- **Project Title: Improving potato production for increased food security of indigenous communities in Colombia**

- **IDRC Project Number: 106926**

- **Research Organizations involved in the study**:

- Universidad Nacional de Colombia
- McGill University
- University of New Brunswick
- International Potato Center
- Fundelsurco

- **Location of Study**:
  Bogotá - Colombia
  Nariño - Colombia
  Montreal - Canada

- ***Research locations also include***:
- Fredericton – Canada
- Lima - Peru

- **By**: *Full name of author(s): name(s), organization(s)*
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Project research outputs

1. Executive Summary

Nariño rural communities are characterized by their food insecurity and potato is a staple food, highly consumed in Nariño province, so even a small change in nutritional quality of potato may have a significant impact on FSN. The general objective of this project was to improve global food security in indigenous communities by selecting potato cultivars with high yield and nutritional qualities to improve their daily diet, to empower women as axes of the family, to adopt new nutritional habits and to develop participative research on Good Agricultural and Postharvest Practices. Main results include:

- Three new potato cultivars were selected in participatory research. These cultivars were registered at the *Instituto Colombiano Agropecuario* (ICA). Smallholder's participation in trials for potato selection has been a powerful tool to promote social and technical changes. To be successfully adopted new cultivars should be perceived by producers as a new opportunity to improve their income: new cultivars presented higher resistance to late blight so they have lower production costs and higher yield, shapes and colors appreciated for consumers. Smallholders were satisfied with these cultivars because they get 18% higher revenue than prevailing commercial varieties, more resistance to late blight and good tuber shape according to market requirements. The nutritional evaluation showed that these cultivars have 24% iron and 16% zinc contents than the prevailing commercial cultivars. Certified seeds of new cultivars were released to 650 potato producers for cropping.
- Potato breeding in Colombia had never considered nutritional quality criteria for selecting new cultivars. This project built technological basis to do it: research in potato genetics, recovering genetic biodiversity, measuring the variability on nutritional quality of potato tubers, introducing new genotypes selected for their high iron content from International Potato Center (CIP).
- Production techniques considered Good Agricultural Practices (GAP) and environmental protection as a result of education on GAP. Participants recognized the importance of working in partnership groups. The use of certified seed increased from 0 % to 19 %; 32% of participants resumed the practice of intercropping between production areas of potato – corn, potato - vegetables or potato- grass. Participants now regularly review their crops before agrochemical applications. All farmers today identify natural enemies and recognize the importance of biological control of pests and diseases in crops.
- Colombian Food Security and Nutrition (FSN) policies do not consider that women and men perform different roles. Basic research- action on family roles with focus in women and ethnical differentiation was carried out to support policies. We identified the roles regarding FSN of women and their partners, both in the family and in the community. We found that the men decide about food shopping, so nutritional education should involve not just females. Rural women must perform the traditional roles of the care and protection of their families and, therefore, their work and working hours are significantly increased, but this is not a complaint, as these works, provide them other personal satisfactions. The new gender roles in rural family life, in principle, imply for men to assume, housework, such as preparing food or caring for infants or the elderly. Focus groups dealt with social issues and found that domestic violence has direct effects on FSN. When women are abused or ignored, they cook with reluctance, do not put "color" to the preparations, or do not combine the dishes in the same way they do when they have a good relationship. With the

project, the women managed to become relevant in the spaces for discussion and analysis. Their presence and participation achieved a qualitative leap.

- To have a sustainable impact we worked together with local and regional authorities as well as indigenous autonomous authorities in nutritional and agricultural components.
- We developed three activities for recovering of ancestral knowledge to strengthen communities´ self-identity:
    - On ancestral gastronomic knowledge to support food security and nutritional programs. Recipes were documented and their nutritional value was calculated.
    - Life history of three generations (grandmother, mother and daughter), were documented to understand trends in social changes related to family and FSN.
    - On native potato varieties to protect biodiversity. 118 native varieties were collected, characterized and given back to communities and to National Potato Germplasm Bank.
- Scientific analysis to design public policies on FSN was carried out in 847 homes. We found that food insecurity is 90.8% in the population under study. For anthropometry component, were assessed a total of 1,511 people. Children between 5 to 12 years and adults, show malnutrition related with intake of fundamental nutrients. Iron: 29%, zinc: 91.1%, calcium: 82.7%, vitamin A: 70.4% and vitamin C: 20.8%.
- We documented life stories regarding women, family and work with a video, and we delivered a manual on good nutritional practices to support educational programs and enhance community's self-identity.
- A clinical experiment was carried out to determine the incidence of new potato cultivars with higher content of iron and zinc in the nutritional status of children under five. Results showed 10.6% less iron deficiency in children that consumed improved potatoes compared to those that consumed other varieties. This is reflected on children with adequate size and decreased percentage of children with stunting.
- Several micronutrients, macronutrients, functional foods and vitamins have been identified in breeding clones. Potato nutritional analysis showed a wide diversity for nutritional compounds. This knowledge is fundamental for starting a biofortification-breeding program. Nutrients: A comprehensive analysis of micronutrients, sugars, starches, proteins and functional foods (phenols) present in Colombian potatoes was carried out. Nutritional analysis showed a wide diversity for nutritional compounds.
- Process of transformation and bioassimilation of potato extracts were evaluated in a gut simulated. We found that chlorogenic acid is transformed and assimilated and it got the colon and had effect on control over the growth of tumor cells.
- Ten novel genes associated with the most devastating disease of potato, late blight, were identified and for one set of them, their resistance function proved. Their resistance function have been proved to be due to hydroxycinnamic acid amides and others that enhance cell wall thickness.
- We have taken advantage from the integration among natural and social researchers around a complex problem and from the good collaboration among Canadians and Colombians researchers.
- We have qualified Colombian and Canadian young scientists. The research team has learned to work on solving community problems in a trans disciplinary approach and in a

collaborative synergy with Canadian researchers. Additionally, we profited from the CIFSRF official's experience in project development.

2. The research problem:

The basic rationale of the project considered that FSN is a complex concept that requires different strategies to deal with. The project intended to impact Nariño rural native communities on food quality, nutrition, family income, family roles and gender, environmental sustainability and public policies regarding FSN and their implementation.

- Nariño rural communities were characterized by their food insecurity. In five municipalities selected for this project, the Index of Unsatisfied Needs reported ranged from 46.1% to 70.9% (DANE, 2005). We currently know that average food insecurity was 90% for the five municipalities under study (November 2012) and that rural population is more vulnerable than urban.
- Potato is a staple food, highly consumed in Nariño province,
- Potato breeding in Colombia had never considered nutritional quality criteria for selecting new cultivars.
- Small farmers in Nariño considered necessary to have available potato cultivars with higher yield and resistance to late blight in order to increase the family income. Potato production presented poor agronomic practices, including applications of fungicides to manage late blight.
- Colombian FSN public policies did not consider that women and men perform different roles.
- Nariño rural women lacked of skills or were limited by their families, to participate actively in community processes.

3. Progress towards milestones

The Project involved from the beginning the civil and indigenous authorities in each municipality and offered the pertinent information about the objectives and methodologies of the project and we came to agreements. We managed to approach appropriately to the community: to conform the groups for School Field for Farmers (ECA); to establish the breeding trials, to establish groups interested in engaging in a dialog about the roles of the family members in relation to nutrition and feeding and to execute in the surveys to characterize the daily diet and nutritional status of native families. On the other hand: green house and lab protocols for nutritional quality, metabolomics and genomics were established as well as ethical protocols. Through this process, the Project generated robust information for policy makers, trained undergraduate, master and Ph.D. students

and implemented technologies and methodologies that contributed to build scientific capabilities in Colombia and Canada advanced also in scientific knowledge in relation with transformation and bioaccessibility of functional food and in the understanding of late blight resistance in potato. The generated information in each research component of the project was being shared within the team in a transdisciplinary approach. This strategy allowed keeping the comprehensiveness of the project to get the general objective.

