Assessment of Pest Diagnostic Capacity in Plant Health Related Laboratories for Maize and Rice in Tanzania

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Rice, Maize and Chickpea IPM for East Africa Project

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This IPM series record assesses pest diagnostic capacity of Plant Health laboratories for Maize and Rice in Tanzania. The intent is to capture better understanding and identify the capacities of the laboratories and how they perform in the country in identifying established and potential invasive pests affecting maize and rice production. The series also ensures that recorded data and other information gathered, generated and analyzed are part of the research work of International Centre of Insect Physiology and Ecology (http://www.icipe.org). The series is reviewed internally by icipe staff. It can be freely accessible both in hard copy and electronically and cited due acknowledgement.

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LIST OF ACRONYMS

AAVLD	American Association of Veterinary Laboratory Diagnosticians
APS	American Phytopathological Society
CBO	Community Based Organisation
CVL	Central Veterinary Laboratories
GAPs	Good Agricultural Practises
GHPs	Good Handling Practises
IPM	Integrated Pest Management
ICT	Information and Communication Technology
IT	Information Technology
IITA	International Institute of Tropical Agriculture
IPPC	International Plant Protection Convention
KEPHIS	Kenya Plant Health Inspectorate Service
MARI	Mikocheni Agricultural Research Institute
MLFD	Ministry of Livestock and Fisheries Development
NARS	National Agricultural Research Institutes
NGO	Non Governmental Organisation
PCR	Polymerase Chain Reaction
PHS	Plant Health Service
PCR	Polymerase Chain Reaction
SUA	Sokoine University of Agriculture
SSA	Sub-Saharan Africa
SWOT	Strength, Weakness, Opportunity and Threats
SOPs	Standard Operating Procedures
TPRI	Tropical Pesticide Research Institute
TVLA	Tanzania Veterinary Laboratory Agency
TOSCI	Tanzania Official Seed Certification Institute
UDSM	University of Dar Es Salaam
UW	University of Wisconsin

EXECUTIVE SUMMARY

This report has identified maize and rice threat pests and diseases diagnosis as an important issue in the government of Tanzania. Established and potential invasive and regulated plant pests (*ie* insects, mites, fungi, bacteria, viruses, rodents, birds, nematodes and weeds) directly affect the competitiveness of agricultural and agri-food industries by reducing crop yield quality, and increasing the cost of production. Furthermore, loss of market access due to the presence of regulated invasive species. The government has a legitimate role to protect the economy, the environment, agricultural and natural land resource from the negative impacts of plant pests.

The plant protection related laboratories in the Ministry of Agriculture and Food Security used to be well equipped and staffed before 1996. Due to infrastructure deterioration, poor recruitment of new staffs in various disciplines of plant protection (entomology, plant pathology, weed science, seed health, vertebrate pests, regulated and non-regulated pests), and diagnostic services is done in few renovated and equipped laboratories. Furthermore, they use old references and guidelines materials. There is critical shortage of budget for supporting regular pest surveillance and monitoring.

The primary data were collected through use of close and open ended questionnaire that was administered to the key informants, consultative meetings, Plant Health Service (PHS) staffs, Pesticide Research Institute, National Agricultural Research Institutes, staffs from Sokoine University of Agriculture, University of Dar Es Salaam as well Tanzania Mikocheni Agricultural Research Institute, Seed Certification. Secondary data was collected from various reports as well as internet search. Need to establish plant health experts recommended to assist laboratory scientists to diagnose problems that are difficult to identify using morphological observations. Without this support they are limited to make reliable recommendations to maize and rice growers. Major assessments are summarized below:

1. Universities (Sokoine, Dar Es Salaam) and government research institutions (NARS) under Ministry of Agriculture were reported to be involved in insect pest, diseases diagnosis and form a national network. Identified services provided by these institutions includes insects, bacteria, fungi, nematodes and viruses using biochemical and molecular techniques (PCR and DNA bar-coding)

2. There is good collaboration between research Institutions and Universities as they can use internet to communicate and share experiences. Increased collaboration with extension officers improves diagnosis as most of the problems are reported through extension officers.

3. Lack of data base that could facilitate pest diagnostic service in Tanzania.
4. Budget allocated for pest diagnostic service is very low to meet the required demand.
5. Use of SWOT analysis was suggested as it assists in identifying weakness within and outside the project at all stages of implementation.
6. Lack of good equipment supplies, infrastructure, and reference materials were identified as major constraints in pests and disease diagnostic service.

7. Lack of staff recruitment in National Agricultural Research Institutions (NARS) as well as Universities involved in plant diagnostic.
8. Mikocheni Agricultural Research laboratory was the only laboratory in Tanzania identified with Bio-safety Level 2 but not accredited according to ISO 17025.

Recommendations to improve plant and disease diagnostic service in Tanzania

1. Identifying other source of funds to meet government needs.
2. To establish national network of diagnostic laboratories within a quality assurance (QA) framework.
3. To enhance networking among diagnosticians and plant health management experts within Tanzania and East Africa region.
4. To harmonize laboratory diagnostic protocols in Tanzania and across borders.
5. To improve equipment supplies, infrastructure and reference materials.
6. To establish short and long training program to technicians and plant experts (MSc and PhD) involved in plant diagnostic service.
7. To develop capacity for the use of existing and modern diagnostic tools and technologies through frequent training programs for the personnel involved in pest and disease diagnosis.
8. To establish at least one or two laboratories fully equipped and be accredited according to ISO 17025

1. INTRODUCTION

1.1 Historical Perspective of Pest Diagnostic

The pest diagnostic and management practices have existed for quite long in the history of agricultural systems having a key drive on human population trends. From1940's to the 1970's, there was a serious crop losses due to pest and diseases and thus, Ministry of Agriculture started giving attention on major pests affecting crop production. The results of this survey showed that there was an increase in yield after intensive development of various technologies, including development of pest management, weed management, improved seeds and use of suitable pesticides. More than 75% of Tanzanian depends on agriculture for their livelihoods and the sector contributes to 25 percent of gross domestic product (GDP) and accounts for 25 percent of the country's export earnings.

Tanzania Veterinary Laboratory Agency (TVLA) is an Executive Agency of the Ministry of Livestock and Fisheries Development (MLFD) that was established under the Executive Agency Act Cap 245 (Revised Edition; R.E 2009) to address livestock problems in urban and rural areas. It is also mandated to provide testing and diagnostic services for all types of livestock diagnostic services necessary to meet the requirements of the country. The laboratory was gazetted on GN number 74 of 9th March 2012 supplement Number 8 and instated by the Chief Permanent Secretary on 11th of July, 2012. The Agency operates in multiple sites across the United Republic of Tanzania, which includes the headquarters at Temeke – Dar Es Salaam; Central Veterinary Laboratories (CVL) at Temeke, Centre for Infectious Diseases and Biotechnological (CIDB) at Temeke, Tanzania Vaccine Institute – Kibaha (TVI) the only Vaccine producing institute in the country and a zonal network of laboratories across Tanzania mainland (Arusha, Dodoma, Iringa, Mtwara, Mwanza and Tabora). The diagnostic laboratory also have two Vector and Vector Borne diseases Centre's in Tanga and Kigoma including two research farms at Luguruni in Dar Es Salaam and Mivumoni in Tanga region. In cooperation with the Department of Agriculture, Trade and Consumer Protection, TVLA participate in research and in the provision of field services, consultation services and education as determined to be appropriate by the livestock diagnostic laboratory.

