Participatory Evaluation of Resilient Potato Varieties in Climate-Smart Villages of Lushoto in Tanzania

Working Paper No. 192

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Dieudonné Harahagazwe, Roberto Quiroz, Stephen Kuoko, John Recha, Maren Radeny, George Sayula, Elmar Schulte-Geldermann, Gladness Brush, Elizabeth Msoka, Mary Rimoy, Asrat Asfaw, Merideth Bonierbale, Vivian Atakos, James Kinyangi

Working Paper

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Photos: CIP/SARI

Abstract

This three-year study conducted by the International Potato Centre (CIP) in collaboration with Selian Agricultural Research Institute (SARI) was based on demand by Lushoto farmers through the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). This participatory action research (PAR) was aimed at developing more resilient potato varieties that can grow in both long and short rainy seasons and give higher yields. The approach involved training-of-trainers (ToT) and participatory varietal selection (PVS) experiments. The ToT comprised five training events using modules. Three training events were done in the long rainy season and two in the subsequent short rainy season. The topics covered in the first round of training were on integrated crop management, from land preparation to seed storage. The second round of training was participant-driven whereby topics emerged from the first training. A total of twenty-one participants representing farmers, extension services and local non-governmental organizations were trained. The training was supported by field experiments using the CIP Mother and Baby Trials model. The trials were carried out in five villages: Kwesine, Boheloi, Maringo, Kwekitui and Milungui. Experimental materials comprised six advanced and heat tolerant clones from CIP (CIP390478.9, CIP388767.1, CIP392797.22, CIP300055.32, CIP398208.29 and CIP397073.7), two local varieties (Kidinya and Obama), an improved variety recently registered in Tanzania (Asante) and a popular farmer's variety but registered in Kenya (Shangii). A cross-analysis of field and culinary data combining quantitative and qualitative assessments from the three seasons of field evaluations showed a certain consistency in the high yielding ability and acceptability of four genotypes, namely Asante, Shangii, CIP392797.22 and CIP398208.29. The two clones were then named by farmers and proposed for official release while Shangii was proposed for registration for commercial use.

Keywords

Participatory action research; climate-smart villages; training-of-trainers; resilient potato, multi-partnership; Lushoto

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Contents

Acronyms

ABC	Spelled out here
DEF	And spelled out here
CIP	Centro Internacional de la Papa/ International Potato Center
DAICO	District Agriculture, Irrigation and Cooperatives Office
FAO	Food and Agriculture Organization of the United Nations
HI	Harvest index
JICA	Japan International Cooperation Agency
LB	Late Blight
PAR	Participatory Action Research
PVS	Participatory Varietal Selection
RCBD	Randomized Complete Block Design
RH	Relative Humidity
SARI	Selian Agricultural Research Institute
SRS	Short Rainy Season
SSA	Sub-Saharan Africa
Tmax	Maximum Temperature
Tmin	Minimum Temperature
ToT	Training of Trainers

1. Introduction

Lushoto is the most densely populated rural district in Tanzania with an average agricultural land size of 0.81 ha (Förch et al. 2013). Situated in the Northeast of the country, the district of Lushoto is part of the so-called highlands of Tanzania where potatoes are traditionally grown (figure 1). Potatoes have been playing a major role in Lushoto agriculture and food systems since the 1980's without much support from research or development agencies. As a result, the potato growers in Lushoto lack access to clean seed and new productive varieties. Furthermore, farmers have limited knowledge on crop husbandry, including seed-related practices while safeguarding the environment.

Even though there is a potential to grow potatoes throughout the year (existence of irrigation facilities), farmers cannot plant more than once due to heat and lack of resilient potato varieties. The implication of this situation is that there is nothing farmers can do to overcome this abiotic constraint except using resilient germplasm (i.e. heat tolerant or early maturing). The other constraint expressed is biotic but climate-related. During the long rainy season, it is too humid and wet plus low temperatures so that the late blight pressure is so high. In most cases farmers lose all the crop especially when they grow the local variety called Kidinya which is extremely susceptible to this disease.

Therefore, this action research was an attempt to respond to these climate-related challenges faced by potato growers of Lushoto, one of the climate-smart villages of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) in East Africa. The aim of the study was to support farmers so that they can plant at least twice a year by introducing new and resilient materials while empowering them in all aspects of the crop. In this end, this initiative aims at improving livelihoods of smallholder potato growers through better food security and increased income.

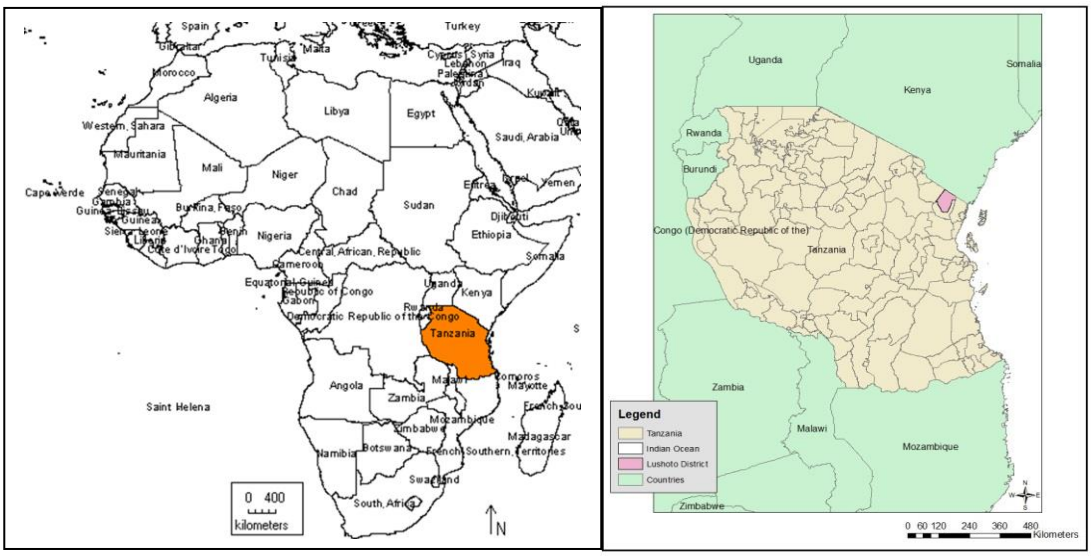
The specific objectives of this study were:

- Screen and identify heat tolerant and adapted potato clones so that farmers can plant potatoes at least twice a year;

- Enhance the knowledge and practices of potato farmers, extension agents, NGOs and other stakeholders in various aspects of integrated potato crop management;
- Develop and strengthen strong partnership with other potato stakeholders in the district.

This study was articulated on two pillars as follows: (i) weather assessment and monitoring, (ii) participatory action research comprising training-of-trainers (ToT), and (iii) field experiments. The participatory action research model applied was intensive because most of the partners involved in facilitating training and trials were also trainees. The approach consisted of combining ToT and participatory varietal selection (PVS) experiments in the different villages of Lushoto. The evidence for this work has been extensively published through the Web (CIP 2014, Harahagazwe et al. 2014, Recha et al. 2015, Harahagazwe and Atakos 2015, Kuoko et al. 2016).

Figure 1. Localization of the study area on the continental (Left) and the country (Right) maps



Source: Authors

2. Potato sub-sector in Lushoto

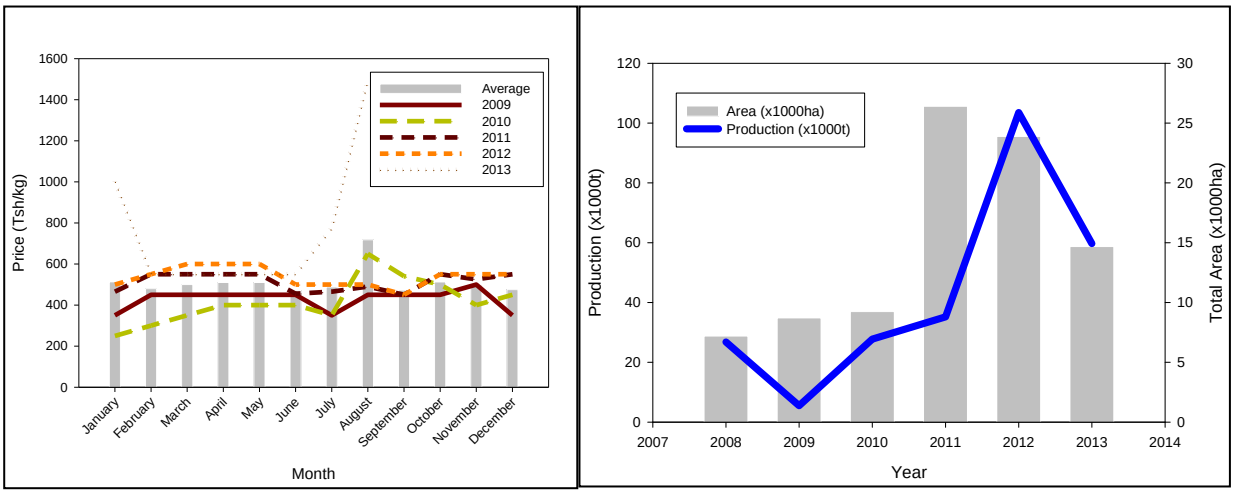
Statistics show that Lushoto may be producing more potatoes than some countries like Burundi, Democratic Republic of the Congo or Mozambique. As reported by farmers during the scoping visit of this study, maize, beans and potatoes are the major food security crops in Lushoto.

Potatoes, in addition to having a food security role, serve as a major source of income and improved livelihoods.

However due to the challenges explained above, seed prices are too high at planting sometimes fourfold of normal prices (from USD 2.5 to USD 10 per basket of around 10 kg in 2013) as shown on Figure 2 (left) whereas the prices of ware potatoes seem to have low variations in price except in 2013.

