Korea Program on International Agriculture
(KOPIA)
Dominican Institute of Agricultural and Forestry Research
(IDIAF)

Final Report of Component I

Project:

Development of Technologies for the Sustainable Management of Fertigation and Diagnosis of Diseases in the Vegetable Crops for Exportation in the Greenhouse Effect Environment in San Juan, DR, with the sponsorship of the Technical Cooperation -TCP / KOPIA

Final Report of Component II

Project:

Development of Precision Fertilization and Disease Control Technology in Greenhouse Cultivation in San Juan, Dominican Republic., with the sponsorship of the Technical Cooperation -TCP / KOPIA

DOMINICAN INSTITUTE OF AGRICULTURAL AND FORESTRY RESEARCH (IDIAF)

South Center

Final Report of Component I

Mr. Martín Feliciano Frías
Research Assistant, IDIAF

Project:

Development of Technologies for the Sustainable Management of Fertigation and Diagnosis of Diseases in the Vegetable Crops for Exportation in the Greenhouse Effect Environment in San Juan, DR, with the sponsorship of the Technical Cooperation -TCP / KOPIA

Final Report of Component II

Dr. Graciela Godoy de Lutz
Principal Investigator, IDIAF

Project:

Development of Precision Fertilization and Disease Control Technology in Greenhouse Cultivation in San Juan, Dominican Republic., with the sponsorship of the Technical Cooperation -TCP / KOPIA

October, 2018

KOPIA Project Final Report

Title of the project	*Development of Technologies for the Sustainable Management of Fertigation and Diagnosis of Diseases in the Vegetable Crops for Exportation in the Greenhouse Effect Environment in San Juan, Dominican Republic. Component I*		
Responsible Cooperating Institute	Dominican Institute of Agricultural and Forestry Research (IDIAF)	**Main Researcher**	*Mr. Martín Frías Component I*
RDA/KOPIA counterpart Institute	Protected Horticulture Research Institute, National Institute of Horticulture and Herbal Science (NIHHS)	**Collaborator**	*Director Yongbum Kim*
Project Period	Aug. 2014. ~ Jul. 2017 (3 years)		
Budget	2014	USD$40,000	
	2015	USD$40,000	
	2016	USD$40,000	
	Total	**USD$120,000**	

Title of the project	*Development of Precision Fertilization and Disease Control Technology in Greenhouse Cultivation in San Juan, Dominican Republic. Component II.*		
Responsible Cooperating Institute	Dominican Institute of Agricultural and Forestry Research (IDIAF)	**Principal Investigator**	*Dr. Graciela Godoy de Lutz. Component II*
RDA/KOPIA counterpart Institute	Protected Horticulture Research Institute, National Institute of Horticulture and Herbal Science (NIHHS)	**Collaborator**	*Dr. Ju Hyeon Choi*
Project Period	Aug. 2014. ~ Jul. 2017 (3 years)		
Budget	2014	USD 40,000	
	2015	USD 40,000	
	2016	USD 40,000	
	Total amount	**USD 120,000**	

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DOMINICAN INSTITUTE OF AGRICULTURAL
AND FORESTRY RESEARCH
(IDIAF)
South Center

Final Report of Component I

Mr. Martín Feliciano Frías
Research Assistant, IDIAF

Project:

Development of Technologies for the Sustainable Management of Fertigation and Diagnosis of Diseases in the Vegetable Crops for Exportation in the Greenhouse Effect Environment in San Juan, DR, with the sponsorship of the Technical Cooperation -TCP / KOPIA

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KOPIA Project Final Report

Title of the project	Development of Technologies for the Sustainable Management of Fertigation and Diagnosis of Diseases in the Vegetable Crops for Exportation in the Greenhouse Effect Environment in San Juan, Dominican Republic		
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Contenido

1.- Summary

Agricultural Importance

The province of San Juan, which has an area of 3,569.39 km^2, located in the southwest of the Dominican Republic, has great potential to diversify its agriculture with horticultural crops under greenhouse, to supply both the local and export markets. In the province, there are more than 30,000 producers with plots of less than 3 hectares that annually sow legumes, rice, sweet potatoes and corn, important crops for food security, but with marketing problems and low prices for the producer. The Dominican government through the Ministry of Agriculture has initiated a program to improve the practices of crop management, and introduce new crops, along with planting methods which include better production technologies under protected environment (greenhouse).

