Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 16 (XXXI), number 4, 2016: 44–54

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Genetic Technology Transfer to Kenyan Agriculture in the Context of Biotechnology Research[3]

Abstract. Technology development is a crucial issue for economic development in Sub-Saharan African countries. In this paper current research on biotechnology and the potential of biotechnology absorption in Kenya is analyzed. The institutional character, areas of research and funding mechanisms of the research institutions contributing to agriculture sector technological advancements were examined in the context of local farmer's needs. Also factors, such as legal framework and cultural and social values for the biotechnology research in the region were explored. Literature review and the qualitative analysis of data on research facilities and the papers from the region were applied in the research. OLS correlation method was applied in the analysis of the data.

Key words: technology development, biotechnology, research and development, Sub-Saharan Africa, GMO, Cartagena Protocol, technology transfer

Introduction

Majority of population in Africa is employed in the agriculture, but the productivity of the sector is limited. A number of factors, such as decline in food production caused by flawed agricultural policies, political and institutional instability, chronic droughts, disease epidemics, environmental degradation, deterioration of infrastructure, and insufficient investments in agricultural research, have negative influence on Sub-Saharan African (SSA) agriculture performance (Paarlberg, 2005; Karembu et al., 2009; Jha et al., 2011; Interview, 2015). The agricultural policy reforms are advocated especially in the states with growing population (Cochrane, 2014), part of them leading to increased interest in the science based approach to improve the performance of the sector. In order to enhance pro-poor growth, amelioration of the productivity of farming with benefit for the least favored groups is needed. It is crucial to seek means of insertion of technology, which could be used by dominating group of small scale farmers, who use minimal external input (Karembu et al., 2009). For these reasons, and based on the green revolution experiences from Asia, biotechnology became a potentially promising branch of applicable science which could serve the needs of the region (Gordillo and Jimenez, 2006; Bothma et al., 2010; Uctu and Jafta, 2014).

Biotechnology is any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use

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[3] This research is a part of Sonata Project no. DEC-2013/09/D/HS4/01849 financed by the National Science Center in Poland.

(UN, 1993). It has therefore wider meaning than only genetically modified organisms (GMO) or genetically modified living organisms (LMO). Tissue culture, genetic modification (genetic engineering) and molecular breeding (marker-assisted selection) are most commonly used scientific techniques in the agriculture (Karembu et al., 2009). Compared to traditional methods, genetic ones are described as rapid, cost-effective and precise technology which enable improvements in agricultural production (Karembu et al., 2010). Currently, developed countries are still more advanced in the biotechnology research. Some biotechnology technics for strain improvement, which are widely employed in developed countries (eg. classical mutagenesis and conjugation, hybridization) are only beginning to be applied in developing countries for the improvement and development of starter cultures (FAO, 2011). However, the situation is dynamic, and the North is now facing a strong increasing market competition from both emerging economies and developing countries. Especially farmers from Chile, Argentina or China which are capable to profit from genetically modified crops are important competitors for producers from developed markets (FAO, 2011).

The use of biotechnology as a panacea for productivity problems in agriculture in African, and especially Sub-Saharan countries is an up to date topic in scientific literature. Current scientific research focuses on both the suitability of biotechnology for the farmers (constraints, opportunities, mechanisms), and on biotechnology solutions *sensu stricto* for Sub-Saharan agriculture. However, there is a number of issues of social, political, institutional, economic, legal and ethical character considering biotechnology use in African states, which need to be addressed. A systemic analysis of the biotechnology research in Sub-Saharan African states requires especially institutional and legal context, as twin processes of modern biotechnology transfer and development of a regulatory regime evolve in some African states (Kingir, 2011).

The aim of this study was to verify how the scope of the research in the Sub-Saharan Africa responds to the technology transfer challenges described in economic literature. First literature review on the suitability of biotechnology transfer in the agriculture of the region in the context of social and institutional challenges was conducted, then current biotechnology research in Kenya was presented. Next statistical data for Kenyan agriculture for the period of 1982-2010 was explored and analyzed the content of biotechnology research papers affiliated in Kenya, which was chosen as a case study. The idea was to verify, whether biotechnology research in this country support the capacity to produce locally focused innovations suitable for the technology transfer inside the country. Our results include the correlations of economic growth with agricultural research in Kenya and the assessment of biotechnology research goals.