In Tanzania plant pests diagnostic and diseases laboratories are responsible for about 25% of crop yield losses annually. Plant diagnostic have been working in the country to help small holder farmers to reduce any losses (Boa, 2010). This is the main reason for putting in place the Plant Health Services as integral part of any cropping system. Plant specialists occasionally need expert support from plant health diagnostic laboratories to accurately diagnose various plant health problems in maize and rice growing areas. They maintain a regional laboratory to undertake and strengthening surveillance and diagnostic services.

1.2 Evolution of Pest Diagnosis in Tanzania

Introduction of new pathogens and pests in Tanzania that are threats to agricultural crops raised need of pests and diseases diagnosis. New pests significantly contributes to low yield production. Resource poor farmers are directly affected by using more resources for pest management. For example resistance to pests is the rule rather than the exception in the plant kingdom. In the coevolution of pests and their plant hosts have evolved defence mechanisms. Such mechanisms may be either physical (waxy surface, hairy leaves etc.) or chemical (production of secondary metabolites) in nature. Pest-resistant crop varieties either suppress pest abundance or escape damage. In other words, genetic resistance alters the relationship between pest and host. The inherent genetically based resistance of a plant can protect it against pests or diseases without pesticide uses.

Tanzanian crop breeders regularly select new varieties for their pest and disease resistance. For example, maize varieties (e.g. TMVI, Staha, Kilima) have been selected for resistance or tolerance to maize streak, the viral disease that causes significant yield loss to late planted maize. All of the cotton varieties produced at Ukiriguru had resistance to jassids since they have hairs to interfere with sucking insect pests. Varieties have also been produced with varying degrees of resistance to fusarium wilt and bacterial blight. Rice varieties have been selected with resistance to Rice Yellow Mosaic Virus (RYMV).

Furthermore, Landscape modification resulting from urban and rural development and potential pressures of climate change may as well result in population changes in pathogens and pests. For example coconut mites (*Aceria guerreronis*) recently has evolved and considered as threat pest (Coconut report 2013). Detection and diagnosis threats is more important than threat of internal and accidental introductions. To prevent the establishment and dispersal of pests and pathogens after introductions and to minimize subsequent impact, a plant bio security system requires the capability for early detection of threat pests, accurate diagnosis, and rapid response (Cook and Madden 2002; Myerson and Reaser 2002).

1.3 Pest Management and Diagnosis

Sustainable pest management and diagnosis is knowledge intensive. Generation of this knowledge is the role of scientists. It has been argued that Integrated Pest Management is the creation of scientists, and it is scientists who have largely controlled its evolution, albeit subject to various pressures (Morse and Buhler, 1997). Before deciding to take any pest control action, it is necessary to identify the disease or the pest. Proper pest or disease identification is essential to develop and select the best suited control options.

Furthermore, it is important to look for pest injury symptoms regularly. Use of traps for monitoring insects, diseases, or vertebrates can be used when available and appropriate for the situation. Sampling frequently will depend on the pest situation, but a general guideline for many insects and diseases is done every one to two weeks during the main season. For example mango fruit fly (*Bactrocera dorsalis*) monitoring in mango growing areas in Tanzania. Traps can be hanged in places where pests commonly occur *ie* underside the leaves, shade area or in soil (Diane, 2011).

Various techniques are used in the pest’s diagnostics and vary from one pest to another. Insect pests diagnostic in Tanzania are identified using morphological characteristics, digital imaging technology to capture detailed images of suspected pests which can then be transmitted electronically to qualified specialists for identification. Additionally, with advancement in technology, use of molecular diagnostics by use of DNA barcoding, PCR and ELISA is gaining popularity in the identification of insect's pest and diseases worldwide.

1.4 Integrated Pest Management (IPM)

Integrated Pest Management involves Good Agricultural Practices (GAP), such as use of host resistance varieties, crop rotation and biological control to plants against pests. On the other hand, interactions between insects and their natural enemies are essential ecological processes that contribute to the regulation of insect populations.

Therefore, greater reliance should be given to use (GAP) in agrarian system, rather than resorting to use of pesticides, which poses health hazard problem to applicators and consumers, adverse impact on ecosystem by polluting environment and affecting biodiversity. Development of pest diagnostic capacity in plant health related to maize and rice have become more concern in many laboratories in the world.

Seliani maize research institute and Dakawa rice research institute identified critical weaknesses in agriculture. These are: low productivity of land, labour and production inputs. These are mainly caused by inadequate finance to obtain productivity-enhancing inputs or capital, limited availability of support services (research and extension, agricultural information and plant protection) and lack of appropriate technologies forcing the majority to produce for subsistence. The agriculture contributes around twenty five percent of the country's export earnings and employs about ninety percent of working population (Food security Programme, 2012).

FAO, 2015 report revealed that in Tanzania, Maize yield from an area of 34, 075,972 ha was 70, 076,591 tonnes, while rice yield from 19,998,008 ha was 16,008,838 tonnes. Similarly, inappropriate postharvest handling of grain leads to an estimated 20% of the total production. These are avoidable losses in the post harvesting stage.

1.5 Importance of Pest diagnosis for Tanzania National Economy

A pest is one that is judged by man to cause harm to his crops, animals or his property. In farming an insect may be classified as a pest if the damage it causes to a crop or livestock is sufficient to reduce the yield and/or quality of the 'harvested product' by an amount that is unacceptable to the farmer. Therefore, presence of various economically important pests and diseases that are threatening food production demands the development of good quality IPM systems on identified pests. Pest diagnosis will assist to design the type of control measures *ie* cultural control especially manipulating planting dates of maize and rice or burning of crop residues after harvesting.

Respondents from Tropical Pesticides and Seliani Research institutes identified tomato leaf miner (*Tuta absoluta)* as threat pest. Primary growers fail to identify the pest as a result they opt for wrong pesticide use to manage the pest. The identified pest estimated to cause more than 50% crop losses that could have significant impact on food security. If the pest could have been well diagnosed farmers could not get such huge loss. Absence of strong national pest's diagnostic arrangements would increase crop losses from pests and diseases, leading to misuse of chemicals which are detrimental to our life and environment. Furthermore, regular surveillance to update existing information and to detect presence of invasive pest species should be carried out timely followed by accurate diagnosis. Proper diagnosis of the pests and diseases in maize and rice will assist to identify threat pests and diseases with significant risk in Tanzania in particular and East Africa in general. Wrong identification of the problem or lack of information related to the causes might lead to choose the wrong control method which might also lead to failure of the control programme. Therefore, proper identification is needed to avoid extra cost in pest management, profit maximization, and to improve yield quality and quantity of maize and rice in Tanzania.

