SASHA
PHASE 2 FINAL

Main Technical Report

JULY 2014 - FEBRUARY 2020

SASHA
Sweetpotato Action for Security and Health in Africa

BILL & MELINDA GATES foundation

Final Narrative

Use this form to provide your final update to your foundation program officer regarding the results achieved for the entire project. In addition, please provide your perspective on key lessons learned or takeaways and input on the foundation's support of your work to ensure that we can capture and share learnings as appropriate both internally and externally.

The Final Narrative must be submitted in Word, as PDFs will not be accepted.

General Information

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[1] Feedback Contact/Email: the full name and email of the contact whom foundation staff queries for various surveys. * No cost extension granted

Submission Information

By submitting this report, I declare that I am authorized to certify, on behalf of the grantee or vendor identified on page 1, that I have examined the following statements and related attachments, and that to the best of my knowledge, they are true, correct and complete. I hereby also confirm that the grantee or vendor identified on page 1 has complied with all of the terms and conditions of the Grant Agreement or Contract for Services, as applicable, including but not limited to the clauses contained therein regarding Use of Funds, Anti-Terrorism, Subgrants and Subcontracts, and Regulated Activities.

Date Submitted	December 17, 2019 Re-submission March 31, 2020	**Submitted by Contact Name**	Jan W. Low
		Submitted by Contact Title	Principal Scientist & SASHA Project Manager
		Submitted by Contact Email	j.low@cgiar.org
		Submitted by Contact Phone	+254-20-422-3601

Progress and Results

1. Final Progress Details

I. Executive Summary

The 5-year (July 2014–October 2019) Sweetpotato Action for Security and Health in Africa Phase 2 project (SASHA2) has succeeded in almost all its objectives centered on resolving the major bottlenecks for fully exploiting sweetpotato's potential to serve the needs of resource-poor farmers in sub-Saharan Africa (SSA). By continuing to build a vibrant community of practice (CoP), SASHA2 has accomplished the following: 37 new nutritious varieties bred in Africa with superior traits have been released since 2014, use of the heterosis exploiting breeding scheme (HEBS) validated, use of accelerated breeding scheme (ABS) widely adopted, the efficiency of the pre-basic seed system enhanced in 10 countries, new techniques to improve seed systems evaluated, the orange-fleshed sweetpotato (OFSP) purée has been improved and is an economically viable product, and a regional laboratory of excellence in nutrition composition analysis has been established and fully operational. These advances have underpinned the ability of partners under the Sweetpotato for Profit and Health Initiative (SPHI) to reach 6.2m households (HH) with improved varieties of sweetpotato since 2009. Of the 32 key milestones set, 22

(68.8%) have been achieved, 3 (9.4%) have been achieved with modification, 4 (12.5%) almost achieved, and 3 (9.4%) did not meet the desired level of success and will require new approaches. The major problematic areas not reached are the transgenic work on sweetpotato weevil and economically viable, solar-powered cold storage. However, considerable progress was made on the latter. Appendix A provides the detailed Results Tracker and Appendix B the expenditures report. A reference list of all articles, manuals, and brochures published to date is provided at the end of the technical report.

Research Program 1 (RP1): Breeding. Population development is conducted at subregional "sweetpotato support platforms" (SSPs) in Uganda (East and Central Africa), Mozambique (Southern Africa), and Ghana (West Africa), with backstopping from the headquarters of the International Potato Center (CIP-HQ). Collaboration with 14 national partners ensures efficiency of breeding efforts. Specific breeding objectives are to (1) continue to improve sweetpotato population development in SSA, linked with participatory varietal selection at national level; (2) breed for key biotic constraints, especially viruses, in Africa; (3) breed OFSP populations for drought-prone regions in Africa; (4) breed quality types of sweetpotato for urban markets; and (5) in collaboration with RP5 and the Genomic Tools for Sweetpotato project (GT4SP), establish a vibrant CoP of sweetpotato breeders, using common protocols and analytic tools.

Overview of Breeding Progress. The program established genetic gains (GG) for traits such as root yield, foliage yield, and beta-carotene content by examining released varieties over the last two decades in the four programs (Uganda, Mozambique, Ghana, and Peru) where population development programs led by CIP are based. Two periods were considered: normal harvest: 120 days after planting (DAP) as well as for Peru only, early harvest (90 DAP). The current GG for storage root yield range from 0.5% (West African Breeding Platform) to 2.5% (Amazon Basin, Peru, 120 DAP harvest). For foliage yield, the annual GG ranges from -1.9% (West African Platform, 120 DAP) to 1.2% (Southern African Breeding Platform, 120 DAP). For root beta-carotene content (fwb), the GG range from 1.0% (Southern African Breeding Platform) to 6.0% (West African Breeding Platform). The GG for beta-carotene is influenced by the baseline values. In Mozambique all the initial releases were orange-fleshed (beta-carotene baseline: 4.6 mg/100 gm fwb [fresh weight basis]), in contrast to zero values in Uganda and West Africa.

A goal of having at least 30 new varieties *bred in Africa* was set for this phase. **During SASHA2, 42 new varieties were bred and released by 10 SSA countries,** 22 of these (52%) were OFSP, 5 were purple-fleshed (PFSP) (12%), and 15 (36%) were white- or yellow-fleshed. In addition, 6 OFSP and 5 non-OFSP varieties were selected from seed from the Ugandan breeding program in three SSA countries. There is also sharing of released varieties among countries. Five countries released 21 varieties (15 of them orange-fleshed) that were bred in another African country. Two of the most popular are the variety 'Irene' from Mozambique, which has been released in 4 other SSA countries, and the variety 'Kabode' from Uganda, which has been released in 5 other SSA countries. Sweetpotato breeding programs in 14 SSA countries have been active participants in the *SpeedBreeders* CoP,[1] with an additional 6 "spillover" countries[2] benefitting from varieties and limited technical support. The commitment made by national program breeders in 2014 to mainstream the beta-carotene trait, by assuring that at least 50% of the varieties submitted for released would be biofortified, has been kept.

Evidence of Ability to Exploit Heterosis in Sweetpotato. The strategy for exploiting heterosis in sweetpotato breeding was validated in three distinct populations in Peru and in Uganda and Mozambique. Storage root yield GG estimates following gene pool separation and one complete cycle of reciprocal recurrent selection (RRS) in three OFSP H1 breeding populations in Peru were: 85.0% for the wide and early adaption (WAE) group at 90 days; 68.8% for the WAE group at 120 days; 110.3% for the non-sweet taste (NSSP) group (at 120 days); and 95.5% in the high iron (HIFE) group (also at 120 days). This is truly revolutionary for speeding up GG. **The GG achievable by one RRS cycle is remarkable and, on the basis of our calculations, the GG found in our three H1 populations correspond to 3–5 decades of polycross breeding**. RRS increased GG for storage root yield by 40–82%. An additional outcome is the emergence of the concept of "elite crosses"[3] using a limited number of parents that exhibit high general combining ability (GCA). This has led to a new sweetpotato breeding concept at CIP to develop hybrid populations and cultivars which exploit heterosis, including use of RRS, elite crosses, and hybrid variety selection. This approach will be implemented at all CIP-led breeding platforms. In Peru, four potential testers (materials with

[1] Uganda, Kenya, Rwanda, Burundi, Ethiopia, Tanzania, Malawi, Zambia, Madagascar, Mozambique, South Africa, Ghana, Nigeria, Burkina Faso

[2] Angola, Democratic Republic of Congo, Benin, Ivory Coast, United Arab Emirates, Bangladesh.

[3] Elite crosses as well as bi-parental isolation crosses are the repetition of the best set of crosses on large scale. Parents of these crosses have high general combining ability across prioritized key traits such as storage root yield, sweet potato virus D (SPVD) resistance, root dry matter on the East African breeding platform. Simply put, the best hybrid crosses in population improvement tested by a small number of genotypes per offspring and a bunch of half siblings are repeated on large scale with 500–2,000 true seed generated per elite cross to fully exploit the potential of a good cross.

positive, high GCA to the complementary gene pool) were identified that will be used to evaluate more parents for their value in population improvement.

Since July 2018, CIP has strengthened breeding platform data management, field trial design, and statistical analysis with the statistician, Dr. Bert De Boeck, joining the breeding program. The use of trial design and data management tools, field plot techniques, including the use of the Westcott row-column design and standard checks, significantly reduced experimental error and allowed more rapid progress to be made. In 2019, the breeding team began transitioning to using (augmented) p-rep designs at the first step of selection and row column designs at the second step of selection.

Progress in Sweetpotato Virus Disease (SPVD) Resistance Breeding (East and Central Africa Platform and CIP-HQ). Enhancing the of frequency of SPVD resistance from less than 0.2% to 2% in breeding populations annually at Namulonge has proved to be a critical challenge. During SASHA2, the procedure to discriminate between genotypes susceptible, tolerant, and resistant to SPVD was optimized. Four different approaches have been used, but offspring testing, in combination with implementation of HEBS at Namulonge, has been the most successful to date. Starting in 2016/2017 two populations, population Uganda A (50 parents) and population Uganda B (80 parents), separated by simple sequence repeat (SSR) markers, were evaluated for three seasons. A total of 5,031 genotypes were generated from all possible cross combinations. Crossing parents from the two distinct populations resulted in a 16% storage root increment. Best linear unbiased prediction (BLUP) of storage root yield for elite crosses was 13.7 t/ha compared with 8.1 t/ha for the entire population. Moreover, a test cross of 999 genotypes from "elite" SPVD field-resistant parents (3X5) were also evaluated for three seasons at Namulonge station, a renowned SPVD hotspot environment. The mean SPVD score in the progeny of these elite resistant parents increased from 10% in the parental population to 23%, a highly significant increase and a breakthrough for this difficult trait. The East and Central Africa Platform disseminated 303,047 seeds from 320 families to 10 countries during SASHA2. One country, Madagascar, released 5 varieties selected from this seed.

Progress in Breeding for Drought Tolerance (Southern Africa Platform). Three crossing blocks (two OFSP and 1 PFSP) were annually established in Mozambique at two major breeding sites during SASHA2. A total of 179 trials in different categories (seedling nurseries, observational trials, preliminary trials, advanced trials, and other specialized trials (e.g., GG, vine survival, drought tolerance, heterosis trials) were successfully evaluated during the 5-year period. Progress has been made in understanding the negative storage root yield consequences of early-season drought compared with terminal drought. Erect (short) and thick stems are associated with varieties with better drought tolerance. This program established that the ABS approach can be implemented with success.[4] Seven varieties were released in 2015; and an additional five in 2019; seven were OFSP and the five were PFSP—the first time these anthocyanin-rich materials have been bred in Africa. Among the earlier 2011 ABS releases, the varieties 'Delvia' and 'Irene' have emerged as the most widely adapted and widely adopted OFSP varieties. They both outperform dominant local varieties yield-wise, are easy to establish, have good vine multiplication rates, and sprout well after the dry season. The crossing blocks in Mozambique yielded more than 1m true seed (TS) during SASHA2. A total of 234,962 of these seeds were shared with 18 national agricultural research systems (NARS) partners in Southern Africa, East and Central Africa, West Africa, Brazil, and Southeast Asia. Two separate breeding populations have been created, based on DNA fingerprinting, in preparation to exploit heterosis using RRS in the next phase.

Progress in Breeding for High Iron (Fe) OFSP (Southern Africa Platform). Given that iron (Fe) deficiency is also a major micronutrient deficiency, a double-biofortified OFSP is the goal of this research. By 2018 we had identified one contamination-free OFSP clone, MUSG1 5052-2, with 44 ppm Fe dry weight basis (dwb)—over twice as high Fe values compared with typical values of around 18 ppm. In 2019 ETH-Zurich conducted a multiple-meal feeding trial among 25 women of reproductive age to determine the bioavailability of the Fe in this clone compared with 'Irene', a variety representative of typically lower Fe concentration. Fractional Fe absorption for both test meal types was 5.8%; however, absorption varied based on initial ferritin status. Those with low status absorbed 8.1%; those with adequate status, 3.6%. Thus, the enhanced Fe clone provided 0.09 mg absorbable Fe/100 g of cooked OFSP, equivalent to 14.1% of the target 50% estimated average requirement (EAR) for children aged 1.5–2.5 years. The breeding effort needs to continue as we need to reach 30% of the target EAR value required to consider the variety biofortified in Fe. So far, per breeding cycle, Fe (dwb) is increasing at 0.05–0.08 mg/100 g.

Progress in Breeding for Low-sweet Sweetpotato (West Africa Platform and CIP-HQ). A key focus of the newest CIP-led breeding platform[5] has been the development of less sweet (i.e., sugary) types preferred by West African consumers. The

[4] 15 varieties were released in 2011 in Mozambique during SASHA Phase 1 (SASHA1), from 2009-2014, using the ABS approach.

[5] The population development platform in Ghana was established in 2010 at the beginning of SASHA1.

northern savannah and southern environments of Ghana are agro-ecologically distinct and broadly representative of environments across West Africa. During SASHA2, we began separate selection efforts in the northern and southern regions of Ghana, demonstrating that more rapid gains can be made by targeting these agro-ecologies separately. The breeding pipeline in Ghana is now producing a supply of high-yielding, high dry matter (DM), low-sweet genotypes, many with variety potential. Four candidate varieties with consistently higher yields than checks were released by the Council for Scientific and Industrial Research Institute- Southern Agricultural Research Institute (CSIR-SARI) and CIP in January 2020. In addition to low-sweet, consumer-preferred taste, one of the new varieties exhibits consistently lower weevil infestation. Release of these high-yielding varieties achieves our milestone of 10–20% yield increases in less-sweet hybrid progenies. Using genotyping and pedigree analysis, we have divided our breeding parents in two groups for continued breeding to exploit heterosis using RRS. Sensory analysis work to improve targeting of breeding efforts revealed that there is little relationship between sweet taste and the sugar content of the genotypes evaluated, meaning that analyzing boiled root samples for sugars was not leading to the identification of less-sweet genotypes. We combined using a trained sensory panel with consumer sensory evaluations of boiled and fried sweetpotato and determined sensory traits associated with two distinct clusters of consumer preference, one around a higher DM OFSP variety ('Nan") and the other around low-sweet, yellow- or white-fleshed staple types. An in-depth study to define gender-relevant product profiles for fried sweetpotato was conducted in Nigeria and Ghana following the RTBfoods methodology and will guide future breeding efforts in West Africa.

Compared with SASHA1, we significantly improved our crossing capacity through timely multiplication of parents to synchronize flowering and using a protected screenhouse environment for crossing and seed production. We produced 240,798 seeds from 65 adapted parents, many selected for less-sweet taste; 48,810 seeds were shared with 10 NARS breeding programs. We will reach our milestone target of 100,000 seeds distributed in the coming year.

Results from breeding for low-sweet sweetpotato from the Peruvian heterosis experiment found GG after one RRS of 50.3% of OFSP-NSSP in terms of lower sweetness in the H1 offspring after cooking compared with two widely adapted check clones, 'Dagga' and 'Cemsa'.

Progress in Understanding the Genetics Underlying Continuous Storage Root Formation (East and Central Africa Platform). Lack of attention in breeding programs to the preferred practice by smallholders of piecemeal harvesting—continuous root formation and bulking (CRF)—may have led to the release of some new varieties that were not well adopted because their roots mature all at one time (indeterminate root formation), a trait suited to commercial production but not for food security needs. Research discovered molecular markers and putative genes for these two distinct (CRF and indeterminate root formation) types of growth. Thus, yields for piecemeal harvest may be increased through HEBS.

Research Program 2 (RP2): Weevil Resistance. From 2009 to 2017, transgenic sweetpotatoes with sweetpotato-like *cry* genes and with high-expresser *cry* genes were developed at the Applied Biotechnology Laboratory (ABL) in Peru and the Donald Danforth Plant Science Center (DDPSC) in the United States as a strategy to confer resistance to weevils. Well over 150 transgenic events were produced, of which 132 transgenic events were tested in a bio-assay using storage roots infested with 10 weevil females. We identified 12 with apparent differences with the non-transgenic materials in adult emergence. Storage roots from 10 of them were shipped from DDPSC to Biosciences Eastern and Central Africa (BecA) and tested for resistance against weevils. Four of them presented various degrees of differences compared with the untransformed storage roots, such as small number or delayed adult emergence. However, these positive events were not confirmed. Results indicate that the amount of *cry* protein accumulating in the storage roots is not high enough to confer a significant level of resistance to the sweetpotato weevils.

An RNAi strategy was developed to complement the *Bt* strategy. Two gene constructs from variety 'Jonathan' were used to produce transgenic events. As funding ended in 2017, the potential of the RNAi approach remains untested. However, a PhD thesis published a year later,[6] concluded that the discovery of dsRNA-degrading enzymes reduces the RNAi efficacy in *C. puncticollis* compared with *C. brunneus*. Therefore, additional research will be needed to protect the dsRNA from degradation to effectively deliver these molecules into sweetpotato weevil larvae. We conclude that, so far, the weevils are winning.

[6] Prentice Muro, Katterine. The potential of RNAi technology to control the African sweetpotato weevils, *Cylas puncticollis* and *Cylas brunneus*. Diss. Ghent University, 2018.

Research Program 3 (RP3): Seed Systems. Our vision of success for SASHA2 seed systems management is that cost-effective technologies and strategies for both male and female farmers will ensure improved access to quality planting materials. This component focused on addressing key bottlenecks in the system: (1) inadequate and costly pre-basic seed; (2) the lack of sufficient basic seed multipliers ("the missing middle") to serve as the link between pre-basic seed multipliers and smaller, community-based decentralized vine multipliers (DVMs); (3) cost-effective technologies for multiplying quality seed in areas of high virus pressure and prone to drought; and (4) inadequate virus diagnostics and quality standards for assuring quality seed.

Towards Sustainable Pre-Basic Seed Production. A major achievement during the past 5 years is the work with 13 partners (11 public sector NARS, one regulatory body, and one private sector) in 11 countries to ensure sustainable production of early generation seed (EGS)[7] by strengthening technical, business, and institutional components of EGS production. At the beginning of SASHA2, none of these institutions understood their costs of seed production nor did they have marketing strategies. Each institution developed a business plan with a description of product (pre-basic and/or basic seed) and their detailed cost structures. Real-time or recall cost data were collected and then used to establish the unit cost of production and pricing strategies. Once these were known, alterations were made, for instance, in how many tissue culture (TC) plantlets are produced relative to multiplying cuttings in the screenhouse to maximize efficiencies and lower costs per cutting. Production processes with internal and external quality assurance mechanisms were put in place. Marketing strategies targeted at different market segments (e.g., institutional markets, commercial seed producers) were implemented. Revenues from the sales of seed were paid into institutional revolving fund mechanisms to support continued seed production. An analysis of the capacity of the institutions to cover the cost of production for target sales showed that the majority were able to cover their costs in 2018 and will continue to do so in 2019. An EGS requirement estimate tool was developed and validated. Seven institutions participated in *peer-to-peer review* studies to validate each other's EGS business models and to assess the level of institutionalization of the business plans and revolving funds.

Only a handful of private companies in SSA are commercializing EGS of sweetpotato. We conducted a financial feasibility study to produce EGS for multiple root, tuber, and banana (RTB) crops for a private seed company based in East Africa. The study showed that the business is financially viable based on the existing business model for production and sale of banana, cassava, sweetpotato, and potato planting materials. The business required an initial total investment of $1m (with the assumption that grants contributed approximately 18%) and running costs of $0.15m during an 8-month establishment period. The payback period was 3–7 years, with an average annual return of 34–70%.

On the technical side, through the use of an optimized media we demonstrated that the pre-basic cutting multiplication rate in the sandponics system was 21.8% higher when compared with using conventional soil substrate. The cost of producing a 3-node sweetpotato cutting in the sandponic system (10.5 KSH/$ 0.105) is significantly lower by 0.27 KSH than using the conventional soil substrate (at 13.2 KSH).

Understanding the Returns and Needs of Basic Seed Producers. Studies were undertaken in Tanzania and Uganda to address the gaping lack of information on medium- to large-scale multipliers of basic seed. In Tanzania, we found that basic seed multipliers can produce high quality seed. An initial investment of $6,241 is required to produce 1,680,000 cuttings. The total cost of production during the 12-month crop cycle is approximately $4,927. However, to be successful, commercial seed producers must plan their production so that their multiplication calendar is aligned with market demand, and increase their economies of scale at the open multiplication stage to ensure that they sell at a competitive price.

In Uganda, we examined the feasibility of supplying quality vines from low virus pressure areas in the north to the high virus pressure areas in the south. We actually found that the current flow of vines is from the high virus pressure areas in the south to the more drought-prone low virus pressure areas in the north, because of the latter's high loss of planting material during the dry season. The maximum distance at which the sale of vines from low SPVD to high SPVD pressure areas is still profitable is 280 km, when using a 7-t lorry or 380 km when using a bus. Findings also revealed that it is cost effective for multipliers in the high SPVD pressure areas to buy pre-basic seed annually from pre-basic sources that are within a 250-km radius for multiplication in open fields, rather than conserving seed in protected structures for 3 years, for annual multiplication in open fields.

[7] EGS in this context consists of the production of TC plantlets that are subsequently hardened, then cut and grown in a protected screenhouse to grow and multiply cuttings known as pre-basic seed. National programs often have the mandate for producing EGS for certain crops in their countries. Also, several national programs go one step further to produce basic seed, the next level of multiplication, which is typically carried out in an open field.

Larger vine multipliers need a reliable and cost-effective water supply in the face of climate change. A study in Tanzania found the highest vine yields at a 10-kPa[8] watering schedule for both on- and on-farm trials; drip irrigation was the most cost-effective approach. Vine production was higher under net tunnel management, indicating that net tunnels play a role in moisture retention. The average costs of production per cutting for drip and furrow irrigation in net tunnels were TZS. 81.5 ($0.039) and TZS. 97.0, respectively, whereas for farmer-practice (control) it was TZS. 106.5. In Ethiopia, a study in Hawassa-Zuria showed that irrigation at 60% ETc[9] could be the best irrigation level for sweetpotato vine and root production during the dry season (November–March) to optimize yield and water use efficiency.

In northern Uganda, we explored the agronomic and economic benefits of introducing sweetpotato in rotation with rice at a major rice scheme, Agoro. This would enable more sweetpotato planting material to be available when the rains begin. It was observed that the rotation benefitted both rice yields and sweetpotato root yields. The comparison of net profit ratio by treatment and control shows that the net profit ratio in the treatment was 0.43 higher than in the control group, which is a significant and positive difference. The overall impact of rotation is significant for both sweetpotato and rice crop. This indicates that sweetpotato and rice under certain conditions can be rotated with each other to generate better net profits.

Improving Technologies for Quality Seed Multiplication. Building on earlier work done during SASHA1, in-depth research was undertaken to determine the costs and benefits of using protective structures (with insect-proof netting) in high virus pressure zones and expanding the use of the Triple S (storage in sand and sprouting), a root-based system for generating planting material in drought-prone, low virus pressure areas.

The study in Rakai, Uganda, to compare the use of different types of aphid-proof net structures with open-field multiplication, concluded with three important findings. First, although the net tunnel model produced more cuttings per unit/area, planting material sourced from the mini-screenhouse model produced higher root yields (8.2 t/ha) than the net tunnel (6.6 t/ha) and the open-field setting (5.7 t/ha). Virus testing indicated high virus incidence as follows: 66.6% using mini-screenhouses, 63.6% using net tunnels (63.6%), and 80% in the open-field setting. Second, using planting material that was conserved under either type of protected structure and then further multiplied in open fields results in a 16% lower per unit cost of root production compared with material only multiplied under open-field conditions. Third, investing in a mini-screenhouse for seed multiplication is, however, financially viable only when the multiplier can sell seed at a price range of UGX 65–120 ($0.018—0.033) per 20-cm cutting, which is more than four times the current market price. Securing reliable and expanded markets with farmers willing to pay a higher price for quality planting is critical for resolving the seed system bottleneck.

Triple S research in Kenya concluded that this method has high potential to store sweetpotato roots for prolonged periods of time (up to 7 months) under the dry agro-ecologies in western Kenya for subsequent planting material. In Ethiopia, Triple S consistently had the highest performance for root survival and number of cuttings produced compared with traditional conservation practices (under enset shade and mulch; reliance on volunteer roots). Extensive training materials for use by extensionists were developed and a grant from the RTB's[10] Innovation Scaling Fund obtained to test the Triple S technology at scale in Ethiopia and Ghana, further expanding the use of this technology.

Economic analysis and field experience with basic multipliers and village-level vine multipliers leads to the recommendation that the use of protected structures, due to their cost and need of regular maintenance, be focused on basic multipliers only. The Triple S technology, however, can be correctly adopted and maintained by smallholder farmers.

Assuring Quality Seed with Improved Diagnostics for Detecting Viruses. Ten SSA countries have drafted seed standards for sweetpotato (where none previously existed) or have revised existing seed standards (e.g., Malawi). The seed standards for Ethiopia, Rwanda, Kenya, and Tanzania (formal seed classes only) have now been officially approved (gazetted). This has been done in consultation with key stakeholders and with support from different projects and organizations (e.g.,

[8] Soil water tension was measured using a tensiometer. The higher the tension, the drier the soil. The tensiometer is a sealed, water-filled device that exchanges water with the soil through a porcelain cup. As plants remove water from the soil, water is drawn from the porcelain cup, developing a partial vacuum in the tensiometers, which is measured in kPa [kPa = centibars (cbar)] of soil water tension. This physical force that plants exerts to remove water from the soil ranges from 0 to 100 kPa (Shock and Wang 2011).

[9] The evapotranspiration rate from a cropped surface can be directly measured by the mass transfer or the energy balance method. In the crop coefficient approach the crop evapotranspiration, ET_c, is calculated by multiplying the reference crop evapotranspiration, ET_o, by a crop coefficient, K_c: $ET_c = K_c\ ET_o$, where (1) ET_c crop evapotranspiration [mm d^{-1}], (2) K_c crop coefficient [dimensionless], and (3) ET_o reference crop evapotranspiration [mm d^{-1}].

[10] RTB is the CGIAR Research Program on Roots, Tubers and Bananas.

HarvestPlus, University of Makerere, and Jumpstarting OFSP in West Africa, a BMGF-funded project). The challenge remains to have the standards implemented to ensure that the costs of quality verification do not outweigh the benefits.

Prior to SASHA2, the economic importance of begomoviruses in Africa was not known. A study was conducted for two seasons on yield and yield-related traits using virus-tested plants and those infected with begomovirus, sweet potato feathery mottle virus (SPFMV), and sweet potato chlorotic stunt virus (SPCSV), alone and in all possible dual combinations, for the varieties 'Kakamega' and 'Ejumula'.[11] Treatments with multiple viruses exhibited more severe disease symptoms and greater yield reduction than plants infected with only a single virus. Nevertheless, even single infection with begomovirus resulted in a significant yield effect of 47% for 'Kakamega', whereas there was no appreciable yield effect for 'Ejumula'. This confirms previous reports that yield effects by begomoviruses is highly cultivar dependent.

Quality inspection systems would benefit from tools that do not require sending samples to a laboratory. We developed and field tested in four sites a user-friendly, thermostabilized field-based loop mediated isothermal amplification (LAMP) test for SPFMV, SPCSV, and begomoviruses that can be deployed directly in the field providing real-time results. The LAMP assays used were equally sensitive and reproducible as RT-qPCR[12] "gold" standard, being able to detect virus from samples diluted over five orders of magnitude.

Another major goal was to reduce the time required for virus removal or "clean-up" by being able to substitute time-consuming grafting of a sample onto *I. setosa* (a 6–12 month process) coupled with testing via nitrocellulose membranes-enzyme-linked immunosorbent assay (NCM-ELISA), with a test that is accurate and fast. Over 9 years, we developed and validated the ClonDiag array. ClonDiag costs $70 per sample and detects up to 21 viruses in just 2 days, whereas grafting/ NCM-ELISA costs $130 to test 10 viruses per sample. Unfortunately, the manufacturer of the arrays unexpectedly discontinued production in 2018. However, another technology based on high-throughput sequencing (sRSA) developed in a complementary BMGF-funded project will be used at Kenya Plant Health Inspection Service (KEPHIS) instead. This ultra-sensitive technology costs $100/sample but can detect all viruses. It takes 1 week to do the extraction of 96 samples, and around 1.5 months to receive results from the outsourced laboratory. In 2019, requisite equipment was installed at KEPHIS, and three CIP and three KEPHIS staff members were trained in sRSA extraction techniques.

Research Program 4 (RP4): Postharvest. This research program had two distinct goals: to reduce seasonality in fresh root supply through better storage and handling technologies and to expand the use of OFSP purée through developing a product that did not require refrigeration, assuring the quality and safety of products developed using that purée.

Understanding and Improving Existing Handling Practices. Studies undertaken in Kenya, two led by the Natural Resources Institute (NRI) and Ghana, two led by the University of Development Studies, resulted in a deep understanding of current transport practice and a series of recommendations for how to handle sweetpotato roots before and during harvesting to prevent damage that leads to decreased shelf-life, and the most cost-effective way of handling, packaging, and transporting the roots postharvest. A practical 10-page brochure entitled *Handle with Care: Maintaining the quality and value of your sweetpotato roots during and after harvest through better practice* targeting extension personnel and farmers is available on the Sweetpotato Knowledge Portal (SKP).

Affordable Fresh-Root Storage. Good handling is key to having undamaged roots to go into longer term storage, regardless of the type of storage used. Building on work being done jointly with a project in Malawi and Ghana funded by the U.S. Department of Agriculture (USDA), the ability to store up to 100 kg of fresh roots using the Double S (storage in sand) technology for 4–6 months (depending on the environment) at the HH level was validated. A brochure describing how to construct and manage the Double S storage technique is available on the SKP.

Tackling storage of fresh roots at a commercial level has proved to be a challenge. Given the high cost of electricity in East Africa, research over 4.5 years led by NRI in Kenya (seven different trials) sought to develop a solar-powered storage facility prototype that could store fresh roots cost-effectively for 4 months. The team made significant progress, but the solar-powered storage still had too high levels of rotting and too high fixed and maintenance costs to be economically viable (i.e., not exceed $270/t). The storage process consists of the curing phase (4–7 days at 28–30°C and relative humidity [RH] of 90%), followed by cold storage at 13–15°C and RH of 85–90%. The latter was achieved with the solar-powered system in

[11] 'Kakemega' is a Kenya OFSP local landrace considered to be moderately resistant to SPVD. 'Ejumula' is an Ugandan OFSP local landrace, considered to be susceptible to SPVD.

[12] Quantitative reverse transcription PCR (RT-qPCR) is primarily used to measure the amount of a specific RNA. This is achieved by monitoring the amplification reaction using fluorescence, a technique called RT PCR or quantitative PCR (qPCR).

Kenya, but the curing process initiated a rotting problem that carried over into cold storage. In Mozambique, the storage container was split in separate curing and cold-storage chambers, in contrast with the design in Kenya. During the single trial conducted in Mozambique, any roots with signs of rotting after curing were removed before going into cold storage. Levels of rotting were lower than in Kenya, but weight loss was still 25–30% of the initial weight after 4 months of storage. Economic analysis demonstrates that the fixed costs and maintenance costs need to be lowered by more than half, and the percentage of initial weight loss reduced to 15% for solar-powered storage to be viable. Clearly, further research is required in this area, as the potential impact on fresh sweetpotato, vegetable, and fruit availability in the off-season could be tremendous.

Shelf-storable OFSP Puree. Results from SASHA1 proved the potential for OFSP purée to substitute for 25–60% of wheat flour and make economically viable baked products. But having to process the roots into purée or use a cold chain to manage frozen purée was a significant barrier for many bakers. In SASHA2, we successfully developed an economically viable food-safe, vacuum-packed OFSP purée prepared with locally available preservatives (0.25% sodium benzoate, 0.25% potassium sorbate, and 1% citric acid) that can be stored at ambient temperatures (15–23°C) for up to 3 months without significant beta-carotene loss. Using the shelf-storable purée required recipes to be adjusted, but the final products using 3-month old purée was acceptable to consumers. However, proofing time for bread is increased significantly, meaning that the shelf-storable purée is most appropriate for bakeries with a limited number of batches per day and flat products, like chapati. In addition, washing practices and equipment were improved to enable use of sweetpotato roots with intact skins. The resultant "high-fiber" purée significantly improves the profitability of the product and does not alter the consumer acceptance of the baked product.

Establishment of a Regional Laboratory of Excellence for Food Analysis. In SSA the lack of modern, high-throughput analytical tools, coupled with limited capability to conduct accurate nutritional analyses, food chemistry, food safety, and product development studies, delays progress in many projects. In 2014 the Food Analysis and Nutritional Evaluation Laboratory (FANEL) was established. Its main objective was to strengthen the food and nutritional evaluation capacity within SSA, equipped with advanced analytical tools[13] operated by knowledgeable and well-trained staff who will in turn train others. SASHA2 provided a full-time technician for this laboratory, overseen by Dr. Tawanda Muzhingi, whose position was financed by the Department for International Development (DFID). Over the 5-year period, the laboratory established capacity to undertake detailed carotenoid analysis; proximate analysis; microbial analysis; and the analysis of anthocyanins, vitamin C, glycoalkaloids, and minerals, especially for Fe and zinc (Zn). FANEL is serving many biofortified crops. Since its inception, 4,794 samples have been analyzed for beta-carotene content out of 19,213 analyses in total. FANEL played a critical role in the development of the shelf-storable OFSP purée. In 2018 an online system, known as FANEL-FLOW, developed under RP5 was installed to improve workflow management. As a sustainability strategy, a business plan was developed. As of January 1, 2019, FANEL became an official CIP service unit.

Research Program 5 (RP5): Support Platforms, Knowledge Management, and Governance. This component has assured the good governance of the project and the growth of a vibrant CoP, based on sharing knowledge. Annually, meetings were held for the four CoP technical working groups: (1) Breeding and Genomics; (2) Seed Systems (twice per year); (3) Marketing, Processing, and Utilization (MPU); and (4) Monitoring, Learning, and Evaluation (MLE). During the past 5 years, the CoP meetings have served 999 participants (31% women).

In addition, six annual SPHI[14] technical meetings were held during SASHA2. The overriding objective of these meetings was to bring researchers and development practitioners together so that the latest advances in research would be presented to the next users *and* researchers would be more exposed to the challenges faced by those disseminating new technologies. In total, there were 591 participants (32% women). Many organizations covered their own costs to come to the event, with the number of organizations attending ranging from 21 to 52. The meeting was 2.5–3 days long, except in 2016 and 2019 when the meeting was aligned with the Triennial African Potato Association (APA) meeting. Each year, two- to four-page briefs were prepared for new findings describing SASHA research outputs and on each development project. In 2019 25 SASHA and 17 SPHI briefs were prepared, with hardcopies provided to SPHI meeting participants. The SASHA briefs focused on major findings from SASHA2. A survey of SPHI technical meeting participants found that the two most appreciated

[13] The core equipment for this laboratory was provided by Australian donors in a separate BecA project in 2012. However, with no staff, this equipment was not being used until FANEL came into being.

[14] The multidonor, multipartner SPHI was launched concurrently with SASHA1. The goal is to improve the lives of 10m African households in 17 target countries by 2020 through access to improved varieties of sweetpotato and their diversified use.

features of the meeting were knowledge-sharing and networking. All briefs and presentations from the SPHI technical and CoP meetings are posted on the SKP (www.sweetpotatoknowledge.org).

