

Effects of Agronomic Factors, Physiological Factors, Seed Supply Systems and Seed Marketing Systems on Sustainability of Crop and Quality Seed Production: A Review

Merkebu Ayalew

Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center, Ethiopia

Abstract

Seed can be defined in the agronomic sense which includes any type of planting material intended for use in producing a crop, i.e. either generative or vegetative. It is basic agricultural input and a means for delivering technology to farmers. Main factors which contribute effects on crop and quality seed production are agronomic factors, physiological factors, seed supply systems and seed marketing systems. Performing good agronomic practices help to assure sustainable crop as well as quality seed production. Most researchers or literatures grouped agronomic factors as land requirements and preparation, isolation (seed), nutrition, weed control, roguing (seed) and hybrid seed production. Physiological factors also able to determine sustainable crop and quality seed production which can be grouped as variety maintenance and early generation seed multiplication, physiological nature of improved seed, and physiological quality of seed. Seed supply systems play a crucial role in providing farmers with access to adaptable crops and varieties, and the flexibility of obtaining seed when required. Sub factors categorized under this main factor are sources of new seed varieties, potential of policies, seed system efficiency, seed systems gaps and identifying potential areas of activities on seed system gaps. The fourth factor seed marketing systems also have great effects on production of diversified crops and quality seeds. Generally for better sustainability of crops as well as quality seed production agronomic, physiologic, seed supply systems and seed marketing systems factors should be considered and supported by scientifically studies.

Keywords: Seed, Agronomic, Physiologic, Supply, Marketing, Sustainability, Quality

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1 INTRODUCTION

The term “seed” is used in the agronomic sense, to include any type of planting material intended for use in producing a crop, i.e. either generative or vegetative such as roots, tubers, bulbs, cuttings, rhizomes and apomictic seed. Seed is not only a carrier of the genetic resources for food and agriculture, it is also a basic element of any crop production system and thus fundamental for food security and rural development. In this sense, seed has to be physically available at an affordable price, at the right time, in the right place and in the right quantity, and with the right genetic attributes and quality (purity, physiological and sanitary conditions) for it to have the desired impact (FAO, 2011).

Seeds are basic agricultural input. Among all inputs for agriculture whether commercial or subsistence seed has a unique feature; as it is a means for delivering technology to farmers. Seed quality, particularly its genetic attributes, determines the level of crop productivity in the presence of other crop-production inputs (FAO, 2011; Pelmer, 2005). Accessibility and availability of quality seed is the basis for food production, improved yields, and a source of crop and food variety since they respond to farmers needs for both their increasing productivity and crop uses (Setimela *et al.*, 2004; Pelmer, 2005; Bellon *et al.*, 2003; Munyaka *et al.*, 2015).

Decline in yield affected farmer seed saving, increased grain prices due to high demand, affecting seed availability and affordability (Monica & Astrid, 2016). For example, in Africa, the majority of farmers mainly get their seeds from informal channels which include farm saved seeds, seed exchanges among farmers or/and local grain/seed market. Even if it rarely supported, it has negative effects on agricultural productivity and income of farmers and more particularly to poor and marginalized farmers (Jean *et al.*, 2007).

In Africa even governments and donors established highly subsidized formal seed sector mainly seed parastatals farmers are facing many various constraints both biotic and abiotic (Jean *et al.*, 2007). Some of the constraints include (i) decreasing farm size (ii) location on marginal land and with decreasing soil fertility (iii) unavailability and/or inaccessibility of farm inputs including **seeds** (unavailability and **poor access to quality seed**) of the variety of their choices (iv) in-existent research and **extension support system/services**/lack of small scale farmers' orientation and (v) inadequate integration in **market** (Jean *et al.*, 2007; Munyaka *et al.*, 2015).

As different studies and reports show that shortage and inaccessibility of **quality seed** is one of the main problems for many crops which can be leads into crop production productivity reduction. Even if there are multi and interlinked factors described in many literatures, the main contributing factors that impose **effects on quality seed and crop production** are **agronomic factors, physiological factors, seed supply systems and seed marketing systems** (Lyon and Afiko-Danquah, 1998; Zerbe, 2001; Munyaka *et al.*, 2015).

In this review many literatures have been reviewed. The paper reviewed that 'effects of agronomic factors, physiological factors, seed supply systems and marketing systems on sustainable crop and quality seed production'. As it is known that the production of quality seed is the leading function for sustainable crop production or to ensure food security, the paper refers them more closely, side by side and sometimes simultaneously. Objectives of this review are:

- To review effects of agronomic factors on sustainable crop and quality seed production,
- To review effects of physiological factors on sustainable crop and quality seed production,
- To review effects of seed supply systems on sustainable crop and quality seed production and,
- To review effects of seed marketing systems on sustainable crop and quality seed production
- To draw possible conclusions for which may be used for further studies/researches

2 EFFECTS OF AGRONOMIC FACTORS, PHYSIOLOGICAL FACTORS, SEED SUPPLY SYSTEMS AND SEED MARKETING SYSTEMS ON SUSTAINABILITY OF CROP AND QUALITY SEED PRODUCTION

2.1 Effects of Agronomic Factors on Sustainability of Crop and Quality Seed Production

Selecting genotypes under conditions of real farmer input (**agronomic practices**) have positive impact on sustainability of crop and quality seed production (Jean *et al.*, 2007). Even planting quality seeds on a farm, without good agronomic practices it is not possible to assure sustainable crop production productivity as well as itself quality seed (FAO, 2011; EIAR, 2012).