The annual potato production in Lushoto exceeds at times 100,000 t but harvested on a large area (over 25,000 ha) as happened in 2011 (figure 2, right). Therefore, tuber yield is very low with an average of 2.7 t/ha on a period of six years (2006 – 2013).

Figure 2. Potato statistics of Lushoto District: annual production and area (right), and monthly prices (Left).



Source: Authors (data provided by the Lushoto district office)

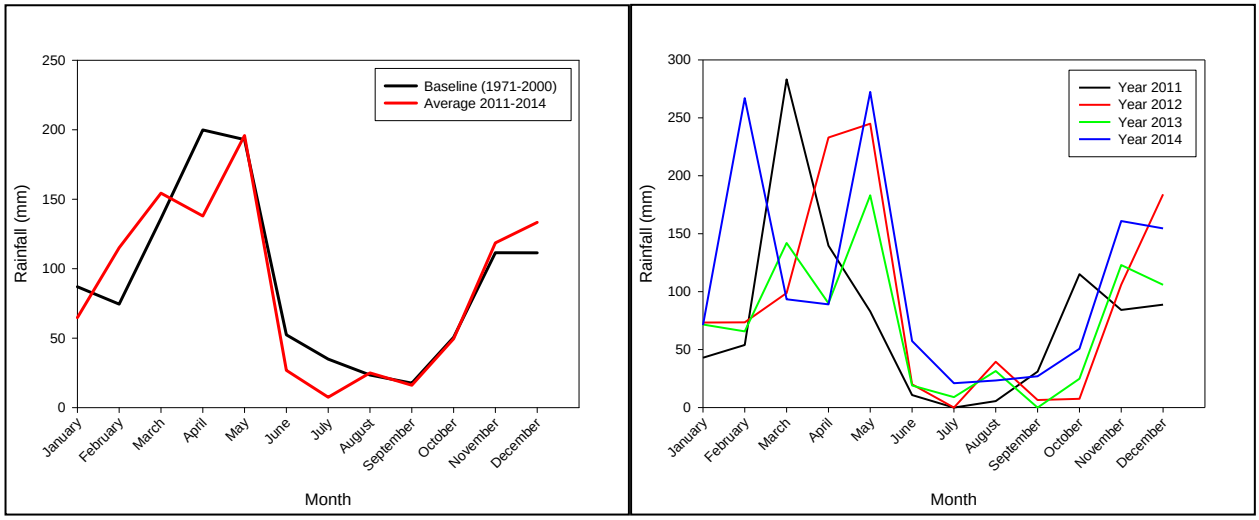
3. Meteorological data

3.1 Gauged rainfall

On the basis of four year datasets (2011 – 2014) provided by the District of Lushoto we conducted an analysis on the rainfall patterns in comparison with the historical data from literature. As expected the long rainy season called *Masika* in Lushoto is reported to record more rain than the short rainy season named *Vuli* (Recha et al. 2015) with an average of 527.8 mm against 272.4 mm with one peak in April (figure 3 left) for an average rainfall of 190 mm (Mahoo et al., 2015). But our analysis shows that the rainfall pattern in Lushoto may have changed in two ways. Rather than having one peak in Masika season the tendency is now to

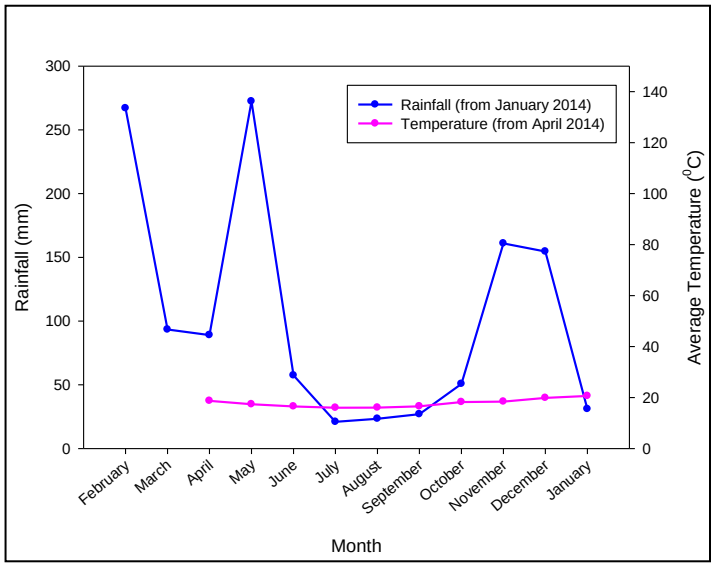
have two peaks (figure 3). This occurred from 2011 to 2014 with an exception in 2012 (figure 3 right). The second possible change is that the month of peak has shifted from April to May with occasional peaks in February and March (figure 3 right). However, these changes need to be monitored over time for confirmation as they may just be anomalies that occurred during this period.

Figure 3. Rainfall patterns in Lushoto: four-year average (2011 – 2014) in comparison with the baseline (Left) and current patterns for the studied years (right)



Source: Authors (data from the Lushoto district office and Mahoo et al. (2015) for the Baseline)

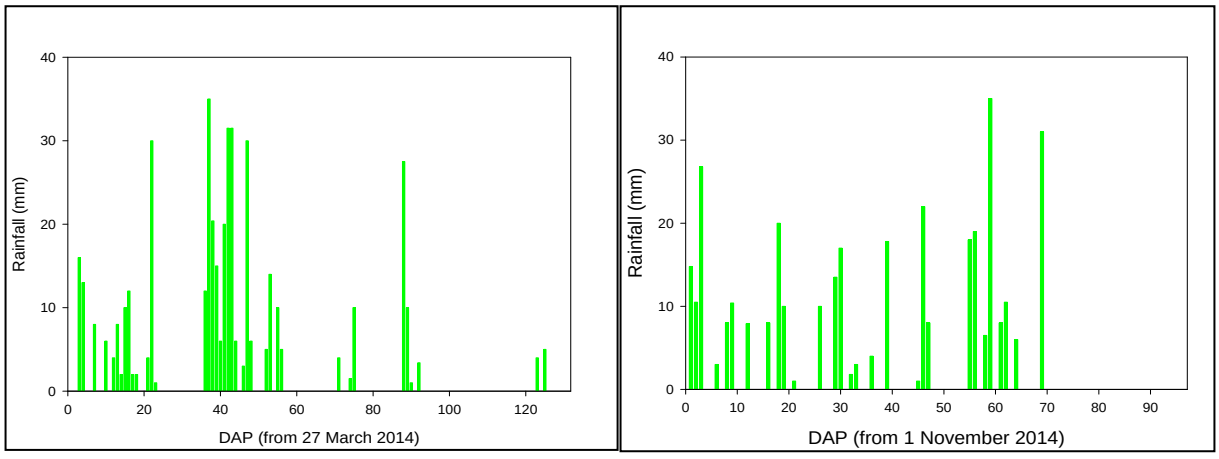
Figure 4. Ombrothermic diagram of Lushoto using data collected from January 2014 to January 2015



Source: Authors (rainfall data from Lushoto district office)

The ombrothermic diagram generated using our temperature datasets collected by loggers installed in Lushoto shows that the district is prone to severe droughts for three months after Masika season (July to September) and one month (January) after Vuli season (figure 4). Figure 5 shows that rains are not continuous throughout the growing season. There are short dry spell periods that seem not to affect much soil moisture on the basis of field trials conducted.

Figure 5. Rainfall observed in Lushoto during the long (Left) and short (Right) rainy seasons of 2014



Source: Authors (data provided by the District office)

3.2 Temperature and relative humidity in Lushoto

Installation of weather data loggers

In order to monitor temperature and relative humidity prevailing in the study areas, three data loggers HOBO Pro v2 were installed in three villages on 28 March 2014 (Kwesine) and 29 March 2014 (Lushoto District Office and Boheloi) as shown on Table 1 and photo 1-3. These automatic devices registered data at hourly interval using HOBOware 3.7.2 software sourced from Onset Computer Corporation.

Table 1. Coordinates of the weather data loggers installed in Lushoto.

Waypoint	District office (DAICO)	Boheloi	Kwesine
Latitude (South)	4o47'23.67''	4o47'49.62''	4o48'21.28''
Longitude (East)	38o17'24.73''	38o21'47.00	38o23'53.82''
Altitude (masl)	1391	1210	1441

Photo 1. Weather data logger installed under a banana plantation in Kwesine Village in collaboration with farmers. Photo: D. Harahagazwe/ CIP

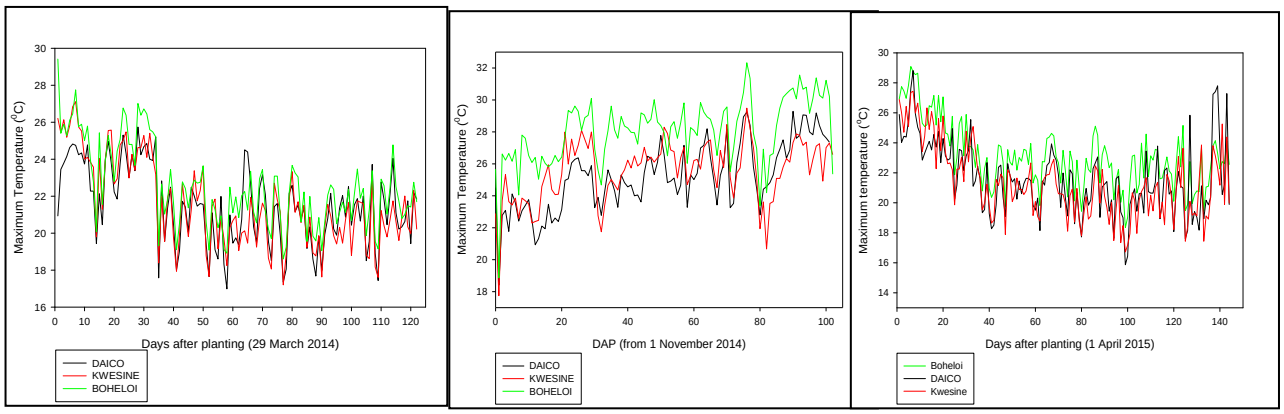
Photo 2. Weather data logger on a tree at Lushoto District Office. Photo: D. Harahagazwe/ CIP