Knowledge exchange was a key objective of RP5. By November 2019, the SKP had 872 registered users and 2,344 files. However, one does not need to be registered to access information, just to contribute documents. The number of users of sessions (visits) to the site rose from 15,709 in Y3 of SASHA2 to 38,151 in Y5. Monthly "E-Digest" e-mail-based newsletters with stories linked to the SKP started in October 2018, with 2,024 subscribers as of October 2019. The portal has an active presence on Facebook, Twitter, Flickr, and YouTube. As of July 2019, our Facebook site had 17,838 followers and our Twitter site 838 followers. Information is also exchanged through active participation of SASHA-supported scientists in international, regional, and national conferences and events.

All major SASHA non-breeding datasets have been curated and are available in Dataverse. All breeding data generated will been curated and loaded into SweetPotatoBase by December 15, 2019. The development of breeding tools to ensure consistent data collection, curation, analysis, and storage was a joint effort of CIP under SASHA2 and Boyce Thompson Institute (BTI) under the GT4SP.

Monitoring progress toward the goal of the SPHI to reach 10m HH was a key responsibility. Every year, an annual status of sweetpotato in SSA report was produced as well as an update report on the status of DVMs operating in active target countries. As of July 2019, 6.2m HH had received improved varieties of sweetpotato since 2009. This September, 741 of the 1,030 DVMs recorded in previous years were reached by phone for an update survey in 11 SSA countries. Some 76.2% of DVMs were actively producing vines, and 23.8% had stopped vine production, citing lack of market as the biggest barrier and drought as the second to continued vine production. A dashboard feature added to the SKP provides users with graphic representation of the number of beneficiaries reached under the SPHI by country and by organization, the number of varieties released since 2009 and characterized by key traits, and information on the gender and location of DVMs. In addition, the CIP MLE team developed a 13-module toolkit known as *Tools and Techniques for Monitoring Key Indicators of Sweetpotato Interventions*, which has been used by many CIP-led sweetpotato projects.

II. Main Progress Report (1 July 2014–31 October 2019) by Objective/Milestone

A. RP1: Breeding (details provided in Appendix C)

The breeding program is characterized by a high level of success, especially in terms of outputs of adapted varieties bred in Africa, continued implementation of the ABS, and the validation of HEBS. Six of the 10 milestones were achieved; two were achieved with modification and two were almost achieved. The latter were the milestones for the West Africa program, which will be fully achieved during the first year of the SweetGains project.

Breeding activities at CIP-HQ in Peru (Details in Appendix C1).

Milestone (MS) 1.1.2 Led by CIP, this milestone seeks to estimate yield gains achievable by reciprocal recurrent selection (RRS) exploiting heterosis in sweetpotato. In addition, CIP-HQ collaborates with CIP-Uganda in tackling SPVD-resistance breeding. This section reports on the (1) validation of experimental heterosis populations, (2) improvement of statistical analysis of heterosis studies (capacity building in statistics), (3) GG studies, and (4) SPVD-resistance breeding.

1. Validation of experimental heterosis populations. All the milestones of the heterosis studies at CIP-HQ have been reached. Moreover, we established "elite crosses" (an additional milestone not in the original project plan) with an outline to line up "elite crosses" with "*in vitro* germination" and "genomic selection" to be investigated in the SweetGains project. The GG were determined for one complete RRS cycle with three different population breeding targets and three different hybrid populations, respectively. These hybrid populations are (1) improving a population for OFSP with wide adaptation and earliness (WAE), (2) improving a population for OFSP with no or very low sweetness after cooking (NSSP), and (3) improving a population for OFSP for high Fe and Zn (HIFE). The foundation of all three hybrid populations is 49 PJ and 31 PZ clones (two gene pools, namely "Population Jewel" and "Population Zapallo"). These 49 PJ x 31 PZ were developed to hybrid population zero (H0 from 49 PJ x 31 PZ), via intra-gene pool recombination to new sets of PJ' and PZ' parents, and by inter gene pool recombination to three hybrid 1 populations (H1 for WAE, NSSP, and HIFE). These baseline or foundation clones were moved into CIP's genebank (BMGF funds used). We have also started to move the new parents PJ' and PZ' parents into CIP's genebank (using funds from the United States Agency for International Development [USAID]) to make the GG in population improvement available for worldwide distribution.

The GG achievable by one RRS cycle is remarkable and, on the basis of our calculations, the GG correspond in our three H1 populations to 3–5 decades of polycross breeding. The GG in the H0 population due to heterosis increments are still moderate with 18.5% for storage root yield and 19.8% for number of commercial roots per plant (95% confidence limits of 15.0–22.0% and 15.8–23.8%), respectively (Appendix C1.1 for details). **The RRS increased GG (estimated on basis H1 population BLUPs) by 40–82% for storage root yield (Table 1)**. Further GG are then achievable by the establishment of "elite crosses" and by multi-stage selection from H1 breeding populations and from "H1 elite crosses" at scale (N> 10,000 TS). Figure 1 illustrates this new breeding scheme, combining population hybrid improvement and multi-stage selection from hybrid population and from elite crossings. The results from studies conducted by teams at CIP-HQ, CIP-Uganda, and CIP-Mozambique were convincing. Consequently, CIP-Uganda established a H0 population (foundation of 150 parents), "elite crossings" (8 parents), and selected parents for an RRS cycle to generate a H1 population (20 parents in the gene pools Uganda A and Uganda B). Similarly, CIP-Mozambique is in the process to establish a H0 population with a foundation of 100 parents.

CIP-HQ demonstrated that very high selection intensities can be applied with respect to parents. Based on offspring performance in H0, 23 PJ and 17 PZ parents for WAE were selected, but only 5 PJ and 5 PZ parents for NSSP and 5 PJ and 5 PZ parents for the HIFE RRS cycle. No trade off was observed in H1 NSSP and H1 HIFE by using this extremely high selection intensity in NSSP and HIFE compared with WAE. GG for storage root yield in H1 NSSP (73.3%) and H1 HIFE (81.8%) were much higher compared with H1 WAE at 90 DAP (59.4%) and H1 WAE at 120 DAP (40.2%) (Table 1). We hypothesize that 6–12 parents in each gene pool for population hybrid breeding in hexaploidy sweetpotato is adequate for incorporation into one RRS cycle. The selection of 20 parents in each gene pool at the breeding platform in Uganda is very conservative and will reduce risks of establishing a reduced effective population size among parents. Finally, we want to highlight that all three H1 population exhibited variety ability as indicated by comparing them to the checks 'Dagga' and 'Cemsa' (Table 1). For example, for root Fe content the entire H1 HIFE population is better than checks (100%). CIP-HQ has already sent TS from elite crossings to Bangladesh (n=22,591), India (n=20,000), Panama (n=3,000), Turkey (n=5,000), and Canada (n=800). In December 2019, additional TS elite crossing shipments will be made to India, Vietnam, the Philippines, Tajikistan, Brazil, and Haiti. We have more than 100,000 TS from elite crossings in our seed stocks (Appendix C1 for details).

2. Improvement of statistical analysis of heterosis studies. CIP has strengthened its breeding platforms' data management, field trial design, and statistical analysis. Since July 2018, Dr. Bert De Boeck from Belgium (a mathematician with a PhD in statistics) has been serving as a breeding statistician, supported by a CIM-GIZ Fellowship secured through competitive bidding. CIP-HQ leads the sweetpotato breeding CoP in data management and analysis improvement. In 2019, we began using field designs with p-rep designs, analysis with mixed models, including considering the covariance structure of genotypes, BLUP estimates instead of lsmean estimates, and optimization of multi-stage selection in later breeding stages as recommended by the Excellence in Breeding (EIB) platform. Two training courses[15] (2018 in Ghana, 2019 in Uganda) have been conducted for breeders on applied statistics for breeding.

Different breeding scenarios have been analyzed in later breeding stages with formulas to calculate the response to selection for one-, two-, or three-stage selection scenarios. We have implemented the corresponding formulas in R and SAS to determine the response to selection for one to three selection stages in the later breeding stages. The R and SAS programs are available on https://www.sweetpotatoknowledge.org/files/the-stage-selection-gain-1to3/. This research is carried out with the Institute of Plant Breeding, Seed Science and Population Genetics, University of Hohenheim in Germany. This university has more than 50 years of experience in model calculations for multi-stage selection. Our R and SAS programs will also be used to analyze early breeding stages and the ABS, respectively, for which CIP-HQ has variance component estimates available (σ_G^2, $\sigma_{G\times L}^2$, $\sigma_{G\times S}^2$, $\sigma_{G\times L\times S}^2$, and σ_ε^2).

Later breeding stages are now using (augmented) p-rep designs at the first step of selection and row column designs at the second step of selection. Selections from three H1 populations (early breeding stages) are used for applied demonstration: 400 clones for OFSP WAE, 200 clones for OFSP low sweetness after cooking, and 135 clones for OFSP HIFE were planted in p-rep designs at three locations (33% of genotypes replicated at each location).

[15] SASHA2 sponsored the 10-day *Statistics for Applied Breeders* in Kumasi, Ghana, 17–26 January 2018. RTB and the Wageningen University sponsored the 5-day *Phenotypic modelling of multi-environment trials* in Kampala, Uganda, 25–29 March 2019. The latter session trained sweetpotato breeders on the use of mixed models.

Table 1. Offspring predictions (BLUPs), heterosis increments, GG relative to 49 PJ and 31 PZ baseline clones, and frequency of offspring clones superior to checks in H1 hybrid population wide adaptation and earliness (WAE, N = 9,881), low sweet (LS) sweetpotato (NSSP, N = 3,742), and high Fe (HIFE, N = 3,292) for storage root yield, number of commercial roots per plant harvested, foliage yield, biomass yield, root beta-carotene in fresh matter, root DM, storage root sweetness after cooking by taste scores, and root Fe content in DM evaluated at Canete (arid pacific coast) and Satipo (humid tropics) in Peru.

H1 Population	Trait§	H1 Offspring Mean§§	Heterosis Increment‡ (%)	GG (%)	Frequency of Offspring Clones Superior To Checks‡‡ (%)
WAE 90d harvest	Storage Root Yield (t/ha)	17.6	18.3	59.4	23.2
	No. Commercial Roots per Plant	1.84	8.6	45.1	56.4
	Foliage Yield (t/ha)	44.6	0.9	13.4	11.7
	Biomass Yield (t/ha)	62.2	4.8	21.8	7.8
	Beta-carotene fwb (ppm)	4.95	-6.7	-10.0	100.0
	DM (%)	26.2	0.3	-0.8	30.2
WAE 120d harvest	Storage Root Yield (t/ha)	37.5	7.1	40.2	0.7
	No. Commercial Roots per Plant	3.15	3.3	26.9	58.6
	Foliage Yield (t/ha)	58.4	-1.0	13.7	8.3
	Biomass Yield (t/ha)	95.9	2.0	21.8	1.2
	Beta-carotene fwb (ppm)	5.87	-11.7	-13.6	100.0
	DM (%)	27.6	-0.1	-1.6	22.7
NSSP 120d harvest	Storage Root Yield (t/ha)	31.2	27.2	73.3	0.2
	No. Commercial Roots per Plant	2.71	18.8	40.2	32.6
	Foliage Yield (t/ha)	67.6	4.1	13.6	1.4
	Biomass Yield (t/ha)	98.6	9.5	25.1	0.1
	Beta-carotene fwb (ppm)	5.01	-12.4	-9.7	100.0
	DM (%)	26.4	1.1	-0.1	43.2
	COOSU	5.74	2.3	2.8	50.3
HIFE 120d harvest	Storage Root Yield (t/ha)	44.5	32.7	81.8	43.1
	No. Commercial Roots per Plant	3.49	17.4	46.8	91.0
	Foliage Yield (t/ha)	40.4	13.9	10.3	34.7
	Biomass Yield (t/ha)	84.8	22.8	38.3	39.2
	Beta-carotene fwb (ppm)	8.46	-17.1	5.0	92.4
	DM (%)	24.0	-1.7	-12.9	2.6
	Root Iron Content in dwb (ppm)	21.7	-0.1	17.7	100.0

§ RYTHA, storage root yield in t/ha; NCRP, number of commercial storage roots per plant harvested; FYTHA, Foliage yield in t/ha; BYTHA, Biomass (roots and foliage) yield in t/ha; BC, beta-carotene root content on a fresh weight basis, DM, storage root dry matter content, FE, storage root Fe content on a dry weight basis; COOSU, sweetness taste score from 1- not sweet to 9- very sweet;

§§ Offspring family estimates WAE (n = 742), NSSP (n = 336), and HIFE (n = 272).

‡ Relative to 42 PJ', 42 PZ', 25 PJ'', 28 PZ'', 23 PJ''', and 23''' PZ parents for WAE, NSSP, and HIFE, respectively.

‡‡ Relative to widely adapted check clones 'Dagga' and 'Cemsa'.

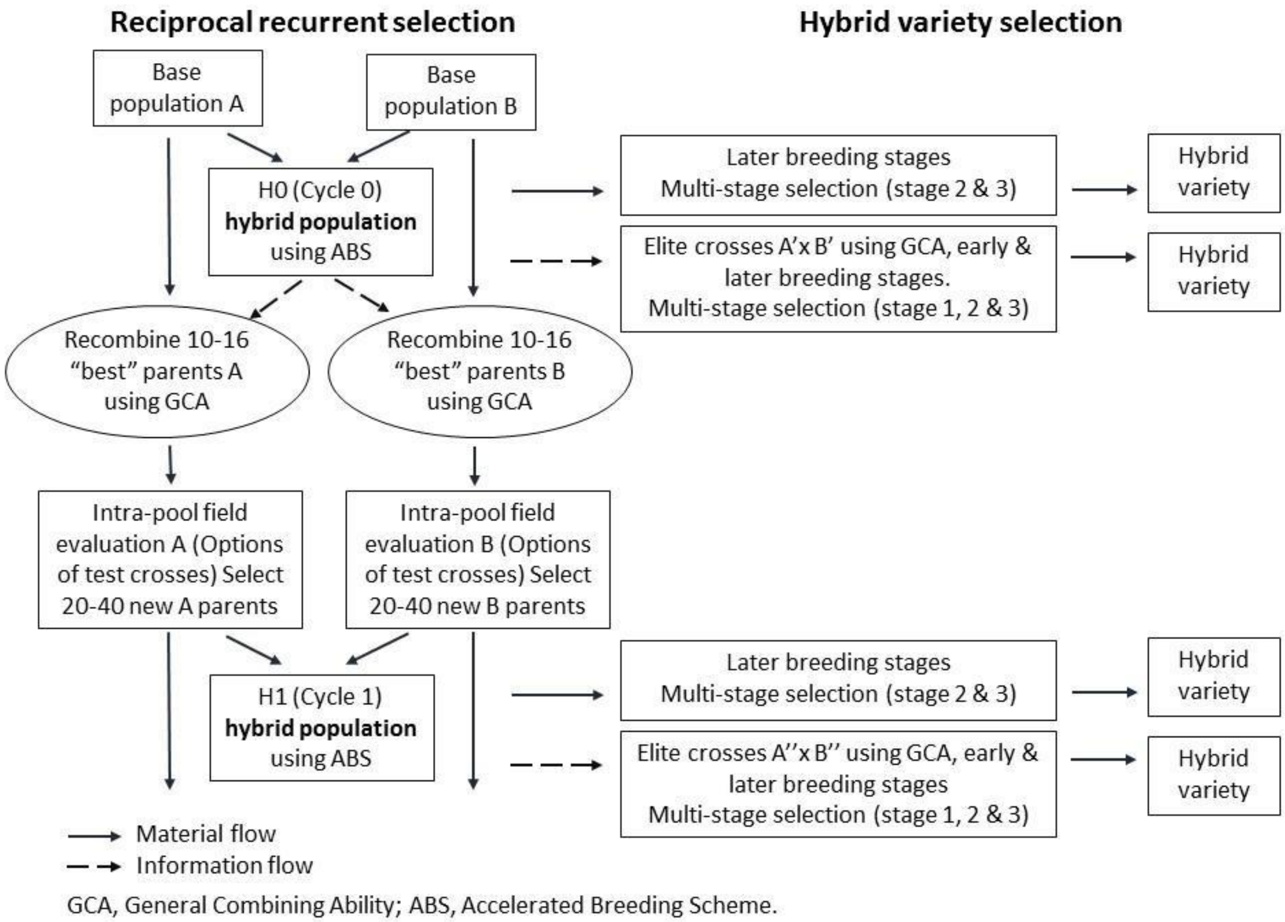

Figure 1. The new sweetpotato breeding concept at CIP - Developing hybrid populations and cultivars. Diverse aspects of the hybrid breeding approach are elsewhere described (David et al. 2018; Grüneberg et al. 2009, 2015; https://doi.org/10.13140/RG.2.2.13436.18569). The concept for sweetpotato is illustrated below, which describes CIP's approach to exploit heterosis, including RRS (left), elite crosses, and hybrid variety selection (right) –it is built on Gallais (2003). Best parents are selected based on their GCA. Note: Elite crosses (using parents exhibiting high GCA values) are being set up to increase GG and to exploit within family variation. This procedure is used at CIP–Peru based on hand crosses as well as CIP–Uganda as bi-parental isolation crosses. The latter is like "isos" established in corn breeding and uses open pollination among two parents, enabling large amounts of true seed from best combinations to be obtained without the need of large numbers of laborious hand crosses, which require skilled technicians. Populations from elite crossings shall be used in the "Sweet Gains" project to move with genomic selection into applied sweetpotato breeding.

Only the checks are replicated more often. Note these activities of selection in later breeding stages at CIP-HQ are funded by USAID. **On the basis of the results of model calculations, we only use two-step selection in later breeding stages to register and release genotypes**. Selections in later breeding stages are done with the BLUPs across traits via the Elston index (modified by r the number of key traits used: $\sqrt[r]{I_E}$), followed by additional discarding among top ranked clones (mainly on basis of yield performance). In our demonstration, the target is for the second selection step to select 32 clones for OFSP WAE, 16 clones OFSP LS after cooking, and 12 clones for OFSP HIFE to be evaluated at eight locations with the final target to register and disseminate five genotypes.[16]

[16] Varieties to replace are widely adapted OFSP such as 'Benjamin'/CIP 105085.2 in Peru and Tajikistan; 'Shokhin'/CIP106603.1 in Panama, Guatemala, Haiti, and Tajikistan; and 'Dagga'/CIP199062.1 in South Africa, Ghana, and Haiti.

Early breeding stages are in the process to change from the Westcott design to augmented p-rep design in which only the parental material is replicated. BLUPs are estimated for key traits (yield and quality traits including taste). Selections for later breeding stages are done with the BLUPs across traits via the Elston index with additional discarding among top ranked clones (mainly on basis of yield performance). Selections for new set of parents and elite crosses are done by calculating BLUPs in offspring clones into GCA values for parents and then using the Pesek Baker index with the square root of $\sqrt{Vg}$ for each trait as desired GG with modifications in the range of $\pm 2\sqrt{Vg}$. This procedure to select new parents and elite crosses is so far only used by the breeding platforms CIP-HQ and CIP-Uganda. Under the SweetGains project, this procedure to select parents and elite crosses shall be extended to other platforms.

3. GG studies and breeding progress with new sweetpotato varieties. In 2019, CIP-HQ re-analyzed the GG trials across breeding platforms which were carried out by modified demo trials (trials with varieties released across time), whose results were reported earlier. Table 2 shows results from GG studies for four climatic zones, mainly for normal harvest times (120 DAP) and early harvest times (90 DAP). The current GG for storage root yield range from 0.5% (West African Breeding Platform for 120 DAP) to 2.5% (Amazon Basin, Peru Program, 120 DAP harvest). For foliage yield, the annual GG ranges from -1.9% (West African Program, 120 DAP) to 1.2% (Southern African Breeding Platform). For root beta-carotene content, the GG range from 1.0% (Southern African Breeding Platform) to 6.0% (West African Breeding Platform).

Table 2. Annual genetic gains by regions estimated on basis of variety releases across two decades (updated October 2019, estimates by lsmeans followed by regression analysis).

Agro-ecological zone	Genetic gain parameters and year period considered	Storage root yield (90 days harvest) t/ha	Storage root yield (120 days harvest) t/ha	Foliage yield (90 days harvest) t/ha	Foliage yield (120 days harvest) t/ha	Harvest Index (120 days harvest %)
Arid Pacific	release period	1992-2014	1992-2014	1992-2014	1992-2014	1992-2014
coast	Baseline	5.1	10.1	43.1	52.4	15.8
Ng = 17	annual gain	0.29*	0.47*	-0.31$^{n.s.}$	-0.34$^{n.s.}$	0.70*
Ne = 3	predicted eoop[ǂ]	11.5	20.4	36.3	44.9	31.1
	est. gain eoop %	2.5%	2.3%	-0.9%	-0.8%	2.2%
Amazon	release period	1992-2014	1992-2014	1992-2014	1992-2014	1992-2014
basin[#]	Baseline	5.6	9.2	34.5	26.2	25.8
Ng=17	annual gain	0.30*	0.49*	0.04$^{n.s.}$	-0.02$^{n.s.}$	0.89*
Ne=6	predicted eoop[ǂ]	12.1	20.1	35.4	25.7	45.5
	est. gain eoop %	2.4%	2.5%	0.1%	-0.1%	2.0%
Southern	release period	n.a.	2000-2016	n.a.	2000-2016	2000-2016
Africa	Baseline	n.a.	7.1	n.a.	14.5	29.3
Ng=31	annual gain	n.a.	0.17*	n.a.	0.23*	0.21$^{n.s}$
Ne=16	predicted eoop	n.a.	9.8	n.a.	18.2	32.7
	est. gain eoop %	n.a.	1.7%	n.a.	1.2%	0.64%
East Africa	release period	n.a.	1995-2013	n.a.	1995-2013	1995-2013
Ng = 17	Baseline	n.a.	9.7	n.a	21.8	33.2
Ne = 6	annual gain	n.a.	0.40$^{n.s.}$	n.a	-0.05$^{n.s.}$	0.66$^{n.s}$
	predicted eoop	n.a.	16.9	n.a.	21.0	45.0
	est. gain eoop %	n.a.	2.4%	n.a.	-0.2%	1.46%
West Africa	release period	n.a.	1999-2015	n.a.	1999-2015	1999-2015
(Ghana[##])	Baseline	n.a.	7.6 (6.0)	n.a	15.6 (14.6)	30.3 (27.0)

Ng = 14 (10##)	annual gain	n.a.	0.04$^{n.s}$	n.a	-0.27$^{n.s}$	0.55$^{n.s}$
Ne = 9 (9##)			(0.35$^{n.s}$)		(-0.08 $^{n.s}$)	(1.22$^{n.s}$)
	predicted eoop	n.a.	8.3 (12.0)	n.a.	11.0 (13.2)	39.6 (47.7)
	est. gain eoop %	n.a.	0.5% (2.9%)	n.a.	-1.9% (-2.5%)	1.40% (2.57%)

Ng, number of genotypes; Ne, number of environments; n.p., so far not predicted; n.a., not available; n.s., not significant, .
ǂ eoop, end of observation period that is 2014, 2014, 2016, 2013, and 2015 for Arid Pacific coast, Amazon basin, Southern Africa, East Africa, West Africa (Ghana). # assumed to be transferable to other humid topical zones with high rainfall.
in brackets only Ghanaian genotypes, all genotypes from Burkina Faso and Nigeria excluded.

Table 2. continued.

Agro-ecological zone	Genetic gain parameters and year period considered	Biomass (120 days harvest t/ha)	Dry matter (120 days harvest %)	β-carotene (120 days harvest) mg / 100g root fresh weight	Iron (120 days harvest ppm root fwb	Zinc (120 days harvest ppm root fwb
Arid Pacific	release period	1992-2014	1992-2014	1992-2014	1992-2014	1992-2014
coast	Baseline	62.5	28.8	0.68	4.81	3.60
Ng = 17	annual gain	0.12 $^{n.s}$	-0.07$^{n.s}$	0.27*	0.01$^{n.s}$	0.01$^{n.s}$
Ne = 3	predicted eoopǂ	65.3	27.4	6.64	5.05	3.80
	est. gain eoop %	0.20%	-0.25%	4.1%	0.22%	0.24%
Amazon	release period	1992-2014	1992-2014	1992-2014	1992-2014	1992-2014
basin#	Baseline	35.4	31.5	0.92	5.50	4.13
Ng=17	annual gain	0.47*	-0.11$^{n.s}$	0.32*	-0.01$^{n.s}$	-0.01$^{n.s}$
Ne=6	predicted eoopǂ	45.7	29.1	7.87	5.26	3.89
	est. gain eoop %	1.0%	-0.37%	4.0%	-0.20%	-0.28%
Southern	release period	2000-2016	2000-2016	2000-2016	2000-2016	2000-2016
Africa	Baseline	21.5	30.4	4.6	5.73	3.53
Ng=31	annual gain	0.40*	0.07$^{n.s}$	0.05$^{n.s.}$	0.02$^{n.s}$	0.01$^{n.s}$
Ne=16	predicted eoop	27.9	31.6	5.42	6.03	3.64
	est. gain eoop %	1.43%	0.22%	1.0%	0.31%	0.19%
East Africa	release period	1995-2013	1995-2013	1995-2013	1995-2013	1995-2013
Ng = 17	Baseline	31.5	32.9	0.0	6.02	3.52
Ne = 6	annual gain	0.35$^{n.s}$	-0.12$^{n.s}$	0.35*	-0.07$^{n.s}$	-0.04$^{n.s}$
	predicted eoop	37.8	30.8	6.2	4.80	2.73
	est. gain eoop %	0.92%	-0.38%	5.6%	-1.42%	-1.63%
West Africa	release period	1999-2015	1999-2015	1999-2015	1999-2015	1999-2015
Ng = 14 (10##)	Baseline	23.3 (20.8)	30.2 (29.0)	0.0 (0.95)	5.20 (5.29)	2.87 (2.94)
Ne = 9 (9##)	annual gain	-0.23$^{n.s}$	-0.43$^{n.s}$	0.20$^{n.s}$	-0.04$^{n.s}$	-0.02$^{n.s}$
		(0.26$^{n.s}$)	(-0.16$^{n.s}$)	(-0.025$^{n.s}$)	(-0.05$^{.n.s}$)	(-0.03$^{.n.s}$)
	predicted eoop	19.4 (25.2)	22.9 (26.2)	3.3 (0.53)	4.59 (4.42)	2.61 (2.47)
	est. gain eoop %	-1.19%	-1.88%	6.0% (-4.6%)	-0.78%	-0.58%
		(1.03%)	(-0.63%)		(-1.15%)	(-1.15%)

Ng, number of genotypes; Ne, number of environments; n.p., so far not predicted; n.a., not available; a., available; n.s., not significant.
ǂ eoop, end of observation period that is 2014, 2014, 2016, 2013, and 2015 for Arid Pacific coast and Amazon basin, Southern Africa, East Africa, West Africa (Ghana).
assumed to be transferable to other humid topical zones with high rainfall.
in brackets only Ghanaian genotypes, all genotypes from Burkina Faso and Nigeria excluded.

4. Progress in SPVD resistance breeding. The milestone enhancing the frequency of SPVD resistance from less than 0.2% to 2% in breeding populations **at Namulonge fully achieved with more than 10% SPVD resistance in breeding populations.** This breakthrough in SPVD resistance was mainly reached by offspring-parent observation/analysis in which 5 x 3 crosses were selected for SPVD resistance and yield. These crosses became also bi-parental isolation crosses at the East African Breeding Platform which produces TS for East African countries. This is one out of four approaches which were used in SASHA2 to enhance the frequency of SPVD resistance from less than 0.2% to more than 2%. However, this so-called approach 4 is also by far the most complex approach and is reported under breeding at the East African Breeding Platform in this report. The other approaches made progress but have not reached a point at which the results could be implemented in applied breeding at a platform. These remaining three approaches are reported here, in order from least to most complex.

Approach 1: Search for less SPVD susceptibility in advanced breeding lines and varieties with good agronomic performance followed by intensive recombination. Advanced breeding clones with observed resistance to SPVD (from historical data in case of SPVD disasters in field experiments in Peru) were selected and crossed with six important orange-fleshed Peruvian varieties. All selected clones were at least evaluated across 3 years in environments with high SPVD pressure at the Peruvian coast.

TS from these crossing (Appendix C1.2) were sent to Ghana and evaluated in high virus pressure Southern Ghana for SPVD resistance (3,060 genotypes) and in the low virus pressure Northern Ghana (2,414 genotypes) for weevil tolerance. Southern Ghana (Kumasi) **found a frequency of 3.4% SPVD resistance/tolerance under field conditions** (Appendix C1.3)**.** On the basis of yield and SPVD performance, 65 clones were selected for the next multi-stage selection step. The evaluation in Northern Ghana at Nyakpala emphasized selection of material that also had tolerance to weevil damage and found **corresponds to a frequency of 7.1% weevil resistance/tolerance under field conditions** (Appendix C1.3). On the basis of yield performance and weevil resistance/tolerance, 141 clones were selected for the next multi-stage selection step.

The search for less SPVD susceptibility in advanced breeding lines and varieties with good agronomic performance followed by intensive recombination is also an approach which can be successfully used to breed for SPVD resistance/ tolerance with the expectation of about 3-4% SPVD resistance/tolerance after the first breeding stage. In contrast, with the approach of offspring parent analysis and elite crossings/bi-parental isolation crossings in Uganda at Namulonge (Approach 4 implemented in the East African Breeding Platform), about 30% of the material exhibited SPVD resistance/ tolerance at the first selection stage.

Approach 2: Pre-breeding with germplasm resources exhibiting confirmed SPVD resistance associated with weak agronomic performance. Details on the background of this approach undertaken first under screenhouse conditions and then in the field are provided in Appendix C1. The results of screenhouse and field tests combined showed that screenhouse test with ELISA tests alone—even with grafting on infected material, two plant replications, and two repeated measurements—was not enough to determine whether a clone is resistant or not. This is particularly relevant to know for molecular marker studies for SPVD resistance. In fact, only one clone with desirable agronomic characteristics and a certain degree of resistance[17] was observed (VZ08.290 with yield of 28.9 t/ha across both locations and 8.39 mg beta-carotene per 100 g of raw fresh weight of sweetpotato roots).

We conclude that pre-breeding with a combination of screenhouse/laboratory with ELISA testing (to confirm virus presence), followed by testing under field conditions, is a tool for SPVD selection in breeding with a success rate of approximately 2% to find resistances for SPVD. However, the chances to find SPVD resistance in combination with good agronomic performance is very low (in this study only 1 out of 455 clones). However, at the end of SASHA2, we delivered 10 parents in which offspring is segregating or is entirely resistant to SPVD (e.g., selfing of CIP-107729.9 [VJ08.330]). In SASHA2 these parents have been recombined in a complete diallelic cross with a production of 21,913 TS and genotypes, respectively (100 potential families, 89 families with seed, 85 families with more than 3 seeds) (see Appendix C1 for details). We now aim to identify (1) more resistant clones in offspring and, even more importantly, (2) 2–3 families suitable for finding validated marker associations for SPVD and other genomic studies on virus resistance. These parents have proven to provide offspring with resistance to SPCSV in forced (grafting) and natural (vectors in field) infection. **The new pre-breeding population was named PV19 and used for *in vitro* germination. About 2,000 genotypes will be tested for SPVD resistance rapidly in the high virus pressure zones in the fields at Namulonge in Uganda** and under controlled screenhouse conditions/ELISA laboratory tests at CIP-HQ under the upcoming SweetGains project.

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[17] A certain degree of resistance was defined as no virus detection when cultivated in Huaral (arid Pacific coast) but SPCSV was detected in it in San Ramon (humid tropics) but with no clear virus symptoms.

Approach 3: Identification of molecular marker associations and validation. The approach to identify molecular markers for applied SPVD resistance breeding has not been successful. **All marker associations failed so far in validation**, and new DArT markers found in association with SPVD in population VZ08 have so far not been validated (Appendix C1 for details). However, we argue that this does not merit further investment at the present time because to the lack of genetic diversity among the few resistant clones identified to date. This leads to the markers falsely declaring a clone to be virus resistant, when in fact the marker is just detecting the family linkage between the related clones. Instead, use of bi-parental mapping populations would be required, but at least an estimated 20% of offspring from these parents must exhibit virus resistance for meaningful segregation to occur.

Breeding in East and Central Africa (details in Appendix C2).

MS 1.1.1. Studies demonstrating that significant GG (2% per year in yield) can be achieved in 2 years in early generations and 4 years for selected varieties. In field experiments conducted in 2015B and 2016A seasons, sweetpotato breeding progress made in Uganda since 1995 was estimated using the first modern-bred sweetpotato variety, 'Sowola'. Data of 14 sweetpotato varieties were used for the comparison, including 'Sowola', 'NASPOT 1', 'NASPOT 2', 'NASPOT 3', 'NASPOT 4', 'NASPOT 5', 'NASPOT 6', 'NASPOT 7', 'NASPOT 8', 'NASPOT 9 O' ('Vita'), 'NASPOT 10 O' ('Kabode'), 'NASPOT 11', 'NASPOT 12 O', and 'NASPOT 13 O' (Mwanga et al. 2016). The effect of breeding was estimated as GG for storage root yield (in t/ha per year) by regressing the mean of each character for each variety against the year of release of that variety. There is an annual rate of increase of storage root yield, estimated by the regression coefficient of 0.40 t/ha per year (Table 2), clearly indicating that breeding efforts in Uganda have had significant improvement on storage root yield over the years. GG have also been obtained β-carotene content (0.35 mg/100g, FWB per year). However, dry matter (DM) content has been reducing, respectively, during the breeding process (-0.12% annually). This is driven by the baseline variety, 'Sowola', being cream-fleshed variety with high DM (34%). But five of the released varieties are orange-fleshed, hence, with lower average DM contents and thus the negative GG for DM content.

MS 1.1.3. At least 14 African sweetpotato breeders breed using the latest knowledge and efficient methods. Fourteen African countries made strides in sweetpotato breeding. Thirteen established crossing blocks for some period during SASHA and 9 implemented the ABS or modified ABS while interacting with sweetpotato breeders across the globe through the SpeedBreeders and genomics sweetpotato CoP. Three countries (Madagascar, Kenya, and Malawi) used ABS principles to select varieties from TS. Sweetpotato breeders from 17 SSA countries participated in at least one of the annual Sweetpotato SpeedBreeders meetings, trained in modern breeding techniques at BecA, Nairobi, or University of Ghent (during SASHA1) or during their MSc or PhD training conducted sweetpotato breeding trials in their home country or in another country. From 2014 to 2019, 13 SSA countries released 88 sweetpotato varieties, of which 53 were OFSP (60%), 8 were purple-fleshed (PFSP) (9%), and 27 were white- or yellow-fleshed sweetpotato (YFSP) (31%). In terms of origin, 42 varieties (48%) were bred in the country that released them; 11 (12%) were selected from seed from an African population development program; 21 (24%) were varieties obtained from another African country; 9 (10%) were African landraces; and only 5 (6%) were varieties imported from outside of the continent. Given the high prevalence of vitamin A deficiency in SSA among young children (48%), 14 sweetpotato breeders committed in 2014 to mainstream the beta-carotene trait into their program, which they defined as assuring that at least 50% of all varieties submitted for release would be orange-fleshed. Clearly, that commitment has been kept.

Sweetpotato breeding since 2009 has undergone a revolutionary change (Grüneberg et al. 2015; Mwanga et al. 2017), due to the support provided by SASHA and breeding grants provided by the Alliance for a Green Revolution in Africa (AGRA) to nine national sweetpotato breeding programs. Figure 2 compares the varieties released from 1978 to 2008 (30 years) and the two phases of SASHA (2009–2014, 2015–2019). There has been a shift from selecting among introduced clones/varieties from outside of Africa to breeding *in* Africa. There has been a major switch among most African breeders from the traditional breeding scheme (taking 8–10 years to release) to the ABS (taking 4–5 years to release). There has been a decrease in the release of landraces, but sharing of varieties among SSA countries remains a utilized strategy. In the past 5 years, selecting varieties from seed produced from population development programs in Africa has emerged as a new strategy.

