Hungarian Association of Agricultural Informatics
European Federation for Information Technology in Agriculture, Food and the Environment

Journal of Agricultural Informatics. Vol. 8, No. 2
journal.magisz.org

Pests and disease diagnostic mobile tool "m-wheat" for wheat crop in ethiopia

Paul Mansingh, J.[1], Velmurugan, L.[2], Dejene Techane Shenkuta[3], Debella Deressa Bayissa[4]

I N F O
Received 30 May 2017
Accepted 16 Jul. 2017
Available on-line 14 Aug 2017
Responsible Editor: M. Herdon

Keywords:
Android Mobile Application in Agriculture, eAgri, ICT in Agriculture, mAgri,
Pests and Diseases Diagnostic Mobile Tool

A B S T R A C T

Information is power only when used and applied. Farm Management Information Systems in agriculture have evolved from simple farm recordkeeping into sophisticated and complex systems to support production management. African agriculture is largely traditional and practised by smallholders and pastoralists, predominantly rain-fed, has low-yielding production, and lacks access to critical information, market facilitation, and financial intermediation services. The role that Information Communication Technologies (ICT) can play in addressing these challenges is increasing. Mobile technology, on the other hand, is increasingly being adopted as the technology of choice for delivery of ICT services and solutions. New applications present an opportunity like no other to revolutionize life for farmers. The mobile is not only a communication tool, in future, it will be an important agricultural tool for the farmers. Most mobile applications focus on improving agriculture and have a wide range of functions, such as providing market information, increasing access to extension services, and facilitating market links. For extension workers, it is an additional tool in their kit in the technology transfer. For scientists, it acts as a readily available reference on demand and for students in agriculture, it acts as a learning tool. Mobile application for pest and disease management of crops is an application that allows farmers to identify pests and diseases using their mobile phones and provides remedial measures is the latest addition to using modern digital tools to benefit smallholder farmers. Ethiopia is the largest wheat producer in Sub-Saharan Africa. Wheat is the 4th important cereal crop in the country. Although Ethiopia is the largest wheat producer in Sub-Saharan Africa, it is reliant on foreign wheat imports to satisfy its annual domestic demand. Considering its importance, and also in recent years the crop was affected by rust disease and incurred significant economic loss, wheat crop was selected for this pilot study. Keeping this in to consideration, the mobile application namely, m-WHEAT, was developed, as a pests and diseases diagnostic tool for major pests and diseases of Wheat crop in Ethiopia. The application is developed using android with the help of Extensible Markup Language (XML) for encoding documents in machine-readable form and includes java development tools. The XML based user interface with Java programming in Android SDK is developed to present pests and diseases of wheat and its control measures.

1. Introduction

Information is data that is accurate and timely, specific and organised for a purpose, presented within a context that gives it meaning and relevance and can lead to an increase in understanding and decrease in uncertainty (http://www.businessdictionary.com/definition/information.html). Information is

[1] Paul Mansingh, J.
Professor, Department of Rural Development and Agricultural Extension, Ambo University, Ambo, Ethiopia.
paul461967@gmail.com
[2] Velmurugan, L.
Velmurugan, L., Professor, Department of Computer Science, Ambo University, Ambo, Ethiopia.
vel.erode@gmail.com
[3] Dejene Techane Shenkuta
Assistant Lecturer, Department of Information Technology, Ambo University, Ambo, Ethiopia
dejene.techane@gmail.com
[4] Debella Deressa Bayissa
Lecturer, Department of Rural Development and Agricultural Extension, Ambo University, Ambo, Ethiopia
dabalaataf@gmail.com

valuable because it can affect behaviour, a decision or an outcome. Information is power only when used and applied (Boon 1992; Martin 1984; Paez-Urdaneta 1989) effectively.

Knowledge management includes knowledge sharing, exchanging, and dissemination as elements. The main purpose of knowledge management is to transform information and intellectual assets into enduring value (Metcalfe 2005). The basic idea is to propel the development by using the wealth of information for the benefit of community.

There is a wide, and probably growing, gap between the scale of the problems we face and the scale of the solutions on offer. New methods for advancing social innovation are relevant in every sector especially in fields where new possibilities (such as mobile technologies and open source methods) are not being adequately exploited. Farm Management Information Systems (FMIS) in agriculture have evolved from simple farm recordkeeping into sophisticated and complex systems to support production management (Fountas et al. 2015).

