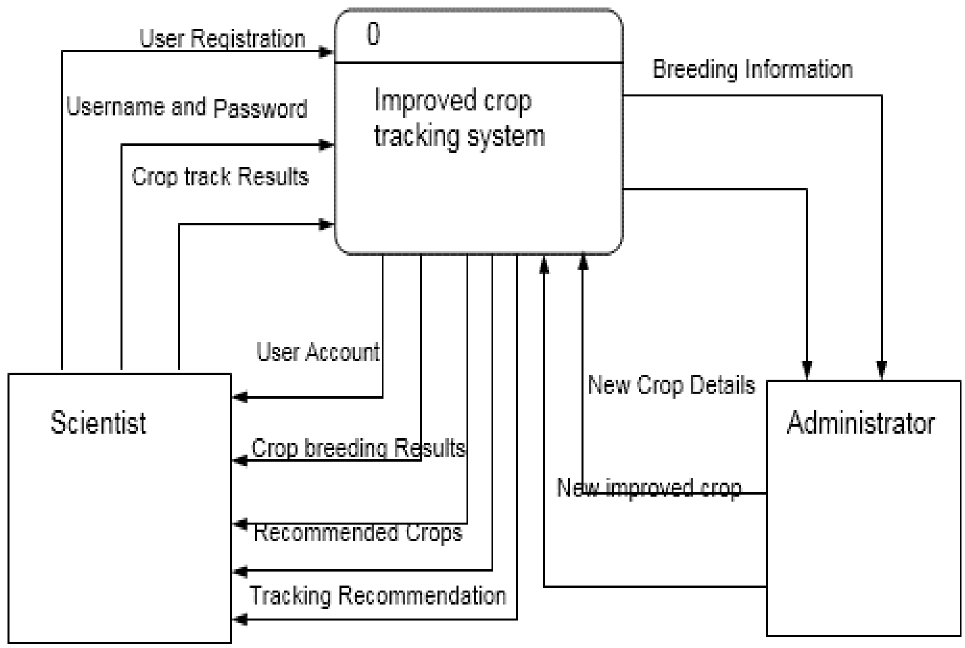

Figure 1. System context diagram.

information system. It represents the logical design of the database for a system. It identifies major entities/ database tables, attributes of the entities and establishes the relationship between the entities.

The entity-relationship diagram for an information system for tracking information about improved crops is as shown in Figure 2.

The ERD was used to illustrate the data model of the tracking system. An ERD comprises entities, identifier and relationships. An entity is a tangible object of interest that exists in the user's domain. It is usually something of interest to the user and they (users) keep track of it. Collective noun, or nouns, are usually used to name (describe) entities. In this case the entities for the system for tracking information about improved crops were germplasm, crops, crossing, users, selection field testing, lab multiplication, field testing and tracking.

Administration user interface

Login page: This is an interface that gives the user access to the system when the application loads it, prompt the login interface which requires the user to enter the username and password and then click the login button. The login page for users is as shown in Figure 3.

Germplasm: Germplasm is a living genetic resource such as seeds or tissues that are maintained for the purpose of plant breeding, preservation, and other research uses. It can be a seed or another plant part like a leaf, a piece of stem, pollen or even just a few cells that can be turned into a whole plant. Germplasm collections can range from collections of wild species to elite, domesticated breeding lines that have undergone extensive human selection. The germplasm component contains information for a plant name, genetic makeup and a valuable natural resource of plant diversity. Genetic diversity of germplasm gives plant breeders the sustained ability to develop new high yielding, high quality varieties that can resist constantly evolving pests, diseases and environmental stresses. This component (Figure 4) allows scientists to capture and store information about germplasm. While entering germplasm records, it has germplasm name. It is a name given to the germplasm generated by the breeder. Institute is the institute where germplasm was generated from. Exact location is the location where the germplasm is located.

Conventional plant breeding: Can be seen as a collection of techniques aimed at bringing together good parents to generate a better crop in the progeny. It is therefore essential for plant breeders to be entirely sure of what the parents of a cross are. Crosses between breeding stocks are generally done manually.