Replacing CloneSelector to improve breeding efficiency, the highly interactive data analysis platform (HIDAP) was launched in June 2017 in Kigali, Rwanda. HIDAP was integrated with the SweetPotatoBase developed by the GT4SP for data curation, and the Fieldbook App for data collection (Appendix E for details). Under SASHA2, Astère Bararyenya from Burundi, a country where sweetpotato is the most important food crop, completed his doctoral research investigating the "piecemeal harvesting" trait, or continuous root formation and bulking in sweetpotato, a trait highly preferred by smallholder farmers (Bararyenya et al. 2019).

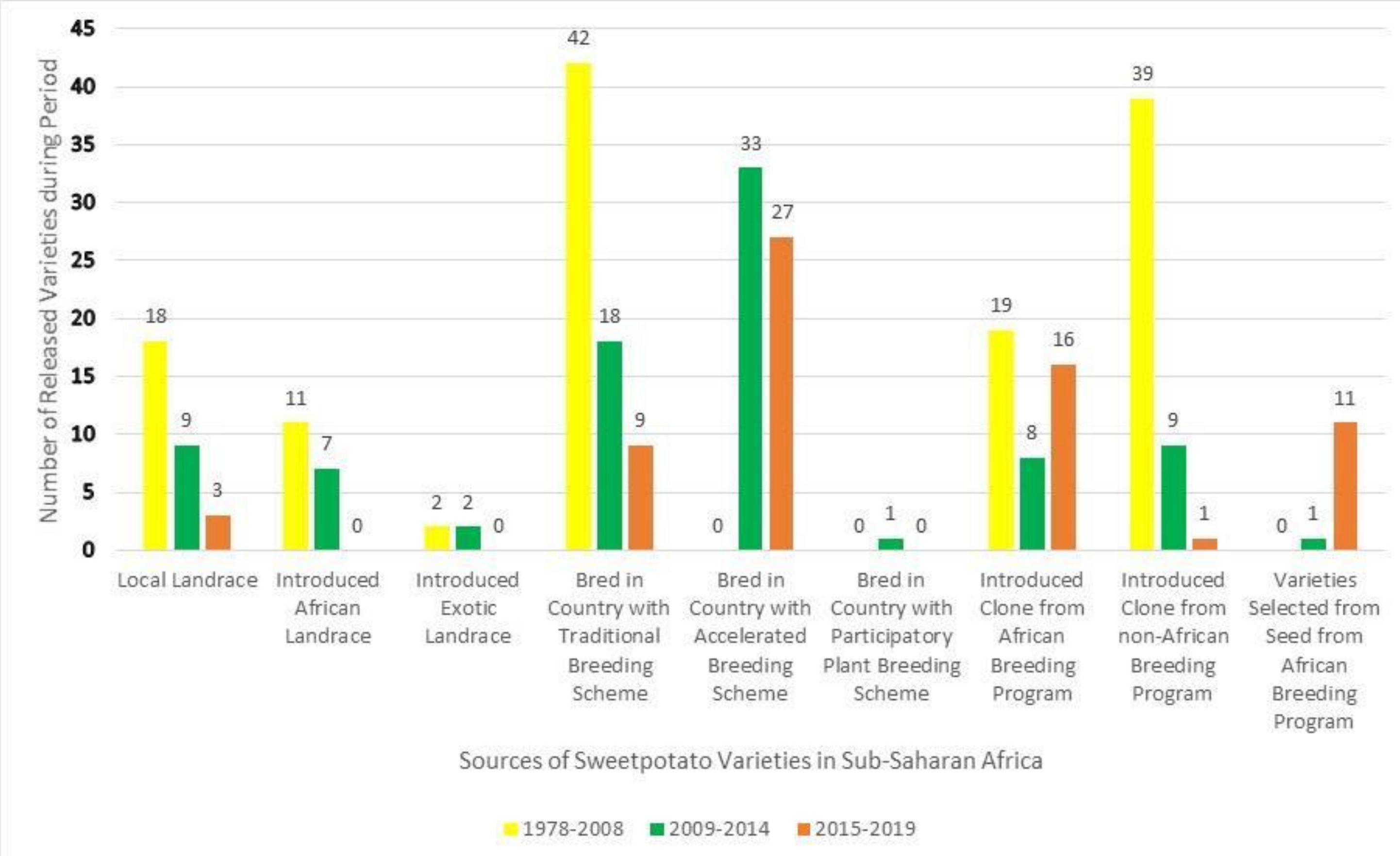


Figure 2. Number and sources of sweetpotato varieties released in 16 SSA countries over three time periods.

MS 1.2.1. At least 250,000 seeds with increased frequencies of resistance to SPVD (2–10%) disseminated to at least 10 NARS partners. The East and Central Africa Breeding Platform disseminated 303,047 seeds from 320 families to 10 countries during the SASHA2 period. TS was generated by poly-crosses and planned controlled crosses from populations with increased frequencies of resistance to SPVD as the years progress. The frequency of resistant genotypes to SPVD calculated as the percentage of genotypes with a SPVD score below 3 increased. (Proof of concept is provided in Appendix C2.) Elite cross combinations produced progeny with SPVD-resistant genotype frequency of 23%. This is an increase of 13% in the new population compared with the progeny of the original population (50 parents in population Uganda A, and 80 parents in population Uganda B).

MS 1.2.3. Selected hybrid progeny demonstrating yield increases of 10–20% from populations with SPVD resistance. HEBS were proposed in SASHA2 as a strategy for increasing sweetpotato productivity. The objective of the heterosis study was to estimate yield gains in early-generation sweetpotato clones derived from a breeding scheme that entailed inter- and intra-population crosses of two East African gene pools (Population Uganda A with 50 parents and Population Uganda B with 80 parents from which an 8x8 cross was made at Namulonge) hypothesized to be mutually heterotic. The populations forming the two gene pools were assembled from germplasm sourced from different areas across Uganda and a few selected introductions. They were initially separated using 31 SSR markers (David et al. 2018). Crossing parents from the two distinct populations resulted in a 16% storage root increment. BLUP estimates of storage root yield for elite crosses was 13.7 t/ha compared with 8.1 t/ha for the entire population.

On the basis of the offspring performance in the B80 x A50 trial, the best 20 parents from population A and the best 20 parents from population B were selected. These parents are high SPVD field-resistant progenitors with good yield combining ability and will be used as the basic set to start RRS to exploit heterosis in a systematic way. A total of 11,454 clones were evaluated in multiple seasons at multiple sites. Selection was based on scores for SPVD (score below 4), Alternaria blight (score below 3), vine vigor (score above 6), uniform root size (score below 5), number of commercial roots (above 2), and commercial root yield (above 12 t/ha).

Breeding in Southern Africa (Details in Appendix C3).

MS 1.1.1. Studies demonstrating achieving significant GG (2% per year in yield) in 2 years in early generations and 4 years for selected varieties. A total of 179 trials in different categories (seedling nurseries, observation trials, preliminary trials, advanced trials, and other specialized trials like GG and heterosis trials) were successfully evaluated during the 5-year period. Side-by-side trials of released varieties to measure GG showed a gain of 0.17 t/ha/year of storage root yield on annual basis and 0.23 t/ha/year for vine yield realized annually since 2000. In early breeding trials, GG varying from 0.5 to 2.4 t/ha/cycle were observed for storage root yield and 0.3 to 1.8 t/ha/cycle for vine yield. Micronutrients such as Fe and Zn increased by 0.02 and 0.031 mg/100g (dwb), respectively, per breeding cycle in early-generation Umbeluzi populations, whereas the increases were slightly higher in the early-generation populations at Gurué (0.08 and 0.04 mg/100g (dwb), respectively). In 2016, seven varieties (three purple-fleshed, two dual-purpose orange-fleshed, and two orange-fleshed) were released in Mozambique (Andrade et al. 2016b) which were superior to varieties released in 2011 (Andrade et al. 2016a) in terms of DM content. In November 2019, two deep purple-fleshed (higher in anthocyanins content, storage root yield, and vine vigor than those released in 2016) and three orange-fleshed clones (superior in storage root yield under both optimum and drought conditions, root shapes and sizes, and vine vigor compared with varieties released in 2011 and 2016) were released.

In experiments which used clones derived from TS of the CIP-Uganda program to prove the heterosis concepts under drought conditions, the heterosis increments in the A x B crosses were clearly higher than the A x A and B x B crosses under the drought treatments for storage root and foliage yield. The heterosis increments were 10.4% for storage root yield and 20.7% for foliage yield under drought treatments.

MS 1.3.1. At least 150,000 seeds with drought tolerance genes disseminated to at least 10 NARS partners in SSA and Southwest and Central Asia (SWCA). Two distinct OFSP breeding populations were maintained in Mozambique, with separate crossings blocks established at *Instituto de Investigação Agrária de Moçambique* (IIAM) stations in Gurué and Umbeluzi. An additional "mini-block" for PFSP clones was also maintained in Gurué. The major theme of this breeding program is drought tolerance, and all parents for OFSP improvement program were selected based on history of drought tolerance, beta-carotene content, DM levels, and Fe and Zn contents. A total of 234,962 TS harvested in the three crossing blocks were distributed to partners in Southern Africa, East and Central Africa, West Africa, Southeast Asia, Brazil, and the USA. Over the 5-year period, TS was distributed as follows: Malawi (n=19,285), Madagascar (n=14,285), South Africa (n=9,500), Zambia (n=14,285), and Mozambique (n=40,642) in Southern Africa; Ethiopia (n=9,285), Kenya (n=17,570), Uganda (n=6,000), Rwanda (n=17,185), and Burundi (n=9,000); Burkina Faso (n=12,285), Ghana (n=18,120), Nigeria (n=14,380), and Ivory Coast (n=9,285) in West Africa; Brazil (n=5,000) in South America; Bangladesh (n=6,285) and India (n=6,285) in Southeast Asia; and the USA (n=6,285). Bangladesh also received TS from purple-fleshed crossing block. In Mozambique, 10,000 TS came from the mini-block with purple-fleshed clones. In addition, all seeds were germinated and evaluated in different trials, with some trials conferring early maturity as an important drought tolerance trait (Alvaro et al. 2017). In other trials, some clones exhibit vine vigor (thickness and length) as an important morphological trait for adaptation in drought-prone environments (Andrade et al. 2017; Andrade et al. 2016c; Makunde et al. 2017). More than 300 t of vine cuttings were distributed by CIP-led projects, namely SUSTAIN, VISTA, OFDA, and IFAD during their start-up phases and NARS partners in Malawi, Madagascar, and South Africa.

MS 1.3.3. Hybrid progeny exhibiting yield increases of 10–20% in hybrids from populations with drought tolerant and enhanced efficiency for drought tolerance breeding. In 2018 a diversity analysis on 138 parents (68 parents from Umbeluzi and 70 parents from Gurué) was done using 38 SSR markers. Two distinct gene pools were defined as Umbeluzi and Gurué populations with six parents from Umbeluzi assigned to Gurué population and four Gurué parents assigned to Umbeluzi populations. These admixtures were 199062.1, 'Tio Joe', 'Esther', 'Resisto', 'Ininda', and 'Sumaia'. These clones are released varieties, and some originated in Umbeluzi but have been utilized as parents in Gurué or vice-versa. Based on the SSR marker data, 50 parents from each population were selected to constitute a crossing block, to generate hybrids from the two distinct gene pools. For the first time, a crossing block with 50 parents from Umbeluzi and another 50 parents from Gurué was established at Umbeluzi in March 2019, following the diallel mating design. In 2019 the amount botanical seed harvested was 37,320 seeds from 6,000 bi-parental families.

In experiments which had clones from the CIP-Uganda program to prove the heterosis concepts under drought conditions, the heterosis increments in the inter-gene pool A x B crosses were clearly higher than the intra-gene pools A x A and B x B crosses under the drought treatments for storage root and foliage yield. The heterosis increments were 10.4% for storage root yield and 20.7% for foliage yield under drought treatments.

MS 1.3.4. Clones with 200% RDA for young children of pro-vitamin A, 25% RDA of iron, and 35% RDA of zinc under high intakes. Three crossing blocks were maintained at IIAM sites in Gurué and Umbeluzi. The parents were continuously selected based history of drought tolerance, beta-carotene (BC) content, DM levels, Fe and Zn contents, starch, and reducing sugars using the recurrent selection method. Ninety percent of the 56,844 clones processed in the quality laboratory had complete data sets (DM, BC, Fe, Zn, starch, and the reducing sugars). From 2016 the Southern African Sweetpotato Platform in Mozambique used near-infrared spectroscopy (NIRS) to initially select 300 OFSP clones with the highest Fe content. These 300 clones were then sent to CIP-HQ, where they were analyzed using the more accurate x-ray fluorescence technology (XRF) for more precise Fe measurements. The top 30 OFSP clones in terms of Fe content were then sent to a lab in Australia, which analyzed the samples with an inductively coupled plasma (ICP). The ICP can determine whether contaminants such as aluminum are present. If contaminants are present, the Fe reading cannot be considered valid. One clone (MUSG1 5052-2) had 44 ppm Fe (dwb), over twice as high as typical values around 18 ppm and had no contaminants. Hence, it was selected for use in a trial to assess bioavailability of Fe in Malawi in 2019. The trial was conducted by ETH-Zurich and the College of Medicine in Malawi.

A total of 235 kg of roots of MUSG15052-2, the enhanced Fe clone and 200kg of 'Irene', the check clone, were sent to Malawi, Zomba district, to study bioavailability of Fe. The test meal-feeding with 25 women of reproductive age started on February 25, 2019 and was completed on 22 March. The test meal size was 400 g per feeding; 250 test meals were prepared for each variety and these 400 g portions of OFSP purée prepared. On a fwb, the enhanced Fe OFSP clone had 12.4 µg Fe/g, <0.1 µg phytic acid/g, and 14 µg ascorbic acid/g compared with a typical OFSP variety ('Irene'), with a lower concentration of Fe (6.4 µg Fe/g, <0.1 µg phytic acid/g, 46 µg ascorbic acid/g). Results showed that fractional Fe absorption from both OFSP test meal types was 5.8%, resulting in a total daily Fe absorption of 0.20 mg from the 'Irene' and 0.33 mg from MUSG15052-2 ($p<0.001$). However, fractional Fe absorption varied based on initial ferritin status of the women. Those with low status absorbed 8.1%; those with adequate status, only 3.6%. The enhanced Fe clone provided 0.09 mg of absorbable Fe/100 g of cooked OFSP. This would supply 14.1% of the target 50% EAR for absorbable Fe for children 1.5–4.5 years of age and 6.4% for young women of reproductive age. The study implied that (1) the high polyphenol content of both varieties inhibited Fe absorption, (2) the low vitamin C content did not enhance Fe absorption, and (3) Fe was better absorbed by those who need it the most, suggesting that biofortification is a viable tool to improve human nutrition. However, additional cycles to raise the Fe content will be need to reach 50% EAR target/100 g to be classified as biofortified. The breeding program will explore reducing polyphenol content in sweetpotato and work with partners to identify specific polyphenols responsible for the inhibition.

Breeding in West Africa (Details in Appendix C4). The Sweetpotato Support Platform for West Africa (SSP-WA) is based at the CSIR-Crops Research Institute (CRI), Kumasi (Fumesua). In close partnership with CSIR-CRI and CSIR-Savanna Agricultural Research Institute (SARI), Tamale (Nyankpala), the breeding program targets regions of Ghana where sweetpotato is important (Bidzaken et al. 2014). It covers the major agro-ecological zones of southern Ghana, characterized by coastal Savanna and Forest zones with weakly bimodal rainfall and northern Ghana, known as Guinea Savanna with unimodal rainfall. These zones in Ghana are broadly representative of the lowland tropical agro-ecologies across West Africa, where Nigeria and Burkina Faso represent important SASHA target countries. The SSP-WA has the development of LS varieties as its signature focus (Carey et al. 2019), given the significant potential that these types may have for use as a staple menu item in West African diets as snacks (fried, roasted, or boiled) or for processing into convenient products to serve rapidly growing urban populations (44% of West Africans already live in urban areas). This focus, however, is not exclusive. We also breed for various quality types and flesh colors and disease resistance (Baafi et al. 2016a, 2016b). In Ghana (Baafi et al. 2015) and throughout the region, there is growing demand for OFSP in both fresh and processed (purée) forms for local, regional, and global markets.

MS 1.4.1. At least 100,000 seeds with less-sweet taste genes disseminated to at least 10 NARS partners in SSA and SWCA. Hybridization of sweetpotato in West Africa has been challenging because (1) some sweetpotato parental genotypes are slow to flower, (2) flowers often abort due to unfavorable temperatures during the dry season, and (3) insect pests destroy pollinated flowers in the open field. In 2016 a technician from CIP-HQ introduced us to making controlled crosses in the screenhouse using flowering vines brought in from the field. Since then, we have produced 86,362 seeds from controlled crosses and 154,436 open pollinated seeds from flowers that had already been pollinated at the time picking the flowering vines to take into the screenhouse. Notably our breeding site in the North, where pest pressure is considerably lower than

Fumesua, has the potential for generating polycross seed, presenting a location for future production of isolated paired elite crosses. We started tracking crossing and seed production at the SSP-WA in 2018 using barcode labels, ODK forms, and R scripts to produce daily counts and weekly summaries of crosses made and seeds produced. This simple suite of tools has been shared with colleagues from other support platforms and NARS, and optimal integration with SweetPotatoBase is being explored. We have been able to share 48,810 seeds with 10 NARS programs (Burkina Faso, Burundi, Ethiopia, Ivory Coast, Madagascar, Malawi, Nigeria, Rwanda, South Africa, and Zambia) during the SASHA2; 42,030 of these from the 2018 crossing block shared in 2019. This year we expect to produce 30,000 seeds from controlled pollinations and 100,000 open pollinated seeds (details of 2019 seed production provided in Appendix C4). We anticipate using these in collaborative trials under SweetGains in West Africa. With the distribution of 50,000 seeds to other programs in 2020, we will achieve this milestone during the first year of SweetGains.

MS 1.4.3. Hybrid progeny with yield increases of 10–20% from less-sweet, less perishable parents. Our ABS runs parallel selection efforts for adaptation to the northern and southern (high virus pressure) agro-ecologies, with routine evaluation across regions at the preliminary yield trial stage. With two trial seasons per year, time to release can be 4 years or less while still satisfying requirements of Ghanaian release committees for 2 years of data obtained on-station and on-farm. The strategy of separating environments, begun in 2015, is clearly justified as revealed by stability analysis of genotypes selected in the two zones and by GXE analysis (manuscript led by Dr. Jolien Swanckaert accepted by *Crop Science;* additional information in Appendix C4). Progress has been made in the northern savanna zone, and four high- yielding, LS clones selected from SSP-WA seed germinated in 2014, were released by CSIR-SARI with CIP in January 2020. Performance of these new varieties is presented in detail in Appendix C4. Southern-selected genotypes are currently in year 2 on-farm trials, with potential for release later in 2020.

With the positive results emerging from the heterosis experiments in other countries, the Ghana team began a diversity assessment in 2017 to be able to divide their breeding population into mutually heterotic populations to apply HEBS RRS going forward. We have done this diversity assessment based on DNA from 60 parents in the Ghana breeding population. The DArTSeq method implemented by BecA’s Integrated Genotyping Service and Support platform (IGSS) was used and a set of 205 high-quality (hard filtered), single nucleotide polymorphic (SNP) markers were used to estimate allele sharing distance (ASD) of the Ghana breeding population. ASD was used to detect sweetpotato population stratification in Ghana using the using DARwin 6.0.21 tree function. The parents were grouped into three clusters (cluster I with 22 genotypes, cluster II with 26 genotypes, and cluster III with 12 genotypes). Cluster I and cluster II were considered as the core of two pseudo-heterotic groups, and pedigree information of the parental genotypes in cluster III was used to regroup them into either cluster I or II to be used in RRS (Appendix report C4 provides details).

Breeding for quality is a central element of our work at the SSP-WA, with the development of non-sweet or LS types for staple (Ousu Mensah et al. 2016) and alternative uses. To help us in our efforts to effectively breed to meet consumer preference in Ghana, we turned to the tools of food science. We recruited and trained a sensory panel of 12 individuals with the ability to precisely distinguish sensory characteristics (appearance, taste, texture, mouthfeel, and aroma). We then used this panel to develop vocabularies (lexicons) to describe sensory attributes of boiled and fried sweetpotato using a broad range of sweetpotato germplasm available to us. We included yam as a reference, given its importance in Ghana, and similarity of use to sweetpotato in boiled or fried forms. Our lexicon for boiled sweetpotato currently has 30 terms, whereas that for fried sweetpotato has 22 terms for describing appearance, texture (touch), mouthfeel, aroma, and taste attributes.

Comparison of trained sensory panel results with sugar content in cooked sweetpotato that we routinely determine using our NIRS revealed that there was little relationship between sugary sweetness evaluated by the panel and the sugar content of the genotypes evaluated. This means that our instrumental sugar data were not really helping us to identify genotypes that were more or less sugary. This does not mean that sugars have no importance to sweetpotato sensory qualities, since we know that reducing sugars contribute to browning during frying of sweetpotato, and aromatic compounds produced from sugars during cooking contribute strongly to aroma and perhaps taste. While we considered that it was reasonable to adjust our sugar data (determined on a dwb) to their fresh-weight equivalent when looking at the relationship of sugar content to taste, analysis of starch and sugar results from raw and boiled sweetpotato samples taken from trials conducted across environments revealed far cleaner data (and the absence of genotype x environment interactions) when results were analyzed on a dwb. Furthermore, while starch declined significantly during cooking, there was not a proportional increase in maltose content, indicating that a large fraction of the starch was not fully hydrolyzed on cooking. Yet this probably remained as oligosaccharides or other starch residues that are likely contributing significantly to sensory quality, but which we have not previously considered in our analyses.

Consumer sensory evaluations of a set of boiled and fried sweetpotato were conducted in urban centers including Accra and smaller towns in regions where sweetpotato is important to try to relate panel described attributes to consumer preferences. For boiled sweetpotato, generally consumers preferred the moderately sweet 'Okumkom', followed by the sweeter high DM OFSP 'Nan', and the LS PGA14372-3, with the least sweet genotypes, 'Bohye' and PGA14351-4 least preferred. Clusters of preference could be distinguished, however, with some consumers preferring the LS types. Mapping the clusters to the sensorial space generated by the trained panel provided information on the sensory attributes (from the lexicon) that helped to distinguish the preference clusters. One cluster was associated with the OFSP variety 'Nan' and 13 traits from the lexicon, including appearance (1), aroma (4), mouthfeel (4), texture (3), and the basic taste, sweetness (1), contributed more strongly than others to differentiate this cluster. Another preference cluster was associated with the LS clone PGA14351-4 and 7 different traits, including appearance (3), texture (3), and the basic taste *umami,*[18] contributed strongly to defining this cluster. For fried sweetpotato, 'Nan' was preferred over other genotypes, with appearance contributing heavily to its evaluation. Preference clusters for fried sweetpotato were associated with the contrasting genotypes 'Nan' and 'Bohye', with 10 traits contributing strongly to the first cluster and 8 different traits to the second. Results from the sensory and sugar analyses related to quality are found in Appendix C4.

Given the importance of fried sweetpotato in West Africa, and the commitment of CIP and SASHA to contribute to the RTBfoods project, managed by CIRAD, we conducted work to develop fried product profiles using the multidisciplinary RTBfoods methodology in two states in Nigeria and one region of Ghana. The qualitative work included gender-sensitive stakeholder interviews as well as detailed evaluations with expert processors and consumer sensory analyses using preferred and less-preferred genotypes to provide contrasts in order to elucidate the preferred product profile for fried sweetpotato. Together the results, which are undergoing analysis, are providing a clear picture of the importance of fried sweetpotato in the areas studied and of the desired attributes in a fried sweetpotato which will help greatly in targeting breeding efforts for this product. A preliminary description of the study and fried sweetpotato product profile emerging from the study are presented in Appendix C4.1. A comprehensive milestone report was submitted in January 2020.

B. RP2: Weevil Resistance (refer to the Year 3 SASHA2, Appendix D for the detailed report)

Weevils, *Cylas puncticollis* and *C. brunneus*, are responsible for 28% of crop losses in Uganda, according to a farmer survey (Kiiza et al. 2009). Currently, there is little farmers can do when weevils infest their fields, other than to quickly harvest and salvage what is left of their crop. In addition, one of our studies has also highlighted a potential health threat when farmers consume the undamaged parts of weevil-infected sweetpotato storage roots due to high accumulation of plant toxins. Our goal was to have proof-of-concept of weevil resistance in sweetpotato roots using a transgenic approach. There were two major milestones representing distinct approaches to tackling the problem. Unfortunately, we concluded that the *Bt* approach has not succeeded and this research was concluded in 2017. Unfortunately, so far in the ongoing battle against the weevil, the weevil is winning.

MS 2.1.4. Bt Approach: Mortality assessment for each transgenic event with enough Cry protein to expect efficacy. We introduced synthetic *cry* genes that produce proteins with activity against sweetpotato weevils into various sweetpotato varieties, including some grown in SSA (i.e., 'Jewel', 'Jonathan', 'Huachano', an unknown variety, and 'Imby') after improving sweetpotato regeneration protocols (Manrique-Trujillo et al. 2013). Two series of gene constructs were used to generate more than 100 transgenic events at the ABL at CIP-HQ and the DDPSC in the USA. We used a whole-storage roots bioassays to test activity against weevils (Runyararo et al. 2013). A first screening of storage roots for apparent difference in weevil adult emergence led to the identification of a small number (12) of promising events.

Out of 12 transgenic events to be tested for validation, 8 were using storage roots provided by the DDPSC team in the USA. Two additional transgenic events not tested before were included as well; 4 have shown differences with the untransformed storage roots. The observation that 5 transgenic events with previous observation "no damages" were in this repetition not different from the untransformed storage roots confirms previous suspicion that the bioassay could identify false resistant materials. However, it does not rule out that those transgenic events with apparent difference in this second repetition are not resistant. We decided to continue this experiment with a new production of storage roots and bioassay at BecA. All the transgenic events tested in this third bioassay turned out to have either nonsignificant differences or no differences at all with the untransformed materials. Hence, it appears more clearly now that none of the sweetpotato transgenic events have an accumulation of *cry* protein in their storage roots at a level high enough to confer full weevil protection. It is possible,

[18] Umami is one of the five basic tastes, described as savory, characteristic of broths and cooked meats.

however, that some of the events with apparent differences in our bioassay may display field resistance under low-level infestation.

MS2.2.2. RNAi Approach: Efficacy data for several dsRNA (single and in combination) against weevil larvae. An RNAi strategy was developed to complement the *Bt* strategy. Our partners at the University of Ghent identified three target genes that gave good mortality results for both weevil species using nano-injections of dsRNA, soaking, and artificial diets: Proteasome 20 kD subunit, ribosomal protein S13e, and *snf7* genes. Five hairpin gene constructs were designed based on Prot20kd and snf7 from *C. puncticollis* (Cp) and *C. brunneus* (Cb) in single and double combinations (two fragments in sense and two in the anti-sense separated by an intron). All hairpin genes are driven by the double enhancer 35s promoter, use the 5'UTR of PVA, intron from catalase gene, and the nos gene poly-adenylation signal sequence. These genes are inserted into a pCAMBIA backbone vector.

Two gene constructs from 'Jonathan' were used to produce transgenic events: (1) pUG01 contains the ds-snf7 (Cp24) hairpin targeting *Cylas puncticollis* and (2) pUG04 contains ds-Prot20Kd (Cb12) hairpin targeting *C. brunneus*.

At the ABL, we used the best genotype for genetic transformation ('Jonathan') using *Agrobacterium tumefaciens* and somatic embryogenesis methods which were previously optimized (Manrique-Trujillo et al. 2013). Of 4,800 explants (leaves with petioles) infected with pUG01, 71 regenerated on media with 25 and 50 mg/L kanamycin; 169 were obtained from 3,672 explants infected with pUG04. However, the use of higher concentration of kanamycin (100 mg/L) did not confirm these regenerants as resistant. Attempts to isolate transgenic events failed**.** As funding ended, the potential of the RNAi approach remained. However, a PhD thesis published a year later,[19] concluded that the discovery of dsRNA-degrading enzymes reduces the RNAi efficacy in *C. puncticollis* compared to *C. brunneus*. Therefore, additional research will be needed to protect the dsRNA from degradation to effectively deliver these molecules into the sweetpotato weevil larvae.

C. RP3: Seed Systems (details provided in Appendix D)

Our vision of success for SASHA2 seed systems management is that cost-effective technologies and strategies for both male and female farmers will ensure improved access to quality planting materials. This is a very diverse component. Five of the eight milestones have been successfully completed; one was achieved with modification and two are almost achieved (i.e., results are ready but papers need to be finalized). There are four major objectives linked to these milestones.

1. Objective 3.1 aimed to refine the efficiency of disease-free planting material production and better understand how virus degeneration and reversion affect specific varieties. A key challenge with vegetatively propagated crops such as sweetpotato is accumulation of pests and sweetpotato virus diseases. Under SASHA1, a technology using insect-proof netting was developed to conserve pathogen-tested derived materials before field multiplication. Under SASHA2 and HarvestPlus, additional options for protected structures (size, construction materials) have been developed and assessed for technical, social, and financial feasibility in Tanzania and Uganda. In **Tanzania,** one study investigated the ability of net tunnels to reduce degeneration in sweetpotato under farmer-multiplier management (Ogero et al. 2019). Infection and degeneration were assessed for two cultivars, 'Kabode' and 'Polista',[20] grown in net tunnels and open fields at two sites with varying virus pressures. Seed degeneration modelling illustrated that for both varieties, degeneration was reduced by the maintenance of vines under net tunnel conditions. The time series of likely degeneration based on a generic model of yield loss suggested that, under the conditions experienced during the experimental period, infection and losses within the net tunnels would be limited. By comparison, in the open field most of the yield could be lost after a small number of generations without the input of seed with lower disease incidence. In **Uganda**, we compared two different types of protected structures (net tunnels and mini-screenhouses) with an open-field control to assess cost effectiveness for quality seed production and subsequent root production. Results showed that mean percent SPVD infection was not significantly different across methods of protected and open-field conservation; however, there was increasing virus infection from generation 0 to generation 2 for each method. Although net tunnels produced more cuttings per unit area, sweetpotato planting material sourced from the mini-screenhouse produced higher root yields (14.2 t/ha) than planting material from the net tunnel (11.5 t/ha) or open field (9.3 t/ha). Furthermore, sweetpotato root production (per kg) is cost effective, and root producers can reduce their production costs by 21% if they buy planting material from commercial multipliers who use mini-screenhouses for conservation of planting material.

[19] Prentice Muro, Katterine. The potential of RNAi technology to control the African sweetpotato weevils, *Cylas puncticollis* and *Cylas brunneus*. Diss. Ghent University, 2018.

[20] 'Polista' is a popular local, white-fleshed variety; 'Kabode', bred in Uganda, is an OFSP variety known to be moderately virus resistant.

We analyzed the financial feasibility of net tunnels and mini-screenhouses in **Tanzania**. The study concluded that for a 12-month production cycle (two seasons); the net present value is positive and the respective investments in either net tunnels or mini-screenhouses for basic seed production are financially viable in the long-run, *provided* seed multipliers align their production calendar to the market situation and seasons. Sensitivity analysis shows that the investments are stable even if there are price shocks. While a mini-screenhouse requires a higher initial investment compared with a net tunnel, the annual running costs are slightly higher for a net tunnel. Moreover, the payback period is shorter and the average annual return higher for a mini-screenhouse than for a net tunnel. Thus, it appears that if a multiplier can access the initial investment cost, the financial feasibility is greater for mini-screenhouses. Future work will include development of co-investment packages and sensitivity analysis to provide commercial seed producers different scenarios depending on the level of investment they are able to commit.

On the basis of the experience in SASHA2, a brochure with improved designs for net tunnel construction was published in 2017 and is available at https://www.sweetpotatoknowledge.org/files/protecting-sweetpotato-planting-material-from-viruses-using-insect-proof-net-tunnels/.

***MS 3.1.1. Improved protocols for Triple S*.** The Triple S technology aims to improve capacities and options to conserve and access quality planting material at the HH level in areas with a long dry season. In-depth research activities were conducted in Kenya and Ethiopia. Since January 2018, Triple S is being validated and scaled up in 10 countries, with a focus on Ethiopia and Ghana through support from the RTB Scaling Fund and scaling partners. Under SASHA2, improved protocols and training tools for implementing the Triple S method were developed and are available at https://www.sweetpotatoknowledge.org/triple-s-2/.

In **western Kenya**, a validation study concluded that the Triple S method has high potential to store sweetpotato roots for prolonged periods of time (4–7 months) under dry agro-ecological conditions. The use of coarse textured sand resulted in more than 70% healthy sprouted roots after 7 months of storage compared with 40% survival using fine textured sand. Using planting material sourced from Triple S seed root beds compared with the current farmers' practice, sweetpotato yields were 13 t/ha compared with just 4 t/ha, respectively, under on-farm conditions. The higher yields observed using planting material derived from the Triple S method compared with current farmers' practice were related to less SPVD and weevil infestation during the growth period. Maintenance of the seed-root beds for successive harvests emerged as a major constraint, resulting in a significant reduction in number of cuttings with each harvest.

In **Ethiopia**, we validated Triple S against two local methods (shade/mulch and volunteer roots) for conservation of planting material. The study was conducted across four districts in SNNPR for varieties 'Kulfo' (OFSP) and 'Awassa 83' (WFSP). Triple S resulted in a higher survival rate (81–95%) in storage during the dry season compared with the local conservation methods (7–57% survival rate). Plants of both varieties grown from roots conserved with the Triple S method showed significantly higher vine growth and lower weevil and virus infection rates compared with those using the two local methods. Survival rates using the local conservation methods were much lower in the driest and harshest districts (Mirab-Abaya and Hawassa-Zuria), and Triple S performed well. Medium-sized roots grew more vigorous plants than small or larger root size for areas with long dry seasons. Loss of roots in Triple S through drying and rotting can be reduced by improving initial root selection and covering the upper layer of roots with a layer of 5–10 cm of sand. Damage by rodents and livestock were other factors contributing to the low survival rate in the two conventional methods.

Irrigation methods for sweetpotato seed production. The objective was to identify appropriate and cost-effective irrigation approaches for vine production. In Tanzania, we assessed different types of irrigation equipment (drip and furrow) and soil water tensions (10, 40, 70 kPa) for varieties 'Kabode' and 'Mataya' under net tunnel and open-field (control) conditions at on-station and on-farm sites. Findings showed the highest vine yields at a 10 kPa watering schedule for both on-station and on-farm trials; drip irrigation was the most cost-effective approach; however, the scale of production should be considered before deciding to use drip kits. Vine production was higher under net tunnel management, indicating that net tunnels play a role in moisture retention. Vine production under 10 kPa was more cost-effective compared with 40 kPa, 70 kPa, and farmer-practice. This is because a significantly higher number of cuttings were produced under 10 kPa compared with other watering schedules. Average costs of production per cutting for drip and furrow irrigation in net tunnels were TZS. 81.5 ($0.039) and TZS. 97.0, respectively, whereas for farmer-practice (control) it was TZS. 106.5.

