DESCRIPTION of SCIENTIFIC ACTIVITIES and CHALLENGES

DESCRIPTION of SCIENTIFIC ACTIVITIES and CHALLENGES ADDRESSED *(2 pages maximum).* *Please state clearly and briefly only those that concern the Prize, i.e., the quality of the contribution in terms of training and education, research and development in the field of food and agriculture. This concerns the whole chain, i.e., from the production of agricultural raw materials through their transformation and final utilization (food and non-food uses). All scientific disciplines (natural and social sciences) are considered.*

Since Dr. Silvia Restrepo started her professional career she has always been interested in the protection of food available to both humans and animals in Colombia and other developing countries, through the study of plant pathology. The crops she has been more concerned about are potato (different species within the genus *Solanum*) and cassava (*Manihot esculenta*) both of mayor importance to our country.

According to the FAO statistics it is estimated that more than 600 million people depend on cassava in the World. The cassava bacterial blight caused by *Xanthomonas axonopodis* pv. *manihotis* (Xam) may cause 100% losses in young crops if the environmental conditions are adequate, being the major biotic constraint on cassava production. In her first doctoral year at the Université Pierre et Marie Curie, Paris VI, France, Dr. Restrepo learned about a collaborative project between Centro Internacional de Agricultura Tropical (CIAT) and the Institut de Recherche pour le Développement (IRD). The project focused on the study of the bacterial blight and its impact on the cassava production in Colombia, Venezuela, and Brazil.

In 1995, after travelling around the main cassava growing areas in Colombia she identified three areas where the disease was causing major damages. These were the eastern valley, specifically the Colombian department of Meta, the northern coast, from Córdoba to Magdalena departments, and in the Cauca department in the Piendamó and Mondomo areas. From this findings, she designed a disease study strategy whose main purpose was to contribute in the reduction of crop losses in a short, medium and long term. To fulfill the objectives she was in close communication with the cassava plant breeders because the most efficient and appropriate control strategy for this disease is the use of resistant varieties. The structure of the bacterial population was characterized, assesing the quantity and distribution of the genetic and phenotypic diversity. There are four publications for this initial research (Restrepo et al., 1997; Verdier et al., 1997; Verdier and Restrepo, 1997; Restrepo and Verdier, 1997). Additionally, they found specific haplotypes of Xam for each eco-zone where cassava is grown in Colombia. This allowed the evaluation of each cassava genotype with a reduced number of bacterial strains representing the actual bacterial genotype to which the crop would be exposed in each zone. Finally, she demonstrated that the host played a key role in the interaction that shapes the structure of the pathogen's population in the field; as more genotypes of cassava are grown in the field, the pathogen's population would be more diverse (Restrepo et al., 2000a). All this research both in the field and laboratory led to the formulation of a new set of recommendations to small and medium-size growers for successful agricultural practices.

In the process of understanding the biology of the pathogen, Dr. Restrepo characterized the races or pathotypes within the populations of Xam. This information is useful to plant breeders and growers because the variation in pathogenicity, which defines the races, determines if the pathogen can overcome the host defenses. These studies allowed the description of the races in each agro-ecological zone and consequently provided the characteristics to suggest the appropriate germplasm to growers (Restrepo et al., 2000b). By doing this, they were able to identify the resistant genotypes of cassava in every region.

Given that these studies were done under greenhouse conditions, Dr. Silvia decided to evaluate the resistance of the genotypes in the field (Restrepo et al., 2000c). This study corroborated the resistance of some of the cultivars that had been identified as promising for agricultural use (Restrepo et al., 2003). Their next step in the exploration of the pathosystem Xam – cassava was the study of the genes that determined the interaction between the two organisms: genes that are expressed in the bacteria when it is infecting cassava (Gónzalez et al., 2002), and genes that are expressed in the plant when it is defending itself against this pathogen (Santaella et al., 2004). These genes were identified with high-throughput massive ESTs ("Expressed Sequence Tags") sequencing techniques (Anderson et al., 2004, López et al., 2004), and microarrays (López et al., 2005). Identifying the genes that were being expressed in the bacteria was important to identify markers associated to virulence and to be able to monitor the changes that were taking place in a pathogenic population (Verdier et al., 2004). Additionally, knowing the genes that are being expressed in the plant during the interaction with Xam is useful for designing long term strategies for marker assisted plant breeding (Verdier et al., 2004). From these studies, Dr. Restrepo together with her group was able to identify a gene, which was mainly responsible for the resistance of cassava to Xam. Today this gene is being cloned, which is an innovating methodology in Colombia.