We got the following outcomes:

- We selected in participatory trials, three new best cultivars based on production, nutritional and postharvest processing qualities. Selected potatoes from CIP's biofortification program were multiplied in Colombia and incorporated to breeding program.
- We identified nutritional quality of 147 potato landraces: concentration of micronutrients (Iron, zinc, manganese, cupper, calcium, magnesium, sodium, potassium, phosphorous, sulphur), macronutrients (Ash, soluble fiber, insoluble fiber, protein), functional food compounds (Chlorogenic acid, neo-chlorogenic acid, crypto-chlorogenic acid, caffeic acid), sugars (sucrose, glucose and fructose) and vitamin C.
- We employed advanced methodologies such as next generation sequencing, association mapping to apply to genomics, and metabolomics to identify genes for controlling resistance to late blight. We identified five genes that are involved in the quantitative resistance to late blight and we could demonstrate that resistance is associated with thickness of cell wall.
- We did the first study to examine the possible anti-cancer benefits following digestion of a polyphenol-rich potato (new potato cultivar, *Criolla Sua Pa*) meal using a human simulated gut model. We showed that a meal of the polyphenol-rich cv. *Criolla Sua Pa* generated polyphenolic antioxidant metabolites in all colon regions of the human gut model. Human colon cancer cells showed markedly greater inhibition in their proliferation as compared to normal cells when exposed to digests of the cv. *Criolla Sua Pa* meal obtained from the gut model. These data indicate that intake of cv. *Criolla Sua Pa* could have the potential for protective effects against the development of colonic cancer.
- We assessed the impact of improved potato in the nutritional status of children under five and changes of iron in blood. Results showed changes in the children population under study, with an increase in the percentage of children with adequate size and decreased percentage of children with stunting (Annex 4).
- In the research proposal we pretended that women would assume a greater role in Food Security at the household and community level and liaise with government agencies dealing with FSN. We found more important for the family to perceive and value the women roles in FSN. We found that patriarchal cultural patterns have persisted over several centuries, so the barriers to change are deep and are rooted from the very conception of *woman, family, heads of household, family and gender roles*. Nariño rural women, whom we work with, lacked of skills or were limited by their families, to participate actively in community processes. We identified the roles regarding FSN of women and their partners, both in the

family and in the community; their family types; their approaches to dealing with social issues and family especially domestic violence looking for democratization of social and gender relations. With the project, the women managed to become relevant in the spaces for discussion and analysis. Their presence and participation achieved a qualitative leap (Annex 5). The methodology of ECA was enriched with the spaces of dialogue about gender roles.

- We implemented a scaling strategy to involve institutions. This strategy started from the beginning of the project. We did a census of organizations related with FSN and we got in touch with them. We presented the project objectives and methodologies and got agreements with them. We informed authorities about advances through the entire project.
- To scale up results we held meetings with authorities and institutions and we involved them in the project and some of them such as, ICBF and Corpoica and municipal mayors participated actively in some activities of the Project (See details in objective 7 and Annex 2).

In developing communication strategy we organized meetings, developed videos and submitted papers to scientific journals:

Meetings to release results:

- In Bogotá (International workshop on food security through potato production and human nutrition, supported with complementary funds from *Fondo Nacional Hortofrutícola*), to present and analyse project results regarding: food security and nutrition; gender, family and nutrition; contributions of potato breeding to food security and nutrition; and new technologies in potato post harvest, at national level. Policy makers, academics from Bolivia, Brazil, Canada, Colombia, Ecuador, Guatemala, Peru and United States, peasant leaders, producer leaders, and students attended the workshop in June 24th and 25th 2013. More than three hundred people attended.
- In Pasto (Regional workshop, jointly organized by the Government of Nariño and the National University) to present and analyse project results, at regional and local level. Policy makers, academics from different universities, ECA's leaders, indigenous leaders, peasant leaders, producer leaders, and students attended the workshop. More than hundred people attended.
- We presented the new cultivars for registration in a seminar to Colombian Agrarian Institute, July 30 /2014 (Annex 6) and delivered elite and certified seeds for farmers, who are organized in groups to multiply and distribute these seeds (Annex 2).
- In Guachucal, vereda San Ramon, we organized the *Festival del Campo*. 554 participants were gathered in the festival (Annex1). *Festival del Campo* was the closure of activities with the communities to: i) release the three new potato cultivars (*Criolla Ocarina, Criolla Sua Pa* and *Criolla Dorada*), for Andean Nariño region (Annex 2), ii) provide elite seeds of the new potato cultivars to 21 farmers groups committed to multiply the seeds, iii) give back to the communities the native potato collection with added value, iv) release the booklet entitled *Sabores y saberes de las comunidades andinas nariñenses* and v) communities presented their achievements as a result of the project in each locality and each project component.

In developing the communication strategy:
We built a web page http://www.seguridadalimentarianarino.unal.edu.co/:
We elaborated two videos http://www.seguridadalimentarianarino.unal.edu.co/:

- *Caminos amorables* ("Lovely paths"), video about gender results.
- *Mejores papas para la seguridad alimentaria en Colombia*, video about the impact of the project and results released in the *Festival del Campo*.

We submitted 10 scientific papers to Journals (Annex 34).
We presented oral reports in seven international conferences (Annex 34)

We got agreements to scale up results:

- We gave certified seeds to Corpoica, the national agency in charge of rural development, for the National Seed Program to contribute with this program and to scale the seed production of new potato cultivars.
- With Universidad del Cauca, professors Consuelo Montes and Alfredo Londoño, to scale up results in Cauca department. Currently we are applying for local funds in Cauca province.
- We held a meeting on 4thAugust/2014 with Cauca´s governor to present the initiative derived from the Nariño's experience in order to scale up the results project in Cauca.
- With ICBF Nariño branch to improve the regional differential *minuta* for school restaurants, since current food list was built with an urban bias.
- With the Nariño Governor´s office to scale up the seed multiplication to other municipalities and potato growers groups. We gave out seed to eleven groups selected by Governor´s office (Annex 2).

Different activities to scale up results:

- We presented our research results in scientific meetings and publications, in Colombia and in other countries (Annex 7).
- The team Project (Canadians-Colombians) wrote the proposal *Sustainability of indigenous communities in Colombia through healthy nutrition and education* linked to improved agriculture to scale up results obtaining in this Project. We will present this proposal to different funding agencies.
- The academic program *Seguridad Alimentaria y Nutrición* at the magister level was created for the first time in Colombia. It will start on January 2015. This program received the academic support from our Project. Prof. Sara Del Castillo is the leader of this academic proposal (Annex 8).
- We got agreement with Guachucal Major to present a project for scaling up results to *Conpes Nariño* call for funds.

4. Synthesis of research results:

Objective 1: ***Characterize the daily diet of indigenous communities and develop a manual on Good Diet Practices***.

Activity 1: An in-depth study was conducted on dietary intake and household consumption pattern using a Dietary Recall 24 hour method. This study allowed the scientific publication entitled: Nutritional Situation of Rural Communities in Nariño, Colombia 2013 (Annex 9).

A significant stunting was reported in children up to 7 years. In children aged 0-5 years group and children aged 5-17 years group, the results exceeded by more than double the department data (according to National Survey of the Nutritional Situation in Colombia ENSIN 2010), and almost three times the national data. The underweight was generally low in all the analyzed groups, although concerned the significant overweight percentage. In children aged 0-5 years group, the overweight data (above 2 standard deviation) exceeded twice the department and national data according to the ENSIN 2010, although in the children aged 5-17 years group, the overweight and obesity was lower than the departmental and national data. In adults, the results reported that one of each two people in the range of 18 to 64 years in the five municipalities had excess weight (overweight or obesity) which was similar data respected to the department and national data. Additionally, it was noted that 18% of households were found among adults with overweight, and simultaneously, children with stunting, this situation is called double burden.

The study of the pattern of consumption of the households in the five municipalities, by applying the R24 (24-hour recall), revealed that potato is a caloric basis of this population in all age groups, reaching over 20% in the adult population (Annex 10).

Activity 2: Training: Formative modules completed and implemented.
A Manual of Good Diet Practices (GDP) was developed taking into account the research results obtained in the study of consumption pattern. This manual is important to impact on public policies implemented by ICBF and on women's leadership. The manual on GDP, *De la huerta a la mesa* is being used by ICBF as an educational tool on FSN with community mothers. *Community mothers* is a national program; in Nariño 500 community mothers were trained with this manual.

Activity 3. Traditional gastronomic culinary practices of community and improvement of basic diet. Focus groups and workshops were held to recover gastronomic memory. The booklet *Sabores y saberes de las comunidades andinas nariñenses, identidad gastronómica ancestral de cinco municipios de la zona andina del departamento de Nariño, Colombia*, included representative recipes and knowledge regarding culinary traditions (Annex 11). This manual was used by ICBF as an educational tool on FSN for diversifying the diet, with community mothers.

