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CENTRE FOR ADVANCED STUDIES IN ENVIRONMENTAL LAW AND POLICY (CASELAP)

TOWARDS A REGULATORY FRAMEWORK FOR INCREASED AND SUSTAINABLE USE OF BIO-FERTILIZERS IN KENYA

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been presented for a degree in any other University or any other award. No part of this work should be reproduced without the prior permission of the author and/or University of Nairobi.

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DEDICATION

Dedicated to my family for their continued support and my friend

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Above all, I thank God for His help and strength in many challenging moments that I faced during the study and for always being there for me.

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ABSTRACT

To meet the increasing food demand for a growing population, chemical fertilizers play an important role in enhancing crop productivity. However, continuous use of chemical fertilizers has caused pollution of the environment. Bio-fertilizers are environmentally safe products that can be used to complement chemical fertilizers. Lack of policy and legal framework on bio-fertilizers has weakened monitoring and control mechanisms thus contributing to availability of low quality products in the Kenyan market. Thus, the regulation of bio-fertilizers is necessary to ensure availability of adequate quality products and an increased awareness and uptake by farmers. The aim of this study was to examine whether the current regulatory framework provides mechanisms for appropriate production and use of environmentally safe bio-fertilizers. Specifically, the study (i) investigated the level of uptake of bio-fertilizers among farmers; (ii) assessed different kinds of regulatory mechanisms used to regulate bio-fertilizers, (iii) explored best practices of corrective measures in other countries, and (iv) investigated strategies that could increase awareness and uptake of bio-fertilizers. The research involved field studies whereby primary data was collected through administration of questionnaires and interviews of key informants. Secondary data was obtained from relevant literature, and best practices were inferred from regulations in Canada and India. Three hundred farmers and thirty agro-dealers in ten villages were sampled to obtain information on bio-fertilizer uptake in Siaya County. Interviews were conducted with national and international non-governmental organizations, industry players, regulatory bodies and Egerton University, which is involved in quality verification of bio-fertilizers. Only one farmer in the surveyed area (0.33 %) applied bio-fertilizer, indicating that the level of uptake of the products among farmers was very low. The major factors affecting the uptake in the area were lack of knowledge by farmers and agro-dealers, lack of product application knowledge, lack of demand and resistance to change. The regulatory bodies revealed that the current monitoring system is weak resulting in inefficient regulation of bio-fertilizers. Lack of a legal framework to enforce regulation has lead to infiltration of low quality products into the market. This is compounded by a lack of extensive research, training and market development that are necessary in enhancing awareness of the products. It is recommended that a comprehensive legal framework should be set in place to control for quality of products and increase awareness on proper use and benefits of bio-fertilizers.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFT	American Farmland Trust
AGRA	Alliance for a Green Revolution in Africa
AKTP	Africa Knowledge Transfer Partnership
BGA	Blue Green Algae
BNF	Biological Nitrogen Fixation
CAN	Calcium Ammonium Nitrate
CFIA	Canadian Food Inspection Agency
COMPRO	Commercial Products
DAP	Di-ammonium Phosphate
ECA	Essential Commodities Act
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
FCO	Fertilizer Control Order
FFTC	Food and Fertilizer Technology Centre
FNCA	Forum for Nuclear Cooperation in Asia
GHG	Greenhouse Gas
GMO	Genetically Modified Organisms
ICIPE	International Centre of Insect Physiology and Ecology
IFDC	International Fertilizer Development Company
IITA	International Institute of Tropical Agriculture
IPNI	International Plant Nutrition Institute
KALRO	Kenya Agricultural and Livestock Research Organization
KARI	Kenya Agricultural Research Institute
KEBS	Kenya Bureau of Standards
KEPHIS	Kenya Plant Health Inspectorate Service
KFA	Kenya Farmers Association
KOAN	Kenya Organic Agriculture Network
KSTCIE	Kenya Standing Technical Committee on Imports and Exports
LARMAT	Land Resource Management and Agricultural Technology
MAP	Mono-ammonium Phosphate
MIRCEN	Microbial Centre
MOA	Ministry of Agriculture
MT	Million tons
NASEP	National Agricultural Sector Extension Policy
NEMA	National Environment Management Authority
NEP	National Environment Policy
N2Africa	Nitrogen to Africa
NCPB	National Cereals Produce Board
PCPB	Pest Control and Products Board
PGPR	Plant Growth Promoting Rhizobacteria
PSB	Phosphate Solubilizing Bacteria
PSM	Phosphate Solubilizing Microbes
R&D	Research and Development
Rs	Rupees

SSA	Sub Saharan Africa
SSP	Single Superphosphate
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
VAM	Vesicular Arbuscular Mycorrhiza
VBA	Village Based Advisor

1.0 INTRODUCTION

In the context of projected global population growth and improving income levels, food production will have to be increased by 70% (FAO 2009, Alexandratos and Bruinsma 2012). This will require intensified and increased agricultural production per land area since the amount of available arable land is finite (IPNI 2009). Environmental destruction including disappearing fallows, land degradation and low soil nutrients are as a result of farmers' lack of success in intensifying agricultural production in a manner that maintains soil productivity (Crawford et al. 2006).

Fertilizer application is considered to play an important role in enhancing crop productivity and slowing the rate of environmental degradation (Heisey and Mwangi 2006, IPNI 2012). In sub-Saharan Africa, fertilizer use is as low as 8-10 kg/ha compared to 50 Kg/ha as recommended by the Abuja Fertilizer Summit in 2006 (Sommer et al. 2013).

In 2006, Kenya's nutrient depletion rates were nitrogen (N) 40 kg/ha/yr, phosphate (P) 6.6 kg/ha/yr, and potassium (K) 33.2 kg/ha/yr (Makokha et al. 2006). Continued low use of fertilizers has negative environmental impacts which are more inevitable and devastating than those anticipated from increased fertilizer use such as nutrient mining and increased use of marginal lands (Heisey and Mwangi 1996). However, another important aspect of fertilizer use involves crop quality and human health (IPNI 2009).

The constant use of chemical fertilizers especially N or P has led to pollution of soils, water and air as well as increased deterioration of the ecological system (Kim and Stoecker 2006, Magiroi et al. 2011, Savci 2012). This is largely through contamination by the leakage and infiltration of nitrates and phosphates from chemical fertilizers (Hafizul et al. 2010). The high concentrations of N or P can increase the growth of algae, decrease water clarity, result in water treatment problem like odour or bad taste, and deplete oxygen levels in the water that can affect human and animal health (AFT 2013). This reduction of water quality is costly and is a cause of global environmental challenges (Steffi et al. 2003).

Prolonged use of high amounts of chemical fertilizers especially in acidic soils reduces the long term crop productivity (Mupenzi et al. 2010). Sanchez (2002) found average annual nutrient depletion rates across a number of African countries were 22 kg N /ha, 25kg P/ha and 15kg K/ha. On average, combined rate of depletion of nutrients in Sub-Saharan Africa is 54 Kg/ha/yr (Sommer et al. 2013). Therefore, there is need to explore the technologies for improving crop productivity with less environmental impacts.

Among the potential technologies, the use of bio-fertilizers is considered as an optimal solution (Ghaderi-Daneshmand et al. 2012; Pindi 2012). Nevertheless, in the use of new technologies the precautionary principle should be exercised. As stated in the Environmental and Management Coordination Act 1999, "where there are threats of damage to the environment, whether serious or irreversible, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." Though bio-fertilizers are environmentally friendly, precaution has to be exercised to ensure the products available in the market do not contain contaminants that are of harm to the environment thus negating the benefits in their use. Regulation and quality control of bio-fertilizers plays a critical role towards achieving good quality and environmentally safe products.

Research towards development of bio-fertilizers is still developing in Africa and is derailed through lack of awareness, infrastructure and human capacity (Dhlamini et al. 2005, Njira 2013), and the absence of a supportive regulatory framework. In sub-Saharan Arica, the potential benefits of bio-fertilizers remain largely untapped due to inadequate national policy and regulatory framework (Simiyu et al. 2013).

Bio-fertilizer use is a technological innovation that potentially increases crop yield, reduces production cost and improves soil condition (Baconguis et al. 2012). For instance, crop yields can be improved 10 to 25 % by the application of bio-fertilizers to seed or soil without contamination (Muraleedharan et al. 2010). It can also enhance the efficient uptake of nutrients, leading to a reduction in the amounts of chemical fertilizers to be used (Chen et al. 2007). The production technology for bio-fertilizers is relatively simple and installation is less costly compared to chemical fertilizer plants (Chen 2006).

Microorganisms, which can be used in bio-fertilizer formulation, include bacteria, fungi and blue green algae (Boraste et al. 2009). Some of the bio-fertilizers used are nitrogen fixers, phosphate solubilizers, micro nutrient enhancers and growth promoting Rhizobacteria (Patil et al. 2013).

Bio-fertilizers can be easily contaminated because of non-availability of good and suitable carrier materials (Pindi 2012). Owing to its inherent deficiencies, biological sources which act as effective supplements to the chemical sources in crop management have not been regarded as fully reliable (Kahangi et al. 2011). Poor quality bio-fertilizers also cause smallholder farmers to lose out on the benefits of the products. Therefore, it is necessary to increase the quality of rhizobial inoculants that are sold (Gomez et al. 1997).

Bio-fertilizer is explicitly different from green manure, manure, intercrop i.e. organic fertilizer that contains compounds that directly, or by their decay, increase soil fertility, or organic supplemented chemical fertilizer (Vessey 2003).

According to India's legal framework on bio-fertilizers (Essential Commodities Act of 1955 and Fertilizers Control Order 1985; amended in 2009), bio-fertilizer means "the product containing carrier based (solid or liquid) living microorganisms which are agriculturally useful in terms of nitrogen fixation, phosphorus solubilization or nutrient mobilization, to increase the productivity of the soil and/or crop." Bio-fertilizers are also included under the broad definition of fertilizers, which "means any substance used or intended to be used as a fertilizer of the soil and/ or crop" (Malusa and Vassilev 2014).

Current economic thinking and development planning in Kenya is set out in the long-term economy policy, formally known as Sessional Paper No. 10 on Vision 2030. The Second Medium Term Plan (MTP) (2013-2017) to Vision 2030 recognizes the need to increase use of environmentally safe bio-fertilizers though it does not single out microbial inoculants. However, smallholder farmers would only benefit with the use of bio-fertilizers in the event of governmental regulation (Olsen 1994). Legal requirements and controls can therefore improve the quality of inoculants and thus their efficacy (Catroux 2001).

In Kenya, challenges in commercialization of bio-fertilizers are due to lack of adequate legislation (Simiyu et al. 2013). Kenya has incomplete regulatory proposals that are to be found in draft form such as the Kenya Standard 2356: 2011, and this has impeded implementation of quality control (Kahangi et al. 2011). The draft standards provide for general and specific quality requirements without distinction between the different types of bio-fertilizers (Huising et al. 2013). This may be insufficient for effective quality control.

Therefore in Kenya, unlike in India, the principal law regulating fertilizers, the Fertilizer and Animal Foodstuffs Act Cap 345 is silent on any definition or specific mechanisms for bio-fertilizer governance. This is not surprising as this law was enacted prior to bio-fertilizer technology. However, as this research later demonstrates, in chapter 4, other laws, institutions and policies in the overall fertilizer regulatory framework could be deployed to govern bio-fertilizers, but with minimal efficiency, unless changes are made, taking into account some of the specific issues raised by this thesis.

Apart from the problem of the technical efficacy of bio-fertilizer, in Kenya there is also a dearth of information on product quality, extension services and policy support at the national level (Odame 1997). In order to enhance smallholder farmers' access to bio-fertilizers institutional constraints in agricultural innovation must be removed (Odame 2002). Weak linkages with private-sector manufacturers, local stockists, NGOs and smallholder farmers have affected the uptake of bio-fertilizers (Odame 1997). NGOs that play a big role in research, formulation and creating increased awareness of bio-fertilizers have to come up with products that can be easily handled by farmers and which manufacturers can distribute at a profit. Free flow of information facilitates the formulation of products that are adapted to the local conditions.

Similarly, there is poor support of production, distribution and use of bio-fertilizers (Simiyu et al. 2013). Moreover, the availability of adequate quality and effective bio-fertilizers from manufacturers is dependent upon the presence of a policy, law and regulation on the commercial products (Ghosh 2004). Regulation of bio-fertilizers is crucial to ensure farmers get value for their investments and increased food production yet safeguarding the environment.

Besides policy aspects, efficacy of bio-fertilizers, availability and accessibility, knowledge on bio-fertilizer development and proper application as well as promotion and marketing, limit the use of the products among smallholder farmers (FFTC 2007). Increase in awareness and uptake of bio-fertilizers is a path that can reduce the use of chemical fertilizer to avoid further pollution problems (Chien et al. 2011).

1.2 Statement of the Research Problem

Fertilizers are used to restore the mined minerals from the soil and to obtain high yields (Zhu and Chen 2002). Chemical fertilizers have been shown to cause environmental degradation (Ayoub 1999) by affecting soil quality, ground water and water bodies because of the vast quantities of chemicals in the runoff (Hafizul et al. 2010). In addition, chemical fertilizers are costly and are a source of greenhouse gas (GHG) emissions such as N_2O (Halvorson et al. 2014) that is aggravating the effects of climate change (Adler et al. 2007). For instance, the estimated amount of GHG emitted from Nitrogen fertilizer use in Europe is 47.6% (Franks and Hadingham 2012).

From an environmental perspective, bio-fertilizers are better than chemical fertilizers as they do not pollute the soil, air and water (Mehrvarz et al. 2008, Hafizul et al. 2010). They also increase yields of up to 33.2% (Esitken et al. 2010) and do not emit GHG into the atmosphere (Kaswan et al. 2012). The amount of chemical fertilizer can be reduced by 25% with use of bio-fertilizers and give an equal yield increase similar to 100% of the recommended chemical fertilizer rate (Adesmoye et al. 2009). However, their quality and efficacy must be properly evaluated before they are commercialized (Carullo 2002). Quality of bio-fertilizers is one of the most important factors resulting in their success or failure and acceptance or rejection by the farmers (Sethi & Adhikary 2012).

The current Fertilizers and Animal Foodstuffs Act Cap 345, does not incorporate bio-fertilizers. This lack of clear and sufficient regulation is a leeway to distribution of low quality and ineffective products from manufacturers. There should be corrective measures inclusive of penalties stipulated in law, if low quality products are distributed to farmers (Carullo 2002).

Availability of a comprehensive policy and legal framework on bio-fertilizers can guide compliance and enforcement of high quality standards. This study highlights the importance and challenges in the adoption of bio-fertilizers due to absence of such a framework. In addition, it informs a policy on sustainable agricultural practices. Finally, good practices must be adopted in the handling of the bio-fertilizers in order to ensure the benefits are obtained and the environment is protected. Bio-fertilizer use can enhance food security in Kenya; however, there is a need for increased awareness and training of farmers on how to handle the products. Lack of awareness contributes to poor uptake thus the need for strategies to increase the uptake of adequate quality bio-fertilizers.

1.3 Research Questions

The following questions were addressed by the study:

1.3.1 Overall research question

What is the significance of effective regulation in enhancing uptake of environmentally safe bio-fertilizers?

1.3.2 Specific research questions

1) What is the level of uptake of bio-fertilizers among farmers?
2) What regulatory mechanisms are available for bio-fertilizers in the market to ensure they are environmentally safe?
3) What are the best practices of corrective measures in other countries?
4) What are the strategies for increasing awareness and uptake of bio-fertilizers among farmers?

1.4 Objectives

The following objectives were addressed:

1.4.1 Main Objective

To develop an effective regulatory framework scenario for appropriate use of environmentally safe bio-fertilizers and mechanisms for enhanced use

1.4.2 Specific Objectives

1. To investigate the level of uptake of Bio-fertilizers among farmers in Uranga
2. To assess regulatory mechanisms for bio-fertilizers in the market
3. To explore best practices of corrective measures in other countries
4. To investigate the strategies that can increase awareness and uptake of bio-fertilizers among farmers

1.6 Justification

Poorly defined, lack of, or unenforced standards can lead to low quality bio-fertilizers in the market. Improper or misleading labeling and underweight bags will increase investment risk for smallholder farmers and may dissuade them from use of bio-fertilizers (USAID 2012). There is need for standards and regulations to control such practices.

A strong bio-fertilizer law should contain basic requirements for the registration, deregistration, licensing, import, and sale of the products (USAID 2012). It should address the implementation of these procedures in regulations where they are more easily amended (USAID 2014).

Bio-fertilizers introduced into the market must be of adequate quality and without contamination of any kind in order to protect the environment. The products must be safe to humans, plants, animals, and the environment and be efficacious in boosting crop yields as indicated on the labels by the manufacturer. This will protect the farmers' investments as well as ensure increased crop yields.

A national focal point government organization should have adequate resources to promote training and education on proper use of bio-fertilizers, increase awareness on their availability and monitor the products in the market to ensure poor quality products are eliminated.

2.0 LITERATURE REVIEW

This chapter is divided into various sections discussing the general use of fertilizers, the merits and demerits of their use, types of bio-fertilizers, production and distribution and the importance of regulations. Section one, discusses the importance of fertilizers as a source of plant nutrients in order to enhance yields on available land. It highlights the need to increase production on limited parcels of land due to limitations in increasing the cultivated area. The impacts of overuse and underuse of fertilizers to the environment are also explained.

Section two introduces bio-fertilizers as environmentally safe products. It gives a brief background on wide array of beneficial microorganisms that can be used as bio-fertilizers. The uptake of various plant nutrients important for plant growth through use of bio-fertilizers is discussed. Such an informative discussion highlights opportunities that can be explored in the formulation of different bio-fertilizers that are environmentally safe.

Section three gives an overview of the production, distribution and use of both chemical bio-fertilizers in Kenya. Use of subsidies for chemical fertilizers by the government and challenges in the distribution and use of bio-fertilizers are explained. The section also displays some challenges in the dissemination of bio-fertilizer technology to farmers.

Section four brings out important factors in ensuring bio-fertilizer quality such as the viable cell count and the permissible level of contamination. It highlights the need for effective regulation and quality control in order to ensure availability of adequate quality bio-fertilizers in the market.