The investigations on the interaction between Xam and cassava generated important information about this

disease, which included resistant cassavas, and management strategies. This work left Dr. Restrepo the personal satisfaction of having worked with Colombian growers. Her work was recognized with the Christiane Doré Award in 1999 as the best fellow of the IRD. After finishing her Ph.D. studies, Dr. Restrepo decided to investigate another disease of economical importance in Colombia, the potato late blight. This is the most important potato disease in the world, caused by the oomycete *Phytophthora infestans*. Initially she started working on the year 2000 as a post-doctoral assistant in William Fry's laboratory located in Cornell University (New York, United States), and after in the year 2003 she started to work in Christine Smart's laboratory at Cornell University. While she worked in Cornell, she divided her time between basic investigation on the molecular interaction between potato and this oomycete and extension activities with potato growers. The result of this investigation was a better understanding of the activated metabolic routes in potato and tomato when they are infected with *P. infestans* (Smart et al., 2003; Ronning et al., 2003; Restrepo et al., 2005). From the extension work, Dr. Silvia learned about how potato production in a country different from Colombia works, which allowed her to identify the agricultural deficiencies that we have in our country, and the strengths that we could use to obtain a better production. One of these strengths includes the genetic diversity of our potato crops and the diversity of environments to grow these crops.

In the year 2005, Dr. Restrepo started working at Universidad de los Andes, and since the beginning she assumed the leadership of the Uniandes Mycology and Phytopathology Laboratory (LAMFU). Two years after Dr. Restrepo was in charge of the laboratory, it increased from Category C to A according to the Colciencias classification. In the University Dr. Restrepo has had the opportunity of participating in different activities including: investigation, teaching, and administration. As an investigator, Dr. Restrepo decided to continue her research on the oomycete *P. infestans* given that this disease in Colombia is of major concern not only on potato crops but also on several species in the family Solanaceae. This family includes several fruits of great economical importance such as tomato, tree tomato, cape gooseberry, lulo or naranjillo, and pepper.

Dr. Restrepo began her investigations by reviewing the principal diseases of the Solanaceae specially those caused by *Phytophthora* (Carreño et al., 2007) in order to quantify the problem she was dealing with. Afterwards, she developed molecular tools for the study of the populations of plant pathogens of the genus *Phytophthora* (Garnica et al., 2006) with the aim of getting to know the epidemiology of the pathogen in order to implement better control strategies. This work not only allowed the identification of sequences that allowed the comprehension of the pathogen's population but also marked the beginning of a new investigation line in her laboratory, bioinformatics. For this study, Dr. Restrepo and her students created a very usefull free access database, especially for researchers working on plant pathogens in the genus *Phytophthora* (http://bioinf.uniandes.edu.co/phytossr.php). In later investigations Dr. Restrepo's group did major contributions such as the discovery of new hosts for *P. infestans*, and the isolation of an A2 mating type for the first time in Colombia (Vargas et al., 2007; Vargas et al., 2009). This last finding was one of major concern given that it opened the possibility of sexual recombination of this pathogen in our country, which meant that the pathogen could recombine and produce new genotypes that can be resistant to potatoes grown in the field. Because of this Dr. Restrepo started to work with the Colombian Agricultural Institute (ICA) in order to continue monitoring the pathogen's population. Additionally, Dr. Restrepo is constantly searching for alternative methods of control of this devastating disease with chemicals of low toxicity, mainly with natural compounds produced by antagonists of this plant pathogen (Prada et al., 2009). Other alternative control strategies may arise from a better understanding of the oomycete's effectors, and because of this she actively participated in the sequencing and annotation of the *P. infestans* genome (Haas et al., 2009).

