The Andhra Agric. J 71 (3): 246-251, 2024
doi :10.61657/aaj.2024.124

INVITED ARTICLE

Citrus germplasm information system using 3 Tier Architecture

V V Sumanth Kumar, Guntukogula Pattabhi Sandeep, I P Singh, D D Banerjee and Sneha Patel
ICAR-National Academy of Agricultural Research Management, Rajendranagar, Hyderabad

ABSTRACT

The systematic conservation and management of Plant Genetic Resources (PGR) play a pivotal role in combating environmental stresses and ensuring global food security. The increasing challenges of preserving and utilizing genetic diversity in plants, coupled with the need for advanced tools to manage germplasm data, have necessitated the development of efficient, scalable systems. This study presents the design and implementation of a Citrus Germplasm Relational Information System (CGRIS), a 3-tier architecture-based solution developed for efficient data management of citrus germplasm. CGRIS addresses the challenges associated with managing complex datasets, offering an advanced system architecture that integrates client, middle, and database tiers. The client tier, represented by a web browser, provides an intuitive graphical user interface (GUI) for users to interact with the system. The middle tier, powered by Apache HTTP Server and Tomcat engine, handles the application logic, mediating between the user interface and the database. The database tier, implemented on a MySQL server, stores a wide array of data types, including numeric, text, and binary data, enabling users to perform diverse queries and analyses. The system architecture ensures robust transaction management, concurrency control, and efficient data retrieval processes. CGRIS was developed on a Linux platform using CentOS Linux as the operating system, with hardware including Intel Pentium processors and server-side logic was implemented using Java Server Pages (JSP) and PHP technologies. The relational database was structured to facilitate the association of disparate datasets through a central accession ID. This unique identifier enables the integration of multiple data types, enhancing the system's analytical capabilities and providing comprehensive insights into the citrus germplasm collection. To evaluate the system's performance, data from citrus germplasm collected from various countries were loaded into the database. Testing focused on the efficiency and robustness of data loading, updating, and querying processes. Results demonstrated the system's ability to handle complex datasets, ensuring fast

Dr V V Sumanthkumar
Principal Scientist, ESM Division,
National Academy for Agricultural Research Management
Rajendranagar, Hyderabad 500 030

Dr Sumanth Kumar serving as a Principal Scientist at Education Systems Management program of National Academy for Agricultural Research Management (ICAR-NAARM), Hyderabad. In this capacity he oversees the activities of ICT Tools for Agricultural Education and works Artificial Intelligence applications and tools suitable to the Indian National Agricultural Education and Research System. He designed and developed various IT tools for better dissemination of knowledge and best practices generated at agri research organizations to different stakeholders by leveraging high end digital technologies based on cloud. He has got vast expertize on how IT can help in bringing the socio-economic development of rural youth and farmers; communicating masses; organizing capacity building programs; coordinating with government departments. Currently he is working on a AI powered e-learning platform for Indian Agriculture named "AgAcademy". Prior to joining ICAR-NAARM, Dr Sumanth worked at International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, Directorate of Groundnut Research, Junagadh, Gujarat and Central Cirtus Research Institute, Nagpur. He also contributed to the projects of several national and international agencies in various capacities that include World Bank funded National Agricultural Innovation Project; GoK; SEWA; ANGRAU; AgMIP; DGR; NRCC, USDA; UKaid; University of Florida; World Bank etc. He is a Oracle 10g Certified Professional and also VMWare Certified Cloud expert.