The rationale for selecting Kenya was based on several individual factors. First, it has the experience with biotechnology use. Kenya has tested with GM since 90s, and because of establishment of legal framework is in the confined field testing phase. Moreover, there is a significant body of literature on Kenya (in some cases on Kenya and Uganda) experiences with GMO crops. Also improved agricultural production is an important factor of Kenyan GDP performance. An inductive approach was adopted. Methods of system and comparative analysis were applied in order to find crucial factors of institutional and legal capacity for biotechnology application in the Sub-Saharan region. Discovering the scope of the biotechnology research in these countries in the context of legal and social factors of technology transfer allowed some overall concluding remarks.

Data and method

This research was organized in two phases of empirical analysis. First, a method of ordinary least squared modelling was applied in order to check the influence of selected explanatory variables on economic growth in Kenya in 1982-2010. Economic growth value was taken in per capita measure and constant 2005 USD value. Since the goal of the study was to verify the importance of knowledge and research on economic expansion in Kenya, a set of explanatory variables consisted of: number of primary education pupils, researchers in higher education as a share of all researchers, the overall number of researchers per 100 000 farmers, and the agriculture value added (as annual % of growth). Data was extracted from the World development indicators and Agricultural Science And Technology Indicators, which provide on-line datasets. The analysis was conducted with the use of Gretl software.

In the second step of the research, biotechnology research papers were studied and their content analysis was conducted to review the scope of genetic modification possible application in Kenya. Papers were analyzed with the aim to determine the orientation of biotechnology research and did not focus on their biological scientific aspects. The Scopus database was searched using the keywords such as “transgenic crop”, “transgenic plant”, “agricultural biotechnology”, “bt maize”, “bt cotton” for Kenya. The screening was performed on publications from 2005 to January 2015. The papers were affiliated in Sub-Saharan African institutions, however for many cases, they were delivered in collaboration with the facilities from outside the region. 114 papers were found. All of them were analyzed against the methodology, crop species, institutions responsible and funding sources.

Literature review

By some researchers, increased use of biotechnology in agriculture could improve yields also in African agriculture and ameliorate food security (Chataway, 2005; Karembu et al., 2009; Dargie et al., 2013; Abidoye and Mabaya, 2014). It is expected to contribute especially towards arresting the effects of climate changes (savings in carbon dioxide emissions, fewer insecticide and herbicide sprays, conservation tillage) and drought-tolerant traits (Karembu et al., 2009; Bothma et al., 2010; Jha et al., 2011). Particularly, biotechnology may address problems such as effective control of the plant parasitic nematodes and other diseases of crops (Hassan et al., 2013). According to Food and Agriculture Organization (FAO) report, in the nearest future, a broad range of additional species and traits combinations will be launched in different regions of the World. Among them four crops: soybean, maize, cotton and canola, and two traits: herbicide tolerance and insect resistance, are the most likely to be released as GMOs in the World trade (FAO, 2014).

Nevertheless, the recognition of the advantages of biotechnology use in developing countries agriculture is ambiguous in the literature. First, implementation of biotechnology is costly, while especially small farmers in Sub-Saharan Africa (SSA) suffer because of insufficient level of state funding and domination of private equity (Chataway, 2005). The GM seeds as the object of Intellectual property protection (IPR) are expensive (Chataway, 2005). Apart from IPR, the international trade barriers and regulations concerning modified products are a potential limitation for the farmers to profit from biotechnology use. Diverse biotechnology regulations and zero tolerance policy in some countries affect the international trade of modified products (Paarlberg, 2005; FAO, 2014). Developing countries policy makers fear of running commercial risks of losing sales to markets such as European Union, where the consumers are not confident about GMO safety for health and the environment (Paarlberg, 2005). Rejection or market withdrawals of modified products by importers in developed countries may have several socio-economic impacts on producers, consumers and agribusiness firms (FAO, 2014). Different policies on GMOs, unintentional movement of GM crops, different timing of approvals for GMOs, and difficulty in accessing information for products are the major constraints in the GMO related trade according to FAO (FAO, 2014). For less experienced farmers they may prove to be insurmountable.