Dr. Restrepo is a highly motivated professor; she has advised and mentored a significant amount of students in Colombia. It is easy to perceive her passion for teaching and transferring her knowledge and research experience to students. She has developed new web tools for teaching science in an aim to benefit the greatest amount of students possible. She also encourages students to take advantage of her international collaborations to continue their studies abroad. At the undergraduate level at Universidad de los Andes, she has taught Cellular Biology, Fungal Biology and Plant Pathology. These courses usually enroll around 40 students, and cover the basic aspects of the biology of fungi and plant pathology. Silvia has always emphasized to her students how basic knowledge of fungi, their development, and ecological relevance are determinant to understand processes such as pathogenicity, mutualism, commensalism and other types of interactions. She always insists in the holistic understanding of interactions in nature. To complement basic concepts required for the class, she usually assigns weekly readings to the students in relation to recently published research articles that pertain to a particular topic. She encourages student discussion regarding the manner in which the authors use basic concepts in their experimental design and in their data analysis to draw conclusions. This has been a very useful tool to provide the students with a current perspective on why they are learning a particular topic. In her five years as a teacher at Universidad de los Andes, Silvia has received teaching mentions regarding these courses and has been chosen as third best teacher (two years ago) and best teacher (last year) of the biological sciences department.

At the graduate level she has taught several courses. The molecular biology and biotechnology of fungi course covers concepts of molecular markers developed and used to study different aspects of fungi: their development, metabolism, and again, interactions. She covers the fungal biotechnology field, protocols to transform fungi and rational evolution of proteins. In the course she carries out weekly discussions on assigned research articles from top journals with the students. This has been useful in the development of analytical and communication skills for the students. The students are also required to write a research proposal. The purpose of the class, beyond

covering basic concepts in current techniques, was to generate in the students a sense of research, experimental design, and critical thinking. There was also a strong emphasis on developing scientific writing skills.

Since her arrival to the University she has taught a genomics/bioinformatics course. She strongly believes that students should know how to manipulate DNA/RNA/protein sequences and how to handle large amounts of molecular data. She teaches the next generation of sequencing technologies, the basic algorithms of several bioinformatics tools and developed an online tutorial for basic bioinformatics (http://bioinformate.uniandes.edu.co). She brought the study of bioinformatics to the University as a tool that has allowed a greater understanding of plant-pathogen interactions.

DESCRIPTION OF IMPACTS AND CONTRIBUTION TO SUSTAINABLE DEVELOPMENT *(2 pages maximum).*
Please state clearly and briefly only those that concerns the scientific activities described in preceding pages. Describe impacts and achievements in terms of quantity (e.g., number of people or villages affected, reduced level of poverty, etc) and quality (e.g., effect over time on well-being, geographic boundaries, policy changes, spin-offs, etc.)

Dr. Silvia Restrepo has worked in Plant Pathology for the last 15 years. Her main concern has been to conduct research with a social relevance for Colombia and other developing countries. She has devoted herself to the study of the most important causal agents of diseases in cassava and potatoes in an aim to favor small and medium size farmers.

During her studies in cassava, she studied a total of fifteen (15) different sites in Colombia, sixteen (16) in Brasil and eight (8) in Venezuela. More than 1'400,000 people from poor towns in Colombia are being positively affected by Dr. Restrepo's research. These include larger towns such as Villavicencio (Meta) with 788,000 habitants, Sincelejo (Sucre) with 261,187 habitants, and Carmen de Bolívar (Bolívar) and Corozal (Sucre) with more than 60,000 habitants each, as well as other smaller villages and localities. The research conducted by Dr. Restrepo has always benefitted the small farmers rather than industrial farmers as they have been of major concern for the country. It is very important for a developing country such as Colombia to have self-sustaining small farmers in this areas where the cassava may be grown and marketed.