Activity 4. Provide a workshop to define strategies for food security and nutrition, with women leaders, government agencies and the research team. Throughout the Project we implemented focus groups and encounter spaces with women to train them about good practices for nutrition and to talk with ICBF officers. This training reached 500 community mothers. Throughout the Project community mothers and, we had a very close relationship with ICBF officers. ICBF appropriated methodologies and results.

Activity 5. Clinical experiment for assessing nutritional impact: McGill University and National University, in collaboration with ICBF Nariño branch, developed a clinical experiment in

order to determine potential impacts of the introduction of cultivars with higher content of iron and zinc in children´s diets, as an important input for nutritional policies. The experiment consisted of a randomized trial to determine the serum levels of iron and zinc before and after consumption of improved potato cultivars in a controlled experiment. This experiment assessed the impact of yellow potato consumption in children between 12 and 59 months old. Results showed positive changes in children population under study, with an increase in 10.6% of children with adequate size in children that consumed the improved potatoes compared to those that consumed other varieties (Annex 4). Size parameter is a robust parameter to measure nutritional status; therefore we can affirm the new potato cultivar evaluated has a positive direct impact on nutritional status in children under five and the new potato cultivars have the potential to improve both the daily nutrition of communities and their long-term health. These results will guide ICBF decisions regarding food menus of targeted social programs to children and food and nutrition education.

Objective 2: ***Select potato cultivars with high yield, late blight resistance, processing quality and community acceptance, for immediate release through indigenous community participatory research***.

Potato elite seeds from three new cultivars with superior agronomical traits were delivered to smallholders in July 31/2014. Smallholders have cultivated them and consider these new cultivars as their own (Annex 2, Annex 3). Small farmers working in participatory research have appropriated these new cultivars. Male and female peasants closely followed the trials and they showed interest in new cultivars and they recognized better agronomic traits such as yield, resistance to biotic and abiotic stresses, color and shapes, and also culinary traits.
Three potato genotypes were presented for registration as new cultivars at ICA. they were sown in eight different environments trials and during two cycles. We presented a scientific report and a scientific seminar to ICA. This report contains all the required information by Colombian Agrarian Institute (ICA) to register new cultivars (Annex 3, Rodríguez, L. E. *Informe de resultados prueba de evaluación agronómica (PEA) de genotipos de papa criolla S. tuberosum grupo Phureja para la región natural andina, subregion Nudo de los Pastos. Universidad Nacional de Colombia, Julio de 2014*).

A catalog on regional potato varieties collected was published. This catalog presents each of 118 potato varieties through photographic records of plants and tubers, passport data and information regarding morphology, postharvest and culinary uses (Annex 25).

Objective 3. ***To select potato genotypes based on concentration of minerals, nutrients and functional food compounds***

We evaluated the nutritional contents (Fat, protein, ash, dietary fiber, and mineral) of 147 potato landraces, 12 advanced clones and two commercial cultivars (Criolla Colombia and Criolla Galeras). This evaluation was carried out on boiled tubers. We took the decision to do the analysis of nutritional contents on boiled tubers because this is the most common way that people consume potatoes. In some cases we evaluated also the nutritional contents on raw tubers in order to compare and to know the influence of boiling on the nutrients. The mineral content (K, Fe, Mn, Zn, Ca, P, S

and Mg) of potato tubers was determined by inductively coupled plasma optical emission spectroscopy (ICP-OES) (Annex 13b).

Nutrients were quantified per 100 g dry weight (DW) of potato. Nutritional contents in the advanced clones were in general higher than in the commercial cultivars. The advanced clone-04 had the highest levels of protein (9.7 g) and magnesium (107.0 mg) as compared to Criolla Colombia (4.0 g of protein and 99.5 mg of magnesium) and Criolla Galeras (3.1 g of protein and 95.0 mg of magnesium).

The highest contents of fat (0.7 g), soluble dietary fiber (4.9 g) and manganese (0.8 mg) were found in advanced clone-09, values that represented 3.9, 1.7, and 1.2 fold increase as compared to Criolla Colombia, respectively, and 3.9, 1.8, and 1.1 fold increase as compared to Criolla Galeras. The advance clone-51 had the highest content of insoluble dietary fiber (13.8 g). Among all genotypes the advanced clone-52 had the highest contents of iron (1.3 fold increase), zinc (1.2 fold increase), and calcium (1.3 fold increase) as compared to Criolla Colombia (Annexes 13a, 13b).

A manuscript containing information about the chromatographic method, developed and validated for sugar content analysis, was accepted to publish by Journal of Chromatography B (Annexes 13c, 14). This method assured the robustness of the quantifications carried out. We quantified sugars in boiled advanced clones and all genotypes in raw form, because this is an important trait for frying processing industry. This analysis was useful to select the new potato cultivars (Annex 13c).

14 advanced clones, 3 commercial cultivars and 50 genotypes from Colombian Central Collection of *S. tuberosum* group Phureja, were evaluated for their vitamin C content by liquid chromatography reverse phase high efficiency (RP-HPLC) with detection at 254 nm. Since potatoes in Colombia are mainly consumed boiled, vitamin C analysis was performed on whole potatoes boiled to consider the effect of this vitamin degradation suffered during boiling processes. The content of vitamin C on new advanced clones ranged from 7.0 ± 0.3 mg / 100 g wet base (BH) to 33.1 ± 0.2 mg / 100 g BH. The content of vitamin C in these advanced clones was three times higher than in Criolla Colombia (commercial variety) (11.5 ± 2.0 mg / 100 g BH) (Annex 13, table 3). Advanced clones have greater potential to contribute to a better bioavailability of iron and zinc considering their higher content of vitamin C than vitamin C provided by the commercial variety Criolla Colombia. When the analysis was done at the Colombian Core Collection, genotypes were found containing between 63.3 ± 4.9 mg / 100 g BH, which constitutes an important trait when considering these genetic materials in breeding programs (Annex 13d).

The consolidated results from the nutritional analysis are shown in Annex 13e.

Functional foods: Boiled potato tubers of eight genotypes belonged to advanced clones (AC) were analyzed for functional foods. 302 metabolites with functional food properties such as anticancer, anti-HIV, anti-malarial, anti-hypertension, anti-inflammatory, antimicrobial, anti-diabetic were identified. One manuscript has been submitted for publication (Annex 12a, 12b). Another study of eight AC genotypes, including three new cultivars released (*Criolla Dorada, Criolla Ocarina and*

Criolla Sua Pa) also identified several functional foods. A draft manuscript is presented (Annex 15b).

Bioavailability of foods in potato variety Criolla Sua Pa (advanced clone No. 59)

In addition, a meal-sized portion of the new potato variety Criolla Sua Pa was tested in an artificial gut (which mimics the human digestive system). The potato was found to release significant quantities of disease-ameliorating metabolites, capable of being absorbed into the blood. These active metabolites showed anti-proliferative effects in Caco-2 tumor colonic cells to a much greater extent than the normal colonic cells, which indicates that regular consumption of this cultivar could be protective against colon cancer, which is occurring in an increasing incidence in Colombia.

Objective 4: ***To identify potato clones with broad genetic resistance based on metabolomics and molecular technologies***

Field evaluations for resistance to late blight: trials to evaluate the resistance in Colombian germplasm to late blight were successfully carried out in two locations in Colombia. We evaluated Colombian Core Collection for *S. phureja*, advanced clones and native potatoes from Nariño. We found two extremely resistant genotypes to late blight. They are being used as parentals in potato breeding program in Colombia.

Metabolo-genomics: We have identified and cloned three quantitative resistance genes with known functions, for the first time in potato in the world. Two papers have been published (Annex 15a, 15b), and two more, on stem analysis and gene silencing, were submitted for publishing. These genes biosynthesize complex metabolites that are deposited on cell walls around the invaded pathogen and they prevent its further spread in the plant.