Different studies indicated the effects or the results of agronomic practices on crop and quality seed production. Especially on seed technology some literatures describe agronomic practices as other supportive technologies. For example Jean *et al.*, (2007) expressed as "**non seed technologies**" (i.e. In order to improve the quantity crop produced, quality of seed and to meet the demand and increase local stock of the varieties, other yield enhancing technologies are also required, therefore the interventions should go beyond the seed aspects and other **non-seed technologies** like **agronomic practices**). Whereas Monica & Astrid (2016) expressed agronomic practices as a **component** of seed technology (i.e. Cropping cycle, field preparation, planting and field management practices can influence the expected yield which affect the amount and quality of seed farmers saved for subsequent planting seasons. As grain price tend to increase particularly at planting time it can affect farmers' access to seed from market sources).

Seeds are the part of a plant when planted under favorable conditions and are capable of germinating to reproduce the original plant. Examples are grain/true seeds (rice, maize, millet), rhizomes (ginger, some grasses), tubers (yam, cocoyam) and stem portions (cassava, sweet potato). Improved seeds are seeds derived from the efforts of research and so are genetically superior to the traditional varieties (Ajeigbe *et al.*, 2009). Among many factors that determine sustainable crop and quality seed production **agronomic factors** have direct effects on quality seed as well as crop production (Jean *et al.*, 2007; EIAR, 2012; Monica & Astrid, 2016). Even they are so much and interlinked most researchers or literatures grouped agronomic factors as follow.

2.1.1 Land requirements and preparation

Choosing fertile land having a good capacity for water retention gives good and productive plants. The cropping history for most seed crops prescribes that a period of at least one fallow season is required between two seed crops of the same variety and the same generation to prevent contamination from the previous seed crop through volunteer stands and diseases (Ajeigbe *et al.*, 2009; EIAR, 2012).

Land preparation like slashing, burning any previously growing bush, plowing, harrowing, and application of a herbicide before planting to be the land clean and free of weeds and diseases are essential agronomic practices in seed production technology (Ajeigbe *et al.*, 2009 ; EIAR, 2012; Jean *et al.*, 2007; Monica & Astrid, 2016).

2.1.2 Isolation (seed)

To prevent contamination by foreign pollen, a certain isolation distance in terms of land area is required between seed crops of the same species or different varieties of the same species, of the same color, or different colors (Ajeigbe *et al.*, 2009; EIAR, 2012; Monica, & Astrid, 2016).

Isolation distance is also a check on pest infestation and disease infection. An isolation distance should be maintained round the seed crop. A larger isolation distance is required for cross-pollinated crops than for self-pollinated crops. Most crops that are considered as self-pollinating are not 100% self-pollinated. They have some percentage of out-crossing. Therefore, even in the real self-pollinated crops, a certain distance is required between two fields and such a distance too, is required to prevent diseases and pests (Ajeigbe *et al.*, 2009; EIAR, 2012; Monica & Astrid, 2016).

2.1.3 Nutrition

A healthy seed crop will give rise to seeds/yields with high vigor if other conditions are optimum. Based on soil tests, the right fertilizer should be applied to the seed crop. Lack of nutrients (macro/micro) can lead to some deficiency diseases. It is important that all fertilizer applications to most varietal seed plots/crop farms

are completed before the flowering stage (Ajeigbe *et al.*, 2009; EIAR, 2012; Monica & Astrid, 2016).

2.1.4 Weed control

Keep the seed field weed-free and clean. Noxious weeds must be avoided totally and are difficult to get rid of using normal cultural practices. Especially if a seed crop is too weedy, the certification inspector may fail it, usually after the seed grower has been warned (Ajeigbe *et al.*, 2009; EIAR, 2012; Monica & Astrid, 2016).

Weeds compete with the seed crop for soil nutrients, water and sunlight. Weeds can carry/harbor diseases and pests. Weeding can be manual or through the use of suitable herbicides. It is essential that seed plots/crop fields are free of weeds, especially during the early stages of growth and harvesting (Ajeigbe *et al.*, 2009; EIAR, 2012; Monica & Astrid, 2016).

2.1.5 Roguing (seed)

This is the removal of off-type plants and variants. The certification inspectors will show you what rogues are in a particular seed crop. Uproot rogues, collect and throw them out of the seed field and burn them. Seed fields are rogued several times to remove off-type varietal contaminants, diseased plants, other crop plants and troublesome weeds (Ajeigbe *et al.*, 2009; EIAR, 2012).