1.6 Pest diagnostic in relation to National food Security

The consultative meeting results revealed that plant health clinic is an innovative paradigm which plays a vital role in assuring food security. It can provide timely diagnosis and render necessary advice to the growers, gardeners and other stakeholders for managing pest problems. For example reliance on pesticide use leads to an increase in pest problems in maize and rice production. Use of pesticides tends to reduce natural enemies whereby pest remains without their natural enemies.

Diagnostic capacity is a critical foundation supporting surveillance and keeping records up to date. In order to increase food security we need to create enough well-organized plant clinic at prime location in urban or in rural areas at grass root level on the analogy of primary health centre, with easy access to growers (Mahendra, 2013).

The Ministry of Agriculture, Food Security and Cooperatives has initiated a Community-Based Armyworm Forecasting (CBAF) for the control of armyworm outbreaks *Spodoptera* in Hai, Kilosa (in the Morogoro Region) and Moshi districts. The results showed thatCBAF achieved a high level of forecasting accuracy, with 75% of all positive forecasts having corresponding outbreaks (Mushobozi report. 2005). The researchers were able to demonstrate that ground and aerial sprays of *SpexNPV* gave effective control of outbreaks, and therefore could be used to replace chemical insecticides for armyworm. This approach is likely to have a number of benefits.

i. Less pesticide will be used because farmers will be able to identify and apply control measures at the most vulnerable stage of the pest, which is not possible in the current central system of early warning.
ii. Farmers can use less toxic and environmentally friendly proven alternatives to pesticides e.g. botanical extracts and/or bio-pesticides at relatively low cost with minimum environmental hazards.
iii. The information generated by farming communities would be integrated in the national monitoring and early warning system to improve the quality of the information at national and regional levels. This requires well coordination.

Other studies carried out in two sample villages, namely: Kipera Njiapanda in the Morogoro region and Bwawani Visegese in the Coastal, where culturally and ecologically rice is grown. In these areas, the Farmers Field Schools are main platform to introduce innovative technology that increases yield and promote food security. Smallholders and local authorities also involve in the development of innovations.

The results showed that high income farmers were able to control major pest in rice production compared to the middle and small income farmers (Table 1).

Table 1: Empowering smallholder rice farmers in Tanzania to increase productivity for promoting food security

Group of farmers	Rice yield Kg/ha
Well to do	2,400-3,600
Middle income	1,200-2,400
Small income	120-600

Source Rugumamu, 2014

Failure in timely diagnosis of pest as well as diseases has often been responsible for devastating losses. Reducing crop losses by keeping pests population to acceptable economic threshold is crucial to food security in Tanzania.These examples describe basic requirements are needed to assist laboratories conducting plant pest and diseases diagnosis in designing their quality diagnosis management system. Quality management consists of activities that ensure the quality and confidence of a diagnosis performed in a laboratory.

1.7 Plant Health Unit Vision and Mission

High quality agricultural food crops are produced using economically viable, environmentally sustainable Integrated Pest Management practices. As part of the Plant Health Service's vision, this will not be attained without the adoption of a more coordinated and strategic approach built based on support, input and involvements of multiple stakeholders (government, industry and private sector).

Plant Health Services (PHS) is part of regulatory body that undertakes regular surveys and monitors different pest species to detect new species in different agricultural production. Its mission is to work with government and different stakeholders to protect capacity of agricultural land resource from the adverse impacts of plant pests. It also protect plant health and their quality through application of Integrated Pest Management technologies that enhances consumer confidence and economic growth.

Another activity assigned to PHS is to control migrant pests, inputs and pesticide imported in the country. All imported materials should be approved and registered for use in the country. Inspections are conducted according to policy of the government for all imported and exported materials at border entry points. Similar activities is carried out at Dar Es Salaam International Airport and Kilimanjaro International Airports as well as harbors. The harbors include: Dar Es Salaam, Tanga, Mtwara,and Bukoba; Ports include: Mwanza Port, Kigoma Port, Musoma Port; Mbamba bay Port, Itungi Port, and Lindi Port. Overland border entry points: Namanga, Tunduma, Sirari, Mutukula, Rusumo, Tarakea, Horohoro, Mpulungu, Kibondo, Holili, Kasumulo, Isongola, Kalema, Makambe, Mkomazi and main railway stations in Dar Es Salaam and Tunduma. All these institutions try to monitor the introduction of newly pests and diseases.

The establishment of well-equipped laboratories and assigning qualified personnel will help to minimize the large losses caused by introduced pest and diseases in the country.

2. SURVEY METHODOLOGY

This assignment commenced with the submission of an inception report outlining the methodology and plan of this work on early September 2016. Further consultation took place in MARI, TPRI, IITA Dar Es Salaam, University of Dar Es Salaam, Sokoine University of Agriculture (SUA), Tengeru, Seliani, Dakawa and Plant Health Service (PHS) offices at Kurasini to see the actual situation and to run the questionnaire from 17/10-15/11/2016.

A sample size of 10 key respondents were selected from different agricultural research Institutes that were used for administering of the questionnaire. The key respondents were those who have been involved in diagnostic activities. Stakeholders interviewed include students, inspectors, laboratory technicians, researchers and extension staff. Face to face consultative meetings held with different stakeholders using both open and close ended questionnaire. The questionnaire depicted a set of questions whereby participants were able to prioritise and rank the most priority area. Primary data was collected through consultative meetings, an open and close ended questionnaires/group discussions whereby researchers, technicians, inspectors and other different stakeholders were involved. Respondent's answers were dully filled into the appropriate forms for statistical analysis. Secondary data was obtained from reports and literature reviews *ie* PHS, research institutions, national reports, internet search and various meetings.

2.1 Stakeholders Participation

The consultancy concentrates on active participation of researchers, students, plant specialists from National Agricultural Research Institutes (NARS), Universities, growers, input suppliers, extension officers as source of information. Therefore, the consultancy information wouldn't be possible without relevant stakeholders involved.

2.2 Evaluation Team

The evaluation was carried out by Dr Christopher L. Materu (Entomologist) Mikocheni Agricultural Research Institute (MARI) Dar Es Salaam Tanzania.

3. ANALYSIS AND FINDINGS

3.1 Assessment of the overall capacity of pest diagnostic services in Tanzania

Pest diagnostic services in Tanzania's Ministry of agriculture and Universities are still at varying level despite its importance to increase the country's economy, protection of environment, community and negative effects from plant pest's species. The assessment focuses on pest diagnosis services providing institutions; such as the national plant health laboratories and departments in agricultural research systems, the roles of the institutions and national strategies/policies for pest diagnosis.

3.1.1 Institutions involving in pest diagnostic services

In Tanzania most of primary plant diagnostic services are carried out by Universities and research centres, specifically at University of Dar Es Salaam, Sokoine University of Agriculture and National Agricultural Research Institutions (NARS). Similarly, national agricultural research institutions are well linked through internet for collaboration. Both Universities and research institutions have capacity to handle large volume of samples but due to lack of sufficient funding only few samples are been handled. This situation lowers their efficiency in performing diagnostic work, as a results extension workers fail to promote sustainable IPM measures for managing threat pest in maize as well as in rice.