retrieval and seamless interaction. Additionally, the user-friendly interface and analytical tools were developed to maximize accessibility and usability for researchers, agricultural scientists, and policymakers. The adoption of CGRIS offers significant advantages over conventional, paper-based record-keeping methods. Traditional methods pose challenges in terms of data preservation, retrieval, and accessibility. CGRIS overcomes these limitations by providing a reliable, scalable solution for managing voluminous data related to citrus germplasm. Its advanced features include flexibility, granularity, and the ability to link related datasets, making it an indispensable tool for the effective conservation and utilization of plant genetic resources. In conclusion, CGRIS serves as a model system for managing PGR data efficiently. The relational database management system developed for citrus germplasm at the ICAR-Central Citrus Research Institute, Nagpur, has proven effective in identifying promising accessions from the vast collection. The system's design enables future expansions, including the adoption of database standards and broader applications in PGR conservation. The integration of technological advancements and relational database principles positions CGRIS as a critical tool for addressing the challenges of genetic resource management and ensuring sustainable agricultural practices.

Keywords: *3-Tier Architecture, Citrus Germplasm Resources, Germplasm Conservation, and Plant Genetic Resources (PGR)*

The plant genetic resources community has put huge amounts of effort into systematically generating, gathering and storing plant data in germplasm collections. The motivation for these efforts is to quantify and preserve genetic diversity in plants and facilitate the selection of germplasm for utilization in breeding projects. New approaches to maintaining and analyzing genetic resources, alongside the technological advances made within the genomics revolution, have resulted in the generation of substantial amount of data of varying types for many plant species. However, most plant databases hold limited subsets of data and do not offer many opportunities to link between the different types of data, limiting the investigations which can be carried out on the germplasm. We propose 3-Tier architecture for conservation and management of germplasm information as it provides finer granularity. Granularity is the ability of a system, in this case, germplasm application, to be broken down into smaller components or granules. The finer the granularity, the greater the flexibility of a system. The proposed three-tier architecture enforces a general separation between the following three parts *viz,* Client Tier or user interface, Middle Tier or business logic and Data Storage Tier. The client tier interacts with the user through GUIs (Graphic User Interfaces) and with the application and the application server. In the proposed application, the client tier is a web browser. It communicates with other tiers by outputting results to the browser/client tier and all other tiers in the network. This layer calls custom tags throughout the network and to other networks. It also calls database stored procedures and web services, all in the goal of providing a more sophisticated response. It is located in the application server.

An efficient management of data related to Plant Genetic Resources (PGR) has become very essential for researchers, agricultural scientists and policy makers for research and reference purposes. We at the ARIS cell of Central Citrus Research Institute addressed this problem of managing data related to citrus germplasm material. A 3 tier relational information system is designed and developed using client-server approach. CGRIS is the Relational Database support system for the collected information on the germplasm of Citrus. We want to implement CGRIS in Linux using Apache/Tomcat as Application Server and MySql as the Database Server. The Server side logic has been implemented by using Java Server Pages (JSP™) and/or PHP Technologies.

Development of Citrus Germplasm Resource Information System (CGRIS) is an attempt to address the problem of managing data related to citrus germplasm material. CGRIS increases the scope of the distribution of citrus germplasm available at ICAR-Central Citrus Research Institute, Nagpur to researchers spread over India. The main goal of this software is to give working solutions to researchers in identifying the required germplasm for conducting experiments.

MySql™ cs database server, Tomcat™ js application server and Java Server Pages are used for implementing the programming logic. The efforts shall be focused on the graphical user interface, which shall not be restricted to static pages, rather the user can experience a dynamic environment, in which he or she can navigate in a natural way. Its abilities are

demonstrated on the concrete application of CGRIS. The CGRIS has been designed using platform independent methodology and implemented using HTML, Java & JSP. An efficient Database Management System like CGRIS proved very useful in identifying promising accessions from the vast working collection available at the ICAR-Central Citrus Research Institute, Nagpur.

The genetic resources community has put huge amounts of effort into systematically generating, gathering and storing plant data in germplasm collections. The motivation for these efforts is to quantify and preserve genetic diversity in plants and facilitate the selection of germplasm for utilization in breeding projects. In order to combat new environmental stresses as they are encountered and to ensure future food security, it is vital to use the biodiversity that has been so carefully preserved in these germplasm collections. The characterization and analysis of plant genetic resources are integral to the usefulness of germplasm collections. New approaches in maintaining and analyzing genetic resources, alongside the technological advances like genomics revolution, have resulted in the generation of substantial amount of data of varying types in many plant species. However, most plant databases hold limited subsets of data and do not offer many opportunities to link between the different types of data, limiting the investigations which can be carried out on the germplasm.