The research facilities and inoculation methodologies needed to undertake the disease resistance analyses in Colombia with Colombian germplasm were successfully constructed and adapted. From Colombian collections, we have profiled three genotypes and identified resistance genes, especially the genes that biosynthesize alkaloids that have antimicrobial effect, for the first time in diploid potato with gene functions known (Annex 15c). Another four sets, each with 2 resistant and one susceptible diploid potato genotypes have been profiled for metabolomics. A postdoc from UNC was trained on metabolomics. We separately analyzed leaf and stem samples, as opposed to only leaves as stated originally in the project. The articles published were:

a. Yogendra KN, Pushpa D, Mosa K, Kushalappa AC, Murphy A and Mosquera T. 2014. Quantitative resistance in potato leaves to late blight associated with induced hydroxycinnamic acid amides. Functional and Integrative Genomics. 14:285–298.
b. Pushpa D, Yogendra K, Gunnaiah R, Kushalappa AC and Murphy A. 2014. Identification of late blight resistance related metabolites and genes in potato through non-targeted metabolomics. Plant Molecular Biology Reporter. 32:584-595.
c. Yogendra KN, Kushalappa AC, Sarmiento F, Rodriguez E, Mosquera T. 2014. Metabolo-genomics to Decipher Quantitative Resistance in Diploid Potato Clones Against Late Blight. Functional Plant Biology (Accepted with minor revision).

Genomics: In total we identified five allelic variants associated with resistance to late blight to be used in breeding programs to select resistant progenitors and progenies previous their validation.

Candidate approach allowed us to identify two genes associated to resistance to late blight in *Solanum tuberosum* group Phureja. First gene is the called *TMV response protein 1* located in chromosome III containing three variations and second gene called *Thylakoid lumenal 15 kDa protein 1* located in chromosome VI containing two variations. The variations mean small changes on the gen and these changes are responsible of the resistance to the pathogen. These variations explain between 10-15% of the resistance to late blight. This value is considered the major effect.
This study is the first study done in Colombia that applied association mapping or association analysis to associate molecular data with phenotypical data. As well as this is the first study according to the knowledge of author to be implemented in *S. phureja*, this is an important result to contribute to build scientific capabilities for Colombia. This study involved a PhD student who presented her thesis at international evaluating committee a manuscript of this research is annexed (Annex 16). This thesis was considered meritorious.

DNA samples from the 190 clones were sent to Canada (University of New Brunswick) to generate data of genome sequencing (2b-RAD and GBS technologies) and to have a whole genome analysis. Approximately, 9,000 and 41,000 SNPs were identified using the 2b-RAD and GBS platforms, respectively. The SNP data were used for association analysis for resistance to late blight. Using GBS, we identified nine genes associated with quantitative resistance to late blight; four of them control the resistance in more than 4%. With 2b-RAD technology we identified two genes with unknown function. These results allow us to understand better the complexity of resistance to late blight in potato. These results contribute to the international scientific community to understand the nature of resistance to pathogen causes late blight. These results are important because from them molecular markers could be designed and implemented in potato breeding programs to select parents and progenies. Agriculture is advancing to apply this knowledge and scientist and breeders are committed to move the laboratory results to the field, in this sense Colombia and Canada have advance in that direction. This research contributed to build scientific capabilities for Canada and Colombia. A PhD student from Colombia was trained in these methodologies in Canada. Articles submitted for publishing are:

- Genetic diversity and population structure in diploid potatoes (Accepted, to Crop Science journal) (Annex 17).
- Identification of novel candidate genes associated with quantitative resistance to late blight in *Solanum tuberosum* group Phureja through association analysis (Annex 16)

Objective 5: ***Develop an educational program for the indigenous and poor smallholders in Nariño to introduce good agricultural and postharvest practices, including sustainable agricultural practices***

The first ECA involved 406 farmers, men and women, from five municipalities. A baseline was constructed from a survey to 326 participants. In each municipality the mayor supported a crop to implement good agricultural practices (GAP). An advanced training program was agreed with ECAs´ participants. Technological and managerial needs were identified for designing training programs. The educational program included: training workshops; workshops following breeding trials; organized purchase of inputs; practical training for GAP with participatory approach; knowledge exchange; tours and field days and spaces of encounter for gender analysis. 80% of

participants enrolled in ECA remained throughout the first cycle. For the second ECA, 400 farmers, men and women, were enrolled. 80% of producers inscribed participated throughout the cycle.

The results of the educational program showed progress in each of the objectives:

1. Rational use of inputs: It went from 10% of participants aware of the existence of natural enemies of pests and diseases to 89%; 100 % of participants received training on calibration of spraying equipment and label interpretation of agrochemical containers; women who used to do directly the fumigation of crops reduced from 23% to 8%; 59% who planted several seeds per site passed to 100 % planting a single seed.
2. Decision making according to the assessments of pests, diseases and nutritional requirements: according to baseline 89% of participants visited their crops to take decisions, currently 99% of farmers check the crop before applying pesticides.
3. Records of production. 94% of participants stated that keep records of production costs, the baseline indicated that only 27% did it.
4. Conservation of soil, water and beneficial macro and micro fauna: 100% of the farmers said to be aware of the importance of the conservation of soil, water and beneficial macro and micro fauna; 53% of the participants stated that they use crop residues for the production of organic fertilizers, previously just above 3% did it.
5. Associations and cooperation: 100% of ECA' students reported that today they are aware of the importance of working together in associative groups.
6. Entrepreneurship: ECA' students made teamwork exercises along the ECA training and 100% in the survey recognized the importance of such work.
7. Gender analysis: ECA stimulated women communication.

We closed the cycle with ECA, by developing the regional evaluation of cultivars, for registration. We released to the ECA participants the Guide *Talleres para facilitar el aprendizaje sobre el sistema productivo papa y la emprezarización de los productores*. This guidebook included 75 guidelines for all workshops held in ECAs (Annex 18). We, also, released the manual *Procesamiento y agroindustria de papa criolla*, which presented an update information on technology to produce dried starch extraction, mashed potatoes and criolla potato chips; technology on cooked products: *Criolla* potato canned, precooked and frozen. The emphasis of the manual is on small-scale processes and included results of research on *Criolla* potato, developed at the National University of Colombia (Annex 19).

Objective 6: ***to identify sustainable strategies to empower Nariño´s indigenous women as axes for the achievement of Food Security and Nutrition (FSN) for their families and their communities***

To develop this objective, we worked with 433 men and women: Farmers: Men 209 and 143 women; 15 local government actors; 36 people belonging to indigenous councils and 120 community mothers.

Through research-action methodologies: focus groups, encounter spaces, quantitative instruments and life stories, we looked for women to speak up and raise some of their problems, their dreams

and interests, especially the protection of their families and territory and their own personal projection as women. Men who wanted to participate were welcomed. Women and their partners identified their roles regarding FSN, both in the family and in the community; so, we found that the men decide about food shopping, so nutritional education should involve not just females. Rural women must perform the traditional roles regarding care and protection of their families plus new roles; therefore, their working hours are significantly increased. However these new roles provide them other personal satisfactions. The new gender roles in rural family life imply for men to assume, housework, such as preparing food or caring for infants or the elderly. Focus groups dealt with social issues and found that domestic violence has direct effects on FSN. When women are abused or ignored, they cook with reluctance, do not put "color" to the preparations, or do not combine the dishes in the same way they do when they have a good relationship (Annex 5).

The baseline showed that there are laws and public policies, conducted by national and regional organizations aimed at improving access to food. However, its implementation usually does not take into account the particularities and differences of the roles of family members, especially women. Intervention designs do not consider their needs, educational background, cultural practices, and their perspectives and expectations regarding the improvement of their economic and social conditions.

One important result was the participation of men. They considered relevant the topics raised therein; not only in the sense that men want to intervene and "take the floor" (as was usual) but also becoming listeners or raising issues of privacy, which was not part of the traditional dynamics of men's participation in public discussions. This behavior was indicative of "changes" in dynamics and practices of women and men in public life.

We found that patriarchal cultural patterns have persisted over several centuries, so the barriers to change are deep and are rooted from the very conceptions of *woman, family, heads of household, and gender roles*. Nariño rural women, whom we work with, lack of skills or were limited by their families, to participate actively in community processes.

Objective 7: ***Establish public policy advocacy strategies for the incorporation of the results of the project.***

- We developed a base line of programs authorities and institutions working in FSN, gender and agriculture as potential partners in the five municipalities and in the department of Nariño.
- In order for the local and regional agencies and authorities to incorporate results, we kept in touch with them from the starting point of the project. We informed about project objectives and methodologies, asked for support and invited to share activities.
- We informed authorities and agencies of advances and dialogue about them along project development. First we informed and discussed the base lines of the project.
- We released project results, recognizing the collaboration gotten.

