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Sunil Neelam
Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Rajendranagar, Hyderabad, India

Srinivasa Rao Nukella
Information and Communications Management Division, ICAR-NAARM Rajendranagar, Hyderabad, India

Chikkappa G Karjagi
ICAR-Indian Institute of Maize Research, Pusa Campus, New Delhi, India

Chandrasekhar Javaji
Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Rajendranagar, Hyderabad, India

Om Prakash Yadav
ICAR-Central Arid Zone Research Institute Jodhpur, India

Correspondence
Sunil Neelam
Winter Nursery Centre, ICAR-Indian Institute of Maize Research, Rajendranagar, Hyderabad, India

Decision support system for efficient utilization of maize germplasm for hybrid development

Sunil Neelam, Srinivasa Rao Nukella, Chikkappa G Karjagi, Chandrasekhar Javaji and Om Prakash Yadav

Abstract
A Decision Support System (DSS) for efficient utilization of maize inbred line germplasm has been developed using the latest version of Drupal (7.34); Hypertext Preprocessor (PHP) was used for frontend development and database (backend) was developed in My Structured Query Language (MySql). The DSS houses a database with information on 12 traits *viz*. days to 50% anthesis, days to 50% silk emergence, density of spikelets, number of kernel rows, grain type, plant height, ear placement height, anthocyanin colouration at base of glume, anthocyanin colouration of anthers, anthocyanin colouration of silks, kernel row arrangement and 1000-kernel weight against each inbred lines in addition it has *Image Library* feature which displays ear and tassel images of the maize inbred lines. The system was designed as per the requirements and available at http://wnciimr.org. The DSS is first of its kind developed for maize in India. It helps in taking informed decision to accelerate the utilization of germplasm. It significantly reduces the duplicity of experiments to generate information on simply inherited traits and thus, enhances the scientific productivity to a great extent.

Keywords: maize; inbred; germplasm; decision support system; database

Introduction
The challenges faced by agriculture production systems today are diverse and sometimes interlinked with one another. The solutions to such challenges need to be in line *i.e.* having a holistic and integrated systems approach. One of the major challenges is to enhance the productivity of major food crops under changing climate and maize is no exception. Application of knowledge or information generated will greatly facilitate to find solutions to the problems faced while meeting the challenges. In fact the availability of information would greatly facilitate to focus and direct research activities to achieve desired results. However, difficulty in accessing information may act as major limitation while developing suitable strategies to face the emerging challenges. Nonetheless, development of digital tools which support, aid and abet the researcher for better and efficient decision making or planning his/her research will play a crucial role, especially in the present context where wealth of information being generated. Kaul *et al*. (2017) [5] have touched upon the existence of various databases for plant genetic resources in general and maize in particular. The need of the hour is a user friendly Decision Support System (DSS) which can store the existing authenticated information and be amenable to retrieve, arrange, interpret and make decisions based on the existing/ generated information. DSS tools may cater to the specific area of research but a comprehensive outlook may be generated by developing a research tree involving all the areas of research domain with interlinking relevant areas of research. This paper deals with a DSS for identifying the prospective inbred line with combination of desired trait(s) for developing potential hybrids in maize.

Maize improvement in India has charted a unique success story during 1950-2015 with respect to expansion in maize area (3.3 to 8.69 million ha) and increase in production (from 1.7 to 22.57 million ton) and productivity (from 547 to 2597 kg/ha). The larger part of the above success has been attributed to recent surge in the adoption of hybrid technology. The basic elements of the hybrid technology in maize are inbred lines, which are developed by cyclic selection and advancement through selfing in the broad base segregating germplasm/populations like landraces and exotic germplasm over six (S_6) to seven (S_7) generations. However, availability of information on morphologically desirable phenotypes, their pedigree, source etc. generated based on the characterization will greatly facilitate selection of inbred lines/any germplasm to use in regular breeding programme. In addition, it also reduces time to initiate any specific breeding programme considerably. Presently around 2500 inbred lines with diverse genetic background are being maintained at Winter Nursery

Centre, Indian Institute of Maize Research, Hyderabad. The considerable amount of information has been generated on these inbred lines through characterization for various aspects like disease resistance, prolificacy, maturity, kernel traits, plant aspects etc. However, the information is available and lying with limited number of researchers. In order to make this information available to large pool of researchers spread across the nation, and also to facilitate them in the process of selection of inbred lines based on the already characterized data, a Decision Support System was developed.