Moreover, a wide social support for genetic technologies is indispensable for large scale on field application of biotechnologies, and it is not evident in Africa. According to Muchopa, Munyuki-Hungwe and Matondi, Africans exist in a value system which respects products as provided by the Creator both socially and culturally, so the ideas of cloning or by-products thereof are not acceptable in African beliefs and myths and affect the social and cultural lives of African people (2006). The opposition to GMO is represented in Sub-Saharan Africa by organizations such as South African Freeze Alliance on Genetic Engineering (SAFeAGE), The African Centre for Biosafety (ACB) and Biowatch South Africa (Bothma et al., 2005). According to Ogungbure’s comment on applicability of biotechnology in Sub-Saharan, the culture in the region which embodies the totality of human experience and the tendency for survival within a social environment is in compliance with biotechnology (2011:94).

The reception of Western culture patterns, including technology and biotechnology in particular, may not be thoughtless process; attitudes towards biotechnology should be neither too enthusiastic nor too hostile, but rather cautious, rational and controlled (Tangwa, 2005). Application of modern biotechnology shall not conflict with conservation of traditional values and native heritage (Steenkamp and Wingfield, 2013). Successful introduction of biotechnology techniques in the region requires appropriate integration of science-based and traditional knowledge sources (Dargie et al., 2013). In this context, lack of incentives from private companies to research tropical plants constitute a certain risk for the maintenance of traditional crops (poor farmers may be perceived as week target market) (Paarlberg, 2005). People fear the risk of dominance of agricultural production for exports over-responding to local demand for consumption and the reinforcements of big plantations position in comparison to small ones (Andrzejczak, 2014). However, at the same time a niche for locally focused African biotechnology research appears.

Despite divergent opinions, the process of commercialization of biotechnology crops commenced in African continent (Egypt, Burkina Faso, South Africa) and is expected in other countries, such as Kenya (ISAAA, 2016). A *sine qua non* for biotechnology transfer to be enhanced is the introduction of an adequate legal framework. Research and innovation in biotechnology with respect to health and environment issues require a well-designed regulatory framework to evaluate genetically modified crops (Cochrane, 2014).

Biotechnology as an element of a broader concept of biosafety is an internationally regulated issue and requires implementation of multilateral agreements into national system. The laws derive from the Rio de Janeiro 1998 United Nations Summit, where the Convention on Biological Diversity was adopted under the UN Environment Programme. Kenya was the first country to sign the Cartagena Protocol, but it took Kenya almost a decade to enforce the National Biosafety Framework (NBF) (SCBD, 2014). Some African states, such as Burkina Faso, Liberia or Senegal made their biosafety framework operational before Kenya, and some have not yet succeeded (e.g. Democratic Republic of Congo, Djibouti) (COP-MOP, 2014).

Based on the evidence from Kenya, the consensus between key government actors, clearly assigned responsibilities, strategy plan to advocate desired law and policy, alliances with different stakeholders, engaging experts from different fields in the regulation process, communication strategy, stakeholder mapping, involvement of good legislators, media strategy, involvement of public opinion are fundamental elements of the biotechnology legislation process (Karembu et al., 2010). Introduction of biotechnology laws does not mean allowing GMO crops in the economy. In the regulatory process in Kenya a decision to ban the import and planting of GMOs in 2012 due to health concerns ended the period of legal uncertainty on the issue (Nang'ayo, 2014). Since the decision to allow the cultivation of GMO maize and cotton are currently being pushed for approval by pro-GMO organizations, the situation may change according to different on-line sources, such as Ecowatch. In the meantime, there is a number of initiatives of international and regional character aimed at capacity building and direct biotechnology research in Kenya (NBS, 2016). These programs aim at solving institutional problems of research and education systems. Institutions such as International Institute of Tropical Agriculture (IITA) concentrate on research for development issues R&D, finding solutions for hunger, malnutrition, and poverty, including biotechnology research.

In Kenya large as well as small-scale farmers produce the crop and a significant part of the population depends on maize farming as an income-generating crop. The main problem are high yield losses and the necessity of pesticide application caused by five major stem borer species *Chilo partellus*, *Chilo orichalcociliellus*, *Eldana saccharina*, *Sesamia calamistis* and the economically important *Busseola fusca* (Mugo et al., 2005). The Insect Resistant Maize for Africa (IRMA) project is a collaborative effort between the International Maize and Wheat Improvement Centre (CIMMYT) and the Kenya Agricultural Research Institute (KARI). It has been developing genetically modified maize varieties by incorporating modified gene with constitutive expression derived from the soil dwelling bacteria *B. thuringiensis* (Bt) (Mugo et al., 2005).

