SASHA Phase 1 Final Report: Narrative for 1 August 2009–30 June 2014

Executive Summary

The first five-year phase of the Sweetpotato Action for Security and Health in Africa (SASHA) five-year project sought to directly improve the food security of at least 155,000 sub-Saharan Africa (SSA) families by exploiting the untapped potential of sweetpotato and to create the conditions for going to scale. This required (1) transforming sweetpotato breeding; (2) developing innovative seed systems; (3) strengthening partners' capacities; and (4) understanding how to link these components to market and food-based nutritional interventions while ensuring gender equity. The first phase (i.e., SASHA1) finished on 30 June 2015 and the second five-year phase (i.e., SASHA2) began on 1 July 2014. A no-cost extension was obtained for SASHA1 through 31 October 2014 so that we could finalize analysis and reporting. This report covers the major achievements during the entire project (1 July 2009–30 June 2014) for the breeding and weevil-resistance activities and through 31 October 2014 for the other research programs (RP) as part of the no-cost extension. SASHA2 began financing breeding and weevil-resistance activities on 1 July 2014.

SASHA1 had five RP, with 227 initial milestones. With donor approval, 60 milestones were dropped, mostly due to the redesign of RP2 (weevil-resistant sweetpotato) in year 3. Of the revised 167 milestones,[1] 110 (65.9%) have been fully achieved, 35 (21.0%) have been achieved with modification,[2] and 22 (13.2%), mostly from breeding (RP1) and weevil resistance (RP2), will be achieved during SASHA2. Appendix A provides an updated log frame of outputs. Appendix B provides the detailed milestone table, including comments explaining any reasons for delayed achievement. Concerning milestone reports cited in the report, reference numbers consisting of OBJx (objective numbers) and *MSx.x* (milestone numbers) correspond to those listed in Appendix B. If only the milestone number (*MSx.x*) is presented, it refers to the milestone for the given RP, not to a report.

To date, the project so far has produced 35 published research articles (fully or partially financed by SASHA funds), 100 briefs (two to four pages each), three brochures, one flipchart, one variety catalog, four videos, and launched a Sweetpotato Knowledge Portal (SKP) that contains 7,004 items. In collaboration with the Reaching Agents of Change (RAC) project, SASHA scientists helped to develop a comprehensive training of trainers course and segments for eight episodes of the "Shamba Shape-up" television program. Since its inception, the project submitted 42 milestone reports. Fifty-six students have been aligned to SASHA project research needs; only 5 have been fully funded by SASHA, with 42 provided logistic and technical support for field activities. The project held a major launch event in October 2009 and annual meetings at which results were shared with the broader community of practice (CoP). SASHA support enabled the launching of the Sweetpotato for Profit and Health Initiative (SPHI) in 2009, with the goal of improving the lives of 10 million African households (HH) in 16 SSA countries by 2020 through access to and diversified use of improved sweetpotato varieties. By July 2014, over 900,000 HH had received these improved materials.

RP1: Breeding and Varietal Improvement. RP1 aimed to develop improved breeding methods and establish efficient population improvement programs at a sub-regional level in SSA, linked

[1] Note that 3 additional milestones were added to RP4 when the COVA study was added in May 2012; 51 milestones from RP2 were dropped and 3 new ones added when the sub-program was redesigned in year 3.

[2] "Achieved with modification" means that the original target number was altered once the activity was underway or the target was partially achieved.

with participatory varietal selection at the national level. Sweetpotato support platforms (SSPs) were established in East Africa at the National Crops Resources Research Institute, Uganda (NaCRRI), Southern Africa at the Instituto de Investigação Agrária de Moçambique, Mozambique (IIAM), and West Africa at the Crops Research Institute, Ghana (CRI). Each SSP, staffed with a senior CIP sweetpotato breeder and linked to key national breeding programs, established a population development effort with specific goals and a quality lab with near-infrared spectrometry (NIRS) to support fast analysis of nutrient composition of roots and virus-elimination services for the sub-region. Among the 40 breeding milestones, 23 (57.5%) were fully achieved, 4 (10.0%) achieved with modification, and 13 (32.5%) have been carried over into SASHA2.

Major improvements in efficiency in conventional breeding through the development of an accelerated breeding scheme (ABS), proof of exploitable heterosis (hybrid vigor), and common protocols and tools for designing and analyzing multilocational trials (CloneSelector) were developed. Results from a large five-year experiment comparing the efficiency of polycross with controlled cross breeding found that good progress can be made for foliage or root yields using either approach. Marker development for sweetpotato chlorotic stunt virus (SPCSV) detection was slower than anticipated, as first the number of SPCSV-resistant clones had to be increased. Thirteen identified molecular markers are now being validated.