Thirteen years after her initial research, Dr. Restrepo returned to all the cassava fields in Colombia, it was clear that the bacterial blight was not a limiting disease in the crops anymore. It was very gratifying for her to know they had implemented the recommendations made before and how well her long term expectations were working. Cassava, the most important food commodity for some localities in the northern coast, such as Ciénaga de Oro and Carmen de Bolivar just to name a couple, is growing without constraints with as low as 5% losses due to bacterial blight. This decrease in the disease is significant because in Colombia there are over 165,000 harvested hectares with a production of over 1'800,000 tonnes of cassava.

During her last visit to Venezuela as a key speaker in the International Phytopathology Meeting in 2009 there were several discussions with the cassava growers. It is estimated that in Venezuela the losses due to the disease have been reduced from 100% to 50% and cassava is being able to be grown and harvested again. In Venezuela there are 37,000 havested hectares with a production of 285,000 tonnes of cassava. She was specially thanked for her contributions in the understanding of the disease. The eight sites studied in Venezuela located in Anzoategui, Monagas and Bolívar are being productive once again.

In central and south Brazil the situation is similar. The sixteen sites studied located in Goias, Sao Paulo, Bahia, Ceara and Mato Grosso do Sul have incresed its productivity. Overall, there are aproximately 100,000 less hectares harvested comparing the harvested area in 1995 and 2008 and the productivity has increased in half a million tonnes. It can be noted that the small- and medium-sized farmers have been greatly benefitted and are incresing their production.

Her intense study of the bacterial blight has now left a great deal of information on the disease, the resistance in cassava and disease management strategies. Nonetheless, her efforts on fighting the disease are not over. Currently, she is involved in new projects to monitor the bacterial populations, sequence the Xam genome, and to develop new control strategies. Her scientific cooperations with the IRD are still active through the Ecos Nord – Colciencias program and thus establishing an exchange program for students and researchers between Universidad de los Andes and IRD.

Dr. Restrepo's studies on potato in Colombia started in 2005 when she visited small- and medium-sized farmers in the Cundinamarca department. At that time the disease was obviously present in most of the potato fields. Potato is one of the most important crops in Colombia, particularly in the Andean region. There are more than 130,000 harvested hectares with a production of over 2'300,000 tonnes of potatoes in Colombia. She started to characterize the *P. infestans* population in the Colombian Andes and there was an immediate need to expand to other areas in order to understand the behavior of the pathogen. As there was evident lack of history of the *P. infestans* population and its impact on crops in the South American Northern Andean region, she associated with colleagues

from different research institutes in and outside the country to sample the complete area. They were able to sample in four departments in Colombia (Cundinamarca, Antioquia, Nariño and Boyacá), three in Venezuela (Táchira, Mérica and Trujillo) and three in Ecuador (Tungurahua, Napo and Pichincha). These ten sites covered the Northern Andean region and the study revealed a low genetic diversity at both in mitochondrial and nuclear regions of the *P. infestans* genome. A manuscript is now being under consideration for this study on the *P. infestans* population.

Colombia also produces other kinds of potatoes, such as yellow potato (*Solanum phureja*) that are also attacked by *P. infestans* but posses a different kind of resistance towards the pathogen. In this scenario and based on the previous findings, Dr. Restrepo decided to continue the study of the interaction of potato – *P. infestans* with an innovative approach with genomic and high-throughput tools. Studying different kinds of potatoes and comparing them it is possible to find key resistance genes that can be easily transferred and this obtaining resistant varieties. Her studies are still in progress and it seems too soon to measure an impact based on the preliminary findings but it is expected to start to see results in about seven years. Most important, her successful experience with cassava will lead her research to cause an impact on potato too.

DESCRIPTION OF THE QUALITY OF PARTNERSHIP DEVELOPED/ESTABLISHED *(2 pages maximum)*
This should include an account of the functional involvement (i.e., roles, contribution, etc.) of actors and collaborators including scientists, civil society groups, professional organizations, private enterprises, etc. To the extent possible, please describe in terms of quantity (e.g., number of collaborators) and quality (e.g., effect over time, contribution to building social capital).