Category of information collected, stored and used on improved crops

As shown in Table 1 and Figure 5, different crop researchers collect different information depending on the research they are conducting. Most researchers collect

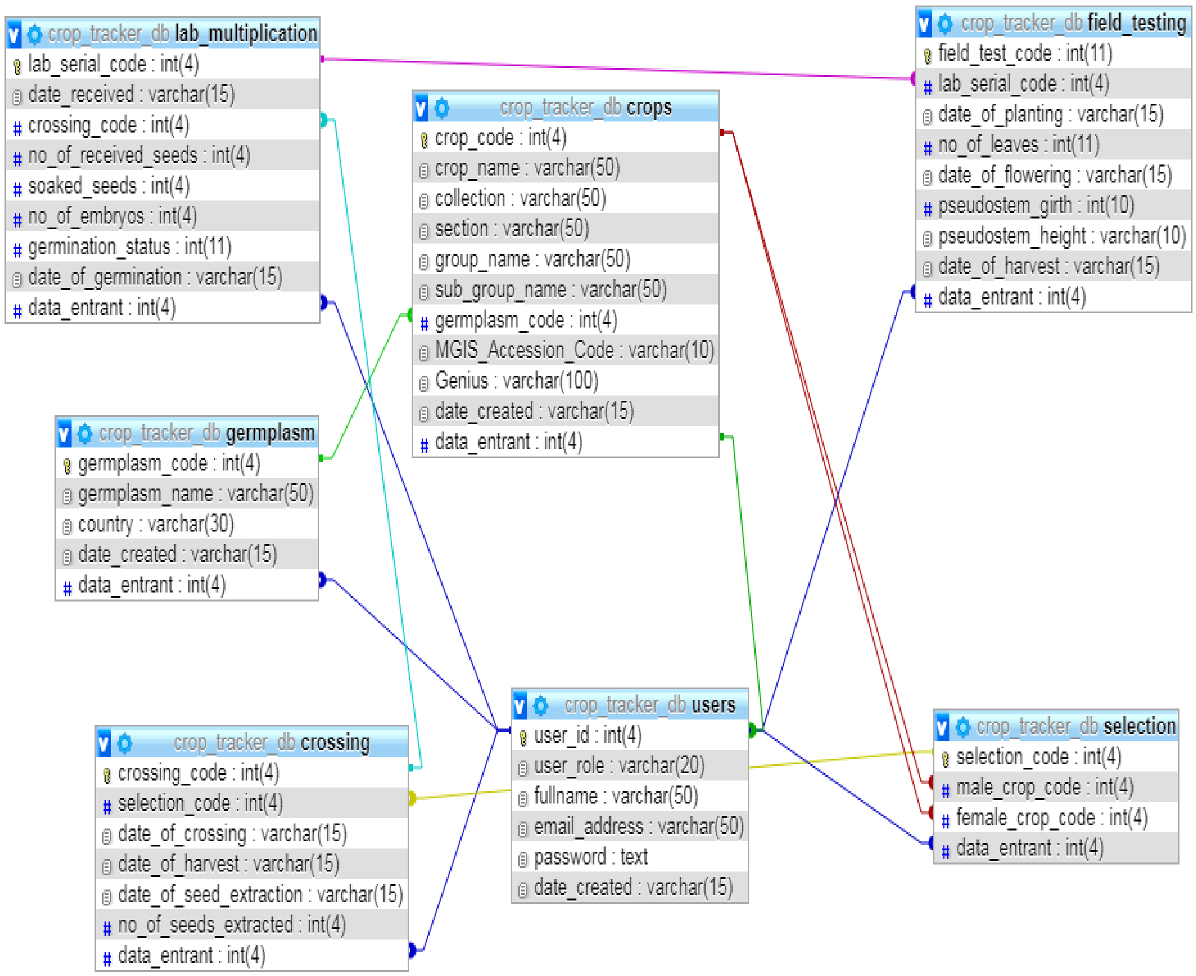

Figure 2. The entity relationship diagram for an information system for tracking information about improved crops.