2.1.6 Hybrid seed production

Mark the end of either the male or female row in the seed field for proper identification. The tassel of the female parent must be removed before pollen shedding by male parents starts to prevent self-pollination (Ajeigbe *et al.*, 2009; EIAR, 2012).

2.2 Effects of Physiological Factors on Sustainability of Crop and Quality Seed Production

Seed is a living organism and requires appropriate handling, processing and storage operations in order to ensure that its viability is maintained until it is sown in the field. Seed quality is an essential element of seed systems: when provided to farmers seed should have high **germination** and **vigour**, high levels of genetic and physical purity and be free from pests and diseases. While the availability of quality seeds is no longer a critical issue for farmers in the developed world, most developing countries still face serious fundamental problems related to farmers' access to quality seed and improved varieties of crops species suited to their needs and adapted to their agro-ecological conditions (FAO, 2011; EIAR, 2012; Elizabeth *et al.*, 1992).

Varieties made available to farmers ensure crops' **physiological** performance and diverse in their characteristics than existing varieties on the market. It can be prevent the use of varieties that might have a negative impact on agriculture, such as those susceptible to major diseases that could create the risk of significant grain/seed production loss (FAO, 2011; EIAR, 2012; Elizabeth *et al.*, 1992).

2.2.1 Variety maintenance and early generation seed multiplication

The production of quality seed and especially the preservation of the characteristics of varieties throughout generations require that the breeder maintain a quantity of very high-quality seed, often called **nucleus seed**. The multiplication of subsequent early generations of seed, pre-basic and basic seed (also known as breeder and foundation seed), which requires high technical expertise and specific equipment and infrastructure is generally carried out under control of the breeder. In many developing countries, these functions are often undertaken by the public sector's breeding institutions. Issues relating to delays in timely availability of adequate quantities and quality of early generation seed can cause major bottlenecks for the production of improved seed in many developing countries (FAO, 2011; EIAR, 2012; Elizabeth *et al.*, 1992; Cromwell, 1990).

2.2.2 Physiological nature of improved seed

There are two sources of improvement in seeds, which together make up the 'quality' of seed:

- The genetic information contained within the seed itself;
- The physical and **physiological** attributes of the seed lot-purity, germination capacity, vigour, health and freedom from disease.

These are independent of each other but both are required for improved seed to contribute fully to better crop production performance. Thus genetic quality is the ultimate determinant of performance but, if physical quality is poor, the benefit of improved genetic potential cannot be realized. However, the relative importance of genetic and physical quality varies, and formal sector seed production has to be sensitive to this: in one farming system, the most important need may be for seed with assured genetic potential; in another, the genetic quality of an established variety may be quite adequate but storage difficulties or pest and disease problems may still enable the formal seed sector to supply a useful product, by concentrating on **physiological** quality. This in turn affects the type of variety best suited to meeting these needs. If based on genetic quality, profitable formal sector seed production depends largely on being able to offer hybrid varieties because these have recurrent sales potential (FAO, 2011; EIAR, 2012; Elizabeth *et al.*, 1992).

2.2.3 Physiological quality of seed

This refers to the **viability**, **germination**, and **vigor** of seed which determines the germination and subsequent seedling emergence and crop establishment in the field as well as the storage potential of the seed lot, thus it needs high care for seed physiological quality. If seed is poor in physiological quality it will lead to lose seed as

well as crop production totally (EIAR, 2012; Elizabeth *et al.*, 1992).

2.3 Effects of Seed Supply Systems on Sustainability of Crop and Quality Seed Production

Seed systems play a crucial role in providing farmers with access to adaptable crops and varieties, and the flexibility of obtaining seed when required. Seed systems are important even for decrease climate induced stress as seed security has direct links to food security and resilient livelihoods in general (Monica & Astrid, 2016).

Studies show that most farmers especially in developing countries like Africa, in average 82% of farmers reported that home saved seed was their most important source of seed and only 2% of farmers obtained certified seed. To solve this problem many developing countries seed companies usually contract small scale seed producers supported by either NGOs/GOs and farmers' organizations. This approach is now increasingly taking place in many countries such as Ethiopia, Malawi, Kenya, Uganda etc. (Jean *et al.*, 2007).

The shortage of land in the smallholder farming sector has been cited as one of the causes of reduced seed production (CIAT *et al.*, 2009). Even new crop variety developed farmer seed supply is the slow move of the varieties (Jean *et al.*, 2007). This indicates the informal seed system that consist smallholder farming sector can affect **quality seed production** (Munyaka *et al.*, 2015). To alleviate those problems especially in Africa in most of East, Central and Southern Africa commercial seed enterprises were established and tried to support them. But the supported commercial seed enterprises in place have not provided options attractive for poor farmers. That is why there is a need to devise other avenues to avail seeds of improved varieties of their choices (Jean *et al.*, 2007).