We got collaboration agreements with:

- Municipal authorities in five municipalities facilitated plots to develop agronomy trials and they invited the potato producers and organizations to participate in the activities of the project. The Guachucal Major is continuing the educational program with Umata.
- We promoted and orientated the organization of the Food Security and Nutrition committee in Pasto (capital city of Nariño).
- Indigenous authorities (Governors and *cabildos*) signed authorizations to work with communities and informed consents. They called their communities to participate in the project activities
- *Ministerio de Salud y Protección Social* (*Subdirección de Salud Nutricional, Alimentos y Bebidas*): In this Ministry, the Committee responsible to deal with micronutrients (CODEMI) got support and collaborative job around research methodologies. They will use the neutral modules for The Colombian National Survey for FSN 2015 (ENSIN). These neutral modules were an innovation implemented in this Project.
- *Gobernación de Nariño, Secretaria de Agricultura de Nariño*: they provided basic information to design the samples for population studies in five municipalities. They are promoting adoption of new cultivars with producers of other municipalities; they selected small potato producers from the municipalities of Muellamues, Iles, Chiles, Guachaves, and other groups in Cumbal, Pasto, Carlosama and Tuquerres to provide seeds of new cultivars (Annex 2).
- ICBF, regional Nariño. This institution facilitated the activities with Community Mothers' organizations and school restaurants in five municipalities. They are using the manuals (*De la Huerta a la mesa* and *Sabores y saberes de las comunidades andinas nariñenses*) (Annex 11a and 11b) and information on gender, nutritional status, food insecurity, consumption pattern, and they, also, were partners in the execution of clinical study to measure the incidence of new potatoes in nutritional status in children.
- ICBF Nariño branch. With the participation of this Institution, we developed a clinical experiment in order to determine potential impacts of the introduction of cultivars with higher content of iron and zinc in children´s diets. This experiment assessed the impact of improved yellow potato consumption in children between 12 and 59 months old. Results showed an increase in 10.6% of children with adequate size in children that consumed the improved potatoes compared to those that consumed traditional white potato. These results will guide ICBF decisions regarding food menus in school restaurants.
- Corpoica, the national agency responsible for agrarian development, at national level and at Nariño branch. Corpoica facilitated plots for multiplication of 119 native potatoes collected in Nariño. We released the new potato cultivars to incorporate them to the National Program of Seeds.
- Universidad de Nariño: to advance trials in agroforestry and participate with students interns in farmers' field schools with Fundelsurco.

5. Synthesis of results towards AFS Outcomes:

1. New technologies and/or farming systems and practices. How has the project developed new and improved agricultural technologies and/or farming systems and practices that increase food production? (e.g. technologies and innovations; staple crops; crop-livestock interactions; agricultural water management; new seeds and plants).

The project jointly with ECA participants selected three new cultivars: *Criolla Dorada, Criolla Ocarina* and *Criolla Sua Pa*. They were registered in Colombian Agrarian Institute (ICA) (Annex 6). These cultivars have higher yield, better nutritional content, higher resistance to late blight and round shape and yellow color. Certified seed of the three new cultivars were provided to 650 potato growers for multiplication, in the *Festival del Campo*.

Trough participatory research and an educational program, we got several changes in farming practices:
1. Rational use of inputs: It went from 10% of participants aware of the existence of natural enemies of pests and diseases to 89%; 100 % of participants received training on calibration of spraying equipment and label interpretation of agrochemical containers; women who used to do directly the fumigation of crops reduced from 23% to 8%; 59% who planted several seeds per site passed to 100 % planting a single seed.
2. Decision making according to the assessments of pests, diseases and nutritional requirements: according to baseline 89% of participants visited their crops to take decisions, currently 99% of farmers check the crop before applying pesticides.
3. Records of production. 94% of participants stated that keep records of production costs, the baseline indicated that only 27% did it.
4. Conservation of soil, water and beneficial macro and micro fauna: 100% of the farmers said to be aware of the importance of the conservation of soil, water and beneficial macro and micro fauna; 53% of the participants stated that they use crop residues for the production of organic fertilizers, previously just above 3% did it.
5. Associations and cooperation: 100% of ECA' students reported that today they are aware of the importance of working together in associative groups.
Fundelsurco released the guide *Talleres para facilitar el aprendizaje sobre el Sistema productivo papa y la emprezarización de los productores*. This guidebook includes 75 guides for all workshops held by the ECA participants in two previous years (Annex 18)

2. Dietary diversity & nutrition. How has the project contributed to dietary diversity/balanced diets, particularly for women and children? (e.g. food safety practices and regulatory frameworks; food fortification; local nutritional needs)

We developed three yellow potato cultivars have 24% iron and 16% zinc contents in relation with current yellow commercial cultivar in Colombia. We could demonstrate with the clinical study, that those potatoes are effective to improve the nutritional status of children under 5 in 10.5%. This result is being used by ICBF to re-design the menus of school restaurant. This policy could be scale up to the Colombian Andean region.

We published and released 1000 copies of the manual *Sabores y Saberes de las comunidades andinas nariñenses* (Annex 11). This manual compiles information regarding ancestral gastronomic recipes and culinary uses and describes the participatory methodology to recover ancestral memory. The manual was delivered to community mothers of five municipalities in workshops and to community mothers and women participants in ECAs from other municipalities in the *Festival del Campo*. The ICBF is using this manual in its regular training agenda of community mother in Nariño. We also released through workshops with community mothers 1000 copies of the manual *De la huerta a la mesa* (Annex 11a). It compiles good dietary practices and it is being used by ICBF for training their personal.

A scientific paper was published in Food and Nutrition Sciences journal: Nutritional situation of rural communities in Nariño, Colombia, 2013 (Annex 9). This paper provides robust information for policy makers.

3. Engagement of Canadian researchers with Southern researcher organizations (for CIFSRF-funded projects only). Is there increased use of Canadian knowledge and resources to address environmentally sustainable agricultural productivity and nutrition problems in developing countries?

All the research conducted in Canadian institutions was done in collaboration with one or more researchers from UNC. Advanced metabolomics technologies were used at McGill by Prof. Kushalappa to identify late blight resistance genes in potato and one postdoc from UNC (Dr. Felipe Sarmiento) was trained in McGill in this area. The UNC professors and students were also well informed through discussion and seminars by Prof. Kushalappa, on novel metabolomics, transcriptomics and genomics to identify candidate genes. Bioavailability of nutrients in potato was analyzed by Prof. Kubow at McGill using an artificial gut model in collaboration with UNC professors. Genotyping by sequencing was done in New Brunswick in collaboration with UNC students and professors. Two doctoral students, Deissy Juyó and Clara Piñeros developed research in genomics in Fredericton, working with Dr. David DeKöeyer and Dr. Helen Tai. They applied new technologies and they identified genes related to quantitative resistance to late blight in potato.

We held a final meeting in Colombia (Bogota and Pasto) from July 27th to August 1st. Professors Ajjamada Kushalappa, Stan Kubow and Philip Oxhorn from McGill University; David DeKöeyer from University of New Brunswick, Gabriela Burgos from CIP and all the Colombian research team participated. We assessed project methodologies and results and we found that we accomplished the objectives of the project regarding relationship among Canadians and Colombian researchers addressing agricultural productivity problems related with the knowledge of resistance to *Phytophthora infestans* pathogen and to the effect of chlorogenic acid compounds as protectant regarding colon diseases. The scientific collaboration contributed to build scientific capabilities for Canada and Colombia. Canada had the opportunity to analysis a wide genetic diversity represented in Colombia germplasm and to learn about practices developed in field, in lab and different strategies that Colombia employees to deal with unexpected situations. Colombia built scientific capabilities represented in training for students to PhD and master levels and to implement new

methodologies such as: metabolomics, analysis for functional foods, high-throughput sequencing. Skills for communication were strengthened between Canadian and Colombians.

4. Research groups. How has the project contributed to stronger research groups for improved food security policies and decision-making?

We contributed to the development of the first postgraduate program in South America on Food Security and Nutrition. Professor Sara Del Castillo from faculty of medicine is in charge of directing the program (Annex 8). This program contributes to train researchers in FSN.

A Ph.D. student, who did her thesis in this project, using association mapping for first time in Colombia, was hired in International Center for tropical Agriculture (CIAT). She is using the methodologies learnt in rice.