Materials and Methods

The database was developed using the latest version of Drupal (7.34); Hypertext Preprocessor (PHP) was used for frontend development and database (backend) was developed in My Structured Query Language (MySql). The database is equipped with a general search facility and also trait filters which enable search of the germplasm accessions by either single filter or combination of filters. The database has been programmed to collate the documented traits and also the images of tassel and ear to help the scientists in their decision making. In addition, the database is kept dynamic to include additional features of inbred lines like its heterotic group, special traits etc. as and when the addition data gets generated.

System Architecture

Decision support system has been developed and implemented using Drupal (Butcher, 2010 and Todd, 2010) [1, 13] as it is open source content management framework and more flexible with Xampp server. Xampp stands for Cross-Platform (X), Apache (A), MariaDB (M), PHP (P) and Perl (P). It is a lightweight Apache distribution that makes it extremely easy for developers to create a local web server for testing and deployment purposes. Xampp is also cross-platform, which means it works equally well on Linux, Mac and Windows. The user interface consisting of forms for accessing maize germplasm information, accepting information from the user and validate those forms at server side using PHP scripting. PHP is a popular server-side scripting language for the web (Lambert, 2010) [6]. The database has been implemented using MySQL (DuBios, 2007 and Dyer, 2008) [2, 3]. PHP is particularly good at interacting with MySQL databases and MySQL is a powerful open access relational database for creating data warehouses. The relational approach has been used to design the database. The fundamentals of normalization theory have been used to normalize different tables of the database. All tables have proper interaction among themselves via primary key – foreign key relationship.

Database design

Data on Maize germplasm were collected and maintained by Winter Nursery Centre, Indian Institute of Maize Research (IIMR), Hyderabad, India. The database consists of information on 12 traits *viz*. days to 50% anthesis, days to 50% silk emergence, density of spikelets, number of kernel rows, grain type, plant height, ear placement height, anthocyanin colouration at base of glume, anthocyanin colouration of anthers, anthocyanin colouration of silks, kernel row arrangement and 1000-kernel weight against each inbred lines. This database has been used for the web development.

System design

The DSS of maize germplasm is developed as a web-based application using PHP, Drupal, Xampp and MySQL. Therefore, it is platform independent and can be accessed from any computer connected to the internet. The only requirement at the client side is a web-browser. The most commonly used web browsers are internet explorer 6.0 or above from Microsoft Corporation, Google Chrome from Google Corporation and Mozilla Firefox from Open Source. This application successfully runs on all the browsers. However, to avoid misuse of information, the login page will also be integrated.

Implementation and Deployment

The system was designed as per the requirements and available at http://wncciimr.org. For effective implementation of the system, the responsibility has been given to the nodal officer located at the IIMR for adding, updating and modifying the information in the master database at regular interval. In addition, web manager located at the National Academy of Agricultural Research Management (NAARM), India is responsible for maintenance, strengthening of website, creation of new modules *etc*. The data was stored as rules of inference for use during the reasoning process. The interface engine was designed to accept the user input queries and responses to questions through the Input Output interface. The user-friendly interface was developed with graphical user friendly (GUI) which allows the user to communicate with system in a simple selection way through menus. Through user-interface, the user is allowed to view, query the germplasm information.

Results and Discussion

The DSS on maize germplasm was developed based on the technical aspects and various symptoms. The system was hosted at http://wnciimr.org. The home page of this website consists of About Us, Search Database, Useful Links, Contact Us, Feedback and Login (Fig. 1).