Findings showed that 80% of the laboratories dealing with maize and rice research such as Seliani and Dakawa respectively do not have the capacity to deal with all of the problems facing maize and rice in the country. Therefore, most of invasive species are not known and they are not well mapped and factors related to problems have not yet been studied. On the other hand laboratories lack sufficient equipment, reagents, and trained personnel, and have not been able to fully comply with bio security and bio safety guidelines. Stakeholders believe that standardization of the diagnostic labs will facilitate collaboration as well as communication between them.

During the group discussions researchers from Mikocheni, Tanzania Official Seed Certification Institute (TOSCI), Seliani and Dakawa research institutions ranked the importance of pest diagnosis laboratory for decision making (see Figure1).

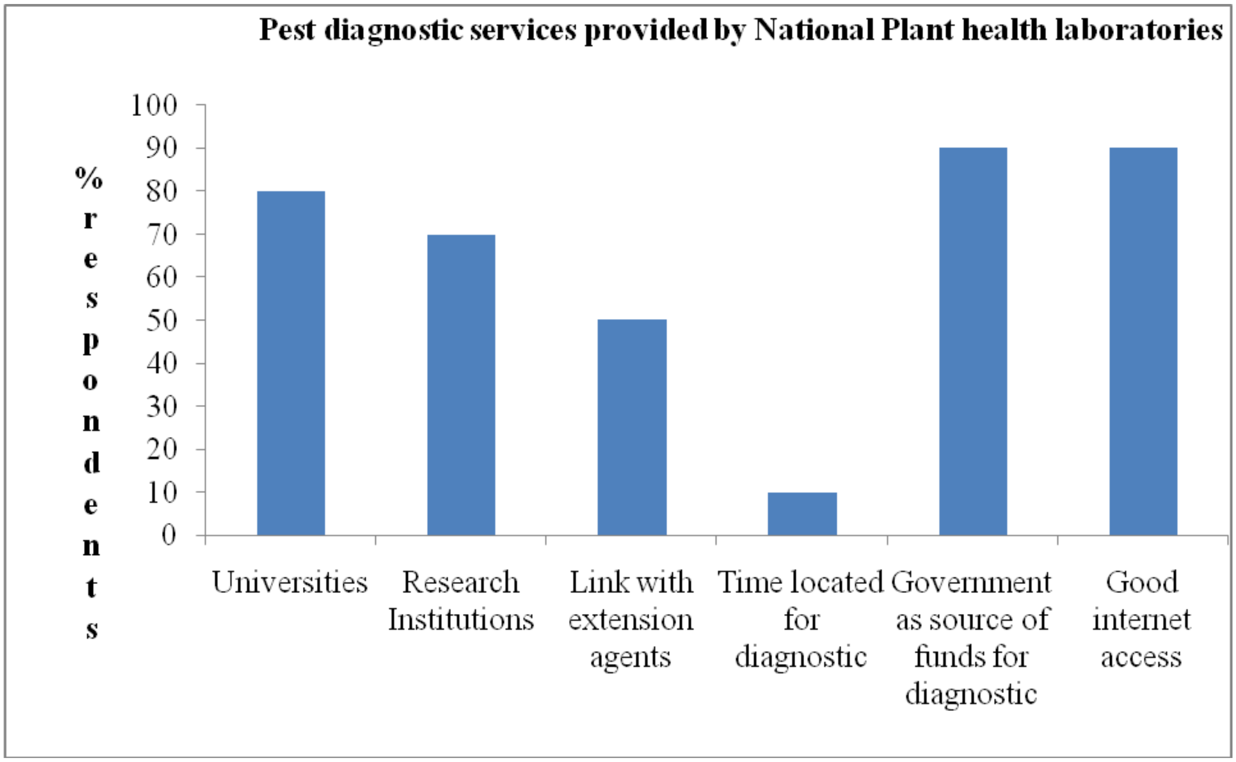

Figure 1: The roles of **p**lant health laboratories for maize and rice in decision making

3.1.2 National Plant Health Strategy

National Plant Health Strategy need to create awareness to stakeholders to address present situation, future challenges facing the system and also opportunities. More than 80% of the respondents showed that introducing Farmers Field Schools as an approach was considered as capacity building for efficient, sustainable and inclusive food production systems. Furthermore, introducing new tools for detecting pesticide residues and regular farmers training and other related disciplines could revolutionize pesticide use in different crops. This will increase participation of all stakeholders working together as a team. Information should be collected in coordinated manner and need to shares with all stakeholders.

3.1.3 National Plant Health Diagnostic roles

Tanzania is a resource-constrained country that faces challenges in establishing and sustaining laboratories. The country has a long tradition of collaborative laboratories, dating back to the country's early colonial era. However, economic fluctuations have resulted in significant cutbacks to the laboratory system. The need to establish diagnostic laboratory becomes high due to the increase in tourism industry and exchange of plant materials, which may result into introduction of new pests. The existence of good diagnostic laboratory in the country will assist to maintain and protect pest pressures that are considered as threat pests in agriculture. Furthermore, food production and supply will continue to have high benefits accrued from the investment *ie* export plant products. Laboratory can diagnose wide range of plant pests and diseases. For instance; Mikocheni Agricultural Research Institute is conducting white flies vector of plant virus diagnosis using serology and DNA-based techniques.

Group discussions showed that Plant pest diagnostic capacity is an essential component of detection of invasive pests and propose eradication program before its establishment. It was agreed that plant diagnostic capacity is required to address the problems and play a major role to:-

(i) advice sustainable pest control measures
(ii) keep record of threat pests and diseases in the country
(iii) establish economic threshold of pests considered as economic pests
(iv) conduct regular surveillance and update database for new detected pest species
(v) plan and execute eradication program for new pest species
(vi) collect diagnostic data that will assist to provide framework for development of an action plan
(vii) report on challenges phasing the system periodically

3.1.4 Knowledge sharing between institutions involving pest diagnostic services

Group discussions with different plant health diagnostic experts mentioned that plant diagnostic experts need to form networks associated with linking all entry points as reported from other studies (Boa, 2010). New pests and diseases detected can be compared or cross checked with the existing information or verified in collaboration with other laboratories. Laboratories of research institutions and Universities are well equipped and staffed with qualified personnel to handle plant diagnostic, but due to lack of funds they are operating at low level. Information can be accessed linking research institutions to Universities through internet facility or mobile phones. All research institutions were observed striving to develop new technologies through researching and recommend suitable IPM and disseminate training manuals to final user *ie* maize and rice growers. Knowledge sharing with research institutions and Universities results showed that different actors need to involve different stakeholders. These include; community based organization, NGO, input suppliers, traders, extension agents, commercial banks, TV and radio programme as well as mobile phones (Figure 4).

Mikocheni Agricultural Research Institute and IITA were considered relevant institutions in the country where Plant Health Services laboratory could refer and establish network of plant diagnostic center. Key respondents mentioned that laboratory managers should conduct regularly the periodical review of data collected. It implies routine data assessment, recording and take necessary corrective actions to improve quality of data collected.