African agriculture is largely traditional and practised by smallholders and pastoralists. This type of agriculture is predominantly rain-fed, has low-yielding production, and lacks access to critical information, market facilitation, and financial intermediation services. Information and Communication Technologies (ICTs) can help poor people improve their lives. They have the potential to reduce poverty, deliver basic education, improve agricultural outputs, increase access to healthcare information and improve incomes (http://www.rgs.org/NR/rdonlyres/27A6CB1E-5AAE-4B8C-A42C-FBFD6569A20C/0/ICTsAtechnologicalfix.pdf). The role that ICT can play in addressing these challenges is increasing as personal ICT devices – such as mobile phones are becoming more widely available. ICT, when embedded in broader stakeholder systems, can bring economic development and growth as it can help bridge critical knowledge gaps. Mobile technology, on the other hand, is increasingly being adopted as the technology of choice for delivery of ICT services and solutions (Enock et al. 2012).

New applications present an opportunity like no other to revolutionize life for farmers. The mobile is not only a communication tool, in future, it will be an important agricultural tool for the farmers. Most mobile applications focus on improving agriculture and have a wide range of functions, such as providing market information, increasing access to extension services, and facilitating market links. For extension workers, it is an additional tool in their kit in the technology transfer. For scientists, it acts as a readily available reference on demand and for students in agriculture, it acts as a learning tool. The end users should find the applications easy to use and the technology should be cheap, available, reliable and can be run offline when necessary.

"Sub-Saharan Africa is currently undergoing a mobile digital revolution with consumers, networks and even media companies wakening up the possibilities of 3G and 4G technology," said Fredrik Jejdling, sub-Saharan Africa head of Swedish tech company Ericsson. In five years, the research predicts, voice call traffic in Sub-Saharan Africa will double and there will be an explosion in mobile data, with usage growing 20 times between 2013 and 2019, twice the anticipated global expansion (Ericsson Mobility Report 2014).

Mobile subscriptions in sub-Saharan Africa is predicted to rise, to about 1030m and smart phone subscriptions 800m by 2022 (Ericsson Mobility Report 2016). It is estimated that three in four mobile subscriptions will be internet inclusive by 2022. The growth is attributed to the rise of social media, content-rich applications and video content accessed from a new range of smartphones costing less than $50 (£30) (Ericsson Mobility Report 2014). Access to mobile broadband in Sub-Saharan Africa has been rising steadily, with a current penetration rate of around 35 percent. Affordability is also driving the increase in mobile broadband uptake in Sub-Saharan Africa. Alongside declining data prices, which is stimulating traffic, there is an increase in the accessibility of smartphones due to lower prices as a result of subsidies and access to purchase plans (Ericsson Mobility Report 2016).

The mobile has had a unique impact on Africa because of its relative lack of physical connectivity and access to reliable electricity. The report says that 70% of users in the countries it researched browse the web on mobile devices, compared with just 6% who use desktop computers. "Mobile users in the

region have shown a preference for using their device for a variety of activities that are normally performed on laptops or desktops" (Ericsson Mobility Report 2014).

Tele-density is rapidly increasing, as shown by the ITU ‘s ICT Development Index (IDI) (ITU 2010). Mobile penetration in rural areas is also growing strongly (ITU, 2010). In some African countries, more people have access to a mobile phone than to clean water, a bank account or even electricity. Mobile phones are now being used as a platform to provide access to the internet, to applications, and to government services. Africa is still at the beginning of its growth curve and, to date, most ICT applications have been pilot programmes. Now is the time for rigorous evaluation, replication and scaling up of best practice (Enock et al. 2012).

From its use in farming to banking, mobile technology is changing many lives in Africa - fast. Nearly two-thirds (65%) of households in 23 countries in sub-Saharan Africa had at least one mobile phone in 2013, with median growth of 27% since 2008 and median annual growth of 5%. In 2013, 80% of urban households had at least one mobile phone, compared with 63% of rural households that have at least one mobile phone. This is a change from six years ago when 63% of urban households had at least one mobile and 43% of rural households did. In Ethiopia, the percentage of households with at least one mobile phone in 2013 was 64% (http://www.gallup.com/poll/168797/africa-continues-going-mobile.aspx).

As quoted by Enock et al. (2012), Africa was once an ICT laggard, but is now becoming an ICT leader. In virtually every area of ICT – mobile, broadband, international bandwidth, PC penetration – Africa is closing the gap with the rest of the world and in some areas, like mobile financial services, it is setting the pace. According to David (2014), Africa's claim to be the "mobile continent" is even stronger than previously thought, with researchers predicting internet use on mobile phones will increase 20-fold in the next five years – double the rate of growth in the rest of the world. (https://www.theguardian.com/world/2014/jun/05/internet-use-mobile-phones-africa-predicted-increase-20-fold)

The Africa Scan provides an overview of ICT solutions in the agricultural sector in Africa: DrumNet-using ICT to bring together multiple stakeholders in Kenya, Sissili Vala Kori in Burkina Faso, Kilimo Salama-index-based agriculture insurance on agricultural inputs in Kenya, Liber- using ICT to improve forest governance in Liberia, MXit-in South Africa, and MedAfrica as a mobile application providing basic information about health and medicine, reducing the need for travel and the pressure on doctors. "Affordable access to mobile broadband is not a luxury, but a necessity in regions such as sub-Saharan Africa." Deloitte and GSMA research states that a 10% increase in mobile penetration in developing economies is likely to increase productivity by 4.2% (Deloitte 2014).