2.1 Impact of Fertilizer on Food Security and the Environment

For up to an estimated 2.3 billion more persons by 2050, food production will have to increase by 70% (FAO 2014). To satisfy the growing worldwide food demand, two options are available; (1) increasing the cultivated area under production and (2)

improving crop production on existing land (Edgerton 2009). Kyomugisha (2008) reported that most increases in aggregate crop production have been achieved from the area production rather than increased investment in production technologies. The ultimate goal should be attainment of increased yields with limited environmental impacts (Tilman et al. 2011).

Future increases in food production will have to occur on less available arable land, which can only be accomplished by intensifying production (Burney et al. 2010). For example the agricultural potential in Kenya is only 16% of the land mass and 84 % being used for ranching, agro-pastrolism and game parks (FAO 2013). Achieving consistent production at these high levels without causing environmental damage requires improvements in soil quality and precise management of all production factors in time and space (Cassman 1999).

Soil nutrients are depleted through continuous cultivation when crops explore and exploit the entire root zone leaving the soil stripped of nutrients (Asadu and Dixon 2002). Low soil fertility is a major constraint to crop production (Agyarko 2011). Depletion of soil fertility, along with the concomitant problems of weeds, pests, and diseases, is a major biophysical cause of low per capita food production in Africa (Sanchez 2002). Restoration of soil fertility is necessary to increase crop yields and food production in order to combat the worsening food security situation in Africa (Henao and Baanante 2006).

The Fertilizer Institute (2008) stated that fertilizers are currently responsible for between 40% and 60% of the worlds food supply. This trend promotes increased food production via increased chemical fertilizer use which has negative environmental implications. The level in agriculture productivity needs to be maintained, but this has to be achieved in a sustainable manner, both environmentally and economically, in order to preserve ecosystem services (Bettencourt et al. 2010).

Promoting awareness of new ideas and discoveries to the general public to create and deepen awareness of science technology and innovation is important (ASDS 2010-2020). Bio-fertilizer technology dissemination should be at the forefront as a technological innovation that can be used to increase yields obtained by smallholder farmers. The increase of agricultural production through heavy use of chemical fertilizers is a threat to the natural resource base. Environmental concerns such as depletion of natural resources, pollution of air and water, and chemical residues in foods must be factored in agricultural practices (Munyua 2003).

Agricultural technologies or practices that could reduce the current pressure of chemical fertilizers to the environment must be developed. Modern agriculture should be able to balance both agronomy and ethics to sustain both ecological and human needs in the future (Burney et al. 2010). Land, a natural resource and a factor of production, is degraded by excessive use of fertilizers (Acharya and Kafle 2009). Continued destruction of land resource will eventually lead to food insecurity due to decreased yields. This promotes the shift to sustainable agricultural production systems that enhance environmental protection.

The fertilizer industry is a source of natural radionuclide and heavy metals. It contains a large majority of the heavy metals that are harmful to health (Savci 2012). Production of chemical fertilizers is expensive and alternating this with bio-fertilizers can play an important role. This will avoid negative pressure to environment and as a result, use of bio-fertilizers is one of the effective managerial methods to keep soil quality in favorable level (Bohlool et al 1992).

The environmental angle of fertilizer use in Africa is not one of overuse but of under use and has an impact on soil health (IFDC 2006). The rate of fertilizers used by small-holder farmers in Africa is low and this causes the depletion of soil nutrients (Kelly and Crawford 2007, Smaling 1993). Soil-fertility depletion in smallholder farms is the fundamental biophysical root cause for dwindling per capita food production in sub-Saharan Africa (ICRAF 1997).

Cassman (1999) and Roberts (2009) stated that increase in food production must be done in an environmentally safe manner through ecological intensification whose goal is to increase yield per unit of land, i.e. intensify production, while meeting acceptable standards of environmental quality. They also stated that, integrated production seeks to integrate economic and ecological considerations.

According to FAO (2007) conservation agriculture is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving and protecting the environment. Compared with conventional production, it is characterized by a shifting of focus from harvest maximization to harvest optimization through cost saving and quality enhancement. This involves a reduction in chemical fertilizer input, a preference for non-chemical pest control methods wherever possible and use of adapted cultivation schemes, including more frequent crop rotation (Meysner et al. 2006).

Fertilizers are important in achieving increased yields but the need to conserve the environment prompts research into environmentally safe agricultural inputs. There is need to adopt new technologies such as use of bio-fertilizers that are not harmful to the environment.

2.2 Impacts of Bio-fertilizers on Crop Productivity and the Environment

Due to various anthropogenic activities, over dependence on chemical fertilizers may degrade the environmental system for the future agricultural growth (Board 2004). This model of agriculture has led to resource degradation, prominent being; depletion of natural resources, increased erosion and reduced soil quality, increased incidence of new pests and diseases, reduction of biomass production and biodiversity, and water contamination (Conway and Barbier 1990, Chopra 1997, Ghosh 2003). Consequently, this has an overall impact on the sustainability of various agricultural production systems. Exploration of alternatives to chemical fertilizers for increased crop production without further negative impacts on environment is necessary. In this context, the use of bio-fertilizers is essential to meet this purpose (Xiang et al 2012).

Bio-fertilizers which are considered eco-friendly and environmentally safe are cost-effective agro-inputs intended to improve the supply of available plant nutrients to crops (Muraleedharan et al. 2010). They are of enormous help to the farming community (Kuntal et al. 2007). In some cases they can significantly complement chemical N fertilizers (Alam 2000). When these fertilizers are applied to seeds, plant surfaces or soils, the living organisms from them colonize the rhizosphere or the interior of the plant (Vessey 2003).

In the case of nitrogen fixing bio-fertilizer technologies, it is achieved through Biological Nitrogen Fixation (BNF), a microbiological process which converts atmospheric nitrogen into plant usable form (Bohlool et al. 1992). By the process of BNF, the availability or uptake of plant nutrients can increase (Selvakumar et al. 2012). Use of chemical nitrogen fertilizers in crop productivity can be reduced with incorporation of bio-fertilizers (Mehboob 2009). It is estimated that 80 to 90% of N available to plants in natural ecosystems originates from BNF (Rascio and La Rocca 2008).

Bio-fertilizers are gaining momentum due to the increasing emphasis on maintenance of soil health, minimizing environmental pollution, and cut down on the use of chemicals in agriculture (Muraleedharan et al. 2010). In addition, they are being considered as essential components of organic farming which has emerged as an important priority area for safe and healthy food, long term sustainability and prevention of environmental pollution associated with indiscriminate use of agrochemicals (Patil et al 2013).

On the other hand, most small-holder farms in Africa have little access to chemical fertilizer because of the high price. The dramatic increases in world fertilizer prices recorded recently are especially damaging to African farmers' hopes of improving their productivity (Hargrove 2008). Currently, fertilizer use in SSA averages 9 kg per hectare, the lowest of any developing country by far (FAO 2004) compared to the recommended 50 kg per hectare (Abuja Declaration 2006) and crop yields are correspondingly lower (Mwangi 1996).

Profitability remains one of the key factors determining the quantity of fertilizer used; farmers will not use fertilizer if it is not affordable and profitable (Guo et al. 2009). Bohlool et al (1992) reported that low fertilizer use is attributed to high cost of fertilizer. In rain-fed agriculture, bio-fertilizers gain added importance in view of their low cost, as most of the farmers cannot afford to buy expensive chemical fertilizers (Muraleedharan et al. 2010).

Bio-fertilizers complement chemical fertilizers by reducing the amount of chemical fertilizer required while still increasing yields (Chen 2006, Hellal et al. 2011). This is important considering that most smallholder farmers actually underuse chemical fertilizer which still contributes to environmental destruction. Reduced use of chemical fertilizers with increased application of bio-fertilizers can alleviate the pressure on the environment derived from agricultural practices (Malusa et al 2012).

Most bio-fertilizers belong to one of two categories: nitrogen fixing and phosphate solubilizing. Nitrogen fixing bio-fertilizers fix atmospheric nitrogen into forms which are readily useable by plants. The following is a broad classification of bio-fertilizers that can be used by farmers shown in **Figure 2.1**.

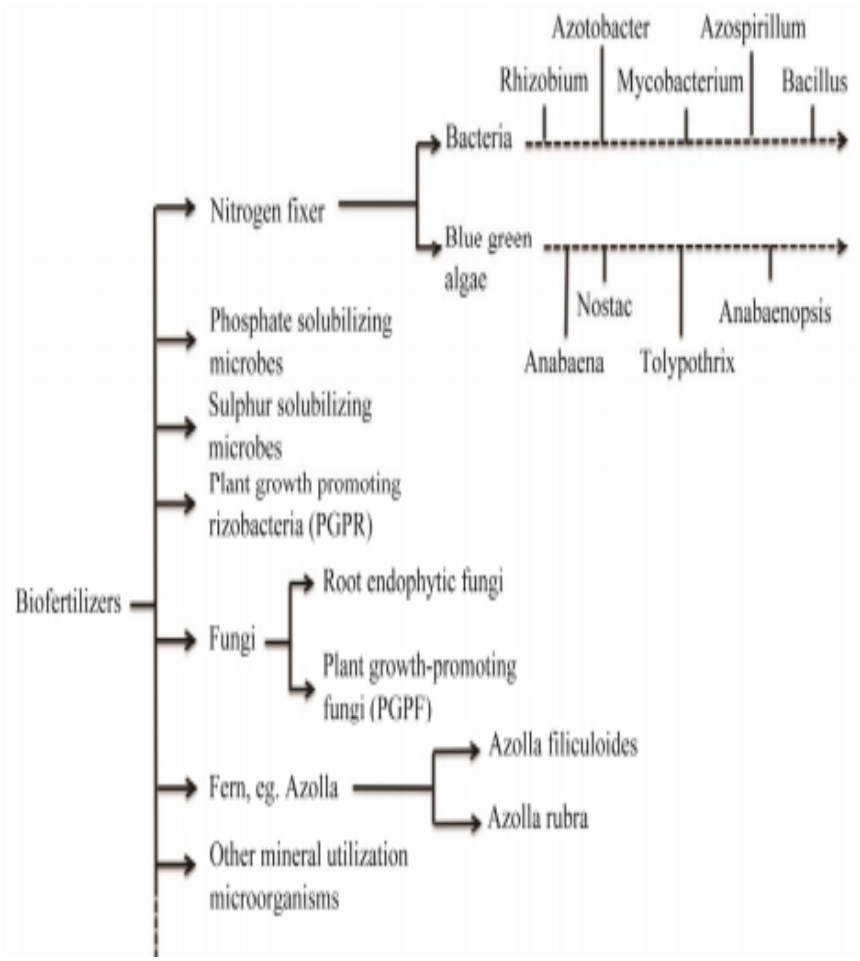


Figure 2.1: Types of Bio-fertilizers (Adapted from Xiang 2012)

2.2.1Nitrogen fixer

The nitrogen fixer includes bacteria (rhizobium, azotobacter, azospirillum, mycobacterium and bacillus) and Blue Green Algae (BGA) (anabaena, nostoc, tolypothris and anabaenopsis). Rhizobia are symbiotic bacteria that fix atmospheric nitrogen gas in plant root nodules and have a mutually helpful relationship with their host plants. The plant roots supply essential minerals and newly synthesized substances to the bacteria.

Rhizobium inoculation is a well-known agronomic practice to ensure adequate N supply for legumes in place of N fertilizer. It is reported that rhizobium can fix 50-300 kg N/ha (Chen 2006). Field experiments in Vertisols in India have demonstrated that high-quality

soybean Rhizobium inoculants increased yield (by >100%) in comparison with yields obtained in non-inoculated trials. It was found that seed inoculation treatments with *Bradyrhizobium japonicum* gave higher grain yields, optimum growth and nodulation in soybean crop (Rawat et al. 2013).

Inoculation of wheat seed with *Azatobacter chroococcum* strain MSX-9 resulted in higher grain yield. The increase in these growth parameters; dry matter, may be due to higher uptake of nutrients (Gupta and Aggarwal 2008). Azotobacter and azospirillum are free-living bacteria that fix atmospheric nitrogen in cereal crops without any symbiosis and they do not need a specific host plant. Azotobacters are abundant in well-drained, neutral soil. They can fix 15-20 kg/ha N per year. Azotobacter sp. can also produce antifungal compounds to fight against many plant pathogens. They also increase germination and vigor in young plants leading to improved crop stands (Chen 2006).

Blue green algae represent a self-supporting system capable of carrying out both photosynthesis and N fixation (Venkataraman 1981). Free living BGA constitute a major group of nitrogen fixing microorganisms in rice fields and have a potential as bio-fertilizer in rice cultivation (Roger et al. 1987). The cost-benefit ratio of algal bio-fertilizer is quite lucrative and within the reach of average farmers.

2.2.2 Phosphate solubilizing microbes (PSM)

Under acidic or calcareous soil conditions, large amounts of phosphorus are fixed in the soil and are unavailable to the plants. Phosphobacterins, mainly bacteria and fungi, can make insoluble phosphorus available to the plant. The solubilization effect of phosphobacterins is generally due to the production of organic acids that lower the soil pH and bring about the dissolution of bound forms of phosphate. It is reported that PSB culture increased yield up to 200-500 kg/ha and thus 30 to 50 kg of superphosphate can be saved (Chen 2006).

The efficiency of phosphate fertilizers during the first year of application is very low (15-20%) due to its fixation in acidic and alkaline soils. Therefore, the inoculations with Phosphate Solubilizing Bacteria (PSB) and other useful microbial inoculants in these

soils is beneficial to restore and maintain the effective microbial populations for solubilization of chemically fixed phosphorus and availability of other macro and micronutrients to harvest good sustainable yield of various crops.

Research has indicated that for example, acidifying rock phosphate by mixing rock phosphate with sulfur and organic matter and using rock phosphate with microorganisms including P solubilizing bacteria, sulfur oxidizing bacteria and Arbuscular Mycorrhiza enhances P availability (Mishra et al. 2013, Khatibi 2011).

2.2.3Sulphur solubilizing microbes (SSM)

Bacteria of Thiobacillus genus are the main sulfur oxidizers in soil. Application of the Sulphur solubilizing bacteria *Thiobacillus thioparus* has also been shown to increased yield (Afkhami et al. 2014). Increase in yield at a lower cost to smallholder farmers promotes sustainable agriculture which conserves the environment while enhancing food security.

2.2.4. Plant Growth Promoting Rhizobacteria (PGPR)

Plant Growth Promoting Rhizobacteria (PGPR) represent a wide variety of soil bacteria which, when grown in association with a host plant, result in stimulation of host growth. PGPR modes include fixing nitrogen, increasing the availability of nutrients in the rhizosphere, positively influencing root growth and morphology and promoting other beneficial plant–microbe symbioses.

Ratti et al. (2001) found that a combination of the arbuscular mycorrhizal fungi Glomus aggregatum, the PGPR Bacillus polymyxa and Azospirillum brasilense maximized biomass and P content of the aromatic grass palmarosa (Cymbopogon martinii) when grown with an insoluble inorganic phosphate.

Inoculation with PGPR such as Bacillus, Streptomyces, Pseudomonas, Burkholderia or Agrobacterium increases plant access to nutrients, suppresses pathogens and directly stimulates plant growth, increasing crop yields and reducing requirements for chemical fertilizers and pesticides (Atieno 2011).

Plants inoculated with PGPR take up N, P, K and microelements more efficiently from the soil. Benefits of PGPR in crop production include improved soil ecology, plant development and resistance against diseases and certainly help in the fight against hunger (Egamberdieva et al. 2013).

2.2.5Fungi

Mycorrhizal fungus affects two aspects of sustainable agriculture: plant production and soil quality. Arbuscular Mycorrhizae have multiple functions in the effective exploitation of soil mineral resources; improved plant physiological performance (growth and development, productivity, crop quality) under normal growing condition. They also have bio-protective role against many soil pathogens; VAM pre-inoculated potato plants resisted more effectively to infection by pathogens *Rhizoctonia solani*.

Mycorrhizae can alleviate abiotic and biotic stress factors, thus can be used as biotechnology tools in sustainable horticulture for arid and semi-arid areas including many species of cultivated plants (Delian et al. 2011).

Mycorrhizae are mutually beneficial (symbiotic) relationships between fungi and plant roots. The plant roots transmit substances (some supplied by exudation) to the fungi, and the fungi aid in transmitting nutrients and water to the plant roots. The hyphae reach into additional and wetter soil areas and help plants absorb many nutrients, particularly the less available mineral nutrients such as phosphorus, zinc, molybdenum and copper. Mycorrhizae provide a protective cover thus increasing seedling tolerance to drought, high temperatures, infection by disease fungi and even to extreme soil acidity.

Application of VAM produces better root systems which combat root rotting and soil-borne pathogens. The greatest growth response to Mycorrhizal fungi is probably in plants in highly weathered tropical acid soils that are low in basic cations and P, and may have toxic levels of aluminium. Plants that have coarse or limited root systems should benefit the most (Chen 2006).

Hence the group of fungi, include microorganisms that improve nutrient availability to plants (bio-fertilizers), increase tolerance to biotic stress such as soil born diseases (bio-pesticides or bio-control agents), or have dual properties i.e. both bio-fertilizer and bio-pesticide properties.

2.2.6 Fern

The use of nitrogen-fixing organisms, like *Azolla*, could effectively help developing countries to achieve sustainable agriculture, without the risk of problems associated with the adverse effects of chemical fertilizers on long term soil fertility, soil productivity and environmental issues (Carrapico 2000). The Azolla-Anabaena symbiosis is outstanding due to its high productivity combined with its ability to fix nitrogen at high rates.

Growing concern about conservation of the environment and the need for deploying renewable, sustainable resources; the application of Azolla as a bio-fertilizer on agricultural crops, in order to provide a natural source of the crucial nutrient N, can be very beneficial to the future of our planet. Besides the environmental appropriateness of the use of Azolla, for multitudes of farmers in many parts of the world who cannot afford chemical fertilizers, Azolla application can enhance their economic status, increasing yields while minimizing costs (Wagner 1997).

The water fern Azolla lives in a symbiotic relationship with a diazotrophic cyanobacterium, Anabaena azollae. Because of its high productivity and nitrogen content of its biomass, this association has been used as a bio-fertilizer for centuries in South East Asia, mainly in rice cultivation. Use of Azolla is beneficial to the crop by providing growth stimulating compounds produced by the endosymbiotic cyanobacterium (Milicia and Favili 1992).