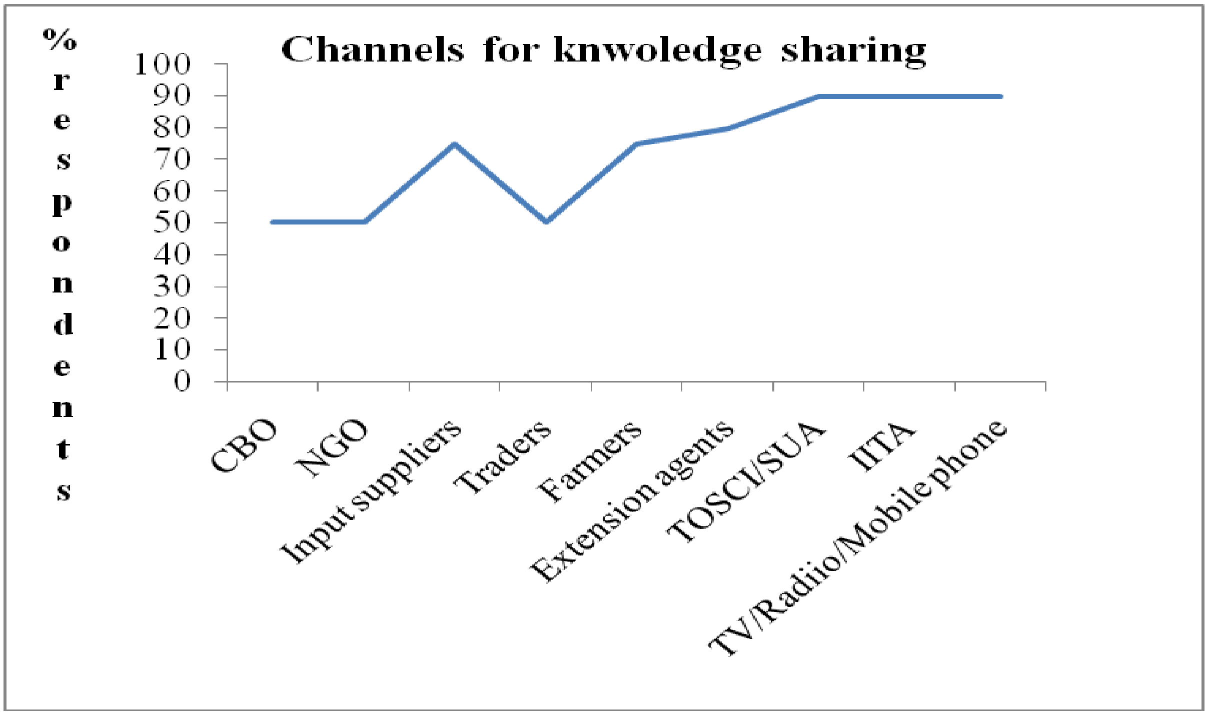

Figure 2: Knowledge sharing with different actors involving in agriculture

3.1.5 Use of information and Ccommunication Ttechnology (ICT)

Findings showed that ICT have the potential to reach more maize and rice growers with timely and accessible content in agreement with other studies (Choubey, 2009). Good dissemination of agricultural informatics development could lead to sustainable agricultural growth and livelihood, adopting good agricultural practices and empowering farming community (Figure 4). Similarly strengthening Research and Education, Training, Extension and Development of linkages among stakeholders can improve income and livelihood of maize and rice growers in the country.

Internet is one of the most efficient channel to transfer information. Good internet facility can be a valuable source of information to farmers in developing countries. The end user, beneficiaries and all concerned especially exporters of agricultural products should trained to access the Internet facilities. The major constraints of this technology is that very few people have access to computers, but with growing awareness and availability of computers, smart phones, internet usage may become a popular means of plant health clinic communication. Nevertheless, it may take some time in rural areas where electricity is not readily available compared to towns.

Group discussions revealed that the role of ICT play a vital role of agricultural development and it has to be holistic, well-defined and focused towards overall wellbeing. Government policy makers have also realized that ICT can improve people's livelihood by facilitating access to various markets, acquisition of proper inputs at the right time and affordable prices. The quality of rural life in Tanzania can also be improved by quality information inputs which provide better decision making abilities. It can also play a major role in facilitating the process of transformation of rural farmers where maize and rice is produced for food as well as cash crops. (Figure 4).

3.1.6 Coordination, consultation and communication between stakeholders involving in pest diagnostic services

Consultative meetings with plant diagnostic experts showed that plant health diagnostic laboratory is functioning as national wide network of National agricultural research institutions in the country. Network includes good coordination, consultation and communication among stakeholders involve in agricultural sector in Tanzania, particularly maize and rice growers. Effective implementation of good communication requires effective use national partnership and other various approaches. Sustainable co-ordination need to establish active focal points (diagnostic points) in all agricultural zones linked to national plant diagnostic centre.

The national diagnostic centre should be accessible at all times to communicate with the regional focal points. Regional focal points should directly link to different stakeholders in the country. Stakeholder will identify suitable staff that can generate good data that can be used to develop sustainable pest and diseases control measures of reported pests and diseases. Respondents showed that good coordination improves knowledge ownership as well as responsibility among stakeholders (Non-Governmental Organisation, Common Based Organisation and private sector). Consultative group discussions ranked source of information for plant diagnostic. national research organisation selected on the top for source of information, followed by Extension agents, NGO/CBO, TV/Radio programmes, traders, and Farmers Field Day (Figure 5).

For effective adoption of IPM technologies promotion of farmer's participation from village to regional level was recommended as capacity building. Furthermore, information collected can be used by different stakeholders *ie* academicians, policy makers, as well planners for sustainable decision making. The consultation proposed post-establishment of plant diagnostic laboratories focusing on delimiting a selected set of capacity building and strategic issues. In addition, to evaluate how data collection and diagnostic results are coordinated among members. Common based Organisations, extension and NGOs were proposed to encourage knowledge transfer among stakeholders involved in maize and rice production.