1.1 Problem Statement

Over the past 50 years, crop yields have grown at very different rates around the world as quoted by Syngenta Foundation (2011) (Annexure-1). The information and skills gap constrains the adoption of available technologies and management practices. As a result, most smallholder farming systems are much less productive and profitable than they could be (Syngenta Foundation 2011).

Limited access to education and basic crop information kept many farmers locked in a cycle of low productivity and poverty. In general, lack of awareness among traditional farmers contributes to the low level of adoption of agricultural-production technology. It seems that the extent to which information users in developing communities are able to handle information (i.e., the extent to which they use information) will also determine the usefulness of information as a development resource.

Although information is recognised as an important development resource and it is acknowledged that an absence of information may impede development (Boon 1992; Camble 1994), little has been done in the field of agricultural extension to determine the use of information among the farmers especially in the field of plant protection in Ethiopia through mobile phone.

A push towards higher productivity will require an information-based decision-making agricultural system. Farmers must get information at the right time and at less cost. Information asymmetry is an important contributor to overall transaction costs (De Silva & Ratnadiwakara, 2008). Mobile

applications are committed to create an end to end information symmetry consisting all the stakeholders, to ensure real time flow of customized information. It will help to reduce the inefficiency in the sector. In India, mobile applications are taking advantage of the high mobile penetration to help farmers improve their bottom lines. Jayalaxmi Agro Tech created an application to equip illiterate farmers with crop-specific information using audio-visual tools. Mandi Trades lists government crop price updates, important information for farmers in remote villages; RainbowAgri connects local buyers and sellers; and mPower Social offers simple veterinary advice for cattle owners.

Studies found ―mobile phones do have a multi-dimensional positive impact on sustainable poverty reduction and identified accessibility as the main challenge in harnessing the full potential (Bhavnani et al. 2008). More critical political economists (Leye 2009) contest the assumption that technologies are autonomous forces or independent variables causing change in every domain of human life.

Poverty is a multidimensional phenomenon, and lack of access to information and communication can exacerbate its causes. They see ICT not as an end in itself but as an important enabler. The strategic application of ICT to the agricultural industry, the largest economic sector in most African countries, offers the best opportunity for economic growth and poverty alleviation on the continent. Food security is paramount for the survival of individuals, families and ultimately nations, yet Africa's agriculture sector has been in decline over the past 40 years. Poor farmers have largely remained poor with 73 per cent of the people living in rural areas subsisting on less than a dollar a day.

The Ethiopian economy is mostly based on agriculture, with industry and services slightly increasing recently. The country's Gross Domestic Product (GDP) is US$54 798 million in 2014 with an annual growth of around 10 percent since 2004, placing Ethiopia among the fastest growing non-oil producing economies in Africa. Agriculture accounts for 42 percent of GDP in 2014 and about 85 percent of exports earnings in 2010. It also employs 83 percent of the active population (MoA 2011). Agriculture is primarily rainfed and thus highly dependent on rainfall. Smallholders dominate the sector and the land holding is increasingly fragmented. In 2015, there were 15.6 million agricultural households with an average farm size of 0.95 ha (CSA 2015). (http://www.fao.org/nr/water/aquastat/countries_regions/ETH/)

Pests and diseases in plants cause major production and economic losses in agricultural industry worldwide. Information on crop health and disease detection can facilitate the control of diseases through proper management strategies such as vector control through pesticide applications, fungicide applications, and disease-specific chemical applications; and can improve productivity (Sindhuja et al. 2010). Disease diagnosis based on the detection of early symptoms is a usual threshold taken into account for integrated pest management strategies. Early phytosanitary treatment minimizes yield losses and increases the efficacy and efficiency of the treatments (Alexander et al. 2017). Mobile application for pest and disease management of crops is an application that allows farmers to identify pests and diseases using their mobile phones and provides remedial measures is the latest addition to using modern digital tools to benefit smallholder farmers (http://www.icrisat.org/mobile-app-for-pest-and-disease-management-of-crops/).