Photo 3. Weather data logger installed on a tree at Boheloi Village in collaboration with the Village extension agent (Left) and household head (Right). Photo: D. Harahagazwe/ CIP

Temperatures and relative humidity registered

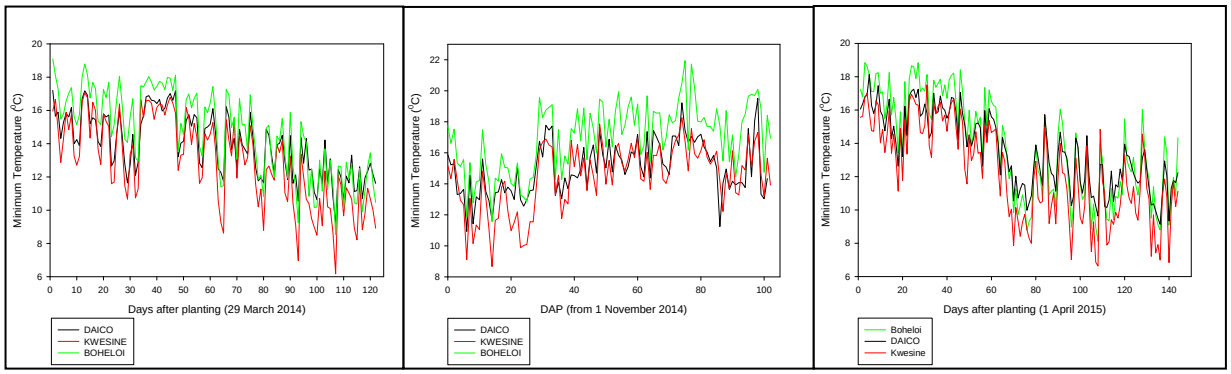
In all the three villages data loggers registered almost the same temperature and relative humidity patterns in Masika and Vuli seasons except in Boheloi which appeared to be hotter and dryer than the two other sites where data loggers were installed. Furthermore, maximum temperature (Tmax), minimum temperature (Tmin) and average relative humidity (RH) graphs from Kwesine and the District Office look alike for both Masika and Vuli seasons except for Tmin and RH that prevailed in Vuli season (figure 6 to 8).

Figure 6. Maximum temperature observed during Masika 2014 season (left), Vuli 2014 season (Middle) and Masika 2015 season (right) in three sites of Lushoto.



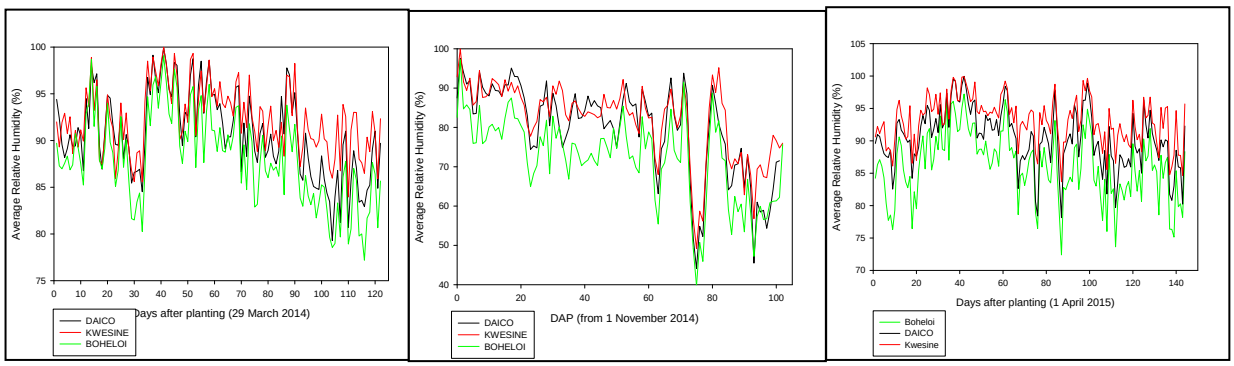
Source: Authors. DAICO stands for District Agriculture, Irrigation and Cooperatives Office.

Figure 7. Minimum temperature observed during Masika 2014 season (left), Vuli 2014 season (middle) and Masika 2015 season (right) in three sites of Lushoto.



Source: Authors. DAICO stands for District Agriculture, Irrigation and Cooperatives Office.

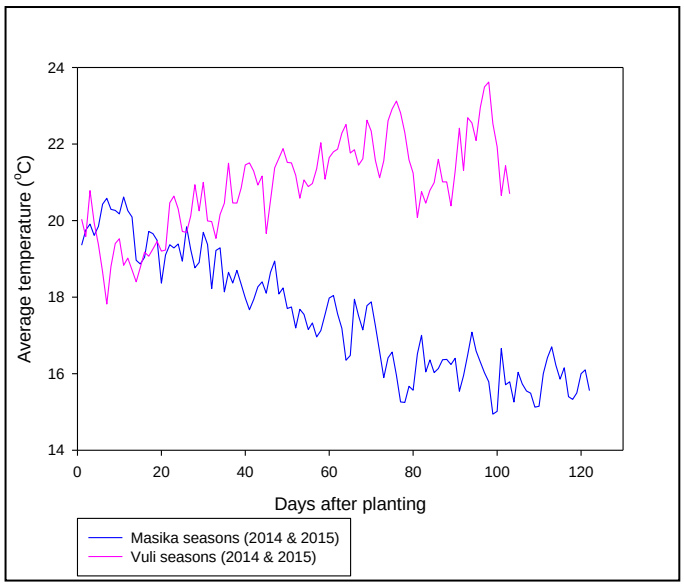
Figure 8. Average relative humidity across sites observed in Lushoto during Masika and Vuli seasons in 2014 and 2015.



Source: Authors

Based on data collected during two years, the average temperatures of Masika and Vuli seasons cross at around the 20th of April and 20th of November at a temperature of around 19oC but split thereafter as it decreases for Masika season and increases in Vuli with a maximal amplitude which exceeds 60C from one season to the other as shown on figure 9.

Figure 9. Average temperature across sites observed in 2014 and 2015 during Masika and Vuli seasons.



Source: Authors

During the Vuli season temperatures revealed to be beyond the comfort zone of the potato crops with maximum temperatures beyond (Boheloi) or close to (DAICO and Kwesine) 28^0C just before tuber initiation (figure 6 middle) and 18^0C for minimum temperature (figure 6 right). This ecology is normally found in tropical lowlands where high temperature and low irradiance during the rainy season are the main constraints to potato production (Menzel 1984). Heat stress presumably affects interrelationships among enzymes, hormones, and perhaps membranes and the resulting shift in metabolic balance decreases the amount of photosynthates required for better growth (Ewing 1981). Scientists showed that when temperature is above 25°C, the photosynthesis process is limited by the stomatal and mesophyll resistances, in addition to its inhibition by O_2 since potato is a C_3 plant (Ku et al. 1977). The second main effect of high temperature to the potato crop is the reduced assimilates allocated to the tubers in comparison to what is allocated to other plant organs resulting in reduced harvest index (HI). The change in partitioning is assumed to be the major problem resulting from high temperatures prevailing in most parts of the world where potatoes might be otherwise grown (Ewing 1981). Normally higher (0.8) than what is found in other crops such as cereals (0.5 – 0.6) in optimal conditions (Condori et al., 2008), potato HI decreases significantly when temperatures exceed the optimum

(Ewing, 1981; Harahagazwe et al. 2012). Therefore, this kind of environment requires special materials with heat tolerance trait.

Analysis of graphs outlined in figures 6 through 9 reveals that during Masika season prevailed optimal conditions - over 95% of RH up to 90 days after planting - for occurrence and development of late blight as the temperatures were below 22^0C with a relative humidity that was close to 100% throughout the season (FAO 2009). These conditions significantly changed during the subsequent season. This might be the reason why this disease which had created much problems in Masika season despite chemical control measures did not show up in Vuli season.

4. Training-of-trainers

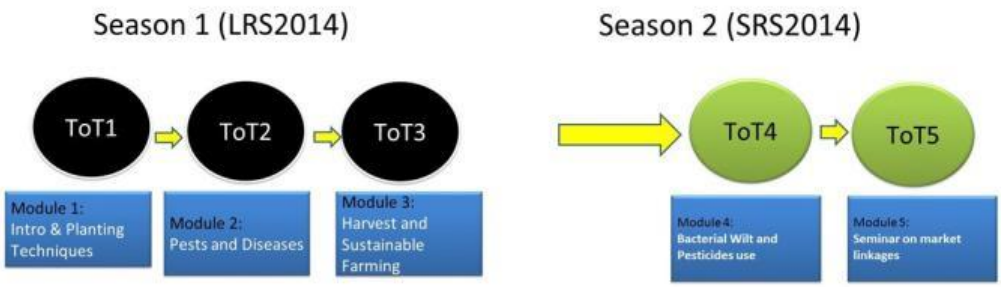
The training-of-trainers (ToT) was a complementary activity to field introduction of several heat tolerant potato genotypes in the district. Trained farmers were expected to train their peers in subsequent seasons through farmer-run-field schools. In this effort to empower potato growers of Lushoto, CIP scientists developed strong synergies with other key players such as JICA and YARA Tanzania Ltd, in addition to the district agricultural officers.