In Ghana, steps were taken to improve efficiency of trial data collection through the introduction of bar code labels for field plot identification and PDAs (handheld data entry machines) for direct input of data into CloneSelector. This "Accu-log" system will be extended to Mozambique and Uganda during SASHA2. Considerable progress was made in increasing the frequency of sweetpotato virus disease (SPVD) genotypes in Uganda, drought-tolerant genotypes in Mozambique, and low-sugar genotypes in Ghana.

Significant investment in strengthening the capacity for sweetpotato breeding in 12 SSA countries has been made, in close collaboration with the Alliance for a Green Revolution in Africa (AGRA). Annual *Speedbreeders* meetings were held and all breeders trained in the use of CloneSelector. Since 2009, 46 new varieties have been released, of which 37 are beta-carotene-rich, orange-fleshed sweetpotato (OFSP) varieties. In 2014, 60 varieties were described in the second edition of the "Orange-fleshed Sweetpotato Catalogue."

RP2: Breeding Weevil-Resistant Sweetpotato (WRSP). This RP aimed to develop weevil-resistant varieties of sweetpotato using biotechnology for SSA. Three weevil-resistant genes expressing Cry proteins known to be toxic against the African weevils were introduced into sweetpotato varieties initially as sweetpotato-like *cry* genes (borrowing gene elements from existing sweetpotato genes) and, recently, as high-expression-reputed *cry* gene. The transgenic events—close to 100—with the SP-like *cry* genes have not been able to control weevils, likely due to low accumulation of the *cry* toxin in the storage root. New transgenic events with the new *cry* genes are now in the biosafety greenhouse to produce storage roots to be tested for weevil control in 2015. Complementary to the *Bacillus thuringiensis* (Bt) technology, a RNAi strategy for weevil control was shown to be promising when we observed that both weevil species larvae can be killed if RNAi targets any of seven essential genes. Recently, we have shown that weevil resistance will also bring health benefits by avoiding intoxication by consuming undamaged parts of infected sweetpotato roots that have considerable amount of ipomeamarone, a toxic phytoalexin. RP2 has built considerable human capacity—three doctoral degrees for African scientists, biotechnology and biosafety training courses—and improved infrastructure for testing transgenic sweetpotato. Fourteen

scientific papers were published, 3 are in preparation, and 17 posters were presented at various scientific events. Among the revised 34 milestones, 24 (70.6%) were fully achieved, 3 (8.8%) achieved with modification, and 7 (20.6%) carried over into the first year of SASHA2.

RP3: Sustainable Seed Systems. This is a diverse RP with the overall goal of addressing the recognized bottleneck of adequate quantities of quality planting material when farmers want to plant. Significant learning occurred as research for development activities progressed. Hence, 17 (53.1%) of the 32 milestones were achieved with modification, 14 (43.8%) fully achieved, and only 1 milestone related to advanced diagnostic tool work carried over into SASHA2.

Two technologies under Objective 1, improved conservation and multiplication, are already being further deployed in other projects: (1) net tunnels, which protect pre-basic material from virus infection in the field at a reasonable cost, and (2) the Triple S method, which stores roots in sand and re-sprouts them—an appropriate strategy for drought-prone areas. Research to improve the efficiency of pre-basic seed production using sandponics has promising initial results and will continue to be refined under SASHA2.

Underpinning this work was research to better understand how sweetpotato seed systems currently operate in East Africa. A much better understanding of how viruses affect different varieties and how to manage them is emerging. Evidence demonstrated reversion from sweetpotato feathery mottle virus (SPFMV) in certain varieties. Virus degeneration studies in Tanzania and Uganda indicate that "cleaned-up" virus-susceptible varieties are quickly re-infected and breakdown within a generation or two. However, investing in virus removal and training of multipliers in rouging out infected material are promising approaches for sustaining yields of varieties with at least moderate virus resistance over time.

A validation study of a community-based, quality-declared planting material (QPDM) inspection scheme conducted in Tanzania recommended that physical inspections should be focused on larger sites (secondary multiplication sites) only and found that trained local inspection teams were as competent as external inspectors. On the basis of this study, a draft protocol for establishing tolerance levels to be used in sweetpotato QPDM inspection schemes has been developed. Further work on QPDM will be undertaken in SASHA2, expanding to more East African countries.