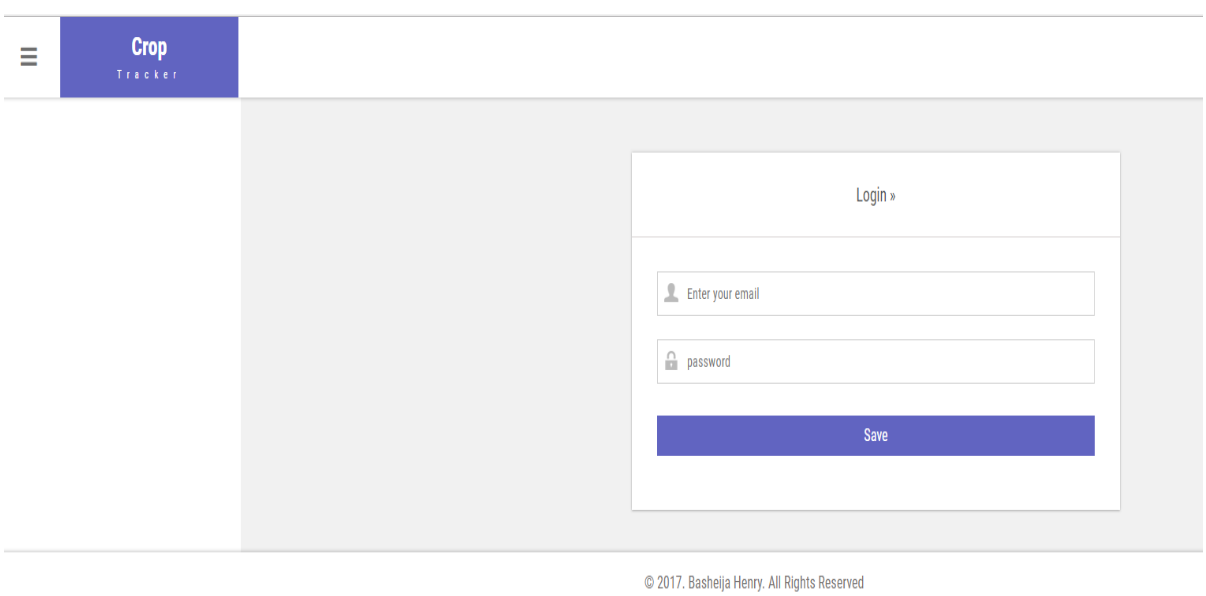

Figure 3. Crop tracker login.

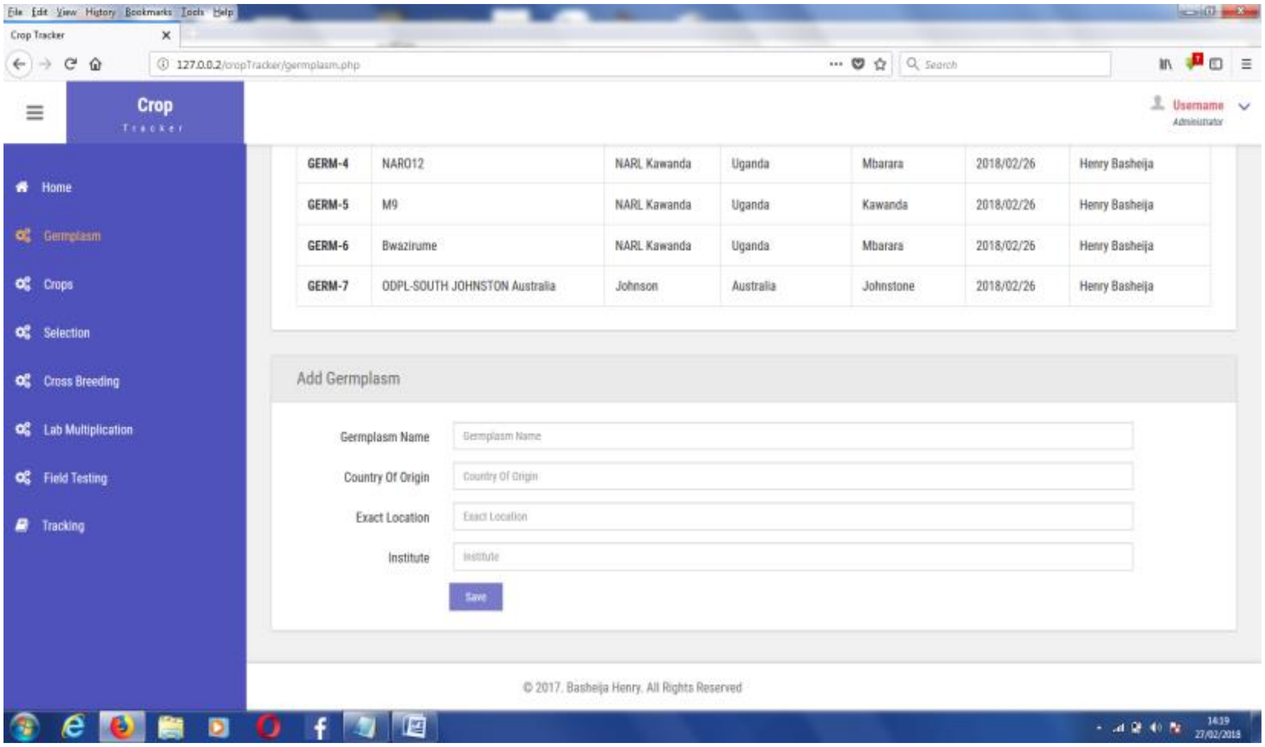

Figure 4. The interface for germplasm crops available in the system.

Table 1. Category of information collected on improved crops.