The specific objectives of this ToT were:

- Raise the awareness of farmers and other stakeholders on the importance of properly managing potatoes.
- Enhance knowledge and skills of farmers on all aspects of potato from planting to storage and processing.
- Enhance skills of extension agents and local NGOs on potato integrated crop management for subsequent scale out and scale up.
- Strengthen research and extension partnership in the target area.

This main participatory training course was simultaneously conducted in English and local language (Swahili). It took place in the district of Lushoto where the experiments—living illustration of the course—were being carried out. The ToT comprised five training modules that spanned two growing seasons of 2014, three modules during the long rainy season (LRS) and two in the subsequent short rainy season (Figure 10). The topics covered in LRS were proposed by facilitators in order to cover important components of crop management. The second round of training was participant-led as topics emerged from the first round.

Figure 10. Logical sequence of participatory training sessions conducted in Lushoto in 2014.



The first round of training comprised three modules of two days each during the long rainy season of 2014 (LRS2014). For each module, the first day was allocated to training sessions taking place in a conference/meeting room and covering theoretical aspects of the crop (photo 4) but the second day was mostly dedicated to field work and hands-on demonstrations (photo 5). The modules were organized in such a way they followed a certain logic in relation to crop growth phases as shown in figure 10 and table 2. After the third session of training, participants were formally assessed in a bid to determine areas that needed further clarifications. Therefore, two more training sessions were organized during the second and short rainy season of 2014 (SRS2014). This approach emphasizes the fact that the course was co-designed between the facilitators and the beneficiaries. Annexes 1 – 5 provide more details on the contents of the different training sessions.

Photo 4. Training taking place in a meeting room on day 1 of each module. SARI scientist introducing participants to major bacterial diseases and their impact to the potato crop. Photo: D. Harahagazwe/ CIP

Photo 5. Hands-on practice on topics covered in the meeting room. Maringo extension officer showing participants how to detect Bacterial Wilt in the field. Photo: D. Harahagazwe/ CIP

Table 2. Key topics covered during the training campaign held in Lushoto, Tanzania in 2014.

	ToT1	ToT2	ToT3	ToT4	ToT5
Module	General introduction and planting techniques	Integrated pest and disease management	Potato value chain and sustainable development	Refresher course on Bacterial wilt and pesticide use	Seminar on input and output market linkages
Date	26 – 27 March 2014	6 – 7 May 2014	23 – 25 June 2014	29 October 2014	10 February 2015
Key topics covered	Knowledge assessment (baseline test) General overview on the potato crop (origin, value, morphology, phenology, yield, etc.) Choosing land and soil preparation (choice of land, planting date, slope, plough, etc.) How to plant and fertilize potatoes Crop rotation, weeding and earthing-up	Local knowledge on pests and diseases Disease triangle Major fungal diseases Major bacterial diseases Viral diseases Major potato pests in the region Smart Spraying techniques Positive and negative selection	Potato production costs Dehaulming and harvesting techniques Seed potato Importance of working in associations Role of women in potato production: current status, gaps and solutions Desired market linkages: input acquisition and output market Knowledge assessment	Bacterial Wilt control Pesticides (accessibility, quality, how to apply, etc.…) Pesticides and the environment See seminar outcomes in Table 3	Input market (fertilizer quality, packaging, agro-dealer training, etc...) Output market and linkages

The course was designed for 16 farmers' representatives of three villages: Boheloi, Kwesine and Maringo (photo 6 and annex 6). Farmers' representatives to the ToT were selected by their peers in their respective associations on the basis of their capacity to learn fast and cascade down the training. In addition to three ward extension officers, two representatives from local NGOs operating in the district attended the course throughout the year. It is worth emphasizing the fact that 50% of farmers' representatives were females.

Photo 6. Group photo on the first day of training conducted in Lushoto, Tanzania in 2014.

As a response to a rising demand from neighboring areas, another training course was conducted by SARI scientists on 2 – 3 August, 2015 at Kwesine Primary School but for farmers' representatives from Kwekitui and Milungui in a bid to accompany the potato trials extended to those villages during the long rainy season of 2015 (Annex 7). The session was opened by the newly elected Kwesine Village Secretary, Mr. Juma Shemkindo and officially closed by Kwesine Primary School Head teacher, Mr. Michael Mhina. The course was attended by 18 farmers' representatives and almost half of them were females.

Table 3. Perspectives of potato value chain actors in Lushoto, Tanzania expressed during a seminar held on 10 February 2015.

Value chain actors	Perspectives
Potato traders	Some farmers are not honest as they tend to put small sized potato down and large ones on the top of the sack. It is believed that white potatoes have more water than pink/red ones There is a growing demand of potatoes in cities such as Dar es Salaam, Arusha and Morogoro where some of the hotels import potatoes from Kenya or even Europe Grading is not properly done Traders prefer variety Shangii from Kenya as it fetches higher price especially in Dar es Salaam Traders complain that Lushoto farmers cannot supply potatoes throughout the year Farmers are penalized because they harvest altogether and then get lower prices
Transporters	Farmers should avoid to expose tubers to direct sunshine or wound them Potatoes should be packaged in such a way there is not mix of varieties within a bag Potatoes from Lushoto are not very competitive at market in comparison with those coming from Uyole or Kenya because they are dirty and roads are of poor quality Stepping on the potato bags deteriorates the quality of potatoes sold on the market
Potato processors/restaurants	Need potato varieties that are especially suitable for processing into chips and crisps – mature tubers with good shape, good size (80-120 g), shallow eyes with attractive skin color normally red or reddish. Local processors have limited access to reliable markets because their customers are normally students. Proposed products are based on consumers' preferences Farmers should harvest mature potatoes to avoid that chips become too oily.

5. Field experimentation

During the scoping study conducted in November 2013, two major climate and climate-related stresses were identified by potato farmers and extension officers for hindering potato cultivation in the district of Lushoto. The first constraint was heat during the short rainy season and late blight induced by too much humidity and lower temperatures during the long rainy season. Therefore, this chapter summarizes a three season work in an attempt to address these constraints through introduction of CIP-bred genotypes. Findings co-generated through participatory action research, where members of communities are not treated as passive subjects but co-learners (Whyte et al. 1991), are very promising and constitute a note for great hope for potato growers and other value chain players as described in the following sections.

5.1 First field season

The first set of trials conducted in Lushoto started with the introduction of mini-tubers from CIP Nairobi. The materials introduced were proposed by the CIP Potato Breeding Unit in SSA for their potential in tolerating both late blight and a warm environment.

5.1.1 Materials and methods

The experiment was conducted in a Mother (photo 7) and Baby Trial design following the CIP Participatory Varietal Selection (PVS) Protocol (CIP 2013).

The mother trial was planted at the Resource Center of Jegerstal in Lushoto on 27 March 2013 and harvested on 28 July 2013. Experimental materials comprised eight CIP advanced heat tolerant clones (CIP390478.9, CIP388767.1, CIP392797.22, CIP300055.32, CIP398208.29 and CIP397073.7), two local varieties (Kidinya and Obama), an improved variety recently registered in Tanzania (Asante or CIP381381.20) and Shangii, a popular farmer's variety but registered in Kenya. The experiment was executed using a randomized complete block design (RCBD) with three replications. Each plot contained 36 plants located on three rows of 12 plants each but data were collected from only the 30 inner plants. Plots were aligned horizontally on three terraces for the three blocks as shown on picture 7. Tubers were planted at 75 cm in-between rows and 25 cm between plants within rows, meaning a plant density of 5.3 plants m-2. In each hole, around 500 g of organic manure were applied together with around 14.3 g of NPK (17-17-17) fertilizer. This means an application of 763 kg ha-1 of mineral fertilizers which is equivalent to 130-130-130 units of N, P2O5 and K2O, respectively. Pests and diseases were controlled using the following chemicals: Milthane Super (contact fungicide) and Sunstar 72%WP (systemic fungicide) against late blight (LB), Twigathoathe against aphids and Duduthrin as large spectrum insecticide. Those chemicals were recommended by the National Potato Program and they are available on the local market. Several and relevant parameters were collected using CIP Mother & Baby Design and data collection protocol, including emergence rates, tuber yield (number per category and weight), and culinary attributes.

Picture 7. Mother trial conducted on terraces of the resource center of Jegerstal in Lushoto during the long rainy season of 2014. Photo: D. Harahagazwe/ CIP

Farmers' perceptions and preferences with gender disaggregation on materials tested were collected during field days organized at flowering stage and harvest. To this end, we used the seed technique provided by the same CIP protocol where males were given maize grains and beans for females (picture 8). The choice of beans by females was made by themselves and males approved the choice. Each evaluator received six grains to be dropped in a kaki envelope as per his/her preferences: three grains for the first choice, two grains for the second choice and a grain for the third one. During the vegetation stage, four parameters were scored: (i) Resistance/tolerance to late blight; (ii) Foliage abundance; (iii) Erectness of the plant; and (iv) General appearance of the plant. At harvest, the ranking was based on subjective appreciation of the tubers harvested regardless of traits. With regard to the mother trial, 36 females and 31 males participated in the ranking against LB whereas the harvest was conducted by 76 females and 43 males.