On the other hand, even improved varieties alone will not give the desired impact if seed of those varieties cannot be made available to farmers. In many countries, improved varieties with high genetic potential do not have impact on food production because **seed systems** are not in place. It is for this reason that the germplasm conservation/crop breeding/variety development complex needs to be properly integrated and synchronized into seed systems, so that the desired effect on crop production/productivity can be obtained (FAO, 2011).

2.3.1 Sources of new seed varieties for farmers

Farmers accessed germplasm of new varieties mainly from **NGOs** and other **farmers** which is not ideal. These the two sources are informal and may not have the best technical ability to support the varieties they introduce. For example most countries in the Southern African Development Community (SADC) region have less than 10 % of their area planted to improved sorghum or millet varieties. The challenges faced by farmers emanates from problems in distribution and seed multiplication of improved varieties. There has been considerable breeding research, but the rate of adoption of improved crop varieties by farmers in sub-Saharan Africa remains less than 5 % (Monyo and Mgonja, 2004). The low rate of adoption can be attributed to the unavailability of foundation seed of the improved seed and lack of promoters for the new varieties. The slow filtering of improved seed varieties is a result of the **absence of a clear policy** of cascading the varieties to farmers from research organizations. The fact that NGOs distribute new varieties to farmers means the varieties would only be available when some company has bulked or multiplied the particular variety or varieties in response to the NGO tenders but not as a deliberate commercial strategy to have farmers access the improved germplasm. This practice is **not sustainable** as this is a humanitarian rather than a technical or **market-driven** intervention (Munyaka *et al.*, 2015).

2.3.2 Potential policy issues for consideration

Community seed enterprises run by farmers along business lines are one way to increase the supply of unavailable self-pollinating crops to smallholder farmers. This implies that, the involvement of all potential stakeholders will increase seed availability (Giller, 2008).

The involvement of smallholder farmers in seed production has the potential of increasing access to seed by the local farmers compared to when they are consumers only. The policy on seed production may consider having a certain quota of all seed produced in the country for all crops, where possible, produced by the smallholder farmers. Thus a deliberate plan linking research institutions with smallholder farmer institutions will increase access to new germplasm (Munyaka *et al.*, 2015).

2.3.3 Develop an efficient seed system for the poor

As Jean *et al.*, (2007) described that to overcome negative effects of seed supply system on sustainability of crop and quality seed production efficient seed system for the poor is the primary solution and to develop efficient seed system for the poor there are steps to be followed. Those steps are; (1) Engaging (including) the end users in participatory crops' varieties selection, (2) Participatory assessment of existing crops' seed channels and testing alternative seed channels, (3) Limitation of local seed systems, (4) Addressing limitation by integrating formal and informal seed systems, (5) Farmers' skills and knowledge enhancement and (6) New crop varieties demand creation and their promotion (Jean *et al.*, 2007).

2.3.4 Major elements of the seed systems

2.3.4.1 Breeding and seed systems

For seed enterprises to be successful, a steady stream of new varieties into the market is needed. To ensure a

favorable correlation between plant breeding and seed systems, various components need to be in place namely: **i)** a variety release system; **ii)** varietal development and extension; **iii)** variety maintenance and early generation seed multiplication and **iv)** an intellectual property rights system (FAO, 2011).

The connection between breeding and the informal seed system is in general more fragile than that with the formal sector. The weak position of research systems in generating new varieties and inefficient extension systems in developing countries contribute to the irregularity of the injection of improved varieties into the informal seed supply system. However, the informal sector can play a crucial role in the diffusion of new varieties among farmers, especially in countries where the formal sector cannot produce the large quantity of seed necessary to satisfy farmers' needs (FAO, 2011; Elizabeth *et al.*, 1992).

2.3.4.2 Formal and informal seed supply systems

Formal and **informal** seed supply systems are the two terms used to describe the systems of seed delivery to farmers and both are operational in developing countries and to a lesser extent in developed countries. Some literatures also described third type of seed system called **intermediate seed system**. It is characterized by entrepreneurial farmers and farmer groups that produce and market crops that are not covered by the formal seed system. For example in Uganda these groups are called Local Seed Businesses (LSBs) that produce Quality Declared Seed (QDS), which is inspected by the Ministry of Agriculture, but sold within their communities (Subedi *et al.*, 2013). But most known and widely used systems are the two above described. These seed supply systems have their distinct characteristics (Almekinders and Louwaars, 1999; FAO, 2011).

I. Formal seed supply system

The formal seed supply system is highly regulated and involves a chain of activities leading to clear products which are certified seed of verified varieties. The chain usually starts with plant breeding and selection, resulting in different types of varieties, including hybrids, and promotes advanced fixed germplasm materials leading to formal variety release and maintenance. Guiding principles in the formal system ensure that varietal identity and purity are maintained throughout the various generations of seed multiplication (breeder or pre-basic, foundation or basic registered and/or certified in some cases commercial), with optimal physical, physiological and sanitary quality (Almekinders and Louwaars, 1999; FAO, 2011; Louwaars, 1994).