The Login module allows the administrators to manage the data uploading and data handling. It allows entering all the available germplasm information with digital photographs, delete unwanted information from the database and modify the existing database *etc*. This tool facilitates data entry only through single source unlike the Maize GDB, wherein data from literature cited is entered through manual curation, data provided directly by the maize researchers with assistance from Maize GDB and also data from other databases is also entered (Harper *et al*., 2016) [4]. The user allows to access information from About Us, Search Database and Useful Links. The user is allowed to provide feedback from the Feedback option and can contact the concerned persons from Contact Us.

The main module of DSS is search database, that gives the different options such as Tassel, Ear, Kernel, Plant of maize inbred lines based on multiple traits, where one can select the required options (Fig. 2), which searches the entire database and gives the matching records in the next window (Fig. 3). From this list, user can select a required record by clicking the plot no. / pedigree and access the detailed information such as pedigree, seed image, year, season, tassel, days to 50% anthesis, days to 50% silk emergence, length of inbred lines, number of rows of grains, type of grains, row arrangement etc., for decision making (Fig. 4) and the *Image Library* feature provides the ear and tassel images of the search results

(Fig.5)

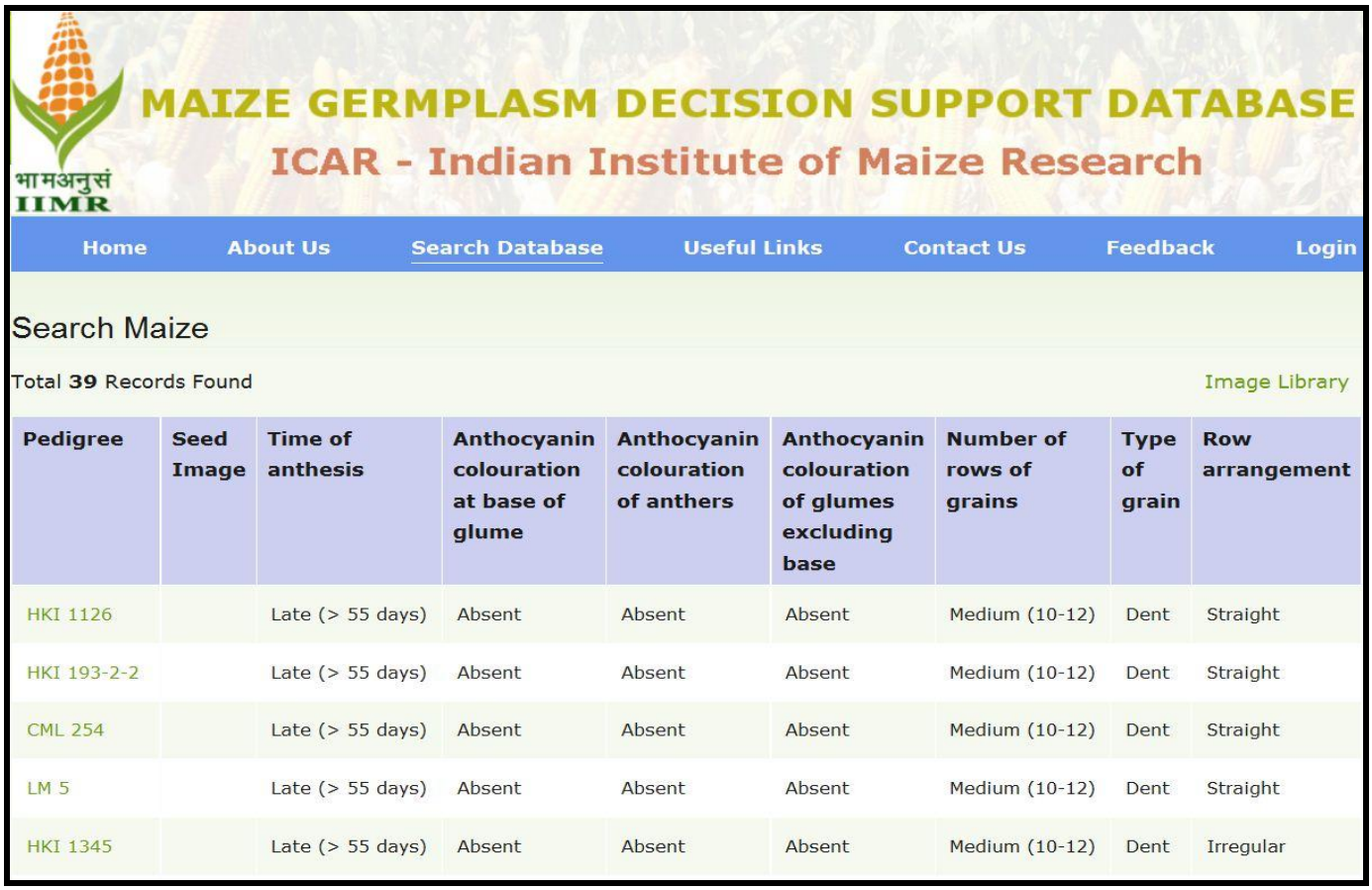
DSS serves the needs of the focused breeder by cutting down the time required for initiating breeding/research programme, preliminary selection of inbred lines to develop prospective hybrids. The key elements of the DSS are identification of the traits/characters that are needed for selection of inbred lines; there are 14 such traits housed in the DSS. The traits which were recorded in the field are supplemented with the images of the tassel and ears of the inbred lines as they form the primary source of information for short listing of lines. The DSS is supplemented with information on the pedigree of the germpalsm lines. The strength of the DSS lies in its potential to allow a permutation and combination of the traits and collating the information and displaying the same along with the images. The DSS has a provision for having the information such as Growing Degree Days (GDD) of the inbred lines. Our DSS meets most of the checklist for good design and development of DSS as outlined by Rose *et al*. (2016) [10] *viz.* Performance (tool has a useful function and works well), Ease of use (user interface easy to navigate), Peer recommendation, Trust (as it is evidence based), Cost (initial cost and recurring cost are not very high), Relevance to the user, IT education (the tool does not require any IT education for its use) and Facilitating conditions (compatibility with use of existing devices).