The mobile diagnostic tool was developed to identify pests and diseases of wheat crops in Ethiopia as a pilot study. Ethiopia is the largest wheat producer in Sub-Saharan Africa and has a favourable wheat growing climatic environment. Predominantly grown by subsistence farmers under rain-fed conditions, wheat is the 4th important cereal crop in the country. Although Ethiopia is the largest wheat producer in Sub-Saharan Africa, it is reliant on foreign wheat imports to satisfy its annual domestic demand. Therefore, the Ethiopian government through the Agricultural Growth Program is active in efforts to improve the production and productivity of wheat to increase domestic supply (http://ethioagp.org/wheat-3/). Considering its importance, and also in recent years the crop was affected by rust disease and incurred significant economic loss (www.fao.org/emergencies/fao-in-action/stories/stories-detail/en/c/451063/), wheat crop was selected for this pilot study. Keeping this in to consideration, the mobile application namely, m-WHEAT, was developed, as a pests and diseases diagnostic tool for major pests and diseases of Wheat crop in Ethiopia.

2. Methodology

The database on pests and diseases of wheat was created by the research team. The data were obtained from Ambo Plant Protection Centre, Ambo, the District Agricultural Office at Ambo and Ambo Farm Service Centre. Also, data pertaining to the symptoms of pests and diseases were accessed and obtained from various web sites (Abraham 2008; Abraham 2009; Alem et al. 2015; Marco 2014 & Prescott et al. 1986). The relevancy of this database was checked by the scientists in Ambo Plant Protection Centre and experts in the District Agriculture Office besides the careful examination for its validity by the research team.

The database was categorised into: Name of the pest/disease, name of the pathogen (in the case of disease), symptoms (with description and photographs) and pest/disease management. The database was created in English, Amharic and Oromifaa. The application works both in online as well as in offline.

2.1. Design and Implementation

2.1.1 Requirement Specification

The application is developed using android with the help of Extensible Markup Language (XML) for encoding documents in machine-readable form and includes java development tools. All the environmental setup for the application development is as follows:

One of the greatest strengths of the Android platform is that it leverages the Java programming language. The Android SDK does not quite offer everything available to the standard Java Runtime Environment (JRE,) but it supports a very significant fraction of it. The Java platform has supported many different ways to work with XML for quite some time, and most of Java's XML-related APIs are fully supported on Android. For example, Java's Simple API for XML (SAX) and the Document Object Model (DOM) are both available on Android. Both of these APIs have been part of Java technology for many years. The newer Streaming API for XML (StAX) is not available in Android. However, Android provides a functionally equivalent library. Finally, the Java XML Binding API is also not available in Android. This API could surely be implemented in Android.

2.1.2 Design Approach

The XML based user interface with Java programming in Android SDK is developed to present pests and diseases of wheat and its control measures. The scheme of operation is as sketched in the dataflow diagram. The end user can use this application offline and feedback can be sent to admin by online.