In **Ethiopia**, we assessed vine and root production performance of a drought-sensitive OFSP variety ('Kulfo') and a drought-tolerant WFSP variety ('Hawassa 83') under different moisture levels for the 2017/2018 cropping season. This concluded that, despite marginal rainfall during December 2017 and January 2018, about half of the sweetpotato stands (53% for

‘Kulfo’ and 54% for ‘Hawassa 83’) from the control (rainfed) plots survived the drought and recovered following the onset of rainfall. This implies good drought tolerance potential for both varieties. The study showed that irrigation at 60% ETc could be the best irrigation level for sweetpotato vine and root production during the dry season (November–March) in Hawassa Zuria to get the optimum yield and best water use efficiency during this period.

MS 3.1.5. Determining the cost and benefits of sandponics for pre-basic seed production. Using an optimized media, it was demonstrated that sweetpotato pre-basic seed can be multiplied cost effectively in a sandponics system. The vine multiplication rate in the sandponics system was 21.8% higher when compared with using the conventional soil substrate. The cost of producing a three-node sweetpotato cutting in the sandponic system (10.5 KSH [$0.105]) is significantly lower by 0.27 KSH than using the conventional soil substrate (13.2 KSH). Moreover, when grown in the open field, the storage root yield potential of planting materials multiplied by sandponic system was 7.1 t/ha higher than vines sourced from the conventional soil substrate. In addition to two published research articles (Makokha et al. 2018, 2019), a manual with step-by-step instructions for setting up a sandponics systems was produced and is available on the SKP.

MS 3.1.3. Support to 10 national programs to improve management and oversight of quality pre-basic (foundation) seed production. This challenging milestone has been achieved. We worked with 13 partners (11 public sector NARIs, one regulatory body, and one private sector) in 11 countries to ensure sustainable EGS production by strengthening technical, business, and institutional components of EGS production (Rajendran et al. 2017). Each institution developed a business plan with a description of product (pre-basic and/or basic seed) detailed cost structures, real time or recall cost data, which were then used to establish the unit cost of production and pricing strategies. (The business plans are available at: https://www.dropbox.com/sh/h1leqh0jf3aqo6w/AABT3ot62bW1cVDR4br HYxkra?dl=0.) Production processes with internal and external quality assurance mechanisms were put in place. Marketing strategies targeted at different market segments (e.g., institutional markets, commercial seed producers) were implemented. Revenues from the sales of seed were paid into institutional **revolving fund mechanisms** to support continued seed production. An analysis of the **capacity of the institutions to cover the cost of production for target sales** showed that most were able to cover their costs in 2018 and will continue to do so in 2019. Three institutions were only partially able to cover their production costs in 2018, but showed an upward trend in the balance of their revolving fund. Some of the institutions showed a positive compound annual growth rate indicating a trend of increased production from 2015 to 2018. However, others showed a negative growth rate. This could be due to inefficient production planning, leading to overproduction in relation to customer requirements; or reduced production in response to institutional buyers (projects) decreasing their purchases. The reported sales figures show an increase in the marketed surplus with most institutions selling over 80% of the seed that they produce. This demonstrates increased confidence in production planning and deliberate and targeted marketing activities. We conducted a peer-to-peer review study to **validate the EGS business models** and to assess the level of institutionalization of the business plans and revolving funds. Analysis considered four pillars (technical, administration and finance, socio-cultural, and policy) which all contribute to the sustainability of the business. Results show that the NARIs need to strengthen the financial and administration pillar to run a sustainable EGS business. We used the findings to develop a set of strategies using a “strengthens, weaknesses, opportunities, and threats” analysis for NARIs to improve their weakest pillars and sustain their sweetpotato business in the long-run.

We also conducted a **financial feasibility study to produce EGS for multiple RTB crops** for a private seed company based in East Africa. The study showed that the business is financially viable based on the existing business model for production and sale of banana, cassava, sweetpotato, and potato planting materials. The business required an initial total investment of $1m (with the assumption that grants contributed approximately 18%) and running costs of $0.15m during an 8-month establishment period. The payback period was 3–7 years, with an average annual return of 34–70%. Establishing realistic **seed requirement projections** is essential for good EGS production planning, to maximize profit and to avoid financial loss from unsold seed. An additional study was conducted to develop a national-level seed requirement estimation tool for use with country-specific multiplication calendars so that NARIs can efficiently plan their seasonal EGS production cycle. Based on 17 years of historical data from the United Nation’s Food and Agriculture Organization (FAO), a linear projection model was used to forecast area under sweetpotato in Uganda from 2017 to 2023. A series of assumptions was made for adoption rates; replacement rates; and proportion of area under improved sweetpotato planted with purchased seed. The results showed that a future scaling strategy would require (1) trebling the existing capacity for pre-basic seed production, (2) decentralizing screenhouse capacity to get broader national coverage, and (3) continuing innovative production practices to reduce costs and increase multiplication rates. This EGS requirement estimate tool is available at: https://www.dropbox.com/sh/28dlhqiuy10wiuw/AAAeLfnQ9jzijO_3O6BGX7ita?dl=0.

MS 3.1.4 Evaluating the effect of begomoviruses. In an initial countrywide survey, begomoviruses were found to occur in all sweetpotato-growing regions in Kenya. We then evaluated the effect of a Kenyan begomovirus isolate of the species SPLCV, SPFMV, and SPCSV alone and co-infections on sweetpotato root yield of two varieties ('Ejumula' and 'Kakamega') with contrasting resistance to SPVD (Wanjala et al. 2019). Results showed marked differences in the effect of SPLCV infection on the two varieties despite only mild symptoms occurring in both varieties: 'Ejumula', which is susceptible to SPFMV and SPCSV, suffered no significant yield loss from SPLCV infection, whereas 'Kakamega', which is more resistant to SPFMV and SPCSV, suffered on average a 47% yield loss. Results highlighted the variability in sensitivity to SPLCV between sweetpotato cultivars as well as a lack of correlation of SPLCV-related symptoms. The impact was on yield from the virus and the lack of correlation between resistance to the RNA viruses SPCSV and SPFMV and the DNA virus SPLCV. Thus, resistance to SPVD and SPLCV (and likely other sweetpotato viruses) is not necessarily linked. Finally, yield losses and symptoms caused by co-infections of SPLCV with SPFMV, SPCSV, or both viruses were not significantly different, suggesting a lack of synergistic and limited additive effect of the different groups of viruses on yield.

2. Objective 3.2 sought to improve and validate diagnostic methods for support of seed quality and germplasm management and exchange.

MS 3.2.1. Assure the availability of disease-free pre-basic material within 12 months of initiating clean-up. Low virus titers, uneven virus distribution within the plant, presence of inhibitors, the occurrence of mixed infections, and diverse viral strains make diagnosis of sweetpotato viruses difficult. Current nitrocellulose membrane ELISA diagnostic tests are not sensitive enough to reliably detect viruses directly from sweetpotato. However, available molecular tests require expensive laboratory equipment and a high level of experience. The current phytosanitary screening/cleaning process typically requires a year or even more to remove viruses and verify if material is virus-free. We aimed to have a test that can significantly reduce this time and detect more than 10 sweetpotato viruses at one go. During the ninth year, we developed and tested the ClonDiag microarray. The final microarray can simultaneously detect all the 10 viruses detected by NCM ELISA plus an additional 5 viruses. Time to results for grafting/NCM ELISA is 6–12 months, while ClonDiag is 2 days. ClonDiag costs $70 per sample and detects up to 21 viruses; grafting/NCM ELISA costs $130 to test 10 viruses per sample. The sensitivity of the ClonDiag test is higher than that of NCM. The ClonDiag array appears to be suitable for routine diagnosis of sweetpotato viruses. However, the manufacturer of the arrays unexpectedly discontinued production in 2018. Fortunately, another technology based on sRSA, developed in a complementary BMGF-funded project, will be used instead of the ClonDiag technology. This ultra-sensitive technology costs $100 per sample but can detect all viruses. It takes 1 week to do the extraction of 96 samples and typically about 1.5 months to receive the results back from the outsourced laboratory. We trained one KEPHIS staff in sRSA during 2018, and in 2019 performed a follow-up course at KEPHIS in Kenya for six staff members (three from CIP and three from KEPHIS).

MS 3.2.3. Prototype LAMP tool developed for detecting SPFMV and SPCSV. We developed a thermostabilized field-based LAMP test for SPFMV, SPCSV, and also begomoviruses that is user-friendly for field diagnosticians. We demonstrated that LAMP can be deployed directly in the field providing real-time results. The LAMP assays used were equally sensitive and reproducible as RT-qPCR being able to detect virus from samples diluted over five orders of magnitude. Also, a simple PEG-based extraction was as efficient as Ambion RNA extraction kit. Field testing validated the accuracy of the tests (by comparison to subsequent lab tests by PCR of the same samples) at the four sites, from the hot and humid coast to central and Lake Victoria regions, giving the following times to positivity for the three viruses: SPFMV 5–20 min, SPCSV 15–35 min, and begomoviruses 15–40 min.

MS 3.2.2. Improve germplasm management and exchange. CIP-KEPHIS is the regional germplasm unit for SSA. In 2010–2019, CIP-KEPHIS distributed 1,436 varieties to 24 countries, 4 of which were outside Africa. During SASHA, many physical improvements were made at the KEPHIS facilities to improve the functionality of this unit (see Appendix D for details). This unit receives requests for pathogen-tested *in vitro* plantlets and cuttings. If a request arrives and the material is only available *in vitro* but the country does not have TC facilities, it can take several months before sufficient, vigorous cuttings are ready to send. Thus, national sweetpotato breeders agreed in 2016 to nominate their "best bets" (i.e., the most popular varieties) in their country—these could be local landraces or breeding program releases of any flesh color. Fifteen countries sent 115 varieties to KEPHIS and South Africa sent the DNA of 5 varieties. One died and the rest were put into thermotherapy for virus removal. DNA extracted from 94 varieties were sent to DArT Arrays Technology in Canberra, Australia, for fingerprinting. In collaboration with KALRO at their Kiboko station, all surviving varieties were planted out, characterized morphologically at 120, 150, and 180 DAP, and photographed. Roots were sent to Uganda for NIRS characterization of nutrient content; confirmation of these results was done by CIP-HQ. Any mix-ups or duplicates had to be discarded.

Concurrently, the data manager worked with breeders, the Research Informatics Unit at CIP-HQ, and a Kenyan web development company to develop a digital catalogue. The resultant 2019 Sweetpotato Digital Catalogue was launched at the Speedbreeders CoP meeting in June 2019 and is available at https://research.cip.cgiar.org/sweetpotato-catalog/cip_sp_catalogue/. It contains standardized information on 80 varieties in use in 15 SSA countries, with pathogen-tested cuttings of those materials maintained at KEPHIS in double cages[21] for fast access to high-quality pre-basic planting material. Contact information to obtain varieties, either at the country level or from KEPHIS, is included. The catalogue contains a section for adding new varieties, and breeders were exposed to the guidelines for taking quality photographs at the 2019 breeders meeting and have the requisite databases to fill in descriptive information. Annual assessments of which varieties should be among the "best bet" varieties should be made, based on demand considerations.

3. Objective 3.3: Further adapt quality declared planting material standards and inspection protocols in collaboration with national regulatory bodies.

MS 3.3.1. At least five countries have draft standards and protocols for quality assurance of sweetpotato seed based on evidence**.** Interest among countries has exceeded expectations. Ten countries (except Zambia) have drafted seed standards for sweetpotato (where none previously existed) or have revised existing seed standards (e.g., Malawi). **The seed standards for Ethiopia, Rwanda, Kenya, and Tanzania (formal seed classes only) have now been officially approved** (gazetted). This has been done in consultation with key stakeholders and with support from different projects and organizations (e.g., HarvestPlus, University of Makerere, Jumpstarting project).

4. Objective 3.4: Test and document models for medium- to large-scale basic seed production ("The Missing Middle").

MS 3.4. Different strategies tested for ensuring adequate quality seed supply for both low and high SPVD pressure areas. The research had three thrusts: (1) assessing the cost and quality implications of producing planting material in low virus pressure areas and transporting to high virus pressure areas; (2) identifying how to strengthen the institutional linkages and fill the gap between upstream, EGS production at NARIs and DVMs producing quality declared seed (QDS) at community level as an interface between the "formal" (public sector) and "informal" seed systems; and (3) developing technical recommendations for rotation and isolation distances.

In **Uganda**, we found that the current flow of vines is from the high virus pressure areas in the south to the more drought-prone low virus pressure areas in the north. The maximum distance at which the sale of vines from low SPVD to high SPVD pressure areas is still profitable is 280 km when using a 7-t lorry or 380 km when using a bus. There is a loss if vines are transported from Agoro Irrigation Scheme (a low SPVD pressure area) to high SPVD pressure areas. Vines can be sold from the nearest low SPVD area (Karuma) to a high SPVD area at a farmgate price of UGX18.1/cutting but with a final cost to the buyer of UGX 31.6/cutting. Findings also revealed that it is cost effective for multipliers in the high SPVD pressure areas to buy pre-basic seed (each year) from pre-basic sources that are within a 250-km radius, for multiplication in open fields rather than conserving seed in protected structures for 3 years, for annual multiplication in open fields. However, there is higher wastage when vines are transported over long distances. Moreover, other research in Uganda has shown that using planting material sourced from multipliers conserving under mini-screenhouses leads to increased root yield.

At the second research area In **Tanzania**, we found that basic seed multipliers can produce high-quality seed. To produce 1,680,000 cuttings annually, an initial investment of $6,241 is required of which $1,314 is for the screenhouse. The balance ($4,927) is estimated to be the total cost of production during the complete 12-month crop cycle. However, to be successful, commercial seed producers need to plan their production, aligning their multiplication calendar with market demand, and increase their economies of scale at the open multiplication stage to ensure that they sell at a competitive price. Strengthening marketing and promotion along the value-chain through use of SMS platforms and WhatsApp on phones can be effective marketing tools. In addition, local radio plays an important role in marketing, especially for smallholder farmers.

Under the third research area in **northern Uganda**, we conducted agronomic research and cost-benefit analysis on **sweetpotato-rice rotation.** Overall results for the sweetpotato-rice rotation show that the yield of rice grown after sweetpotato was significantly higher than the control ($P=0.001$), where rice followed rice. The rotation produced yield gains in the three rice varieties tested. Rotating sweetpotato with rice had a significant effect on root yield (average yield = 28 t/ha) than in the control (average yield = 19.8 t/ha) but not on vine yield. The higher root yields in the rotation experiment could have been due to the residual fertilizers applied in rice each previous season. Economic analysis showed that there is

[21] Once viruses are removed, the plantlet is hardened and the cuttings are moved into a screenhouse covered with insect-proof netting. Although there is a double-door to the screenhouse to try and ensure no insects enter, as an extra protection, a "cage" consisting of insect-proof netting over a wooden frame is placed around the pot containing the pathogen tested cutting. Thus, each of these best bet varieties is doubly protected.

a statistically significant difference in mean profit ratio between rotation and control. The comparison of net profit ratio by treatment and control shows that the net profit ratio in the treatment was 0.43 higher than in the control group which is a significant and positive difference. The overall impact of rotation is significant for both sweetpotato and rice crop. This indicates that sweetpotato and rice can be rotated with each other to generate the net profit. A simple brochure designed to raise the interest of farmers in sweetpotato-rice rotation is available at: https://www.dropbox.com/sh/96di545qm1loob5/AACkm6x0-BQ66znrcRlwOnx9a?dl=0.

The annual Seed System CoP meetings are a key avenue through which new practices or insights occurring through SASHA research can be shared. However, training materials are key as well for extension personnel. The first edition of the 13 modules of the *Everything You Ever Wanted to Know about Sweetpotato: Reaching Agents of Change ToT Manual* was released in 2013. By 2017, it was clear that an update was needed due to new findings. Many SASHA scientists worked with Dr. Tanya Stathers, who led the revision effort. The revised module on Sweetpotato Seed Systems was published in 2018 and is available at 10.4160/9789290605027T5 https://hdl.handle.net/10568/98337.

D. RP4: Postharvest and Nutritional Quality (details provided in Appendix E)

This RP has been jointly led by NRI and CIP. Handling research undertaken by graduate students in northern Ghana was supervised by professor Francis Amagloah of the University of Developmental Studies (UDS). Four of the six milestones were achieved, but two did not reach the desired level of success. The latter were related to the objective of developing an economically viable, solar-powered cold storage system for commercialized sweetpotato roots. Progress under each milestone is described below.

MS 4.1. Cost-effective technologies developed to enable commercially oriented farmer organizations to supply quality sweetpotato roots year-round to specific agro-processors or urban markets. **Formative research.** Surveys were carried out in Kenya and in Mozambique to identify appropriate sites and partners to test the concept of using storage to provide a year-round supply of OFSP for processing.

A survey in eight counties in Kenya (Milestone Report OBJ4MS1.1.A), carried out in December 2014, indicated that although there were seasonal price differentials for sweetpotato, storage was not necessary for domestic fresh marketing. OFSP supply is limited but provides higher profits than white roots. The greatest market potential for OFSP was identified for processed products; in particular, CIP negotiated a new opportunity based around supply of bakery products to Tusky's a large supermarket chain with many outlets in Nairobi. To provide a reliable supply of OFSP for this venture the recommendation was to focus on staggered planting and use storage facilities for up to 4 months. Although the financial advantages of such a storage facility in the season of low availability is clear, this is not so obvious for the high season when roots are readily available. (A more detailed analysis is provided in the milestone report.)

A survey of Maputo and Manica provinces in Mozambique (Milestone Report OBJ4MS1.1.B)[22] indicated that sweetpotato produced in these regions was traded to the urban centers of Maputo and Chimoio, respectively. The OFSP supply was lower than WFSP varieties, and usually commercialized directly by the producers. Business opportunities were identified for OFSP in urban centers based on health concerns. Storage was identified as a means to reduce imports from neighboring South Africa. Two storage sites were identified in Mozambique for further study: first, the possibility to install curing and storage structures for a group of commercial farmers in Namaacha district (Maputo province) and second, for a processor of OFSP-based products located in Chimoio (Manica province). Andrew Marchant, NRI engineer, visited these sites to provide technical advice.

Northern Ghana was also considered to be a potential site for larger scale storage due to strong existing demand for affordable storage facilities based on the high level of commercialization of sweetpotato roots and the short growing season in this semi-arid climate. Roots travel long distances to various markets to Burkina Faso in the north as well as to the capital city of Accra in the far south. In December 2014, a reconnaissance survey (Milestone Report OBJ4MS4.1.A) was conducted through which the types of packages, modes of transport, and transportation routes were identified. The most commonly transported varieties were also identified. Polypropylene and jute sacks were the commonly used packaging containers to transport sweetpotato in Ghana.

[22] Data were collected at two different time periods: between 27th and 30th October 2014 and 20th and 30th April 2015.

Given resource constraints, a decision was made initially to focus on western Kenya for the storage component and in Kenya and Ghana for the handling components. These areas were selected because of the existence of other CIP-led projects that could facilitate logistics for the research teams and be able to benefit immediately from findings.

MS 4.1.4.A. A comparison of different postharvest handling methods on the quality and shelf-life characteristics of OFSP roots intended for processing into purée in Nyanza area of Kenya. Previous data indicate that rates of deterioration for washed roots was very high, and that it would therefore be better to avoid washing of roots before delivery to the processing plant and instead wash just before processing. As a result of this, a trial for storage life comparing different OFSP postharvest handling methods was undertaken in August 2015 by Tanya Stathers, Penina Muoki, and the project team (Milestone Report OBJ4MS1.1.C). The trial focused on the effects of a range of factors on root storage life once stored in the newly updated holding facility (see following sections). The factors under test included variety 'Kabode' (550 kg), with a smaller component of variety 'Vita' (120 kg) as well as different methods of cleaning roots (washing, dry removal) and packing (wooden crates, plastic crates, and sacks). The effect of poor roads was included by transporting the roots on bumpy roads for 1 hour.

The results indicate that for short-term storage, it is beneficial to manually wash the soil off the roots and then air-dry them, discarding those with weevil damage or rot before marketing them. Later trials, however, indicated that for long-term storage it is better not to wash the roots, just brush off the dirt. Holding roots in sacks maintained good quality, which is probably due to efficient curing (more details later).

MS 4.1.4.B. Packing containers for long-distance transport of sweetpotato storage roots in Ghana. In 2015 and 2016, experiments were conducted in two locations in Ghana: Eastern (Afram Plains) and Upper East (Bawku) regions, where a high level of commercial production of sweetpotato exists, to test alternative containers for transporting storage roots. The key findings from the packaging and transport study (Alhassan et al. 2018) for fresh roots were:

- Both 50-kg wooden crates and 50-kg polypropylene sacks performed well in terms of low damage to fresh roots while being transported to urban markets in large trucks. They were superior to large polypropylene and jute sacks typically holding 130 kg of roots.
- A 50-kg polypropylene was recommended over the wooden crates given that wooden crates are bulky and expensive to transport to production centers compared with sacks and difficult to maneuver due to their weight and shape.
- The amount of bruising and breaks for the four types of packaging containers did not differ from each other when either donkey cart or Motor King transport was used. Root quality at aggregation site was similar to that at the destination site.

Drawing on the findings from the handling studies conducted in Kenya (led by NRI) and this study conducted by UDS, Tanya Stathers of NRI prepared a brochure entitled, *Handle with Care: maintaining the quality and value of your sweetpotato roots during and after harvest through better practice,* which is available on the SKP.

MS 4.1.1. Awareness, demand and packaging of vitamin A-rich OFSP roots for different markets in Nairobi, Kenya. Once handling guidelines were in place, to tackle improving OFSP supply to urban centers, there was a need to better understand and address the demand side of the equation. The marketing of OFSP in the Nairobi market is still very limited, in part because most OFSP-related projects and promotions have been concentrated in the major sweetpotato production zone of western Kenya. A small study carried out in May–July 2018 (Milestone Report OBJ4MS1.1.D) explored the impact of visually differentiated packaging (e.g., orange crates and orange net bags with labels) on OFSP sales and customer engagement and demand.

Surveys in seven Nairobi markets confirmed that most traders are not aware of OFSP and have no customer demand for OFSP; they therefore do not sell it. In contrast, in the high-end grocery chain stores visited, the owners were aware of OFSP and reported high customer demand for it but low availability.

For the component of the study in the informal markets, a small display table was set up with OFSP roots (which respondents could study and purchase) in crates with visually attractive signs. Each respondent was given a flyer with summary information about OFSP and four recipes for using and a link to a website set up with other OFSP recipes. A similar process was conducted in the high-end grocery stores, but with the addition of OFSP roots packed in info-labelled orange net bags but without the tasting part of the survey. A total of 347 respondents from three informal markets and 371 respondents from three high-end grocery stores were interviewed between June and July 2018.

In the informal markets, the predominantly Kenyan consumers purchased fresh sweetpotato roots one to three times per week and preferred YFSP roots. When asked to visually compare the steamed OFSP and YFSP roots, they overwhelmingly

(>90%) reported preferring the OFSP; but when it came to tasting the roots, the results were more mixed: 51% preferred YFSP over OFSP. Prior to our survey, 88% of the 347 respondents in the informal market had never heard of OFSP, highlighting the lack of awareness that exists in urban centers.

In the high-end grocery stores, the customers were more ethnically diverse. Of the 371 people interviewed, 178 had bought sweetpotato roots on the day of the interview, with the majority (83%) having bought YFSP and just 13% OFSP. Most respondents (68%) said they prefer YFSP due to a combination of factors, including it being sugary, tasty, nutritious, dry, and familiar. Of the 272 respondents who preferred YFSP, 47% of them had tried OFSP previously and most had found it tasty. Of those respondents who had not tried OFSP, most explained this was because they had never heard of it or seen it before. Of the 73 respondents who purchased OFSP on the day of the interview, 46.5% purchased the OFSP roots pre-packed in a net bag. They explained this was because it was easier, faster, the packs looked nice, and they did not have to choose roots and get soil on their hands; whereas others explained they like to hand-pick their sweetpotato roots so as to choose the best quality and required size and shape.

This study highlights the lack of knowledge and awareness about OFSP among customers in the informal markets of Nairobi, which translates to a lack of demand for OFSP, and thus a lack of market-pull which would drive OFSP production by farmers in the country. Visually attractive information signs and promotional events in markets as well as TV, radio, and internet communications will attract consumers to OFSP, and many of the informal market respondents understood the importance of consuming nutritionally dense foods and a diverse diet. However, OFSP roots would also need to be easily and continually available to consumers alongside the awareness campaigns. To facilitate this, there may initially be a need to de-risk traders' activities while the OFSP fresh root value chain develops in informal urban markets. Clearly, more in-depth marketing studies are needed to guide future efforts to build OFSP value chains seeking to increase urban consumption levels.

MS 4.1.3. Development and testing of medium- to large-scale curing and storage technologies independent of the national electricity grid. To ensure that OFSP purée production is not constrained by root supply, there is a need for cost-effective storage, capable of maintaining fresh roots with good quality for processing for at least 2 months (ideally 4 months). The key requirements for a storage facility were defined by this project as follows:

- Low cost, in terms of construction of the store, power supply installation, and running costs (including power consumption and maintenance).
- Reliable, and therefore independent of the national electricity grid. This could involve the use of solar power, or a generator. However, the former is preferred as, although initial capital input is greater, it is expected to incur lower running costs.
- Capable of maintaining storage temperatures suitable for sweetpotato (ideally 15–17°C).
- Capable of maintaining temperatures for curing at the start of storage (28–32°C for 3–6 days) and high levels of RH (>85%).
- User friendly to run and to repair using local suppliers.

To address the objectives set out above, a curing and storage facility for fresh OFSP roots was constructed at the Organi Ltd site in western Kenya. The facility consisted of two stores, each designed to both cure and store OFSP. The stores worked using an evaporative cooling system developed with low installation costs and low power demand; one powered by solar panels and the other through the existing main electricity system. Four rounds of storage trials were carried out as described below. The evaporatively cooled stores maintained temperatures that were generally in the range of 20–22°C. This temperature range is higher than the optimum recommended for sweetpotato (15°C). A curing treatment (with heating to achieve 28–32°C and high humidity achieved for reducing ventilation) was carried out for 4 days, followed by cooling with the evaporative system. Using this system, the percent of root material suitable for purée production after 4 months of storage, relative to the initial weight (accounting for weight loss due to metabolism, water loss, rot, insect damage, and sprouting) was 75–87% and 55–66% for the varieties 'Vita' and 'Kabode', respectively.

To reduce problems due to weevil infestation and sprouting, it was considered important to develop stores capable of reducing temperatures to the lower, recommended levels. Consequently, a second store design, capable of maintaining lower temperatures, was constructed based on a sea-freight container and using a low-cost refrigeration technique known as CoolBot.[23] The environmentally controlled sweetpotato storage unit was designed to cure 4 t of roots at a temperature

[23] The CoolBot is a unit attached to an air conditioner that uses multiple sensors, a heating element and a programmed micro-controller to direct an air conditioner's compressor to operate in a such a way to cool the room to 36°F without freezing up.

of 28°C and RH of >85%, followed by storage at 15°C and RH >85%. The system was built using a 6-m-long intermodal dry freight container and was designed to be affordable, durable, and easy to operate. Components were selected so that the unit can be manufactured and repaired locally without the need of special imported items. The entire system is powered by solar energy using a rooftop photovoltaic system.

The refrigerated sea-freight container store was also tested through three rounds of storage trials using OFSP. Key observations were that during the curing process, roots could produce significant heating and therefore it was necessary to have the capacity to cool the unit during this phase to prevent overheating. Despite the lower temperature that could be achieved in this store, the losses during storage due to weight loss and rotting did not decrease as much as anticipated; and in fact, the levels of rot at the later stages of storage (beyond 1 month in some cases) increased. To investigate ways to improve storage, in the final trial air exchange was increased to prevent CO_2 build up and internal airflow was slowed down to reduce desiccation. A summary of findings is given in a later section.

Storage trial in Mozambique. Given the challenges faced by the solar-powered storage trials in Kenya, in 2017 a second solar-powered storage unit was commissioned to be designed and built by a South African company, Ecotech Hydro. It was installed in Marracuene, Mozambique, in June 2018. The design differed from the unit in western Kenya as it split the container into three rooms: a curing room, a cold room, and a control room (see Appendix E for details). One trial with three OFSP varieties ('Irene', 'Delvia', and 'Sumaia') and one local WFSP variety was conducted from July to December 2018. There was no in-ground curing; curing in the chamber lasted 6 days, then roots were transferred to the cold room after removing roots that showed any signs of rot. Humidity conditions during curing were less than ideal (76% RH), considerably below the desired 90%.

Four months after moving into the cold room, which was able to maintain desired temperature and humidity levels, the percentage of root weight was above 70% of the initial weight for all four varieties. Cooking taste was good for all varieties after 1 month of storage, and good for all varieties, except 'Sumaia' after 4 months. The cooking taste of 'Sumaia', the variety with the lowest DM (23%), was poor after 4 months. Significant beta-carotene loss for two of the three OFSP varieties occurred after 2 months of storage. No significant changes were seen in DM, Zn, fructose, glucose, sucrose, or protein during 4 months of storage.

Overview of storage trials on OFSP. Because of the lower temperatures achieved, we had expected the refrigerated store constructed in the second phase of storage trials to exhibit lower weight loss and levels of rot than the evaporative cooling store. A comparison of data from both stores and one parallel trial carried out in Mozambique was carried out.

- Both systems were able to achieve and maintain cold storage temperatures at 13–15°C, which effectively suppressed weevil outbreaks and sprouting. Rotting was the main challenge.
- The levels of weight loss for the refrigerated store were lower than for the evaporative cooled store for the first 3 months of storage and were similar to those seen in Mozambique.
- The levels of rotting for the refrigerated store were similar to those for the evaporative cooled store for the first 3 months of storage, but thereafter increased more. The levels of rotting in the Mozambique store were much lower.

To obtain more information that might inform us on the efficacy of the curing and storage conditions being used, the roots stored within LTS7 (the last trial) were sorted after 2 months, with the removal of all roots showing signs of rotting, and then stored for a further 5 weeks. This also provided an opportunity to compare the use of wooden and plastic crates. The results obtained showed no difference between the state of roots stored in wooden or plastic crates. The overall rate of weight loss decreased, but not significantly. The levels of rotting were reduced.

Conclusions from storage trials on OFSP and way forward. Given the results of all the trials, the conclusions on the factors that should be considered to improve storage are:

Quality of roots. In the phase 1 trials, there was a very significant difference in the storability of the consignments of varieties 'Vita' and 'Kabode'. It was not possible to determine how much this is due to varietal differences and how much it is due to the growing conditions, harvesting practices, and so on; but it does indicate the impact of root quality. This may explain some of the differences between trial results in Kenya and Mozambique—for example, we know that the roots from Mozambique placed in the store were larger on average than those in Kenya.

Strategies for harvesting and handling of roots. Experts from the United States have advised that to optimize sweetpotato storage, roots should be packed straight into boxes in the field and not handled again before storage. In the African context, however, we do not consider this to be practical. In our trials the roots have been carefully handled and then sorted. We do not anticipate that we can achieve a significant improvement in this stage of the handling process.

We have demonstrated that de-haulming approximately 1 week before harvesting has a significantly positive effect on stored root quality, and this should be included as standard practice for roots to be stored. This is only possible in dry weather, as rainy conditions promote sprouting. Harvesting during wet weather should be avoided.

Storage boxes. A trial has been conducted to compare wooden and plastic boxes. No effect on storage quality was found. Wooden boxes have the advantage that they can be constructed to the optimum size and repaired as necessary.

Curing conditions. The curing conditions recommended for sweetpotato in the UK are 25–32°C under high RH (>90–100%) for several days to 1 week. In these trials we have used 28°C, 90% RH for 4 days. Given the high levels of rot, we should investigate whether the conditions we are using should be adapted. For example, it is possible that the promotion of rot growth at the high temperatures are more detrimental compared with the wound-healing process. In parallel UK trials on Kenyan roots (white-/cream-fleshed), we have found that curing is more effective at 90% RH than 80% RH and have demonstrated the advantages of curing in terms of reducing weight loss, respiration, and rotting.

Air exchange rates. One difference between the trials in Mozambique and Kenya was that the density of root packing in the store was much greater in Kenya than Mozambique, to the extent that there was a build-up of carbon dioxide in the Kenyan trials up to 3%. However, increasing air exchange to prevent carbon dioxide build up in subsequent storage trials appeared to have little effect, and discussion with experts indicates that this is not really considered a problem.

Air flow rates within the store. One question is whether with the current phase 2 store in Kenya condensation on roots is promoting rotting, and whether this would be reduced by higher rates of air flow. This needs to be tested. The storage technicians did check roots for condensation. However, it may be necessary to have someone experienced with storage to confirm this, as some of the change to be detected is subtle. A parallel set of trials are being set up at NRI UK to investigate the effect of air flow rates on sweetpotato roots.

Economic analysis of storage strategies. An economic analysis of storage strategies has been carried out based on the analysis of technical efficiency and cost of the two store types constructed in western Kenya, with additional consideration of strategies to reduce storage costs. Western Kenyan conditions are represented of bi-modal production zones in East Africa where sweetpotato is highly commercialized. None of the scenarios brings the cost low enough to ensure that storage is more economically viable than buying on the open market during the scarce season ($270/t). However, with the additional factor of supply security, storage may become more advantageous. Figure 3 captures the five components of cost for each of the scenarios presented below:

- 1A Evaporative cooling powered by photovoltaic (based on container store with 25% loss over 4 months)
- 1B Evaporative cooling powered by national grid (based on container store with 25% loss over 4 months)
- 1C As 1A, but with lower cost store building and 20% loss
- 1D As 1C, but 50% capacity for photovoltaic, and using grid when load is high
- 2A Air conditioner powered by photovoltaic (based on container store with 25% loss over 4 months)
- 2B Air conditioner powered by national grid (based on container store with 25% loss over 4 months)
- 2C As 2A, but with lower cost store building and 15% loss
- 2D As 2C, but with 50% capacity for photovoltaic, and using grid when load is high
- 3A Air conditioner powered using DC photovoltaic only active in sunlight (based on container store with 25% loss over 4 months)
- 3B As 3A, but with lower cost store building and 15% loss

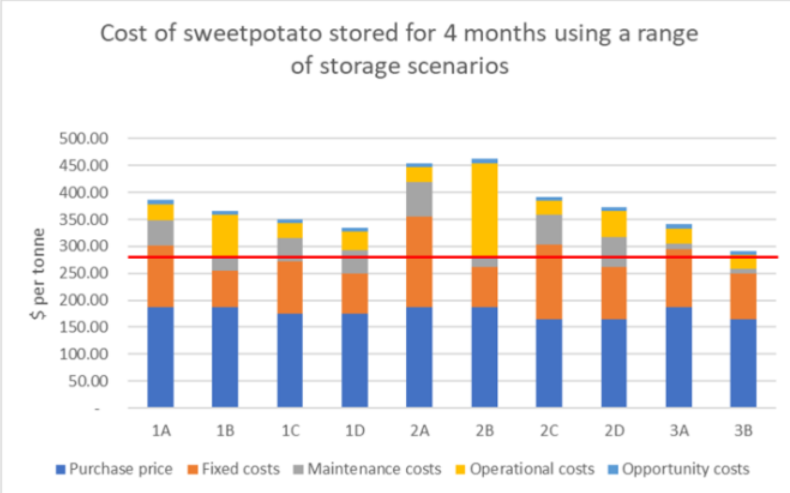


Figure 3. The cost of sweetpotatoes ($/t) after storage for 4 months using a range of storage scenarios (as summarized in the text). The red line indicates the cost of sweetpotatoes on the market when supply is at a minimum. The objective is to bring cost of stored sweetpotato below that level.

