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Adoption of Improved Sorghum and Millet Cultivars in SSA

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Introduction

Over the past several decades, donors, multilateral organizations and governments have invested substantial resources in developing and disseminating improved varieties of sorghum and millet in Sub-Saharan Africa (SSA). Sorghum and the millets, a group of small-seeded grasses indigenous to SSA, are two of the most important staple foods in this region. Primarily cultivated by smallholder farmers for domestic consumption, these two native crops thrive in harsh climates, are drought resistant, and do not require agricultural inputs such as inorganic fertilizer. Mostly grown in arid and semi-arid regions of the continent, sorghum and millet are an important source of protein and nutrients for millions of people.[i,ii] In West Africa, these two crops account for nearly 70% of total cereal production.[iii] Researchers believe that sorghum and millet have the ability to improve food security and mitigate the influence of climate change on food production for some of the most vulnerable populations.[iv,v] As a result, agricultural scientists have focused on developing improved cultivars to increase the relative benefits of these two crops and disseminate this technology to a larger number of farmers.[vi]

Despite these efforts, adoption rates of improved varieties of millet and sorghum vary significantly within SSA, with southern Africa having higher adoption rates than other parts of SSA. In 2008, of the total cereal crop area harvested in Africa, sorghum and millet made up 31% and 25%, respectively. For perspective, the only cereal crop having more total area harvested was maize with 33%.[vii] Currently, improved cultivars represent approximately 34% and 23% of the total area of millet and sorghum planted in SSA, respectively.[viii] Parts of southern Chad and northern Cameroon have high sorghum adoption rates and Namibia and Zimbabwe have high millet adoption rates. Conversely, in West and Central Africa, where 80% of SSA's arid and semi-arid cereals are produced, improved sorghum and millet varieties represent less than 2% and 1% of the total amount cultivated.[ix] Studies suggest that improving the development, distribution and adoption of improved sorghum and millet cultivars has the potential to increase food security and mitigate the effects of climate change in arid and semi-arid agro-ecological regions of SSA.[x]

This report provides an overview of the development and dissemination of improved sorghum and millet cultivars, factors that influence the adoption of improved cultivars among farmers in SSA, and examples of interventions designed to encourage adoption in SSA. A literature review was conducted using the Google Scholar search engine. In addition, numerous NGO and government websites were searched including the FAO, CGIAR, ICRISAT, and IFPRI. Search terms included, among others: improved sorghum/millet adoption rates, uptake rates, improved cultivars, agricultural technology, impact assessment agriculture, modified sorghum/millet, drought resistant sorghum/millet.

Background Information on Sorghum and Millet

Sorghum and millet are suited to the arid climate of the Sahel region. However, over the past 30 years climate conditions in the region have become more severe. Annual rainfall has been below the long-term average (from 1922 to 1994) and average regional temperatures have increased.[xi,xii] While sorghum and millet are able to grow in these conditions, they typically offer lower yields and take longer to mature than input intensive crops, such as maize.[xiii]

<u>Sorghum</u>

Sorghum is mainly produced in Nigeria, Sudan, Ethiopia, Burkina Faso, Mali and Niger, but it is also prominent in a number of other African countries.[xiv] In 2008, approximately 27.5 million hectares (ha) of sorghum were cultivated in Africa, approximately 31% of the total land devoted to cereals. Since 1970, the overall cultivation area for sorghum increased by nearly 50% due to an expansion of agricultural land. Yields per hectare, however, have remained stable or have declined in some countries.[xv] While sorghum is responsive to fertilizer use and weeding, it remains productive without the use of inputs, which makes it attractive to smallholder farmers.[xvi] Despite being relatively robust, sorghum is prone to several stresses, including the pathogen anthracnose, downy mildew fungus infestations, the striga weed, and pests.[xvii]