2.1.3 Flow Chart

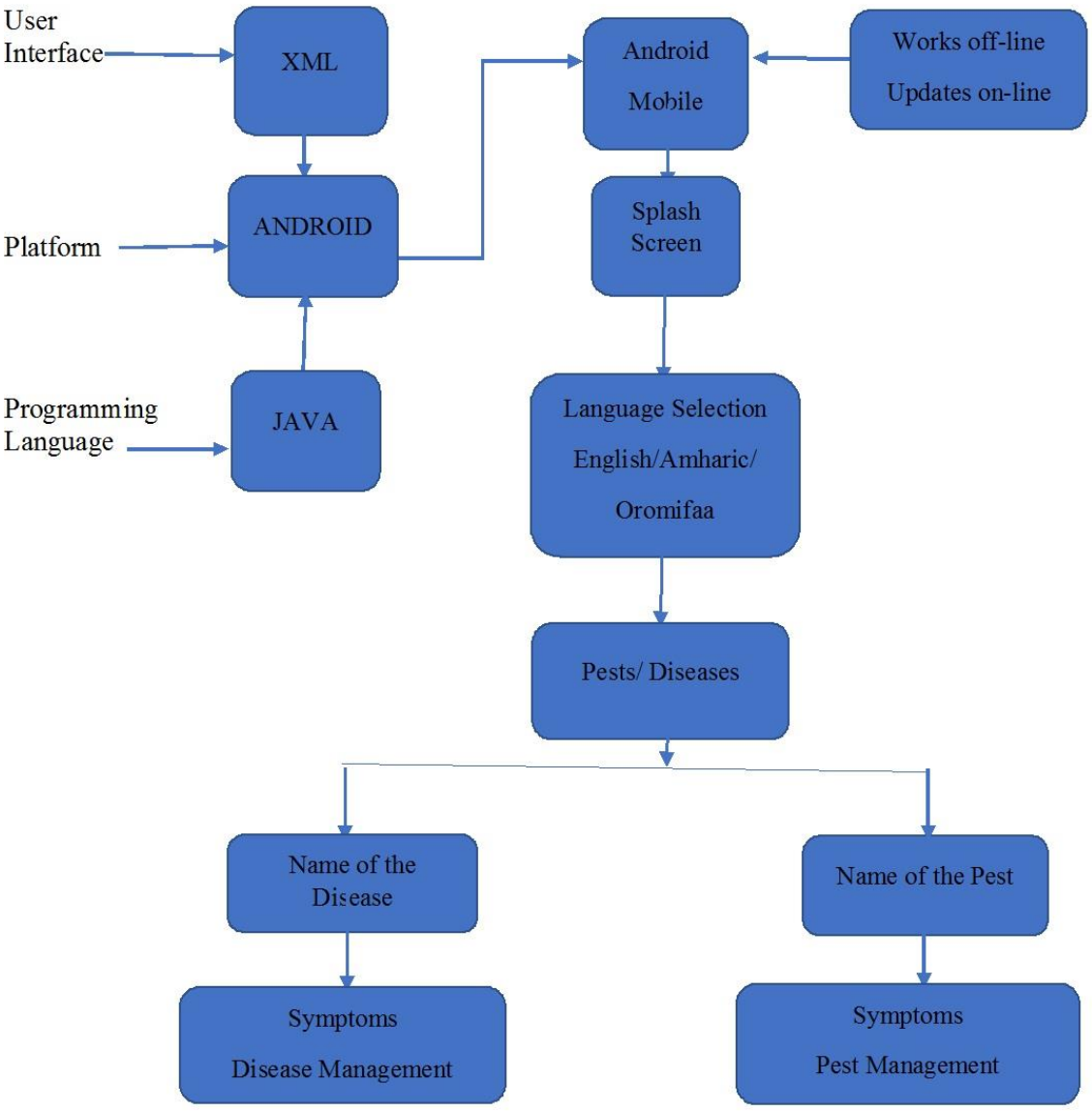


Figure 1 Flow Chart Showing the Structure of the Application

3. Results and Discussion

The developed mobile application contains the following sequence of pages. Upon clicking the icon (Figure 2), the splash screen will be displayed (Figure 3). It contains the name of the application and the languages in which this application is available. The next screen displays the languages and the individual is prompted to select the language option (Figure 4). The application is available in English, Amharic and Oromifaa.

Figure 2. Icon

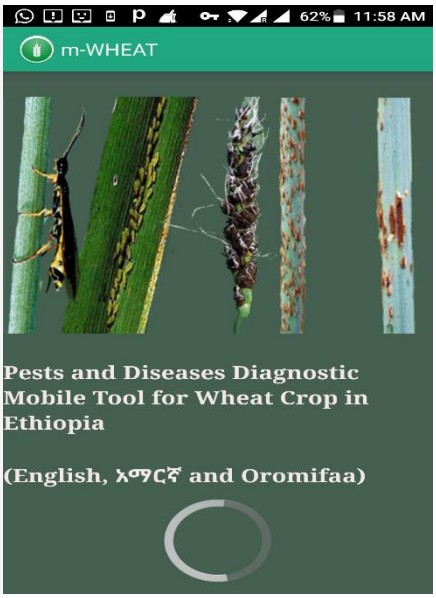


Figure 3. Splash Screen

Figure 4. Language option

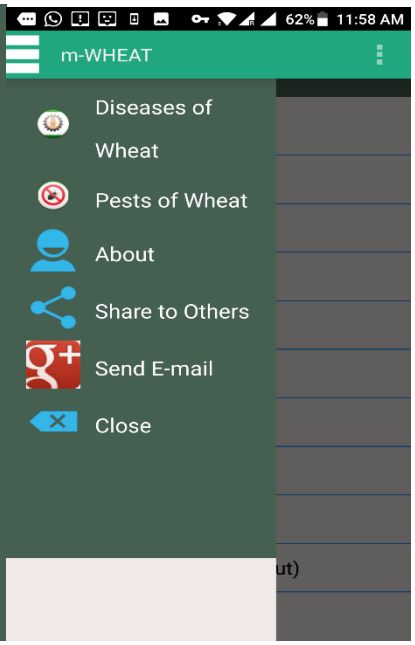


Figure 5. Drop Menu

Upon selecting the language option, the next screen will be displayed which has the drop menu (Figure 5). The items available in the drop menu are: disease, pest, about us, share to others, send email and close. Upon selecting the diseases from the drop menu, the major diseases of wheat in Ethiopia will be shown (Figure 6). Upon clicking the selected disease, the next screen with the details of the disease symptoms and disease management will appear. This page includes photographs and description of disease (Figure 7).