Bt maize leaves were first introduced into Kenya in 2002 following National biosafety regulations (Mugo et al., 2005). This was followed by the first introduction of Bt maize seeds in 2004, after completion of biosafety facilities including the first Biosafety Level II green house and the first confined field trial site for growing the transgenic maize plants in Kenya (Mugo et al., 2005). From that time on they are still research carry on new resistance genes identification, safety use as well as fast detection of GM plants.

There are some evidence that pests quickly develop resistance to Bt maize. To delay the development of insect resistance to Bt maize it is recommended that farmers create a "refugia" of non-GE crops for the pests to feed on (Mulaa et al., 2011). Most small-scale farmers will not be able to create the required buffer zone or allocate land for a "refugia". That's why the interesting approach is the push-pull system, which was developed by International Centre of Insect Physiology and Ecology (ICIPE) in Kenya. Close collaborators include the governmental KARI and the Institute of Arable Crop Research (IARC) in UK. This technology intercropped repellent plants "push" the insects out of the fields to trap crops outside the fields that "pull" the insects in. It has been developed for integrated management of stemborers, striga weed and soil fertility. It is appropriate and economical to the resource-poor smallholder farmers in the region as it is based on locally available plants, not expensive external inputs, and fits well with traditional mixed cropping systems in Africa (Pickett et al., 2014). It is now beyond the trial phase and is being actively disseminated in Kenya. Push-pull is a sustainable farming system, which can also protect the new generation of GM crops against development of resistance by pests (King et al., 2013). Genome engineering and creation of synthetic crop plants by combining approaches including new crop genomic information can contribute to push–pull farming systems (Pickett et al., 2014).

Another type of biotechnological approach in Kenya is *Agrobacterium*-mediated transformation. This approach is the gene delivery system, which is most preferred by plant biotechnologists because of its easy accessibility, tendency to transfer low copies of DNA fragments carrying the genes of interest at higher efficiencies with lower cost and the transfer of very large DNA fragments with minimal rearrangement (Gelvin, 2000). Therefore, plant transformation through Agrobacterium-mediated DNA transfer has become a favored approach for many crop species (Barampuram and Zhang, 2011). However, there are only few articles concerning uses of this modification to transferring important traits such as viral and bacterial disease resistance, prolonged shelf life and nutritional enhancement for African farmer-preferred cultivars of maize (Ombori et al,. 2013) as well as cassava (Nyaboga et al., 2013) and bananas (Uganda mainly, Tripathi et al,. 2010, Tripathi et al., 2012; Namukwaya et al., 2012).

New type of modification, which is now developed worldwide not excepting the African researchers is RNAi-mediated gene silencing. RNA interference (RNAi) is a promising gene regulatory approach in functional genomics that has significant impact on crop improvement. RNAi has also been exploited in plants for resistance against pathogens, insect/pest, nematodes, and virus causing significant economic loss (Younis et al., 2014).

The scope of the research which is conducted in Kenya will be reflected in the potential introduction of biotechnology to Kenyan agriculture. This will have important consequences for the market structure, the overall situation in the sector as well as the whole economy. In the next section, the assessment of the research will be provided in the context of economic development and agricultural research nexus in Kenya.

Results and implications

Agriculture is an important engine of growth for Kenya, so the decisions concerning rejection of genetic modifications of crops will have serious consequences for the future development. A model of the importance of the number of primary education pupils, researchers in higher education as a share of all researchers, the overall number of researchers per 100 000 farmers, and the agriculture value added (as annual % of growth) for the GDP per capita in Kenya in the period of 29 years was devised. The R squared correlation value for the OLS model was 0.67. It was found, that both the education on basic level and the research in agriculture do contribute to the overall economic outcomes in Kenya, and hence, constitute an important factor for its economic development possibilities. The more educated is the population, and the stronger is the role of education system both on the basic level, and the research – especially research in agriculture, the better are the outcomes of rural sector in the economy, and hence the economic performance of the country contributes to individual conditions of citizens.