Although the present Decisions Support System builds on the earlier databases on maize at the international level for example GENESYS- a global portal to information about Plant Genetic Resources for Food and Agriculture (https://www.genesys-pgr.org/) and The Genetic Resources Program at CIMMYT manages CIMMYT's gene bank. The maize bank contains 28,000 samples of seed, including the world's largest collection of maize landraces – varieties developed by farmers over decades, centuries or even millennia – along with samples of maize's wild relatives, teosinte and *tripsacum*, and of improved varieties (http://www.cimmyt.org/seed-request/#maize) and at the national level *viz.* information on the parental lines of public-bred hybrids (Rakshit *et al*., 2008) [8] and documentation of the information on the public-bred cultivars including hybrids and OPVs (Kaul *et al*., 2008) [8] but the database provides a comprehensive information on established maize inbred lines with high-quality images of tassels and ears. The DSS is unique in the sense that it caters to the needs of breeders by supplementing their efforts and the beginners to take informed decisions while choosing inbred/parental lines based on information housed in the database. Of late the DSS are becoming part of many areas of agriculture research owing the complexity and profundity of the challenges being faced. For example, Navarro-Hellín *et al*. 2016 have discussed the importance of DSS in scheduling and managing irrigation; for calculating crop water stress index (along with all the selected traits). Recently, several decision support systems (DDSs) were developed across the global. In 2004, a Tobacco Germplasm Information System was developed by Central Tobacco Research Institute (CTRI) to store and retrieve information on tobacco germplasm data (Ravi Sankar *et al*., 2004) [9]. Herbal gardens of India (HGI), a web based decision making system was developed by Directorate of Medicinal and Aromatic Plants (DMAPR), provides information about the herbal gardens in India and facilitates the exchange of planting material (Srinivasa Rao *et al*., 2014) [11]. *DHMAPI: A Knowledge-Based System for Identification of Medicinal and Aromatic Plants* has been developed by DMAPR to help farmers and extension workers to identify medicinal and aromatic plants (Srinivasa Rao *et al*., 2015) [12].