As a result of the good quality of research results, the Latin American Potato Association invited Professors Kushalappa, Kubow, Del Castillo, Melgar and Mosquera to present project results as keynote speakers at the ALAP 2014 conference (http://www.alap2014.co/). SOL 2014, the most important worldwide solanaceae meeting, invited our students Diana Duarte and Wilson Santiago Díaz as oral speakers (http://www.sol2014.com.br/images/stories/Sol2014Program-Final.pdf).

In our regular monthly meeting, the researchers of different components analysed the importance of transdisciplinary work for mutual learning, so we decided, in relation with the proposal submitted for the second phase, to scale up project results in a context of strengthened governance of the communities, the proposal will be submitted to different funding agencies for affording resources.

Colombian researchers learned methodologies and research approaches on genomics and metabolomics and governance. The research groups in food security and nutrition and family and gender developed a strong relationship with ICBF which facilitated support, joint research and interchange of knowledge and project results in relation to FSN. This relationship allowed impacting on FSN policies.

5. Food distribution. How has the project contributed to more equitable food distribution for food security? (e.g. more equitable access to quality food)

NA

6. Food processing and storage. How has the project contributed to improve post-harvest food processing and storage techniques for food security?

We developed and released the *Manual de procesamiento y agroindustria de la papa*. This manual included information and research results regarding processing of yellow potato obtained in ICTA. This manual was developed in collaboration with the Institute of Food Science and Technology (ICTA) from Universidad Nacional de Colombia and released to ECA participants in *Festival del Campo* (Annex 19).

7. Risk-mitigation. How has the project contributed to better risk-mitigation for food security? (e.g. mechanisms that cope with the impacts of climate change, and other shocks such as food price volatility)

The yield of new potato cultivars is higher and their moderate resistance to late blight contribute significantly to the income of families and to reduce the impacts by climate change reducing food insecurity.

As the new cultivars are adopted, Colombians will have access to potato with improved nutritional contents.

8. Access to resources. How has the project contributed to improved access to resources for food production and security? (e.g. land tenure, extension and credit, market access)

The new cultivars were registered in ICA and the good quality seed delivered to the farmers allow them to add value to their production cycle.

9. Income generation. How has the project contributed to improving vulnerable/poor people's ability to purchase more and better quality food, in particular for the benefit of women and children?

The use of good quality seed in cropping allows duplicating yield. According to López and Porras (2014), the average yield of yellow potato is 17,400 K/Ha. The average yield for the new cultivar Criolla Sua pa, in research plots using good quality seed in Nariño was 37,430 K/Ha. The economic analysis comparing new potato cultivar Criolla Sua Pa with Criolla Colombia, the most cultivated yellow potato commercial variety in Colombia, cropped in similar conditions, showed 18.0% higher income when using new cultivar Criolla Sua Pa (Annex 22).

Corpoica received elite seed of the three new cultivars to support the National Certified Seed Program. The direct impact is in 650 potato producers in Nariño. Corpoica will extend these cultivars in Cundinamarca and Boyaca provinces.

10. Policy options. How has the project influenced the development and implementation food security policies?

The project built the base line in food security for five municipalities that did not have this information, which contributed to the formulation of future public policies in this field. Project generated representative and disaggregated information about FSN. This kind of information is obtained for first time in Colombia. The results have enabled the ICBF, Nariño branch, to strengthen their programs to target rural populations, since we found that the FSN situation in the rural area is very serious (food insecurity reached an average of 90% in 2012). The data from ENSIN 2010 did not allow differentiating urban from rural population. We found that the population did not recognize the state agency (ICBF) as the entity that cares for the welfare, which aims to provide a comprehensive service, because ICBF hires different service operations with third parties. ICBF has decided to work more closely with operators (Contractors performing operation) to make state action more comprehensive and visible, which will benefit the population.

Our results showed a facet of the problem that was not known by ICBF: the complex malnutrition – obesity (double burden). This problem is increasing in Colombia. ICBF recognized that it must also

educate men as well as women, since men decide on purchases from the market, in many cases. Today, the ICBF is re-designing policies to address this issue.

We provided to the Ministry of Health and Social Protection, new information that the national survey (ENSIN 2010). The construction of the sample for the 2015 national survey, is taking into account our methodologies that differentiate urban and rural population, indigenous and peasants and between municipalities in the same region. The Ministry hired as Director of the Food and Beverage Department a researcher from the Project, who is orientating the national policies in food security; also this person will orient the National Survey in FSN 2015.

The robust results obtained from clinical experiment on impact of new yellow potato cultivars with higher iron content and zinc on children under 5 are being used by ICBF decisions regarding food menus of targeted social programs to children and food and nutrition education for the population to encourage consumption (Annex 5, Annex 23).

11. Information and Communication Technologies (ICTs). Has the use of ICTs contributed to increase access to information and improved food security for the most vulnerable? (e.g. equitable use of technologies, such as radio, television, telephones, computers, and the Internet).
NA

12. Gender. How has the project considered women's specific needs in the design of the research, participation of women in the research, and potential impact of research on women? How has the project: a) improved women's access to and control over income? b) reduced women's drudgery or workload (time spent) in agriculture?; and/or c) improved women and children's access to adequate and diversified diets?

All the activities of the project in Nariño were designed with the active participation of women and men. We were actively looking for women genuine participation. Through the research-action methodologies we used, we looked for women to speak up and raise their opinions, their problems, their dreams and interests, and their own personal projection as women in these social settings. Women and their partners described quantified and analyzed their roles regarding FSN, both in the family and in the community so; they got aware of overload of women. We achieved an active participation of women in focal groups and in ECAs activities in field and in classroom, as qualitative results. An important result was to identify that men decide about food shopping, so nutritional education should involve not just females.

Besides we got a reduction of women fumigating crops. Women who used to do directly by themselves the fumigation of crops reduced from 23% to 8%.

We documented that intra-familiar violence inside on FSN.

13. Environment. How has the project tested for and contributed to environmental sustainability? (e.g. Has the project affected the environment? If so, are contributions environmentally sustainable?)

The three new potato cultivars requiring lesser use of pesticides and better soil management practices (Annex 24). This means in general that the Project develops new more friendly cultivars with the environment, and also they are more productive.

We worked under the concept of Good Agricultural Practices in the Educational Program. We advanced in better agronomical practices such as:
1. Rational use of inputs: It went from 10% of participants aware of the existence of natural enemies of pests and diseases to 89%; 100 % of participants received training on calibration of spraying equipment and label interpretation of agrochemical containers; women who used to do directly the fumigation of crops reduced from 23% to 8%; 59% who planted several seeds per site passed to 100 % planting a single seed.
2. Decision making according to the assessments of pests, diseases and nutritional requirements: according to baseline 89% of participants visited their crops to take decisions, currently 99% of farmers check the crop before applying pesticides.
3. Records of production. 94% of participants stated that keep records of production costs, the baseline indicated that only 27% did it.
4. Conservation of soil, water and beneficial macro and micro fauna: 100% of the farmers said to be aware of the importance of the conservation of soil, water and beneficial macro and micro fauna; 53% of the participants stated that they use crop residues for the production of organic fertilizers, previously just above 3% did it.

6. Problems and Challenges:

- We had difficulties in signing the collaboration agreement with CIP because of internal procedures at the legal offices of both institutions. However, it has not impacted the project because we have advanced in academic activities.
- We have learned to handle the administrative bureaucracy, since national laws for contracts and purchases in public institutions are complex. The import process for necessary goods was slow and the adaptation of the greenhouse was delayed; however the number of assays was doubled in order to meet the objectives, specifically in the metabolomics component.
- Weather conditions: On first crop cycle we had highly rainy weather, so the harvest was lower than expected; however an additional crop was planted near Bogotá for providing enough plant material. This situation delayed some research activities generating additional costs that were not included in the project budget.
- Ticket fares from Bogotá to Pasto exceeded the initial budget allocation for this category. However, we made internal transfers in the "In- Country travel" category for handling with this difficulty.