Picture 8. Participatory evaluation of potato genotypes at flowering stage (Left) and harvest (Right) from the mother trial conducted in Lushoto. Photo: D. Harahagazwe/ CIP

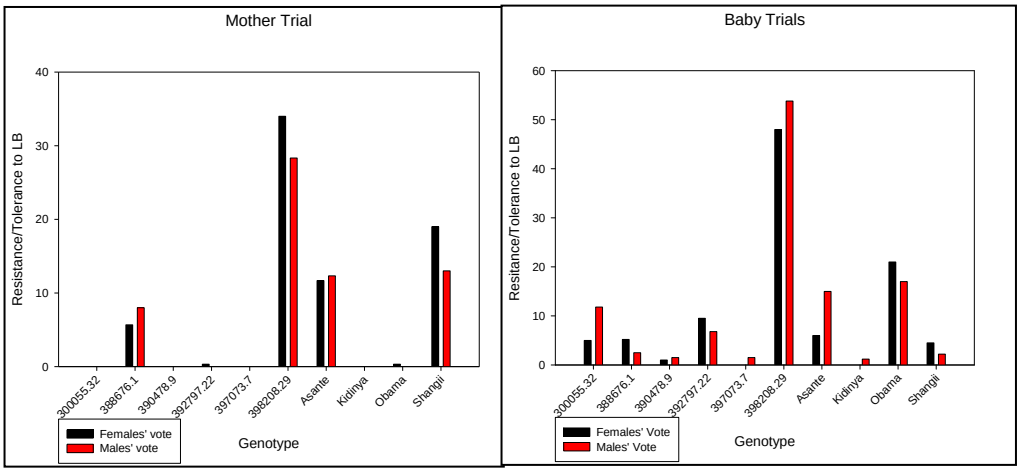
The baby trials were conducted in two villages (Boheloi and Kwesine). In total four trials serving at the same time as experimental and demonstration plots for training were conducted by four farmers—Florian Vitus and Amiri Shemzize in Kwesine, and Zainab Hossein and Waziri Shekomba of Boheloi—following the management and evaluation protocols used in the mother trial except that each farmer was representing a repetition. These farmers volunteered themselves from the trainees to carry out these trials in their respective farms. For the participatory assessment conducted on the vegetation attributes, 24 females participated in Kwesine against 43 in Boheloi. Males were respectively 45 and 30. At harvest a total of 62 females ranked the materials in both sites against 69 males. These on-farm trials were set up on 28 -29 March 2014 and the harvest took place on 29 – 30 July 2014.

5.1.2 Results and discussion

Susceptibility to late blight

As described above under weather section, the conditions that prevailed in LRS2014 were very conducive for outbreak and severe pressure of late blight in Lushoto. The participatory assessment made on the mother and baby trials showed that there was a strong variability between the genotypes despite contact and systemic fungicides were used. As shown on Figure 11 male and female evaluators agreed that CIP3982018.29 outperformed the rest of genotypes both in the mother and baby trials. The level of resistance of this clone was so high that you could not even see a single LB symptom on the foliage until the end of the growth period (picture 20). In general, all genotypes expressed a certain level of tolerance to LB except CIP390497.9, CIP397073.7, and Kidinya which is the local variety.

Figure 11. Gender disaggregated participatory assessment of resistance/tolerance to late blight in mother (left) and baby trials (right). Figures in Y-axis mean number of grains counted from the votes.

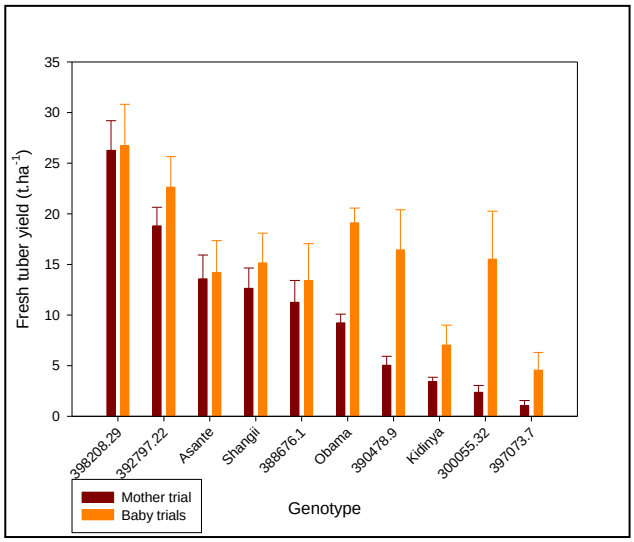


Picture 9. Outstanding field resistance of CIP clone (CIP398208.29) as expressed in one of the baby trials conducted in Boheloi during LRS2014. Photo: D. Harahagazwe/ CIP

Tuber yield

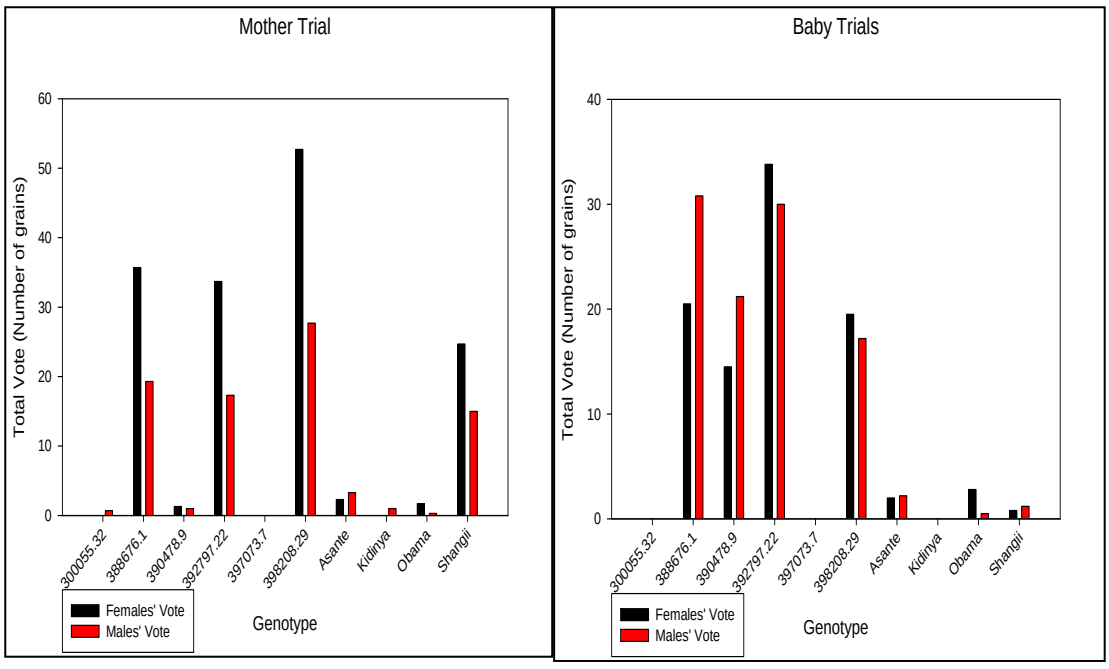
Potato genotypes tested in Lushoto during the long rainy season of 2014 showed significant differences in terms of tuber yields from both mother and baby trials ($P<0.001$). CIP398208.29 and CIP392797.22 turned to be the top best genotypes regardless of the type of trials whereas CIP397073.7 and Kidinya yielded less compared to the rest of materials (figure 11). Same figure shows that three genotypes (Obama, CIP390478.9 and CIP300055.32) expressed better yields in baby trials than in mother trial but the reasons behind this behavior change are unclear. It is worth mentioning that these yields look low when compared to the ones normally achieved in similar conditions. This is due to the formula used in calculating the yield which was based on the plot area instead of using the average production per harvested plant (CIP 2013). This approach was deliberately chosen in order to take into account any other uncontrolled factors that may influence on-farm cropping, including emergence rate, pests and diseases, etc.

Figure 12. Average fresh tuber yield of genotypes tested through mother and baby trial approach during the long rainy season of 2014



On the basis of subjective judgement through participatory ranking, three genotypes emerged to be the most preferred by both males and females in all trials. Those materials are CIP398208.29, CIP392797.22 and CIP388767.1 (figure 12). Other preferred genotypes include Shangii and CIP390478.9 in the mother and baby trials, respectively. On the other hand, the evaluators did not like the following three genotypes: CIP397073.7, CIP300055.32 and Kidinya.

Figure 12. Participatory assessment of genotypes at harvest of mother (left) and baby (right) trials conducted in Lushoto during the long rainy season of 2014

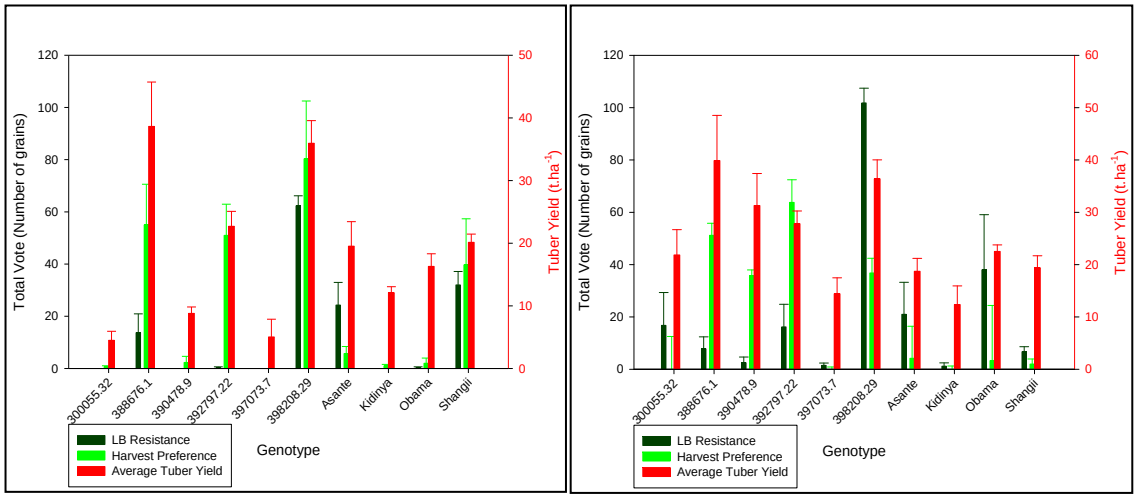


Links between susceptibility to LB and tuber yield

A combination of the participatory assessment with measured yields into one graph as shown on figure 13 outlines a possible positive relation between late blight participatory assessment, yield participatory assessment and measured yields. This trend was mainly evident on the following genotypes: CIP398208.29, CIP392797.22, CIP388767.1 and Shangii.