Dr. Silvia Restrepo is a member of the Institut de Recherche pour le Développement (IRD) scientific committee. Being part of this Institute has allowed her to participate in important decisions that influence third world countries.

She is an active member of the American Phytopathological Society (APS), assisting annually to the meetings and very involved with the other members in the Society. She is constantly in touch with other plant pathologists to broaden her research, keep up to date and trying to reach as much people as possible. She is a volunteer in the APS and this allows her to participate in several committees that decide the topics on the meetings. During the committees she always promotes talks from third world countries to involve the agricultural problems that these countries are facing currently.

She is an associate editor of the Phytopathology journal, one of the APS journals.

Dr. Restrepo has become a member of the American Society for Microbiology (ASM) recently. She decided to expand into the ASM to contribute with her findings in the field of mycology as an important group of in plant diseases causing agents.

Dr. Restrepo has very close academic partnership with the following:

- William Fry, Cornell University, New York, USA
- Christine Smart, Cornell University, New York, USA
- Niklaus Grünwald, USDA/ARS, Oregon, USA
- Valérie Verdier, IRD, France
- Gustavo Fermín, Universidad de los Andes, Mérida, Venezuela
- Luz Stella Lagos, Universidad de Nariño, Pasto, Nariño, Colombia
- Mary Hausbeck, Michigan State University, Michigan, USA
- Carlos Ñústez, Universidad Nacional de Colombia, Bogota, Colombia
- María Mercedes Zambrano, Gebix, Bogotá, Colombia
- Patricia del Portillo, Corpogen, Bogotá Colombia

Her partnerships include research projects, exchange of students and researchers.

LIST OF MOST SIGNIFICANT PUBLICATIONS *(1 page maximum).* *Start from the most recent.*

1- Prada, H., Ávila, L., et al. 2009. Caracterización morfológica y molecular del antagonismo entre el endófito *Diaporthe phaseolorum* aislado de frailejón (Espeletia sp.) y el fitopatógeno *Phytophthora infestans*. Rev Iberoam Micol. 26(3):198–201

2- Vargas, A.M., Ocampo, L.M.Q., et al. 2009. Characterization of *Phytophthora infestans* Populations in

Colombia: First Report of the A2 Mating Type. Phytopathology 99:82-88.

3- Haas, B. J., S. Kamoun, et al. 2009. Genome sequence and analysis of the Irish potato famine pathogen *Phytophthora infestans*. Nature 461(7262): 393-8.

4- Vargas, A.M., Correa, A., et al. 2007. First Report of Late Blight Caused by *Phytophthora infestans* on Cape Gooseberry (*Physalis peruviana*) in Colombia. Plant Dis 91:464.

5- Herman, M.A.B., Restrepo, S., and C.D. Smart. 2007. Defense gene expression patterns of three SAR – induced tomato cultivars in the field. Physiological and Molecular Plant Pathology 71:192-200

6- López, C., Restrepo, S. and V. Verdier. 2006. Limitaciones de la bacteriosis vascular: nuevos avances. Acta Biológica Vol. 11: 21-45

7- Garnica, D. P., A. M. Pinzon, et al. (2006). Survey and analysis of microsatellites from transcript sequences in *Phytophthora* species: frequency, distribution, and potential as markers for the genus. BMC Genomics 7: 245.

8- Restrepo, S., Myers, et al. 2005. Gene profiling of a compatible interaction between *Phytophthora infestans* and *Solanum tuberosum* suggests a role for carbonic anhydrase. Mol Plant Microbe Interact 18(9): 913-922

9- López, C., Soto, M., Restrepo, S., et al. 2005. Gene expression profile in response to *Xanthomonas axonopodis* pv. *manihotis* infection in cassava using a cDNA microarray. Plant Mol Biol. 57:393-410

10- Verdier, V., Restrepo, S., et al. 2004. Recent progress in the characterization of molecular determinants in the *Xanthomonas axonopodis* pv. *manihotis* – cassava interactions. Plant Mol Biol 56(4): 573-584

11- Santaella, M. Suarez, E., et al. 2004. Identification of genes in cassava that are differentially expressed during infection with *Xanthomonas axonopodis* pv. *manihotis*. Molecular Plant Pathology 5(6): 549-558.