<u>Millets</u>

The most common types of millet cultivated in SSA are Pearl millet (*Pennisetum americanum*) and Finger millet (*Eleusine coracana*). Pearl millet accounts for approximately 90% of total millet cultivated. Major producing nations include Niger, Nigeria, Mali, Burkina Faso, Sudan and Chad. Pearl millet is appropriate for grain and fodder and is capable of producing yields in locations too hostile for maize or sorghum production. Pearl millet can withstand drought, heat, insects, poor soils, and flash floods, making it one of the most resilient crops in agriculture.[xviii] However, conventional varieties are susceptible to downy mildew – a parasite that replaces good grains with non-productive tendrils.[xix] Other common diseases are smut and ergot.[xx]

Finger millet, another common variety, accounts for nearly 10% of millet cultivated in SSA. It is particularly important due to its ability to grow in a variety of climates, ranging from sea level agro ecological zones to the highlands of Ethiopia, and for its high nutritional value.[xxi] Finger millet is an excellent source of amino acids, calcium, iron and manganese and can be stored for a long period without the threat of pests.[xxii] One of its major drawbacks is its susceptibility to Pyricularia blight.[xxiii]

Adoption of Improved Varieties[1]

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[1] The overall impact of agricultural research and development programs are often determined by estimating the adoption rate of new cultivars among farmers. Empirical studies of adoption rates in agriculture are typically divided into two categories: cross-sectional and temporal studies. Most researchers use cross-sectional analysis to determine the reasons why a farmer may or may not have adopted new technologies. These studies generally look at adoption rates at a point in time across individuals, households, or even countries or crops, to try and understand what characteristics, such as gender, age, wealth, agro-ecological zone, etc., may explain observed variations. Temporal studies, on the other hand, usually look at the same farmers across time, and are designed to determine, for example, why some farmers are early adopters while others are not.

Despite the research that has gone into creating improved varieties of sorghum and millet, farmers may fail to adopt improved seeds due to factors related to seed supply and access, or farmer demand. Weaknesses at different stages of the seed supply chains may arise with research, production, or distribution. Demand side issues may include farmer's risk attitudes, the perceived appropriateness of the seed, and access to fertilizer or other complementary inputs.

Example: Mali

Sorghum and millet are the major crops grown by subsistence producers in Mali, and are the basis of the rural diet. Despite continued releases of improved varieties, the adoption of improved seeds remains limited. In 2006, the *Bureau Central du Recensement Agricole*, estimated that at most 10% of sorghum and millet producing areas utilized improved seed, compared to 89% of the areas producing industrial crops, including rice and cotton. Sorghum and millet yields remain low, with national average yields at about 0.89 and 0.66 tons per hectare, respectively. By comparison, rice averages 1.7 tons per hectare and maize averages 1.0 tons per hectare.[xxiv]

Low adoption rates for improved sorghum and millet cultivars are variously attributed to both inadequacies in the formal seed system and demand-side factors. Mali's seed legislation prevents the sale and distribution of non-registered, non-certified varieties, however, "breeding germplasm that surpasses the performance of the farmer's own millet and sorghum landraces in the Sahel is not easy."[xxv] The harsh, rain-fed environment favors the use of local and narrowly adapted seed rather than externally developed seeds. Local sorghum and millet grain - where the seed output quality is evident and variety identity is recognizable - are an attractive source of seed. Additionally, sorghum and millet store well for at least one season and have low seeding rates (eg. estimated at 4% of a farmer's harvest for pearl millet), making farm-saved seed an attractive alternative to an untested, more expensive, new variety. [xxvi]

<u>Seed Systems and Dissemination of Improved Cultivars</u>

Kopainsky and Derwisch (2009) suggest that the successful adoption of improved cultivars is dependent on "[a] well functioning seed supply chain that generates improved varieties through research, produces them, and delivers them to farmers."[xxvii]

While there are not as many improved varieties of sorghum or millet, compared to maize and cotton, research centers have successfully developed and released over 40 sorghum cultivars in 23 countries and 16 millet cultivars in 12 countries in SSA.[xxviii] The Consultative Group on International Agricultural Research (CGIAR) centers and their national partners developed most of the improved sorghum and millet cultivars used in SSA. Breeders have focused on strengthening important characteristics, such as drought resistance, pest and parasite resistance, and yield, while continuing to maintain other desirable characteristics.[xxix] Most varieties developed for SSA are open-pollinated and early maturing to decrease susceptibility to droughts.[xxx] Other medium or long maturing varieties have also been developed, which are beneficial under better growing conditions.[xxxi]