- We underestimated the amount of labor inherent to nutritional analysis. The lyophilization process and the sample preparation implied more work and time than planned.
- The UHPLC technology was new in Colombia and the expertise was limited. The equipment calibration was a challenge not only for researchers but also for the supplier company.
- The director of field work in Nariño had a sickness treatment, so the direction of field work had temporary problems.
- To solve budget limitations we moved funds allocated specifically for each component research to other within in the same budget category "research expenses". These financial movements maintained the balance of the budget project.
- UNC suffered a workers strike. This strike disturbed our work properly in laboratory analysis, so we designed a plan B to recover time.
- The administrative managerial of the project was a challenge by itself, because the complexity of the official regulations and excessive controls for public entities like UNC. This management implied to train the administrative staff of the Project how to deal with the changing procedures and those novel procedures that implied to invest long time such us to declarate the Project free of taxes or to get an individual Project account bank.
- The academic direction of the Project was a challenge because the complexity of the project. The Colombian team established a coordination system with clear cut rules funded in the respect, the compromise and the confidence of researchers. This facilitated a good working atmosphere. In relation with Canadian partners the respect was also fundamental principle.
- Transfer of resources to Fundelsurco: Fundelsurco has not delivered all established products, so we have not transferred money as set in the collaboration agreement. We have transferred partial amount to facilitate field activities.
- *Ley de garantías*: Currently Colombia is in government elections process so the university had to implement all administrative process through *Ley de garantias* which increases the procurement processes, demanding more time from the management team for each process. We planned well in advance procurement requirements

7. Recommendations:

In our regularly meeting, all the researchers strongly recommended to IDRC and DFATD to keep the support to projects as they did in this project. All of us agreed in the excellence of the IDRC administrative and follow up procedures. With this project we learnt ways to solve administrative and research problems. We started learning in this project with the call itself, since the call asked for a transdisciplinary approach. IDRC team was practically one member of research team and IDRC built the relationship with the Project team in confidence, this was central to achieving the objectives and openly discuss concerns, as well as to share the happiness generated for the achievements gotten over these 2.5 years in the project implementation.

We would like to recommend IDRC and DFATD to make calls for projects with longer period than 2.5 years for their implementation.

Annexes

1. List of participants *Festival del Campo*
2. Farmers groups committed to multiply new cultivars
3. Prueba de evaluación agronómica
4. Clinical essay
5. Cambios roles de la mujer
6. Registro ICA e información nuevos cultivares de papa
7. Scientific meetings and publications
8. Resolución creación Maestria Seguridad Alimentaria y Nutrición
9. Scientific publication-Nutritional Situation of Rural communities in Nariño, 2013
10. Potato consumption pattern
11. De la Huerta a la Mesa (11a), Manual Sabores y saberes de las comunidades andinas nariñenses (11b)
12. Scientific publication on functional foods from tuberosum group Phureja (a, b)
13. Nutritional quality results
14. Scientific publication Chromatographic method for sugar content
15. Scientific publication on metabolomics-genomics (a,b,c)
16. Scientific publication: Identification of novel candidate -resistance to late blight
17. Scientific publication: Genetic diversity and population structure in diploid potatoes
18. Talleres para facilitar el aprendizaje sobre el sistema productivo papa
19. Manual de procesamiento y agroindustria de la papa
20. Scientific publication: Los roles de las mujeres rurales en el departamento de Nariño
21. Scientific publication: Criolla Dorada, Criolla Ocarina y Criolla Sua Pa
22. Comparison of potato cultivars in Nariño by income
23. Sobre adopción de resultados
24. Results educational program
25. Catálogo papas nativas nariñenses
26. Photos Festival del Campo
27. The 13 AFS Expected Outcomes
28. Presentaciones
29. Scientific publication Non –targeted metabolomics of potato genotypes reveals potential functional food.
30. Scientific publication: Functional food chemicals in cooked Colombian diploid potatoes
31. Scientific publication: nutritional content new cultivars
32. Scientific publication: Hidroxycinnamic profile in boiled Colombian diploid potato genotypes
33. Video SAN Nariño 02
34. Publications

Annex 1: The 13 AFS Expected Outcomes

This list of outcomes should be referred to when completing **question #5 above** (Synthesis of results towards AFS Outcomes).

1. New technologies and/or farming systems and practices. How has the project developed new and improved agricultural technologies and/or farming systems and practices that increase food production? (e.g. technologies and innovations; staple crops; crop-livestock interactions; agricultural water management; new seeds and plants).

The project jointly with ECA participants selected three new cultivars: *Criolla Dorada, Criolla Ocarina* and *Criolla Sua Pa*. They were registered in Colombian Agrarian Institute (ICA) (Annex6). Seed of the three new cultivars were delivered to 650 potato growers for multiplication in the *Festival del Campo*.

Fundelsurco released the guide *Talleres para facilitar el aprendizaje sobre el Sistema productivo papa y la emprezarización de los productores*. This guidebook includes 75 guides for all workshops held by the ECA participants in two previous years (Annex 18)

Scientific publication to be summited at American Potato Research journal: Potato breeding at diploid level (Annex 21)

14. Dietary diversity & nutrition. How has the project contributed to dietary diversity/balanced diets, particularly for women and children? (e.g. food safety practices and regulatory frameworks; food fortification; local nutritional needs)

We developed three yellow potato cultivars have 24% iron and 16% zinc contents in relation with current yellow commercial cultivar in Colombia. We could demonstrate with the clinical study, that those potatoes are effective to improve the nutritional status of children under 5 in 10.5%. This result is being used by ICBF to re-design the menus of school restaurant. This policy could be scale up to the Colombian Andean region.

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A scientific paper was published in Food and Nutrition Sciences journal: Nutritional situation of rural communities in Nariño, Colombia, 2013 (Annex 9). This paper provides robust information for policy makers.

2. Engagement of Canadian researchers with Southern researcher organizations (for CIFSRF-funded projects only). Is there increased use of Canadian knowledge and resources to address environmentally sustainable agricultural productivity and nutrition problems in developing countries?

All the research conducted in Canadian institutions was done in collaboration with one or more researchers from UNC. Advanced metabolomics technologies were used at McGill by Dr. Kushalappa to identify late blight resistance genes in potato and one postdoc from UNC (Dr. Felipe Sarmiento) was trained in McGill in this area. The UNC professors and students were also well informed through discussion and seminars by Dr. Kushalappa, on novel metabolomics, transcriptomics and genomics to identify candidate genes. Bioavailability of nutrients in potato was analyzed by Dr. Kubow at McGill using an artificial gut model in collaboration with UNC professors. Genotyping by sequencing was done in New Brunswick in collaboration with UNC students and professors. Two doctoral students, Deissy Juyó and Clara Piñeros developed research in genomics in Fredericton, working with Dr. David DeKöeyer and Dr. Helen Tai. They applied new technologies and they identified genes related to quantitative resistance to late blight in potato.

We held a final meeting in Colombia (Bogota and Pasto) from July 27th to August 1st. Professors Ajjamada Kushalappa, Stan Kubow and Philip Oxhorn from McGill University; David DeKöeyer from University of New Brunswick, Gabriela Burgos from CIP and all the Colombian research team participated. We assessed project methodologies and results and we found that we accomplished the objectives of the project regarding relationship among Canadians and Colombian researchers addressing agricultural productivity problems related with the knowledge of resistance to *Phytophthora infestans* pathogen and to the effect of chlorogenic acid compounds as protectant regarding colon diseases. The scientific collaboration contributes to build scientific capabilities for Canada and Colombia. Canada had the opportunity to analysis a wide genetic diversity represented in Colombia germplasm and to learn about practices developed in field, in lab and different strategies that Colombia employees to deal with unexpected situations. Colombia built scientific capabilities represented in training for students to PhD and master levels and to implement new methodologies such as: metabolomics, analysis for functional foods, high-throughput sequencing. We adequated infrastructure for implementing advanced methodologies. This infrastructure is currently used at the university and it will be used at the future. Skills for communication were strengthening between Canadian and Colombians.

3. Research groups. How has the project contributed to stronger research groups for improved food security policies and decision-making?

We contributed to the development of the first postgraduate program in South America on Food Security and Nutrition. Professor Sara Del Castillo from faculty of medicine is in charge of directing the program (Annex 8).

As a result of the good quality of research results, the Latin American Potato Organization invited Professors Kushalappa, Kubow, Del Castillo, Melgar and Mosquera to present project results as keynote speakers at the ALAP 2014 conference (http://www.alap2014.co/). SOL 2014, the most important solanaceae meeting, invited students Diana Duarte and Wilson Santiago Díaz as oral speakers (http://www.sol2014.com.br/images/stories/Sol2014Program-Final.pdf).