In conclusion, participating farmers together with extension officers and NGO's representatives made a consensus on the materials that deserved to continue the evaluation process during the subsequent growing season. Those genotypes are as follows: CIP398208.29, CIP392797.22, CIP388767.1 and Shangii. It is worth mentioning that during the whole process of evaluation from plant germination up to the harvest, evaluators realized that Obama variety was in reality Shangii from Kenya which was introduced to Tanzania during the first Presidential campaign of Barack Obama in the United States of America. Rather than having two names for the same variety, they agreed to keep its original name of Shangii.

Figure 13. Participatory assessment of resistance/tolerance to late blight and harvested tubers along with measured tuber yields of the mother (Left) and baby (Right) trials conducted in Lushoto during the LRS2014.



5.2 Second field season

On the basis of findings from the first season, a second evaluation of selected materials was conducted through the same multi-stakeholder partnership. Due to seed increase from the previous season the number of trials was increased and one more village called Maringo was included.

5.2.1 Materials and methods

During the short rainy season of 2014 twenty-five evaluation trials were conducted in three villages of Lushoto, namely Kwesine (14 trials), Maringo (5 trials) and Boheloi (6 trials). All these trials were planted on 5 – 8 November 2014 and they were harvested between February 17 and March 7, 2015. Five genotypes were evaluated in comparison to the local check as shown on Table 4. Each farmer received 50 tubers to be planted following the same protocol as during the previous season and all inputs were provided by the project.

Table 4. Genotypes used in the on-farm trials conducted in three villages during the short rainy season of 2014.

Village	Farmer's name/trial	398208.29	392797.22	388676.1	Shangii	Asante	Kidinya
Kwesine	Hamida Salimu						
	Francis Juma						
	Amiri Shemzize						
	Anthony Joseph						
	Alex Shemagembe						
	Florian Vitus						
	Perto Mweta						
	Juliana Philemon						
	Anna Joseph						
	Daniel Petro						
	Hassan Juma						
	Aloyce Joseph						
	Gervas Vitus						
	Kibuha Mdoe						
Maringo	Samwel Tendwa						
	Mussa Saidi						
	Yasentha Viaheli						
	Grace Swai						
	Zefania Charles						
Boheloi	Abdulaizi Tandiko						
	Zainabu Hussein						
	Aziza Amiri						
	Anjelina Aloyce						
	Waziri Shekomba						
	Batuli Athumani						

Due to the large number of trials spread across three non-adjacent villages, tuber yield and its components and the culinary attributes are the only variables that were collected. The culinary

tests for chips and boiled potatoes took place in Kwesine and Maringo respectively on 28 February 2015 and 7 March 2015 following the participatory assessment module proposed by CIP which collects gender-disaggregated traits preferences (picture 9). This exercise involved only farmers as the researchers and extension officers were not allowed to score or vote. Female farmers used dry beans to score and the male ones were given maize grains. For each of the three attributes scored (chips' appearance and taste of chips and boiled tubers), each farmer received nine grains and he/she would be required to put two grains into the envelope for the genotype that he/she preferred most and one grain for the second best genotype. Beans and maize grains were then counted and recorded on the score sheet.

Picture 9. Female (left) and male (right) farmers expressing their preferences for culinary attributes of potato genotypes harvested in Maringo village. Males used maize grains whereas females used dry beans to cast their vote. Photo: S. Kuoko/ SARI

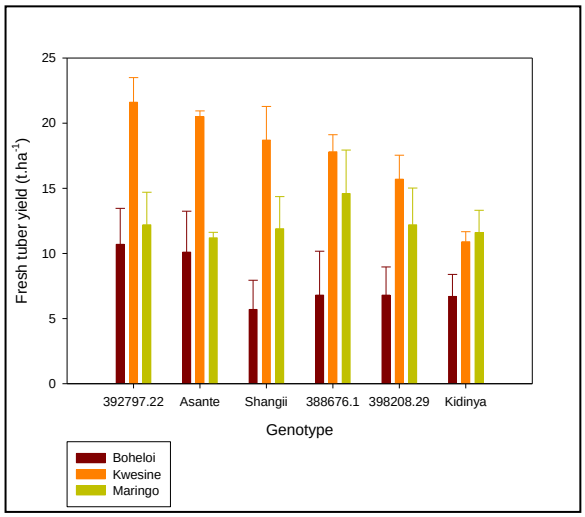
5.2.2 Results and discussion

Agronomic results

Among the three villages where trials were carried out, Kwesine seems to have been more productive than the others in terms of tuber yields (figure 14) with an average productivity of 17.6 t/ha. Average yield across genotypes tested in Maringo was 12.1 t/ha against 7.7 t/ha in

Boheloi. But what is important to notice is how genotypes reacted differently to prevailing conditions.

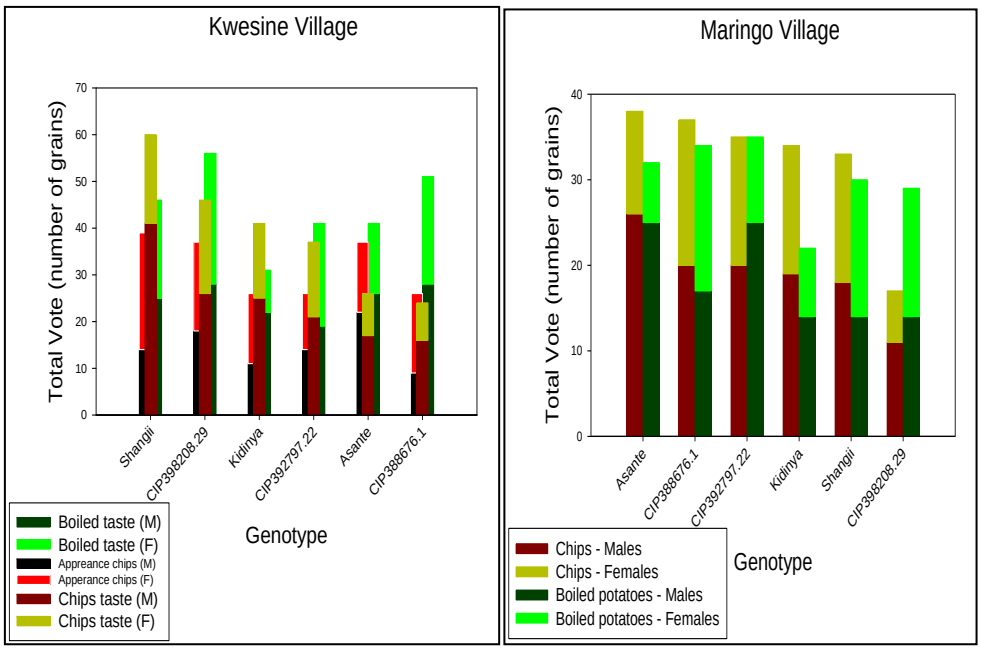
Figure 14. Fresh tuber yields from potato trials conducted in three villages of Lushoto during the short rainy season of 2014



Culinary results

All genotypes tested in Kwesine and Maringo turned to be good for consumption in the form of boiled potatoes except for the local variety Kidinya (figure 15). It was even reported to be bitter and probably toxic when you eat freshly harvested tubers. With regard to chips, Shangii appeared to be very attractive especially to females just at looking but its taste was mostly liked by males. The same figure shows that CIP398208.29 ranked second in Kwesine for the taste of its chips but became last in Maringo. The other interesting clone is CIP392797.22 which was judged to be good by evaluators for its taste (chips and boiled potatoes) in the two villages even though its chips did not attract much attention through visual observation.

Figure 15. Culinary traits' preferences expressed by male and female farmers in Kwesine (Left) and Maringo (Right) on genotypes harvested during the short rainy season of 2014.



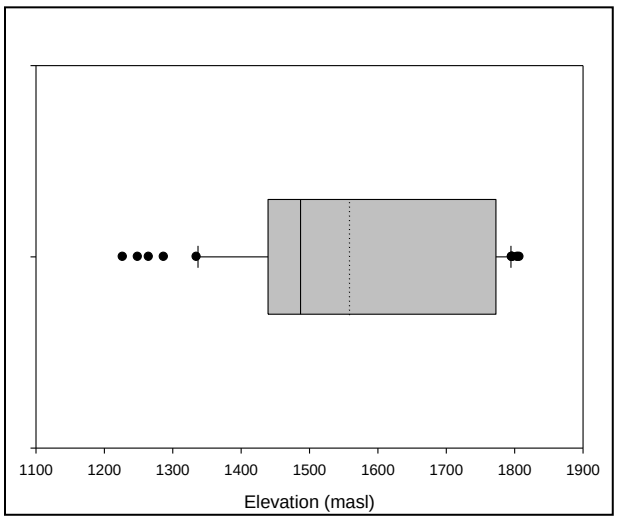
5.3 Third field season

For the third and consecutive season, the potato materials introduced from and by CIP were tested in Lushoto but with expansion to a neighboring district called Bambuli. The objective was to expose the materials to many farmers with a relatively diverse environment in a bid to collect a more consistent opinion.

5.3.1 Materials and methods

The experiment was conducted in five villages through 64 on-farm trials distributed as follows: Kwesine (23 trials), Boheloi (9 trials), Maringo (20 trials), Kwekitui (6 trials), and Milunui (6 trials). Trials were conducted in an agro-ecology that could be qualified of mid-elevation with an average altitude of 1558 masl (figure 16).