In the Dominican Republic, the production under protected environment has had an extraordinary growth in the cultivated area, increasing from 2,946,319 m^2 in 2013 to 8,763,008 in 2014. The most important crops in 2014 were bell peppers, with a production of 658,241 quintals (65,824,100 kg) (corresponding to 46.92 % of the production obtained under greenhouse) and secondly the tomato, with 368,188 quintals (36,818,800 kg), which represented 26.24 % of the total produced under protected environment in that same year.

Agriculture under controlled environment requires precise management of the factors involved in the production process, including irrigation water and fertilizers, the latter being a major factor among the components of production cost, and both water and nutritious elements have a high incidence in production levels, the quality of the harvest and the profitability of the production process. The precise and effective management of fertigation is key for the success of the greenhouse production system and, with this project, it is intended to increase efficiency in the management of irrigation water and fertilizers applied jointly through pressurized irrigation systems.

With the establishment of new crops and production technologies, there is the possibility of introducing new pests or diseases that may affect the deployment and expansion of these crops. This project will contribute to the availability of specific tools to detect and accurately identify the pathogens of economic importance and quarantine that could seriously affect the production, quality and safety of high-yield horticultural crops under greenhouse and open field conditions..

Economic Importance

The general production under greenhouses in 2014 generated US$111,625,484.00 through exports, and a total of RD$904,000,000.00 for sales in the local market. Given the importance of this type of cultivation and its impact on the generation of foreign exchange, it is necessary to improve management practices and optimize the resources involved in the production process, intending with this research to contribute to the efficient management of fertigation, and to increase the productivity and profitability of this production system. In addition, to prevent losses in production due to the incidence of pests and diseases in crops under controlled environment, researchers will also work on those oriental vegetables that are currently planted in the open field in the municipality of Las Matas, where the 150 members of the Association of Agro-Exsur Exporters have invested considerable economic resources. Also, the government project for the agricultural reconversion in the province of San Juan will benefit from a planned investment of US$35 million.

Technical Importance

The method of sowing under protected environment involves the use of fertigation, which is a fundamental activity for the success of this production system, with water requirements that varies between crops, and by stages of the same crop. The estimates of the water requirements of the crops are of great importance for an adequate management of irrigation water in any agricultural production system and mainly in fertigation, where the water, in addition to its vital functions, transports the nutrients that are supplied to the soil or substrate, taking with it dissolved salts that must be delivered to the root zone of the crop with layers of water from over irrigation, for which it is also necessary to know the water demand of the crop.

In the phytosanitary management area, under this project, assets and laboratory materials that have contributed to the identification of viruses and other pathogens that cause diseases of economic importance in horticultural crops were purchased. Correct and timely diagnoses, especially in the initial stages of cultivation, such as while in seedbed, allow producers to use effective control measures and reduce the applications of pesticides, and cultural practices in greenhouses or in the open field framed within Good Agricultural Practices (GAP), will ensure the safety of their products, in addition to prevent the spread of pathogens.

Main Results and Achievements

Among the main results obtained under the first component of the project were:

- The optimal volumes of water consumption were established for each stage of the cycles of tomato (*Lycopersicon esculentum* Mill.) and pepper (*Capsicum annuum* L.) crops under protected environment.
- The levels of nitrite and nitrate leached and in drainage water were determined in the tomato crop (*Lycopersicon esculentum* Mill.) under protected environment.
- The most suitable potassium doses for the improvement of substrates in the tomato crop (*Lycopersicon esculentum* Mill.) under protected environment in the San Juan Valley (Figure 1) were determined.

- The most appropriate dose of nitrogen for the improvement of substrate in the tomato crop (*Lycopersicon esculentum* Mill.) under protected environment in the San Juan Valley (Figure 2), was determined.

Figure 1. Research activities in tomato (*Lycopersicon esculentum* Mill.) and pepper (*Capsicum annuum* L.) crops under protected environment.

Figure 2. Tomato plantation (*Lycopersicon esculentum* Mill.) in greenhouse at harvest stage.

- It was determined how the frequencies of drip irrigation affect productivity and moisture tensions in the soil for the cultivation of pepper (*Capsicum annuum* L.) in the San Juan Valley (Figure 3).
- The optimal distance between laterals (polytubes with the emitters) was established in relation to the productivity and profitability of the onion crop (*Allium cepa* L.) in the San Juan Valley (Figure 4).
- The most suitable drip fertigation programs were determined for the cultivation of pepper (*Capsicum annuum* L.) for the San Juan Valley..

Figure 3. Experiment with pepper (*Capsicum annuum* L.) in open field.

Figure 4. Onion experiment (*Allium cepa* L.) in open field.