Kenya is among the leaders of the region not only due to regulative activity, but also in the agricultural R&D spending and human resource capacity. Along with Nigeria, South

Africa, these three countries accounted for half the region's agricultural R&D investments in 2012 (WDI, 2016). In Kenya much more researchers are employed in the public sector than non-profit researchers. Among them, the number of researchers in higher education is significantly smaller than in the government agencies, but its share is constantly growing (ASTI, 2013). This indicates an increasing role of tertiary education and increasing importance of universities. On the other hand, negative correlation of researchers in higher education with per capita growth revealed by the model may indicate that researcher contribute more to economic development while conducting their studies than while engaging in the education process.

Table 1. Variables of GDP per capita (constant USD 2005) using observations for 1982-2010 in Kenya

Variables[a]	Coefficient	Std. Error	t-ratio	p-value	
const	−3134.13	561.271	−5.5840	<0.0001	***
Enrol. Prim Edu. log	540.632	83.3762	6.4842	<0.0001	***
Researchers HE	−3.82166	1.0405	−3.6729	0.0011	***
Res. Total per 100 000 farmers	11.1317	3.66303	3.0389	0.0055	***
Agric. VA annual growth	1.86145	0.78503	2.3712	0.0257	**

[a]No collinearity problem was detected, Variance Inflation Factors were respectively: 5.042, 4.048, 1.861, 1.113.

Source: (WDI, 2016), own elaboration.

Being aware of the possible revolution in Kenyan agriculture with a possible GMO allowance, current research in the field of biotechnology was analyzed. It was found that maize is the most important food crop in Kenya. The crops researched in Kenya are under the confined field trials, with the exception of Bt cotton, which is in commercial use in the latter. The analysis of biotechnology research papers allowed to report what kind of crops are modified in Kenya and for what purposes (Table 2). The techniques used in the research papers which were explored, are generally less advanced methods than current research conducted in USA, for corresponding purposes. Because of the differences of GMO regulations in USA and Europe, the scope of the research in Kenya is more closely related to issues in North American research on commercialized GMO. Commercial purposes genetic modifications are not conducted in the regions which rejected GMOs. A majority of papers was based on the genetic modifications developed by Monsanto or Syngeta companies. Only 6 papers concerning local plant based modification were found. Therefore the research is rather focused on the endogenous modifications which are subject of transfer into local environment, than on indigenous modifications.

Study results reveal, that research conducted in cooperation with the USA scientists and funded by Monsanto, concentrate mainly on GMO crops effectiveness and increased GMO resistance to larvae compared to non-GMO. They also focus to prove neutral character of GMO to the environment. Whereas the works done in cooperation with French or English researchers embrace fast pest resistance to endotoxines introduced to GMO plants. They also aim at proving the superiority of natural species refugia and technologies such as push-pull (without GMO) over genetic modifications of plants. Majority of publications on Bt rice were funded by Monsanto company. The papers which were published independently by scholars from African universities were in minority. So was the number of papers on new GMO for local farmers.

Table 2. Biotechnology research scope and funding sources in agriculture research in Kenya between 2005 and January 2015

Research interest – crop	Goal of modification	Type of institution	Funding (private, public, country)
Maize	Genetically modified (GM) with *Bacillus thuringiensis* (Bt) endotoxins for insect resistance : - environmental impact - GM detection by PCR (polymerase chain reaction) - Effectiveness of bt modification - Evaluation of maize genotypes - bt vs insect resistance RNAi-mediated, VIGS (virus-induced gene silencing) system	Universities, as well as CIMMYT, ICIPE, KARI, in cooperation with USA and Canada universities	Mainly Syngenta Found. for Sustainable Agriculture and the Rockefeller Found. International Found. for Science (IFS)
Push-pull farming system	Push–pull farming systems for pest control together with bt modification	Universities with cooperation with UK	Governments of SE., DE, CH, DK, NO, FI, FR, KE, GB Gatsby Charitable Found., Kilimo Trust and the EU, Rockefeller Found., Biovision, McKnight Found., Bill & Melinda Gates Found.
Cassava	*Agrobacterium*-mediated transformation for east African farmer-preferred cultivars; transferring virus resistance and prolonged shelf-life	University, IITA in cooperation with swedish university	IITA, USAID
Banana	Gene transfer from rice enhanced resistance against Xcm coused Banana Xanthomonas wilt (BXW)	IITA from Kenya and Tanzania, USA	CGIAR Research Program on Roots, Tubers and Bananas as well as Bill & Melinda Gates Found. and IITA
Sorghum	Anti-fungal genes introduced by particles bombardment	KIRDI* institute in cooperation with German university	n/a
Cowpea	Genetically modified (GM) with *Bacillus thuringiensis* and electroporation-mediated insecticide genes	Universities in Kenya and Nigeria	IITA Nigeria
Sweetpotatoes	Genetically modified (GM) with *Bacillus thuringiensis* - analysis of non-target effects in agroecosystems caused by GM	Uganda university and NaCRRI** cooperation with Kenya African Institute for Capacity Development, International Potato Center	Regional Universities Forum for Capacity Building in Agriculture (RUFORUM)
Yam	*Agrobacterium*-mediated transformation using axillary buds as explants	IITA Kenya	(IFS)