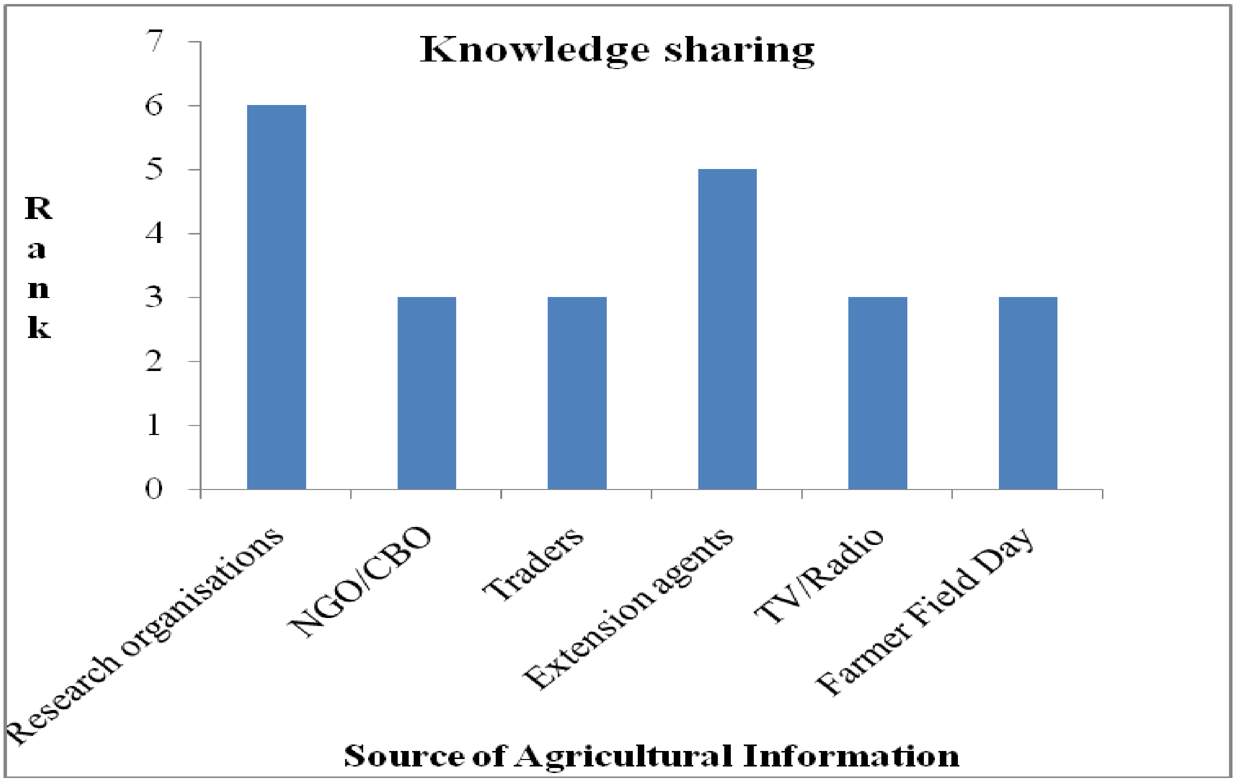

Figure 3: Communication between stakeholders in the agricultural sector

3.2 Strength, Weakness and Opportunities to enhance national pest diagnostic capacity

The group discussion was able to identify strength, weakness, opportunity and threats of National Plant Health Service system that complies with International phytosanitary measures.

Major Strength: Eighty percentages (80%) of key informants identified that active engagement of staff in conducting regular plant diagnostic as major strength. For example; 2PhD, 4MSc and 4BSc with different disciplines from Tropical Pesticide Research Institute (TPRI) are engaged in plant health diagnostic. This group of scientists are supported by 3 technicians. Other major strengths include:

- Good dissemination of information and diagnostic results to farmers and other customers through technology transfer unit, media (radio, TV) programme and mobile phones.
- Increase the demand of clean plant materials
- Increase the motivation of scientists for plant diagnostic

Major weakness: Key respondents identified inadequate funds and lack of skilled personnel constitutes 80%, followed by inadequate or poor equipment which represented 60% and the least was limited transparency in decision making 50%. The following are some other manor weaknesses of pest diagnostic capacity

- Poor coordination and transparency in Plant pests diagnostic
- National standards and regulations comply with Codex
- Poor sample collection and delivery to laboratory for analysis

- Limited provision of information to different stakeholder as well as consumers

Opportunities: Respondents pointed out that establishment of good pest database and other sources of funding represents 70%, followed by good network among plant health diagnostic laboratories (60%). Plant pest diagnostic is well supported from fields where samples are collected and transferred to the laboratory. More importantly:

- The use of GAPs and GHPs systems increased
- Development of new consumer associations and industry associations
- Competing development priorities and needs
- Adequate resources allocated for plant diagnostic laboratory are gold opportunities to strengthen the pest diagnostic capacity

Threats:

- Increased of pest/disease problems or outbreaks (white flies in rice).
- Low confidence and quality of data collected from the diagnostic laboratories
- Inadequate funds from the government/donors
- Changes in technology

4. RECOMMENDATIONS

4.1 Specialized diagnostic laboratory equipment and infrastructure needs

The survey results revealed that the government built National Plant Health Service laboratory building at Kurasini. The building structure was constructed with an idea to enhance plant pest diagnostic as part of research institutes.

1) Equipment needs

The key respondents identify a list of common equipment needed to be fitted in diagnostic laboratories as listed below (Table 3). Furthermore, supply of water, energy, computing facilities as well as sewage system is needed to increase working efficiency. These findings are in agreement with other studies (Bulletin OEPP/EPPO 2007). For instance; ninety percent (90%) of the key respondents from Mikocheni Agricultural Research Institute, Tropical Pesticides Research Institute, Universities and IITA identified the following equipment for laboratory diagnostic as summarised below (Table 3).

Table 2: Common identified equipment for plant diagnostic laboratory

Thermo cyclers	Moisture meter
Working thermometers	Germination test
Autoclaves (for destruction)	Viability test
Safety cabinets	Electrophoresis
Laminar air flow cabinets	Laboratory environment (entomological)
Growth chambers	Conical flasks
pH meters	Colony counters
Temperature-controlled equipment	Spiral platers

Incubators, baths, refrigerators,	Pipettes
Freezers,	Automatic media preparation
Stereo microscope	Gravimetric diluters
Light microscope	Check weight (s)
PCR machine	Balances
ELISA	Safety cabinet
Sequence	Berlese funnels
ELISA reader	Slide drying
Oven	Humidifier
Water distiller	Dehumidefier

Furthermore, equipment required for better and efficient plant diagnostic in Dakawa and Seliani research institutes is summarized in Table 4. Most of the identified equipment was weighing balances, pipettes, autoclaves, deep freezer and service is carried out annually except for the microscope which is carried out after seven years.

Table 3**:** Calibration and calibration checks for equipment

Type of equipment	Recommendations	Service frequency
Calibration weights	Full traceable	Annually
Microscope	Full traceable	More than seven years
Pipettes	Calibration	Annually
Autoclave	Calibration	Annually
Deep freezer	Calibration	More than two years

2) Infrastructure needs

During consultative meetings participants showed that diagnostic laboratory infrastructure used for the isolation, identification, and diagnosis of different important pests in maize and rice at different levels is needed. Laboratories used for different plant diagnostic need to be renovated and fitted with modern equipment. Furthermore, members identified in vitro diagnostic work as an important area to put more effort. Such work would include identification of different pests and diseases in maize and rice using polymerase chain reaction (PCR). They are additional to morphological which is mostly used in many of diagnostic laboratories.