2.- Introduction and Importance of this project

Entities of the Dominican Government, together with horticultural producers in various parts of the country, are developing a production program under protected environment in order to guarantee the supply of the domestic market and improve competitiveness for exports of the products obtained under this modality. Fertigation and proper management of pests and diseases are fundamental to the achievement of the proposed goals.

Due to the lack of a national production system of certified seed, and a laboratory equipped with instruments, reagents and qualified personnel to monitor the health situation of crops in the province, over the years pathogens that are transmitted by insects or seeds have been introduced, which have caused considerable losses in traditional crops (Arias et al., 2003). Also diseases of economic importance caused by potyviruses such as the Bean Common Mosaic Necrotic Virus (BCMNV) (ICTVdB, 2006a). Most viruses (begomoviruses and potyviruses) that affect legumes are pathogenic to Solanaceae such as tomato (*Lycopersicon esculentum* Mill) and pepper (*Capsicum annuum* L.) (Brunt et al., 1996), which are the most important crops of export that are sown under greenhouse. The introduction of other viruses such as the Tomato Spotted Wilt Virus (TSWV) and the Tomato Yellow Leaf Curl Virus (TYLCV) (ICTVdB, 2006b; 2006c) in the province, in the San Juan Valley and the rest of the southwest, would be a setback for government programs aimed at the conversion of crops in the province, in order to promote the export to markets in the United States and Europe.

There is a precedent in the country when the TYLCV was introduced to industrial tomato fields in Azua, causing losses of more than US$50 million during the years 1989-1995 (Polston and Anderson, 1997). TYLCV is a begomovirus similar to the one that causes the Bean Yellow Mosaic Virus and is transmitted by the Silverleaf whitefly *Bemisia tabaci* (Gennadius). On the other hand, the TSWV is a tospovirus transmitted by the larva and the adult of more than 20 species of thrips that are present in the Dominican Republic (Martínez et al., 2014). None of these viruses are transmitted by seed (Maule and Wang, 1996). The TSWV was reported in greenhouses of Jarabacoa, Constanza and San José de Ocoa, infecting pepper plants and tomatoes. The presence of new pathogens associated with horticultural crops in the greenhouse together with the endemic pathogens in San Juan with the ability to infect new crops, represents a threat to the production of horticultural crops of high market value.

With the economic and technical support from the KOPIA Dominican Republic Center, the IDIAF plant protection technical team based at the Arroyo Loro Experimental Station (EEAL) carries out reconnaissance visits to detect and monitor the presence of new pests or diseases and train producers about practices that prevent the introduction or dissemination of these pathogens, thus reducing the likelihood of economic losses in production or the quality of horticultural products.

The province of San Juan has great potential to diversify its agriculture by planting crops in greenhouses for local consumption and fresh export. Several producers have started production under protected environments, and the Ministry of Agriculture intends to begin a process of conversion of agricultural production in the San Juan Valley, one of the components being the establishment of infrastructure for greenhouse production, so the generation of fertigation and phytosanitary technologies is necessary to guarantee the increase in productivity, profitability and innocuousness of the production.

3. General Goal of the Project

Develop efficient management technologies and increase the productivity of export vegetable crops produced in greenhouses, focusing goals on two important aspects, such as plant nutrition and disease prevention.

General Objectives of Component I

3.1 Generation of technologies for adequate fertigation under protected environment.

3.2 The modification made for the execution of the third year had as a General objective: Validate and transfer technologies that propitiate an adequate management of the horticultural crops pepper (*Capsicum annuum* L.) and onion (*Allium cepa* L.) with fertigation system in the province San Juan.

Specific Objectives of Component I

3.1.1 *Activities within farming houses:*

3.1.1.1. Establish the optimal volume of water consumption in each stage of the pepper culture (*Capsicum annuum* L.), under protected environment.

3.1.1.2. Establish the optimal volume of water consumption in each stage of the tomato crop (*Lycopersicon esculentum* Mill.), under protected environment.

3.1.1.3. Establish the nitrite and nitrate drainage levels, coming from a greenhouse planted with tomato crops (*Lycopersicon esculentum* Mill.), in the San Juan Valley.

3.1.1.4. Obtain the optimum dose of nitrogen in tomato (*Lycopersicon esculentum* Mill.), under protected environment.

3.1.1.5. Obtain the optimum dose of potassium in tomato (*Lycopersicon esculentum* Mill.), under protected environment.

3.2.1. *Activities in Open Field:*

3.2.1.1. To evaluate the effect of the separation between laterals on the productivity and profitability of the onion crop (*Allium cepa* L.), in the San Juan Valley.