MATERIAL AND METHODS

The system was developed using specific hardware and software tools to ensure optimal performance and efficiency. On the hardware side, the server utilized an Intel Processor 4X2.4 GHz with an original Intel Server Board, 16 GB RAM, and a 40 GB SCSI HDD. For client devices, the system required a normal desktop with any browser software for user interaction. The software setup included CentOS Linux as the server's operating system. The client-side interface was accessed through standard web browsers such as Internet Explorer or Chrome. The back-end database was managed using MySQL for Linux, which provided the required relational database management functionality. The web server, acting as the middle tier, was implemented using the Apache HTTP Server integrated with the Tomcat Engine to handle application logic and facilitate seamless interaction between the client interface and the database server. A relational database information system is designed and developed based on client-server approach. CGRIS has been designed as a relational database for the collected information on the germplasm of Citrus. CGRIS has been implemented in Linux machine using Apache/Tomcat as Application Server and MySql as Database Server. The Server side logic has been implemented by using Java Server Pages (JSP) Technologies. The database is designed to hold a range of data types, and shall permit users to query between these different types of data.

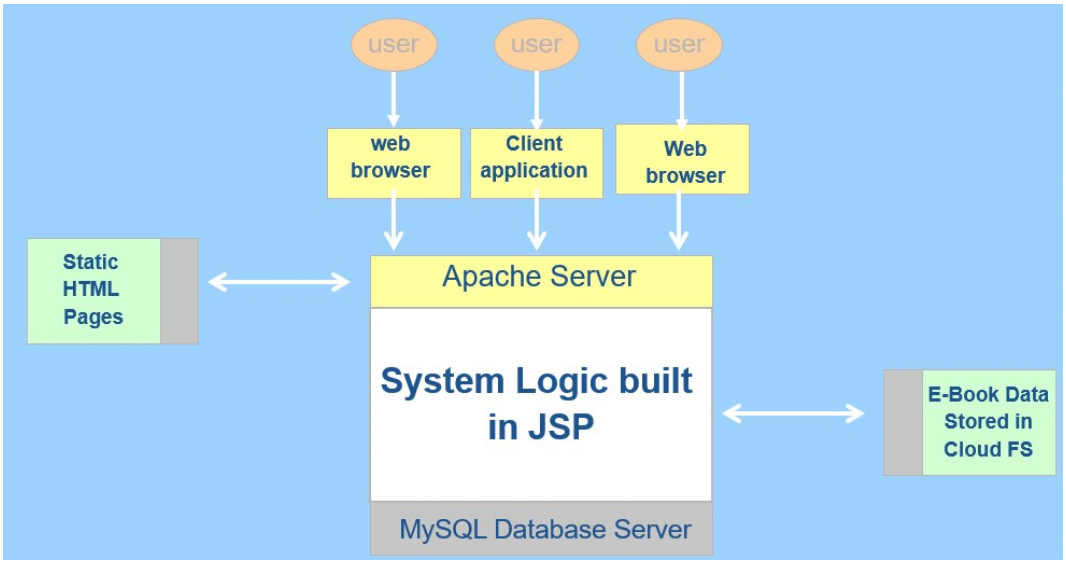

Figure 1. Architecture of CGRIS

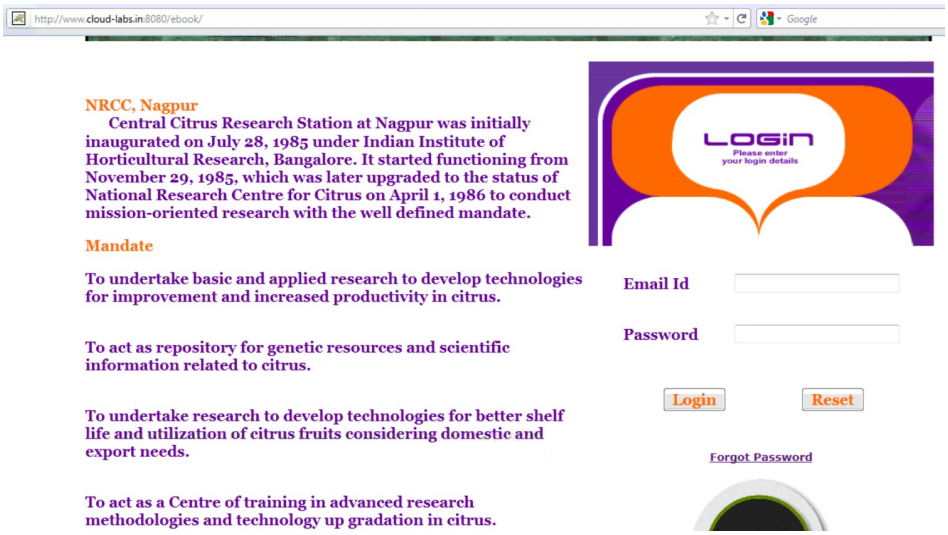

Figure 2. Login page of CGRIS

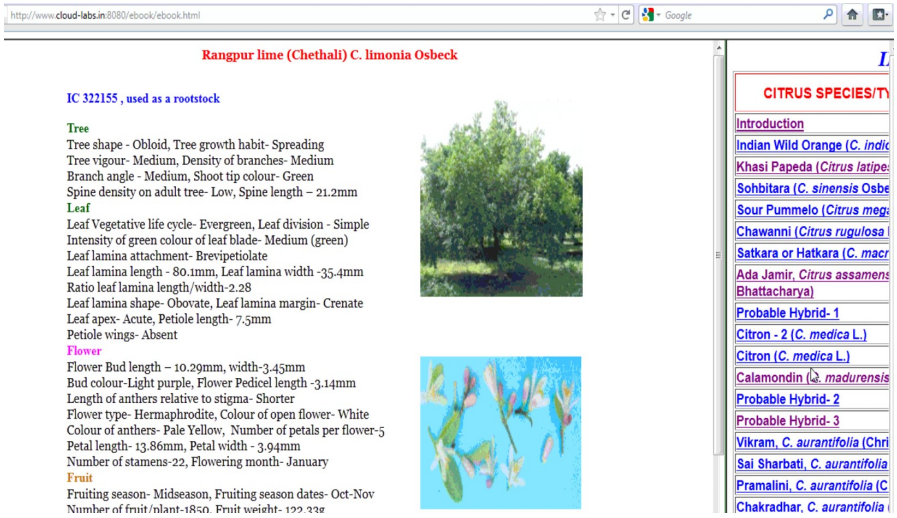

Figure 3. Browsing options in citrus germplasm