As on date, the database has been updated with the information of over 300 maize inbred lines with full pedigree information. Additional feature of "Image Library" is also enabled to support the breeders in their decision support. The database is being updated with additional features *viz.* Growing Degree Days (GDD), year and season of evaluation, heterotic group, special traits etc. The database will be up for use once after addressing all the suggestions and concerns of the breeders/users.

Fig 1: Home page of website

Fig 2: Search options available in the DSS



Pedigree	Seed Image	Time of anthesis	Anthocyanin colouration at base of glume	Anthocyanin colouration of anthers	Anthocyanin colouration of glumes excluding base	Number of rows of grains	Type of grain	Row arrangement
HKI 1126		Late (> 55 days)	Absent	Absent	Absent	Medium (10-12)	Dent	Straight
HKI 193-2-2		Late (> 55 days)	Absent	Absent	Absent	Medium (10-12)	Dent	Straight
CML 254		Late (> 55 days)	Absent	Absent	Absent	Medium (10-12)	Dent	Straight
LM 5		Late (> 55 days)	Absent	Absent	Absent	Medium (10-12)	Dent	Straight
HKI 1345		Late (> 55 days)	Absent	Absent	Absent	Medium (10-12)	Dent	Irregular

Fig 3: Search for maize inbred lines based on multiple traits

Fig 4: Detailed record of each maize inbred line

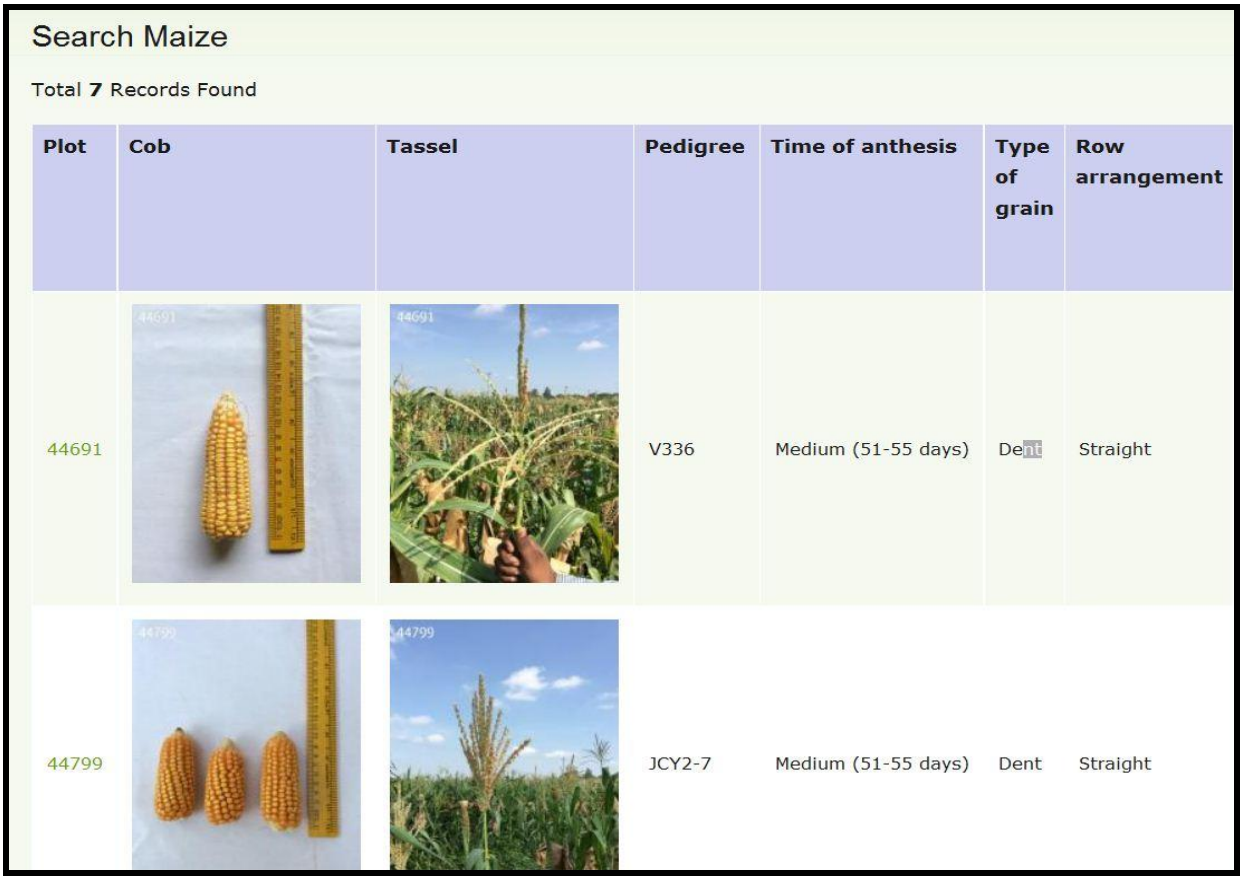


Fig 5: The *Image Library* feature displays the images of the cobs and the tassel of the inbreds along with data

Conclusions

In general, the decision support systems are developed for evidence-based decision-making in agriculture to achieve desired results depending on the objectives. Our decision support database with information on the trait search and image information of the maize inbred lines would serve the maize breeders in making better-learned choices. The database is first of its kind developed for maize in India. The database helps in taking informed decision to accelerate the utilization of germplasm with useful traits based on already existing information/ knowledge regarding the germplasm. It significantly reduces the duplicity of experiments to generate information on simply inherited traits and thus, enhances the scientific productivity to a great extent.