3.2.1.2. To evaluate the effect of different frequencies of drip irrigation on productivity and moisture tensions in the soil for the cultivation of pepper (*Capsicum annuum* L.) in the San Juan Valley.

3.2.1.3. To compare different drip fertigation programs for the cultivation of pepper (*Capsicum annuum* L.) in the San Juan Valley..

4.- Materials and Methods

4.1. Execution Methodology to obtain objectives 3.1.1.1. and 3.1.1.2

To determine the optimal consumption of water in each stage of the pepper crop (*C. annuum* L.) and tomatoes (*L. esculentum* Mill.), two field experiments were established, consisting of experimental units of beds or plastics containers with rice straw substrate burned as a culture medium, measured for the plantings of one, two and three plants, distributed in three blocks at random, in order to measure the unit and average consumption of experimental units with more than one plant. Containers 20 cm long x 28.5 cm wide for one plant, 40 cm long x 28.5 cm wide for two plants, and 60 cm x 28.5 cm for three plants were used, all 20.2 cm in depth. These beds were located inside a greenhouse or tropical culture house, model TME-628, 40.2 meters wide with six tunnels 70 meters long, with maximum height of 5.2 m and minimum to the channel of 3.2 m, with the ceiling of the structure in the form of an arch and fixed overhead ventilation windows of 0.70 m in height. The daily water consumption of the pepper plant was measured. For this, water was applied until the saturation of the substrate, two, three and four times per day at a fixed pre-established time (8:00 am, 3:00 pm), (8:00 am, 11:00 am and 4:00 pm), (8:00 am, 11:00 am, 1:00 pm and 4:00 pm), respectively, depending on the state of development of the plants and conditioned by the weather. From this process, consumption was obtained by subtracting the volume applied and the drained volume of each water application.

4.2. Execution Methodology to obtain objective 3.1.1.3

For the calculation of nitrate and nitrite leached from the beds with burned rice straw substrate, planted with tomato (*Lycopersicon esculentum* Mill.) under protected environment, a field experiment was installed with a planting system on beds or containers. To determine the content of nitrite and nitrate contributed by the planting system in containers with substrates and the intensive fertilizer applications that the production process of fertigation involves, samples were taken from the drainage water of different beds, and these samples were sent to the laboratories of water quality and environmental management of the INDRHI, in a monthly manner. The volume of drained water was determined by direct measurements, three times a day at preset times of 8:00 a.m., 11:00 a.m. and 4:00 p.m. from two beds or containers, with the placement of bucket at the end of the drainage channel, and measuring the volumes accumulated in the buckets between two consecutive readings, and by summing the partial volumes of each day, the daily volume was determined. Prior to the establishment of the experiment, laboratory analyzes were performed on the substrate in order to determine the initial contents of nitrate and nitrite.

4.3 Execution Methodology to obtain objectives 3.1.1.4 and 3.1.1.5

The field research was carried out in two experiments, installed on October 20, 2015, using a randomized complete block design, with seven treatments and four repetitions, installing each test in the middle of a greenhouse, located in the Arroyo Loro Experimental Station, with a total area of 2,814 m^2 (Figure 5). The experimental area of each treatment consisted of seven beds separated at 1.67 m, occupying a total area of 417.62 m^2. Each bed represented a treatment and in them the four corresponding repetitions were located. The length of block or repetition was seven meters, with 28 plants separated at 0.25 m. The evaluations were carried out in the six central plants of the block for a useful area of 2.51 m^2. Fertigation was carried out with two drip hoses per bed, providing 1.2 liters per hour per 0.20 m, with a total flow rate of 456 l/h/bed, making four daily applications of five minutes, during the first 40 days of the crop cycle, with a volume of 152 liters of water/bed.

Three applications of irrigation of 10 minutes between 40 and 75 days of the vegetative cycle, for a volume of 228 liter/day/container, and four applications of 10 minutes from 75 days after the establishment of the crop, with volume of water applied of 304 liters/day/container.

Fertilizer applications were made using five Venturi-type injectors, to supply nitrates, sulfates, micronutrients, acids, and an additional one for potassium, each Venturi contributing a flow of 60 liters/hour of nutritional solutions to the fertigation system, with electrical conductivity of 1.4 to 1.6 dS/m in the first 45 days, and from 1.7 to 2.0 dS/m after that period.

Figure 5. Investigations carried out in doses of nitrogen and potassium.