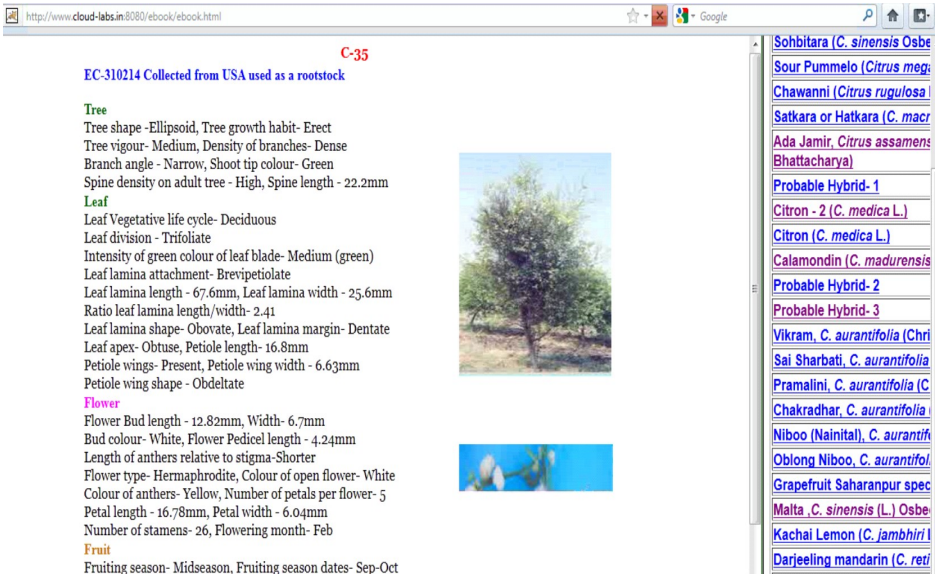

Figure 4. Browsing options in citrus germplasm

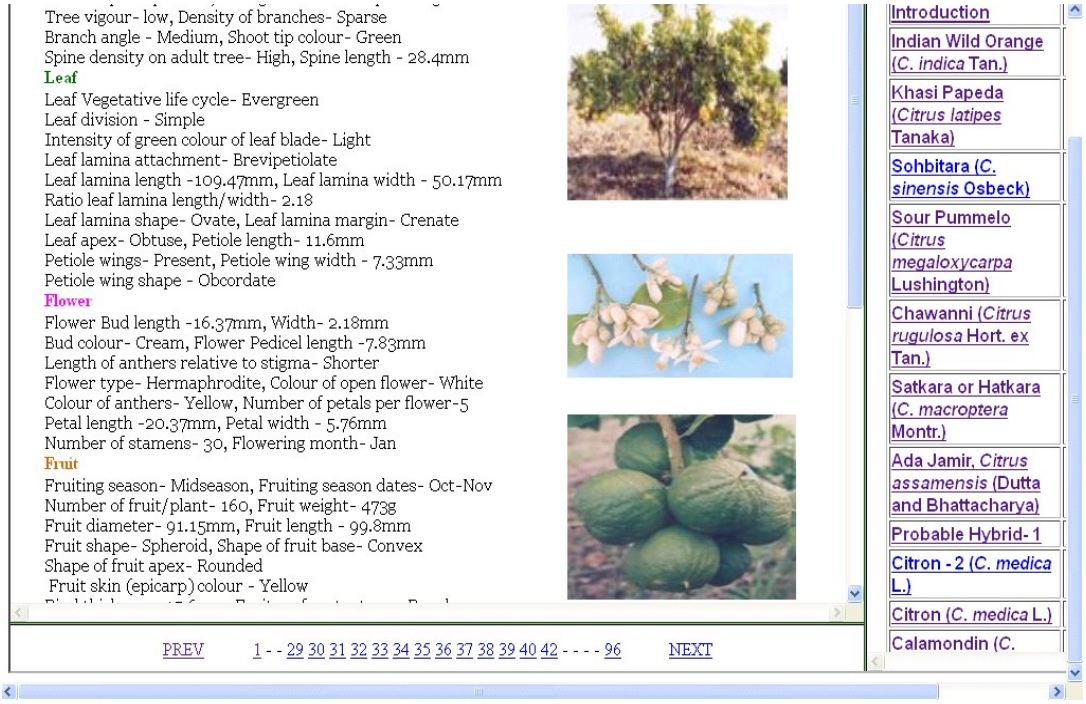

Figure 5. Browsing options in citrus germplasm

At the core of the system is data on the citrus germplasm acquired from various countries. A range of data types have been created based on integer and real numeric data, short- and long-text data and binary data. An additional cross-reference data-table relates any information to any other information in the database. In general, the reference table links the data to the accession with which the data is associated but the table is flexible enough to be used for other purposes. The data tables are structured in a way that allows the storage of information ranging from simple data, associated with a single accession or plant, to complex datasets and detailed text information.