12- López, C., Jorge, V., et al. 2004. A unigene catalogue of 5,700 expressed genes in cassava. Plant Mol Biol 56(4): 541-554.

13- Anderson, J., Delseny, M., et al. 2004. An EST resource for cassava and other species of Euphorbiaceae. Plant Mol Biol 56(4): 527-539.

14- Smart, C.D., Myers, K.L., Restrepo, S., Martin, G.B., and W.E. Fry. 2003. Partial Resistance of Tomato to *Phytophthora infestans* is not Dependent upon Ethylene, Jasmonic Acid, or Salicylic Acid Signaling Pathways. Mol Plant Microbe Interact 16(2): 141-148.

15- Ronning, C.M., Stegalkina, S.S., Ascenzi, R.A., Bougri, O., Hart, A.L., Utterbach, T.R., et al. 2003. Comparative analysis of potato expressed sequence tags. Plant Physiology 131: 419-429.

16- Restrepo, S., Vélez, C.M., Duque, M.C., and V. Verdier. 2003 Genetic structure and population dynamics of Xanthomonas axonopodis pv. manihotis populations in Colombia during 1995-1999. Applied and Environm. Microbiol. 70(1): 255-261.

17- Gonzalez, C., Restrepo, S., Tohme, J., and V. Verdier. 2002. Characterization of pathogenic and non-pathogenic strains of Xanthomonas axonopodis pv. manihotis by PCR-based DNA fingerprinting techniques. FEMS Microbiology letters 215(1):23-31.

18- Restrepo, S., Duque, M.C., and V. Verdier. 2000c. Resistance spectrum of selected Manihot esculenta genotypes under Field Conditions. Field Crops Research 65: (1) 69-77.

19- Restrepo, S., Duque, M.C. and V. Verdier. 2000b. Characterization of pathotypes among strains of Xanthomonas axonopodis pv. manihotis in Colombia. Plant Pathology 49: 680-687

20- Restrepo, S., Vélez, C. M., and Verdier, V. 2000a. Measuring the Genetic Diversity of Xanthomonas axonopodis pv. manihotis Within Different Fields in Colombia. Phytopathology 90: (7) 683-690.

21- Sánchez, G., Restrepo, S., et al. 1999. Characterization of the genetic base of resistance to cassava bacterial blight with amplified fragment length polymorphism. Genome, 42: 163-172.

22- Restrepo, S., Sánchez, G., et al. 1999b. Assessing genetic variability among Brazilian strains of *Xanthomonas axonopodis* pv. *manihotis* through RFLP and AFLP analyses. Canadian Journal of Microbiology 45: (9) 754-763.

23- Restrepo, S., Duque, M.C., et al. 1999a. AFLP fingerprinting: an efficient technique for detecting genetic variation of Xanthomonas axonopodis pv. manihotis. Microbiology 145: 107-114.

24- Verdier, V., Restrepo, S., et al. 1998. The Xanthomonas axonopodis pv. manihotis population in Venezuela: its genetic and pathogenic variation. Plant Path 47:601-608

25- Verdier, V. and S. Restrepo. 1997. Répartition géographique de la bactériose vasculaire du manioc en Colombie et variabilité du pathogène. Les cahiers de la recherche développement, 44: 16-27.

26- Verdier, V., Restrepo, S., et al. 1997. Cassava bacterial blight: recent achievements in understanding the disease. Afr. J. Root Tuber Crops, Vol 2, p. 64-68

27- Restrepo, S., and V. Verdier. 1997. Geographical differentiation of the population of Xanthomonas axonopodis pv. manihotis in Colombia. Appl Env Microbiol 63:4427-4434.

28- Restrepo, S., Verdier, V., et al. 1997. Cassava bacterial blight in South America: pathogenic and genetic characterization of the causal agent and its application to screening methods. Afr. J. Root Tuber Crops, Vol. 2, p. 61-63.