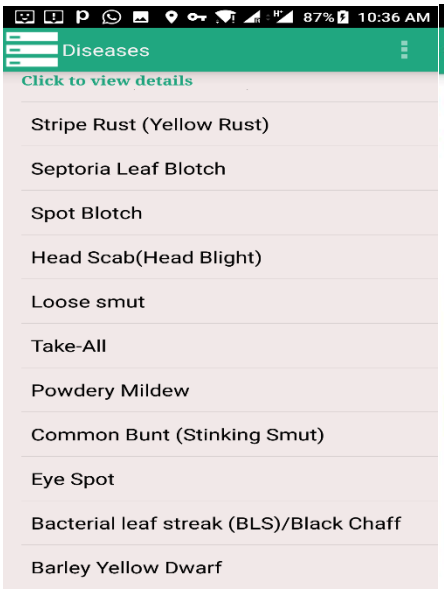


Figure 6. List of Diseases

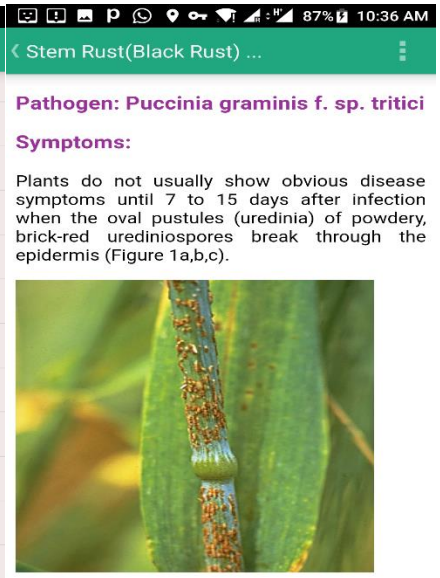


Figure 7. Description of Disease

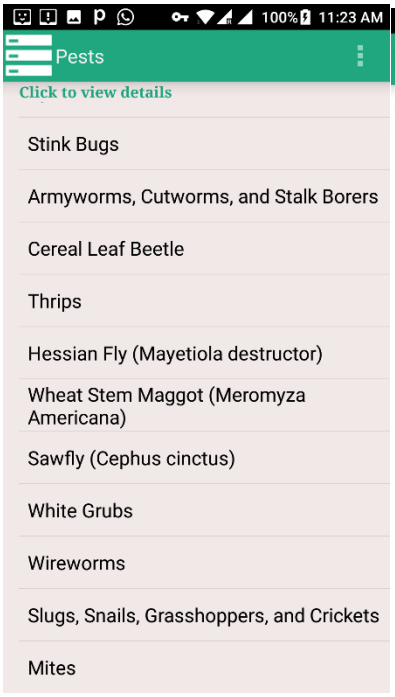


Figure 8. List of Pests

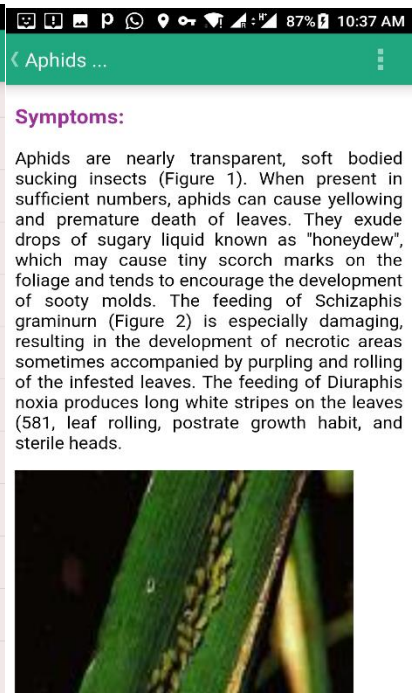


Figure 9. Description of Pest

The drop menu has also an option to select the pests of wheat crop. Upon selecting the pest of wheat crop from drop menu, the list of pests of wheat crop will be displayed (Figure 8). The details of the symptoms and pest management will be displayed upon selecting the pest (Figure 9).

AgriApp (version 2.1.3, 2017) is an android based mobile application providing information on crop production and crop protection, available in Kannada, English, Hindi, Telugu, Tamil and Marathi languages (https://play.google.com/store/apps/details?id=com.criyagen). Agrobase (version 1.0.7, 2017) includes database of pests, weeds, and diseases catalogue and all registered pesticides and herbicides (https://play.google.com/store/apps/details?id=lt.farmis.apps.farmiscatalog). MyCrop Wheat (version 1.0.16, 2016) includes a diagnostic tool, variety selector, economic risk analysis, crop monitoring tips and an integrated PestFax reporting tool.