MS 4.2. To ensure year-round supply of OFSP in nutritionally at-risk households, develop convenient and low-cost methods for fresh root storage. At the HH level, storage in sand (Double S) has clearly emerged as the best option for storing sweetpotato roots (Abidin et al. 2016). In areas with long dry seasons, storage up to 6.5 months is possible in stepped pits and up to 4.5 months in sandboxes. Both approaches use dry, cooled sand as the substrate between root layers. Dr. Erna Abidin was lead author on a 10-page brochure, entitled *A Guide to Storage of Fresh Sweetpotato in Sand Pits or Boxes: Extending Fresh Sweetpotato Root Availability in Drought-Prone Areas after Harvest,* launched at the annual Marketing, Processing and Utilization CoP meeting in April 2018.

MS 4.3. Report on viability of storing purée/concentrate without a cold chain and the quality and safety of products made from stored purée versus fresh. During SASHA1, considerable experience was gained in Rwanda on the manufacture and marketing of bakery products in which 20–45% of wheat flour has been replaced by OFSP purée (boiled and mashed roots). Experience across many SSA countries has shown that although given the current price of sweetpotato roots, the use of OFSP flour as a substitute for wheat flour is not cost effective, the use of OFSP in purée form (steamed and mashed roots) is economically advantageous. Moreover, products made using OFSP purée are highly acceptable to consumers. The major bottleneck though to expanding use of purée over flour is the inconvenience of having to prepare and store the purée. Currently, processors store and utilize the roots for purée as needed or prepare and freeze it for future use. Processors with mixed operations, such as livestock, can easily deal with the waste from processing roots, but those with limited space find dealing with the root waste highly inconvenient. In the US, high-end continuous-flow microwave systems with aseptic packaging exist that are difficult to transfer to SSA. Other studies indicate that there is potential to store purée without refrigeration using sealed vacuum packaging. Our objective was to develop a vacuum-packed purée that is food-safe to store at room temperature for 3–6 months. The purée must be cost-effective (i.e., lower than the price of wheat flour) if we expect the baking industry to use it. Shelf-storable OFSP purée has the potential to be the breakthrough technology for the expanded use of this product in SSA.

In undertaking this research, keen attention had to be paid to food safety. OFSP purée is a wet product and good hygiene is essential in processing it. In addition, there is a need to ensure that sufficient beta-carotene is retained when the purée is stored, so that both the purée *and* the final product can be considered good sources of vitamin A. The multiple topics to be researched provided an opportunity to train graduate students under the supervision of CIP's food scientist, Tawanda Muzhingi. While much of that research was undertaken at FANEL (see Objective 4.4), for the food safety work we collaborated with Organi Ltd, a company in western Kenya producing OFSP purée as a business. Organi established purée OFSP manufacturing in 2015, freezing the purée and sending it to a centralized bakery at Tuskys Ltd in Nairobi, where OFSP bread is produced and distributed to its stores in the city (Bocher et al. 2017). Clearly, cold chains are expensive to maintain and a shelf-storable purée not requiring one would result in considerable cost reduction. Given that OFSP bread was the commercial product of interest, verification that the bread would be acceptable to consumers would also be required.

Research for this component was concentrated in the first 3 years of SASHA2, with further consumer testing spilling over into Y4. Results from key experiments are summarized below; all results have been published and articles are cited where appropriate.

Affordable and effective preservatives. Several sets of initial studies were conducted for 12-week intervals. Different combinations of chemical preservatives and natural preservatives (natamysin and nisin at 0.08% w/w[24]) were tested--packed in polythene bags, with or without vacuum seal. Results found that treatment of OFSP purée with either chemical preservative or natural preservative and in combination with vacuum packaging, reduces bacteria count in OFSP purée. However, the natural preservatives were very expensive ($0.40/kg) compared with the chemical preservatives ($0.04/kg). In addition, HPLC data demonstrated that at 12 weeks in vacuum-packing, purée with both preservative treatments retained over 80% of β-carotene content.

Building on these results, Musyoka (2018) conducted a challenge test to determine the antimicrobial effect of sodium benzoate (0.25%), potassium sorbate (0.25%), and citric acid (1%) on the growth of *Staphylococcus aureus* and *Escherichia coli* in OFSP purée stored at ambient conditions in vacuum-packed bag over 12 weeks. The OFSP purée was stored at room conditions and refrigeration (control). The microbiology of the purée was evaluated during storage for a period of 12 weeks. Inoculation of purée with *E. coli* and *S. aureus* at 10^9CFU/ml resulted in less than 1-log increase after 10 weeks' storage of non-supplemented purée at room temperature and a 3-log decrease in purée at refrigeration temperature. Significant reduction of bacteria counts was observed for the supplemented purée with preservatives and citric acid both at room and refrigeration temperatures ($p<0.05$). There was total inhibition of total viable count of bacteria, yeasts, and molds during the storage period of the purée both at room and refrigeration temperatures compared with controls with no preservatives. A more significant reduction of the counts was observed in refrigerated purée compared with that at room temperature ($p<0.05$). In conclusion, the preservatives at the concentration used in purée are adequate to keep off pathogenic microorganisms and ensure extensive use of purée.

Assuring safe production of purée. Malavi (2017) assessed the level of food safety knowledge, attitude, and hygiene practices of OFSP purée handlers at Organi Ltd Compliance to Good Manufacturing Practices and environmental hygiene was also assessed (Malavi 2018). Equipment surfaces, processing water, and hands of personnel were the major sources of contamination. Data generated were used for designing and conducting a comprehensive training program of all factory staff, an effort that enabled the factory to attain required food safety standards.

Lowering the production cost and improving the nutritional content of purée. At Organi Ltd, women were peeling the roots by hand. The dominant OFSP variety was 'Kabode', known for its bumpy surface. This was leading to considerable weight loss (20–40%) of the initial weight. CIP collaborated with Euro-Ingredients Ltd (EIL) in developing a solution. The introduction of stiff brushes to thoroughly clean the roots and a more powerful purée unit enabled the development of high-fiber OFSP purée, in which the roots are thoroughly washed, not peeled. The skin or peel of sweetpotato is known to contain dietary fiber, Fe, and Zn as well as an acidic glycoprotein that has anti-diabetic properties. The quality of the equipment means that in the so-called "high-fiber" purée, the skin appears as tiny flecks, which are not even noticed by consumers of the high-fiber OFSP bread. EIL subsequently developed a mechanical washer for sweetpotato roots that combines water pressure and abrasion to remove dirt from the roots. This machine, costing €8,000, can clean 100 kg in 6 min and is suitable for larger scale operations.[25]

Characteristics and acceptability of OFSP bread made with shelf-storable purée. To be a successful product, the shelf-storable purée must be acceptable to the bakers and to the consumers. Owade (2018) determined the difference between bread made with fresh OFSP purée and 3-month old preservative-treated OFSP purée bread. Both recipes substituted 40% of wheat flour requirement with OFSP purée. Shelf-stable OFSP purée bread proofed much longer than expected (3–4 hours) compared with 1 hour for fresh preservative-free OFSP purée and standard white bread. Moreover, the shelf-stable OFSP purée breads had a lower volume than the standard weight of bread made with fresh OFSP purée without preservatives. We hypothesize that sorbate slowed down the yeast activity in shelf-stable purée breads. To correct these dough conditioners, baking powder, purée, and yeasts amounts were varied. We found that using yeast at 1.5% of the wheat flour, using 1% baking powder, and adding functional gluten in the 40% wheat flour substitution with shelf-stable preservative treated OFSP purée produced a standard volume bread.

[24] 2% w / w solution means 2 g of solute is dissolved in 100 g of solution.

[25] Organi Ltd continues to wash manually, but a major bakery in Blantyre, Malawi, is now successfully using the mechanical washer in their purée production process.

The next study found that the shelf-storable purée[26] used to substitute either 30% or 40% of wheat flour produced an OFSP bread acceptable to consumers. The saltiness, smoothness, and crumb color scores for shelf-storable OFSP purée bread were similar to those of fresh purée bread but were significantly ($p<0.05$) higher than that of white bread. Shelf-storable OFSP purée bread also had similar sensory profile to fresh OFSP purée bread.

Further investigation of physiochemical properties and shelf-life of OFSP purée bread (30% wheat flour substitution) by Wanjuu (2018) found that the moisture content, beta-carotene content, and the color of OFSP bread significantly decreased with increase in storage temperature and time ($p < 0.05$). Compared with 100% wheat flour bread, OFSP purée bread had a longer shelf-life, showing spoilage on day 6 compared with 4 days for the 100% wheat flour bread. This was attributed to the significantly higher water activity found in the 100% wheat flour bread than in the OFSP bread. However, specific volume of the 100% wheat flour bread was significantly ($p < 0.05$) higher than that in OFSP bread, due to reduced extensibility of gluten. Refrigeration increased crumb firmness, chewiness, and cohesiveness in both types of bread. In conclusion, OFSP purée use at 30% substitution of wheat flour increases the water-binding capacity of the bread, which reduces water activity and increases its shelf-life.

Bioaccessibility of beta-carotene in the OFSP purée bread.[27] Bioaccessibility is defined as the quantity of a compound that is released from its matrix in the gastrointestinal tract, becoming available for absorption (e.g., enters the blood stream). The beta-carotene in an OFSP purée product must be bioaccessible before it can be absorbed and become bioavailable. Using *in vitro* methods, the bioaccessibility of beta-carotene and starch digestibility was determined in OFSP purée bread. OFSP purée–wheat composite breads were prepared by substituting 10–50% wheat flour with OFSP purée in the dough during the bread-making process. The amount of all-*trans*-beta-carotene (βC), 13-cis βC and 9-cis βC in in 10–50% OFSP bread ranged 3.13–25.51, 1.01–7.31, and 0.13–0.77 µg/g fresh weight, respectively. Efficiency of micellarization[28] of all-*trans*-βC, 13-cis βC, and 9-cis βC after simulated oral, gastric, and small intestinal digestion ranged 1.4–6.4%, 1.4–7.2%, and 1.1–6.9%, respectively. The amount of micellarized βC was linearly proportional to concentration in OFSP bread ($r = 0.8927$, $p<0.05$). *In vitro* starch digestion profile showed significant variations from 60 to 120 min. Rapidly digestible starch (SDS), slowly digestible starch (SDS), and resistant starch[29] (RS) fractions significantly differed ($p<0.05$) in 0–50% OFSP bread. RS increased from 9.4% in white bread to 40.7% in 50% OFSP bread. **The bioaccessible beta-carotene and the altered starch digestibility highlight the usefulness of the OFSP-wheat breads to fight vitamin A deficiency *and* help improve the glycemic index (i.e., lower it) in bread.**

Way forward. OFSP purée bread is economically viable, has longer shelf-life, good taste, and good levels of beta-carotene and resistant starch. Shelf-storable OFSP purée lasts well up to 3 months and can be successfully used to make OFSP bread by adjusting the recipe. However, longer proofing time than for 100% wheat flour bread is a barrier for larger bakeries. Hence, the shelf-storable purée product is best suited for baked products that do not need to rise (flat breads and biscuits) and for smaller bread-makers doing a few batches a day. Recently, a 2-year project has been funded to facilitate training small-scale bakers in the use of shelf-stable purée.

Fortunately, there are more advanced technologies for larger agro-processing enterprises to consider. CIP, together with North Carolina State University (NCSU), SinnovaTek Inc., a US-based equipment manufacturer, and Burton & Bamber Ltd, a Kenyan food processing company, are engaging to commercialize aseptic production of non-acidified sweetpotato purée using continuous microwave processing, a technique already in commercial use in the US. Continuous-flow microwave heating system produces a unique, natural, value-added, 2–3-year shelf-stable purée product that can be consumed directly as a food, baby food, used in bakeries, school-feeding programs, and the like. Best of all, the technology retains over 94% of the beta-carotene in the raw sweetpotato samples after processing the purée. Working with NCSU and CIP, SinnovaTek designed smaller microwave unit, NOMATIC™ Small Scale Processor, that reduced the cost from $2.5m to $450,000. The unit can be built to suit specific production needs. In addition, talks are underway with McCains South Africa, which sees OFSP purée as a product that can absorb the unused root portions and peels from their sweetpotato chips production line.

[26] Two different types of OFSP shelf-storable purée were used: treatment 1 with 0.5% potassium sorbate+0.5% sodium benzoate+1% citric acid and treatment 2 with 0.2% potassium sorbate+0.2% sodium benzoate+1% citric acid. Both were acceptable, so the latter as is the recommended level, given the lower cost.

[27] A SASHA technician based at FANEL, Daniel Mbogo, received a Borlaug Fellowship to spend 4 months at South Dakota State University in the US studying the application of *in vitro* methods to assess bioaccessibility of β-carotene and starch digestibility in of OFSP purée composite bread.

[28] The transfer of the beta-carotene into *micelles* or micellerization is part of the process of making the nutrient in foods bioavailable.

[29] Resistant starch functions like soluble, fermented fiber. Part of it goes through the stomach and small intestine undigested, reaching the colon, where it feeds the healthy gut bacteria. Health benefits associated with resistant starch include lower blood sugar levels, improved insulin sensitivity, and reduced appetite.

Efforts are underway to explore new types of private-public partnership models and explore innovative financing options for supporting some of the research and development required for technology transfer and adaptive research.

MS 4.4. Regional capacity and appropriate protocols developed for analysis of roots and derived products at reasonable cost to ensure that they have adequate nutritional quality and meet safety standards.

Research services through FANEL. Since FANEL was established in 2014 within the BecA facility on the campus of the International Livestock Research Institute (ILRI) in Nairobi, Kenya, our main objective has been to build an accessible food and nutritional evaluation laboratory within SSA, equipped with advanced analytical tools operated by knowledgeable and well-trained staff who in turn trains other food scientists. An advanced lab for food safety, specializing in mycology, already existed at BecA. There was, however, a need to expand this capacity to include nutritional evaluation, food compositional analysis, food product development, food safety analysis, and postharvest research. FANEL needs to operate efficiently using standard operating procedures validated by international organizations and working according to international standards. FANEL is committed to supporting a strong capacity-building component, bringing in NARS scientists and graduate students from local and regional universities in partnership with the BecA–ILRI hub or CIP. FANEL has been providing service support to other CGIAR centers and CIRAD, particularly for biofortified crops.

Capacity building is a crucial determining factor for the success of FANEL. FANEL is an innovation platform where motivated students converge and explore their ideas in food science, nutrition, technology, and postharvest management. FANEL thrives as a hub for collaboration between disciplines (breeding, food science, biochemistry, and engineering), crops (sweetpotato, cassava, potato, plantains, etc.), and themes (economics, postharvest processing, and storability).

Over the 5-year period, the laboratory established capacity to undertake detailed carotenoid analysis; proximate analysis; microbial analysis; and the analysis of anthocyanins, vitamin C, glycoalkaloids, and minerals, especially for Fe and Zn. FANEL is serving many biofortified crops. Since its inception 4,794 samples have been analyzed for beta-carotene content out of 19,213 analyses in total. FANEL played a critical role in the development of the shelf-storable OFSP purée. In 2018 an online system known as FANEL-FLOW, developed under RP5, was installed to improve workflow management. As a sustainability strategy, a business plan was developed. As of January 1, 2019, FANEL became an official CIP service unit.

In 2019 Derick Malavi (a research associate in FANEL) attended a hands-on mineral analysis using an inductively coupled plasma (ICP-OES) machine at the Maize Quality Laboratory at the International Maize and Wheat Improvement Center in Mexico. New methods have since been developed in FANEL enabling quantification of minerals (especially Fe and Zn) in different food samples. The ICP-OES, obtained in 2018, was upgraded to include an autosampler, which enables high-throughput analyses of up to 100 samples within a short period of time. This has greatly improved our capacity to quantify the mineral composition of different samples.

FANEL successfully registered for proficiency testing of our protocols with LGC Standards, an accredited proficiency testing laboratory based in the UK. The test samples were received and all members of the FANEL team participated in carrying out the analyses. The protocols which were reviewed are those for vitamin C, carotenoids, minerals, crude fiber, moisture, fats, total sugars, proteins, and ash. Results were uploaded on the LGC portal, and we are currently waiting for the results.

FANEL also enabled partnerships with commercial processing sector in many more countries. OFSP purée processing is gaining the attention of the commercial sector. Uptake by larger agro-processors will ensure that OFSP purée is well adopted. Our role has been the development of innovations and technology demos. Through other projects, CIP is providing the technical expertise to the food industry on the use of OFSP purée in their products and making the business arguments for its commercial viability. FANEL is evolving into an innovation platform that enables partnerships with food technology and other technical service providers. By working with other service providers, we were able to borrow expertise and technologies across this diverse sector to enable many OFSP purée applications. Sweetpotato processing and transformation into a functional ingredient is not well advanced worldwide, although it is extensively processed in China. The development of OFSP purée processing technology involved adoption and modifications of technology from potato, meat, cake-baking, and ice cream-processing technologies. The food technology service providers customized solutions that enabled rapid utilization and adoption of OFSP purée; they understand the whole food manufacturing chain and can assist with strategic positioning of OFSP purée and OFSP bakery product marketing.

E. RP5: Support Platforms, Knowledge Management, and Governance (details found in Appendix F)

To support the achievement of the SPHI vision, CIP is working with national sweetpotato program partners, development actors, and other sweetpotato stakeholders to establish an Africa-wide network of technical support. The Regional Technical Sweetpotato Support Platform (SSP), established during SASHA1, is composed of three subregional breeding platforms hosted by national programs: IIAM in Mozambique, CRI in Ghana, and the National Crops Resources Research Institute (NaCRRI) in Uganda. These host SSPs have NIRS analytic capabilities for high throughput quality analysis. The subregional facilities are linked to KEPHIS, which is responsible for cleaning and distributing sweetpotato germplasm within the entire region and, under SASHA2, training technicians. In addition, BecA now has the support function of sweetpotato genomics and transgenics, and through FANEL nutritional composition and microbial analysis. The subregional SSPs provide parent material and TS to national sweetpotato programs for further varietal selection and evaluation and technical backstopping from three CIP breeders in the region, each supported by a postdoctoral scientist as a part of CIP's succession strategy. Under SASHA2, there were two meetings annually of the Seed Systems and Crop Management group, and an annual meeting for the other three CoP domains: (1) MPU; (2) MLE; and (3) breeding and genomics, with the genomics component supported by the GT4SP, led by NCSU.

All four milestones for this RP were achieved (see Appendix A). The vision of success for RP5 is a vibrant and growing sweetpotato CoP, in which knowledge advances are shared through virtual media and meetings, field visits, trainings, and services for key functions of germplasm exchange, virus diagnostics, and comprehensive training on sweetpotato. There is only one major objective of this RP: to strengthen the expanding sweetpotato CoP. Key activities achieved during SASHA2 are discussed below. Details on activities just for the final year are presented in Appendix F.

5.1. Annual sweetpotato breeding meetings and other CoP meetings. During the past 5 years, the four CoP meetings have served 999 participants (31% women). As shown in Figure 4, the number of organizations participating in the different technical CoPs varied as did the leadership style of each group. The Breeding and Seed System groups strived to have a consistent core group of participants return every year, to steadily build their knowledge base. The breeders adopted the use of common protocols for multilocational trials (Grüneberg et al. 2019) and are committed to using the same data curation and analytic tools. The MPU CoP conducted calls for abstracts on selected themes, so participant composition based on selected abstracts varied significantly each year. However, it is clear from Figure 4 that interest by different organizations in MPU activities has been steadily increasing since 2016. This is driven by growing interest in processing orange-fleshed sweetpotato into diversified products. The Monitoring, Learning and Evaluation (MLE) CoP mostly consisted of CIP staff members engaged in monitoring and evaluation (M&E) activities on different dissemination projects. Other development organizations had their own M&E systems, and hence there were only two other organizations that consistently attended. However, several organizations did adopt or adapt some of the standardized monitoring instruments developed specifically for sweetpotato by the MLE CoP. Two of the CoP groups, Seed Systems and MLE, also held several virtual topic discussions via email in between the annual meetings.

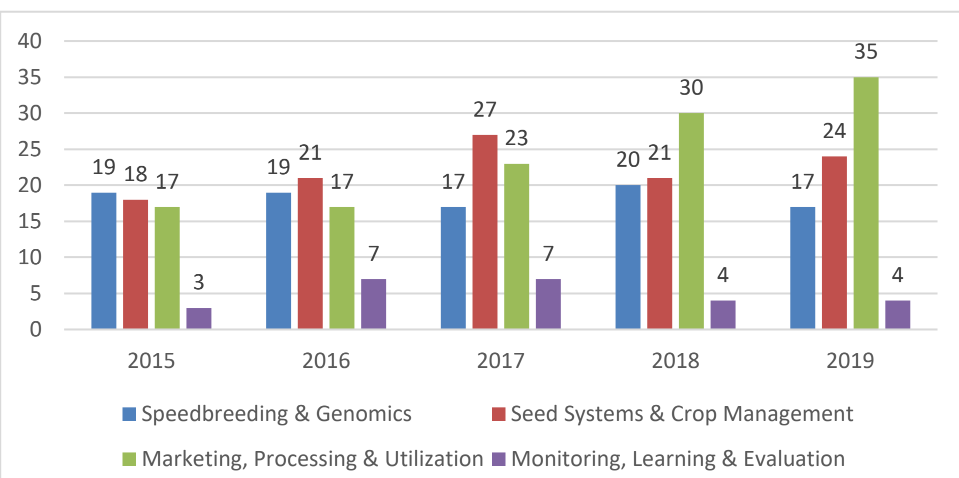


Figure 4. Number of organizations participating in different CoP working groups by year.

5.2. SPHI technical meeting. The overriding objective of the annual SPHI technical meeting was to bring researchers and development practitioners together, so that the latest advances in research would be presented by the next users *and* researchers would be more exposed to the challenges faced by those disseminating new technologies. Six meetings were held under SASHA2, with a total of 591 participants (32% women). Figure 5 shows the number of men and women attending each meeting, in addition to the distinct number of organizations. Many organizations covered their own costs to come to the event. The meeting was 2.5–3 days long, except in 2016 and 2019 when the meeting was aligned with the Triennial APA meeting. The latter is a regional scientific conference held every 3 years focused on advances in sweetpotato and potato research. In those years, presentations on scientific progress were presented in the APA forum and the SPHI technical meeting was 1–1.5 days long.

Minutes have been prepared for each SPHI technical meeting (Table 3) from 2015 onwards, and all presentations and all briefs prepared annually are provided on the SKP (www.sweetpotatoknowledge.org). The minutes also contain an evaluation of the meeting. In addition, two- to four-page briefs are prepared annually that are updates of research outputs achieved under SASHA and then briefs concerning achievements in dissemination by numerous projects under the SPHI umbrella. Hardcopies are provided to SPHI meeting participants. In 2019, 25 SASHA and 17 SPHI briefs were prepared. The 2019 SASHA briefs were focused on major findings from SASHA2.

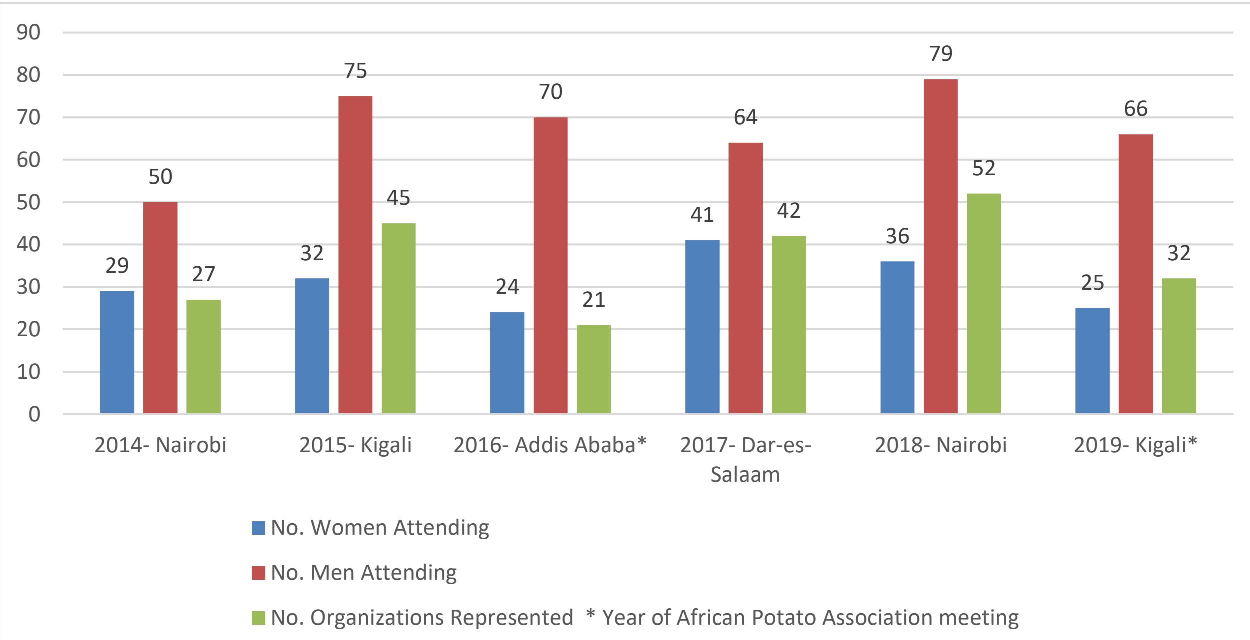


Figure 5. Location and number of men, women, and different organizations attending the annual SPHI technical meeting.

Table 3. Summary of location, themes, and minutes of annual SPHI technical meetings

Date of SPHI Meeting	Location	No. of Days	Theme of Meeting	Milestone Code for Meeting Report	No. of SASHA Briefs	No. of SPHI Briefs
29 Sep–1 Oct 2015	Kigali, Rwanda	3.0	Together, 10m by 2020	OBJ5MS1.2.B	13	17
7–8 Oct 2016	Addis Ababa, Ethiopia	1.5	A Time of Celebration	OBJ5MS1.2.E	14	25
25–26 Sept 2017	Dar-es-Salaam, Tanzania	2.0	Building Resilient Food Systems with Sweetpotato	OBJ5MS1.2.H	17	27
24–26 Sept 2018	Nairobi, Kenya	3.0	Progress in Sweetpotato Research for Development	OBJ5MS1.2.M	21	24
24 August 2019	Kigali, Rwanda	1.0	Sweetpotato's Role in Africa's Food Systems: Reaching Diverse Groups in Diverse Settings'	OBJ5MS1.2.P	25	17

At the end of the last SPHI meeting, a short evaluation of the SPHI technical meetings overall was conducted, with 69 participants responding. Respondents were asked to list the three most useful things they had gotten from attending annual SPHI meetings. Networking ranked as the most important gain. However, if all the responses related to knowledge-sharing are combined (knowledge-sharing, update on sweetpotato research in SSA, exposure to new knowledge and technologies, knowledge on seed systems), it is clearly access to new knowledge that qualifies as the most useful aspect that comes from attending the annual meetings.

Since the start of SASHA2, two additional meetings have been linked to the SPHI technical meeting: the SASHA Project Advisory Board (PAC) and the SPHI Steering Committee meeting (SSC). (Names and contact information of the representatives for these committees are found in Appendix F.) Each of these meetings lasts approximately a half day. For the last SASHA PAC meeting in 2019, however, one entire day was dedicated to letting committee members listen to the research progress under Phase 2 and pose questions (see the minutes Milestone Report 2SS_OBJ5MS1.2.O for details).

PAC members were informed by BMGF representative Jim Lorenzen of the next BMGF-funded project, SweetGains, which will be a 3-year project led by CIP of breeding activities and some seed systems work. Led by Hugo Campos, research director at CIP, the breeding effort captures earlier efforts under SASHA and BMGF-funded projects led by NCSU and NaCRRI of Uganda.

As of 2019, the SPHI SSC was composed of five donor organizations, six research organizations, six NGOs, and one private sector organization. The SSC meeting this year focused on discussions whether or not to continue the SPHI through 2023, as the 2019 Status of Sweetpotato report (Milestone Report 2SS_OBJ5MS1.4.H) presented data that as of July 2019, 6.2m African HH out of the 10m HH target had been reached. Discussions on this issue are laid out in the minutes of the meeting (Milestone Report 2SS_OBJ5MS1.2P). A subcommittee was formed to prepare a proposal for this extension to be submitted to CIP management for approval.

5.3. MLE, capturing dissemination efforts across countries, and SASHA data management. The second phase of the SPHI is focused on "achieving the potential." This means going-to-scale efforts being intensified to reach 10m African HH by 2020 with improved sweetpotato varieties and their diversified use. As the SPHI expanded, more programs and partners have come under the SPHI umbrella (Low and Thiele 2019). At the first SPHI technical meeting in 2010, there were five distinct sweetpotato projects represented; in Y8 (end of Y3 in SASHA2), we had 23 projects represented, 9 led by an organization other than CIP. In Y9 (end of Y4 in SASHA2), we had 22 projects represented, 7 led by an organization other than CIP. In Y10 (end of Y5 in SASHA2), we had 23 projects represented, 9 led by an organization other than CIP.

This year's Status of Sweetpotato in SSA Report (2SS_OBJ5MS1.4.H) was led by CIP's regional economist, Julius Okello, and presented in plenary at the SPHI technical meeting. As noted above, as of July 2019, some 6.2m HH in the 17 target SSA countries have been reached since 2009 (62% of the target). In terms of individuals reached, we estimate 29,595,005 based on average rural HH size for a given country. The countries showing the greatest progress toward their targets set in 2009 are Ethiopia, Tanzania, Mozambique, Uganda, Malawi, Kenya, and Rwanda. DFID, USAID, and Irish Aid have been the principal funders of the scaling effort.

Clearly, getting quality planting material to farmers is core to achieving the goal. During SASHA2, there were annual assessment updates of the status of DVMs. This was the second year that the update was primarily conducted by phone, not through field visits, as a cost-saving measure. In summary, 741 of the 1,030 DVMs recorded in previous years were reached by phone for an update survey in 11 SSA countries. About 76.2% were actively producing vines and 23.8% reported having stopped vine production, citing lack of market as the major contributor and drought as the second most important constraint impeding continued vine production. Vine multiplication in the 11 SPHI countries is predominantly done by men, who constitute 70.3% of those contacted compared with 29.7% women. Details on amount produced, sales, and the dominate varieties disseminated are provided in the detailed milestone report 2SS_OBJ5MS1.4.I.

A major effort of the CIP MEL team[30] during SASHA2 was the development and testing of the survey tools and protocols leading to the subsequent manual entitled, *Tools and Techniques for Monitoring Key Indicators of Sweetpotato Interventions in SSA: A Practitioner's Guide*. There are 13 modules[31] directly relevant to data typically collected in HH surveys and monitoring systems related to sweetpotato. Recognizing that projects and partners have different capacities, three types of data collection tools are included: paper-based systems, ODK tablet-based systems, and CsPro CABI tablet-based systems. In addition, once the data are collected and cleaned, programs written in the statistical package STATA enable users of the

[30]Original 2017 version: Julius Okello, Temesgen Bocher, Jan Low, and Luka Wanjohi. The team working on the revision in 2018 was Julius Okello, Jan Low, Roland Brouwer, Haile Okuku, Luka Wanjohi, Srini Rajendran, Temesgen Bocher, and Kirimi Sindi.

[31] The 13 modules are (1) Household background information; (2) Trends in using sweetpotato; (3) Sweetpotato production and sales volumes; (4) Household food insecurity; (5) Dietary diversity score; (6) Frequency of consumption of vitamin A-rich foods; (7) Capturing sweetpotato vine dissemination; (8) Yield estimation using crop cut; (9) Sweetpotato root market prices; (10) Sweetpotato seed; (11) Knowledge, Attitude and Practice concerning Sweetpotato; (12) Varietal preference; and (13) Household assets (by gender).

guide to analyze the collected data quickly and accurately for major indicators. Final editing is now underway to convert the manual into a published CIP working paper, with plans to have it finalized by 15 January 2020.

Update on sweetpotato breeding information systems. Since 2016, improved trial management software tools such as SweetPotatoBase and HIDAP, have been developed since 2016 by BTI based at Cornell University, Ithaca, New York, and CIP's Research Information Unit, respectively. This was a joint effort with GT4SP, led by NCSU. HIDAP is based on R statistical language and Shiny web framework, and its strength is data curation and data analysis. It can function online and offline. Offline capability is essential for breeders in countries with limited connectivity. The latest offline version, HIDAP 1.0.3, was released in July 2018 and is available at https://research.cip.cgiar.org/gtdms/hidap/ along with a user manual. Unlike HIDAP, SweetPotatoBase (www.SweetPotatoBase.org) is a centralized database, making it possible to issue trials with unique identification numbers and thus, the best application for storing data.

Both HIDAP and SweetPotatoBase offer trial management capabilities. On both systems users can (1) elaborate a germplasm list, (2) design a field trial, (3) elaborate a traits list for a trial from CropOntology.org, and (4) create a field book compatible with Fieldbook app for data collection. The Fieldbook app was developed by Kansas State University and is obtained at https://play.google.com/store/apps/details?id=com.fieldbook.tracker. The statistical design methods, including spatial trends using row and columns such as the Westcott design, are implemented in both HIDAP and SweetPotatoBase. Connections between Fieldbook, HIDAP, and SweetpotatoBase have been done using BrAPI (see Appendix F for details).[32] As of July 2019, after data curation in HIDAP, HIDAP can send the data to SweetPotatoBase for storage, and HIDAP can read stored trial data from SweetPotatoBase to create the statistical, reproducible report.

As new tools or improved versions became available of the different tools, training sessions were built into the annual SpeedBreeders meeting. However, starting in 2018, after the different applications were connected and most bugs worked out, in-country training was essential to get the technicians as well as the breeders using the "Breeding Information System." In-country trainings in both HIDAP and SweetPotatoBase have been conducted by Luka Wanjohi or Jolien Swanckaert in Burkina Faso, Ghana, Rwanda, Uganda, and Mozambique. Ethiopian and Tanzanian teams have also been trained just in HIDAP.

All the CIP population development programs are committed to adopt the use of the SweetPotatoBase for trial management and the Fieldbook app for phenotyping. As of November 2019, 134 breeding trial databases from the Ugandan program, 3 databases from the Mozambican program, 261 databases from Ghana program, and 29 databases from the CIP-HQ program have been loaded onto SweetPotatoBase. All remaining databases from Mozambique (197) and HQ (41) being curated should be loaded by mid-December 2019.

Finally, the development of a tool for managing crossing parents is underway. This is by Kansas State University with input from CIP. Once ready, this application will be connected to SweetPotatoBase using BrAPI.

The development of FANEL-FLOW: Information system for FANEL. FANEL-FLOW is an online laboratory management system developed in-house to help improve information and workflows management within FANEL. The system allows online registration of new samples by authorized FANEL staff members. All registered samples are automatically issued with a unique sample identification number and a barcoded label printed on a self-adhesive paper and affixed before storage. A list of 27 different types of analyses have been built into FANEL-FLOW and each of these can be independently initialized and tracked within the system for every registered sample. The FANEL-FLOW core is based on a Drupal 7 Open source distribution called ERPAL. Drupal is a free and open-source content management framework written in PHP Hypertext Processor and distributed under the GNU General Public License. Since the launch of FANEL-FLOW in 2018, over 1,800 analyses have been processed through the system. Several improvements in the system were made in 2019 (Appendix F for details). These include the ability to setup a bulk sample registration module by way of importing a comma separated values file and being able to have FANEL-FLOW operate in multiple location. In mid-2019, FANEL expanded operations and set up shop in Namulonge, Uganda, linked to the RTBFoods project. FANEL-FLOW is now in use in that laboratory.