2.2.7Other mineral utilization micro-organisms

Some bio-fertilizers are exploited to address some unavailable mineral elements in the soil, such as zinc and potassium solubilizing microbes and so on (Xiang et al. 2012). Substantial quantity of applied inorganic zinc in soil is converted into unavailable form. Zinc solubilizing bacteria such as Pseudomonas and Bacillus strains are potential

alternates for zinc supplement as a sustainable solution to improve plant nutrient and production (Goteti et al. 2013). Potassium solubilizing bacteria such as Bacillus mucilaginosus, increased K availability in soils and increased mineral content in plant (Sheng et al. 2002).

The above outline is important to regulators as it outlines the potential of bio-fertilizers as supplements to chemical fertilizers. Bio-fertilizers can also enhance uptake of micro nutrients and formulation of products should not be confined to those enhancing uptake of macro nutrients only. Manufacturers can also formulate a wide variety of products that can safely enhance uptake of nutrients by plants. Official Bio-fertilizer Standards should be able to cater for a wide variety of products instead of focusing on a limited number which may present a need to formulate new Standards when manufacturers come up with new products.

2.3 Overview of Fertilizer Use, Production and Distribution in Kenya

The government has majorly promoted the use of chemical fertilizers among the smallholder farmers through use of subsidy policy. Subsidized fertilizer is meant to benefit the smallholder farmers who cannot be able to afford chemical fertilizers from the private stockists. Promotion of bio-fertilizers has not received adequate support from the government.

2.3.1 Chemical Fertilizers

Use of fertilizer and application depends on the agro-ecological zones and crops grown (IFDC 2012). Nevertheless, application rates are not high enough to reverse the country's growing national food Deficit (Sheahan et al. 2012). The fertilizer products applied at planting include DAP, MAP and NPK compound fertilizers such as 15:30:15, NPK (25:5:5:5s) for tea and NPK (17:17:17) for coffee. Fertilizers containing secondary and micronutrients are mostly used for horticultural crops.

Fertilizer adoption rates vary from 4 % (Coast Province) to a high of 90 % of households in the high-potential maize zones. Cereals (maize, wheat, rice, sorghum, millet and others), tea and coffee account for 75 %, 13 % and 6 % of the national consumption of

fertilizer products in Kenya, respectively (i.e., over 90 % of all inorganic fertilizers) (IFDC 2012).

The Kenyan fertilizer market is worth Kshs 32 Billion (Ministry of Agriculture 2014). Kenya depends on the international markets for its fertilizer like most SSA countries. Fertilizer imported into Kenya is sourced from the United States, Europe, the Middle East, and South Africa (Wanzala et al. 2001). Local fertilizer production is non-existent or limited (IFDC 2012). The majority of the local companies (Mea Ltd. and Athi River mining Ltd.) only blend fertilizer for various crops and soils.

Plans are underway to have local manufacture of chemical fertilizer such as DAP, CAN and NPK compound fertilizer with different formulation. The manufacturer will be able to produce at total of 1,500 MT per day translating to 300,000 MT a year. The amount of chemical fertilizers imported into Kenya ranges between 450,000 MT to 650,000 MT. The amount of fertilizer consumed is approximately 530,000 MT per year. The amount used for food crop production is approximately 400, 000 MT.

2.3.2 Distribution of chemical fertilizers

Most of the importers for fertilizers do importation and wholesaling only in Kenya. The wholesalers' functions are limited to stocking supplies, order processing, limited advisory services and, in some cases, delivery of fertilizers. Besides selling fertilizers, some stockists also give the farmers information on fertilizer use. The main task of retailers is to provide an 'assortment' or wide variety of fertilizer at a single location, making it convenient for farmers to purchase all their fertilizer needs from one location (Wanzala et al. 2001). Smallholders source their fertilizers mainly from the stockists.

Since the liberalization of fertilizer trade in 1990, change in government policy on fertilizer marketing led to reduced role of government created monopolies that were involved in fertilizer trade such as Kenya Farmers Association (KFA). In 1993, the Government of Kenya withdrew completely from fertilizer distribution and for a period of time relied on the private sector and cooperatives to meet the fertilizer needs of

farmers (Wanzala et al. 2001). However, the government is currently involved in giving fertilizer subsidies to farmers.

Removal of policy related barriers such as import quotas and licensing led to more entrants into the fertilizer marketing chain. Commonly available fertilizer packs are the 50 kg, 25kg and 10 kg packs. Majority of stockists (68%) break open mainly 50kg packs and repack fertilizer in transparent polythene bags and sell it in small quantities using a kilogram measure depending on the quantity demanded. The 50 kg pack is preferred by stockists for breaking open because it rarely sold (due to inadequate quantities demanded) or it could be the only pack available (Mose 1998). Access to fertilizer by smallholder farmers should be achieved cost-effectively, under conditions of liberalized and privatized trade in the input (Omamo 2003).

2.3.3 Fertilizer Subsidies

Subsidy is government money given to an industry to maintain low prices of a good or service (Kamoni and Rotich 2013). Limited adoption of improved technologies such as fertilizer use by farmers contributes to low food productivity and a key policy effort is to promote use of chemical fertilizers through subsidies (IFDC 2012).

Objectives that drive the issuance of subsidies include the need to stimulate agricultural production, improving soil quality in order to combat soil degradation, making inputs available to farmers who cannot afford them and learning the beneficial use of fertilizers (Wiggins and Brooks 2010). Thus subsidies on chemical fertilizers can raise food production through increased fertilizer use (Druilhe and Barreiro-Hurle 2012).

Distribution of subsidies can either be done through ‘Smart’ distribution i.e. farmers access the chemical fertilizers from agro-dealers at 50% of the price, or through government distribution (IFDC 2012). The current method used in the distribution of chemical fertilizers is through the National Cereals and Produce Board (NCPB), Agricultural Development Corporation (ADC) stores and the Kenya Seed premises (MOA 2014).

Access to these subsidized chemical fertilizers is subject to recommendations from the local agricultural officers. There are two types of subsidies:

1. Pro-poor subsidy

This has been allocated a budget of 3 M a year. It targets close to 100,000 poor farmers in each county. The program takes care of households led by women, the sick and elderly and also orphaned families. They are given fertilizers, seeds and agro-chemicals enough for one acre without any charge (MOA 2014).

2. General subsidy

A total of 2.5 B is spent on general subsidies to farmers in different areas. Farmers are issued with vouchers which they present on collection of the fertilizers (MOA 2014). Input vouchers usually reduce the cost of fertilizer by the value of the voucher (Minot and Benson 2009).

Nevertheless, subsidies create huge financial burden to the government (Minot and Benson 2009). In addition, late delivery of fertilizers to farmers is also a downfall of the fertilizer subsidy programme (Dittoh et al. 2012). Other failures experienced through the subsidy system include poor targeting of resource poor farmers, political interference, delays in payment of agro-dealers (Kamoni and Rotich 2014, Nzuma 2013). In general subsidies are costly, disrupt private dealer systems and ineffective in assisting resource poor farmers (Minot and Benson 2009).

The government should thus consider more sustainable options and set strategies of how to get farmers to be aware and adopt new technology that is environmentally friendly and sustainable such as the use of bio-fertilizers (Curtis 2013). Government investment in agricultural research and extension is more sustainable than yearly reliance on fertilizer subsidies to farmers (Minot and Benson 2009). Agricultural research and extension on novel technologies will benefit the uptake of bio-fertilizers. Bio-fertilizers are affordable thus do not create a need for subsiding the cost but regulation of quality to ensure farmers have access to adequate quality products.

2.3.4 Bio-fertilizers

Beside the use of chemical fertilizers, bio-fertilizer application is considered to be a part of the solution to agricultural and poverty reduction problems (Alhassan 2003).The National Food and Nutrition Security Policy 2011 recognizes the need for sustainable and affordable food production increases. However, high fertilizer prices are a constraint to access of these vital inputs and it impacts negatively on crop yields. Both public and private sector interventions are necessary to ensure smallholder farmers access to yield enhancing inputs.

The National Land Policy 2009 recognizes land resource as a factor of food production. The policy proposes creation of an enabling environment for agriculture including research, extension services and training of farmers. This will enable productive use of large tracts of underutilized land and the conservation of good agricultural land. The policy does not clearly point out sustainability issues in agricultural production systems in Kenya.

Crop production systems ought to be regarded as ecosystems and all environmental benefits and costs should be factored in management decisions (Robertson and Swinton 2005). For instance the policy ought to be clear on the type of agricultural inputs that should be promoted among farmers. Excess use or low use of nutrients affects the ecosystem (Robertson and Swinton 2005).

The management of the ecological aspect of agriculture determines the impact that will be experienced in later years (Tilman et al. 2002). Increased yields should be obtained sustainably and is especially considered in terms of external nutrient delivery systems such as the use of fertilizers (Odum 1984). Novel Technology should be used to negate soil mining patterns (Swinton et al. 2003).

Use of bio-fertilizer technology is useful conservation of the environment. Policy has to establish and promote environmental conservation in order to control on long tern

environmental costs (Arrow et al. 1995). The National Land Policy 2009 has not clearly outlined the trends of fertilizer use and the environmental outcomes (Johns 2007).

Research into Rhizobium inoculants in Kenya are technological outputs of over two decades of research by the Department of Land Resources Management and Technology (LARMAT), under the Nairobi Microbial Resources Centre Network (MIRCEN's) project funded by UNESCO since 1977 (Odame and Kangai 2013). The MIRCEN program aims at the conservation of microbial genetic resources and their utilization in environmental management tasks (Keya and Imbamba 1986).

The centre functions as the anchor of a framework that was aimed at promoting high value, low-cost technologies that improve rural agricultural practices, creating rural market economies and providing more technological avenues for employment, increased incomes and ultimate feeder industries to the urban sector, with an emphasis on research and training in the production of bio-fertilizers (N2Africa 2011).

Since 1981 the Nairobi MIRCEN has produced an inoculant known as Biofix which is the main inoculant in East African market (Odame 1997). Biofix is a fast moving product and the Kenyan market consumes approximately 10% of the total production. Demand for the product is in high in Central Kenya where the farmers work in groups. Local demand has also increased from farmers in the Western Region. This is the only legume inoculant commercially available in East Africa and is steadily being promoted among farmer groups and agro-dealer associations (Wafulah 2013).

Biofix inoculant is produced for several legumes including bean, soyabean, pea, groundnut, lucerne by Mea Ltd. Mea aims to expand production to about 10 tons in 2014 to satisfy increasing demand (Huising 2013). The Centre has a collection of more than 250 rhizobial strains from local and foreign sources (N2Africa 2011).

Through the African Knowledge Transfer Partnership (AKTP) supported by the British Council, Mea Ltd. undertakes commercial production, distribution, farmer and agro-

dealer training, demo- set up and marketing of the bio-fertilizer to farmers at an affordable price while the University of Nairobi continues with research and quality control of the inoculant. The company has adopted the Australian regulations for the quality of their product in the absence of official Kenyan standards.

The manufacture of high quality inoculants revolutionized bio-fertilizer technology in Australia in the 1960s as a result of the crop failure experienced in the country. Many improvements to inoculants and the establishment of an inoculant control service ensured that quality was optimized and maintained. Minimum standards for the number of rhizobia per seed ($1x10^9$ Rhizobia per gram) were set after consideration of several factors including seed size and loss of viability during inoculation (Deaker 2004).

The Australian standard of contamination level is also high; 10^{-6} free of contaminants. The quality control bodies set bio-fertilizer standards, approve and supply mother cultures to manufacturers annually, test all batches of bio-fertilizers before sale and sample the products at the point of sale. The control scheme has implemented standards without resort to legislation and this has been possible due to the cooperation of the manufacturers' involved allowing flexibility in applying the standards (Bullard et al. 2004). This is a case where the percentage of satisfactory inoculant products was obtained without enforcement of inoculant quality by official control.

Inoculant manufacturers have the same priorities as farmers but need also to have products with an extended shelf-life, allowing a storage of 1 to 1.5 years in warehouse conditions, in order to be able to sale their products over two cropping seasons (Catroux et al. 2001). However, formulation into products with a long shelf-life is sometimes rather problematic for gram-negative than for spore producing gram-positive bacteria (Berg 2009). The number of viable cells decreases with time thus the short expiration period of bio-fertilizers. Biofix expiration period is 90 days, thus the inoculant produced for one bimodal season should not be used the next.

Nevertheless, the technology has very limited adoption among legume farmers in the country because more emphasis was laid on scientific research and human resource training and less on technology deployment, as per the initial plans (Odame and Kangai 2013). Some factors responsible for the low demand for the inoculants included inadequate and inefficient marketing channels and outlets, as well as inadequate extension services covering inoculant use (Odame, 1997).

Kenya needs to identify a number of key issues covering policies, laws, regulations, standards and institutional arrangement for commercialization of bio-fertilizers. The main objective should be to establish a regulatory framework and provide legitimacy to the process of incorporating bio-fertilizers into the farming production systems, ensuring bio-safety conditions, and to promote the development of modern biotechnology in farming production (Carullo 2002).

Kenya's bio-fertilizer uptake is affected by lack of adequate legislation and capacity (Simiyu et al. 2013). The regulatory frameworks are in drafts and include the draft bill on Fertilizers and Soil Conditioners, Sessional Paper on Soil Fertility and bio-fertilizers Standards KS 2356:2012. The current fertilizers and Animal Foodstuffs Act does not incorporate bio-fertilizers thus the need for amendment.

Aside from extensive research on bio-fertilizers, transfer of the technology to farmers should also be given the same weight. In the formulation of policies, environmental considerations should be integrated to ensure the environment is protected for the benefit of all. Regulations also impact on the adoption of fertilizers in the country and without effective regulations uptake is hampered.

2.4 Regulation and Quality Control of Bio-fertilizers

Effective execution and regulation of the proper procedures to guarantee removal of substandard bio-fertilizers are still needed in Kenya (Liverpool-Tasie et al. 2010). Regulatory systems to ensure efficacy, safety, and cost effectiveness of bio-products have to be established (FFTC 2007).

Application of bio-fertilizers is a potential practice in the agricultural systems for improving farmers' current productivity holding promised results to increase soil and crop productivity (Selvakumar et al. 2012). Thus government should promote the use of bio-fertilizers along with other fertilizers (Ghosh 2003).

Policies made should encourage fertilizer use in ways that are technically efficient, economically rational and market friendly while promoting agricultural intensification in a manner that maintains soil fertility (Morris et. al 2007).Without enabling policies potential benefits of bio-fertilizers remain largely untapped for the small-holder farmers (Simiyu et al. 2013). Simiyu et al. (2013) stated that presently small-holder farmers who venture into the use of bio-fertilizers are confronted by under-regulated increase of poor quality products.

2.4.1 Quality Control

Kenya should focus on policy, quality standards and approval protocols for commercialization of bio-fertilizers (IITA 2014). Sahai (1999) stated that quality control of bio-fertilizers such as the inoculants is very important. Quality control is the process of checking the quality of the material under test against the standard set by the organizations (Singh and Gupta 2014).

Quality i.e. the number of selected micro-organism in the active form per gram of bio-fertilizer is an essential element in the market as the entry of new units also heightens the threat of poor strains appearing in the market and ruining the farmers' confidence for use of products in their fields (Ghosh 2003). The level of bacteria in a bio-fertilizer should be sufficient to inoculate plants and give economic benefits (Bashan 1998).

In addition, bio-fertilizers are carrier based preparations containing beneficial microorganisms for seed or soil application to improve soil fertility and help plant growth by increasing the number and biological activity of desired microorganisms in the root environment (Chairman et al. 2013). Macronutrient content, such as N, P and K, in some bio-fertilizers carriers exceeds that in organic fertilizers depending on the origin or type. This is often questioned whether plant growth increase is due to microbial activities or

nutrients and other compounds added to the carrier. Without proper attention, this condition will negate promotion to develop environmentally benign agriculture through increase use of non synthetic agrochemical inputs on agricultural lands (Husen et al. 2011).

A good carrier should posses as much as the properties such as good moisture absorption capacity, easy to process and free of lump-forming materials, easy to sterilize, low cost and availability in adequate amounts, and good pH buffering capacity (Keyser et al. 1993). On the other hand, some of bio-fertilizer carriers are produced from the municipal waste compost which may contain significant amount of heavy metals (Husen et al. 2011).

When regulation is effective, it contributes to the development of safe and crop production (Tripp and Gisselquist 1996). Regulatory systems often control the quality of products that are sold in the market for checking whether the products are unadulterated and correctly labeled or not (Tripp and Gisselquist 1996).

Labeling is important in the commercialization of the products to inform the user about the product facts (CFIA 2014). Labels of the bio-fertilizers should also not misinform through false, misleading or deceptive representations (IFDC 2012). This important information, i.e. microbial species/strains, densities and functions, as well as direction for application in the label should be obligatory (Husen et al. 2011) since the quality of a bio-fertilizer depends on the number of active microorganisms per gram at the time of manufacture and expiry, shelf life, permissible contamination rate, pH, moisture and carriers (Akter et al. 2013).

Fertilizer Control Order (FCO) (1985) reported that fertilizers should be deemed to be adulterated if they endanger soil microbes and crop quality. Thus, a strict regulation on carrier composition should be defined in quality specification (Husen et al. 2011).

A sustainable agriculture system utilizes renewable inputs, which can maximize ecological benefits and minimize environmental hazards. Use of chemical fertilizers is expensive and their excessive use is a threat to soil health, the environment and sustainability of food production (Dhar et al. 2009). Bio-fertilizers are affordable environmentally safe farm inputs that can be used to increase yields. Nevertheless, adequate quality and efficacious bio-fertilizers should be available to smallholder farmers. Awareness on the benefits and application method of bio-fertilizers can be promoted through farmer training and education.

Work done by several authors on bio-fertilizers in Kenya demonstrates the need for an effective regulatory framework. Odame 1997, states lack of effective cooperation among private-sector manufacturers, local stockists, NGOs and involvement of farmers, as well as policy support at the national level and minimal extension services have affected the use of bio-fertilizers in the country. The Bill on Fertilizers and Soil Conditioners and Sessional paper on Soil Fertility have also been in draft form since 2006. Quality control efforts have also be dampened due to availability of draft standards (Kahangi et al. 2011). This has hampered effective regulation and quality control of bio-fertilizers. Simiyu et al. 2013, singles out that an ineffective regulatory framework in Kenya has hindered commercialization. This research therefore has looked into the aspects that are required or should constitute an effective regulatory framework and strategies to increase use of the products among farmers.