These applications are not specific to Ethiopia. The information on pests and diseases of wheat crop provided in the mobile application, 'm-Wheat' is very specific to Ethiopia. Also, the application is available in Amharic, the official language of Ethiopia and Oromifaa (the language of major region in Ethiopia). The farmers/extension workers can report any new pest or disease appeared in the field using the option of 'send E-mail'. They can attach the photographs of the pest/disease and its symptoms.

4. Conclusion and Recommendations

The pests and diseases mobile diagnostic tool developed will be very much useful for researchers, extension workers, students and farmers. Based on the experiences gained from this study, it is proposed to scale-up this application covering major crops in Ethiopia. Also, it is proposed to develop a mobile application for the production practices for major crops in Ethiopia.

5. Acknowledgements

Our team wish to thank Dr. Belay Habtegebriel, Plant Protection Researcher, Ambo Plant Protection Research Centre, Ambo, Plant Pathology Division of Ambo Plant Protection Centre, Agricultural experts in the Ambo District Agricultural Office and Ambo Farm Service Centre for their valuable help in this project by providing data on pests and diseases of wheat crop.

References

Abraham, T. (ed.). 2008. 'Increasing Crop Production through Improved Plant Protection – Volume I', Plant Protection Society of Ethiopia (PPSE), 19-22 December 2006. Addis Ababa, Ethiopia. PPSE and EIAR, Addis Ababa, Ethiopia. p.598. ISBN 978-99944-53-28-3.

Abraham, T. (ed.). 2009. 'Increasing Crop Production Through Improved Plant Protection - Volume II', Plant Protection Society of Ethiopia (PPSE). PPSE and EIAR, Addis Ababa, Ethiopia. p.542. ISBN 978-99944-53-44-3.

Alem, G., Girmay, T., Girmay, G.S. & D. Legesse. 2015. 'Best Fit Practice Manual for Wheat in Tigray Region, Ethiopia', CASCAPE Best Fit Manual Number BFM_MU_2015_1, Mekelle University, Mekelle, Ethiopia. http://creativecommons.org/licenses/by/4.0/.

Alexander, J., Artzai, P., Aitor Alvarez-Gila, Jone, E., Sergio Rodriguez-Vaamonde, Ana D. N., & A. Ortiz-Barredo. 2017. 'Automatic plant disease diagnosis using mobile capture devices, applied on a wheat use case', Computers and Electronics in Agriculture, 138, (1), pp. 200-209. doi = https://doi.org/10.1016/j.compag.2017.04.013.

Bhavnani, A., Won-Wai, C., Rowena, Janakiram, Subramaniam, & S. Peter. 2008. 'The role of mobile phones in sustainable rural poverty reduction', Washington, DC: World Bank. http://documents.worldbank.org/curated/en/644271468315541419/The-role-of-mobile-phones-in-sustainable-rural-poverty-reduction.

Boon, J.A. 1992. 'Information and development: some reasons for failure', Information Society, 8(3), pp.227-241. http://dx.doi.org/10.1080/01972243.1992.9960122.

Camble, E. 1994. 'The information environment of rural development workers in Borno State, Nigeria', African Journal of Library Archives and Information Science, 4, (2), pp.99-106. http://dx.doi.org/10.1080/01972243.1992.9960122.

CSA. 2015. 'Key findings of the 2014/2015 (2007 E.C.) Agricultural sample surveys', Central Statistical Agency, Addis Ababa. www.csa.gov.et/index.php/survey-report/category/176-eth-agss-2015?...470...2015.

David, S. 2014. 'Internet use on mobile phones in Africa predicted to increase 20-fold', First published on Thursday 5 June 2014 17.58 BST https://www.theguardian.com/world/2014/jun/05/internet-use-mobile-phones-africa-predicted-increase-20-fold.

de Silva, H. and D. Ratnadiwakara. 2008. 'Using ICT to reduce transaction costs in agriculture through better communication: A case-study from Sri Lanka', mimeo, 20. http://www.lirneasia.net/

Deloitte (2014). The Future of Telecoms in Africa: The "blueprint for the brave". http://deloitteblog.co.za/wp-content/uploads/2014/02/Deloitte-article-The-future-of-telecoms-in-Africa.pdf

Enock, Y., Tim K., Naomi, H. and C. Blackman (2012) "eTransform Africa: The Transformational Use of ICTs in Africa." http://www.etransformafrica.org.

Ericsson Mobilty Report (2014). Sub-Saharan Africa, Ericsson, Stockholm, Sweden. https://www.ericsson.com/res/docs/2014/emr-june2014-regional-appendices-ssa.pdf.