5.4. Gender-sensitive communication strategy, including management of the SKP. SASHA outputs are organized into a communication outputs database, and all published articles are being entered into an Endnotes citation database to ease use of SASHA-supported publications by researchers. During the last year of SASHA2, we invested in a software POBUCA, which enables better organization of our contact list into different categories. Moreover, contact lists can be shared across

[32] BrAPI or Breeding API is an interface for exchanging breeding data between different applications, using a set of standard definitions and protocols.

users. This should enhance the quality of our mailing lists for the E-digest and informing users about upcoming CoP meetings and other events. As of November 2019, we have 1,910 contacts organized by categories in the database.

Open access. In 2016 SASHA2 began using the open access support service being provided by BMGF, which pays journal fees for those qualifying journals (i.e., the journal must permit that the articles are published under a **CC BY 4.0 license**). All articles published since linked to SASHA support have taken advantage of this system, when the journal permits open access.

During SASHA2 three separate open access trainings were held in Nairobi for CIP scientists to ensure that all staff understood and could implement the open access process, particularly for preparing databases and articles for loading onto Dataverse, the open access repository that CIP has adopted. SASHA covered 50% of the time of the regional open access officer, who also coordinated the annual archiving of SASHA data in progress during August–September of each year. Datasets related to HH survey work, and datasets linked to publications are found in Appendix F2, 29 in total. Since launching the open access effort in 2015, CIP now has 190 datasets uploaded with good metadata. In 2018 CIP had 40 publications, of which 30 were open access and 10 with limited access.

SKP. The SKP (www.sweetpotatoknowledge.org) serves as the major mechanism for sharing research tools, communication outputs, and SPHI progress data through the Dashboard. Launched in December 2010 as a platform to harness and improve access to technical, scientific, local, and development knowledge on sweetpotato across the SSA, it seeks to link stakeholders from research with policymakers, development and private sectors, farmers, consumers, and students. Initially, the portal was built using Plone, an open-source software that is renowned for its security features, but which requires a high level of technical proficiency. As a result of a BMGF Sentinel Grant, the SASHA project received support to redesign the portal, which was relaunched on 15 February 2016 on WordPress. Further improvements were made to the Portal in 2019 based on a user assessment. (These are described in detail in Appendix F.)

Since 2016 annual traffic (measured by number of sessions) to the portal has almost doubled. The number of visits from tablets and mobile devices has almost quadrupled (Fig. 6): In the annual period ending June 2019, access to the portal using mobile devices stood at 28.66%. The SKP was primarily meant to cater to the sweetpotato CoP in the 17 SSA countries

Fig. 6 Sweetpotato Knowledge Portal Sessions
Jul 1, 2010 - Jun 30, 2019

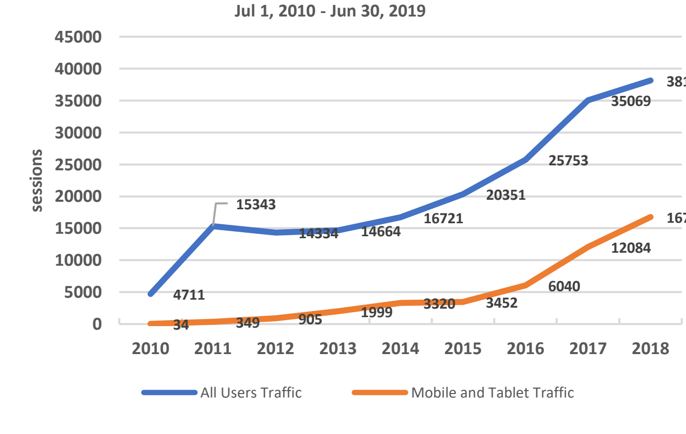
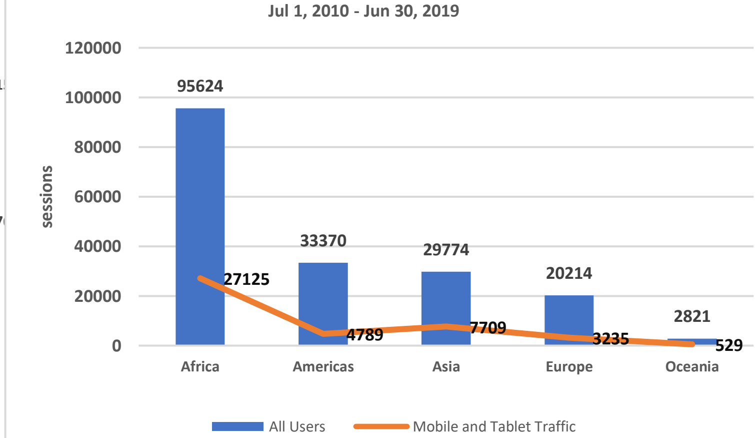


Fig. F7 Sweetpotato Knowledge Portal Sessions by Continent
Jul 1, 2010 - Jun 30, 2019



targeted under SPHI, but usage statistics show that SKP users originate from all over the world (Fig. 7).

Y5 of SASHA2 is officially from 1 July 2018 through 30 June 2019. There was then a 4-month NCE period (1 July 2019–31 October 2019), which overlapped with the annual SPHI technical meeting and the 11th Triennial APA meeting during which more people were exposed to the SKP. Table 4 provides an overview of the evolution of engagement with the portal over the last 4.25 years. There has only been a gradual increase in the number of registered users and files added to the system. However, in the last 4 months, 75 additional users have joined, no doubt due to the assistance received during major technical meetings.

Table 4. Summary of number of users, files, new stores, and links on the SKP by year: July 2017–31 October 2019

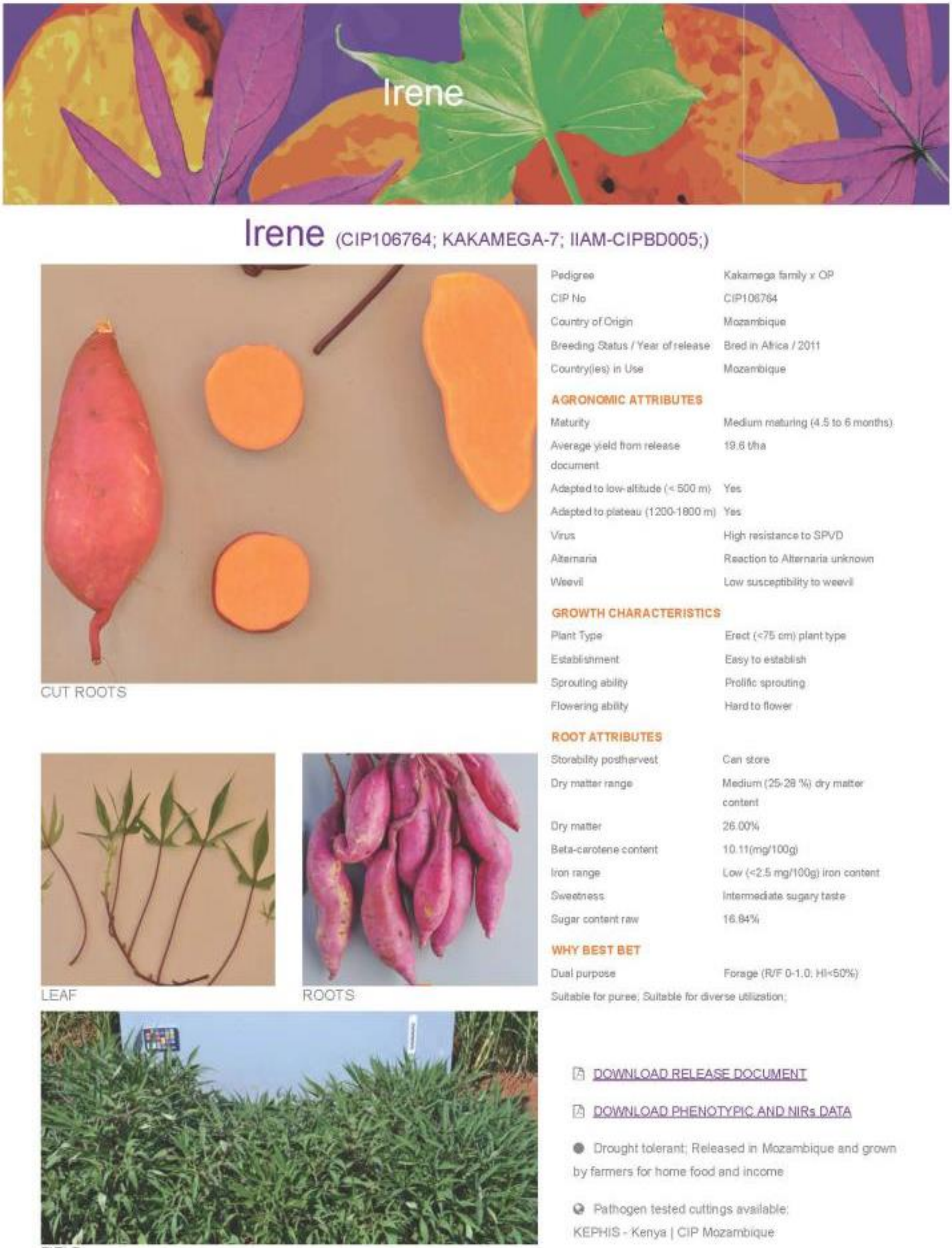
Category	No. of Users and Content Items (July–December 2017)	No. of Users and Content Items (January–June 2018)	No. of Users and Content Items (July–December 2018)	No. of Users and Content Items (January–June 2019)	NCE Period (July–October 2019)
Number of registered users	573	661	729	797	872
Project initiatives	47	48	51	51	51
Institutions	32	32	32	32	32
Files	2,199	2,050	2,287	2,296	2,344
External links	121	100	105	106	116
Events	56	67	79	82	106
News and features	275	314	354	378	404

The number of sessions per year have grown from 15,709 in Y3 of phase 2 to 38,151 in Y5, more than double the Y3 figure. That trend has continued in the last 4 months, with 16,873 users from July to October 2019. Accessing using the mobile phone as opposed to a desktop computer has steadily increased, from 32.4% in the second half of 2017 to 51.1% during the past 4 months. The "bounce rate" has remained around 66%, meaning that many users reaching the site do not stay long; they were not really seeking information on sweetpotato cultivation in use, particularly in Africa. The top four countries using the SPK, in order, are Kenya, the United States, Nigeria, and the Philippines.

Social media. The SKP has an active presence on Facebook, Twitter, Flickr, and YouTube. As of July 2019, our Facebook site had 17,838 followers and with 838 followers on Twitter. The top three countries by number of followers on Facebook are Madagascar (3,257), Ethiopia (2,712), and Uganda (1461). Kenya has the highest number of followers on the Twitter page (27%), followed by United States (12%) and Nigeria (10%). These social media sites have been linked into the improved portal. Media files have been linked into the SKP from Flickr and YouTube.

Starting in October 2018, important sweetpotato updates (e.g., blogs on events and stories, notice of new publications and communication tools, etc.) have been going out to the community as an electronic newsletter (E-Digest). For the October 2019, 2,024 subscribers successfully received the newsletter: 23.4% (474 recipients) of them opened the newsletter. An archive of all the monthly newsletters is available online and the links have been put up on the improved portal, arranged by the month.

Development of an online, digital catalogue for sweetpotato. The first edition of the *Orange-fleshed Sweetpotato for Africa* catalogue was published in 2010, with the second edition coming out in 2014. Both editions were published on print and online as PDF files. In 2016 sweetpotato breeders from 16 countries nominated their "best-bet" varieties (which could include well-performing local landraces as well as released varieties), with the commitment to have them phenotyped in a common location (Kenya) and genotyped at BecA, with information used to establish a digital catalogue that would be easy to update. Section MS 3.2.2 described the process for preparing the information on each variety for the catalogue. The online edition (https://research.cip.cgiar.org/sweetpotato-catalog/cip_sp_catalogue/) presents information on 80 popular sweetpotato varieties in SSA of all flesh-color types using a web-based application accessible via a browser and a mobile application for smartphones. It is easily accessible on the SKP and CIP's website. Each variety has a set of morphological characteristics, root attributes, and other major attributes as well as consumer and processing qualities. Users can search for their favorite varieties by name, country of origin, agronomic attributes, growth characteristics, root attributes, and usage. For every variety, users also have access to detailed phenotypic characteristics, release documents (if available) and DNA fingerprints. The 2019 catalogue with information on 80 varieties was launched at the annual SpeedBreeders meeting in June 2019. Figure 8 provides a sample page for a variety in the catalogue. An online procedure exists within the digital catalogue to "Add a New Variety," which should facilitate updating using protocols provided for taking quality photographs and for recording phenotypic data.



Irene

Irene (CIP106764; KAKAMEGA-7; IIAM-CIPBD005;)

Pedigree	Kakamega family x OP
CIP No	CIP106764
Country of Origin	Mozambique
Breeding Status / Year of release	Bred in Africa / 2011
Country(ies) in Use	Mozambique

AGRONOMIC ATTRIBUTES

Maturity	Medium maturing (4.5 to 6 months)
Average yield from release document	19.6 t/ha
Adapted to low-altitude (< 500 m)	Yes
Adapted to plateau (1200-1800 m)	Yes
Virus	High resistance to SPVD
Alternaria	Reaction to Alternaria unknown
Weevil	Low susceptibility to weevil

GROWTH CHARACTERISTICS

Plant Type	Erect (<75 cm) plant type
Establishment	Easy to establish
Sprouting ability	Prolific sprouting
Flowering ability	Hard to flower

ROOT ATTRIBUTES

Storability postharvest	Can store
Dry matter range	Medium (25-28 %) dry matter content
Dry matter	26.00%
Beta-carotene content	10.11(mg/100g)
Iron range	Low (<2.5 mg/100g) iron content
Sweetness	Intermediate sugary taste
Sugar content raw	16.84%

WHY BEST BET

Dual purpose	Forage (R/F 0-1.0; HI<50%)

Suitable for puree; Suitable for diverse utilization;

CUT ROOTS

LEAF

ROOTS

FIELD

DOWNLOAD RELEASE DOCUMENT

DOWNLOAD PHENOTYPIC AND NIRs DATA

Drought tolerant; Released in Mozambique and grown by farmers for home food and income

Pathogen tested cuttings available:
KEPHIS - Kenya | CIP Mozambique

Figure 8. Sample page for a specific variety on the from the online sweetpotato catalogue.

5.5. Outreach at other international meetings. During SASHA2, many SASHA-supported scientists actively participated in the two Triennial APA meetings: 2016 in Addis Ababa (Low et al. 2015) and 2019 in Kigali; the International Society of Root and Tuber Crop (ISTRC) Global Meetings (2016 in Nanning, China, and 2018 in Cali, Colombia); and African Branch (ISTRC-AB) meetings (2017 in Dar-es-Salaam); the triennial African Crop Science Society meetings (2015 in Abuja, 2018 in Cape Town); and the annual Africa Green Revolution Forum meetings (2014 in Addis Ababa, 2016 in Nairobi, 2017 in Abidjan, 2018 in Kigali, 2019 in Accra). Project manager Jan Low and others linked to the nutrition field usually attended the triennial International Congress of Nutrition (2013 in Grenada, Spain, 2017 in Buenos Aires, Argentina); the triennial Micronutrient Forum (2014 in Addis Ababa, 2016 in Cancun, Mexico); the ANH Academy week (2016 in Addis Ababa, 2018 in Accra, 2019 in Hyderabad, India); and the Federation of African Nutrition Societies meetings (2015 in Arusha, 2019 in Kigali).

After three CIP scientists working on SASHA (Jan Low, Maria Andrade, and Robert Mwanga) won the World Food Prize in in October 2016 (Low et al. 2017a)—a momentous occasion—there have been numerous speaking engagements since then. Moreover, the three laureates are invited back to the Borlaug Dialogue in Des Moines, Iowa, annually to participate on panels and the Global Youth Institute and speak at local universities. Maria Andrade has been awarded several additional prizes: Swaminathan Award for Environmental Protection (2017); ISTRC-AB Appreciation Award (2017); Wonder Woman of Agriculture (USDA, 2018); and Woman of the Year (2018, Cabo Verde, her home country). Both she and Robert Mwanga received the Outstanding Alumnus Award from NCSU in 2017. In addition, CIP won the Al-Sumait Food Security Prize for Development for its work on OFSP in 2016.

5.6. Opportunities for graduate students to be linked to ongoing research projects. The number of graduate students supported by SASHA2 for most or all of their costs has been limited and directly linked to major research outputs for the project.[33] CIP scientists, however, are frequently co-supervisors on sweetpotato graduate research projects, as reflected in the reference list (see Section F below). FANEL is also proving to be a magnet for attracting students and senior scientists who want to conduct quality analysis and consumer acceptability studies. Likewise, breeders and students have been able to get grants through BecA to undertake research with support from CIP's Mercy Kitavi using fingerprinting and other genetic tools. SASHA maintains a database with all students directly or partially supported (i.e., staff supervision) by SASHA-linked scientists. Additional details are provided in Appendix F.

F. Articles, Manuals, and Brochures Published during SASHA2 (2014–2019)—Briefs not included[34]

Abidin, P., I. Dorgbetor, J. Kazembe, D. Akansake, E. Dery, and E. Carey. 2018. *A guide to storage of fresh sweetpotato in sand pits or boxes: Extending fresh sweetpotato root availability in drought-prone areas after harvest*. International Potato Center, Nairobi, Kenya, 10 p.

Abidin, P.E., and E. Carey. 2018. Improving the breeding, cultivation and use of sweetpotato in Africa. Chapter taken from: Wang-Pruski, G. (ed.), Achieving sustainable cultivation of potatoes Volume 1: Breeding improved varieties. Burleigh Dodds Science Publishing, Cambridge, UK: 1-33. (ISBN: 978 1 78676 100 2; www.bdspublishing.com). http://dx.doi.org/10.19103/AS.2017.0016.12

Abidin, P.E., S. Adekambi, J. Nchor, I. Koara, and E.E. Carey. 2017. An Orphan Crop, The Orange-Fleshed Sweet potato, in West Africa: Can We Reposition it? *Research & Reviews: Journal of Botanical Sciences* **6**(4): 37-40.

Abidin, P.E., D.A. Akansake, K.B. Asare, K. Acheremu, and E.E. Carey. 2017. Effect of sources of sweetpotato planting material for quality vine and root yield. *Open Agriculture* **2**: 244-249.

Abidin, P.E., J. Kazembe, R.A. Atuna, F.K. Amagloh, K. Asare, E. K. Dery, and E. E. Carey. 2016. Sand Storage, Extending the Shelf-Life of Fresh Sweetpotato Roots for Home Consumption and Market Sales. *Journal of Food Science and Engineering* **6**: 227-236.

Adam, R. I. 2014. *Gender and the dynamics of production and distribution of sweet potato planting materials among small holder farmers in the Lake Victoria Zone Region, Tanzania*. PhD, Pennsylvania State University, 358 p.

Adam, R. I., L. Badstue, and K. Sindi. 2018. The dynamics of smallholder farmers' acquisition and distribution of sweetpotato vines in the Lake Victoria Zone Region, Tanzania. *Food Security* **10**(2): 339-350.

Adikini, S., S. B. Mukasa, R. O. M. Mwanga, and R. W. Gibson. 2015. Sweetpotato cultivar degeneration rate under high and

[33] The fully supported students during SASHA2 comprise Astère Bararyenya (PhD Breeding- Continuous Root Formation); Bramwel Wanjala (PhD virology-Begomoviruses, LAMP diagnostics; ClonDiag diagnostics); and Phabian Makokha (MSc- Sandponics).

[34] This list includes articles and other outputs that were fully or partially funded under SASHA2 or SASHA1. SASHA scientific staff time on thesis research Is considered to be a SASHA contribution.

low sweetpotato virus disease pressure zones in Uganda. *Canadian Journal of Plant Pathology*: 32.

Adikini, S., S. B. Mukasa, R. O. M. Mwanga, and R. W. Gibson. 2016. Effects of Sweet Potato Feathery Mottle Virus and Sweet Potato Chlorotic Stunt Virus on the Yield of Sweetpotato in Uganda. *Journal of Phytopathology* **164**(4): 242-254.

Adikini, S., S. B. Mukasa, R. O. M. Mwanga, and R. W. Gibson. 2019. Virus Movement from Infected Sweetpotato Vines to Roots and Reversion on Root Sprouts. *HortScience* **54**(1): 117-124.

Agbessenou, A., D. D. Wilson, M. K. Billah, W. Dekoninck, C. Vangestel, E. E. Carey, and K. Adofo. 2016. Survey on the distribution of the Sweet potato weevil, *Cylas* species-complex in Ghana (Coleoptera: Brentidae). *Bulletin van de Koninklijke Belgische Vereniging voor Entomologie* **154**: 81-88.

Akansake Daniel, A., E. Abidin Putri, and E. E. Carey. 2018. Modeling the impact of sweetpotato weevils on storage root yield. *Open Agriculture* **3:** 319.

Alhassan, S., G. Nyarko, R. A. Atuna, E. E. Carey, J. W. Low, and F. K. Amagloh. 2018. Packaging containers for long-distance transport of sweetpotato [Ipomoea batatas (L) Lam] storage roots in Ghana. *Open Agriculture* **3**(1): 596-608.

Alvaro, A., I. Andrade Maria, S. Makunde Godwill, F. Dango, O. Idowu, and W. Grüneberg. 2017. Yield, nutritional quality and stability of orange-fleshed sweetpotato cultivars successively later harvesting periods in Mozambique. *Open Agriculture* **2:** 464.

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Andrade, M. I., J. Ricardo, A. Naico, A. Alvaro, G. S. Makunde, J. W. Low, R. Ortiz, and W. J. Grüneberg. 2016a. Release of orange-fleshed sweetpotato (*Ipomoea batatas* [l.] Lam.) cultivars in Mozambique through an accelerated breeding scheme. *The Journal of Agricultural Science*: 1-11.

Andrade, M. I., A. Alvaro, J. Menomussanga, G. S. Makunde, J. Ricardo, W. G. Grüneberg, J. W. Low, and R. Ortiz. 2016b. 'Alisha', 'Anamaria', 'Bie', 'Bita', 'Caelan', 'Ivone', 'Lawrence', 'Margarete', 'Victoria', Sweetpotato. *HortScience* **51**(5): 597-600.

Andrade, M. I., A. Naico, J. Ricardo, R. Eyzaguirre, G. S. Makunde, R. Ortiz, and W. J. Grüneberg. 2016c. Genotype x environment interaction and selection for drought adaptation in sweetpotato (Ipomoea batatas [L.] Lam.) in Mozambique. *Euphytica*: 1-20.

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2. Geographic Areas to Be Served

Provide the final list of countries and sub-regions/states that have benefitted from this work and associated dollar amounts.

Location Served	Foundation Funding	Year 1 Expenses	Year 2 Expenses	Year 3 Expenses	Year 4 Expenses	Year 5 Expenses	Total	Total Balance	% Spent
	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	
Ethiopia	**926,737**	146,474	202,486	206,606	143,427	119,954	818,947	**107,790**	**88%**
Kumasi, Ghana	**3,732,977**	754,680	778,479	704,822	890,904	809,037	3,937,922	**(204,945)**	**105%**
Maputo, Mozambique	**4,241,184**	868,949	1,042,154	631,993	1,033,932	1,017,198	4,594,226	**(353,042)**	**108%**
Kenya	**4,445,374**	822,475	1,040,174	802,596	342,056	522,150	3,529,451	**915,923**	**79%**
Namulonge, Uganda	**3,848,329**	681,308	869,536	756,231	916,245	892,371	4,115,690	**(267,361)**	**107%**
Tanzania	**748,133**	21,630	158,293	268,320	178,327	260,506	887,077	**(138,943)**	**119%**
SSA in general	**1,416,776**	90,390	276,904	351,626	383,448	186,655	1,289,022	**127,754**	**91%**
World in general	**2,284,198**	300,234	181,244	661,549	482,635	867,703	2,493,365	**(209,167)**	**109%**
Total	**21,643,707**	**3,686,139**	**4,549,269**	**4,383,742**	**4,370,975**	**4,675,573**	**21,665,699**	**(21,992)**	**100%**

3. Geographic Location of Work

Provide the final list of countries and sub-regions/states where this work has been performed and associated dollar amounts.

Location of Work	Foundation Funding	Year 1 Expenses	Year 2 Expenses	Year 3 Expenses	Year 4 Expenses	Year 5 Expenses	Total	Total Balance	% Spent
	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	U.S.$	
Ethiopia	573,155	75,626	98,905	114,086	76,724	75,279	440,620	**132,536**	**77%**
Kumasi, Ghana	2,643,070	389,650	380,249	432,448	507,725	607,945	2,318,017	**325,053**	**88%**
Lima & San Ramon, Peru	3,936,145	938,264	1,165,764	940,140	994,233	337,683	4,376,083	**(439,938)**	**111%**
Maputo, Mozambique	3,159,682	448,648	509,042	386,754	592,467	787,733	2,724,643	**435,039**	**86%**
Nairobi, Kenya	4,811,777	1,108,167	1,538,651	1,670,671	1,358,985	1,719,051	7,395,525	**(2,583,748)**	**154%**
Namulonge, Uganda	3,557,778	351,767	424,726	460,598	520,293	670,582	2,427,966	**1,129,812**	**68%**
Tanzania	698,271	11,168	77,319	152,524	97,225	192,651	530,887	**167,384**	**76%**
UK	523,322	161,166	219,361	69,749	58,529	14,001	522,807	**515**	**100%**
Other SSA	1,148,066	46,669	135,254	156,773	164,794	87,012	590,501	**557,565**	**51%**
Other World	592,440	155,014		-	-	183,636	338,650	**253,790**	**57%**
Total	**21,643,707**	**3,686,139**	**4,549,269**	**4,383,742**	**4,370,975**	**4,675,573**	**21,665,699**	**(21,992)**	**100%**

4. Lessons Learned

Describe the top one to three takeaways or lessons learned from this project.

Lessons Learned and Way Forward

Breeding

1. ABS works well in sweetpotato and enabled NARS with limited grants (3 years from AGRA) to make significant progress in responding to challenges involving malnutrition, food security, and adaptation to climate change. Although a lot of seed from population development programs was distributed, only three countries released 11 varieties selected from seed provided by the Ugandan population development program—5 by Madagascar, 3 by Kenya, and 3 by Malawi. In contrast, when clones or released varieties are sent to different countries as pathogen-tested cuttings, evaluations and uptake are faster. Several countries lacking resources to have crossing blocks or desiring specific traits have released varieties bred in other SSA countries, including Ivory Coast, Madagascar, Rwanda, and Burundi. Given that the implementation of HEBS is more costly than ABS, and the decision by AGRA to no longer support national breeding efforts, it is likely that national programs will rely more heavily on selecting from varieties developed in other SSA countries or from seed from the population development platforms in the future. Having a more refined understanding of target populations of environments is needed and should help guide future breeding investments.

2. Field screening of sweetpotato germplasm for resistance to SPVD, commonly based on symptom severity and incidence of plants infected with SPVD following natural infection, is problematic because vector populations fluctuate over seasons (i.e., some plants may escape infection and might be considered resistant). Large (50,000– 100,000) populations of F_1 seedlings require testing each season to identify agronomically superior SPVD-resistant genotypes. However, plants in the field may initially escape infection, taking 3 or 4 years to show SPVD symptoms, making field screening for resistance slow and inefficient. Making significant progress for SPVD resistance and yield in the SPVD hot spot at Namulonge in Uganda necessitated using a combination of techniques (gene pool separation using SSR markers, discrimination of SPVD-resistant and -tolerant genotypes, elimination of poor progenitors for SPVD resistance, selecting parents in a recurrent selection scheme based on BLUPS, GCA, parents of elite crossings, Pesek Baker index scores, best (top) performing parents, and special consideration for beta-carotene content). From populations of 130 parents (50 population A and 80 population B), the base set of parents (20 genotypes from each population A and B) selected in 2019 to start the first cycle of recurrent selection, a HEBS sin sweetpotato will enable a yield jump in a population with high SPVD resistance.

3. There is no such thing as a “perfect” variety. But with experience and understanding which of the improved varieties are being widely adopted, the list of essential traits is expanding, with implications for breeding programs. The ability to establish easily and having a good multiplication rate are essential features required by vine multipliers. Further, the perishability of sweetpotato, both in-ground and postharvest, is a significant constraint not yet addressed through systematic breeding efforts. In drought-prone areas, the ability of a variety to sprout after the dry season is essential for sustainability in smallholder systems. A key lesson is that apart from good agronomic and adaptation traits, cooking profiles most desired by consumers are critical for wider adoption of a variety. Using DM as an indicator of taste and consumer acceptance is no longer sufficient. The West African program led the way in setting up a sensory panel for more refined evaluation of taste, and Uganda and Mozambique will follow suit. Interaction with the RTBFoods project has been useful for exposure to new tools and methods. Greater attention needs to be paid to defining specific target groups in terms of how the sweetpotato will be utilized.

4. Data collection, management, and analysis tools are essential and the integrated SweetPotatoBase/FieldBook/HIDAP set of tools is powerful. The challenge is the time it takes to develop such a toolset, especially when different institutions are involved, and tool developers are not working on the tool development full-time. At the end of SASHA1, the CloneSelector tool was in use by partner NARIs and CIP programs. CIP-HQ decided to no longer support CloneSelector, with the expectation that the new toolset would be ready within 2 years. However, it really took 4.5 years for the system to be up and running. Some national programs returned to using GENSTAT, etc. due to the delay. In retrospect, existing functioning tools should be supported until new tools truly are ready for use. As was the case for CloneSelector, in-country training of national program technicians and breeders is required for significant use of the new toolset. For those countries not yet trained, this should be a priority activity in the next phase.

5. The idea of exploiting heterosis in a vegetatively propagated crop took 10 years to test and validate. Clearly, the new breeding strategy emerging out of this work will vastly enhance the rates of genetic gain for many traits such as root yield, number of commercial roots, virus resistance, low sweetness, and iron status. This points to the need for longer term, consistent support to test worthy ideas. Sometimes these ideas do not work out, as was the case for transgenic weevil resistance. The 10-year commitment also enabled a new population development platform to get off the ground in West Africa. Experience has demonstrated that each subregional platform is truly serving distinct needs in their respective subregions. During the past 3 years, the Ghana-based breeding program overcame low TS production, a key constraint hampering its efficiency. With these resolved, efforts must be made to sustain this breeding platform, particularly given that West Africa has 381m people (2017 figure), 30% of the continent’s population.

Seed Systems

6. For high sweetpotato virus pressure areas more than 250 km from a reliable source of pathogen-tested pre-basic seed, support for the use of protected structures by medium- to large-scale multipliers is justified to increase availability of quality seed for farmers. Mini-screenhouses have been shown to be superior to net tunnels.

7. The use of an optimized nutrient media in sandponics for sweetpotato pre-basic seed production led to a 22% increase in multiplication rate; reduction in unit cost of production; and, when subsequently used for planting

material, better establishment and increased storage root yield. CIP-KEPHIS will adopt this as the way to multiply pre-basic seed in the future. It is likely national partners will need support to make the transition.

8. Public sector institutions can implement financially viable business models, with revenues from the sales of seed paid into institutional revolving fund mechanisms for sustained production of sweetpotato EGS. An analysis of the capacity of the institutions to cover the cost of production for target sales showed that the majority were able to cover their costs in 2018 and will continue to do so in 2019. All institutions developed marketing strategies, but a concerted effort will continue to be needed to strengthen linkages between these institutions and basic seed multipliers.

Postharvest

9. In hindsight, a technical partner with more hands-on experience in sweetpotato storage might have been a better choice. While the project arranged for the NRI engineer to visit a sweetpotato storage expert at NCSU at the beginning of the project, key aspects of the storage systems in the US were not taken into consideration during initial design. Two years were lost using the evaporative cooling approach. For the storage trials, it would have been useful to have more than one storage facility available for conducting different trials concurrently.

10. Fresh root storability after harvest, both under ambient conditions and in cooled facilities, clearly is a varietal trait that needs more precise understanding and attention paid to it in the breeding programs.

11. One of the big challenges of using OFSP purée has been its perishability, the development a shelf-stable OFSP purée with safe and permitted preservatives in Kenya that can last for 4 months at ambient conditions with limited loss of color and nutrition can increase the utilization of OFSP by informal sector, rural bakeries and small-scale processors. The application of hot-fill and microwave aseptic processing of OFSP purée increases the diversity of utilization of OFSP purée beyond the bakery sector.

12. The establishment of FANEL and its growth into a service unit by the end of the project is a great achievement as a regional center of excellence for nutrient analysis has been a major bottleneck in SSA. We anticipate in the future that demands for work in food safety will expand alongside the growing demand for nutrient analysis and labeling of food products.

Community of Practice and Governance

13. Given the geographical dispersion of the project in SSA, quarterly project management team meetings in person, combined with short biweekly update (two pages maximum) reports per component leader enabled the project to stay on track for the vast majority of activities because most emerging issues could be detected and dealt with in a timely manner.

14. SPHI proved to be a useful mechanism for uniting a diverse set of organizations under a common goal that made minimal, yet acceptable demands on members concerning sharing information. The SPHI provided the interface between researchers and practitioners which is so often lacking. This mechanism facilitated integration of new varieties and technologies into dissemination efforts in a timely manner. Strong positive evaluations were received from those participating in one of the four technical working CoPs and those coming to the annual SPHI technical meeting.

5. Feedback for the Foundation

Provide one to three ways the foundation successfully enabled your work during this project. Provide one to three ways the foundation can improve.

A. Ways in which BMGF enabled our work

1. BMGF's commitment to encouraging linkages between different projects they support enhanced learning opportunities. SASHA2 benefitted greatly through being involved in the EiB initiative, the GREAT training courses, and RTBFoods, in addition to BMGF's commitment to gender equity.
2. Providing grants with a 5-year timeframe enables realistic progress in research to be made, minimizing staff turnover and maximizing time staff can spend on research, as opposed to fund raising. This is particularly true for breeding and seed system research, which typically need 4–5 years of investment to make meaningful achievements.

3. BMGF program officers typically listen and are willing to consider changes in approaches or adjustments to protocols/ milestones as interim findings emerge. This enables the best use of the research funds to achieve meaningful outputs and outcomes.

B. Suggestions for improvement

1. When there is a change in senior leadership at BMGF, new strategies are designed which take considerable time to put into place and often include some dramatic shifts. Progress in agricultural research in some areas requires time and consistent support. While clearly there is a need to respond to the ever-changing world we live in, there is also a need to ensure the return on investment in a concept through staying on course.
2. The number of "focus" countries is very limited. For example, in the context of SSA, virtually ignores southern Africa where climate change is likely to have its greatest impact. While the desire for achieving impact at scale is understood, there is also a risk to concentrating one's resources in few countries, some of which are politically volatile. This would not be as great of a concern, except for the trend for other donors to follow BMGF's lead in terms of focus country concentration and selection. Consequently, technologies for some key environments where millions of people live are not being developed; nor is access to promising interventions occurring in a timely manner. Fortunately, in the case of sweetpotato breeding, drought tolerance breeding based in Mozambique has been well supported and will serve the needs of many countries outside Southern Africa.

6. Global Access and Intellectual Property

If your funding agreement is subject to Intellectual Property Reporting, please click the following link to complete an Intellectual Property (IP) Report.