For the applications of potassium and nitrogen, the general plan of fertigation for the tomato crop of the Refrigeration and Greenhouse Market Program (PROMEFRIN), of the Ministry of Agriculture (MA), were taken as a base and treatment control, and other six alternative treatments were made, three of them constituted by doses of potassium and nitrogen higher than that of the control treatment in proportions of 10 %, 20 % and 30 % and the other three treatments constituted by doses lower than the control treatment in 10 %, 20 % and 30 %, respectively.

4.4 Execution Methodology to obtain objective 3. 2.1.1.

The experiment was installed on December 4, 2017, in the Arroyo Loro Experimental Station, in San Juan de la Maguana, located at an altitude of 419 meters above sea level, in the North Latitude 18º48' and West Longitude 71º 14', with average annual rainfall of 930 mm, average annual temperature of 24.9 ºC, and average annual relative humidity of 71.3 %. (Bera 2000, SEA 1984 and Valdez 2006).

Planting method was direct sowing, with the hybrid Sivan H 222, as this is the one that is the most used in the area. For the trial installation a randomized complete block design was used, with four treatments and four repetitions. The experimental units were composed of eight rows with separations of 0.20, 0.25, 0.30 and 0.35 meters, with four laterals for drip irrigation at 0.40, 0.50, 0.60 and 0.70 meters between laterals and 12 meters in length. The areas of the treatments were 19.2 m^2, 24, 28.8 and 33.6 m^2, depending on the separation between laterals, with a space of 1.0 m between treatments and an experimental area of 691.2 m^2. The harvest was made manually on March 22, 2018.

For the evaluations of the variables, 5.0 m of the four central rows of each experimental plot were selected for useful areas of 4.0 m^2,5.0 m^2, 6.0 m^2 and 7.0 m^2. The calculation of potential evapotranspiration was carried out using the modified Penman-Monteich method, with the help of the cropwat program, presented by the FAO using the climatological data measured daily in the meteorological station of the experimental field. For the calculation of the consumptive use, the crop coefficient (Kc) values of the onion crop were used, obtained by the method recommended by the FAO (FAO 24).

The results for the evaluated variables were subjected to analysis of variance, making, in addition, economic analysis to crop productivity, for which the partial budget methodology recommended by CIMMYT was used, to obtain the costs, benefits, and marginal rate of return for the different separations of drip laterals subjected to the comparison study (CIMMYT 1988.).

4.5 Execution Methodology to obtain objective 3. 2.1.2.

The field trial was installed on November 21, 2017, in the Arroyo Loro Experimental Station in San Juan de la Maguana, located at an altitude of 419 meters above sea level, at Latitude North 18º 48' and West Longitude 71º 14', with average annual rainfall of 930 mm, average annual temperature of 24.9 ºC, and average annual relative humidity of 71.3 % (Bera, 2000 and SEA, 1984).

The sowing of the seedbed was carried out on October 11, 2017, using seeds of the Biscayne hybrid type. The field trial was established on November 21 of the same year, using the transplant method, with a planting frame of 1.0 m x 0.30 m.

The treatments under study were five frequencies of drip irrigation with intervals of 1, 2, 4, 6 and 8 days, using for its distribution in the field a randomized complete block design with four repetitions. The experimental area occupied 1,904.0 m^2, each treatment was constituted by four rows of 12 meters in length separated by 1.0 meter between them, occupying each experimental plot an area of 48.0 m^2, with two meters of separation between plots. For the evaluations of the variables, 6.0 meters of the two central rows of each treatment were chosen, leaving as an edge 3.0 meters at both ends for a useful area of 12 m^2.

Potential evapotranspiration was calculated using the modified Penman-Monteich method, with the help of the cropwat program, presented by the FAO and using the climatological data of the meteorological station of the Arroyo Loro Experimental Station.

To calculate the water requirements of the crop, the crop water consumption factor (Kc) was used, obtained by the method presented in FAO 24 for a vegetative cycle of the pepper culture of 125 days (Doorenbos and Pritt 1978).

For the measurement of the moisture tensions in the soil, a tensiometer was installed per treatment, to which the readings were taken daily before the irrigation. While for measuring the variables numbers and weights of fruits, five cuts or collections of fruits were made manually, doing the counting and weighing of fruits obtained in the useful area of each block or repetition.