The large-scale dissemination project emphasizing QDPM, Marando Bora (Objective 2), completed implementation in June 2012, reaching over 110,000 HH. Operations research on gender in relation to vine multiplication led to changes to increase female participation as trained vine multipliers. An endline survey among 730 HH for Marando Bora found that participation in the project increased willingness to conserve vines and knowledge about vine quality and the benefits of OFSP. A separate study documented that 61 of the 88 decentralized vine multipliers (DVM) used during the project were continuing to multiply vines two seasons after the project ended. Female-majority DVM groups appear to have had higher usage and continued usage of key resources (irrigation pumps, fertilizer use, and rapid multiplication technology) for vine multiplication than did male-majority groups and female individual DVM.

Objective 3 focused on studying whether commercially oriented seed systems emerged in Rwanda, where the Super Foods projects created demand for roots for agro-processing. Twelve of the 20 agro-processor-linked farmer groups who were multiplying quality vines sold to persons/organizations outside the group. Total vine sales rose from $304 in 2012 to $6,302

in 2014, with demand for quality vines outstripping supply as groups wanted to retain vines for their own production as well.

Considerable progress was made in diagnostics research and improving germplasm management under Objective 4. Using siRNA deep sequencing technology on samples from Mozambique and Ghana, complete or near complete sequences have been determined for several new sweetpotato viruses. New strains in distinct geographic regions of Africa were identified. This information has provided essential sequence information for designing appropriate diagnostic methods, but also uncovered some common and potentially damaging viruses not noticed before. Three successive iterations toward a universal diagnostic sweetpotato *ClonDiag* virus tube array were developed and validated, and a fourth iteration is planned for SASHA2. To analyze the result from the arrays, a smartphone app was developed.

Loop mediated isothermal amplification (LAMP) assays were also developed for the two main viruses, SPFMV and SPCSV. LAMP has advantages for virus diagnosis in the field as it works at a single temperature. A simple extraction method for sweetpotato leaves was developed consisting of macerating leaves in a plastic bag with alkaline buffer. Lyophilization of LAMP reagents was also tested but requires further optimization during SASHA2.

The project invested heavily in infrastructure improvement, bar-coding, and staff training at the plant quarantine Kenya Plant Health Inspection Service (KEPHIS) hub (Muguga, Kenya) to improve the regional germplasm management system in vitro and in vivo. KEPHIS was awarded its first ISO 17025 accreditation for sweetpotato virus indexing by the Kenya National Accreditation Services in November 2013. A CIP virologist conducted six trainings in sweetpotato virus testing (indexing) and elimination (cleaning) in the SSA region. Three courses on the use of tube-arrays/LAMP and siRNA sequencing were performed in the United Kingdom, Kenya, and Uganda.

RP4: Effective Delivery Systems (Proof-of Concept Projects). Mama SASHA was the integrated agriculture and nutrition intervention that aimed at improving the health of pregnant women and the nutritional status of children under 2 years of age through an integrated OFSP and health service delivery strategy in Western Kenya. In this proof-of-concept project (PoCP), pregnant women were provided with additional nutrition education and vouchers to be redeemed for vines when they attended ante-natal care (ANC) services and encouraged to join community-level pregnant women's clubs that met monthly. Vouchers were distributed at four intervention health facilities from April 2011 through August 2013. In total, 4,629 pregnant or lactating women received 7,159 pairs of vouchers, 63% of which were redeemed. Results from cross-sectional endline survey (Mar.–June 2014) targeting 2,398 mother-child (under 2 years of age) pairs and 207 pregnant women in intervention and control catchment areas found significant increases in nutritional knowledge and production and consumption of OFSP and other vitamin A-rich foods in intervention area HH compared with those in control areas. Significant differences favoring reductions in child stunting, underweight, and vitamin A deficiency (VAD) among children in the intervention areas, compared with the control areas, from the beginning to the end of the study were also found. But more refined analysis is needed to determine to what extent participation in the Mama SASHA program influenced those differences. Cost per beneficiary who redeemed the vouchers for vines was $105. Taking benefits into account, the intervention was considered cost-effective based on World Health Organization guidelines.

In addition, 384 women completed the complementary longitudinal Cohort for Vitamin A (COVA) study. The study followed the same pregnant women throughout their pregnancy and subsequent mother-child pair until the child was 9 months old, after which a 24-hour recall food consumption study was conducted (Nov. 2013–Feb. 2014). Results indicate a doubling of median vitamin A intakes for both mothers and infants in intervention areas compared with control areas; these differences are attributed to OFSP intakes.

Mama SASHA fully achieved 12 (70.6%) of its 17 milestones and 4 (23.5%) achieved with modification. Only 1 milestone, the cross-sectional endline study, is not yet completed.