4.2 Expertise needs to improve the diagnostic capacity

1) Specialized personnel

The team conducting diagnostic has to understand the methodology that is going to be used for data collection and synthesis. The outcome of the assessment revealed that experts from government and research institutions engaged in plant health diagnostic. For example Mikocheni has a total of 22 staff (5PhD, 7Msc, 4BSc and 6 technicians) with different disciplines. Similarly from Tropical Pesticide Research Institute 15 staff: 2PhD, 6MSc (2 molecular biologist, 2entomologist and 2virologist), 4BSc with different disciplines and 3 technicians engaged in plant health diagnosis.

Personnel performing plant diagnostic task should be well qualified in the particular area *ie* good education background and experienced. Regular training and recruitment for all members involved in diagnostic service was also important ideas emerged out of consultative meetings. Currently only two staff are employed as laboratory scientists at Kurasini (PHS), while one scientist at Seliani and another one at Dakawa research institutions involving in the laboratory team. Therefore, need to employ new staff with expertise in areas such as operating procedures and practices, alarm systems, emergency procedures, instrumentation manuals, maintenance and repair procedures, safety and health, and any other relevant subjects the laboratory demanding.

2) Specific training

Ninety percent (90%) of the key respondents pointed out that wide range of knowledge at different levels is needed to make sure there is high efficiency of work performed. Laboratory staff assessment from Agricultural Research Institutions showed that many of the plant samples received from farmers far away from research centres are poorly packaged, labelled, no coordinates and poorly handled. Such samples are difficult to identify and recommend proper advice to be taken. On job training for plant diagnostic researchers, extension officers and farmers on sample collection and handling is essential for proper diagnosis of the problems, similar recommendations to other work carried out in India Srivastara (2013). Training builds up human capacity to diagnose threat pests in maize and rice production areas. Short and long training programmes for plant experts, laboratory technicians, farmers and extension workers will acquire new skills to close gaps. Mikocheni and IITA were only institutions observed to carry out training once per year.

Agricultural Universities can assist to provide such knowledge to the target groups (Annecke & Moran, 1982). Training programme will cover theory and practical sessions on use of microscopy, visual observations, ELISA, PCR, DNA and bar coding, Bio safety and bio security. However, long term trainings must be clearly defined, such as; type of subject to be covered and goals of the training. Areas where emphasis is needed was summarised in (Table 6). List of common field pests and diseases which are considered as threat in maize and rice production is summarised in Table 7.

Staff or student who is on training need to be monitored or supervised closely to ensure information generated is reliable. Staff record should be maintained especially where specific task is requested. In addition it is expected that increasing laboratory testing will lead to range of tests that will continue to influence negatively the effectiveness of testing service. Therefore, the testing service must have sufficient capacity interns of skilled staffs, experienced and good education background to accommodate changes (Figure 2).

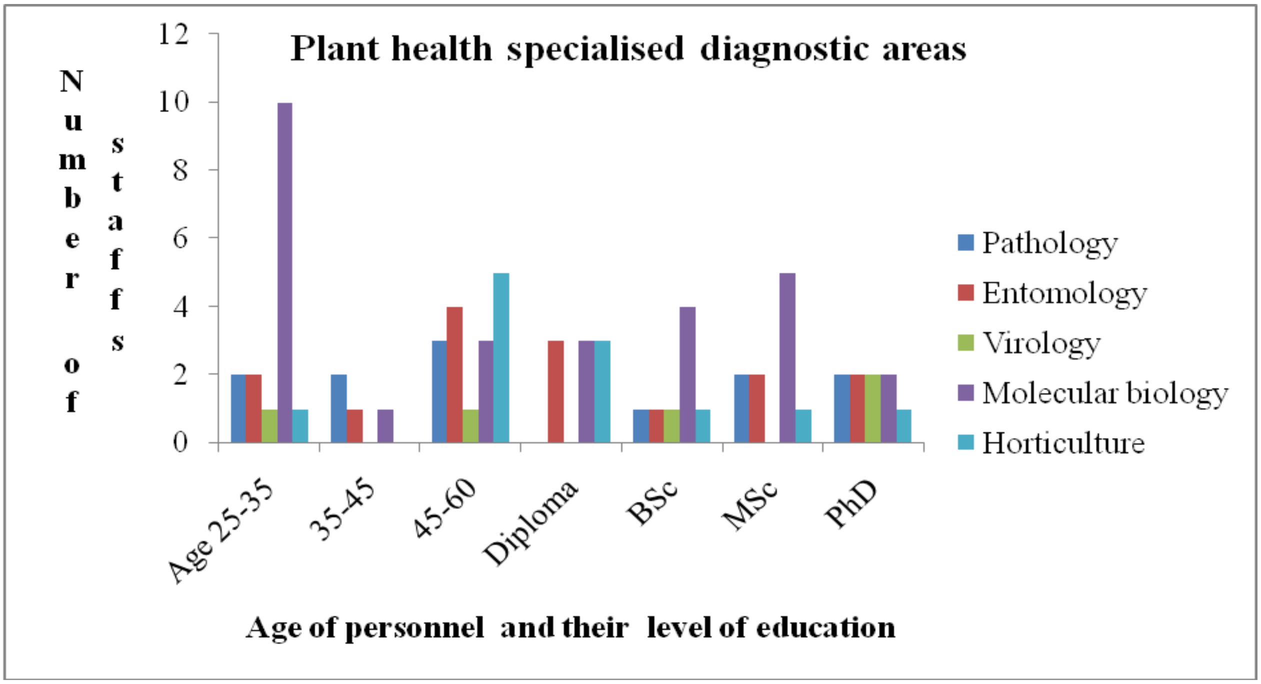

Figure 4: Human capacity for plant health diagnostic laboratory service from MARI and TPRI

Furthermore key respondents from TOSCI/SUA, MARI, IITA, TPRI, Tengeru, Seliani, PHS and Dakawa research institutes were able to identify areas required to carry out specific tasks in their laboratories (Table 4).

Table 4: Identified laboratory specialised areas

SN	**Specialized areas**		
1	Nematology	6	Molecular biologist
2	Mycology	7	Mites
3	Entomology	8	Bacterialogist
4	Seed Botany	9	Weeds (striga)
5	Fertiliser analysis	10	Virology

Table 5: Identified specific training in plant pest diagnostic

SN	**Type of training required**
1	Good qualification at different levels to all scientists involved in laboratory activities:-
2	Insect examination and record keeping
3	General laboratory knowledge
4	Good experimental set-up
5	Crop inspection
6	Pest and disease monitoring
7	Sequencing
8	DNA- bar-coding

Table 6: List of identified as common pests and diseases in maize and rice diagnostic laboratories at Universities of SUA, UDSM and, Dakawa, Seliani, TPRI, Mikocheni Agricultural Research Institutions