The following is a breakdown of how the study was conducted including the foundational aspects.

2.5 Theoretical Framework

This research can be understood through the Precautionary Principle as a keystone. Even though bio-fertilizers are regarded as environmentally safe precaution has to be taken in the widespread use of the products and this can be achieved through effective regulations. Such regulations can ensure the protection of humans, plants and animals with the use of the products; through availability of safety and quality standards and its effective enforcement.

Environmental Law is focused on the prevention or correction of harm to the environment, or creating conditions that ensure environmental preservation and protection. The precautionary principle can be applied in order to protect the environment. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to avoid environmental degradation. Although Bio-fertilizers are regarded as environmentally safe they can be contaminated potentially introducing pathogens in the environment thus the products have to be regulated to ensure that they do not cause any contamination to the environment.

The precautionary principle gives an obligation to regulators to make consideration of harmful effects that may arise from activities in the environment (Cameron and Abouchar 1991) such as the use of bio-fertilizer technology. The government is obligated to ensure protection and conservation of the environment and natural resources by Article 42 and 69 of the Constitution of Kenya 2010. Processes and activities that are likely to endanger the environment should be eliminated. This calls for the need to take precaution in the introduction of new biotechnology products into the market. The role of the government is thus to ensure that only adequate quality bio-fertilizers that are efficient in boosting crop growth are allowed in the market.

First, the laws and policies must be updated as and when necessary, to move with the changing trends and act as directives to ensure protection of the environment is upheld. Secondly, quality standards have to be set before the introduction of any new bio-fertilizer into the market. No product of low quality standards should be allowed into the market. Thirdly, monitoring and compliance system has to be very active in terms of keeping a constant track of all the bio-fertilizers in the market and ensuring that the standards are upheld by manufacturers. Fourth, infringement of any of the requirements should attract severe penalties that would deter any manufacturer or reseller from the distribution of low quality bio-fertilizers.

The constitutional obligation of the government to protect the environment provides a well-established justification for a legal response. Production of food has to be done in a

sustainable manner that ensures conservation of the environment. In addition, the government has the obligation to ensure food security, article 43, in which every person has the right to have adequate food of acceptable quality and access to clean and safe water. Use of adequate quality bio-fertilizers can enhance food security in an environmentally sustainable manner.

Article 69 calls for the protection, sustainable management of the environment and avoidance of environmentally harmful activities through establishment of systems of environmental impact assessment and environmental monitoring. Use of agricultural inputs, fertilizers, is a necessity to enhance food production. Thus, the government has to explore safe and affordable options such as promoting use of bio-fertilizers, in order to enhance food production with minimum destructive effects to the environment. However, availability of adequate quality products must be ensured and this can be provided for in effective regulations that can outline how quality assessments can be done and also continuous sample testing to ensure manufacturers adhere to set quality standards.

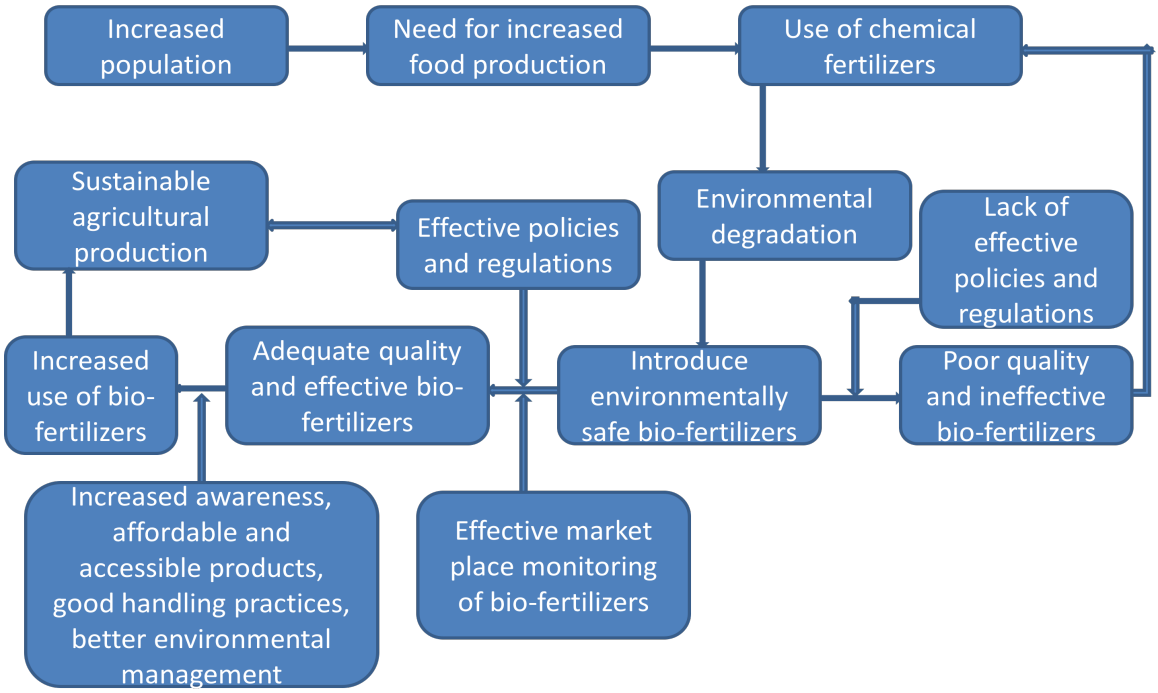
Effective regulations become a necessity to ensure only adequate quality products are available to farmers. The uptake of bio-fertilizers can then be increased and the outcome will be the protection of the environment. Government intervention is required in updating the available laws and setting in place stiffer penalties for law breakers which will lead to environmental conservation.

Then government is also obligated to create awareness on the availability of adequate quality bio-fertilizers. Consumers (smallholder farmers) have the right to products of reasonable quality and the right to information necessary for them to gain benefits from the goods i.e. bio-fertilizers, according to article 46 of the constitution.

The need to promote awareness is also extended by Article 43 of the constitution, in which the state shall publicize important information to the citizens. The government is tasked to ensure smallholder farmers have access to knowledge and training on the use of bio-fertilizers in order to enable them to make informed decisions on environmentally

sustainable agriculture. The government can implement policy actions that will enhance the creation of an enabling environment to facilitate bio-fertilizer market development.

2.6 Conceptual Framework



Population increase prompts the need to increase food production. Fertilizers are used as a source of nutrients for crops and are required to obtain increased yields in intensive agricultural systems. However, overuse or underuse of chemical fertilizers leads to destructive effects in the environment. Bio-fertilizers are technological innovations that can be used to reduce the need for chemical fertilizers yet give optimum yields. Even though bio-fertilizers are termed as environmentally friendly inputs, lack of effective regulation results to poor quality products in the market. Without an alternative, farmers revert to use of chemical fertilizers. Therefore effective regulation of bio-fertilizers will ensure that farmers regain confidence in the products. Nevertheless, for improved uptake, awareness must be increased in addition to ensuring availability and accessibility. Sustainable food production methods can be practiced and this can inform policies to incorporate environmental concerns into agricultural production.

3.0 METHODOLOGY

The following is a description of how the study was conducted

3.1 Study Area

The field survey was carried out in the Uranga ($0^{o}02'12"$ N, $03^{o}43'58"$ E) in Siaya County, South-western part of Kenya. The area was selected because promotion of bio-fertilizer use had been conducted by Farmer Input Promotion Services (FIPS) in the last two years. Farmers in this region have previously been exposed to bio-fertilizers and they would form a good sample to test their uptake of bio-fertilizers. The following is a map of the surveyed area.

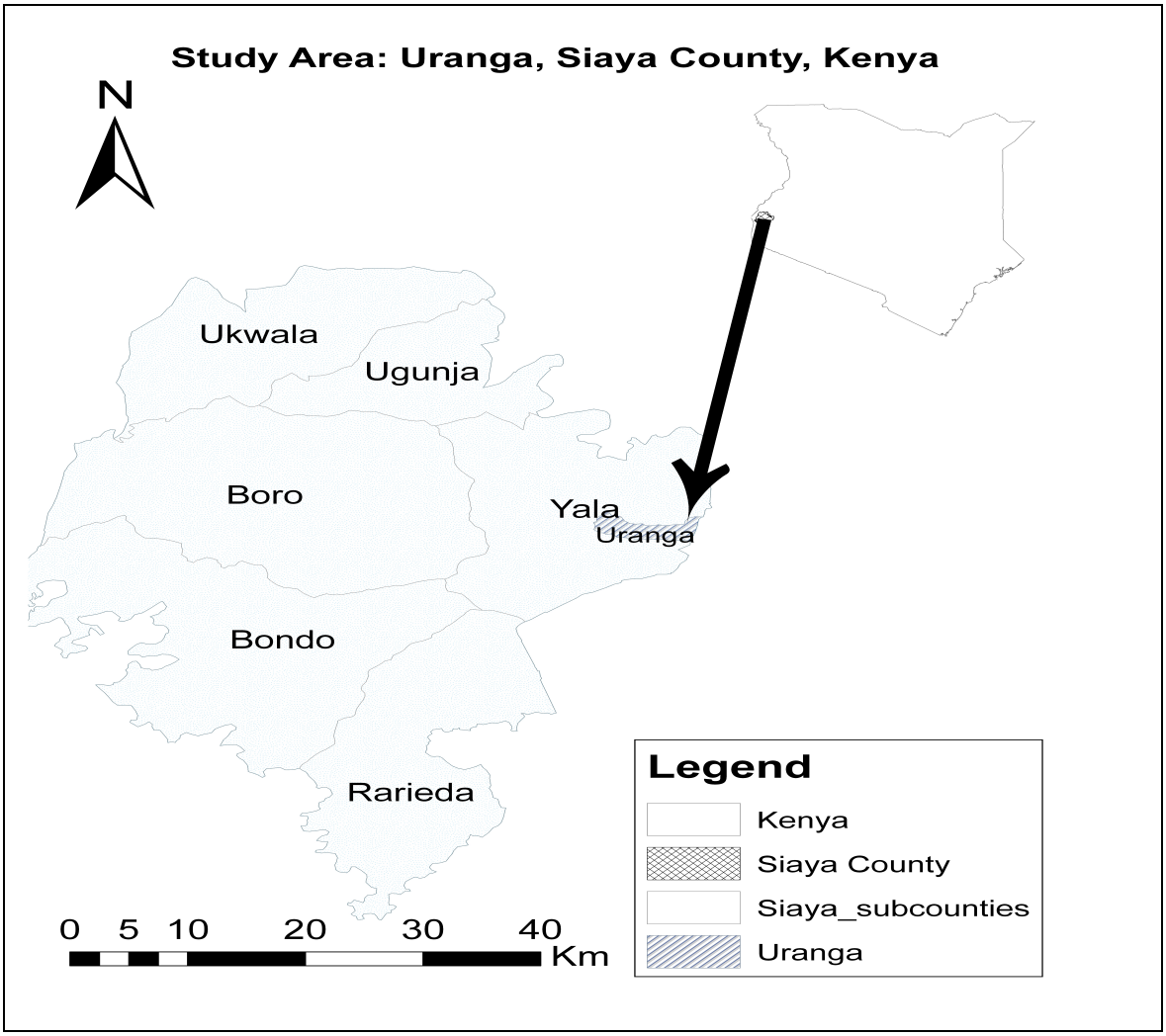


Figure3.1: **Map of the surveyed area showing the location of Uranga in Siaya County, Kenya**

The altitude of this study area ranges from 1140 to 1500 m above sea level (Mango 1999). This area depends largely on the agricultural economy. The climate in the surveyed area is sub-humid with a bimodal rainfall pattern. This allows for crop production during both long (March-June) and short (September-November) rains. Maize is the staple crop, grown on large part of the fields. Other important crops include finger millet, sweet potatoes and cassava. Local farming systems are characterized by a small farm size (0.5 to 1 ha), low agricultural input use and land productivity (Roncoli et al. 2010).

3.2 Methods and Study Design

Simple random sampling technique was used to select thirty households from each village. This sampling technique ensured that each farmer was given equal chance of being selected. The sample size constituted 5% of the farmers in the study area from an approximate total number of 6000-7000 farmers. In total three hundred households were selected from survey villages which included Gamba, Onding, Lwala A, Koga, Odeko, Sinyolo, Nyandiwa, Border, Yenga and Gaga.

The study employed questionnaires to capture the socio-economic characteristics of farmers and their crop production systems. Interviews were held with the head of the household who makes the decision on farming activities. The data was collected using interview methods of data collection with the aid of structured questionnaires. Information was validated with one other household member.

The data collected from the farmers included farmers' demographic and socio-economic characteristics, production variables such as varieties planted, input access, crop management, yields and factors affecting crop production and bio-fertilizer uptake and training access by extension service. Data on agro-dealers' demographic, the types of farm inputs sold to famers, their knowledge on bio-fertilizers, their capacity in terms of training received and inspection activities by government agencies was also collected from agro-dealers in the surveyed area.

Purposive sampling was employed to obtain information from various organizations. Primary data was obtained from Mea Limited which produces bio-fertilizers for the Kenyan market.

Information about the use of fertilizers and pesticides, dissemination of information on new technology was collected from non-governmental organizations (Kenya Organic Agricultural Network (KOAN), International Fertilizer Development Centre (IFDC), Biovision, Dudutech and One Acre Fund). These organizations are involved in disseminating fertilizer technologies to farmers.

Data on the production and use of fertilizer in Kenya was obtained from the Ministry of Agriculture. Data was also obtained from regulatory bodies such as Kenya Plant Health Inspectorate Service (KEPHIS), Pest Control and Products Board (PCPB) and Kenya Bureau of Standards (KEBS). The role of these institutions in the regulation of bio-fertilizers in Kenya was investigated. Data on quality verification of bio-fertilizers was collected from Egerton University. The university has received project support from Commercial Products Project (COMPRO II) to conduct quality verification of bio-fertilizers. The study has also incorporated secondary data in literature review especially for information on established regulations and strategies to increase uptake of bio-fertilizers.

3.3 Statistical Analysis

The frequencies summarizing the socio-economic data, percentage of fertilizer types used, reasons for not stocking bio-fertilizers, wealth class, visits by extension service workers, membership to farmer groups were calculated using the Statistical Package for Social Science (SPSS).

4.0 RESULTS AND DISCUSSION

This section elaborates the findings of the study. Section 4.1 presents the outcomes of the field survey where the responses of both farmers and agrodealers are analyzed. Socio-economic factors have been discussed in their relation to fertilizer use by farmers. The level of uptake of new technology in the study area is illustrated. Factors that affect the uptake such as lack of knowledge, training and demand and resistance to change are discussed.

Section 4.2 is focused on the current regulatory mechanisms of bio-fertilizers in the Kenyan market. This captures information obtained from interviews with different organizations currently involved in bio-fertilizer regulation. It discusses the various steps in the regulation of bio-fertilizers such as enhancing safety of the products, efficacy, standards, compliance and enforcement. The chapter also brings out the deficiency in the regulatory system.

Section 4.3 explores the regulatory system in two selected countries that have been able to achieve increased use of bio-fertilizers. It shows the complementary nature of the policies, laws and standards in regulation of the bio-fertilizer market. It highlights the importance of an effective regulatory system for bio-fertilizers and role of government in promoting uptake. It concludes with a discussion on the deficiency of the Kenyan bio-fertilizer regulatory system.

Section 4.4 introduces other aspects that are connected to the regulatory framework and are equally important in enhancing uptake of bio-fertilizers. It shows the importance of research activities, extension services and bio-fertilizer market development in the uptake of bio-fertilizers.

4.1 Level of Bio-fertilizer Uptake

The section compiles a discussion on socio-economic factors in relation to the adoption of new technology, level of uptake of bio-fertilizers and the contributing factors.

4.1.1 Socio-Economic Factors and Fertilizer Use

The following is a discussion of some socio-economic factors and their importance in enhancing uptake new technologies among farmers.

1. Gender

Gender linked differences in adoption of new technology result from gender linked differences in access to complementary inputs (Doss and Morris 2001). Operations such as pesticide dusting, manure and fertilizer application, marketing of grains are exclusively performed by men while the women are involved in harvesting, carrying head load, threshing and winnowing (Varma 1992). According to Quisumbing et al. (2014), women have important and varied roles in agriculture, but their access to productive resources and opportunities is unequal relative to men. Female headed households are less likely to adopt a new technology than male headed households (Doss and Morris 2001). The sex of the household heads in the surveyed villages comprised 51% male and 49% females.

Table 1.1: Sex of House Hold Heads

Gender	**Proportion [%]**
Male	51
Female	49

More percentage of males (71%) used fertilizers in their farming system as compared to the females (63%) as shown in table 1.2.

Table 1.2: Fertilizer Use by Gender of Farmers

Gender	**Fertilizer Use [%]**
Male	71
Female	63

Males tend to have greater access to credit facilities as compared to females and are associated with possession of productive resources while females may not have the resources to allow them access to fertilizers (Waithaka et al. 2007, Chirwa et al. 2011).

The nearly equal ratio between men and women affected the uptake of bio-fertilizers in the area because, the more men the higher rate of adoption of new technology holding other factors constant. The level of adoption of bio-fertilizers in the area would therefore be negatively affected given the gender representation of the farmers.

2. Age group

There is a positive relationship between the number of years of experience in agriculture and the adoption of improved agricultural technologies in agriculture. Nevertheless, older farmers may be less willing to take the risks associated with new farming practices and technologies (Kebede et al. 1990, Bryan et al. 2009) unlike younger farmers. Therefore, age has an effect on the adoption of bio-fertilizers among the farmers. This finding is supported by Mazvimazi and Twomlow (2009) who state that with age progression, farmers gain more skills through learning by doing. However, the trend attenuates as they reach middle age and their physical strength begins to decline. Also, older farmers are risk averse and less willing to adopt new farming technologies because of the tendency to rely on production technologies they have used overtime.

A greater majority of the respondents were between the ages of 41-60 years which made up 49% while those of <21 years comprised of 1% only.

Table 2.1: Age Group

Age Group	**Proportion [%]**
<20 years	1
21-40 years	21
41-60 years	49
61-80 years	29

The farmers of the same age group, 41-60 years, who applied any fertilizer, comprised a higher percentage (69%) while those of <21 years, applied the least amount 33%.