In our regular monthly meeting, the researchers of different components analysed the importance of transdisciplinary work for mutual learning, so we decided, in relation with the proposal submitted for the second phase, to scale up project results in a context of strengthened governance of the communities, the proposal will be submitted to different funding agencies for affording resources.
Colombian researchers learned methodologies and research approaches on genomics and metabolomics and governance. The research groups in food security and nutrition and family and gender developed a strong relationship with ICBF which facilitated support, joint research and interchange of knowledge and project results in relation to food security and nutrition. This relationship allowed impacting on food security and nutrition policies.

4. Food distribution. How has the project contributed to more equitable food distribution for food security? (e.g. more equitable access to quality food)

NA

5. Food processing and storage. How has the project contributed to improved post-harvest food processing and storage techniques for food security?

We developed and released the *Manual de procesamiento y agroindustria de la papa*. This manual includes general information and research results regarding processing of yellow potato. This manual was developed in collaboration with the Institute of Food Science and Technology (ICTA) from Universidad Nacional de Colombia (Annex 19)

6. Risk-mitigation. How has the project contributed to better risk-mitigation for food security? (e.g. mechanisms that cope with the impacts of climate change, and other shocks such as food price volatility)

The yield of new potato cultivars is higher and their moderate resistance to late blight contribute significantly to the income of families and to reduce the impacts by climate change reducing food insecurity.

7. Access to resources. How has the project contributed to improved access to resources for food production and security? (e.g. land tenure, extension and credit, market access)

The new cultivars were registered in ICA and the good quality seed delivered to the farmers allow them to add value to their production cycle.

8. Income generation. How has the project contributed to improving vulnerable/poor people's ability to purchase more and better quality food, in particular for the benefit of women and children?

The use of good quality seed in cropping allows duplicating yield. According to López and Porras (2014), the average yield of yellow potato is 17400 K/Ha. The average yield for the new cultivar

Criolla Sua pa, in research plots using good quality seed in Nariño was 37430 K/Ha. The economic analysis comparing new potato cultivar Criolla Sua pa with Criolla Colombia, the most cultivated yellow potato commercial variety in Colombia, showed 18.0% higher income when using new cultivar Criolla Sua pa (Annex 22).
Corpoica is receiving elite seed of the three new cultivars to support the National Certified Seed Program. This action, coupled with the intervention of the government of Nariño already gave seed to different groups; the impact will reach 650 potato producers in Nariño. Corpoica will extend these cultivars in Cundinamarca and Boyaca.

15. Policy options. How has the project influenced the development and implementation food security policies?

The project built the base line in food security for five municipalities that did not have this information, which contributed to the formulation of future public policies in this field. Project generated representative and disaggregated information about FSN. This kind of information is obtained for first time in Colombia. The results have enabled the ICBF, Nariño branch, to strengthen their programs to target rural populations, since we found that the FSN situation in the rural area is very serious (food insecurity reached an average of 90% in 2012). The data from ENSIN 2010 did not allow differentiating urban from rural population. We found that the population did not recognize the state agency (ICBF) as the entity that cares for the welfare, which aims to provide a comprehensive service, because ICBF hires different service operations with third parties. ICBF has decided to work more closely with operators (Contractors performing operation) to make state action more comprehensive and visible, which will benefit the population.

Our results showed a facet of the problem that was not known by ICBF: the complex malnutrition – obesity (double burden). This problem is increasing in Colombia. ICBF recognized that it must also educate men as well as women, since men decide on purchases from the market, in many cases. Today, the ICBF is re-designing policies to address this issue.

We provided to the Ministry of Health and Social Protection, new information that the national survey (ENSIN 2010). The construction of the sample for the 2015 national survey, is taking into account our methodologies that differentiate urban and rural population, indigenous and peasants and between municipalities in the same region. The Ministry hired as Director of the Food and Beverage Department a researcher from the Project, who is orientating the national policies in food security; also this person will orient the National Survey in FSN 2015.

The robust results obtained from clinical experiment on impact of new yellow potato cultivars with higher iron content and zinc on children under 5 are being used by ICBF decisions regarding food menus of targeted social programs to children and food and nutrition education for the population to encourage consumption (Annex 5, Annex 23).

9. Information and Communication Technologies (ICTs). Has the use of ICTs contributed to increase access to information and improved food security for the most vulnerable? (e.g. equitable use of technologies, such as radio, television, telephones, computers, and the Internet).

NA

10. Gender. How has the project considered women's specific needs in the design of the research, participation of women in the research, and potential impact of research on women? How has the project: a) improved women's access to and control over income?; b) reduced women's drudgery or workload (time spent) in agriculture?; and/or c) improved women and children's access to adequate and diversified diets?

All the activities of the project in Nariño were designed with the active participation of women and men in focal groups and ECAs as qualitative results (Annex 5, Annex 23). We were actively looking for women genuine participation. Through the research-action methodologies we used, we looked for women to speak up and raise their opinions, their problems, their dreams and interests, and their own personal projection as women in these social settings. Women and their partners described quantified and analyzed their roles regarding FSN, both in the family and in the community so; they got aware of overload of women. We achieved an active participation of women in focal groups and in ECAs activities in field and in classroom, as qualitative results. An important result was to identify that men decide about food shopping, so nutritional education should involve not just females.

Besides we got a reduction of women fumigating crops. Women who used to do directly by themselves the fumigation of crops reduced from 23% to 8%.

We documented that intra-familiar violence inside on FSN.

11. Environment. How has the project tested for and contributed to environmental sustainability? (e.g. Has the project affected the environment? If so, are contributions environmentally sustainable?)

The three new potato cultivars requiring lesser use of pesticides and better soil management practices (Annex 24). This means in general that the Project develops new more friendly cultivars with the environment, and also they are more productive.

We worked under the concept of Good Agricultural Practices in the Educational Program. We advanced in better agronomical practices such as:
1. Rational use of inputs: It went from 10% of participants aware of the existence of natural enemies of pests and diseases to 89%; 100 % of participants received training on calibration of spraying equipment and label interpretation of agrochemical containers; women who used to do directly the fumigation of crops reduced from 23% to 8%; 59% who planted several seeds per site passed to 100 % planting a single seed.
2. Decision making according to the assessments of pests, diseases and nutritional requirements: according to baseline 89% of participants visited their crops to take decisions, currently 99% of farmers check the crop before applying pesticides.
3. Records of production. 94% of participants stated that keep records of production costs, the baseline indicated that only 27% did it.

4. Conservation of soil, water and beneficial macro and micro fauna: 100% of the farmers said to be aware of the importance of the conservation of soil, water and beneficial macro and micro fauna; 53% of the participants stated that they use crop residues for the production of organic fertilizers, previously just above 3% did it.

Annex 2: Digital File Formats Supported by the IDRC Digital Library

Description	Extensions
Microsoft Word	doc
Adobe PDF	pdf
Postscript	Ps, eps, ai
SGML	sgm, sgml
Microsoft Excel	xls
Microsoft PowerPoint	ppt
Microsoft Project	mpp, mpx, mpd
Microsoft Visio	vsd
Filemaker	fmp3, fm
Photoshop	psd, pdd
Audio AIFF	aiff, aif, aifc
Audio/basic	au, snd
Audio MPEG	mpa, abs, mpeg, mp3
RealAudio	ra, ram
Audio WAV	wav
Image GIF	gif
Image JPEG	jpeg, jpg
Image PNG	png
Image TIFF	tiff, tif
Image BMP	bmp

Annex 3: Template for AFS Research Output Title and Abstract Page

Each research output submitted to IDRC must include a title page, abstract, and keywords. The kind of information that should be included is listed below. Items marked with an asterisk (*) are particularly important and **must** appear. A blank title and abstract page follows.

***Title:**

Subtitle:

***By:** *Full Name(s) of Author(s)*

Report Type**:** e.g., *workshop report, research paper, research study, etc.*

***Date:**

Published by: *Full Name of Publisher*

Location: *Name of Place of Publication*

Series Name:

Number of Series part:

***IDRC Project Number, and component number (if applicable):**

***IDRC Project Title:**

***Country/Region:** *Country(ies) or region(s) where project was carried out*

***Full Name of Research Organizations:**

***Address of Research Organizations:**

***Name(s) of Researcher/Members of Research Team:**

***Contact Information of Researcher/Research Team members:**

***This report is presented as received from project recipient(s). It has not been subjected to peer review or other review processes.**

***Abstract:** *Research outputs should include an abstract of 150-200 words specifying the issue under investigation, the methodology, major findings, and overall impact.*

***Keywords:** *Include up to six subject keywords separated by commas.*