Figure 16. Boxplot summarizing the distribution of altitudes where the trials were conducted in 2015. Lines within boxes show the medians (solid line) and means (dashed line), and the boxes and whiskers represent 25th to 75th and 10 to 90th percentiles, respectively.

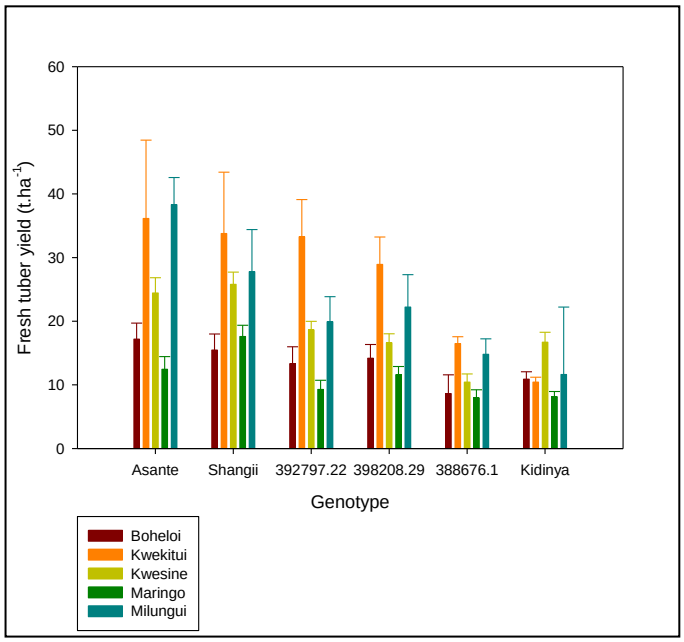


Each farmer received 50 seed tubers of each genotype. Genotypes used were three CIP advanced clones from the previous season, namely CIP388676.1, CIP392797.22 and CIP398208.29, in comparison with three varieties (Asante, Shangii and Kidinya) but all farmers did not plant the same genotypes. The trials were planted between 28 March and 4 April 2015. As usual, all farmers received free fertilizers (NPK 17:17:17) and pesticides and the same protocol for planting and crop management as previous seasons was applied. Due to the large number of trials, only tuber yield was assessed with the facilitation of local extension officers. The harvest of all trials occurred on 15 – 21 August 2015.

5.3.2 Results and discussion

Schematic representation of data collected across sites shows that four genotypes have a high yielding ability: Asante, Shangii, CIP392797.22 and CIP398208.29 (figure 17). On the other end, Kidinya showed low but stable yield across environment. With regard to villages, Kwekitui turned to be more productive than the rest of the sites especially with the same four outperforming genotypes whose average yield exceeded 33 t ha-1. The lowest yields were consistently found in Maringo.

Figure 17. Tuber yields of potato genotypes tested in five villages of Lushoto during the long rainy season of 2015

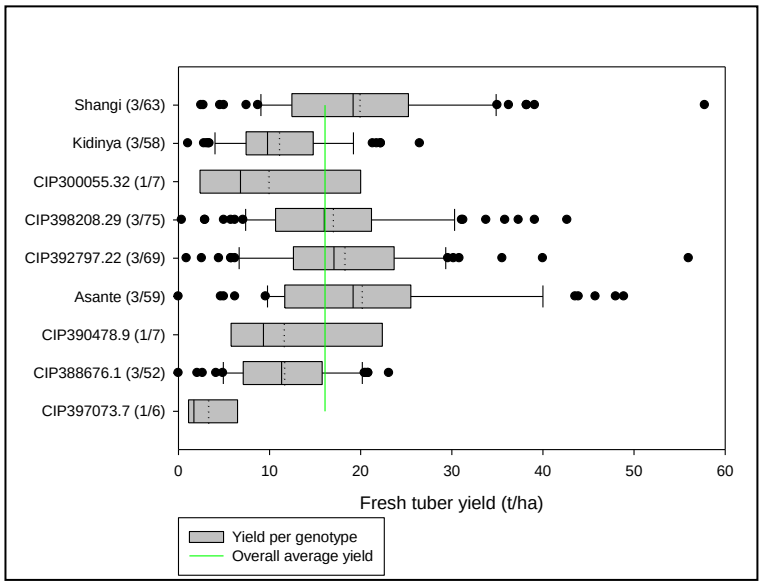


5.4 Cross-season analysis

A cross-analysis of all yield data from the three seasons of field evaluations showed a certain consistency in the high yielding ability of Asante, Shangii, CIP392797.22 and CIP398208.29 (figure 18). The same figure shows the low yielding ability of the local variety, Kidinya.

Based on these quantitative findings reinforced by farmers' preferences on various traits as described in this report, several meetings were convened in order to name the two clones, CIP392797.22 and CIP398208.29 (photo 10). The first clone is already a variety in various parts of the world. For example, it is called Unica in Peru and Qingshu 9 in China. The second clone (CIP398208.29) is completely new and has never been released elsewhere or grown for commercial use.

Figure 18. Schematic distribution of yield data from 3-season trials conducted in Lushoto. Figures in parenthesis represent number of seasons followed by the number of trials.



The two clones were named through a three-day process that took place in March 2016 through a stepwise and participatory approach. First, participating farmers met in their respective villages under the facilitation of CIP, SARI and District Office to make first proposals. Farmers were requested to choose a name that depicts well the perception they have on each clone. After having made their propositions, each village selected a representative who then participated in the final screening process through a small meeting organized at district headquarters (photo 11).

Photo 10. Photos of the two CIP potato clones respectively named Mvono (Right) and Mkanano (Left) and proposed for formal release by participating farmers. Photo: D. Harahagazwe/ CIP

Through the principle of agreement by consensus (photo 11), representatives named the two clones as follows. The clone CIP398208.29 was named MVONO, due to its high yielding ability in terms of number and size of tubers and clone CIP392797.22 was named MKANANO, meaning highly competitive due to its high yielding ability and red skin color which is mostly preferred at local markets and big cities such as Dar es Salaam and Arusha. The two names selected come from the Pare language which is largely spoken in Maringo village despite Kisamba is the dominant language in Lushoto district and surroundings.

Photo 11. Naming process of the selected best clones by farmers' representatives from 4 villages of Lushoto: consultations (left) and outcome (right). Photo: D. Harahagazwe/ CIP

6. Conclusion and recommendations

This participatory action research conducted in Lushoto in response to climatic-related challenges faced by potato farmers proved to be a successful experience that evidenced the high ability of farmers to decide on what they like when presented with several technologies. They also showed the high ability they have in learning and sharing new knowledge. The participatory approach was so intense and very demanding in terms of partnership and trust but the good will and dedication of stakeholders, including farmers, allowed us to come up with results which are likely to change the life of target beneficiaries. To this end, two promising clones were named and proposed for official release. Another popular variety introduced from Kenya was also proposed for official registration. This variety has already been picked up by development agencies that would like to take it to scale pending registration due to its known marketability value.

Even though this work has been a success, all the efforts will be vain if this is not taken to the next level which is releasing/registering the new materials and supporting farmers with clean

seed. This will only happen if funds are raised and secured to support a second phase where trained farmers would share, not only seed but also knowledge that they acquired along the last three years of implementation.

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Appendix

Annex 1: Training schedule for ToT1

Day 1: Wednesday, March 26, 2014

Time	Activity	Facilitator
08:00 – 08:15	Registration of participants	Gladness (SARI/CCAFS)
08:15 – 08:30	Self-introduction	George
08:30 – 08:45	Welcome address by the Local Authority	DED
08:45 – 09:00	Presentation of workshop objectives, expectations and logistics	Dieudonné (CIP)
09:00 – 09:30	Knowledge assessment (baseline test)	George (SARI/CCAFS)
Module 1: General Introduction and Planting Techniques		
09:30 – 10:00	Coffee break and group photo	
10:00 – 11:00	General overview on the potato crop (origin, value, morphology, phenology, yield)	Dieudonné (CIP)
11:00 – 12:00	Choosing land and soil preparation (choice of land, planting date, slope, plough, etc…)	George (SARI/CCAFS)
12:00 – 13:00	How to plant potatoes (plant density, hills)	Dieudonné (CIP)
13:00 – 14:00	Lunch	
14:00 – 15:00	How to fertilize potatoes	Maulid (YARA)
15:00- 15:30	Health break	
15:30 – 16:00	Irrigation applied to potatoes	Gladness (SARI/CCAFS)
16:00 – 17:00	Crop rotation	Mary (DADO)
17:00 – 17:30	Weeding and earthing-up	(Elizabeth (DADO)
17:30	Cocktail and End of Day 1	Elizabeth (DADO)

Day 2: Thursday, March 27, 2014

Time	Activity	Facilitator
08:30 – 09:00	Recap day 1 (in Jegerstal)	George (SARI/CCAFS)
09:00 – 12:00	Planting Mother trial in Resource Center of Jegerstal	Dieudonné (CIP)
12:00 – 14:00	Demonstration on how to put soil on the plants in a farmer's field	Dieudonné (CIP)
14:00 – 15:00	Lunch	
15:00	End of day 2 and Departure of participants	