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References

1. Butcher M, Garfield L, Wilkins J. Drupal 7 Module Development. Packt Publishing Ltd., 2010.
2. Du Bois P. MySQL Cookbook. *O'Reilly Media, Inc*. 2007.
3. Dyer R. MySQL in a Nutshell. *O'Reilly Media, Inc*. 2008.
4. Harper LJ, Gardiner C, Andorf, Lawrence CJ. MaizeGDB: The Maize Genetics and Genomics Database. In Plant Bioinformatics: Methods in Molecular Biology Eds., Edwards D. vol 1374. Humana Press, New York, NY, 2016.
5. Kaul J, Kumar R, Nara U, Khushbu J, Dhirender O, Tanu T *et al*. Development of Database of Maize Hybrids and Open Pollinated Varieties Released and Notified for Cultivation in India. Journal of Agricultural Science. 9. 105. 10.5539/jas.v9n10p105., 2017 Available at: http://www.ccsenet.org/journal/index.php/jas/article/view/68858.
6. Lambert M, Surhone, Miriam Timpledon T, Susan Marseken F. Xampp. VDM Publishing., 2010
7. Navarro-Hellín H, Martínez-Del-Rincon J, Domingo-Miguel R, Soto-Valles F, Torres-Sánchez R. A decision support system for managing irrigation in agriculture. Computers and Electronics in Agriculture. 2016; 124:121-131.
8. Rakshit S, Kaul J, Dass S, Singh RP, Singh SB, Gupta NP, Singh RP. Compendium of extant maize hybrids and composites of India (1992-2007). Technical Bulletin 2008/2 (p. 64). Directorate of Maize Research, 2008.
9. Ravisankar H, Sarala K, Murthy TGK, Rao RVS, Srinivasa Rao N. Tobacco Germplasm Information System. Tobacco Research, 2004; 30(1):48-51
10. Rose DC, Sutherland WJ, Parker C, Lobley M, Winter M, Morris C *et al*. Dicks Lynn. Decision support tools for agriculture: Towards effective design and delivery, 2016. Available at: http://creativecommons.org/licenses/by/4.0/ [Accessed December 29, 2016].
11. Srinivasa Rao N, Geetha KA, Maiti S. Web-based networking of herbal gardens for exchange of planting material. Computers and Electronics in Agriculture, 2014; 103:26-32.
12. Srinivasa Rao N, Geetha KA, Maiti S. DHMAPI: A knowledge based system for identification of medicinal and aromatic plants. International Journal of Applied research on information technology and computing. 2015; 6(3):177-188.
13. Todd Tomlinson. Beginning Drupal 7. Apress, USA, 2010.