Once improved cultivars have been developed, the cultivars are disseminated to farmers through either formal or informal seed distribution systems. In the formal distribution system, state or private companies control key components of the seed supply chain; a system that most government or donor-supported seed programs are based on.[xxxii] A recent International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) report cited the limitations of using such an approach:

> "Western models of highly structured and regulated national seed systems have been too costly and difficult to manage in Africa. For example, over the past three decades, a bevy of donor agencies and the Government of Mali pumped in over $16 million to strengthen the public seed sector in the country. Yet, the sector supplies less than 1% of the total sorghum seed sown every year by farmers."[xxxiii]

The slow evolution of the seed industry and the insufficient supply of seeds in Zambia, Sudan, and several other Sahel countries were cited as farmers' main reason for not adopting improved cultivars.[xxxiv] Tripp (2006) stated that the formal seed system had not served the needs of farmers, because "Parastatal seed enterprises do not provide seed of many of the crops that farmers grow, the commercial sector has shown little interest in non-hybrid crops, and efforts by NGOs and various local-level organizations are limited in scope."[xxxv]

In comparison, the informal seed distribution system, in which farmers breed, multiply and distribute seeds locally, is much larger than the formal seed sector. In southern Africa, for instance, over 90% of farmers' planting materials came from the informal sector.[xxxvi] Farmers often used seeds from the previous harvests or acquired them from another farmer or a local shop. In a 2006 study, Tripp found that most farmers only deviated from local acquisition of seeds for one of the following reasons:[xxxvii]

- Emergency – shortage of seeds due to a drought, flood, or civil disorder
- Poverty – shortage of seeds due to a poor harvest and/or the need to sell or consume the entire stock
- Seed Quality or Variety– desire to acquire seeds with certain characteristics, such as high yield, drought and pest resistance, and taste.

<u>Case Study: Tanzania (Part 1) – Formal Sector Development</u>

Research institutes, international organizations, government agencies, and NGOs have tried several approaches for developing and disseminating sorghum and millet seeds. An ICRISAT/Southern African Development Community (SADC) joint project to promote sorghum and pearl millet in Tanzania highlighted the range of partnerships and distribution channels that are possible. In 1994, the ICRISAT/SADC Sorghum and Millet Improvement Program (SMIP), in partnership with the National Sorghum and Millet Improvement Program (NSMIP) in Tanzania, financially supported an effort to create the following seed development and distribution model:

- ICRISAT/SADC SMIP and the NSMIP developed high quality, drought resistant sorghum and millet seeds based on local conditions and the needs of farmers (referred to as "foundation" seeds).

- All seed growers, formal and informal, that wanted to produce and distribute improved cultivars had to register with the Tanzania Official Seed Certification Agency (TOSCA) and meet specific quality standards for certification.

- TOSCA seed growers produced "certified" seeds by multiplying "foundation" seeds using approved breeding techniques. "Quality declared" seeds could also be produced by multiplying certified seeds.

- TOSCA certified seed growers were then authorized to package, label and sell/distribute seed to farmers.[xxxviii]

Case Study: Tanzania (Part 2) – "On-farm" Seed Production

In a second initiative in Tanzania ICRISAT/SADC SMIP and NSMIP, along with several other organizations, worked to promote "on-farm" seed production. Between 1996 and 2000 the following local models were developed:

- Small-scale farmers registered as seed associations – Farmer groups trained in quality production techniques prepared their surplus sorghum seed for sale. A local NGO purchased the seeds for redistribution to other farmers.

- Seed dissemination through rural schools – Primary schools located in drought-prone areas in Tanzania were used for seed multiplication and distribution. Agricultural teachers were trained in basic seed multiplication techniques and quality control and given 0.5 ha of one sorghum and one millet variety.