Table 2.2: Proportion of farmers that applied fertilizers with respect to age group

Age Group	**Fertilizer application [%]**
<21 years	33
21-40 years	62
41-60 years	69
61-80 years	68

Farmers of a higher age had greater chances for exposure to the benefits of fertilizer use through sources such as extension services, neighbours, media, farmer groups or agro-dealers, unlike those of a lower age who may still be new in farming. Aged farmers have more experience in farming, better access to the technologies, are more risk averse and prudent and have a higher likelihood of applying greater amounts of fertilizer (Zhou 2010).

Even though farmers of a higher age are more likely to be exposed to new technologies, this does not negate their risk averse nature towards new technology. Awareness of new technology through exposure does not cancel out the risk in trying out a new technology. Older farmers have confidence on technology they have used overtime and might have reservations on adoption of new technology. Therefore uptake of bio-fertilizer technology might have been impacted by the age of the famers in the study area. Older farmers made up the greater population of the farmers in the study area and this had an effect on the uptake of bio-fertilizers due to their risk averse nature.

3. Education level

Education is an important tool for social development (Bucch et al. 2012). Households with more education may have a greater ability to understand and use new technologies (Sserunkuuma 2005). Farmers who are well educated are able to initiate the adoption of innovation by introducing novel ideas themselves or taking the lead to copy a successful innovation, and extension workers are most likely to select them for nonformal education (Weir and Knight 2004).

A higher percentage of the farmers had received formal education. 63% had primary level education while only 6% received tertiary education as displayed in table 3.1.

Table 3.1: Education Level

Education Level	**Proportion [%]**
No Education	14
Primary	63
Secondary	17
Tertiary	6

Level of education and training, also had an impact on fertilizer use. 78% of farmers who had university or college level education made use of fertilizers. Table 3.2 below shows farmers with the lowest level of education applied the least amount (63%) of fertilizers.

Table 3.2: Proportion of farmers that applied fertilizers with respect to education level

Education level	**Fertilizer Application [%]**
No education	63
Primary	64
Secondary	76
Tertiary	78

This is relevant because it is consistent with findings by (Lawal and Ayoola 2008) that tertiary education facilitates the transfer of knowledge meant to improve crop production. Therefore, it can be argued that education gives farmers better access to information about fertilizers and more knowledge on fertilizer rates thus favorably impacting fertilizer decisions (Zhou et al. 2010). In addition, non-formal education through extension activities in the area would benefit the uptake of new bio-fertilizers as the majority had access to formal education thus have a greater ability to understand and use the new technology.

4.1.2 Uptake of Bio-fertilizer

Underuse of fertilizer by smallholder farmers contributes to environmental destruction because soil nutrients extracted with crops are not replenished or restored leading to soil degradation and declining yields. Currently there is a gap of ten million tonnes of plant nutrients between removal of crops and supply through chemical fertilizers (Mishra et al 2013). The level of uptake of bio-fertilizers in the study area is a good pointer on whether farmers are aware of the new technology and factors that have impacted the use of bio-fertilizers in the study area. The deduced information is beneficial in informing regulators of the current situation on the ground enabling them to make informed decisions.

Figure 4.1 represents the use of bio-fertilizers by farmers in Gamba, Onding, Lwala A, Koga, Odeko, Sinyolo, Nyandiwa, Border, Yenga and Gaga villages.

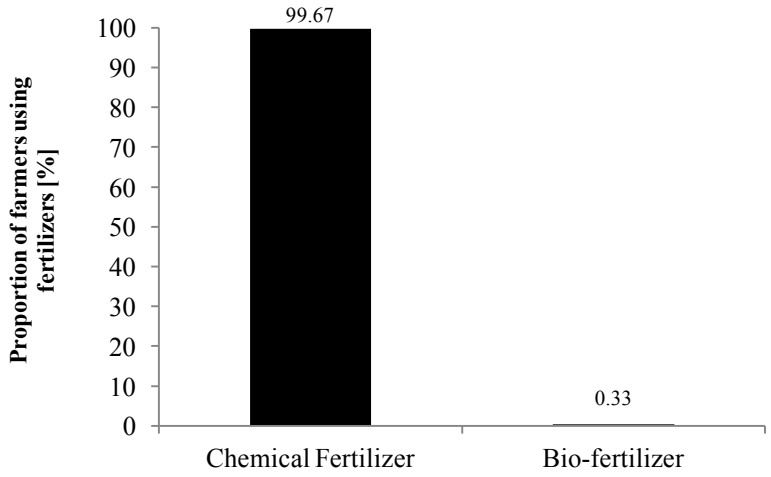


Fig 4.1 Use of Bio-fertilizer in the surveyed villages

Bio-fertilizer use in the sampled area was found to be very low (0.33%) as a result of a number of factors, including lack of knowledge by farmers, agro-dealers, low demand for the products, resistance to change; preference for the commonly used inputs and lack of product application knowledge. The following is a discussion on the various factors that affected the uptake of bio-fertilizers in the study area.

1. **Lack of Knowledge on bio-fertilizer**

Only one farmer in the surveyed area (0.33 %) applied bio-fertilizer (Biofix) to common beans plants in Koga village. Among the sampled farmers, lack of knowledge on bio-fertilizers was found to be 34% while it was 28% among the agro-dealers. Lack of knowledge on application method of bio-fertilizers (6.2 %) is another factor influencing the uptake of bio-fertilizers. Uptake of bio-fertilizers by farmers might be due to the fact that the farmers did not gain full knowledge of the product and its benefits Baconguis et al. (2012).

Availability of improved technology by itself is not sufficient to create a change in farming practices. Other complementary factors such as an effective extension service, an efficient inputs distribution system and appropriate economic incentives, are required for the technology to make a meaningful impact at the farm level (Morris et al. 1999).

Extension is crucial as it facilitates transfer of knowledge from the research centers to farmers. A greater population of the farmers would benefit from extension activities given their exposure to formal education. Possibly low extension activities in the study area might have impacted the access to knowledge on bio-fertilizers thus affecting the uptake of the products. Extension services in the study area will be discussed in chapter 4.

Secondly, an efficient inputs distribution system is also needed to increase uptake of bio-fertilizers. Agro-dealers play an important role in the distribution of agricultural inputs. Some agro-dealers were not aware of the bio-fertilizer technology and this had a negative impact on the uptake of bio-fertilizers as they link farmers to agricultural inputs. The study highlighted other factors that affected the distribution of bio-fertilizers by agro-dealers.

The figure 4.2 below represents the factors for not stocking bio-fertilizers by Agro-dealers

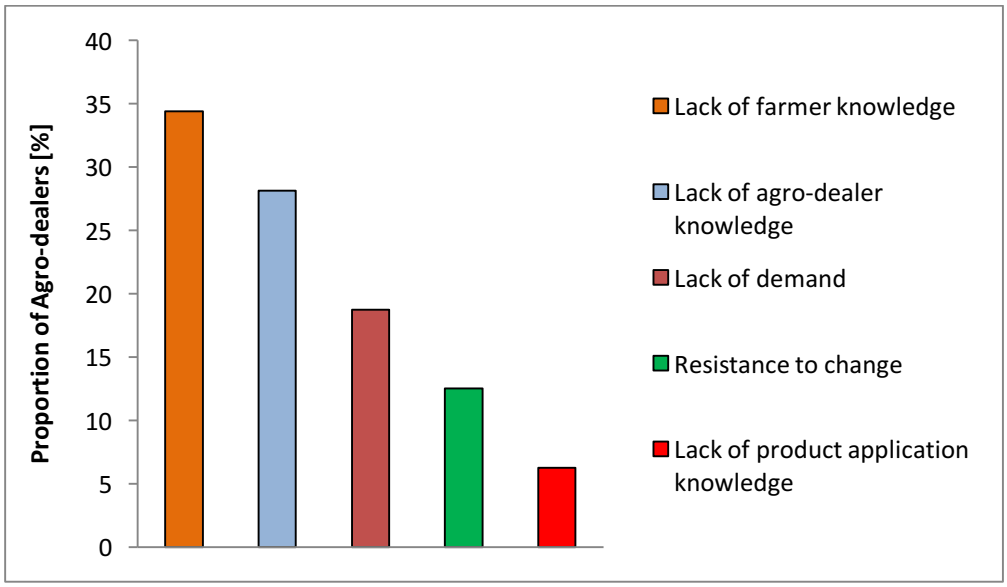


Fig 4.2 Factors for not stocking Bio-fertilizers by Agro-dealers

2. Lack of demand by farmers

Demand is connected to knowledge of the availability and benefits of a product. According to agro-dealers' perception, lack of demand by farmers for bio-fertilizers (18.8

%) is one of the reasons for affecting the uptake of bio-fertilizers in the surveyed area. This might be due to the uncertainty of the product performance coupled with long periods of learning which can lead to poor demand from the farmers (Ghosh 2003). Ghosh (2003) also stated that the low demand of bio-fertilizers could be due to the seasonal production and distribution of bio-fertilizers.

Smallholder farmers' demand for a particular input hinges on their knowledge and training on the benefits of the product. For the agricultural technology to be effective it must be learned and adopted by the farmers (Ahmad 2007). This is mirrored in a study done by Khonje (1989) in which the major constraint to exploiting the Rhizobium inoculation technology was that most farmers were not aware of the technology and its benefits.

Agro-dealers act as a link between farmers and agricultural inputs. Farmers that are not aware of the benefits of bio-fertilizers will not demand it from agro-dealers. Low demand as a result of lack of knowledge by farmers had a negative impact on the uptake of bio-fertilizers by farmers. Since agro-dealers are majorly businessmen pushed by monetary returns, they will not stock products that are not in demand by farmers. Thus uptake of bio-fertilizers in the area has been greatly impacted by low demand for the products. This introduces the aspect of market development as an important factor in enhancing uptake of bio-fertilizers.

3. Lack of Training for Agro-dealers and Farmers

Survey results show that 26.7 % of agro-dealers managed their business on full time basis, while 30 % on a part time basis and a further 43.3 % did not participate in managing their business. This implies employees are the source of most information received by farmers and their lack of training will impact the uptake of bio-fertilizers. Overall 33.3 % of regular employees in Agro-dealer shops had received training on some aspects of agriculture and agricultural products conducted by University of Nairobi, Egerton University, PCBP, KEPHIS and Bukura Training Institute.

Very low percentage (33.3%) of employees in agro-dealer shops had training on agricultural inputs which might hamper transfer of information to smallholder farmers. Agro-dealers link farmers to agricultural inputs and information on the use of bio-fertilizers thus greatly impacting on uptake of the products in the study area. Lack of training among the agro-dealers limits information that smallholder farmers can receive from them. Odame and Muange (2011) reported that lack of products knowledge of agro-dealers means they are ill-equipped to address farmers' concerns on the utilization of bio-fertilizers. Thus, there is need for training in different aspects of agro-inputs and seeds i.e. agro-dealers capacity building (Future Agricultures 2012).

Lack of training likewise among the farmers also contributed to the low uptake of bio-fertilizers in the study area. Smallholder farmers' access to training through tertiary education in the study area was very low as only 6% had access to tertiary education. According to FFTC (2007) and Wanzala and Groot (2013), the uptake of bio-fertilizers by small-holder farmers largely depends on their level of education and training to lead them into rational decision-making given various farm production options. FFTC (2007) also reported that knowledge on their development and proper application, limits the uptake of bio-fertilizers. This might be due to the lack of training on how to apply the bio-fertilizers (Srinivas and Bhalekar 2013).

The low level of training among farmers and input suppliers thus had an effect on uptake of bio-fertilizers. Both famers and agro-dealers require training on bio-fertilizers products in order to enhance the uptake. Lack of formal, informal and nonformal training is linked to lack of knowledge and lack of demand resulting to low uptake of bio-fertilizers. Services that contribute to awareness of bio-fertilizer products such as extension activities should be given priority in order to enhance uptake of new technology.

4. Resistance to Change/ Preference for commonly used Inputs

Resistance to change/ preference for commonly used inputs means unwillingness of farmers to try new products in the market (12.5 %) is another factor limiting the uptake of bio-fertilizers. According to the present surveyed data, 13% of the farmers demand

fertilizers which they have used over time and the traders find it difficult to convince them about new products. Farmers have been able to see benefits of fertilizers used over time and they have a guarantee on the performance of the input as opposed to trying a new product.

Decision to change farm practice is much more difficult for resource poor smallholder farmers who are understandably risk averse, particularly under conditions of uncertainty (Baconguis et al. 2012). Farmers are unwilling to take risk unless their income is guaranteed against possible lower yields during the transition period (Sundaravardarajan et al. 2006). For farmers to accept new technology such as bio-fertilizers they need to be exposed to the benefits of bio-fertilizers over a period of time in such a manner that they can easily see the benefits. They will need to be made aware of the availability of the product, trained and the practice ingrained through continuous interaction with extension officers. Furthermore, greater proportions of the farmers are older and thus risk averse.

The underlying factor affecting the uptake of bio-fertilizers in the area is thus lack of adequate knowledge in terms of availability, method of use and benefits. This draws attention to the need for strategic promotion of bio-fertilizers. Government intervention in terms of enabling policy and regulated environment might prove to be beneficial in increasing awareness and uptake of bio-fertilizers. Institutional structures are important in enhancing uptake of bio-fertilizers. The next section evaluates the regulatory mechanisms for bio-fertilizers in Kenya, to establish how best government can support development of quality bio-fertilizers and uptake by farmers.

4.2 Regulatory Mechanisms of Bio-fertilizers in Kenya

Regulation can be said to be a consolidation of rulemaking (standard setting), monitoring compliance, and enforcement (Picciotto 2002; Scott 2002). The core reason for regulations is the need to protect human, animal and environmental health and likewise enhancing quality and safety standards of products thus facilitating trade (CFIA 2014). During the years 2009 to 2011, an assessment on bio-fertilizer products in Kenya revealed that 90% of the product composition did not match the product labels as

indicated by the manufacturer due to absence of specified strains and some contained pathogens (Masso et al. 2013). This displays the availability of poor quality bio-fertilizers in the market and potential of harm to humans, animals and the environment. The following is a breakdown of pertinent issues in bio-fertilizer regulation.

4.2.1 Safety Requirements and Compliance

Humans, animals, plants and the environment have to be protected from any potential harm that may arise from use of bio-fertilizers. Safety of the products has to be guaranteed even though bio-fertilizers are regarded as environmentally safe agricultural inputs. This is in alignment with the precautionary principle as elaborated in the preceding chapters. According to Wabule et al. (2004) regulatory agencies should take special care on toxicity, infectivity and pathogenicity of all microbial inoculants essentially referred to here as bio-fertilizers.

Kenya Standing Technical Committee on Imports and Exports (KSTCIE) operates under the Plant Protection Act Cap 324 which makes provision for the prevention of the introduction and spread of disease destructive to plants. KSTCIE is in charge of biological control products due to the products phytosanitary concerns. Functions of the committee include offering advice on best ways and means of implementing provisions of the law relating to importation of biological control organisms and bio-pesticides among other agricultural products, for the purpose of essential scientific research, experiment, education or commercial production (Songa et al. 2004).

The committee will make data requirements from potential bio-fertilizer manufacturers. A dossier containing details on the organism of interest, explanation of the product, mode of action of the product, the benefit of the product must be presented. According to Hauschild (2012), requirements should include data from studies on acute toxicity, infectivity and pathogenicity resulting from oral, intravenous or intra-tracheal application. The data presented to the committee is reviewed by experts in the field who ensure the bio-fertilizers introduced will not be of harm to the environment.

Some products can be said to be of dual property where they can be used both as a bio-fertilizer and a bio-pesticide. Such products are assessed by the Pest Control and Products

Board (PCPB). PCPB established under the Pest Control and Products Act cap 346 regulates the importation, exportation, manufacture, distribution and use of products used for the control of pests and of the organic function of plants and animals and for connected purposes. The organization undertakes regulation of pest control products to ensure safe use and mitigation of the potential harmful effects to the environment.

According to the interview with PCPB, the potential manufacturer of a dual property product will submit the sample of the product with the application. The dossier will contain the toxicological profile, behavior of the product in the environment and eco-toxicology report. PCPB reviews the application through a tiered system of assessment:

i. Acute studies-Oral, dermal, eye irritation, carcinogenic and reproductive effects
ii. Pathogenic effects and
iii. Long-term effects

If the product is qualified through the first stage, a permit for efficacy trials is issued. If there was any negative effect from the first stage i.e. acute studies, the products are examined under tier two where pathogenic effects and other infectivity is assessed. Tier three is for the study of any long term effects of the product. The activities of the two organizations thus ensure that bio-fertilizers introduced do not cause harm to the environment. Aside from safety, bio-fertilizers should also be of value to farmers hence the need to test for their efficacy.

Evidence of the claim stated by potential bio-fertilizer manufacturers is tested through conduction of field trials to determine whether the product is effective under existing field conditions. Efficacy trials include performance assessment, laboratory and field assessment, toxic and pathogenic effects and compatibility of the product (Wabule et al. 2004). According to the interview, manufacturer's facilities such as Greenhouse, trial fields, laboratory for quality analysis, and required equipment along with the Standard Operating Procedures are inspected.

KEPHIS efficacy trials are conducted in collaboration with accredited organizations such as the Kenya Agricultural Research Institute (KARI), research institutes such as International Centre of Insect Physiology and Ecology (ICIPE), university; Egerton University and other private entities such as Dudutech. PCPB also conducts efficacy trials in collaboration with other institutions for instance a bio-fertilizer designed for use on pineapples; Delmonte will test it for efficacy.

Controlled field trials allow for risk analysis to investigate whether there are any significant threats posed to the environment by the use of the proposed new bio-fertilizer. Such efficacy trials are important because adoption of bio-fertilizers is affected by the variable response of the products in the field due to technological challenges on the quality of the product, its establishment in the field and shelf life (Jha and Prasad 2006). With assurance that the bio-fertilizer will be effective in the existing field conditions, the manufacturer has to maintain the quality of the product in distribution. This presents the need for continuous quality control of bio-fertilizers in the market.

4.2.2 Quality Control of Bio-fertilizers

Quality control of bio-fertilizers is crucial to ensure consistency of approved quality, reliability in field conditions and reproducibility in the production process. Standards comprise of procedures, strategies, staff and infrastructure for identifying, developing, implementing, enforcing, and redesigning standards and technical regulations, to ensure traded goods are safe, compatible and fit for local consumption and export (Hernendes-Casquet and Abiola 2005). Standards ensure a particular product is of acceptable quality, accurately labeled and that products deficient of laid down standards are eliminated from the market (Mwangi et al. 2004).