RESULTS AND DISCUSSION

The system architecture of CGRIS is shown in the figure 1. The salient features of this software.

(a) Database Server: At the lowest layer CGRIS employs the Database Server. The Server receives requests from clients for various operations. The server is responsible for concurrency control, recovery, transaction and storage management. The Database Server is responsible for query processing and all the operations on CGRIS database. After initialization, the database server waits for a query from its client. The results of the query that are obtained by processing it are sent back to the client.

(b) The Web Server: This is the middle tier between the browser and the Database Server. The user interacts with the Form based GUI through browser and the request that is sent to the Database Server is served by the Web Server. The Web Server waits for the result of the request from the Database Server and sends it back to the browser in suitable form when it is received.

(c) Browser: The browser is the client side interface for interacting with the database server.

The system is developed using MySql as RDBMS. The system was developed in such a way that it becomes user friendly. CGRIS's use of a top level accession NRCC ID allows association between disparate sets of data. This allows for access of any information associated with a group of accessions and relation between different types of information through their association with an accession. The database is currently being implemented in the private domain using MySql RDBMS (http://www.mysql.com/). MySql forms an ideal platform to enable us to develop a range of standard interfaces and analytical tools to interact with the underlying database. As an initial step, various data from citrus was loaded into the CGRIS database and then efficiency and robustness of loading, updating and querying of data was tested. Further a flexible, user-friendly interface to the database and a broad set of analysis and visualization

tools to maximize the accessibility and usefulness of the stored data was developed. In addition, it is hoped that the future development of CGRIS will see database standards come to realization, and be accepted and expanded upon by those involved with development and utilization of CGRIS. Maintaining and accessing above information in record books (conventional, non-electronic media) poses problems associated with preservation of records on paper besides the difficulties in retrieval of desired information. Hence, one requires a system to manage the voluminous citrus data in an efficient way and to provide quick retrieval, is an imperative.

CONCLUSION

The development of the Cirtus Germplasm Resource Information System (CGRIS) represents a significant advancement in the efficient management and utilization of plant genetic resources, specifically for citrus germplasm. By leveraging a three-tier architecture, CGRIS successfully integrates a robust database server, an interactive web server, and a user-friendly browser interface. This architecture not only ensures efficient data storage, retrieval, and management but also enhances the system's flexibility and scalability. CGRIS's design and implementation using MySQL, Apache/Tomcat, and Java Server Pages have demonstrated its capability to handle a wide range of data types and queries effectively. The system's innovative use of cross-reference data tables enables seamless association between disparate datasets, thereby allowing researchers to explore relationships and access comprehensive information linked to specific accessions.

Initial testing has confirmed the system's efficiency and robustness in data loading, updating, and querying. Furthermore, the dynamic and graphical user interface facilitates intuitive navigation, making the system accessible and user-friendly for researchers, agricultural scientists, and policymakers. The ability to link, analyze, and visualize diverse data types significantly improves the utility of CGRIS in identifying promising germplasm accessions for research and breeding purposes.

This database-driven approach addresses the limitations of traditional paper-based record-keeping, which often suffers from inefficiencies in data retrieval and preservation. CGRIS ensures that the vast volume of germplasm information can be efficiently managed, preserved, and accessed, thereby supporting the larger goal of biodiversity conservation and sustainable agricultural practices. Looking ahead, the continuous development and standardization of CGRIS are anticipated to further enhance its applicability and acceptance within the scientific community. This will enable broader dissemination of citrus germplasm data, facilitating collaboration and innovation in crop improvement programs across India and beyond. The successful implementation of CGRIS underscores its potential as a model for developing similar systems for other crops, ultimately contributing to global efforts in food security and agricultural sustainability.

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Received on 13.06.2024 and Accepted on 02.07.2024