- Government-supported on-farm seed production – With funding from the Danish International Development Agency, the Tanzania government provided support for on-farm seed production. A select group of qualified farmers in target villages were trained in seed breeding techniques and provided with technical and financial support for seed production. Their seeds were then sold to their neighbors.[xxxix]

An ICRISAT survey published by Monyo et al. (2004) found that the three "on-farm" seed production interventions above improved availability and adoption of early maturing and drought-resistant varieties of sorghum and pearl millet. Over a four year period, the program in Tanzania resulted in the production and distribution of over 900 tons of improved sorghum and millet cultivars.[xl] Similar analysis by Monyo in Namibia found that participatory breading is effective. A review of the results is found in the final section of this report.

In this ICRISAT program evaluation in Tanzania, researchers randomly sampled villages in a sorghum and/or millet producing district. In each village, eight farming households were randomly selected to take part in the survey during the rainy season. Overall, a total of 267 households from 16 districts in nine regions were used to determine adoption rates in Tanzania.[xli] The study estimated that approximately 36% of sorghum producing areas and 29% of millet producing areas used improved cultivars.[xlii]

Farmer Demand and other Factors that Affect the Adoption of Improved Varieties

Even if improved cultivars are successfully developed and distributed, farmers may not adopt those new technologies for a number of reasons. Major demand-side constraints include risk attitudes, uncertainty, the learning curve, gender, and institutional limitations.[xliii]

Marra et al. (2002) concluded that "[…] recent research about the roles of risk, uncertainty and learning in the adoption of agricultural technologies has finally provided compelling support for the long-held and often-stated view that adoption processes are strongly affected by risk-related issues."[xliv] The body of literature reviewed in their study suggested that farmers are often reluctant to adopt a new technology without knowing the new risks associated with those technologies. A recent IFPRI study by Takeshima and Salau (2009) in

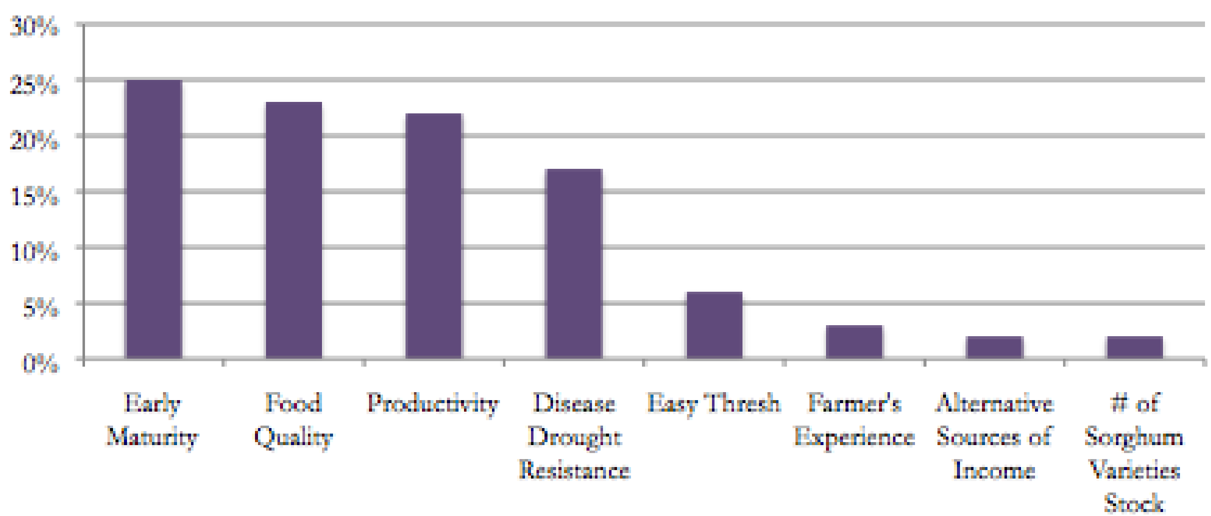
Nigeria suggested that other demand-side determinants of seed adoption might include timing of seed release, the channels by which farmers can obtain seeds, awareness of improved varieties, and the effects of natural and man-made disasters.[xlv]

Another body of literature explores how agricultural technologies, such as improved sorghum and millet varieties, are affected and/or influenced by gender. In general, women have an important role in cultivating sorghum and millet in SSA.[xlvi] The Evans School Policy and Applied Research Group's (EPAR) briefs on gender and sorghum and millet production explore potential gender ramifications of adopting improved cultivars in greater detail.