The Standards Act, Chapter 496 of the laws of Kenya establishes the Kenya Bureau of Standards. It is the main body charged with the responsibility for the protection of consumers, through promoting and introducing Quality Management; Implementation of Kenya Standards to realize Quality Products (Goods and Services); Handling Customer Complaints; and ensuring that the products meet the QMS-ISO 9000, EMS-ISO 14000,

HACC (Hazard Analysis Critical Control Points), and Statistical Quality Control standards (Mwangi et al. 2004).

According to the Standards Act Cap 496, specification of a product includes the nature, quality, strength, purity, composition, quantity, dimensions, weight, grade, durability, origin, age or other characteristics, or the manner, in which it may be manufactured, produced, processed, treated, tested or sampled. A draft bio-fertilizer standard, KS 2356:2012, is currently available for public review.

The draft standard has an aim to promote safe use of bio-fertilizers, promote fair trade practices and ensure safety of consumers. The draft has incorporated aspects such as the specific quality requirements, packaging and disposal of condemned bio-fertilizer, labeling, testing procedure and quality control. Bio-fertilizers ready to be sold to farmers should be subjected to quality controls on a variable time basis by independent laboratories to ensure the products meet the quality standards (Stephens and Rask 2000).

The draft bio-fertilizer standard, KS 2356:2012 has proposed quality requirements for Rhizobia, Phosphate Solubulising Microorganisms, Azospirillum and Azotobacter. These include information on the base material (carrier or liquid based), viable cell count, contamination level, pH, particle size for carrier based bio-fertilizers, nil pathogenic microbes, and moisture percentage by weight, efficiency character, nodulation test, p solubilization and nitrogen fixation.

Labeling requirements include information on: product name, brand name, net weight, batch number, registration certificate number of the product, manufacturers/ importers name and physical address, species/ microbial group, microbial density, dates of manufacture and expiry, method of application, carrier composition , Storage conditions, compatibility with other products and the declaration on GMO status. According to Hungria et al. (2005) and Husen et al. (2007) label should state the nature of the product (nature of the strain(s) included, number of cells guaranteed, nutrients, and other components content), its production (registration information, lot number, expiry date), and its use (dosage and method of application, instructions for disposal, precautions of

use). In addition to the label, products standardized by the organization bear a mark of quality which consumers can use to identify quality products.

The draft Standard KS2356: 2012 has addressed important aspects that ensure bio-fertilizers in the market are of the recommended quality. With availability of quality standards, adherence of manufacturers to set standards is achieved through enforcement.

4.2.3 Enforcement and Compliance

Enforcement can be achieved through issuing warnings, imposing fees and fines, revoking permits and gaining courts assistance to collect fees. Warnings are less severe than fees and fines whereas court actions and permit revocations have the highest degree (Ma and Ortolano 2000). Enforcement and inspection facilitates compliance with regulations (May and Winter 2000).

The Standards Act Cap 496 promotes the standardization and specification of fertilizers in Kenya. The Act has set corrective measures such as withdrawal of permits, imposing fines and imprisonment. Control of bio-fertilizers in the market is conducted by through random checks and use of permits. KEBS Quality Assurance Officers can assess the quality standards of the bio-fertilizers in the market and conduct random checks (at least twice in a year per the manufacturer) and afterwards offer permits to the manufacturer. They visit the premises to verify all the information given by the manufacturer. The Standards Act cap 496 10(A)(1)(a) gives power to cancel any permit where a manufacturer of a bio-fertilizer has failed to manufacture the product in line with the approved Kenyan Specification.

Manufacturers who will comply with the proposed standards are subject to the Standards Act Cap 496 which has corrective measures where a manufacturer fails to adhere to the quality standards. For instance failure to comply with set Standards attracts a fine of Kshs 50,000. However, the bio-fertilizer standard is still in draft stage thus detracting efforts of bio-fertilizer quality control. The regulatory system available displays weakness which has an impact on the use of bio-fertilizers.

4.2.4 Weakness of the Regulatory System

Without a legal framework on bio-fertilizers, institutions that regulate bio-fertilizers operate within a weak system. Thus, products of low quality as revealed by previous research (Masso et al. 2013) have been found in the Kenyan market, though the manufacturers passed through the present regulatory system. Lack of self-regulatory mechanism by manufacturers creates the need for established governmental regulations. Self regulation is usually possible where industry associations and professional organizations use advertising standards, professional standards and future market regulation (Havinga 2006).

The process of application by bio-fertilizer manufacturers to KSTCIE is designed to take a period of one month. However, it may take one year to complete if the dossier submitted by the applicant is incomplete. A complete description of administrative processes required by law through regulations, will act to ease the registration process of new bio-fertilizers. An extended period for registration for bio-fertilizer manufacturers has a negative impact on bio-fertilizer market development. Secondly, committee meetings are usually held quarterly and there is need for more than one application to justify the budget for a meeting. This implies if there is only one application even though the product is beneficial, the registration will be put on hold till other applications are made. Operations of the committee need to be guided by an enabling regulatory framework on bio-fertilizers with clear administrative rules.

Trial requirements may take a long period depending on the crop for which the bio-fertilizer is designed. There is need for regulations on the process of registration. Long procedure during trial stage does not create an enabling environment for the introduction of dual property products. This displays the need for a comprehensive regulatory framework where two organizations work in coordination to regulate a particular product in the market. The regulatory framework should allow a uniform regional approach so that evaluations of an application for registration make use of information from products in other countries in order to reduce the length of the trial period (AATF 2013).

Compliance to quality and safety requirements is important to ensure availability of good quality bio-fertilizers, appropriate to local conditions, effective in use and according to the quality standards as per the label on the packaging (Enti-Brown et al. 2012). Without this activity, smallholder farmers cannot be guaranteed about the quality of bio-fertilizers in the market and there is a potential risk of harm to the environment. Compliance is curtailed where legal provisions fall short.

The Standards Act cap 496 clause 9(1)(a) states that a standard is deemed official through a notice in the gazette declaring the specification prepared by the bureau to be a Kenya Standard. A bio-fertilizer manufacturer would then have to comply with the set standard otherwise guilty of an offence. The system of KEBS can track bio-fertilizers in the market but the challenge is the lack of official standards on bio-fertilizers and a legislative provision that can be enforced with the Standards Act Cap 496 of the laws of Kenya.

Monitoring of registered bio-fertilizers through tracking and sample testing is hampered by the inadequate regulatory framework on bio-fertilizers. There is no law which they can use to deregister products that do not conform to the initial quality during the first registration. The organization cannot resort to any court or out of court action without an enabling law.

Fertilizers are regulated by the Fertilizers and Animal Foodstuffs Act Cap 345. The law regulates the importation, manufacture and sale of agricultural fertilizers and animal foodstuffs and substances of animal origin intended for the manufacture of such fertilizers and foodstuffs. According to the law, fertilizer is a substance or mixture of substances which is intended or offered for improving or maintaining the growth of plants or the productivity of the soil, but does not include manure, compost, wood ash, gypsum or refuse when sold in its original condition and under the same name, nor does it include organic fertilizers, other than lime.

The overarching law on fertilizers does not incorporate environmentally safe bio-fertilizers. The Fertilizers and Foodstuffs Act Cap 345 is not aligned with the

Environmental Management and Coordination Act (EMCA) 1999 and the Constitution 2010 which both state the need to protect the environment for the present and future generations. The Environmental Management and Coordination Act 1999 Clause 5(d) clearly states the principle of intergenerational and intragenerational equity to ensure every person has access to a clean and healthy environment. This should be through promotion of sustainable and environmentally safe agricultural practices through use of bio-fertilizers.

The Constitution 2010 Clause 42 (a) stipulates the right to protect the environment for the benefit of present and future generations through legislative and other measures. The introduction of new technology such as bio-fertilizers ought to be reflected in new legislative measures. However, the Fertilizers and Foodstuffs Amendment Bill 2013, has not created an opening for the incorporation of bio-fertilizer technology. The 2013 Bill is an amendment to the Fertilizers and Animal Foodstuffs Act Cap 345, which does not recognize bio-fertilizers as reflected in its definition of what fertilizers constitute.

The government obligation to protect the environment and ensure inter and intra generational equity as in article 42 of the constitution, should be reflected in the regulatory framework for fertilizers. Article 69 demands that elimination of activities likely to endanger the environment such as continuous cropping with inadequate replacement of extracted nutrients. In this way, the current law ought to be amended to include bio-fertilizers. Food production increase should be attained in an environmentally sustainable manner.

4.3 Best Practices of Corrective Measures in other Countries

The results of the survey displayed low uptake of bio-fertilizers by smallholder farmers. Among the factors contributing to the low uptake is the presence of a weak post registration monitoring and control system, lack of a mandated institution in charge of bio-fertilizers and lack of bio-fertilizer legislative instruments. Legal enforcement of commercial inoculant quality can prove to be a successful approach to enhancing use of bio-fertilizers (Lindstrom et al.2010) in Kenya.

This section discusses the regulatory framework in two countries that have achieved increased uptake of environmentally friendly bio-fertilizers. The study selected countries elsewhere other than from SSA; where lack of or insufficient regulatory frameworks has been identified as a challenge in the region. Taarus et al. 2012, outlines African countries that lack sufficient regulatory frameworks including Kenya, Ghana, Nigeria, Tanzania and Uganda. Exploring best practices in other regions would then be of benefit to inform the regulation of the products; though in the capacity of Kenya as a developing country.

Canada presents an interesting case where regulations on bio-fertilizers were introduced after research conducted revealed the availability of poor quality bio-fertilizers in the market. Agriculture Canada is governmental agency that has continuously regulated inoculants since the 1970s.

A survey conducted by the agency during the same period revealed low levels of Rhizobium in commercial preparations (Olsen et al. 1994a). There was a need to control the quality of the inoculants by setting the numbers of bacteria in the bio-fertilizer and the allowed level of contamination (Bashan 1998).

Canada has an effective regulatory framework on bio-fertilizers that has ensured availability of good quality products and exports bio-fertilizers to the US, Mexico, Spain and France (Chatzipavlidis et al. 2013).

4.3.1 Canadian Bio-fertilizer Regulations

Canada is a developed country that has displayed best practices in bio-fertilizer use through effective regulation of the bio-fertilizer market. Increase in the percentage of satisfactory inoculant products in Canada was obtained only after enforcement of inoculant quality by official control (Rennie & Hynes 1993). Bio-fertilizers are regulated under the same broad environmental legislation and structures, with addition of new regulations and administrative procedures.

The Agencies involved in the regulation of bio-fertilizers in Canada include the Canadian Food Inspection Agency (CFIA), Health Canada and Environment Canada. Health Canada is involved to ensure safety to humans whereas Environment Canada puts a check on potential environmental threats. CFIA is the lead regulatory body under the

Fertilizers Act and Regulations 2006. Prior to any commercial production of bio-fertilizers in Canada, regulatory control measures including approval, registration and licensing is done to assess quality, safety and efficacy of the product (CFIA 2014).

The Canadian Environmental Protection Act (CEPA) 1999 is an environmental law whose purpose is to protect the environment and human health. The Act stipulates the government obligation to protect the environment, including its biological diversity, and human health, by ensuring safe and effective use of biotechnology (CEPA 1999).

Under Canadian Environmental Protection Act (CEPA) 1999, bio-fertilizers undergo a screening assessment to determine their safety to human health and the environment; safe to humans, plants and animals, and efficacious as indicated on the labels by manufacturers. These assessments are conducted by a team of highly qualified and trained evaluators according to CFIA (CFIA 2014). All ingredients including the active components, carriers, additives, potential contaminants and by-products that might be released into the environment as a result of bio-fertilizers are assessed.

The screening process is amended from time to time with the introduction of new products to ensure safety. The CEPA New Substances Notifications (NSN) Regulations outlines the information required for the assessment to be conducted (Jansson et al. 2000). Easily amendable regulations are important due to new biotechnology products that are constantly introduced in the market.

According to Fertilizer Act and Regulations (2006), the analysis of bio-fertilizers in terms of quality standards should at least include:

(i) The genus and, where known, the species of the active microorganism, and
(ii) The minimum number of active viable cells per gram of product of the genus and, where known, the species of the active microorganism in the product.

Bio-fertilizer companies in Canada use an International Organization for Standardization (ISO) standard and Good Manufacturing Practices, Good laboratory Practices and Hazard Analysis and Critical Control Point Processes (HACCP). Voluntary quality standard is set by the industry and products of a company that does not

participate are not recognized as being legitimate and may be shut out effectively removing it from the marketplace (Canadian Fertilizer Products Forum 2008). High quality standards and their enforcement is beneficial in locking out undesirable manufacturers (Thompson 1991). Such a system reduces cost to the government by decreasing the amount of inspection and oversight for bio-fertilizers (Canadian Fertilizer Products Forum 2008).

Bio-fertilizers are properly labeled to ensure safe and appropriate use. Information such as guaranteed analysis, directions for use, company/manufacturer contact information, appropriate units of measurement, and mandatory cautionary statements, must correctly appear and be clearly legible on the label (Fertilizer Act and Regulations 2006). Labeling of bio-fertilizers is one way of informing (CFIA 2014) smallholder farmers and agro-dealers alike of the use and application instructions for bio-fertilizers. Such labels can deliver characteristics of products which the smallholder farmers would not be able evaluate by inspecting the products package (Caswell 2000).

The main panel of the label must display at least the product name, the product net weight and the name and address. Imported products must also contain the name of the country of origin. The lettering must be conspicuous, legible and printed in indelible ink. The language of instruction is either in English or French or both. The product name must not bear wrong information that can mislead the farmer as regards the product composition and intended use (CFIA 2014).

Canadian high standards and government control ensure increased quality of bio-fertilizers by use of sterile carriers or liquid inoculants in order to avoid contaminants and to keep high numbers of rhizobia in the packages for at least 1 year storage at room temperature (Catroux 2001). The extended period of storage is beneficial to traders who stock the bio-fertilizers as they can be safely stored for more than one season.

Legislation is enforced through the Compliance and Enforcement Policy for the Canadian Environment Protection Act (CEPA) 1999. Compliance is achieved through means such

as enhancing access to information, consultation on regulation development and review, environmental codes of practice and guidelines and the conduction of environmental audits. An effective method used to deter potential offenders is making public information on the list of court actions arising from the enforcement of CEPA 1999 (Environment Canada 2001).

Enforcement activities according to the policy include inspection to verify compliance, investigation of violations, out of court action such as ticketing and issuance of compliance orders by enforcement officers, court action such as injunction, prosecution, court orders upon conviction and civil suit for recovery of costs (Environment Canada 2001). Inspectors are empowered to seize or detain any bio-fertilizer that does not meet the set quality requirements. This enhances availability of adequate quality bio-fertilizers for smallholder farmers.

The Fertilizer Act and Regulations 2006 have incorporated the use of bio-fertilizers. The procedure for conducting environmental assessments is described in the Regulations 2006.Unintended and potentially adverse effects of the application of bio-fertilizers are examined and bio-fertilizers found to be non-compliant are subject to regulatory action such as product detention (stop sale) and, in severe cases, prosecution (Fertilizer Act and Regulations 2006).

However, in 2013, the Regulations 2006 were amended and the standards for rhizobial inoculants prescribing minimum number of viable cells per seed were removed. The amendments have an aim to strengthen industry's leadership role in quality assurance and verification, and provide industry with greater flexibility, reduced costs and less red tape. Canada has applied a system of third party quality standards.

The Canadian Food Inspection Agency oversees voluntary labeling and consumer fraud issues. Government bio-fertilizer policy on labeling can be used in prevention of fraud to instituting standards for voluntary labels or mandating labeling (Caswell 2000).

Manufacturers submit copies of the label that is intended to be used for the bio-fertilizer and other information as it is necessary to determine the safety, merit and value of the product. The quality of bio-fertilizer registered must be maintained and any change without proper acknowledgement from the registering body is termed as fraud. No change in the label, chemical composition or ingredients of a bio-fertilizer registered shall be made unless the registration is changed accordingly (CFIA 2014).

Bio-fertilizer labels also bear the registration provided by the CFIA. The number contains information on the year of registration, the number of products registered and the type of product. Lot number is also included and it necessitates product traceability and recall. Bio-fertilizers found to be in contravention of the Fertilizers Act and Regulations 2006 are subject to enforcement action and products with the same lot number are detained.

Canada's environmental policy, fertilizer law and regulations are well aligned exhibiting a positive effect in the use of bio-fertilizers. Through this effective regulatory system, safety, efficacy, compliance and enforcement is achieved, promoting use of environmentally safe bio-fertilizers in the country and even export of the products to other regions. The response to new beneficial technology through amendment of the Fertilizer laws and regulations to capture new biotechnology products, the bio-fertilizer industry is well regulated. Also third party monitoring has facilitated the availability of adequate quality products in the market with less burden on the government.

4.3.2 Indian Regulatory Environment

Agriculture development in India is guided not only by the strong need of improving food and nutritional security, but also by the concerns for environmental protection, sustainability and profitability (Chandrasekaran et al. 2010). India has the highest number of organic producers who incorporate bio-fertilizers into their farming system totaling 340,000 (Yadav 2013).

In India, commercial inoculants are used on a large-scale rice production and have resulted in yield increases of around 10% with a 25-50% reduction of fertilizer, considering India's low phosphorous soils (Chatzipavlidis et al. 2013). Production of

bio-fertilizers in India began in 1956 (Ghosh 2003) and increased use is majorly through government support. Increased commercial production of bio-fertilizers began in 1976 and it was supported by the National Agricultural Innovation Project (NAIP) of Indian Council of Agricultural Research (ICAR) and they received funding by the World Bank in 2009 (NAIP 2011).

Use of bio-fertilizers alongside chemical fertilizers is promoted by the government in India (Ghosh 2002). The country has established a bio-fertilizer production centre where different types of good quality bio-fertilizers are produced in millions of packets (NAIP 2011).

India's National Environmental Policy (NEP) 2012 states that perverse production practices; pointing out improper use of agricultural chemicals, have contributed to environmental degradation. Initiatives by the government include the adoption of science based sustainable land use practices, through research and development, extension of knowledge, pilot scale demonstrations , and large scale dissemination , including farmers training (NEP 2012).