The **Rwanda Super Foods Project** sought to establish a commercially viable OFSP-processed product and carefully examine whether the value chain (seed to product) developed was efficient and benefited both women and men. Four products were developed. The private sector partner, SINA Enterprises, officially launched the Golden Power Biscuit (with OFSP puree replacing 43% of wheat flour) on 9 November 2012, and it is being sold by SINA Enterprises in its eight shops around the country. Since then, SINA has earned $341,874 in sales of OFSP products. Given Rwanda's limited landholding sizes, yield increases were requisite to ensure surplus for sale. Disease-free pre-basic material (tissue culture and screenhouse multiplication) was supplied to growers—individuals and 20 farmer groups—supplying SINA with roots, who were trained on quality vine management. Baseline and endline studies were conducted. Results indicate that value chain participants had significantly higher yields and profits per hectare than control HH, and that farmers in groups, backstopped by nongovernmental organizations (NGOs), had higher economic efficiencies than those delivering individually to SINA. Spill-over HH (i.e., those receiving vines from beneficiaries) also had higher yields and profit per hectare, and were more economically efficient than control HH. The project met its target of having 75% of direct beneficiaries be women farmers; however, on average, beneficiary women earned less revenue and were less economically efficient than beneficiary men. Rwanda Super Foods fully achieved 20 (83.3%) of its 24 milestones and achieved the remaining 4 (16.7%) with modification.

A feasibility study conducted in 2011 examined the opportunities for sweetpotato value chain development in selected states in Nigeria. Results from this study, the only milestone for this objective, provided evidence to convince the Minister of Agriculture and Rural Development to support a sweetpotato value chain project in six Nigerian states, beginning in February 2014.

Four East African M.Sc. students conducted feasibility research examining the potential for sweetpotato as a dairy cattle and pig feed. Appropriate dual-purpose (food and feed) varieties were identified for highland areas in Kenya and Rwanda. Sweetpotato silage recipes were developed and analyzed for protein content, digestibility, and other indicators of quality. One recipe was used in a pig-feeding trial, which found that 30% of concentrate replaced by sweetpotato silage was a viable, economically efficient combination. A training course in 2010 taught 21 participants on how to use the LIFE-SIM model for planning cost-effective diets. The animal feed team fully achieved 7 (70.0%) of their 10 milestones and achieved 3 (30.0%) with modification.

RP5: Management and Support Platforms (SSPs). SASHA1 successfully organized and held annual SPHI annual technical meetings and the aligned SPHI Executive Steering Committee (ESC) meeting. All nine RP5 milestones were fully achieved. The 4th Annual SPHI Technical meeting and the SPHI ESC meeting took place on 7–10 October 2013, in Kumasi, Ghana—the

first time SASHA has held such a major meeting in West Africa. The 5th and last annual SPHI technical and ESC meetings under SASHA1 were held on 9–12 September in Nairobi, Kenya. The meeting celebrated SASHA1's five-year achievements. Nineteen sweetpotato projects were represented, compared with 5 at the 1st SPHI meeting in 2010. A half-day exhibition was held, highlighting work being carried out in 11 SSA countries. In total, 100 briefs were prepared for annual meetings during SASHA1. Most of these were annual update briefs on progress on SASHA RP and other projects under the SPHI umbrella. However, 13 research finding briefs were prepared for the 5th meeting.

SASHA 1 successfully completed its commitment to begin building a vibrant CoP of sweetpotato researchers and practitioners based on an SSP concept. Sweetpotato breeders met annually, with nine SSA countries consistently represented by the same person, and an additional five SSA countries with changing representation. Each year, a different breeding program was visited, enhancing the exchange of experience between programs. Use of common protocols and the CloneSelector tool (designed by SASHA scientists) for experimental set-up, design, and analysis of breeding trials is now standard. In addition, each of the three sub-regions strived to hold two SSP annual meetings on topics of interest, including seed system issues, communication techniques (including training on use of the SKP), gender mainstreaming, dissemination progress, postharvest issues, and marketing. In total, these meetings hosted 758 participants, of which one-third were women.

In addition to meetings for information exchange and learning, the creation of the SKP as a tool for all registered users to post and share information was another major SASHA1 achievement. As of 31 July 2014, the SKP had 600 registered users, over 7,000 content items, and approximately 14,500 visits annually. All briefs and presentations from SASHA-supported meetings are loaded onto the SKP. The SKP has users in 35 SSA countries and considerable use from the USA, Philippines, India, and Peru. During SASHA1, scientists with SASHA support attend 10 major conferences, and project-related materials were displayed at exhibition booths at six conferences and public events.

The project benefitted from a committed SPHI ESC that had limited turnover in members during the requested five-year period of service. Given the growth in projects under the SPHI, the ESC has recommended a separate SASHA Project Advisory Committee along with an expand SPHI Steering Committee for SASHA2.

After reviewing progress made by each of the five RP below, we present key recommendations and lessons learned during SASHA1.