Institutional limitations, such as access to credit or land tenure, may determine whether or not an innovation is adopted or the speed at which adoption takes place.[xlvii] Often farmers have limited access to credit due to asymmetric information between farmers and financial institutions. Excess demand puts upward pressure on credit prices thereby limiting access to credit that many farmers need for improved seeds, inorganic fertilizers, or other agricultural technologies.[xlviii] According to Sunding and Zilberman (2000) tenure relationships affect the adoption of agricultural technologies, "however this impact depends on the arrangements as well as the nature of the technology." Empirical evidence suggests that in the most basic tenure relationships in which a landless farmer rents a parcel of land on a short-term contract, they are less likely to adopt new technologies that require investments in physical infrastructure and improvements in the land. However, if the technologies do not require modification of the land or if they rely on human capital from the farmer, land tenure will not be a major deterrent to adoption.[xlix]

Several additional factors are specific to sorghum and millet. Camara et al. (2006) evaluated the impact of improved varieties of sorghum and millet in Burkina Faso, Cameroon, Chad, Mali, Nigeria and Niger. The 19 studies included in their meta-analysis revealed that characteristics of the variety, such as early maturity, disease and drought resistance, and productivity; and "objectives of farmers," such as taste, influenced their adoption of improved sorghum and millet varieties.[l]

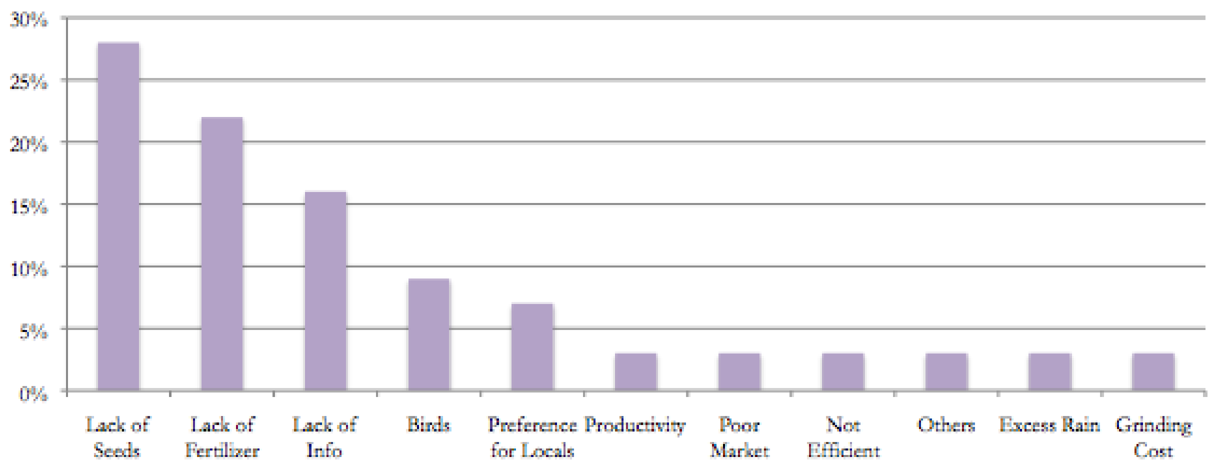
Figure 1. Factors Influencing Adoption



Source: Camara, Y., Bantilan, M. C. S., & Ndjeunga, J. (2006).

Figure 1 highlights the frequency at which farmers cited various factors that influenced adoption across all 19 studies in Camera's analysis. Early maturity, food quality, productivity and drought resistance were the top four reasons given for what determines whether a farmer will adopt a new sorghum or millet cultivar. Figure 2 is a list of factors that prevent farmers from adopting improved cultivars. Among the top reasons cited were the lack of seeds, lack of fertilizer, and lack of information about the new varieties.[li]

Figure 2. Adoption Constraints, as reported by farmers



Source: Camara, Y., Bantilan, M. C. S., & Ndjeunga, J. (2006).