Private seed enterprises (private sector) and **public seed sectors** are in the domain of the formal seed supply system and the bulk of seed generated through this system covers economically viable crop species with good recurrent seed demands of **cross-pollinated**, **self-pollinated** and **vegetative propagated** crops. The system has been referred to by other names including: **a)** organized seed system; **b)** conventional seed system; **c)** commercial seed system and **d)** regulated seed system (FAO, 2011).

II. Informal seed supply system

The informal seed supply system (or informal seed system) refers to the traditional arrangements used by farmers to supply the seeds they need to plant in the following season (FAO, 2011). It is also called '**farmer seed networks**' which transfer seed (and other generative material such as cuttings, pseudo-stems or tubers) from domesticated or undomesticated plants via farmer-to-farmer gifting, swapping, bartering, or purchase, and also via trading or sale which occurs outside of the commercial seed sector and formal regulation (Alvarez *et al.*, 2005; Thomas *et al.*, 2012; Oliver *et al.*, 2015). Other names given to informal seed supply systems include: **a)** farmer-managed seed system; **b)** farm based; **c)** local seed production and supply; **d)** traditional seed system and **e)** farmers' seed system. Activities tend to be integrated and locally organized and embrace most of the ways in which farmers produce, disseminate, and access seed: directly from their own harvest; through exchange and barter within the community; and through local markets. It is a flexible system and varieties of seed may comprise landraces or old or new improved varieties; however the seed is of variable quality. As it is indicated by Monica & Astrid, (2016) informal seed supply system able to provide sufficient planting materials even in unexpected stress season in addition to normal season (Monica & Astrid,2016). The same general steps or processes take place in the informal seed supply system as in the formal sector (variety choice, variety testing, introduction, seed multiplication, selection, dissemination and storage) but they take place as an integral part of farmers' production systems rather than as discrete activities. While some farmers treat "seed" as special, there is not always necessarily a distinction between "seed" and "grain". The steps do not flow in a linear sequence and are not monitored or controlled by government policies and regulations. Instead, they are guided by local technical knowledge and standards and by local social structures and norms (Almekinders and Louwaars, 1999; FAO, 2011).

The relative importance of these two systems varies depending on the state of development of the agricultural system and the crops. About 80 percent of food production reportedly comes from farmers with smallholdings and the majority of farmers in developing countries use seed from the informal seed system (FAO, 2009). Most of the seed covered by this system falls within crop groups that are not of commercial interest to the private sector but the bulk of which constitute important food security crops. Contrary to conventional views, the formal and informal seed delivery systems coexist in large part in developing countries and in some cases in developed countries; farmers will usually resort to either or both of these systems for different crops and for

different seasons (FAO, 2011; Louise *et al.*, 2013).

2.3.4.3 Comparative roles of public and private sectors in seed supply

Both public and private seed enterprises operate within the ambit of the formal seed supply system. However, some reports have been reported that in some countries there is a new distribution of tasks on the basis of the commercial prospects of different crops, with the **public sector** more involved in self-pollinated and in some cases, open-pollinated food crops and underutilized species, while the **private sector** concentrates on hybrids, horticultural crops, major crops, such as wheat, rapeseed, sugar beet, potatoes etc. thus private seed sector activities are geared towards successful marketing of their crop and variety portfolios, including germplasm resource management, breeding, seed production and distribution (FAO, 2011; Elizabeth *et al.*, 1992).

The distribution of task between the public and the private sector is mainly linked to the possible return on the research investment required for developing new varieties. In some countries the success of the private seed sector has led to the development of diverse seed industries. Despite the efficiency and apparent success of private sector seed production and delivery, the range of crops covered and their genetic base are not very broad. This shows that seed system has its own effect on sustainable crop and quality seed production (FAO, 2011; Elizabeth *et al.*, 1992).

2.3.5 Factors contributing for seed systems gaps

Literatures/studies have been described ample of gaps of seed system around the world countries in different ways. Within and among countries they are diverse in nature and in scale. While gaps vary from region to region, there are also intraregional variations. It was also observed that these gaps vary with regard to crop species and the characteristics of prevailing agriculture (subsistence, semi-commercial or commercial). In one or another way those gaps can be classified as follows.

2.3.5.1 Policy and regulatory gaps

A seed policy is the guiding principle by which seed systems can be developed. It expresses government philosophy and intentions regarding key areas of the seed industry and signals its collaborative role and that of its partners. National seed policies and regulatory frameworks have a major impact on the success of the seed sector. This is due to the fact that even in the presence of reasonably sufficient infrastructure, capacity and technology, a **lack of or inappropriate policy and legislation** may create barriers to seed sector development. Such is the case with restrictive legislation that can prevent the free flow of germplasm and seed among country's seed sector partners as well as across a national boundary or throughout a region (FAO, 2011; Elizabeth *et al.*, 1992).