Information category	Total number of respondents	Frequency	Percent
Breeding	50	40	80
Diseases	50	32	64
Pests	50	31	62
Others	50	13	26

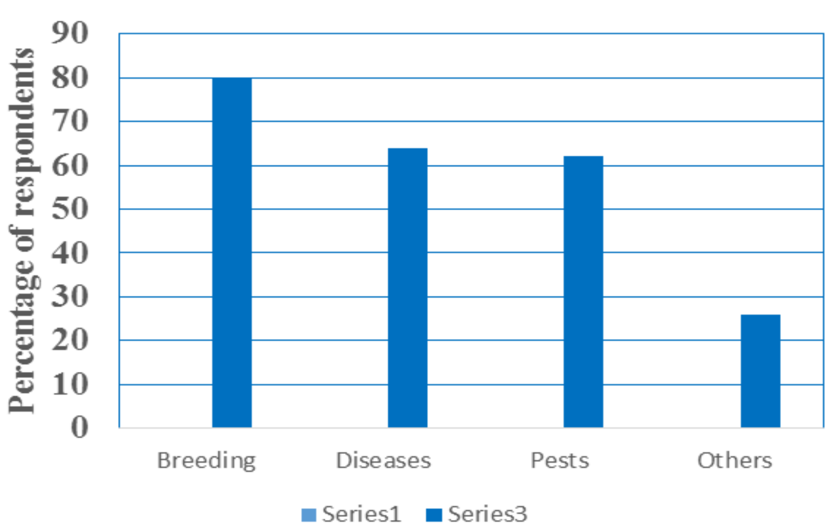

Figure 5. Category of information collected about improved crops.

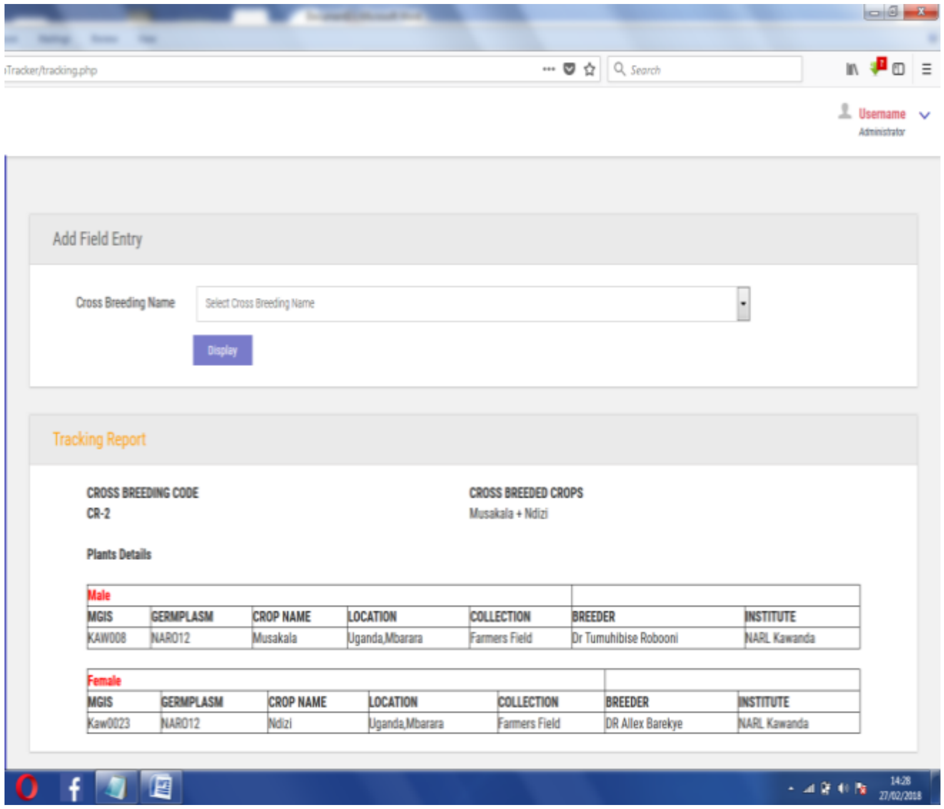

Figure 6. Crop tracking interface.

information about breeding at 80%, 64% collect information about diseases, while 62% collect information about pests.

Tracking: After the plant has gone through the breeding process, users (scientists) can search the system to find the origins of the new crop, that is, the female and male parents. Through this functionality, the user can know the origin of the new crop. This is hoped to help young researchers to know the source of good breeding materials to use in breeding tracking interface. This is hoped to help young researchers to know the source of good breeding materials to use in breeding tracking interface (Figure 6). The system was effective in storage, tracking and dissemination of research data collected during the breeding of improved banana. The system needs validation in different agricultural research programs. Control of entry into the system is based on user names and password. However, the level of security can be increased through adding another layer of security such as encrypting information during transmission and/or biometrics.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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