Successful Approaches to Encourage Adoption of Improved Varieties

Camara et al. (2000), Maredia and Raitzer (2006), and Tripp (2006) analyzed the impact of major sorghum and millet interventions in SSA. Camara et al. (2000) conducted a meta-analysis of ICRISAT, regional, and national, sorghum and millet programs in West and Central Africa. Their analysis included a total of three adoption studies and 10 impact studies. Camara et al. (2000) found that 30 years of sorghum and research breeding by ICRISAT '[generated] benefits in excess of the opportunity cost of the capital invested in these research activities."[lii] In Mali, for instance, rates of return (RoR) for improved sorghum and millet varieties were estimated from 25% to 69%.[liii]

Maredia and Raitzer (2006) assessed the impact of all CGIAR research in SSA, including eight sorghum and millet adoption studies. This study found that in the late 1990s CGIAR improved sorghum varieties (developed by all research centers) were planted on approximately 12% of sorghum producing areas in southern and eastern Africa. Across all of SSA, evidence suggests aggregate improved sorghum adoption of approximately 1%.[liv]

Tripp (2006) reviewed four local-level seed projects for several improved crops, including two sorghum projects in Zambia. The Livingstone Food Security Project (LFSP) in Southern Province, Zambia loaned drought resistant cultivars of sorghum and cowpea seeds to groups of farmers, approximately 5-7 farmers per group. Approximately 1500 groups received a seed loan, managed their stock, and eventually repaid the loan. In the Western Province of Zambia, the Farming System Research Team (FSRT) worked with farmer groups to multiply improved seed cultivars locally. The affect of these projects increased the availability of improved cultivars. Approximately 67% of farmers in LFSP and 31% of farmers in the FSRT program adopted an improved variety of sorghum.[lv]

Overall, these three reports found that the following factors are likely to promote the adoption of improved sorghum and millet cultivars among farmers in SSA:

- **Participatory processes** – ICRISAT seed development programs that included farmers in the breeding process had higher adoption rates than programs that created cultivars without farmer input. Program analysis indicates that farmers are more likely to develop varieties that possess traits they desire, such as drought resistance, high yield, and taste.[lvi] Successful methods of incorporating farmers in the process include:[lvii]
    - Structured group interviews
    - Direct observations of farmers' plots
    - Use of a diverse nursery for trait selection by farmers

- **Improved cooperation between government, NGO, and private sector for seed development** Government, NGO, and private sector programs have tried to increase farmer access to improved cultivars for several decades, however each sector has its own unique constraints. As Tripp explains in a 2006 report, a way to overcome those constraints is to develop a comprehensive seed system in which all three sectors coordinate their activities.[lviii] As the case study from Tanzania illustrates, programs that adopted a collaborative approach to seed development seemed to have had higher adoption rates among farmers in program areas and better results. Rather than the government agencies managing and controlling all aspects of the seed development process, a large body of research suggests that input from all stakeholders, including smallholder farmers, leads to better results.[lix]

- **A diversified seed breeding and distribution system** – Governments and research institutions may improve seed availability by selling first generation seeds to the private sector and NGOs who can then multiply and disseminate them to farmers. In locations where farmers cannot afford top-quality, commercial seeds, communities can produce seeds themselves following quality control standards such as the Quality Declared Seed approach (QDS).[lx] Furthermore, long-tested varieties from one country may be considered for expedited release in neighboring areas.[lxi]

Conclusion

While national governments and international research institutes have successfully developed a number of improved sorghum and millet cultivars, adoption rates in SSA (particularly in West and Central Africa) are low. A common theme is the necessity of improving access to improved varieties through better breeding and distribution systems, and the importance of involving farmers at all stages to increase the attractiveness, appropriateness, and knowledge of the improved seed, and hence the likelihood of adoption. The literature suggests that overall efforts have increased adoption rates, but at varying costs. If more information is desired, we are happy to provide additional details from the Camara et al. (2000), Maredia and Raitzer (2006), and Tripp (2006) meta-studies.

Please direct comments or questions about this research to Leigh Anderson, at eparx@u.washington.edu.

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