2.3.5.2 Variety development

Countries display wide variation in variety development efforts - the first step in the seed multiplication chain. In spite of abundant germplasm resources in region, it lacks regular injection of new varieties into the seed production cycle. This is partly due to limitations imposed by low to average levels of varietal improvement activities. Access to foreign partnerships as well as links between the private and public seed sectors are constrained by restrictive legislation and absence of Plant Variety Protection (PVP) (FAO, 2011; Elizabeth *et al.*, 1992).

2.3.5.3 Seed Production

Some arrangements to provide seeds to farmers are present in all countries, attesting to governments' recognition that provision of seeds is critical for crop production to that of food security. In spite of good intentions, several of the seed production programs do not meet the needs of modern agriculture. So it is clear that some innovative ways need to be found to establish stronger public-private sector partnerships in seed production for major food security crops (FAO, 2011; Elizabeth *et al.*, 1992).

2.3.5.4 Seed quality assurance and certification

In the fact that there is much scope for improving quality not only in informal (farmer networks) but also in formal seed supply systems since seed quality can be poor due to **inappropriate standards** or **weak enforcement** (Tripp and Louwaars, 1997). Basic tenets of seed quality assurance guarantee, through seed generations, varietal identity by means of appropriate crop field inspection techniques and appropriate laboratory checks for seed quality attributes. An appropriate seed quality assurance program, however needs more than legislation; it also requires an implementing and enforcing body and adequate facilities and resources such as seed laboratories and trained staff, all at public expense (FAO, 2011; Elizabeth *et al.*, 1992).

2.3.5.5 Seed conditioning and storage

Modern seed conditioning equipment such as cleaners, graders and dryers as well as appropriate storage systems are necessary for the efficient preparation and storage of the large quantities of seed that are produced. In almost all countries, small (and in some cases mobile) plants are needed first to equip the needs of **breeders** and **public foundation seed agencies**; beyond this further efforts would be required to assist the private sector with incentives and soft credits to design and procure seed plants suited to their own commercial needs (FAO, 2011; Elizabeth *et al.*, 1992).

2.3.5.6 Seed distribution and marketing

Seed distribution and marketing determine to a great extent the effectiveness of the seed industry and its success. They connect the lengthy process of crop improvement, seed multiplication and conditioning to the demand and use of the finished product by farmers. In the past decades of publicly-operated seed programs in most African countries, seed distribution was largely in the hands of seed parastatals and extension agencies, etc. Although this strategy ensured reasonable and affordable seed prices and relatively wider coverage in terms of locations and crops, it was characterized by very high public budgets, quality deterioration, leading to heavy losses; it also led to unplanned carryovers (FAO, 2011).

In-depth studies of market size in all countries will be a major contribution towards obtaining better estimates for the potential of the seed sector's development. Detailed market studies will help seed companies/cooperatives in planning their production strategy for marketing and sales. It will also help breeders starting their activities in the private sector, to identify species and regions where private breeding will be rewarded (FAO, 2011; Jean *et al.*, 2007).

2.3.5.7 Seed promotion

In the era of public sector seed development seed promotion as a component of seed marketing was a public extension activity via radio, newspapers and television. Currently, much less of that occurs and where the private sector has not become well-established and profitable, it has hardly undertaken any responsibility for seed promotion (FAO, 2011). Related to these Louise *et al.*, 2013 described reasons of why public sector varieties are not seen at scale in smallholder farmers' fields. Among many reasons the keys are: failures in getting the right attributes of seed, challenges relating to adoption and also delivery constraints. Under delivery constraints; **i)** proximity of outlets, **ii)** seed pack size and **iii)** marketing and information are front drawbacks that must be solve.

2.3.5.8 Trans-boundary seed trade

Cross-border trade in seeds has continued in different countries over a long period, such in Africa. Furthermore, superiority in varieties of one national program over another has not been so marked as to attract farmers to those varieties across the border. In addition, restrictive laws and procedures, particularly in relation to plant quarantine and customs requirements and in a few cases seed legislation hinder seed exchange among countries (FAO, 2011).

Trans-boundary seed trade is also a relief tool in the event of seed shortages. When harmonization of rules is in place and varieties are recognized in different countries of a given region, export/import alleviates seed insecurity (FAO, 2011; Elizabeth *et al.*, 1992).

2.3.5.9 Extension services

Extension is expected to play a leading role in the promotion of seed and to assist farmers in all aspects of seed use in order to engender crop productivity, but many extension activities have been unable to succeed due to gross budget limitations. In addition, human resources have seriously dwindled, mobility is a major constraint and methodologies are in some instances unclear or ineffective. In most countries, governments recognize their responsibility to ensure that the message of improved varieties is transmitted to farmers. Private sector involvement in extension and variety dissemination is increasingly important (FAO, 2011; Zerbe, 2001).