* Kenya Industrial Research and Development Institute
** National Crops Resources Research Institute

Source: own elaboration.

At this point they are financed by a variety of partners national and international, public and private and cooperate with a number of actors on the local level for the purposes of research and the transfer of developed technology solutions. However, large institutions such as IITA, with a developed collaborative network should concentrate to constitute a framework for conducting research in Africa and focused on African economy's needs. Increasing role of such institutions is crucial, for the agricultural research to serve the needs of Sub-Saharan societies.

Based on these findings, it can be concluded that the agricultural research on biotechnology in Sub-Saharan Africa is highly dependent on the goals of funding entities. Research funded by the private companies and American resources are generally aimed at the promotion of biotechnology, while quite the opposite objectives motivate the Europeans. Neither actually concentrates on local farmer's needs. This is a strong argument towards the increased involvement of state and regional institutions to engage in the selection of research topics and scope.

Conclusions

Innovations, understood as more effective use of resources, require enabling economic environment. The entrepreneurs must be motivated to introduce and use technology, research facilities motivated to conduct research suitable for commercialization and education system to train human capital capable to manage and use the technology. Governments should provide required environment and to finance elements of these processes. Such systems are needed in Sub-Saharan region in order to enhance the catching-up process for pro-poor economic development. The question remains, whether biotechnology can be a potential leverage for African agriculture, which should be supported by vast groups of local interests supporters. This paper addressed agriculture biotechnology research conducted by Kenyan scientists and the focus of that research in the context of the importance of the research for agriculture development and country's economic performance. Our model revealed that Kenyan GDP per capita performance is correlated with the research in agriculture and the level of education of the society. Therefore it can be concludes, that the scope of the research and its future application on the market are important factors of economic development in this country. If a thesis that using genetic modifications increases productivity of agriculture is accepted, than we can assume, that indeed adoption of pro-GMO policy could contribute to economic growth in Kenya.

However, Sub-Saharan African countries represent vast array of approaches to genetic modification, from rejection to approval. Contradictory opinions and polarized attitudes towards the use of biotechnology make regulation process in Kenya challenging – the country first supporting biotechnology commercial use, then rejected it in 2012. Now the question of allowing GMOs is back on the table. This decision is urgent, since appropriate legal framework is required to enable the emergence of a systemic approach for the innovations and transfer contributing to local needs. Financing research from international resources of private and public character is indeed beneficial, but it may not become profitable mainly to the foreign entities. Based on our findings, the choice of technologies appropriate for absorption and research should be motivated by national interests of farmers, not a decision depending on private companies R&D departments. Monsanto and Syngenta companies activities are severely criticized for hostile attitudes towards Kenyan market. At the same time, these companies are financing large part of the local research and hence influence its scope. Foreign governmental agencies are realizing their policy goals from approval to rejection, by choosing the research goals corresponding to their agenda. This indicates that the research in biotechnology is currently orientated towards external interests and promotion of the donor agenda.

The role of regional organizations in Sub-Saharan Africa, as coordinators of regional policy should be enhanced for that matter. Successful research projects require not only the financial resources but also the institutional framework to manage the resources offered. International, indirect technology transfer projects can help overcoming the constraints and building the capacity both to produce or to absorb technology. They may support local technology research initiatives oriented towards local demand, using their experience, knowledge and skills. If Kenya will allow biotechnology in commercial use, effective communication strategy will be required and a national strategy to manage government and foreign funded projects for the profit of local farmers not transnational companies' or foreign developed countries.