Bio-fertilizers in India are regulated by the Fertilizer Control Order (FCO) 1985 and the Essential Commodities Act (ECA) 1955. An order issued by the Ministry of Agriculture in India in 2006, later amended in 2009, included bio-fertilizers under the Essential Commodities Act of 1955 (10 of 1955), in Fertilizer (Control) Order, 1985 (Malusa and Vassilev 2014). In Schedule III of the FCO 1985 as amended in 2009, the specifications, tolerance limit, sampling procedure and method of analysis of bio-fertilizers are outlined. Appended to the order are also laboratory equipment specifications.

In the years 1965-1990 around 30 bio-fertilizers production laboratories were set up in the country to meet the demand (Venkataraman & Tilak, 1990). Production and consumption of bio-fertilizers increased from 1000MT (1989) to 10,000MT (2000) (Dwivedi and Motsara, 2001; Bhattacharya & Dwivedi, 2004). The government formed the National Project on Organic Farming (NPOF) in 2004 and intensive efforts made

under the project caused overall production of bio-fertilizers to grow to more than 20,000 tonnes/annum in 2007-08 (Sangar 2009). This clearly demonstrates the role of government in enhancing increased uptake of environmentally safe bio-fertilizers among small holder farmers.

In India Ministry of Agriculture and Cooperation has devised the specification on registration, standards, procedures and testing protocol for Rhizobium, Azotobacter, Azospirillum and Phosphate solubilizing bacteria (Brahmaprakash and Sahu 2012). Bio-fertilizer standards Rhizobium-IS-8268: 2001; are available for the manufacturers to adhere to (FCO 1985).

Gazette extraordinary [Part II- Section 3- subsection (II)] dated 24th March, 2006 released the specification for bio-fertilizer along with their tolerance limit and method of analysis. The viable count of carrier based microbial inoculant should be 10^7; contamination level nil at 10^{-5}; pH level, 6.5 to 7.5; moisture level, 30– 40% and shelf life must be not less than six months (Jha et al. 2012). The products registered must conform to the specified standards for the carrier material, the viable cell count, contamination level, pH, particle size in case of carrier based material, and moisture percent by weight and efficiency character (FCO 1985).

The specifications for the labeling of the products are clearly outlined in the Indian legislation (FCO1985) include details on:

a. Name of the product,
b. Name and address of the manufacturer,
c. Crops for which intended
d. Type of the carrier used
e. Batch number
f. date of manufacture
g. Expiry date
h. Net mass in kg/gram and area meant for
i. Storage instruction worded as under; “Store in cool place away from direct sun light and Heat”

j. Any other information required under the standards of Weights and Measures (Packaged Commodities) Rule, 1977 (FCO 1985).

Information about compatibility with other products and directions for use and storage conditions must be clearly stated on the labels of bio-fertilizers. More importantly, manufacturer has to instruct the retailers and in turn, the users about the precaution to be taken during storage (FCO 1985).

According to India's Department of Agriculture and Cooperation under the Ministry of Agriculture there is a Central Fertilizer Quality Control Institute and Regional Fertilizer Control Laboratories, where samples of fertilizer are taken for quality control. The procedure for obtaining samples is clearly outlined in the FCO 1985. Inspectors visit facilities, sample bio-fertilizers and review labels. These efforts are focused on verifying that the bio-fertilizers satisfy the safety standards for biological and chemical contaminants (pathogens, heavy metals, pesticide residues, etc.).

Inspectors are empowered to draw samples of the bio-fertilizers for quality testing, enter and search any premises where any bio-fertilizer is manufactured/imported or stored or exhibited for sale (FCO 1985).

The FCO (1985) as amended in 2006 and 2009, Clause 13 restricts manufacture of bio-fertilizers unless they are in conformity to the prescribed standards. Further clause 17 requires the certificate of manufacture to be renewed every three years and in such a case where a manufacturer fails to comply with the FCO (1985), clause 31 allows for the suspension or cancellation of the certificate, or debarring the dealer from carrying out the business of bio-fertilizers (FCO 1985).

India has also achieved increased use of bio-fertilizers through it regulatory system that ensures safety, efficacy and compliance by the manufactures through different means of enforcement. The government has also played a great role in promoting use of bio-fertilizers in the country through amendment of the fertilizer laws appropriately to

incorporate new biotechnology products and setting up a project that has contributed to increased use of bio-fertilizers.

The two countries have a comprehensive framework that has allowed availability of adequate quality bio-fertilizers in the market and increased uptake by famers. This has been expressed through their environmental policy, legislative and institutional provisions as well as government projects in the use of environmentally safe bio-fertilizers. A number of the lessons can be borrowed by Kenya.

4.3.3 Kenya's Shortfall in Bio-fertilizer Regulation

Kenya's draft National Environment Policy (NEP) 2013 points out environmental degradation as a challenge in sustainable development with a causative factor being unsustainable production patterns, specifically poor soil management practices. Soil fertility depletion is a major contributor to environmental degradation. The policy proposes to support eco and organic farming so as to maintain soil fertility. The government will also provide economic incentives for investment in more efficient, clean and environmental friendly technologies and associated capacity building.

Bio-fertilizer technology dissemination has not received support from the government. Policy statements require solid strategies on the ground in order to achieve the objectives without which they remain theory on paper. There is need of an official National Environmental Policy that can guide other aspects of bio-fertilizer regulation. The case of India government in initiating projects such as NPOF has resulted to increased uptake of environmentally friendly bio-fertilizers in the country. Indian National Environmental Policy 2012 has effectively supported sustainable agriculture that incorporates environmental considerations.

Environmental Management and Coordination Act (EMCA) 1999 is Kenya's framework environmental law. EMCA 1999 is an Act of Parliament to provide for the establishment of an appropriate legal and institutional framework for the management of the environment. The act mandates the National Environmental Management Authority (NEMA) to issue biosafety measures necessary to regulate biotechnology, its

development, access and transfer. Degradation of agricultural areas is defined as an illegal activity within EMCA 1999 (Funder and Marani 2013). NEMA has a part to play in the dissemination of environmentally safe bio-fertilizer technology to farmers through promotion of environmentally sustainable agriculture among farmers.

In NEMA's strategic plan 2005-2010, the authority will ensure integration of environmental concerns into national development policies, plans and programmes (NEMA 2005). The National Environment Action Plan Framework 2009-2013, states that it is necessary to strengthen environmentally friendly agricultural practices such as organic farming (NEAP 2009-2013). Bio-fertilizers are a great component of organic farming.

The Authority should be concerned with issues of the degradation of agricultural areas and water quality as a result of pollution through chemical fertilizer use and emissions that contribute to climate change. However; NEMA has isolated its part in the agricultural sector. In its Green Initiatives in Kenya Publication (2012), the Parastatal has not singled out activities in the agricultural sector that help in the achievement of Green Economy in Kenya, overlooking the place of chemical fertilizers in contributing to climate change.

Fertilizers and Animal Foodstuffs Act Cap 345 does not incorporate bio-fertilizer regulation as is the case with Canadian Fertilizers Act and Regulations 2006 and Indian Fertilizers Control Order 1985. The Acts were amended to incorporate bio-fertilizers. However, Kenya's amendment to the Fertilizers and Animal Foodstuffs Act Cap 345 does not incorporate bio-fertilizers. An enabling regulatory framework that clearly outlines the procedures for registration, safety, efficacy, trade, labeling, laboratory requirement as well as sampling of bio-fertilizers is necessary.

Another inadequacy in Kenya is the lack of sufficient laboratories for bio-fertilizer testing. In Kenya, there are three established laboratories (University of Nairobi, Mea Ltd. and Egerton University) that directly handle bio-fertilizers. This might prove to be

insufficient for achieving increased awareness and uptake of bio-fertilizers in Kenya. There must be adequate capacity such as staff, skills and laboratories to meet international standards for fertilizer testing, and maintain a system for tracing adulterated products back to the source (USAID 2012); if the goal of achieved uptake is to be attained.

Quality standards are essential for quality assurance of bio-fertilizers in the Kenyan market (Tandon 2011). Currently there is only a draft bio-fertilizer standards KS 2356:2012, that has outlined bio-fertilizer specification. Furthermore, the document has been confined to a few categories of bio-fertilizers leaving out other types of bio-fertilizers that may warrant introduction into the Kenyan market. The Standards should not be limited to Rhizobium, Azotobacter, Azospirillum and Phosphate Solubilizing Bacteria (PSB) only that are geared towards supply of macro nutrients but other types of bio-fertilizer should be under its ambit (Jha et al. 2012) as there are microorganisms beneficial for uptake of micro nutrients.

A high quality formulation and application must maintain and deliver, in a convenient and economical fashion, a high population of effective rhizobia (Smith 1992).The Kenyan draft bio-fertilizer standards KS 2356:2012 has adopted quality requirements that are used in India and Canada i.e. CFU minimum 10^8/ ml of liquid with the exception of the carrier material being 10^8/ g. Canadian and Indian requirements are CFU minimum $5x10^7$ cell/g of powder, granules or carrier material. For the three countries, no contamination is allowed at the level of 10^{-5} dilution. Two important aspects should be considered in establishing a quality standard for microbial inoculants; one is to maintain a minimum level of viable cells per unit and second is the level of contaminant (Brahmaprakash and Sahu 2012).

With high official standards and their enforcement, rogue manufacturers will be eliminated creating an enabling market for increased uptake of adequate quality bio-fertilizers. This warrants introduction of governmental standards and testing services to achieving adequate quality bio-fertilizers for use by smallholder farmers (Olsen et al. 1994).

Labeling of bio-fertilizers is important to ensure access to information on the product use and instructions. Information on a label should be printed conspicuously, legibly and indelibly in English and Kiswahili. This is important as most the smallholder farmers might not be able to understand the instructions in English. Furthermore, Kiswahili is Kenya's national language according to the constitution of Kenya 2010. In addition to these the information required as per the provision of Canada and India bio-fertilizer labels, the viable cell count (CFU) must also be indicated on the label. This is important because adequate quality bio-fertilizers would be considered to be with high population of desired microorganisms, of sufficient viability, and with ability to remain uncontaminated for longer period of storage (Brahmaprakash and Sahu 2012).

This chapter brings out the importance of a well regulated bio-fertilizer sector in enhancing uptake. Kenya can learn from the two countries. The last chapter combines the importance of regulations and delves into other factors that can help in the uptake of bio-fertilizers in Kenya.

4.4 Increased awareness and uptake of bio-fertilizers in Kenya

Availability of regulations on bio-fertilizers and its effective enforcement plays a key role in increasing uptake as in the case of Canada and India. This has been displayed by the policies and the laws available in the two countries including Compliance and Enforcement Policy for the Canadian Environment Protection Act (CEPA) 1999, Canada's Fertilizer Act and Regulations 2006, India's National Environmental Policy (NEP) 2012, Fertilizer Control Order (FCO) 1985, Essential Commodities Act (ECA) 1955 and India's bio-fertilizer standards Rhizobium-IS-8268: 2001.

Emanating from the established legislations are institutions that have effectively promoted the use of bio-fertilizers among farmers. These include Canadian Food Inspection Agency (CFIA), Health Canada, Environment Canada, and National Project on Organic Farming (NPOF), Central Fertilizer Quality Control Institute, Regional Fertilizer Control Laboratories, and National Agricultural Innovation Project of the Indian Council of Agricultural Research (ICAR).

Strategies to promote increased awareness and uptake of bio-fertilizers thus commence with the availability of a bio-fertilizer policy and law, standards. Other important aspects include research activities, vibrant extension system and market development. The following section consolidates these important aspects in enhancing increased uptake of bio-fertilizers.

4.4.1Establishment of a Bio-fertilizer Policy and Law

The Fertilizers and Animal Foodstuffs Act Cap 345 excludes organic fertilizers let alone bio-fertilizers. A sound foundation for sustainable crop production intensification should be the basis or bio-fertilizer regulations in Kenya (FAO 2011). The regulatory instruments have to be crafted in line with the overarching environmental law EMCA 1999 and the Constitution 2010.

The draft National Environmental Policy 2013 should be harmonized with Kenya's agricultural policies in order to enable an integrated and ecosystem approach to environmental management (NEP 2013). The aim should be to move away from a system of food production that promotes environmental destruction such as excessive or underuse of chemical fertilizers to incorporation of bio-fertilizers and organic matter into the cropping system.

According to Vogl et al. (2005) an enabling policy framework, specific regulations, standards and guidelines for deployment of bio-fertilizers should be provided. The bio-fertilizer policy should take into account the most effective set of investments for achieving an agreed upon set of objectives, given available public funds (Crawford 2005).

The National Environmental Management Authority ought to coordinate its activities with institutions currently involved in the regulation of bio-fertilizers. In this way, they can integrate environmental considerations in strategic agricultural plans. An example is the Agricultural Sector Development Strategy (ASDS) 2010-2020, which currently falls short of promoting the use of environmentally safe bio-fertilizers.

According to the Agricultural Sector Development Strategy 2010-2020, the environment is a subsector of the agricultural sector. ASDS 2010-2020 is a guide for the public and private sectors efforts' in overcoming development challenges in the agricultural sector. Efficient use of inputs has been singled out as one of the challenges. The document has outlined its strategy to increase access of fertilizers to farmers by investing in local blending of chemical fertilizers and enhancing access to credit to smallholder farmers (ASDS 2010-2020). Issues of promoting organic agriculture of which use of bio-fertilizers is a key aspect has not been included in the strategy. This also shows lack of integrating environmental considerations in national strategies. Furthermore, ASDS 2010-2020, states that only 24.3% of farmers are involved in environmentally sustainable agriculture through use of organic manure.

4.4.2 Establishment of Standards

The bio-fertilizer Standards KS 2356:2012 should be gazatted to enable enforcement of bio-fertilizer quality standards. Enactment and enforcement of laws and regulations dealing with quality control, registration, packaging and labeling is required will protect farmers against unfair competition and fraud (Vogl et al. 2005, Gregory and Bumb, 2006). Quality control will ensure the bio-fertilizers in the market are efficacious when used by farmers. According to Sangar (2009), maintaining quality and monitoring by continuous sample testing of bio-fertilizers are the important factors for enabling uptake.

Canada adopted a system of third party regulations which ensures availability of adequate quality bio-fertilizers in their local market and also exporting to other countries. The government can promote private sector self-regulation, through Agro-dealer input Associations, in addition to its regulation, as a cost-effective and efficient means of ensuring high quality fertilizer products (Tripp 2003). Such associations can monitor fertilizer sold by their members by conducting random testing of bio-fertilizer and enforcement of penalties for any member businesses selling adulterated products (USAID 2012).

4.4.3 Research and Development

Bio-fertilizers should contain a level of bacteria sufficient enough to inoculate plants and produce an economic gain but the level cannot be established as a general standard

because it varies from one bacterial species to another and under different conditions (Brahmaprakash and Sahu 2012). Research is thus important in order to obtain appropriate recommendations for bio-fertilizers to be used in different regions of the country. Factors that affect performance of bio-fertilizers in the field include rhizosphere competence in competition with other microorganisms, soil type, management practices (i.e., usage of agrochemicals, crop rotations) and climatic factors explaining inconsistencies in the field compared to the green-house possibly posing a bottleneck in widespread application of bio-fertilizers (Akter et al. 2013).

Agricultural research and farmer education is promoted by an enabling institutional and policy environment (Nyasimi et al. 2014). Kenya Agricultural and Livestock Research Act 2013, repeals the Science and Technology Act Cap 250. It provides for the coordination of research activities and states that research is a key component of technology generation, knowledge management and technology transfer. The Act establishes the Kenya Agricultural and Livestock Research Organization (KALRO). Research is also important in obtaining information that can be used in designing or improving institutions (Schimmelpfenning and Norton 2003).

Kenya Agricultural and Livestock Research Act 2013 gives KALRO function to liaise with and ensure the co-ordination of institutions, agencies and persons involved in agricultural research. An example is Mea Limited, a private company involved in the manufacture of bio-fertilizers and distribution to farmers. The company collaborates with the government through University of Nairobi, where they University cover aspects of research on efficacy and quality, while the company handles the production, marketing and distribution. According to the interview with the company, the Kenyan market consumes approximately 10% of the bio-fertilizers produced by the company. Demand for the product is low among farmers as a result of the factors outlined in the first chapter.

The Agriculture Fisheries and Food Authority Act 2013, provides for the consolidation of the laws on regulation and promotion of agriculture. One of the functions of the Agriculture Food and Fisheries Authority (AFFA), as stated in Clause 4(a) is promotion of best practices and regulation of production of agricultural products. In addition, AFFA will also determine research priorities in agriculture. The act indirectly reflects on the use

of fertilizers which are agricultural inputs through Clause 23(1) (a) on Land preservation guidelines which promotes soil conservation. Organic food production that incorporates bio-fertilizers should be promoted as a best practice in production of agricultural products as it enhances environmental conservation.

According to Aggani (2013), research should focus on the selection of effective and competitive bio-fertilizers that have multiple functions for a variety of crops, quality control in production and application, survival of bio-fertilizers under stressful soil conditions, evaluation of the agronomic, soil and economic benefits in different agricultural systems, transfer of knowledge to manufacturers for best formulations and the availability of a Bio-fertilizer Act to ensure quality control and effective regulation of the market.

Research and development on bio-fertilizers has to be strengthened in order to enhance environmentally friendly and sustainable agriculture that is in line with the requirement of EMCA 1999 and the Constitution article 69'. The national Environment Management Authority (NEMA) has a function to undertake and co-ordinate research, investigation and surveys in the field of environment and collect, collate and disseminate information about the findings of such research, investigation or survey. NEMA can collaborate with research institutions that have conducted studies on bio-fertilizers and thus promote the use of the same in order to conserve the environment. This can be achieved through integrating environmental considerations in relevant policy documents and agricultural strategies.

Bio-fertilizers will be successfully adopted only when convincing evidence is available showing the microbes used sufficiently supplement the nutritional requirements (nitrogen, phosphorus, iron, etc.) of plants. Products should be of high quality with the desired number of propagules present and an acceptable shelf life. Research efforts therefore should be directed towards development of efficient strains with the right host compatibility, better competitive abilities, and improved tolerance to abiotic stresses (Kalra and Khanuja 2007).

4.4.4 Extension Services

Agricultural extension benefits include knowledge diffusion from laboratories to farmers' fields and enhancing information exchange between farmers and research centers (Birkhaeuser and Evanson 1991). Besides technology dissemination, extension facilitates local adaptive research (Mkondiwa and Coe 2013).