Common pests of maize	**Common pests of rice**
Spotted stalk borer (*Chilo partellus*)	Rice stem borer (*Chilo partellus*)
Maize stalk borer (*Busseola fusca)*	African rice gall midge (*Orseolia oryzivora*)
Black cut worm (*Agrotis ipsilon*)	Army worm (*Spodoptera exempta*)
Maize leaf hopper (*Cicadulina mbila*)	Cutworm (*Agrotis* spp.)
Grain ladybird (*Epilachna similis*)	Leaf hopper (*Cicatfulina* spp)
Army worm (*Spodoptera exempta*)	Flea beetles (*Chaetocnema varicornis*)
Termites	Rodents
Pink stalk borer (*Sesamia calamistis*)	Rice stalk fly (*Diopsis* spp)
American bollworm (*Heliothis armigera*)	Rice grasshopper (*Oxya* spp)
Maize aphid (*Rhopalosiphum maidis*)	Striga for upland rice
Bacterial diseases	Sheath rot (*Sarocladium oryzae*)
Leaf rusts (*Puccinia sorghi*)	Sheath blight (*Rhizoctonia solani*)
Nematodes	Rice yellow mottle virus (RYMV)
Virus diseases	Rice blast (*Pyricularia grisea*)
Leaf blights *(P. polysora*)	Birds
Striga weed	

Source Bohlem.1978; Kibanda 2001; Brigitte, 2009; Shao, 2011)

4.3 Collaboration needs with global and regional pest diagnostic laboratories

Collaboration with a number of international partners has also been a very important asset for Tanzania's agricultural sector. Current partners identified by key respondents include MARI, ICIPE, IITA, KEPHIS and the university laboratories *(*Sokoine University of Agriculture, University of Dar Es Salaam and Makerere). Other international laboratories include Colorado University, Maryland University, IPM Innovation labs in Netherlands and California University.
Universities and NARS are the most and common source of reference of common pests and diseases used to ensure quality of data collected as well as biological reference, replicate testing, sequence databases, literature reviews *ie* Bohlem.1978; Brigitte, 2009; and Agrios, 2005 (Table 7).

Thus suggested that a much greater effort should be geared on collaboration with global and regional laboratories to enhance pests, disease detection, and identification and monitoring.

Table 7: List of global and regional pest and diseases diagnostic laboratories that can support diagnosis in East Africa

Type of diagnosis	Global reference	Regional reference
Seed technology	Colorado State University	University of Sokoine, Dar Es Salaam, National Agricultural Research Institutes, IITA ICIPE, KEPHIS in Kenya and Makerere
Entomology	Maryland University	University of Sokoine, Dar Es Salaam, National Agricultural Research Institutes, IITA, ICIPE, KEPHIS, Kenya and Makerere
Nematology	IPM innovation laboratories in Netherlands	University of Sokoine, Dar Es Salaam, National Agricultural Research Institutes, IITA, ICIPE KEPHIS
Pathology including virology	California University	University of Sokoine, Dar Es Salaam, National Agricultural Research Institutes IITA, ICIPE KEPHIS Kenya and Makerere

4.4 Equipping the pest diagnostic laboratories

In laboratories few old specimens were preserved as reference materials for plant pest and diseases diagnostic. Respondents showed diagnose problems which cannot be reliably identified and need regional references for pest diagnostic laboratories. They also stressed that the laboratories should be equipped with seed technology, entomology, nematology and pathology. Despite of the major identified equipments it was recommended the significance of sampling harmonization. All samplers have to harmonise sampling method *ie* use of dissecting kit, Geographical Position System (GPS), soil probe, Shovel, Zip bags, insect vials, ethanol and digital camera. 4.5 On data base needs of the plant health laboratories

4.5 Database management needs of the plant health laboratories

This recommendation emphasizes on the management of the data generated through the diagnostic services. The management system should describe all facilities required and activities to be covered including details and type of customers and tested pests and diseases. Procedures and instructions required for a particular diagnosis are available to suitable personnel. This includes Standard Operating Procedures (SOPs). Similarly participant's priorities for data management, accessibility and good access to internet link as summarized in Figure 3.

Research institution mandated to specific crops available in their Agro ecological zones, should generate information or results obtained and document for various uses. Furthermore, there is a need to have a mechanism in place to deal with various complaints from customers based on record, analysis and incorrect use of recommended procedures or different from customers requirements. For Example; it was found that lack of regular supply of reagent and consumables in Agricultural Research Institutions laboratories. Poor funding was mentioned as causes for delaying as well as poor diagnostic services.

Despite of various suggestions the data generated through plant diagnostic services should focus on the following areas:-

(i) Accurate and timely diagnosis of major pests in maize and rice in the country
(ii) Early detection of invasive species in maize and rice production areas
(iii)Knowledge, occurrence and distribution of invasive species in maize and rice production areas
(iv) Good laboratory data base that meet client interest and Ministry needs

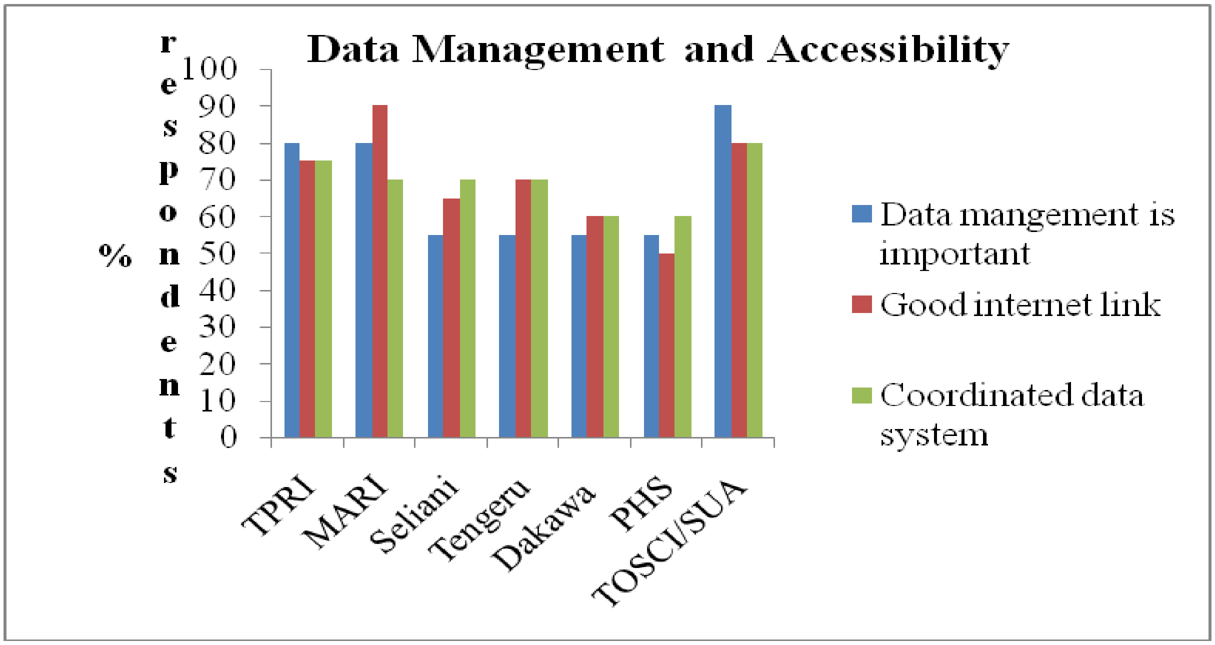

Figure 5**:** Group discussions rank on data management and accessibility

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