Bibliography

Abidoye, B.O., Mabaya, E. (2014). Adoption of genetically modified crops in South Africa: Effects on wholesale maize prices, Agrekon: Agricultural Economics Research, *Policy and Practice in Southern Africa*, 53:1, 104-123, DOI: 10.1080/03031853.2014.887907

Andrzejczak, K. (2014). Technologies Development Perspectives in Sub-Saharan African Countries in: Economy and Social Conditions in Transition, ed. Gorges I., Winkler L., Dr. Kovac GMBH Hamburg, Hamburg: Verlag, 81-104.

ASTI (2013). (Agricultural Science and Technology Indicators). 2013. ASTI database. http://www.asti.cgiar.org/data.

Barampuram, S, Zhang, Z.J. (2011). Recent advances in plant transformation. *Methods Mol Biol*. 701, 1-35.

Bothma, G., Mashaba, Ch., Mkhonza, N., Chakauya, E. and Chikwamba, R. (2010). GMOs in Africa: Opportunities and challenges in South Africa, *GM Crops*, 1:4, 175-180.

Chataway, J. (2005). Introduction: is it possible to create pro-poor agriculture-related biotechnology? *J. Int. Dev*., 17, 597–610.

Cochrane (2014). Agricultural intensification in Ethiopia: Review of recent research, *African Journal of Agricultural Research*, Vol. 3 No 31, 2014, 2377-2390.

COP-MOP (2014).Results of the survey to gather information corresponding to indicators in the Strategic Plan https://bch.cbd.int/database/reports/surveyonindicators.shtml

Dargie, J. D., Ruane, J. and Sonnino, A. (2013). Ten Lessons from Biotechnology Experiences in Crops, Livestock and Fish for Smallholders in Developing Countries, *Asian Biotechnology and Development Review* Vol. 15 No. 3, 103-110.

FAO (2011). Current Status and Options for Biotechnologies in Food Processing and in Food Safety in Developing Countries in: Biotechnologies for Agricultural Development, Food and Agriculture Organization of the United Nations, Rome.

FAO (2014). Low levels of GM crops in international food and feed trade: FAO international survey and economic analysis, Technical Background Paper 2, Rome.

Gelvin, S. B. (2000). Agrobacterium and plant genes involved in T-DNA transfer and integration. *Annu. Rev. Plant Physiol. Plant Mol. Biol*. 51, 223-256.

Gordillo, G., Jimenez, F. (2006). La nueva agricultura. (With English summary). *El Trimestre Economico*, 73(1), 175-196.

Hassan, M. A., Pham, T. H., Shi, H., Zheng, J. (2013). Nematodes threats to global food security. Acta Agriculturae Scandinavica: Section B, *Soil & Plant Science*, 63(5), 420-425. doi:10.1080/09064710.2013.794858.

Interview (2015). An interview with former Agriculture Minister of the Republic of Congo, Brazzaville, August 2015.

Jha, A., Jha, S., Gautam, H. K. (2011). The GM potato issue: A health concern. *International Journal Of Agriculture, Environment & Biotechnology*, 4(3), 213-219.

Karembu, M., Otunge, D., Wafula, D. (2010). Developing a Biosafety Law: Lessons from the Kenyan Experience, ISAAA Afri Center, Nairobi, Kenya.

Karembu, M., Nguthi, F., Ismail, H. (2009). Biotech Crops in Africa: The Final Frontier, ISAAA AfriCenter. Nairobi, Kenya.

King, J., Armstead, I., Harper, J., Ramsey, L., Snape, J., Waugh, R., James, C., Thomas, A., Gasior, D., Kelly, R. et al. (2013). Exploitation of interspecific diversity for monocot crop improvement. *Heredity*, 110, 475–483.

Kingir, A.N. (2011). Conflicting advocacy coalitions in an evolving modern biotechnology regulatory subsystem: policy learning and influencing Kenya's regulatory policy process. *Science & Public Policy*, 38(3), 199-211. doi:10.3152/030234211X12924093660273.

Muchopa, Ch., Munyuki-Hungwe, M. and B Matondi, P. (2006). Biotechnology, Food Security, Trade and The Environment, A Synthesis of Issues Impacting on Consumers Rights in Africa, https://www.google.pl/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#.