2.3.5.10 Private seed sector development

In spite of great advancements made by the private seed sector at a global level, there is a large vacuum of crop species not covered. In most cases, the absence of private sector participation in the seed sectors of the countries studied has been due to the absence of effective demand for seed. The absence of plant variety protection in many countries has also **reduced private sector interest** to invest in plant breeding activities without assurance of returns on investment (FAO, 2011; Elizabeth *et al.*, 1992).

2.3.5.11 The informal seed sector

The informal seed sector has been crucial in meeting the needs of food security, especially for traditional crops that have been abandoned by the formal sector, and has remained the source of seeds for farmers who cannot afford to buy seeds in the formal sector. Moreover, high-yielding improved varieties do not necessarily satisfy the needs of farmers that are seeking other attributes such as yield stability, cooking quality etc. The extent to which the informal seed sector has been assisted example in Africa like in Ethiopia, Gambia and Zambia and a few other countries and the benefits that have accrued from such assistance to the overall benefit of the national agriculture should encourage other countries to rethink their approach to this huge potential source of good seeds to supplement what the formal seed source can offer. In seed conditioning and storage, it should be possible to merge traditional methodologies suited to small-scale endeavours with simple, mechanized systems which are affordable, easily operated and not dependent on modern energy sources (FAO, 2011; Jarvis and Hodgkin, 1999; Dansi *et al.*, 2010).

Overall, the introduction of entrepreneurship into the ranks of willing informal seed sector practitioners could be an excellent step towards bringing the informal sector closer to mainstream seed industries and set the stage for an integrated seed system in which both subsectors together can contribute to their mutual advantage (FAO, 2011; Jarvis and Hodgkin, 1999; Dansi *et al.*, 2010).

2.3.5.12 Technology and capacity

The gaps in activities ranging from variety development to seed production and quality assurance are determined largely by the level of technology and the availability of requisite expertise. Technologies available for seed production, conditioning and storage are limited for several reasons including cost of equipment, availability of local expertise as well as facilitative policy and legislation that constrains the collaborative participation of the private and public sector in the seed industry, thereby limiting incentives for the introduction of new technologies (FAO, 2011; Elizabeth *et al.*, 1992).

Human resources and technical capacities are fundamental to ensure the present and future development of the seed sectors. It should be pointed out that the specialist nature of seed technology aspects requires a pool of adequately trained staff, able to service the private sector, as well as capable local or regional institutions to impart such skills. Overseas fellowship awards have dwindled and expertise in plant breeding, seed technology, agronomy etc. is now hard to come by (FAO, 2011).

2.3.6 Potential areas of activities on seed system gaps

In order to address the gaps identified above, the potential areas of activities on critical gaps are needed. Those are activities on policy and regulatory gaps, variety development, seed production, seed quality assurance and certification, seed conditioning and storage, seed distribution and marketing, and technology and education. The importance of public/private partnership and the need to undertake integrated approaches for the development of formal and informal sectors are cross-cutting issues that are taken into account in the proposed areas of activities. Governments, FAO, technical partners and donors should consider putting their efforts in implementing these activities, in a collaborative manner, in order to facilitate the development of the seed sector especially in developing countries (FAO, 2011; Munyaka *et al.*, 2015).

2.4 Effects of Seed Marketing Systems on Sustainability of Crop and Quality Seed Production

Most of the increase in agricultural production recently experienced came from an increase in land area sown to crops and not from a yield increase. A key strategy for the development of sustainable agriculture is an efficient and well-functioning agricultural input **market** that makes use of the complementarities among fertilizer, improved seeds and crop protection items (Ajeigbe *et al.*, 2009).

There was a positive correlation between the presence of a market and increased seed production by farmers and between training in seed production and interest in seed production (Munyaka *et al.*, 2015).

McGuire and Sperling (2016) have been estimated that farmers in Africa access 90.2% of their seed from informal systems with 50.9% of that derived from **local markets**. The lack of certified seed of most crops is because seed companies are profit-driven and hence concentrate on hybrid seeds targeted for high value markets (Zerbe, 2001; Jones *et al.*, 2001; Daniel & Adetumbi, 2004).

For example, farmers in Tanzania recycled bean seed six times before purchasing new seed. This suggests that one of the reasons why farmers are not getting good yields of most crops is the absence of quality seed and the use of recycled seed (Munyaka *et al.*, 2015).

The farmers end-up using retained seed due to the high cost of certified seed. In case of formal seed system seed marketing and distribution often takes place through a limited number of officially recognized seed outlets, usually for commercial sale (Louwaars, 1994).

The seed sold in informal channels **lacks authentication** and there is **no means of restitution** for buyers in the event of poor performance. The recycling has resulted in poor yields and hence food insecurity (Munyaka *et al.*, 2015). But another literatures indicated that informal systems are already **market driven** mean that around half of seed market transactions involved cash transfer which is a very large seed market out that could be better captured through integrated seed system links (Louise *et al.*, 2013).