Annex 2: Training schedule for ToT2

Second Module: Integrated pest and disease management

Day 3: Tuesday, May 6 2014

Time	Activity	Facilitator/ Responsible
08:30 – 08:45	Recap for module 1	Gladness
08:45 - 09:30	Weeding and earthing-up	Elizabeth
Module 2: Integrated Pests and Diseases Management		
09:30 – 09:45	Presentation of the module objectives, expectations and logistics	Dieudonné (CIP)
09:45 – 10:15	Coffee break	
10:15 – 11:00	Local knowledge on pests and diseases (break out groups)	Mary
11:00 – 11:30	Why is it important to control pests and diseases (disease triangle)	Dieudonne
11:30 – 12:30	Major fungal diseases (late blight, Early Blight, Fusarium)	Elizabeth
12:30 – 13:30	Major bacterial diseases (Bacterial Wilt, Soft Rot/Blackleg)	Gladness
13:30 – 14:30	Lunch	
14:30 – 15:30	Viral diseases (Potato LeafRoll Virus, mosaic symptoms)	Mary
15:30 – 16:00	Major potato pests in the region (aphids, leaf miners, red mites, Potato Tuber Moth)	Gladness
16:00 – 16:30	Smart Spraying techniques (kill crop pests and diseases while saving the environment)	Dieudonne
16:30 – 16:45	Health break	
16:45	End of day 3 and Departure of Participants	

Day 4: Wednesday, May 7, 2014

Time	Activity	Facilitator/ Responsible
08:00 – 08:30	Collective Breakfast	Gladness
08:30 – 09:00	Recap day 3 (outdoor hotel)	Mary
09:00 – 09:30	Positive and negative selection (outdoor hotel)	Dieudonne
10:00 – 13:00	Field work	
	Demonstration on how to put soil on the plants	Elizabeth
	Identification of pests and diseases	Dieudonne
13:00 – 14:00	Lunch	
14:00	End of day 4 and Departure of Participants	

Annex 3: Training schedule for ToT

Day 1: Monday, June 23, 2014

Time	Activity	Facilitator/ Responsible
08:30 – 09:45	Field reports (Lushoto, Kwesine, Boheloi and Maringo)	Mary
Module 3: Potato Value Chain and Sustainable Development		
09:45 – 10:00	Objectives and program of module 3	Dieudonne
10:00 – 10:30	Potato production costs	Elizabeth
10:30 – 11:00	Coffee Break	Gladness
11:00 – 11:30	Dehaulming techniques (removing potato foliage)	Dieudonne
11:30 – 12:00	Harvesting techniques	Gladness
12:00 – 13:00	Seed potato (degeneration, clean seed, seed storage and dormancy)	Dieudonne
13:00 – 13:30	Importance of working in associations	Gladness
13:30 – 14:30	Lunch	
14:30 – 15:30	Role of women in potato production: current status, gaps and solutions	Mary
15:30 – 16:00	Desired market linkages: input acquisition and output market	Dieudonne
16:00 – 16:15	Health Break	Gladness
16:15 – 16:45	Formal Evaluation	George
17:00	End of day	

Tuesday, June 24, 2014: Field Day in Resource Center

Time	Activity	Facilitator/ Responsible
08:30 – 09:00	Breakfast	Gladness
09:00 – 09:30	Travel to the field	CIP driver
09:30 – 10:00	Introductory remarks	Mary
10:00 – 10:30	Presentation of the experiment and day program	George
10:30 – 11:00	Presentation of the evaluation process	Dieudonne
11:00 – 12:00	Gathering and ranking selection criteria	Dieudonne
12:00 – 14:00	Evaluation of genotypes	Dieudonne
14:00 – 14:30	Wrap-up discussions on the Field Day	George
14:30 – 15:30	Lunch and closing ceremony	Elizabeth
15:30	Departure of participants	

Wednesday, June 25, 2014: Field Day in Kwesine

Time	Activity	Facilitator/ Responsible
08:00 – 09:15	Travel to the field	CIP driver
09:15 – 09:45	Introductory remarks	Ward official
09:45 – 10:15	Presentation of the experiment and day program	Ward extension Officer
10:15 – 10:30	Health Breath	Gladness
10:30 – 11:00	Presentation of the evaluation process	George
11:00 – 12:00	Gathering and ranking selection criteria	Mary
12:00 – 14:00	Evaluation of genotypes	Dieudonne
14:00 – 14:30	Wrap-up discussions on the Field Day	George
14:30 – 15:30	Lunch	Elizabeth
15:30	Departure of participants	

Thursday, June 26, 2014: Field Day in Boheloi

Time	Activity	Facilitator/ Responsible
08:00 – 09:15	Travel to the field	CIP driver
09:15 – 09:45	Introductory remarks	Ward official
09:45 – 10:15	Presentation of the experiment and day program	Ward extension Officer
10:15 – 10:30	Health Breath	Gladness
10:30 – 11:00	Presentation of the evaluation process	George
11:00 – 12:00	Gathering and ranking selection criteria	Elizabeth
12:00 – 14:00	Evaluation of genotypes	Gladness
14:00 – 14:30	Wrap-up discussions on the Field Day	George
14:30 – 15:30	Lunch	Elizabeth
15:30	Departure of participants	

Annex 4: Training schedule for ToT4

Day 1: Wednesday, October 29, 2014

Time	Activity	Facilitator
08:15 – 08:30	Registration of participants	Gladness
08:30 – 08:45	Introduction of Dr. Stephen Kuoko	George
08:45 – 09:00	Presentation of workshop objectives, expectations and logistics	Dieudonné
09:00 – 09:30	Synthesis of ToT1 to 3 and updates from the villages	George
Module 4: Bacterial Wilt and Pesticide Management		
09:30 – 10:00	Coffee break and group photo	
10:00 – 11:00	Bacterial Wilt, Enemy number one of seed maintenance	Dieudonné
11:00 – 12:00	Pesticides Part I: accessibility, utilization and quality control	Stephen
12:00 – 13:00	Pesticides II: Impact on the environment	Rimoy
13:00 – 14:00	Lunch	
14:00 – 15:00	Refresher course on planting techniques	Rimoy
15:00- 15:30	Health break	Elizabeth
15:30 – 16:30	Planning meeting for short rain season	Dieudonne
16:30	End of the day	

Day 2: Thursday, October 30, 2014

Time	Activity	Facilitator/ Responsible
08:30 – 12:00	Detailed planning meeting for trials in Kwesine (design, inputs, follow-up, etc.…)	All team
12:00 – 12:30	Lunch for facilitators	
12:30 – 16:00	Detailed planning meeting for trials in Boheloi (design, inputs, follow-up, etc.…)	All team
16:00	End of the day	

Annex 5: Schedule for ToT5

Tuesday, February 10, 2015

Time	Activity	Facilitator	Moderator
09:00 – 09:15	Introductory remark by the DAICO		George
09:15 – 09:30	Self-introduction and Presentation of workshop objectives, expectations and logistics	George	
09:30 – 10:30	Brief synthesis of participatory action conducted in long rain season of 2014	Dieudonné	
10:30 – 11:00	Brief synthesis of on-going field work in 3 villages	Stephen	
11:00 – 11:40	Group photo and Coffee Break	Rimoy	
11:40 – 12:00	Current status of seed and other agricultural inputs (lime, manure/compost, fertilizers, etc…): availability and accessibility in Lushoto	Seed Officer at DAICO, Lushoto	Stephen

12:00 – 12:20	Current status in collecting, packaging and selling ware potato from Lushoto	A representative of ware potato traders	
12:20 – 12:40	Current status and challenges in packaging, collecting, transporting and selling ware potato from Lushoto	A representative of ware potato transporters	
12:40 – 13:00	Current status and challenges in potato processing and marketing in Boheloi	A representative of farmers' processing unit in Boheloi	
13:00 – 14:00	Lunch	Rimoy	
14:00 – 15:00	Breakout group discussion on current status, challenges and recommendations (2 separate groups on input and output markets)	George	
15:00 – 16:00	Plenary on Input and Output markets	Stephen	Stephen
16:00 – 16:30	Planning for the next long rainy season (plan of work, budget and fundraising)	Dieudonne	Dieudonne
16:30- 16:45	Closing Remark by the DAICO		Rimoy
16:45	Tea and End of the day		

Annex 6. Attendance list for the main training campaign conducted in Lushoto-Tanzania.

Village	No.	Full name	Gender	Occupation
Boheloi	1	Angelina Aloyce	F	Farmer
	2	Zainabu Housein	F	Farmer
	3	Waziri Shekomba	M	Farmer
	4	Batuli Athumani	F	Farmer
	5	Abdulazizi Tandiko	M	Farmer
	6	Aziza Amiri	F	Farmer
	7	John S. Sempeho	M	Extensionist
Kwesine	1	Amiri H. Shemzize	M	Extensionist
	2	Froliani Vitus	M	Farmer
	3	Francis Juma	M	Farmer
	4	Hmida Salimu	F	Farmer
	5	Juliana Filemon	F	Farmer
	6	Anna Joseph	F	Farmer
	7	Elisafi Mmbaga	M	Farmer
Maringo	1	Graceana A. Swai	F	Extensionist
	2	Samwel Tendwa	M	Farmer
	3	Zefania C. Magiri	M	Farmer
	4	Saidi Musa	M	Farmer
	5	Yasenta Vihael	F	Farmer

Annex 7. Attendance list for spillover training conducted in Kwesine in 2015.

Village	Number	Full name	Gender
Kwekitui	1	Stephen Simon Shembilu	M
	2	Simon Salim Chahoa	M
	3	Khalfani Kiuzio	M
	4	Iddi Mohammed Kiuzio	M
	5	Mohamed Amir Mput	M
	6	Tupa Kiuzio Tupa	M
	7	Fatuma Amini Shekut	F
	8	Sharifa Mohammed	F
	9	Estrida Joshua	F
	10	Zubeda Athumani Bushiri	F
Milungui	1	Peter Nyaki	M
	2	Issa Kaniki	M
	3	Karim Mohammed	M

	4	Adamu Saidi	M
	5	Jackson Hassan	M
	6	Catherine Mussa	F
	7	Salome William	F
	8	Christina Richard	F
	9	Odilia Hassa	F

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