Variables measured:

Soil moisture tension	centibars (cB)
Number of harvested Fruits	
Weight of the fruit	g
Yield per harvest	Kg/ha
Total yield	Kg/ha

4.6 Execution Methodology to obtain objective 3. 2.1.3.

The trial was installed on March 7, 2018, in the agricultural field of the Arroyo Loro Experimental Station in San Juan de la Maguana, located at an altitude of 419 meters above sea level, at Noth Latitude 18º 48' and West Longitude 71º 14', with average annual rainfall of 930 mm, average annual temperature of 24.9 ºC, and average annual relative humidity of 71.3 % (Bera, 2000 and SEA, 1984).

The sowing of the seedbed was carried out in the first half of March of 2018, using pepper of the Cubanelle type, of the Biscayne hybrid. The field trial was established in April, using the transplant method, with a planting frame of 1.0 m x 0.40 m.

For the treatments under study, four fertigation programs were used for drip irrigation in the pepper crop, (T1, recommended water-soluble fertilization program based on soil analysis (PFHAS), T2, water-soluble fertilization program recommended by FERQUIDO (PFHF), T3, granulated fertilization program based on soil analysis (PFGAS), and T4, recommended by Transferagro (PFHT). For the distribution of treatments in the field, a randomized complete block design with four replications and four treatments was used. The experimental area occupied 1,080 m^2, each treatment was constituted by four rows of 12 meters in length, separated by 1.0 meter between them, occupying each experimental plot an area of 48.0 m^2, with two meters of separation between blocks. For the evaluations of the variables, 4.0 meters of the two central rows of each treatment were chosen, leaving as an edge 4.0 meters in both ends, making five fruit collections, ending the field experiment on July 31, 2018.

Treatments: the treatments under study are described in the following table:

Compared treatments	
Treatment	**Fertilization program**
T1	Water-soluble fertilization program based on soil analysis
T2	Water-soluble fertilization program recommended by FERQUIDO
T3	Granulated fertilization program based on soil analysis
T4	Recommended by Transferagro (Ultra soles)

The variables under study were:

Number of fruits	unit (u)
Weight of the fruit	g
Yield per harvest	kg/ha
Total yield	kg/ha
Cost and profitability analysis	

5. Main Results

5.1 Research under protected environment

*5.1.1. Water consumption evaluation of the pepper crop (*Capsicum annuum* L.) under protected environment, in the San Juan Valley (Figure 6).*

Figure 6. Appearance of the pepper plants (*Capsicum annuum* **L.**) in the greenhouse while being studied.

Results

The electrical conductivities (dS/m) and pH of the irrigation and drainage water, as well as the water consumption (l/m^2/day) during the crop cycle and the potential evapotranspiration (mm/day) for the exterior area of the greenhouse are shown in Table 1.

Table 1. Electrical conductivity (EC) and pH of applied nutritive solutions, water consumption of the pepper culture (*Capsicum annuum* L.), under protected environment and evapotranspiration of the experimental area, Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2015.

Period	Evaluated parameters in nutritive solutions				Water consumption (l/m^2/day)	External ET (mm/day)
	Irrigation water		Drainage water			
	EC (dS/m)	pH	EC (dS/m)	pH		
Jan 16-31	0.74	6.47	2.13	8.9	0.76	3.45
Feb 1-15	1.45	6.26	1.46	8.04	1.31	3.76
Feb 16-28	1.49	6.33	1.57	6.69	2.78	4.18
March 1-15	1.3	-	1.86	-	3.88	4.40
March 16-31	1.64	-	1.58	-	3.97	4.77
Apr 1-15	1.46	-	1.85	-	4.01	5.11
Apr 16-30	1.36	7.01	1.78	7.25	4.14	5.73
May 1-15	1.63	6.44	1.64	6.80	3.71	5.70
May 16-20	1.77	-	1.37	-	3.38	5.39

Water consumptions recorded in the test correspond to the normal behavior of annual crops.

The behavior of the climatic variables during the trial, recorded at the experimental site, are presented in Table 2. The registered temperatures were higher and the relative humidity lower than those reported by Valdez (2006) for a similar period between the years 1993-2002..

Table 2. Climatic information of the experiment period. Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2015.