If not, please acknowledge by typing "N/A": N/A

7. Regulated Activities

Do you represent that all Regulated Activities[1] related to your project are in compliance with all applicable safety, regulatory, ethical and legal requirements? Please mark with an "X":

N/A (no Regulated Activities in project)

_____ Yes

_____ No (if no, please explain below)

8. Subgrants (Not Required by SASHA)

If your grant agreement (not applicable to contracts) is subject to expenditure responsibility and permits you to make subgrants to organizations that are not U.S. public charities or government agencies/instrumentalities, please complete the Subgrantee Checklist and attach a copy with this progress narrative for each such subgrantee. *Not required.*

Financial Update

1. Latest Period Variance:

"Latest period variance" compares expenditures that occurred in the reporting period against the most recent forecast. See "Financial Summary & Reporting" sheet in the foundation budget template for calculated variance (for example, column AD, starting on row 29 for period 1). Note that the allowable variance is defined in your grant agreement.

A. Project Financial Status

At the end of The SASHA II project, CIP spent 100% of the allocated budget. In addition to this, upon approval CIP also utilized income earned from accumulated bank interest and generated income from sale of Sweetpotato germplasm amounting to $21,998 (please see Table 1 and Table 4 below), with the income breakdown in table 5 below.

Table 1: Project life budget versus expenditures status (BMGF contribution only)

1230-BMGF	Revised Project Budget	YEAR 1: Expenses / Budget	YEAR 2: Expenses / Budget	YEAR 3: Expenses / Budget	YEAR 4: Expenses / Budget	YEAR 5: Current Expenditure	Total Project Expenditure	Total Project Balance	% Spent
Budget Category	USD	USD	USD	USD		USD	USD	USD	USD
Personnel	8,658,902	1,459,545	1,585,841	1,721,662	1,827,346	2,060,582	8,654,975	3,927	100%
Travel	2,164,169	373,832	569,595	507,584	404,317	268,893	2,124,221	39,948	98%
Sub grants	2,515,376	463,696	628,429	507,972	432,419	427,980	2,460,495	54,881	98%
Equipment	329,196	138,289	84,797	46,118	25,992	7,284	302,480	26,716	92%
Consulting	124,130	-	45,494	30,035	35,101	5,226	115,857	8,274	93%
Other direct Costs	5,028,841	769,978	1,044,293	998,579	1,075,672	1,293,369	5,181,891	(153,050)	103%
Total, Other Direct Costs	18,820,615	3,205,339	3,958,449	3,811,950	3,800,848	4,063,334	18,839,919	- 19,304	100%
15% Indirect Costs	2,823,092	480,801	590,821	571,792	570,127	612,239	2,825,780	- 2,688	100%
Grand Total	21,643,707	3,686,139	4,549,269	4,383,742	4,370,975	4,675,573	21,665,699	- 21,992	100%

Table 2: Y5 Project budget versus expenditures status

Budget Category	Year 5: Budget	Year 5: Expenditure	Year 5: Balance	% Spent
	USD	USD	USD	USD
Personnel	2,064,509	2,060,582	3,927	100%
Travel	308,841	268,893	39,948	87%
Sub Grantees	482,861	427,980	54,881	89%
Equipment	34,000	7,284	26,716	21%
Consulting	13,500	5,226	8,274	39%
Other Direct Costs	1,140,319	1,293,369	(153,050)	113%
Direct Costs, Total	4,044,030	4,063,334	(19,304)	100%
Indirect Costs, Total	609,551	612,239	(2,688)	100%
Total	4,653,581	4,675,573	(21,992)	100%

Table 3: Project life expenditure analysis and justification

1	Travel	98% spent	Travel expenditure was close to the targeted amount. Traveling is requisite for implementing research activities, supervising those activities, and supporting attendance at CoP meetings.
2	Subgrants	98% spent	A few of the seed systems partners were unable to utilize projected budgets, particularly NRCRI in Nigeria (institutional blockages) and TARI in Ethiopia. We had a policy of "use it or lose it," and annual adjustments in obligated funds were made to provide higher levels to well-performing partners and to lower total amounts to those not performing. Implementing this system enabled to finish very close to the original amount of obligated funds.
3	Equipment	92% spent	This is a difficult category to predict, because frequently equipment thought to meet the $5,000/unit definition of capital equipment, is purchased in parts or falls under the $5,000 cut-off point. When that occurs, the procured item falls under other direct costs, leading to over expenditure in that area.
4	Consulting	93% Spent	The seed system consultant required for Y5 activities finalized by the mid-project report; hence the budgeted amounts were not fully utilized. Clearly compared with the original project budget, more was spent on consultants

			than originally envisaged as the need for consultants with specific areas of expertise arose during project implementation.
5	Other Direct Costs	103% Spent	This category captures all other types of expenditures, including items that do not meet the capital expenditure threshold value, supplies, supervisory visits and workshop costs outside of travel, communication outputs (of particular importance in Y5), outsourced services (i.e., fingerprinting), and so on.

Table 4: Summary of Project Funds versus expenditures (BMGF contribution; CIP income; and CIP contribution)

	Project Budget	CIP Income (1): Bank Interest	CIP Income (2): Seed Systems – Sale of sweetpotato germplasm	Available Funds	Expenditure	Funds Balance	Budget Balance
	US$	US$	US$	US$	US$	US$	US$
BMGF	21,643,707	9,538	12,461	21,665,706	- 21,665,700	6	- 21,992
CIP	2,291,124			2,283,942	- 2,283,942	-	7,183
Total	23,934,832	9,538	12,461		- 23,949,641	6	- 14,810

B. Income from Bank Interest and Sale of Sweetpotato Vines

The project earned a total of $21,998 from bank interest and sale of sweetpotato vines (from the CIP-KEPHIS rotation fund for regional germplasm distribution) as indicated in Table 5 below. This amounts we utilized in purchase of hotfill dosing unit; construction of tissue culture extension in KEPHIS – PQS Muguga; purchase and installation of air conditioning in the tissue culture laboratory and other sweetpotato germplasm management activities. All these expenses are integrated in the report.

Table 5: Project income and interest summary

YEAR	Bank Interest	Sales of SP Germplasm	Total
YEAR 1	2,177	100	**2,277**
YEAR 2	1,670	11,513	**13,183**
YEAR 3	1,694	-	**1,694**
YEAR 4	1,974	568	**2,542**
YEAR 5	2,023	280	**2,303**
Total	**9,538**	**12,461**	**21,998**

C. Mid-Y5 Budget Adjustment Request

We had proposed for approval the shift and reallocation of projected equipment budget under the East and Central Breeding Program. Construction of the screenhouse was finalized and remaining minor costs were charged to other direct costs. The redistribution was to enable us to achieve our targets as the funds were reallocated to meet gaps that emerged during the beginning of the project year. Please see distribution and net effect analysis in Tables 5 and 6 below.

A. Subgrants: SASHA allocated an additional $21,200 to ETH Zurich to cover the additional expenses occurred in setting up the feeding trial in Malawi and the increased price of the tracers required for the trial. An additional $10,000 was allocated to NRI for the seventh storage trial, which included adjustments to the storage unit as well as additional staff time.

B. Other Direct Costs (ODCs): ODC budget was increased to cover payments for communication outputs, including the number of briefs and fourth edition of the OFSP passport.

Table 6. Mid-Y5 budget versus revised budget

Budget Categories	Budget Year 5 USD	Revised Budget Year 5 USD	Variance Year 5 USD	Variance Year 5 %	Variance Year 5	Approval
Personnel	**2,064,509**	2,064,509	-	0%		-
Travel	**308,841**	308,841	-	0%		-
Subgrants	**451,661**	482,861	31,200	7%	Increase	Project Manager
Capital Equipment	**69,000**	34,000	(35,000)	-51%	Decrease	Jim Lorenzen – BMGF
Consulting	**13,500**	13,500	-	0%		
Other Direct Costs	**1,136,519**	1,140,319	3,800	0%	Increase	Project Manager
Direct Costs, Total	**4,044,030**	**4,044,030**	**(0)**	**0%**		
Indirect Costs, Total	**609,551**	609,551	-	0%		
Total	**4,653,581**	**4,653,581**	**(0)**	**0%**		

Table 7 shows the revised project budget following reallocation of equipment budget in Table 5 above.

Table 7: Revised project budget as of mid-Y5

Budget Categories	Expenses Year 1 USD	Expenses Year 2 USD	Expenses YEAR 3 USD	Expenses YEAR 4 USD	Revised Budget YEAR 5 USD	Total Revised Budget Project Life	Original Budget Project Life USD	Variance USD	Variance %	Variance Effect
Personnel	1,459,545	1,585,841	,721,662	1,827,346	2,064,509	**8,658,902**	**9,456,501**	(797,599)	-8%	Decrease
Travel	373,832	569,595	507,584	404,317	308,841	**2,164,169**	**2,312,273**	(148,105)	-6%	Decrease
Subgrants	463,696	628,429	507,972	432,419	482,861	**2,515,376**	**2,444,400**	70,975	3%	Increase
Capital Equipment	138,289	84,797	46,118	25,992	34,000	**329,196**	**209,000**	120,196	58%	Increase
Consulting	-	45,494	30,035	35,101	13,500	**124,130**	**31,188**	92,942	298%	Increase
ODCs	769,978	1,044,293	998,579	,075,672	,140,319	**5,028,841**	**4,367,252**	661,589	15%	Increase
Direct Costs, Total	**3,205,339**	**3,958,449**	**3,811,950**	**3,800,848**	**4,044,030**	**18,820,614**	**18,820,614**	**(0)**	**0%**	
Indirect Costs, Total	**480,801**	590,821	571,792	570,127	609,551	**2,823,092**	2,823,092	**(0)**	**0%**	
Total	**3,686,139**	**4,549,269**	**4,383,742**	**4,370,975**	**4,653,581**	**21,643,707**	**21,643,707**	**(0)**	**0%**	

D. Project Vehicles

Twelve vehicles were purchased during SASHA1. Most of the vehicles purchased by the project are now 9–10 years old, having been used in both project phases. We received approval to sell two vehicles last year in order to purchase a new vehicle for the breeders. However, owing to current vehicle market prices and the age of the vehicles, the proceeds from two vehicles could not purchase a new double cab truck, the vehicle desired.

We are asking that CIP be allowed to use the vehicles as needed, including being able to sell additional vehicles to raise more funds for vehicle purchase. As the SweetGains project did not include new vehicles in its capital budget, the ability to sell more vehicles to support the new project is critical.

2. Sub-awards (if applicable)

Use the table below to provide the detail of all sub-grantee(s) or subcontractor(s).

Organization Name	Actual Disbursement for this Reporting Period	Total Disbursed from Primary Awardee to Sub to Date	Total Sub-awardee Spent to Date	Total Contracted Amount
	U.S.$	U.S.$	U.S.$	U.S.$
Burundi-Support for Breeding (PhD training at Makerere plus field support)	23,755	109,392	109,392	111,408
Kenya- Cold tolerance	-	82,526	82,526	89,526
Flompiana FAmbolena Malagasy NORveziana (FIFAMANOR), Madagascar	18,484	97,500	97,500	100,171
ETH Zurich (Iron bioavailability study)	183,636	183,636	183,636	183,636
Ghent University IPBO (Belgium)	-	63,014	63,014	63,014
BecA/ILRI platform and training	0	35,296	35,296	35,296
Donald Danforth Plant Science Centre (DDPSC)	-	92,000	92,000	92,000
Rwanda Agricultural Board (RAB)	16,349	124,389	124,389	119,564
Sugar Research Institute (SRI) - Tanzania	11,409	121,449	121,449	121,188
South Agricultural Research Institute (SARI), SNNPR Ethiopia	1,225	84,166	84,166	77,929
Tigray Agricultural Research Institute (TARI) - Ethiopia	15,708	71,193	71,193	76,825
Department of Agricultural Research Services (DARS) - Malawi	10,899	49,809	49,809	52,023
Institut de l'Environnement et de Recherches Agricoles (INERA)	847	59,999	59,999	60,000
Zambia Agriculture Research Institute (ZARI), Zambia	2,181	84,064	84,064	83,740
National Root Crops Research Institute (NRCRI), Nigeria	34,173	59,773	59,773	79,185
CSIR-Crops Research Institute	3,579	52,919	52,919	52,349
Biocrops (U)Ltd	6,476	35,313	35,313	49,471
National Agricultural Research Organization (NARO) - Rice Program	-	24,823	24,823	34,340
National Agricultural Research Organization (NARO), NaCRRI - Uganda	1,752	52,900	52,900	54,554
Instituto de Investigação Agrária de Moçambique (IIAM), Mozambique	9,398	92,750	92,750	92,091
Kenya Plant Health Inspectorate service (KEPHIS), Kenya	695	128,095	128,095	128,094
Seed Systems Sub Grants Community of Practice	67,950	177,087	177,087	175,982
FERA Science Limited (FERA)	-	43,803	43,803	43,803
Univ Development Studies (UDS), Ghana	0	24,000	24,000	24,000
Natural Resources Institute (NRI) Faculty of Engineering and Science, University of Greenwich, UK	34,061	479,004	479,004	485,370
Euro Ingredients Ltd, Kenya	-	29,817	29,817	29,817

For sub-awards greater than $1M, please provide explanatory detail as requested in the latest and future period sections above.

Note: It is the foundation's discretion to ask for updated sub-award budget files as part of the traditional progress report review process.

3. Other Sources of Support (if applicable):

Other Sources of Support include interest earned, current foreign exchange impacts, and co-funding (in-kind and other contributions).

Other Sources of Support (if applicable): Explain any notable impacts from other sources of support.

CIP has supported the project in the last 5 years with $2,283,942. Projected contribution target was $2,291,123.97; hence there is a minor variance of $7,182. See Table 7 for details.

Table 7: CIP's contribution to the SASHA project

Year	Amount
Year 1	410,505
Year 2	550,146
Year 3	-
Year 4	507,732
Year 5	815,558
Total	**2,283,942**
Projected	**2,291,124**
Variance	**7,182**

Checklist - As you review your answers to questions in the financial update section, ensure that your report provides the following:

1. Explanation of how project expenditures differed from plan and the implications on programmatic progress to date.
2. Explanation of how future period projections differ from the original budget and previous forecasts, and the implications.
3. Explanation of other sources of support (funds) from other funders, interest earned or converting to non-USD currencies.

APPENDIX A. RESULTS FRAMEWORK: FINAL STATUS FOR SASHA PHASE 2 (JULY 2014-OCTOBER 2019)

Milestone #	Responsible	Key Milestones	Due Date Mon	Due Date Year	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019 Year 5	% progress of milestone as of 31 Oct 2019 Annual	% progress/ planned 31 Oct 2019
1.1.1	MA & RM	Studies demonstrating that can achieve significant genetic gain (2% per year in yield) in 2 years in early generations & 4 years for selected varieties	6	2019	Achieved with modification	**Yr4.** Moz has one remaining trial to be harvested in Zambia and one additional trial in Umbeluzi. OT will use Westcot design to capture genetic gain. Multi-locational trials will result in variety release in 2019. Several more trials were planted and harvested during this quarter. Data from on-station trials in Uganda show 3.1% genetic gain (0.41 t/year). **Yr5**: 18 and 25 trials were harvested and planted respectively. The trials included observation trials (OTs), preliminary yield trials (PTs), advanced yield trials (ATs) and multilocation trials (MTs) were evaluated at Umbeluzi, Gurué and Chilembeni. On-farm trials were also established in Gurué to generate enough data to support the release of varieties from the MTs. In PT harvested at Umbeluzi, nine clones with the highest mean storage root yield were selected. The trial mean for storage root yield was 11.5 t/ha and check clones had population mean of 16.48 t/ha. The MTs with 51 clones (OFSP) and 17 clones (PFSP) were established at three locations (Umbeluzi, Gurué, Chilembeni) in December 2018. These clones showed a storage root yield jump between 8 to 30 % in ATs when compared to the best varieties released in Mozambique. On-farm trials were also established in Gurué. In Uganda, the work on population development resulted in an evaluation of 11454 clones during SASHA2. Eight OFSP clones were evaluated on-farm. Another 24 clones were selected from the PhD work on continuous root formation and bulking.	100	100	100

Milestone #	Responsible	Key Milestones	Due Mon	Date Year	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019 Year 5	% progress of milestone as of 31 Oct 2019 Annual	% progress/ planned 31 Oct 2019
1.1.2	WG	Estimates of yield gains achievable by reciprocal recurrent selection (RRS) in sweetpotato	6	2019	Achieved	Yr1: Have crossed with partially inbred populations, selected parents & crossed again. Y2: Seeds need to be planted out once have enough seed & then one selection cycle will be done. **Y3:** Planted B (non-sweet) & C (high Fe and Zn) in Satipo in November 2016 for Fe & Zn; harvested in April 2017. Under analysis after harvesting: 9881 H1 WAE (early maturing) clones, 3742 H1 NSSP (non-sweet) clones, 3292 H1 HIFE (high Fe) clones in field experiments plus each parent 8 plots and each grandparent 8 plots (80 x 8). **Yr4: All field experiments of this large study in Peru were completed in December 2017.** In all H1 populations large genetic gains were observed. In H1 populations storage root yield genetic gain estimates ranged from 68.8 to 110.3%. Heterosis increments for storage root yield in hybrid population H1 ranged from 9.3 to 37.6%. All H1 populations exhibit variety ability. These H1 studies at CIP-HQ provide useful information for (i) SPVD resistance breeding at the breeding platform Namulonge, (ii) selecting testers and elite crossings in sweetpotato population hybrid breeding, and for genome wide prediction in sweetpotato. **Yr5:** Storage root yield genetic gain (GG) estimates of genepool separation & one complete recurrent reciprocal selection cycle in three OFSP H1 breeding populations were: 85.0% for the wide and early adaption (WAE) group at 90 days, 68.8% for the WAE group at 120 days harvest, 110.3% for the non-sweet taste (NSSP) group (at 120 days harvest), and 95.5% in the high iron (HIFE) group (also at 120 days harvest). **This is truly revolutionary for speeding up genetic gains**: for example, the hybrid breeding GG observed for OFSP 90 days harvest (10.9 -> 18.5 t/ha) corresponds to 36 years of breeding work with polycross breeding achieved in 5 years by hybrid breeding schemes.	100	100	100

Milestone #	Responsible	Key Milestones	Due Date Mon	Due Date Year	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019 Year 5	% progress of milestone as of 31 Oct 2019 Annual	% progress/ planned 31 Oct 2019
1.1.3	RM	At least 14 African sweetpotato breeders breed using the latest knowledge & efficient methods	6	2019	Achieved	Yr1: 14th breeders meeting held in Mukono, Uganda, June 2-5, 2015 June 2015. Needs of breeding programs discussed. Field day emphasized diversified end user involvement in varietal selection. Yr2: Backstopping trips made to Madagascar (2015/07) and Burundi (2016/02); Ghana & Ethiopia received AGRA breeding grants, but funds not given to Ethiopia because of strategy change at AGRA **Yr3:** Backstopping visit to Burundi (Oct 2016) - worked on plans for breeding trials and supplying OFSP planting materials to partners. Breeders from 14 SSA countries agreed to mainstream beta-carotene trait-- at least 50% of clones submitted for release will be orange-fleshed. The 16th Annual Sweetpotato SpeedBreeders and Genomics Community of Practice Meeting held in June 2017 in Kigali updated breeders on progress in sweetpotato genomics and launched HIDAP program for analyzing breeding data. integration of HIDAP and Sweetpotatobase in progress. **Yr4:** A training on applied use of statistics for senior sweetpotato breeders was held in Kumasi, Ghana 11-19 January 2018 with the idea that these breeders would then train others. Progress on integrating HIDAP and SweetpotatoBase made; enabling training on program use to be a core part of the 17th annual SpeedBreeders & Genomics CoP meeting, held 5-8 June 2018 in Nairobi, Kenya. The three sweetpotato support platforms and the national programs (Ghana and Uganda) actively use HIDAP and Sweetpotatobase. **Yr5:** The 18th annual SpeedBreeders & Genomics CoP meeting held 4-7 June 2019 in Maputo, Mozambique focused on modernization, profiling and characterization of desired varieties; official launch of the digital sweetpotato catalogue and training on HIDAP and SweetpotatoBase.	100	100	100

Milestone #	Responsible	Key Milestones	Due	Date	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019	% progress of milestone as of 31 Oct 2019	% progress/ planned 31 Oct 2019
			Mon	Year			Year 5	Annual	
1.2.1	RM	At least 250 thousand seeds with increased frequencies of resistance to SPVD (2 to 10%) disseminated to at least 10 NARS partners	6	2019	Achieved	Yr1: First results on frequencies for SPVD resistant phenotypes were presented at Sweetpotato Breeders meeting June 2-5, 2015, Mukono, Uganda. Seed distributed will be families with high frequencies of SPVD resistant phenotypes. Total of 159,680 seeds were distributed by June 5, 2015. **Yr3:** More seed has been generated in 2016 for sharing with NARS partners (341,463 during July-Dec 2016 period). The genomics project at BecA was allocated 13 families (903 seeds) by CIP/Uganda. To date NARS partners have received 260,316 seeds. **Yr4:** During July 2017–December 2017), 157,830 poly-cross seeds (44,783 and 113,047 from crossing blocks A and B, respectively) were generated. By June 2018, 303,047 seeds sent to 10 countries. From mid-parent values the frequency of SPVD resistant parents (field resistance) is 48%; this is evidence that milestone 1.2.1 has been achieved. **Y5:** The frequency of SPVD resistance in the seed from elite crosses increased to 23% (averaged over 3 sites; 2 seasons).	100	100	100
1.2.3	RM	Selected hybrid progeny demonstrating yield jumps of 10 to 20% from populations with SPVD resistance	6	2019	Achieved	**Yr4:** Sweetpotato genotypes currently used as parents in crossing blocks A and B in Uganda were evaluated in three sites (10 plants per plot, 3 reps, RCBD). The frequency of SPVD resistance (field resistance) parents in population Uganda A and Pop Uganda B from mid-parent values is about 48%. Field trials to validate increase in SPVD resistance based on progenies are underway in Uganda. **Yr5.** Field trials to validate increase in SPVD resistance based on progenies are completed in Uganda. Progeny from elite crosses of SPVD resistant by SPVD resistant parents showed 23% frequency of resistant genotypes (compared to less than 0.5% frequency of resistant genotypes in sweetpotato breeding trials). Furthermore, storage root yield in families from elite crosses was 60% higher compared to the entire H0 population.	85	100	118

Milestone #	Responsible	Key Milestones	Due	Date	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019	% progress of milestone as of 31 Oct 2019	% progress/ planned 31 Oct 2019
			Mon	Year			Year 5	Annual	
1.3.1	MA	At least 150 thousand seeds with drought tolerance genes disseminated to at least 10 NARS partners in SSA and SWCA	6	2019	Achieved	**Yr1**: 35,000 seeds distributed to 7 SSA NARIS **Yr2**: Distributed 42,600 seeds to 11 other countries (June 2016) **Yr3**: 33,000 true OFSP seed were disseminated to 11 NARS from SSA and 11,400 PFSP seed ready for distribution once import permits are sent from 5 NARS in SEA. Total distributed = 128,570 for the past 3 years. 2016 crossing block established. seeds collected in the two sites. **Yr4:** A total of 344 006 true seeds were harvested from 1104 families in the three crossing blocks established in 2017 in Mozambique. The purple-fleshed crossing block established in Gurué gave rise to 21,467 true seeds (257 families) from controlled crosses and 43,640 true seed from polycrosses (47 families). A total of 5 000 true seeds from 50 families harvested in 2017 from polycrosses at Umbeluzi Research Station were sent to Brazil, CERAT, UNESP, Câmpus de Botucatu, in March 2018. Another set of true seeds were distributed to NARS partners from Burkina Faso, Burundi, Rwanda, Cote d'Ivoire, Nigeria, Zambia, Kenya, Ghana, Malawi, Ethiopia, South Africa and Madagascar during the breeders meeting in June, Nairobi, Kenya. Each NARS partner received 3 000 true seeds. **Yr5**: A total of 307,428 botanical seeds were collected at Umbeluzi and Gurué. The PFSP crossing block established at Gurué gave 11,925 and 23,967 true seeds from hand-crosses and polycrosses, respectively. Distribution of varieties and seed: 10 cuttings (30 cm length) for each of the released varieties, Amelia, Victoria, Caelan, Erica, Cecilia, Bita, Ivone, Bie, Lourdes and Tio Joe were sent to our NARS partner in South Africa, ARC-Pretoria in October 2018. Additionally, 5 000 (PFSP seed sent to Bangladesh on 15 October 2018. 27,000 botanical seed distributed to 9 NARS partners during the SpeedBreeders Meeting in Maputo, 02-06 June 2019. **End Yr5 Sept 2019:** Cumulatively, **234 962** botanical seed were distributed to the countries mentioned above.	100	100	100

Milestone #	Responsible	Key Milestones	Due	Date	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019	% progress of milestone as of 31 Oct 2019	% progress/ planned 31 Oct 2019
			Mon	Year			Year 5	Annual	
1.3.3	MA	Hybrid progeny exhibiting yield jump of 10 to 20% in hybrids from populations with drought tolerant & enhanced efficiency for drought tolerance breeding	6	2019	Achieved	**Yr1:** Population A is in Umbeluzi with 68 parents; Population B in Gurué with 56 parents **Yr2:** Pop A with 66 parents & Population B with 56 parents & 2nd round of progeny planted 20 Aug 2015. **Yr3**: Three unreplicated observation trials (OT) were harvested from two treatments (optimum conditions & water stressed) at Umbeluzi (2820 OFSP clones) and Gurué (1868 OFSP & 1246 PFSP clones). From these OTs, 499 OFSP and 239 PFSP clones were advanced to preliminary yield trials (PYT) at Gurué based on higher storage root yield than check clones. At Umbeluzi, 294 OFSP clones were advanced to PYT. **Yr4:** Two OFSP seedling nurseries were established at Maputo and Gurué each with 3000 clones. The clones were planted as OTs in July 2017 following the Westcott design. Based on vine vigor, root yield, root shape and size as well as weevil tolerance 125 & 168 clones were advanced to PTs at Umbeluzi and Gurué, respectively. **Yr5**: Bi-parental crosses and seed collection were the main activities in the crossing blocks at Umbeluzi and Gurué Research Station. A total of 141 clones were selected from one replication of OT harvested in November 2018 at Nwalate for further testing in PTs. Selections were based on storage root yield (>20 t/ha), vine vigor (≥ 7), flesh color (>9) based on color charts, dry matter (hard to break) based on field scale and number of roots per plant. The MTs with 51 clones (OFSP) and 17 clones (PFSP) were established at three locations (Umbeluzi, Gurué, Chilembeni) in December 2018. These clones showed a yield jump between 8 to 30% in ATs when compared to the best varieties released in Mozambique. On-farm trials were also established in Gurué. **End Yr5:** A crossing block was established at Umbeluzi in February 2019 with 100 parents. 50 parents came from the Gurué breeding program while 50 parents came from Umbeluzi program. The parents were planted following the diallel design. Crossing	100	100	100

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						began on 24 June and by 19 July, almost 26000 hand crosses had been made.			
1.3.4	MA	Clones with 200% RDA for young children of pro-vitamin A, 25% RDA of iron and 35% RDA of zinc under high intakes	9	2019	Achieved with Modification	**Yr1:** Fe and Zn measured with NIRS in Mozambique **Yr2**: 200 clones identified and were sent to Lima for confirmation with XFR on 22 Feb1. **Yr3Qtr2:** Results from CSIRO obtained indicating 2 genotypes with high FE and borderline contamination. **Yr3:** The best 200 clones with high iron and zinc (NIRS) from OT at Umbeluzi were sent to Lima for determination of Fe & Zn using the XFR methodology. **Yr4:** A total of 30 clones had Fe content higher than the targeted 2.3 mg/100g DW and sent to Australia for confirmation. Only one clone was found not to be contaminated. The clone is MUSG15052-2 was selected to proceed for a multi-feeding trial. It's rich in Fe (44mg/kg) and was sent to FANEL and ETH-Zurich for Vitamin C analysis on 16 Nov. Hand crossings were initiated in May 2017 and lasted until September 2017 at both Gurué and Umbeluzi. **Year 5:** 7,545 samples were handled and 85 % of the samples have NIRS data. The OTs were harvested from November 2017 to March 2018 and NIRS have been read from these trials. 149 OFSP clones with high Fe and Zn were selected. The variation of Fe among these clones range from 2.6 to 4.6 mg/100g, DW, while Zn varied between 0.98 and 2.84 mg/100g, DW. 3000 true seed were sacrificed and germinated at Nwalate for establishing OTs in April 2019. **Summary of feeding trial results**: A total of 235 kg roots of MUSG15052-2, a high Fe clone and 200kg of Irene were sent to Malawi to study bioavailability of Fe in Zomba district under leadership of ETH Zurich. The test meal size was 400g per feeding and the study started on Feb 25, 2019 and completed on 22 March with the last blood sample collected on 5 April. Fractional iron absorption from both OFSP test meal types was 5.8% resulting in a total daily iron absorption of 0.20 mg from the Irene and 0.33 mg from MUSG15052-2	100	95	95

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						(p<0.001). Absorption among women with low ferritin status was 8.1%.			
1.4.1	TC	At least 100 thousand seeds with less sweet taste genes disseminated to at least 10 NARS partners in SSA and SWCA	6	2019	Almost Achieved	**Yr1:** Distributed 5,580 seed distributed to Burkina Faso & Nigeria; plan put in place to improve seed output **Yr2:** 4th Qtr - with 4 month visit of best technician from Lima to Ghana, we are confident that using grafting, short day treatments and protected environment, that we will boost production of seed. **Yr 3, Q2:** ~20,000 seeds produced at Kumasi from 31 of 34 parents used in the crossing block. Key to success was protected environment. **End Yr4.** 21,733 seeds produced, mostly from controlled pollinations in screenhouse. 1200 open pollinated seeds from two parents, Faara and Otoo, were shared with 10 NARS partners. **MId-Yr5:** Production of seeds in Ghana was at the highest level to date, with roughly similar numbers of full sibs produced in 2018a in 2017 (18,711 seeds from 893 cross combinations among 62 parents) and 54,298 open pollinated seeds from 59 females. All controlled cross seeds were produced in the screenhouse in Kumasi using the" bouquet" method, and many open pollinated seeds were also harvested in the screenhouse, from flowers that had already been pollinated in the field (a total of 31,464 from 59 parents). We also produced 22,639 OP seeds from 10 parents in the relatively pest free open field in Tamale. **Year 5, Q4:** With distribution of ~45,000 seeds from 35 families to 8 NARS partners, including Nigeria and Burkina Faso, we won't actually complete the milestone. However, we are "almost" there. SASHA2 Final: At the end of SASHA2, the breeding pipeline in Ghana is producing a supply of high yielding, high dry matter, low sweet genotypes, many with variety potential for release in Ghana and across the region. Five varieties with consistently higher yields than checks are proposed for release by CSIR-SARI in December 2019. In addition to low sweet, consumer	100	90	90

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						preferred taste, one of the candidate varieties exhibits consistently lower weevil infestation.			
1.4.3	TC	Hybrid progeny with yield jump of 10 to 20% from less sweet, less perishable parents	6	2019	Almost Achieved	**Yr1:** Approach to formulating the populations will be based now on agro-ecology (Northern & Southern); initial approach of population B material did not work. **Yr2:** Evaluation of progenies for heterosis increment complemented by molecular characterization initiated. Will be further pursued in year 3. **Yr 3:** Separate populations in north and south continue under development. MS student Nikiema completed data collection, with preliminary results regarding molecular and yield assessments for identifying heterotic combinations. **End Yr4:** Seemingly robust results of progeny assessment of parents and progenies from program, including low sweet and less perishable genotypes produced large heterosis increments. Based on heterosis increments for yield, we have separated parents in to 2 populations. **Mid-Yr5:** Analysis of molecular diversity and progeny performance is still ongoing; Very high jumps in yield of progenies in seedling nurseries were not replicated in subsequent observational trials. Less sweet germplasm is predominant in our populations, and we are starting to measure storability in parents and progenies. **Y5, 4th Quarter.** Program is successfully developing significant numbers of genotypes with high yields and less sweet taste. The SSP-WA breeding population has many genotypes with good GCA, and not obvious clustering of genotypes into two groups on the basis of molecular markers so parents in 2019 crossings are divided into 2 populations based on the information we have on progeny performance (GCA, SCA). Grouping of parents will be refined further based on on-going observational trials, initiating the process of RRS for long-term exploitation of heterosis. SASHA2 Final: the breeding pipeline in Ghana is producing a supply of high yielding, high dry matter, low sweet genotypes, many with variety potential for release across the region.	95	95	100

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2.1.1	MG	15–30 transgenic events per new cry gene constructs	6	2014	Achieved	**Yr1:** 39 produced at ABL Peru, 2 at BecA Kenya, and 125 at DDPSC in USA	100	100	100
2.1.3	MG	At least 3 to 5 storage roots per transgenic event	2	2016	Achieved	**Yr1**: Storage roots are harvested in BecA greenhouse regularly. Y2: 80% of the transgenic events produced roots. The missing 20% are likely due to difficulties to produce storage roots in greenhouse which is a problem experienced at all three locations (ABL, Danforth, BecA)	100	100	100
2.1.4	MG	Mortality assessment for each transgenic event with enough *Cry* protein to expect efficacy	12	2016	Achieved	All of the transgenic events were tested at least once for efficacy. Several have been tested twice. Those events which seemed to have apparent differences with the untransformed storage roots (12) were retested and turned out to be susceptible.	100	100	100
2.2.2	MG	Efficacy data for several dsRNA (single and in combination) against weevil larvae	6	2017	Not achieved at desired level	The transformation using two of the five RNAi gene constructs was not successful during the project execution period. No other attempts were made due to lack of funding. However, the results from Katerina Prentice PhD thesis that a rapid dsRNA degradation occurs during the RNAi process in C. puncticollis (one of the two African weevil species) complicates the use of RNAi as a pest control strategy. The discovery of sweetpotato-associated microbes or toxins is a new research avenue taken by AgBiome and is worth pursuing.	100	0	0

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3.1.1	MM	Brochure with improved protocols for implementing Triple S method & study of uptake	12	2018	Achieved	**Yr2 Q1**: 8 Target countries status: Dissemination: Uganda; Testing/Adaptation: Ethiopia, Ghana, Mozambique, Malawi; Training planned: Kenya - SUSTAIN (Nov-15); Tanzania -VISTA (Q1-2016); Activities under discussion: Malawi-SUSTIAN/VISTA; Kenya: AVCD; Jumpstarting: BF, Nigeria. **EndYr2:** ToTs conducted in Mozambique, Tanzania and Kenya. Y3Q1: Tanya Stathers will support documentation: Scoped needs. W. Kenya under SUSTAIN continuing implementation. **Yr3Qtr2:** 7/9 countries testing & implementing. **MidYr4:** 3 types of training materials (ToT guidelines, farmers' handouts and flip chart training tool) now completed. These are in process of translation into different languages according to need. Triple S was selected as one of three technologies for support under the new RTB innovation and scaling fund ($700,000). This will be done in Ghana and Ethiopia in 2018; Western Kenya - validation study - write up in process by Agili. Awaiting clarification on outcome of H+ study on uptake of Triple S. VISTA Tanzania endline survey included Triple S question, and this is needed for all baseline and endline survey modules (MLE link). **Yr4Q3:** Brochure and training materials finalized and 50 sets printed for distribution. Triple S questions to be included in Ethiopia IA an Emergency project endline studies. **EndYr4:** Triple S training materials distributed across 8 countries. Milestone complete except for on-going monitoring and endline studies assessing uptake. **Mid-Yr5:** Triple S Scaling under RTB funds in Ghana and Ethiopia. SPHI Deep Dive Session. Technical support for ToT in Malawi provided by Namanda. Endline studies to assess uptake. **End Yr5:** Milestone completed. Sept 2019: Triple S has been validated and used in 10 countries with scaling in process in Ethiopia and Ghana under RTB and scaling partners.	100	100	100