Ericsson Mobilty Report (2016). Sub-Saharan Africa, Ericsson, Stockholm, Sweden. https://www.ericsson.com/assets/local/mobility-report/documents/2016/ericsson-mobility-report-november-2016-rssa.pdf

Fountas, S., Carli, G., Sørensen, C.G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A., Liakos, B., Canavari, M., Wiebensohn, J. & Tisserye, B. 2015. 'Farm management information systems: Current situation and future perspectives', Computers and Electronics in Agriculture, 115, pp. 40–50. https://doi.org/10.1016/j.compag.2015.05.011

ITU. 2010.' Measuring the Information Society', International Telecommunication Union, Geneva, Switzerland. ISBN 92-61-13111-5

Leye, V. 2009. 'Information and Communication Technologies for Development: A Critical Perspective', Global Governance, 15, (1), pp. 29-35. http://www.jstor.org/stable/27800736

Marco, Q. 2014. 'Wheat Technology Implementation Manual', Ethiopian Agricultural Transformation Agency, Addis Ababa. https://agriknowledge.org/downloads/41687h449

Martin, W.J. 1984. 'The potential for community information services in a developing country', IFLA Journal, 10(4), pp. 385-392. https://doi.org/10.1177/034003528401000408

Metcalfe, A.S. (ed.). 2005. 'Knowledge Management and Higher Education: A Critical Analysis', (Online). Inform.Sci.Publ. http://site.ebrary.com/lib/aucario/Doc?id=10084481&ppg=14

MoA. 2011. 'Small-scale irrigation situation analysis and capacity needs assessment', Ministry of Agriculture, Addis Ababa, Ethiopia. http://www.moa.gov.et/documents/93073/147337/Bamboo+shoots/e49851bb-8741-4425-971b-0908bcef8b49?version=1.1

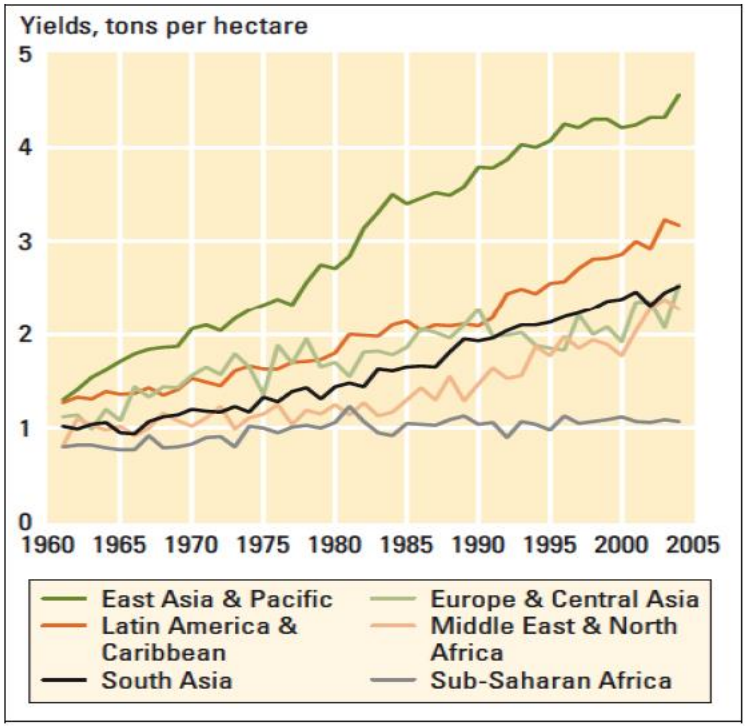
Paez-Urdaneta, I. 1989. 'Information in the Third World', International Library Review, 21(2), pp. 177-191. http://dx.doi.org/10.1016/0020-7837(89)90006-X

Prescott, J.M., P.A. Burnett, E.E. Saari, J.Ransom, J. Bowman, W. de Milliano, R.P. Singh & G. Bekele. 1986. 'Wheat Diseases and Pests- a guide for field identification', International Maize and Wheat Improvement Center, Mexico, D.F., Mexico. http://rusttracker.cimmyt.org/wp-content/uploads/2011/11/CIMMYT_Wheat_Diseases_Pests_ID_GUide.pdf

Sindhuja, S., Ashish, M., Reza, E. & C. Davis. 2010. 'A review of advanced techniques for detecting plant diseases', Computers and Electronics in Agriculture, 72, (1), pp. 1–13. http://dx.doi.org/10.1016/j.compag.2010.02.007

Syngenta Foundation. 2011. 'Mobile Applications in Agriculture', Basel, Switzerland. https://pdfs.semanticscholar.org/c579/b4d800bb866eba834425cafef8204c5c3873.pdf

Annexure 1



Source: Quoted by Syngenta Foundation (2011)