Month	Maximum Temperature ºC	Minimum Temperature ºC	Average Temperature ºC	Relative Humidity%	Wind Speed km/day *
Jan	31.0	16.0	23.5	69.4	76.0
Feb	31.1	16.7	23.9	67.7	101.2
March	32.3	17.7	24.8	66.4	107.9
April	33.2	19.8	26.5	64.0	141.3
May**	33.5	19.4	26.4	62.0	162.0

* Wind speed at 2 m above ground.
** Data until the 20th
Source: Arroyo Loro Experimental Station

Conclusions

- During the period of the experiment, temperatures higher than 33 ºC were recorded in the open field, and high solar intensity inside the greenhouse, which originated temperatures of up to 50 ºC inside it and relative humidity suitable for the crop, with values that varied between 62 % and 69.4 %.
- The concentration of salts and pH of the nutritive solutions used for fertigation were within the ranges recommended for the cultivation of pepper (*Capsicum annuum* L.) on substrates, with electrical conductivity that ranged between 0.74 dS/m and 1.77 dS/m and pH between 6, 26 and 7.01.
- The monitoring of the drainage water of the beds of the crop only showed a slightly high value of 2.13 dS/m in the initial stage, with conductivity levels that oscillated between 1.37 and 1.86 dS/m, from fifteen days after the establishment of the crop until the end of the cycle.
- Under the agroclimatic conditions registered during the different stages of cultivation, the average biweekly water consumption for the cultivation of pepper under protected environment was 0.76 l/m^2/day in the first fortnight or initial stage of the cultivation; consumption oscillated between 1.31 and 3.88 l/m^2/day in the rapid development stage (between 15 and 60 days of the crop cycle); had a slight increase reaching up to 4.14 l/m^2/day in the third month of the crop cycle cultivation, and descended to 3.38 l/m^2/day in the final stage of the crop.

Recommendations

- Establish the plantations under protected environment in the San Juan Valley, between the months August-October, in order to take advantage of the months of lower temperatures and not have very high temperature peaks inside the greenhouse, and also more appropriate conditions for cultivation, in order to achieve less water consumption.
- Make a replica of this research, with the objective of validating the results presented in this technical report.
- Determine the water requirements of crops that are sown under protected environment for each production area and season.

*5.1.1.2 Water consumption evaluation of the tomato crop (*Lycopersicon esculentum* Mill.), under protected environment, in the San Juan Valley (Figure 7).*

Figure 7. Water requirement of tomato crop in a greenhouse.

Results

The behavior of the climatic variables during the trial, measured at the experimental site, are presented in Table 3. The registered temperatures were higher and the relative humidity lower than those reported by Valdez (2006) for a similar period between the years 1993-2002..

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* Wind speed at 2m above ground
** Data until the 20th
Source: Arroyo Loro Experimental Station

The electrical conductivity (dS/m) and pH of the irrigation and drainage water, as well as the water consumption (l/m^2/day), the potential evapotranspiration (mm/day) and the consultative consumption of the crop during the trial period are recorded in Table 4.

Table 4. Electrical conductivity and pH of applied nutritive solutions, water consumption of the tomato crop (*Lycopersicon esculentum* Mill.), under protected environment, and evapotranspiration of the experimental area. Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2015.

Period	Evaluated parameters in nutritive solutions				Water consumption (l/m^2/day)	External ET (mm/day)	Period
	Irrigation water		Drainage water				
	EC (dS/m)	pH	EC (dS/m)	pH			
Jan 16-31	0.95	7.16	3.31	8.92	0.87	3.45	0.25
Feb 1-15	1.71	6.33	2.89	8.24	2.16	3.76	0.57
Feb 16-28	1.93	6.22	1.93	6.97	4.96	4.18	1.19
March 1-15	1.36	-	2.65	-	6.49	4.40	1.47
March 16-31	1.54	-	2.48	-	7.44	4.77	1.56
Apr 1-15	1.72	-	2.46	-	8.05	5.11	1.58
Apr 16-30	1.30	6.73	3.58	6.86	9.37	5.73	1.64
May 1-15	1.51	6.46	2.53	6.66	8.96	5.70	1.57
May 16-20	-	-	1.84	-	9.12	5.39	1.69

Conclusions

- The temperatures registered were higher and the relative humidity lower than those reported by Valdez (2006), for the similar period of 1993-2002.
- During the period of the experiment, temperatures higher than 33ºC were registered in the open field, and high solar intensity inside the greenhouse, which originated temperatures of up to 50 ºC inside it, and relative humidity that varied between 62 % and 69.4 %.
- The concentration of nutritive salts of the solutions used for fertigation ranged between 0.95 dS/m and 1.93 dS/m, adequate values in the water for fertigation, to ensure good development of the tomato crop.
- In the monitoring of the drainage water of the sowing beds, electric conductivity values were recorded that varied between 1.84 and 3.58 dS/m, and pH between 6.66 and 8.92, with higher pH values in the initial stage of the crop.
- Conductivity levels ranged between 2.89 and 3.31 dS/m during the first month of cultivation, levels considered high for this initial stage, and between 1.84 and 3.58 dS/m in the last 30 days of the experimental period, which are acceptable ranges for that period.
- The water consumption of the crop showed an upward rhythm throughout the cycle of the tomato cultivation (*Lycopersicon esculentum* Mill.), under protected environment, with an average water requirement of 0.87 l/m^2/day in the first fortnight or initial stage of the crop. Then values oscillated between 2.16 and 6.49 l/m^2/day in the stage of rapid development (between 15 and 60 days of the crop cycle); average water consumption varied between 7.44 and 8.05 l/m^2/day during the third month or productive stage, and finally water requirements