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3.1.2	MM	Report on validation of pre-basic seed production methods and models in at least 10 national programs	3	2019	Achieved	**Yr2 Q1:** SGA with 8 institutions (7 countries) supporting construction/rehabilitation & pre-basic seed production underway. NaCRRI behind schedule; Y2 SGAs with NRCRI, ZARI, INERA signed, funds transferred & production underway. Sandponics: Kenya start-up Nov-16; Uganda: suspended; Moz: need update. **Mid-Yr2:** Additional SGAs signed with Ghana (CRI) and BioCrops (U) Ltd. NARO-Rice in preparation. Business plans submitted by 10 institutions. Sandponics established in Kenya. Irrigation study for vine multiplication established in Tanzania and Ethiopia. **EndYr2:** SGA countries making progress on technical components. **Yr3:** 2,029,074 pre-basic and 7,103,890 basic cuttings production reported; 11 of 13 institutions have undertaken virus testing; 9 of 13 institutions supported visual inspections of basic multipliers; 67% of 12 institutions reported income to revolving fund;; M**idYr4:** Y4 SGA modifications include business plan cost template, allocation of costs of production to rotation funds (RFs), linked to the SGA funds; and projections for sales targets, revenues and balance of RF anticipated by end Dec 2018, when project support will finish. CRI conducted EGS & business plan institutionalization assessment for KEPHIS. **End Yr4:** 803,043 pre-basic and 4,918,964 basic cuttings production reported; 10 of 13 institutions have undertaken virus testing during year; 12 of 13 institutions supported visual inspections of basic multipliers during year; 6 (5 tbc after FR) of 12 institutions reported income to revolving fund. Costings and price structure updated for: 10 out of 13 institutions. **End SASHA2:** Public sector institutions have financially viable business models with revenues from the sales of seed paid into institutional revolving fund mechanisms for sustainable production of sweetpotato EGS. Majority were able to cover their costs in 2018 and will continue to do so in 2019.	100	100	100

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3.1.4	JK	Report evaluating the effect of Begomoviruses on yields	9	2019	Almost Achieved	**Yr1**: Bramwel Wanjala hired and trained one month in Lima, Peru and 1 week in Uganda; Research protocol developed and material infected with begomoviruses at KEPHIS obtained. **Mid-Yr2:** PhD research protocol approved by University. NCM-ELISA & PCR testing on plants at KEPHIS with symptoms for begomoviruses showed negative using NCM-ELISA and 50% positive using PCR. **End Yr2:** Field samples collected in 4 out of 6 major growing areas of Kenya. **Yr3:** Collected field data in 5th region of Kenya, tested 400 samples for begomovirus infection, infected two varieties with viruses for field trials. Evaluate effect of Begomovirus on yield. Two varieties (Ejumula and Kakamega) graft inoculated with different virus combination. Field experiments to be set up un July 2017. **Mid-Yr4:** 1st field trial completed. **End-Yr4:** Data collected and analysis underway. **Yr5:** Manuscript on effect of begomoviruses on root yields accepted by Plant Disease; will be published in 2019. Summary brief published in August 2019. Dissertation of Wanjala still not complete. Expected early 2020.	100	98	98

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3.1.5	MM	Cost study on different methods of pre-basic seed production	9	2019	Achieved	**Yr2 Q1:** NARIs challenged with developing own business plans as tool to manage pre-basic seed production and sales as part of RF. Contracted consultant to visit & work with each NARI (KEPHIS, RAB, SRI, ZARI visits completed; IIAM, DARS, SARI/TARI in progress). Business plans submitted by 10 institutions, with cost structures for pre-basic, and GMA for basic and QDS seed production. Presentation & discussion at 4th CoP meeting in December 2015. Sandponics established in Kenya. Yr**2Qtr3:** Synthesis document of 10 bizplans prepared & captured 10 take home messages; Business plan preparation started in Ghana, Nigeria and BF. **Yr3Qtr2:** improved real time cost data collection templates in use by CRI, KEPHIS, NRCRI and LZARDI. Light templates developed for other countries. Data collection for sandponics on-going, but design of experiment to be revisited (again). **End Yr3:** Real time cost data collection completed for KEPHIS and CRI, with NRCRI and SRI almost completed. New Post Doc in Uganda Ssali will take over regional backstopping responsibilities on sandponics. **Yr4 Qtr2:** Real time data for PBS costs collected and analyzed for 3 NARIs; 3 NARIs updated costs and prices using recall system. Ssali took over lead of sandponics and redesigned study. MSc intern Makokha identified to conduct study at KEPHIS. New sandpoinics experiment in Uganda has 2 objectives: 1) determining the effect of Gibberellic Acid (GA) on sweetpotato vine yields in sandponic systems and; 2) sequentially increasing the nitrogen levels of the nutrient solution in sandponic systems. **End Yr4:** Sandponics nutrient media optimization trial at KEPHIS PQS completed. Ratooning study on-going in Uganda. **MidYr5:** CBA of net tunnels/miniscreen and open field production completed. CBA of irrigation for net tunnel seed production completed. **End SASHA2:** Analysis of sandponics costs completed.	100	100	100

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3.2.1	JK	Availability of disease-free pre-basic material within 12 months of initiating clean-up	11	2018	Achieved with Modification	**Yr1**: 3rd Iteration of ClonDiag functional after resolving minor problems Y42: 4th Iteration necessary and delivered to Lima and Kenya in December 2015; **Yr2Qtr3:** delay in testing 4th iteration due to time demanding other activities. **Yr2Qtr4:** Testing of ClonDiag on-going in Lima; Reagents received for testing to begin in Muguga where will compare against grafting, NCM-Elisa, and PCR from Aug-Dec 2016 **Yr3Qtr1**: Successful test run of 4th iteration done in Kenya. **Y3Qtr2:** KEPHIS accreditation for virus indexing renewed on 14 Dec 2016 for one year. **End Yr3**: 4th Iteration of ClonDiag received; Interlab testing done between CIP-Lima and CIP-KEPHIS. Sensitivity, specificity, repeatability and reproducibility tested and data being analyzed in comparison with standard I. setosa grafting and testing. **Mid-Yr4:** Experiment comparing use of ClonDiag (21 viruses for $70) compared to grafting (10 viruses for $130) completed. Final comparisons of individual plantlets underway. Array tube reader and Smart Phone App improved & used in data analysis. **End Yr4:** One more validation run, to be confirmed by next generation sequencing; **Mid-Yr5:** Validation run delayed**. End Yr5.** Validated ClonDiag costs USD 70 per sample and detects up to 21 viruses while grafting/NCM ELISA costs USD 130 to test 10 viruses per sample. The sensitivity of the ClonDiag test is higher than that of NCM. The ClonDiag array appears to be suitable for routine diagnosis of sweetpotato viruses. However, the manufacturer of the arrays unexpectedly discontinued production in 2018. Fortunately, another technology based on high-throughput sequencing (sRSA) developed in complementary BMGF funded projects will be used instead of the ClonDiag technology. We trained one KEPHIS staff in sRSA during 2018, and in 2019 performed a follow up course at KEPHIS laboratories themselves for 3 CIP and 3 KEPHIS staff members.	100	100	100

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3.2.2	JK	Validated portable LAMP tool for detecting SPFMV & SPCSV	5	2018	Achieved	**Yr1:** New LAMP assays from FERA designed; started testing re-packaging with SPFMV and SPCSV assays; Assay working for SPFMV and East African strain of SPCSV **Yr2:** a new software, LAMP Designer 1.13, was purchased and installed at CIP-Nairobi and Lima to enable efficient (re-)design of LAMP primers for sweetpotato viruses; conducted field test in Lima to see how long key reagents could store**. Yr2Qtr3:** storability of LAMP reagent in current form <6 months. New tests being performed to improve stability. **Yr3Qtr1:** Trial run for detecting SPCSV and SPFMV in lab and field trial in Kenya in Aug 2016 successful. **Yr3:** New LAMP assays from FERA designed testing for SPFMV and SPCSV assays ongoing; Assay working for SPFMV and East African strain of SPCSV. Primers for Begomoviruses and SPCSV designed with LAMP Designer 1.13 software and ordered. Parameters for field test using LAMP optimized. This included sensitivity, specificity, repeatability and reproducibility. Stability of reagents at room temperature to be evaluated. **Mid-Yr4:** 1st version successfully field tested in October, but reagents had to be kept on ice. Now building in primers for Begomovirus as well. **End Yr4:** New primers ordered and will test in five field sites, with field work completed by mid-September. **Mid-Yr5:** Substantial changes made in LAMP design and new test is more field friendly for 3 viruses: SPCSV, SPFMV, and Begomovirus. **End Yr5:** Field testing validated the accuracy of the tests (by comparison to subsequent lab tests by PCR of the same samples) at the four sites, from the hot and humid coast to central and Lake Victoria regions, giving the following times to positivity (TTP) for the three viruses: SPFMV 5-20 mins; SPCSV 15-35 mins; and begomoviruses 15-40 mins.	100	100	100

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3.3.1	MM	At least three (5) countries have draft standards and protocols for quality assurance of sweetpotato seed based on evidence	6	2019	Almost Achieved	**Yr2 Qtr1:** QDS write shop held in Ethiopia to capture lessons from development of seed standards, plan roll out and design study to assess where farmers benefit from QDS and inspection. Training of inspectors and roll out in progress; Tanzania: QDS inspections continue in LZ (Kinga Marando project) involving TOSCI officials. **End Yr2:** Uganda piloting July 2016; DARS Malawi submitted revised draft standards to Ministry for approval; Zambia will review after new Seed Act passed. **Yr3Qtr1:** Rwanda (RSB) and Mozambique have draft standards for review; Ethiopia approved formal standards (PB,B, C). **Yr3Qtr2:** Tanzania seed standards gazetted Feb17 co. Uganda: ready for publishing. **End Yr3:** Nigeria drafted; Malawi trained inspectors in May 2017 but procedures still awaiting official approval; Kenya drafted. In Ghana, QPDM standards printed; In Moz, stakeholder consultations on draft standards cont.; In Nigeria, stakeholder consultation to review final draft in May 2017; In Burkina Faso, draft submitted for approval. **Mid-Yr4** 10 out of 11 countries (exception Zambia) now have drafted or revised SP seed standards. PIM-RTB-FTA study piloted in Kenya in July 17 and extended to Nigeria and Vietnam; CGIAR Gender Platform awarded additional (small) funds to deepen understanding gender dimensions and implications of current regulatory frameworks in Kenya. **End Yr4:** Rwanda, Mozambique and Zambia officially approved SP seed standards in this period. **Mid-Yr5:** NRCRI hosted stakeholder meeting with NASC Nigeria. Agreement to pilot before final approval. Kenya: MoALFI & KEPHIS leading process for separate regulations for VPM, this will allow different seed classes to be proposed. **End SASHA2:** Ten countries (exc. Zambia) have drafted seed standards for sweetpotato (where none previously existed) or	100	95	95

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						revised existing seed standards (e.g., Malawi). Synthesis report being finalized.			

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3.4	MM	Report on testing medium-large scale models for basic seed production	9	2019	Achieved	Started in Sept 2015 with the receipt of seed systems supplemental funding. Includes work in isolated rice schemes in Uganda. **Mid-Yr2:** Sites and medium scale multipliers identified in Ethiopia and Uganda; ongoing in Tanzania. **Yr2Qtr3**: training and registration of cooperative on-going in Ethiopia; sites under selection in Tanzania; SP-Rice seed rotation study established in Agoro Irrigation scheme in N. Uganda. Rapid Seed Market Assessment underway in Agoro (May 2016). **End Yr3:** Uganda (Agoro): marketing strategy planned and implemented. Tanzania (LZ) marketing strategy under implementation; Ethiopia 27 farmers registered as part of cooperatives and 3 Farmer Training Centers (FTCs) as missing middle operators. **End Y54:** Agoro rice-SP-rice study completed, showing higher profitability of rotation compared to control. Norman K's study completed - providing evidence for focus on medium -to large scale multipliers, with larger protected structures. Multipliers in N. Uganda undertaken seed inspection training, review of business plans, and completing marketing strategies; Joint marketing strategy for Lake Zone multipliers with LZARDI, to strengthen linkages through the chain. **Mid-Yr5:** Data collection and wrap up meetings have been held in each country to assess usefulness/viability of this model. **End SASHA2:** The maximum distance at which the sale of vines from low SPVD to high SPVD pressure areas is still profitable is 280 km when using a 7-ton lorry or 380 km when using a bus. There is a loss if vines are transported from Agoro Irrigation Scheme (a low SPVD pressure area) to high SPVD pressure areas. Vines can be sold from the nearest low SPVD area (Karuma) to a high SPVD area at a farmgate price of UGX18.1/cutting; but with a final cost to the buyer of UGX 31.6/cutting.	100		0

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4.1.1	DR/TS	Year-round supply of OFSP roots for a major urban market significantly improved	6	2019	Not achieved at desired level	**Yr1:** Storage research linked to SUSTAIN projects in Kenya and Mozambique. Feasibility studies conducted in both countries. In Kenya, fresh roots will be linked to agro-processor of purée; In Mozambique, will target fresh root market. **Yr2Qtr1:** harvesting and pre-storage handling identified as having an important impact on root quality in Kenyan case study. **Yr2Qtr2**: Report of trials on impact of handling and transport in Western Kenya. Trials initiated to test efficacy of curing to improve mid-term (1 month) storage. Two larger scale longer-term trials have been initiated. Curing conditions can be effectively maintained, but technical problems have meant that the target temperature for subsequent storage have not been maintained. Supply improvement has been delayed by delays in appropriate storage facility. **End Yr4:** Began handling/marketing study in informal and formal markets of Nairobi. **Mid-Yr5:** Handling/marketing study in Nairobi completed. Backstopped firm of Sammy Agili to start supplying quality OFSP roots to Nairobi. **End Yr5:** Links on improving fresh root supply not completely achieved due to lack of developing solar powered storage facility (milestone 4.1.3)	100	95	95

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4.1.3	DR/TS	Improved techniques for larger-scale curing and storage appropriate for SSA developed & appropriate brochures/briefs produced	6	2019	Not achieved at desired level	**Yr1:** Private sector partner, Organi Ltd, identified in Kenya & short-term holding facility constructed to improve the consistency of supply of OFSP roots to the processor. Protocols to improve handling of roots prior to storage developed. **Yr2Qtr1:** Curing/holding facility created by upgrade of existing facility at purée processing plant in Kenya. Two larger scale longer-term trials have been initiated. **Yr3Qtr2**: 1st three trials did not achieve objective; Re-worked storage facilities in July/Aug 2016; new trials started comparing solar and grid energy supply in Dec 2016, in Kenya but issues still exist with reaching desired temperature of 15°C. Alternative approach using Coolbot under design in Southern Africa. **Yr3:** Western Kenyan stores successfully constructed and tested capable of 4 months storage of roots providing sufficient quality for processing (70% of weight of roots retained). Further trials on storage technology ongoing. Handling trials delayed. In June 2017, built new storage facility in W. Kenya with solar-powered air cooling system that will be able to lower temperatures to 15 degrees C. Mid-**Yr4:** Trial established in solar-powered air-cooled container storage established in October 2017 cured roots at too high a temperature, leading to considerable rotting. **End-Yr4:** Completed 6th experiment in Kenya but had significant rot problem. Solar-powered storage container arrived in Mozambique on 6 June 2018. **Mid-Yr5:** Storage trial in Mozambique completed with lower losses than in Kenya; 7th trial in Kenya failed due to rotting; Report compares data from 4th-7th trial. Further research is needed to resolve challenges with rotting and curing **End SASHA2:** Succeeded in using solar-powered system to maintain temperatures 14-15 degrees C for longer term storage; however, proper curing still not resolved; meaning that losses due to rot are still too high. Will seek additional funds to continue this critical research.	100	92	92

Milestone #	Responsible	Key Milestones	Due	Date	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019	% progress of milestone as of 31 Oct 2019	% progress/ planned 31 Oct 2019
			Mon	**Year**			**Year 5**	**Annual**	
4.1.4	DR/TS	Improved techniques for fresh root harvesting, packaging and transport & appropriate brochures/briefs produced	3	2018	Achieved	**Yr1:** Trials initiated in Kenya on keeping qualities of different harvesting and root cleaning methods and packaging during transport. **Yr2Qtr2:** Trials in Ghana for long distance transport showed roots in tomato boxes suffered least damage; 2nd best were polypropylene sacks with only 50 kg of roots; Harvesting and pre-storage handling identified as having an important impact on root quality in Kenyan case study. **Yr2Qtr2:** Report of trials on impact of handling and transport in Western Kenya finished. **Yr3Qtr2**: UDS validation trials completed. 50 kg polythene bag best container (current method uses extended bags) in Northern Ghana. Storage trial in Kenya testing washed vs unwashed roots. Not much difference, if washed roots are briefly sun dried. **Yr4:** Brochure preparation for improved handling initiated. **Yr5:** 12 Page brochure on proper Handling of Roots during Harvesting and Post-Harvest completed and printed.	100	100	100
4.2	TC	Report and brochures for improved methods for storing fresh roots for home consumption at the household level	12	2018	Achieved	**Yr1:** Positive results from the double S or sandbox storage method tested in Ghana & Malawi **Yr2Qtr2:** Sand box superior to moistened heaps (traditional practices) in Ghana. Evaporative cooling trial started in January 2016 in Ghana. **Yr3Qt2:** Missed trial opportunity in Sept 2016; draft brochure on Double S prepared and revised in 2017 in collaboration with USAID supported storage project. **Mid-Yr4:** Revised draft received of Double S brochure. **Yr4:** Revised draft received of Double S brochure. **End Yr4:** Double S brochure launched at April 2018 MPU meeting.	100	100	100

Milestone #	Responsible	Key Milestones	Due	Date	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019	% progress of milestone as of 31 Oct 2019	% progress/ planned 31 Oct 2019
			Mon	Year			Year 5	Annual	
4.3	TM	Report on viability of storing purée/concentrate without a cold chain and the quality and safety of products made from stored purée vs fresh	10	2018	Achieved	**Yr1:** Protocol designed and first and second rounds of testing in progress. Vacuum packing with preservatives and citric acid very promising. **Yr2:** Repeated testing of vacuum packing & natural vs chemical preservatives revealed 2 high potential solution for storage up to 6 months. We developed OFSP purée shelf-stable for 6 weeks at 20-23C with sorbate, benzoate and citric acid, and developed bread with it. The bread tastes good and but it takes long to proof. **Yr3:** Construction of storage facility just for purée constructed and purée shelf-life now being tested. OFSP bread- HPLC analysis complete. Volume of bread made with OFSP purée with preservatives now attains same volume as 100% wheat flour bread with increased yeast % and adding baking powder. Puree able to withstand microbial 'challenge" for 12 weeks at room temperature. OFSP bread quality best at storage temperatures not exceeding 25°C. The preservative combinations of 1% citric acid, 0.25% potassium sorbate and 0.25% sodium benzoate together with vacuum packing and stored at temperatures below 24 Celsius can be stored for 3-4 months and used to make bread with a proofing time of 1 hour with 1.5% yeast and addition of 1% baking powder to actual the same bread volume at standard bread. Data on OFSP purée bread consumers collected from Tuskys. High fiber purée developed. Shelf stable OFS purée bread had long proofing time because of the sorbate, and citric acid. Adding baking soda at 1% neutralizes the citric acid. **Yr4:** Consumer acceptance studies conducted to determine the differences between fresh OFSP purée versus shelf-stable OFSP purée. Proximate analysis and physiochemical analysis comparing fresh OFSP purée products and shelf-stable purée products conducted in 2nd half. **Mid-Yr5:** All papers relevant to purée studies published by students involved.	100	100	100

Milestone #	Responsible	Key Milestones	Due Mon	Date Year	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019 Year 5	% progress of milestone as of 31 Oct 2019 Annual	% progress/ planned 31 Oct 2019
4.4	TM	Reference laboratory for nutritional quality & food safety in use	6	2019	Achieved	**Yr1:** Food Analysis and Nutrition Lab established in collaboration with BecA. Lab now has CIP Food Scientist and Lab technician; 1st run of HPLC in January 2015; Microbial detection lab setup in progress. **Yr2:** HPCL fully functional for carotenoids, vitamin A, vitamin E and vitamin C. Microbial lab functional. First 4-month intern from Cornell University assisted in food safety training. **Yr2Qtr3**: Proximate analysis equipment installed, the phytonutrient protocol were tested, and second used HPLC from CIP HQ received in Sept 2016. Two Master's students from University of Nairobi working on OFSP purée storage, and OFSP bread consumer profiling studies. **Yr3:** Additional HPLC installed in Sept 2016 expanded analytic capacity. Bioaccessibility studies initiated. To date, 8 graduate students working within FANEL. University of Nairobi collaborator Dr. George Abong obtained ABCF fellowship from BecA to work on phytonutrient analysis of OFSP and in vitro glycemic index of OFSP products. Sarah Chilungo from NCSU working on bioaccessibility studies of beta-carotene from OFSP products. Derick Malavi, Cecilia Wanjuu and Joyce Musyoka submitted their masters' theses in June in 2017. **Yr4:** Proximate and beta-carotene analysis of OFSP purée bread conducted. Protocols developed for transgenic potato for simple sugars, vitamin C and glycoalkaloids and adapted for sweetpotato. **Yr5:** Food Scientist Muzhingi awarded Emerging Leaders Network Award by the Institute of Food Technology in July 2018. Derrick Malavi became new lab manager in August 2018. FANEL now a functional unit in CIP-SSA operation with an operational budget of $450 000 per year, five staff members. FANEL Test Kitchen and Sensory Laboratory established to support quality traits breeding. FANEL-FLOW system developed to measure progress in sample analysis throughout the entire system. Validated and revised after initial testing.	100	100	100

Milestone #	Responsible	Key Milestones	Due Mon	Date Year	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019 Year 5	% progress of milestone as of 31 Oct 2019 Annual	% progress/ planned 31 Oct 2019
5.1.1	JL	Minutes of annual breeding meetings highlight progress being made in capacity building and info sharing	7	2019	Achieved	**Yr1:** Meeting held 2-5 June 2015 in Mukono, Uganda. **Yr2:** Meeting held 6-10 June 2016 in Nairobi, Kenya. Minutes available as milestone reports. Updated breeding progress paper submitted to APA meeting in October 2016. **Yr3:** Annual meeting 15-18 May 2017 in Kigali and minutes produced. **Yr4:** 2018 meeting held in Nairobi, 5-8 June and minutes produced. Specialized internal training on analyzing breeding data held in Kumasi Ghana in January 2018. **Yr5:** 2019 meeting held 7-10 June 2019 in Maputo, Mozambique. Assessment of usefulness of topics covered conducted.	100	100	100
5.1.2	JL	Presentations of SPHI meeting & evaluation of its usefulness	7	2019	Achieved	**Yr1:** Phase 2 financed September 2014 annual meeting. Minutes available as milestone report. Presentations posted on renovated Sweetpotato Knowledge Portal. **Yr2**: 6th Annual meeting held in Kigali, Rwanda. **Yr3:** 7th Annual meeting held Addis Ababa, Ethiopia. Minutes for Yr3 and evaluation completed. Aligned with 10th Triennial African Potato Association meeting. **Yr4:** 8th Annual meeting held in Dar-es-Salaam, Tanzania along with exhibition and field trips. Report of SPHI minutes, SPHI Steering Committee and PAC minutes completed. **Yr5:** 9th Annual meeting held at Concord Hotel in Nairobi, Kenya. Report of SPHI minutes, SSC meeting & PAC minutes completed. **FINAL** SPHI technical meeting under SASHA2 held on 24th August 2019 in Kigali, Rwanda, linked to 11th Triennial African Potato Association meeting 25-29 August 2019 in Kigali, Rwanda. Many presentations and posters presented based on SASHA research at the APA. Assessment and revision of the Sweetpotato Knowledge Portal completed.	100	100	100

Milestone #	Responsible	Key Milestones	Due	Date	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019	% progress of milestone as of 31 Oct 2019	% progress/ planned 31 Oct 2019
			Mon	Year			Year 5	Annual	
5.1.3	JL in coordi-nation with CoP leaders	Presentations and Minutes of Community of Practice Meetings	7	2019	Achieved	**Yr1:** Minutes available for meetings held: Monitoring, Learning and Evaluation (3-4 March 2015); Seed Systems & Crop Management (28-29 April 2015) and Marketing, Processing and Utilization (20-21 May 2015); Breeding & Genomics (2-5 June 2015); **Yr2:** Minutes available for meetings held: Seed Systems-Pre-basic Seed (8-10 December 2015); Marketing, Processing and Utilization (14-16 March); Monitoring, Learning and Evaluation (27-29 April); Seed Systems and Crop Management (9-12 May) in Arusha; **Yr3:** Minutes available for meetings held: 2nd Seed System meeting just for pre-basic seed system sub-grantees held in Nairobi (6-8 December 2016); MLE meeting in Maputo (30 January-2 February 2017); MPU meeting in Kisumu, Kenya (2-3 March 2017); Seed Systems Pre-Basic sub-group and CoP meeting in Mukono, Uganda (12-14 June 2017). **Yr4:** Minutes available for meetings held: Seed Systems Pre-basic Sub-Grantees CoP meeting held in Nairobi, Kenya (20-22 November). MLE meeting held in Nairobi with additional training in STATA statistical package (12-18 March 2018). MPU meeting held in Blantyre, Malawi (23-24 April) with additional Investment Forum day (25th April). Major Seed systems meeting held in Kigali, Rwanda (15-17 May), with a one-day meeting held for the sub-grant recipients on institutionalizing pre-basic seed production (14 May). **Yr5:** Meeting of Seed System SGA group on EGS business plans held in Nairobi, Kenya (12-15th Nov); MLE CoP held in Entebbe, Uganda (5-6 February 2019). MPU CoP held in Entebbe, Uganda (9-11 April 2019); Seed System CoP held in Mekelle, Tigray (14-16 May 2019). Assessment of usefulness of Seed System CoP conducted and brief on Seed System CoP produced.	100	100	100

Milestone #	Responsible	Key Milestones	Due	Date	Final Status	Comment concerning progress/status	Planned % of milestone as of 31 Oct 2019	% progress of milestone as of 31 Oct 2019	% progress/ planned 31 Oct 2019
			Mon	Year			Year 5	Annual	
5.1.4	JO	Database on dissemination efforts updated annually & use of Sweetpotato Knowledge Portal monitored	7	2019	Achieved	**Yr1:** Tested monitoring with smart phones in collaboration with Nigeria project; Began mapping decentralized vine multipliers in each country; Embarked on Knowledge Portal re-design with Netmidas. **Yr2:** 1st Sweetpotato in SSA update report prepared for SPHI Steering Committee Meeting held 2nd October 2015 in Kigali; 2nd update presented in Addis Ababa in October 2016. Renovated Knowledge Portal relaunched in February 2016. Monthly E-Digest of highlights from Knowledge Portal started in May 2016. **Yr3:** New Kenyan company hired to fix remaining Knowledge Portal problems in Dec 2016. **Yr4:** 3rd Sweetpotato in SSA update report presented at SPHI Technical meeting and discussed in SSC; Work on renovating Knowledge Portal completed. Dashboard for key dissemination, varietal release and DVM access completed. Monthly monitoring of social media hits (Facebook; Twitter) began in March 2018. New section on detailed sweetpotato recipes added June 2018. For 1st time, had mid-year dissemination update for period July-Dec 2017. **Yr5:** 4th Sweetpotato in SSA update report presented at SPHI Technical meeting in Nairobi and discussed in SSC; 1st DVM update survey extensively using phones; **End of SASHA2:** 5th Sweetpotato in SSA update report presented at SPHI Technical meeting in Kigali, Rwanda on 24th August 2019 2nd DVM phone survey in 11 SSA countries. 6.2 million SSA household reached with improved varieties. Sweetpotato Knowledge Portal upgraded and all SASHA briefs, brochures, and other communication outputs loaded onto Portal and CGSpace.	100	100	100

APPENDIX B. SASHA2 Y5 ANNUAL DETAILED BUDGET AND EXPENDITURES

Sweetpotato Action for Security and Health in Africa (SASHA): Phase 2
Organization Name: International Potato Centre (CIP)
Financial Year: 2018/2019 : Y5_AnnualYear_Financial_Report_as_of_Feb 28, 2020

Budget Line Items	Year 1: Expenses	Year 2: Expenses	Year 3: Expenses	Year 4: Expenses	Y1 - Y4: Total Expenses	Y5: Budget	Y5: Expenses	Y5: Balance	% Spent	Total Expenditures	Project Life Budget Budget	% Spent
	USD	USD	USD	USD	USD	USD	USD	USD		USD	USD	
Total Personnel	1,459,545	1,585,841	1,721,662	1,827,346	6,594,393	2,064,509	2,060,582	3,927	100%	8,654,975	8,658,902	100%
Breeding	752,313	759,684	712,766	959,256	3,184,019	920,229	949,114	(28,885)	103%	4,133,132	4,104,247	101%
Weevil Resistance using Transge	178,206	60,958	31,985	-	271,148		-	-	0%	271,148	271,148	100%
Seed Systems	176,782	216,427	310,769	320,291	1,024,268	439,071	379,424	59,647	86%	1,403,692	1,463,339	96%
Postharvest management and n	26,463	36,887	80,862	62,911	207,124	96,318	67,169	29,149	70%	274,293	303,442	90%
Governance	325,781	511,885	585,280	484,888	1,907,834	608,892	664,876	(55,984)	109%	2,572,710	2,516,726	102%
Total Travel	373,832	569,595	507,584	404,317	1,855,328	308,841	268,893	39,948	87%	2,124,221	2,164,169	98%
Breeding	133,976	189,320	169,912	204,247	697,456	148,241	132,026	16,215	89%	829,481	845,697	98%
Weevil Resistance using Transge	20,428	3,787	288	-	24,503		-	-	0%	24,503	24,503	100%
Seed Systems	35,991	94,401	115,862	47,190	293,445	45,600	62,962	(17,362)	138%	356,407	339,045	105%
Postharvest management and n	6,409	18,780	13,215	(0)	38,404	15,000	1,587	13,413	0%	39,990	53,404	75%
Governance	177,028	263,306	208,307	152,880	801,521	100,000	72,318	27,682	72%	873,839	901,521	97%
Total Sub-grants to Others	463,696	628,429	507,972	432,419	2,032,515	482,861	427,980	54,881	89%	2,460,495	2,515,376	98%
Breeding	33,077	54,437	70,634	103,863	262,010	230,636	222,109	8,527	96%	484,119	492,646	98%
Weevil Resistance using Transge	190,311	-	-	-	190,311		-	-	0%	190,311	190,311	100%
Seed Systems	69,642	371,996	373,275	270,463	1,085,375	231,857	191,869	39,988	83%	1,277,245	1,317,232	97%
Postharvest management and n	170,666	201,997	64,063	58,093	494,819	20,368	14,001	6,366	69%	508,821	515,187	99%
Governance	-	-		-	-	-	-	-	0%	-	-	
Total Equipment	138,289	84,797	46,118	25,992	295,196	34,000	7,284	26,716	21%	302,480	329,196	92%
Breeding	62,133	59,524	6,199	16,099	143,955	-	(9,759)	9,759	0%	134,196	143,955	93%
Weevil Resistance using Transge	-	-	-	-	-		-	-	0%	-	-	
Seed Systems	34,806	-	14,245	-	49,051	-	-	-	0%	49,051	49,051	100%
Postharvest management and n	41,350	25,273	25,674	9,894	102,191	34,000	17,042	16,958	50%	119,233	136,191	88%
Governance	-	-	-		-	-	-	-	0%	-	-	
Consulting	-	45,494	30,035	35,101	110,630	13,500	5,226	8,274	39%	115,857	124,130	93%
Breeding		15,904	-	-	15,904	-	0	(0)	0%	15,904	15,904	100%
Weevil Resistance using Transgenics		-	-	-	-		-	-	0%	-	-	
Seed Systems		21,500	19,843	32,983	74,326	13,500	7,345	6,155	54%	81,671	87,826	93%
Postharvest management and nutritional quality		-	-	2,119	2,119	-	(2,119)	2,119	0%	-	2,119	0%
Governance		8,090	10,192	-	18,282	-	-	-	0%	18,282	18,282	100%
Other Direct Costs	769,978	1,044,293	998,579	1,075,672	3,888,522	1,140,319	1,293,369	(153,050)	113%	5,181,891	5,028,841	103%
Breeding	510,576	668,583	482,858	599,749	2,261,766	672,371	786,375	(114,005)	117%	3,048,141	2,934,136	104%
Weevil Resistance using Transge	58,830	41,121	44,232	-	144,183		-	-	0%	144,183	144,183	100%
Seed Systems	96,757	148,772	216,218	198,221	659,969	210,321	239,014	(28,693)	114%	898,983	870,290	103%
Postharvest management and n	29,624	88,684	86,421	57,247	261,976	60,000	87,335	(27,335)	146%	349,310	321,976	108%
Governance	74,191	97,133	168,850	220,456	560,629	197,627	180,644	16,983	91%	741,273	758,256	98%
Total Direct Costs	3,205,339	3,958,449	3,811,950	3,800,848	14,776,585	4,044,030	4,063,334	(19,304)	100%	18,839,919	18,820,615	100%
Total Indirect Costs	480,801	590,821	571,792	570,127	2,213,541	609,551	612,239	(2,688)	100%	2,825,780	2,823,092	100%
Grand Total Costs	3,686,139	4,549,269	4,383,742	4,370,975	16,990,126	4,653,581	4,675,573	(21,992)	100%	21,665,699	21,643,707	100%

Summary	Year 1 : Expenses	Year 2: Expenses	Year 3: Expenses	Year 4: Expenses	Total Expenditures	Y5: Budget	Y5: Expenses	Y5: Balance	% Spent	Grand Total	Grand Total	% Spent
	USD	USD					USD	USD	USD	USD	USD	USD
Total CIP Direct costs	2,741,643	3,330,019	3,303,978	3,368,429	12,744,070	3,561,169	3,635,354	(74,185)	102%	16,379,424	16,305,239	100%
Total indirect costs	480,801	590,821	571,792	570,127	2,213,541	609,551	612,239	(2,688)	100%	2,825,780	2,823,092	100%
Total Subgrantees	463,696	628,429	507,972	432,419	2,032,515	482,861	427,980	54,881	89%	2,460,495	2,515,376	98%
Grand totals	3,686,139	4,549,269	4,383,742	4,370,975	16,990,126	4,653,581	4,675,573	(21,992)	100%	21,665,699	21,643,707	100%

For Foundation Staff to Complete

Analysis (required if PO assessment differs from grantee/vendor assessment or if there are unexpended funds)

Progress Analysis

Include analysis of significant project variances and key learnings that may inform portfolio discussions for progress against the strategic goals.

Budget and Financial Analysis

Include analysis of unexpended funds or over expenditures. Refer to the Unexpended Grant Funds Policy for options available when recommending how to handle unexpended grant funds, or reach out to your primary contact in GCM.

CIP
INTERNATIONAL
POTATO CENTER

International Potato Center CIP
Regional Office; P.O. Box 25171
Nairobi - 00603 Kenya
email: cip-nbo@cgiar.org
www.cipotato.org