Mugo, S.N., De Groote, H., Bergvinson, D.J., Mulaa, M., Songa, J., Gichuki, S. (2005). Developing Bt maize for resource-poor farmers - Recent advances in the IRMA project. *African Journal of Biotechnology* 4 (13), 1490-1504.

Mulaa, M.M., Bergvinson, D.J., Mugo, S.N., Wanyama, J.M., Tende, R.M., Groote, H.D., Tefera, T.M. (2011). Evaluation of stem borer resistance management strategies for Bt maize in Kenya based on alternative host refugia. *African Journal of Biotechnology* 10(23), 4732-4740.

Namukwaya, B., Tripathi, L., Tripathi, J.N., Arinaitwe, G., Mukasa, S.B., Tushemereirwe, W.K. (2012). Transgenic banana expressing Pflp gene confers enhanced resistance to Xanthomonas Wilt Disease. Transgenic Res. 12, 855-865.

Nang'ayo, F. (2014). Kenya's ban on imports GM crops, African Agricultural Technology Foundation, [Available at:] http://aatf-africa.org/ [Access: January 2016].

NBS (2016). National Biosafety Authority in Kenya, http://www.biosafetykenya.go.ke/.

Nyaboga, E., Njiru, J., Nguu, E., Gruissem, W., Vanderschuren, H., Tripathi, L. (2013). Unlocking the potential of tropical root crop biotechnology in east Africa by establishing a genetic transformation platform for local farmer-preferred cassava cultivars. Frontiers in Plant Science, 41-11. doi:10.3389/fpls.2013.00526.

Ogungbure, A.A. (2011). The Possibilities of Technological Development in Africa: An Evaluation of the Role of Culture, *The Journal of Pan African Studies*, vol.4, no.3, March 2011, 86-100.

Ombori, O., Muoma, J.V.O., Machuka, J. (2013). Agrobacterium-mediated genetic transformation of selected tropical inbred and hybrid maize (Zea mays L.) lines. *Plant Cell, Tissue Organ Cult.* 113, 11–23.

Paarlberg, R. (2005). From the Green Revolution to the Gene Revolution. *Environment*, 47(1), 38-40.

Pickett, J.A., Woodcock, C.M., Midega, C.A., Khan, Z.R. (2014). Push-pull farming systems. *Curr Opin Biotechnol*. 26, 125-132.

SCBD (2014). Review of the Information Gathered through a Dedicated Survey and Corresponding to Indicators in the Strategic Plan, Secretariat of the Convention on Biological Diversity (SCBD), http://bch.cbd.int/database/record.shtml?documentid=105532, 01/02/2015.

Steenkamp, E.T. and Wingfield, M.J. (2013). Global forest research, science education and community service positively impacted by a unique Centre of Excellence in Tree Health Biotechnology, *Southern Forests*, 75(2), 71–80.

Tangwa, G.T. (2005). Genetic Technology and Moral Values An African Opinion, Forum for Intercultural Philosophy 6/2005, http://them.polylog.org/6/ftg-en.htm.

Tripathi, J.N., Muwonge, A., Tripathi, L. (2012). Efficient regeneration and transformation protocol for plantain cultivar ‘Gonja Manjaya’ (Musa spp. AAB) using embryogenic cell suspension. In vitro *Cell Dev. Biol. Plant* 48, 216–224. doi: 10.1007/s11627-011-9422-z.

Tripathi, L., Mwaka, H., Tripathi, J.N., Tushemereirwe, W.K. (2010). Expression of sweet pepper hrap gene in banana enhances resistance to Xanthomonas campestris pv. musacearum. *Mol. Plant Pathol*. 11, 721–731.

Uctu, R. and Jafta, R.C.C. (2014). Bio-entrepreneurship as a bridge between science and business in a regional cluster: South Africa’s first attempts, *Science and Public Policy* 41, 219–233.

UN (1993). Convention on Biological Diversity, http://www.cbd.int/convention/articles.shtml?a=cbd-02.

Younis, A., Siddique, M.I., Kim, C-K., Lim, K-B. (2014). RNA Interference (RNAi) Induced Gene Silencing: A Promising Approach of Hi-Tech Plant Breeding. *International Journal of Biological Sciences*; 10(10), 1150-1158.

WDI (2016). World Development Indicators data base, http://databank.worldbank.org/ [Access: January 2016].