The pricing model for commodities should be fairly balanced to keep farmers interested in producing a crop. The proper market price of commodities will keep the demand for seed high and in turn can increase the quality of seed as investment increases (Munyaka *et al.*, 2015).

Studies show that the imbalance seed marketing greatly affect the production of diversified crops. For instance, the bulk of global multimillion dollar seed businesses invest in only a limited number of crops: Maize, Vegetable seeds, Wheat, Rice, Sorghum, Barley, Soybean, Sugar Beet, Sunflower, Rapeseed, Bean, Groundnut and Potato. Thus, the bulk of food security/orphan crops is not included (FAO, 2011).

2.4.1 Constraints of Seed Market Development

Different studies indicated lot seed market constraints that affect sustainable crop and quality seed production. Even different studies categorized those problems in different ways they can be described as follows:

- i. Low demand for improved seeds,
- ii. Inadequate arrangements for seed certification and seed control,
- iii. Low funding of public sector institutions,
- iv. Slow release of new varieties,
- v. Inadequate extension services,

- vi. Inadequate funds on the part of the farmers to purchase improved seeds and complementary products,
- vii. Low level of education among dealers and farmers and
- viii. Poor organization to coordinate the activities of the stakeholders.

2.4.2 Solutions for constraints of seed market development

The preconditions for the provision of sustainable seed marketing are as follows:

- i. Create a conducive micro-policy environment,
- ii. Build human capital for market development,
- iii. Improve access to finance,
- iv. Develop and implement a regulatory framework,
- v. Promote marketing transparency through information systems,
- vi. Promote technology transfer activities,
- vii. Strengthen research capacity for the private seed industry and
- viii. Strengthen seed associations of countries.

To facilitate sustainable access to seeds and supplementary inputs, the farmer's partnership between public and private stakeholders must be strengthened (Ajeigbe *et al.*, 2009; Louise *et al.*, 2013).

3 CONCLUSIONS

In order to ensure that quality seeds of preferred varieties are accessible to farmers and to insure sustainable crop production, a systematic pathway combining a set of activities starting from the identification of preferred genotypes including agronomic practices to variety demand stimulation and seed accessibility must be established from the beginning. It is very clear the crop agronomic, physiologic, breeding patterns, seed marketing and seed system arrangement have influence on the availability and seed accessibility to farmers mostly the poor and marginalized. So, research institutions should explore mechanisms of increasing the uptake of their newer varieties by smallholder farmers through increased early interactions with the farmers. Smallholder farmers can be contracted by seed-houses to produce certified seed or to establish community seed enterprises that supply certified seed in their local communities. This would require adequate capacity building (i.e. training, etc.) and availing desired foundation seed.

At last 'effects of agronomic factors, physiological factors, seed supply systems and seed marketing systems on sustainable crop and quality seed production' and possible solutions can be concluded as follows:

- Seed/crop production must be done following the recommended **agronomic package** of the given crop. Beginning from the recommended method of sowing through appropriate fertilizer application, timely tinning, usage of appropriate seed rate, the right depth of sowing, the right amount and frequency of irrigation, timely de-tasseling, weed and pest control and till harvest the field condition must be maintained around optimum.
- Seed quality is a total sum of different aspects of a seed including genetic and physical purity, **physiological quality** and health quality. So, during seed production, strict attention must be given to the maintenance of genetic purity and other quality parameters in order to fully exploit the genetic potential of the variety under production.
- **Farmer seed networks** make a vital contribution to agriculture because they are an effective means of moving seed not only farmer-to-farmer, but also from nature, local markets, national seed agencies, research stations, agro-dealers and agribusiness to farmers throughout the countryside. So it is better to keep it and synchronized with formal seed system for sustainable crop and quality seed production.
- The **formal seed system** is a deliberately constructed and bounded system, which involves a chain of activities leading to clear products: certified seeds of verified varieties. The guiding principles are: to maintain varietal identity and purity; and to produce seeds of optimal physical, physiological and sanitary quality. But it has not been applied in appropriate manner. So it is better to make applicable and consider the modern agriculture's need.
- Scaling the adoption of improved varieties and quality seed among small-holder farmers must include both formal and informal seed systems that forms **integrated seed systems** which imply coordinated actions between the formal and informal seed sectors. This needs a sound and updated policies and strategies with successive follow up.
- Since **marketing** and **information** have their own impacts on crop and quality seed production there are standard marketing tools that must be performed. Those are field demonstration, agricultural shows, posters and technical leaflets. In cumulative way to solved or minimize fluctuation risks of seed marketing it is better to perform the so-called **strategic brokering**. Brokering for seed supply has resulted in seed availability achievements at scale. This type of brokering usually involves links to better market development and more integration of market actors all along the market chain. The brokering of different types can be seminal: linking formal to non-formal groups (for example, certified seed producers to large-scale

seed/grain traders), or linking lower level producers and sellers to more aggregated ones (specialized seed producers to agro-enterprise companies). Brokering can result in leaps in the availability of seed and grain.

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