The National Agricultural Sector Extension Policy (NASEP) 2012 is formulated with an aim to enhance effective management and organization of agricultural extension in a pluralistic system where there is active participation of both public and private service providers (NASEP 2012). The policy brings out the shortfall in numbers of extension workers available to farmers; number of extension workers is about 1:1000 compared to the desired level of 1:400.

Visitation by state extension workers in the surveyed area was found to be low (17%). From the survey data, only three villages; Gamba, Koga and Odeko, out of a total of ten have been able to access government extension services as shown in table 4.1 below.

Table 4.1 Frequency of visitation by extension service workers

Villages	State Extension Services	NGO
Gamba	8	39
Koga	2	43
Lwala A	0	5
Nyandiwa	0	31
Odeko	2	35

The overall downfall in the uptake of bio-fertilizers as revealed by the study is lack of knowledge. Education and extension service plays a very important role in the creation of awareness of new beneficial agricultural technologies.

Bio-fertilizers use needs to be not only demonstrated but also continuous follow-up is necessary to reinforce understanding of the product (Dewasthale 2008). The National Agricultural Sector Extension Policy states that both public and private service providers

are active participants (NASEP 2012). According to the respondent from One Acre Fund, the NGO sends field officers regularly to conduct in-person training for the different farmer groups. On-farm demonstrations are conducted and the farmers participate in doing the activities and this helps to reinforce the knowledge gained from the field officers. The officers meet with the farmers regularly.

Extension, promotes adoption of technology by providing advice to smallholder farmers and Agro-dealers (Makokha et al. 2006), identification of opportunity in terms of new products that may profit them (Eicher 2007) and enhancing adoption of technologies (Okoedo-Okojie et al. 2011). Increase in agricultural extension visit increases the probability of adopting fertilizer technology. Their visit to smallholder farmers has the tendency of creating more awareness and better information to the farming household heads on the importance of fertilizer technology (Akpan et al. 2012). This is because bio-fertilizers are perceived by farmers to have slow positive effect compared to chemical fertilizers, leading to the low farmers' acceptability (FFTC 2007). Without a way to offer extension services to farmers, then dissemination of new beneficial agricultural technologies is limited.

The following are different components of extension that support state extension services.

(i) Role of Field Trials and Demonstrations

Respondents from two private owned companies One Acre Fund and Dudutech Kenya Ltd. are involved in setting up field trials. Field trials are conducted on small-holder farms with their approval and the farmers in the region can easily monitor the whole process. Dewasthale and Bondre (2008) stated that the installation of field trials is meant to demonstrate beneficial effects of bio-fertilizers for different crops. Farmers will do what they see to increase their crop yields; the result as well as method of application that are very effective tools in promoting bio-fertilizer usage. Aside from the impact of bio-fertilizer use farmers should be educated on the economics /returns (Rao and Umesh 2012).

(ii) Role of Farmer Groups

Farmers who are organized in groups can easily access training as compared to farmers who are not in groups. The table 4.2 shows group membership of farmers in the surveyed area.

Table 4.2 Proportion of membership to farmer groups in the surveyed villages

Villages	Membership	No membership
Gamba	0	100
Onding	13	87
Lwala A	7	93
Koga	33	67
Odeko	7	93
Sinyolo	7	93
Nyandiwa	0	100
Border	0	100
Yenga	0	100
Gaga	0	100

For instance few farmers 7% (Odeko, Sinyolo and Lwala 'A') and 33 % in Koga are organized in groups and about 17 % joined the groups as way to access training. This lack of group setting among famers in the surveyed area might also contribute to the low uptake of bio-fertilizers. The table 4.3 shows various reasons farmers organized themselves in groups.

Table 4.3 Reasons for membership to farmer groups

Reason to join farmer group	Proportion of Farmers [%]
Training	17
Exchange of information	9
Collective commercialization	9
Cheap inputs	22
Access to credit	39
Trial crops	4

A different approach that can ensure farmers access training is encouraging group settings among smallholder farmers. Extension agents, both public and private, should

use participatory methods involving feedback from farmers (NASEP 2012). Relationships can then be established to exchange information and disseminate bio-fertilizer technologies which address current and longer-term farmer needs (Dittoh et al. 2012). Therefore extension is important in promotion of innovation, knowledge dissemination and enhancing development among smallholder farmers (Rivera and Rasheed 2009).

Mea Ltd. trains farmers that are in groups on the use of bio-fertilizer. The training is done free of charge and their officers visit farmers during their group meetings. For farmers who are not able to understand the language used by the trainer, other group members who have understood can easily give the information in the local language for the local farmer to understand. The farmers can also order for bio-fertilizers directly from the company and at a cheaper cost when purchased in bulk.

Biovision sends copies of their monthly magazine which is printed in English to farmer groups, not to individual farmers. The farmers hold meaningful discussions regarding the new technology that has been exposed to them. In this way, farmers can easily learn from each other. One Acre Fund also gives affordable inputs to farmers on credit but the condition is that the farmers have to be in a group setting. Holding of awareness meetings is another strategy used to increase farmers' acceptance of bio-fertilizers in addition to visiting demonstration plots (FFTC 2007).

4.4.4Bio-fertilizer Market Development

Bio-fertilizer use will be strongly influenced by an enabling environment, making legal, regulatory, policy, and institutional considerations important in any strategy to encourage increased uptake (USAID 2014). To effectively regulate the bio-fertilizer industry, the government should delegate oversight to a regulatory body with the capacity for enforcement backed by corrective action (USAID 2012).

The Government of India and various State Governments have been promoting the budding bio-fertilizer market both at the level of the user-farmer and the producer-investor through the following measures: (i) farm level extension and promotion

programmes, (ii) financial assistance to investors in setting up units, (iii) subsidies on sales and (iv) direct production in public sector and cooperative organizations and in universities and research institutions (Mazid and Khan 2014). Such activities have built the bio-fertilizer market through increased awareness, demand and availability of the products ensuring a well developed bio-fertilizer market.

The media can also be used as a good channel to facilitate awareness and uptake of bio-fertilizers. Results of the survey ranked Radio as the most important source of information for smallholder farmers as shown by table 4.4 below.

Table 4.4 Information Sources

Information source	Proportion [%]
Radio	15.23
Market	14.89
Neighbour	13.03
Agro-dealer	12.41
NGO extension worker	11.62
Community health worker	7.16
State extension worker	6.71
Newspaper	6.54
Written documents,	4.74
Research center or	4.57
Television	2.99
Other	0.16

KALRO can support training and awareness programmes on bio-fertilizers through Kenya Broadcasting Station (KBC). The main laxity in this performance springs from the lack of integrating environmental considerations in use of agricultural inputs displayed by the lack of an effective regulatory framework on bio-fertilizers in the country.

Finally, increased production of bio-fertilizers from the private sector is a response to the increased awareness and demand from the farmers. This can be achieved through

capacity building of agro-dealers and activities of private bio-fertilizer companies that are mainly driven with an aim of making profits.

(i) Agro-dealers

The low percentage (33.3%) of agro-dealers with training on agricultural inputs needs to be reversed through capacity building. Agro-dealers constitute an important link between bio-fertilizer suppliers and smallholder farmers. Agro-dealers once grounded in the knowledge of bio-fertilizers can then advice the farmers accordingly since they are able to reach many small-holder farmers with their services. Agro-dealers should build on knowledge of different bio-fertilizers and their proper, modern crop production technology and business management (Gregory and Roy 2005).

Most retailers are themselves farmers and are in an ideal position to advise their customers about which types of inputs will work best in local climates and soil conditions (AGRA 2009). Increased awareness of availability and benefits on the use of bio-fertilizers will then result to increased demand for the products in the market. Agro-dealers are majorly businessmen out for profit and they will not stock bio-fertilizers if there is no demand (Dewasthale 2008).

(ii) Role of Private Bio-fertilizer Companies

Mea Ltd. is involved in distributing bio-fertilizers to farmers and the company applies various strategies to increase awareness of the products. The interview with a company respondent revealed that they are sponsors of a program on local TV station; *Shamba Shape Up*, hold radio programs, participate in Agricultural Shows, Road shows, advertise in local Newspapers, and send emails to farmers in their data base, run a website with information on bio-fertilizers and also on social media like Face book and Twitter. Dudutech also gives information on new products through distribution of their magazine Floriculture Horticulture.

Private firms play an important role in researching, developing and trading in new biotechnology goods and services (Mugabe 2002). Such companies need an enabling

environment that can encourage their investment in the market. In order to create a favorable business environment for private investors, a clear and efficient process for licensing, registering products, and enforcing fertilizer quality standards are needed (USAID 2012). Thus, emphasis should be placed on institution building to develop local capacities for structuring regulatory frameworks (Tripp 2003).

Enabling environment considerations or policy measures that support business entry include easing business registration and the acquisition of licenses. These reforms typically have a favorable impact on the business enabling environment by saving firms substantial amounts of time and money (USAID 2014).

Uniformity of bio-fertilizer laws and regulations with other regions (Masso et al. 2013) is also beneficial in luring private investors in the bio-fertilizer market. For imported bio-fertilizers already in use in other countries the registration period especially the trial stage should be shortened. This will aid bio-fertilizer market development, leading to increased availability of adequate quality products in the market. With increased awareness and sufficient production of bio-fertilizers in the market, the goal of increased uptake can be achieved.

5.0 CONCLUSION AND RECOMMENDATION

This chapter compounds the various findings of the study and proposes recommendations.

5.1 Conclusion

Results of this study show that the level of uptake of bio-fertilizers is very low among small-holder farmers in the all the surveyed villages. Socio-economic factors such as gender, age and education have impacted the adoption of bio-fertilizer technology in the study area. Low level of uptake is as a result of lack of knowledge in both farmers and agro-dealers, lack of demand, resistance to change and lack of application knowledge in the surveyed area. Such factors are interlinked to the regulatory system of bio-fertilizers in the country. Effective policy measures are thus required in order to enhance the uptake of environmentally safe bio-fertilizers.

The current regulatory system for bio-fertilizer in Kenya has been shown to be deficient. Post registration monitoring is not effective due to lack of an enabling law. Furthermore, lack of official standards is a hindrance to effective quality control of bio-fertilizers in the market. This creates an entry point for low quality bio-fertilizers in the market since there is no law to pin down offenders. Compliance and enforcement is lacking thus derailing efforts in promoting use of environmentally safe bio-fertilizers. The Fertilizer and Animal Foodstuffs Act cap 345 has been amended but still excludes the use of environmentally safe bio-fertilizers displaying the delinked nature of the draft environmental policy, environmental law and fertilizer regulations.

An effective bio-fertilizer regulation system as shown by Canada and India can enhance uptake of bio-fertilizers. The two countries amended their fertilizer laws and regulations to incorporate bio-fertilizers in the farming systems. Canada has also promoted bio-fertilizer industry responsibility that has enabled effective quality control of bio-fertilizers in the market. Bio-fertilizer standards are also available in the two countries and compliance is enforced through available laws. Indian government has demonstrated full support to the uptake of bio-fertilizers in the country through industry support, availability of quality control laboratories and a government initiated project. The

environmental policy and law and fertilizer laws and regulations for the two countries promoted uptake of bio-fertilizers.

Other complementary factors in addition to an effective bio-fertilizer regulatory framework that are important in increasing awareness and uptake of bio-fertilizers include research activities, extension services and market development. Without research activities, bio-fertilizers will not be adapted to the local conditions. Poor extension services had a negative impact on the uptake of bio-fertilizers due to lack of knowledge on the products. Low demand of bio-fertilizers by farmers and an ineffective registration system has a damping effect on bio-fertilizer market development. In line with these, extensive field trials, organizing farmers into groups, agro-dealer capacity building, and use of media resources are beneficial strategies in increasing awareness and uptake of bio-fertilizers.

5.2 Recommendations

Actions either in the short term, medium or long term can be taken by the government to enhance uptake of bio-fertilizers.

Short Term Recommendations

Draft policy, law and standards should be given speedy attention to ensure they become official regulatory instruments to enhance quality control of bio-fertilizers in the market. Such regulations will enhance continuous monitoring of bio-fertilizers in the market.

Policy should promote investment on environmentally sustainable agriculture and promotion of organic agriculture that incorporates the use of affordable bio-fertilizers. Fertilizer legislation should not only promote the use of expensive chemical fertilizers but incorporate aspects of EMCA 1999 and the draft National Environmental Policy 2013. Therefore, the current amendment to the Fertilizers and Animal Foodstuffs Act cap 345 still falls short. The 2013 Bill should be taken back to the drawing table and amended to include environmentally safe bio-fertilizers. Similarly the draft bio-fertilizer standards should be altered to incorporate other different categories of bio-fertilizers.

Self check system by manufacturers can be promoted to enhance availability of adequate quality products. This can be beneficial for the industry to curb rogue manufacturers as well as saving on government resources for that activity.

Another short term action is advising farmers organize themselves into groups. Farmers should be informed of the importance of organizing themselves in groups in order to access training on the use of bio-fertilizers. This can be done through media (radio) which is easily accessible to smallholder farmers.

Medium Term Recommendations

Streamlining the activities of the organizations currently involved in regulating bio-fertilizers will be beneficial to the industry. The organizations currently involved in monitoring bio-fertilizers operate within a gap for lack of an enabling law. This clearly demonstrates the need for governmental regulations in the Kenyan bio-fertilizer market. Comprehensive regulations should set in place institutional mechanisms that will create a favorable environment for private investors which can ease the registration process, adherence to quality standards by all manufacturers and provide for strong penalties that will effectively control the bio-fertilizer market.

Capacity building through an increase in laboratory facilities and skilled staff for bio-fertilizer quality testing is necessary to ensure availability of adequate quality products in the market.

There is a need to consider reducing the trial period for new products especially for products approved and are in use in other countries. These requirements might hinder the registration process for new beneficial bio-fertilizers creating a negative impact on the bio-fertilizer market in Kenya. Regulations that are too stringent might again hamper efforts in the increased uptake of bio-fertilizers. The environment that is required is one that promotes the availability of adequate quality products with ease of doing business by the manufacturers.

Long term Recommendation

Technical capacities of agro-dealers should be built. Such individuals are important in giving information on bio-fertilizer instructions and dosage. The government can initiate a project targeting agro-dealers to train them on bio-fertilizers since their numbers might be fewer compared to the number of smallholder farmers. The government may need to consider public-private partnerships in achieving such goals.

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7.0 APPENDICES

7.1 Questionnaire sample

The following questionnaire whose aim is to investigate the use of farm inputs is intended for educational purposes. The research intends to abide by all commonly acknowledged ethical codes. Thank you for your time.

Section 1: Identification of the interviewer

1.1. Name of the interviewer:

_____

1.2. Date of the interview: _____ / _____ / 20; Time at start of the interview:

_____

Section 2: Identification of the site

2.1. County: Siaya
2.2. Local Government / Location:

_____

2.3. Ward / Sub-location

_____

2.4. Village

_____

_

2.5. GPS coordinates of the shop: _____N/S:
_____E/W

Section 3: Shop characteristics

3.1. Name of the Shop owner (MUST BE THE RESPONDENT!):

_____

3.2. Sex of the Shop Owner *[**1**= Male;* 2*= female]*:

_____

3.3. Age of the Shop
owner;_____

3.4. Marital status *[**1**= Married-monogamy; **2**= Married-polygamy; **3**= Divorced; **4**= Widowed; **5**= Single, **6**= Other (specify)]:*

_____

3.5. Level of education of the Shop owner [**0**= No education; **1**= Primary education; **2**= Secondary education; **3**= Tertiary education]:

_____

3.6. Main occupation of the Shop owner *[**1**= Agriculture; **2**= Trade; **3**= Labourer; **4** Craftsman; **5**= Other
(specify)]*:_____

Section 4: Government Inspectors

Visited {1=yes 0=no}	Period*	Frequency**

***Period 1**=Last six months; **2**=Last 1 year; **3**=Last 3years; **4**=More than 3years ago; **5**=Other {Specify}*
***Frequency 1**=Once; **2**=Twice; **3**=Three times; **4**=Four times*

Section 5: Products in the shop

5.1. Description of Products in the shop

	Category* {Give specific name}	**Preference order****	**Unit Price** {Ksh}
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			

*** Category **1**=Fertilizers; **2**=Pesticides; **3**=Seeds; **4**=Personal Protective Equipment; 5=other {Specify}*
*** Preference order **1**=High; **2**=Medium; **3**=Low; **4**=Other {Specify}*

5.2. Elimination of products from the market

	Category* {Give specific name}	**Reason****	**Source of Information*****
1			
2			
3			
4			

5			
6			
7			
8			
9			
10			

****** Category **1**=Fertilizers; **2**=Pesticides; **3**=Seeds; **4**=Personal Protective Equipment; **5**=other (Specify)*
******* Reason **1**=Expensive; **2**=Destroys the environment; **3**=Poor quality and non effective; **4**=International ban; **5**=Other (Specify)*
******* *Information **1**=Television; **2**=Radio; **3**=Newspaper; **4**=State Extension Worker; **5**=NGO Extension Worker; 6=Research Centre or University; 7=Written Documents, Leaflets; 9=Other (Specify)*

Section 6: Credit Facilities

Access to credit facilities for purchase of farm inputs

Institution	**Membership1=yes;**	**Name {Specify Name}**	**Interest rate**	**Loan limit**
Banks				
NGOs				
Government				
Microfinance				
Co-operative				
Farmer				
Agro-dealer				

Section 7: Personal Protective Equipment

7.1 Personal Protective Equipment (PPE)

PPE	**Situation 1a**=Yes, Present **; 1b**=Yes, out	**Cost***
Overall		
Rubber Boots		
Long Rubber Gloves		
Aprons		
Nose mask		
Waterproof hat		
Goggles		
Respirator		

***** Cost **1**= <1000Ksh; **2**=<1000-2000Ksh> **3**= <2001-3000Ksh> **4**= >3000Ksh **5**= Other (Specify)

Section 8: Training on the use of Farm Inputs

Have you received training on the use of farm inputs?

Institution	Received training(**1**=yes	Specify Name
University		
Technical College		
State Extension		
NGO Extension		
On-Job Training		
Research Centre		
Other (Specify)		

Section 9: Bio-fertilizers

Do you stock bio-fertilizers? Give reasons