reached 9.12 l/m^2/day in the final stage, up to 125 days after the establishment of the crop. The total water requirement of the tomato crop under protected environment was 770.10 l/m^2, equivalent to 7,701 m³ per hectare of greenhouse planted with tomato.

Recommendations

- Establish plantations under protected environment in the San Juan Valley, in the period August-October, so that the cycle coincides with the months of lower temperatures, which will lead to more appropriate conditions within the greenhouse and thus lower water consumption.
- Perform technological verification studies to validate the results obtained in this research work, on the water requirements of the tomato crop.
- Determine the water requirements of the tomato crop and others, under protected environmental in different periods of the year and locations, in order to make the irrigation applications adjusted to the water needs of the plants.

5.1.1.3. Evaluation of the levels of nitrate and nitrite leached in the drainage water in tomato crop cultivation (Figure 8).

Figure 8. Evaluation of levels of nitrate and nitrite leached in drainage water in tomato crop cultivation.

Results

The nitrate content of the water used for fertigation applications, from the José Joaquín Puello channel, was 25.08 mg/l, a level that allows this water to be used for human consumption (the World Health Organization (WHO) establishes the limit for human consumption in water at 50 mg/l). This concentration of nitrate was exceeded by the values recorded in the leached waters from the greenhouse (Table 5).

The values recorded for the pH, electrical conductivity (dS/m) and the contents of nitrites and nitrates in the drainage waters from the greenhouse planted with tomato on rice straw substrate, are shown in Table 5.

Table 5. pH, electrical conductivity (EC), Nitrite and nitrate content in the drained water, coming from tomato planting under greenhouse, 2015.

Date	pH	EC dS/m	Nitrate No_3 mg/l	Nitrite No_2 mg/l	Comment
29/01/2015	7.9	0.37	25.08	< LD	Water from the reservoir
29/01/2015	8.8	2.01	163.68	4.11	
25/02/2015	7.8	2.77	140.80	17.82	
31/03/2015	6.8	7.32	47.96	0.54	
24/04/2015	8.2	3.04	38.72	0.16	

The volumes of water applied and drained during the experiment are shown in Table 6.

Table 6. Water volumes applied and drained, IDIAF- KOPIA, 2015

Evaluation/Sowing bed					Complete Greenhouse		Volumes per hectare of greenhouse	
Area m^2	**Month**	**Vappl l/day**	**Vdrai l/day**	**% drain**	**Vappl l/day**	**Vdrai l/day**	**Vappl l/day/ha**	**Vdrai l/day/ha**
2,814	Feb	199.00	19.57	9.83	8,358.00	821.94	29,701.49	2,920.90
2,814	Mar	239.53	22.88	9.55	10,060.26	960.96	35,750.75	3,414.93
2,814	Apr	262.45	26.45	10.08	11,022.90	1,110.90	39,171.64	3,947.76

Vappl = Volume applied   Vdrai = Drained Volume   l/day = liter per day   ha = hectare

Conclusions

- The water drained from the greenhouse at Experimental Station Arroyo Loro, presented greater levels of nitrate than the one used for fertigation, measuring 25.08 mg/l and reaching a maximum level of 163.68 mg/liter, and concentrations of nitrites up to 17.82 mg/l of water.
- Higher levels of nitrate and nitrite in the drained waters of the seed beds were recorded from the beginning of flowering until the beginning of fruiting, between 15 and 45 days of the crop cycle, with values of 163.68 mg/l of nitrate and content of 17.82 mg/l of nitrite.
- In the middle stage of cultivation, production and harvest, there were decreases in the nitrate and nitrite contents of the water drained from the greenhouse, with nitrate decreasing to 38.72 mg/l and nitrite to 0.16 mg/l.
- The most dangerous nitrite and nitrate contents found in the water drained from the greenhouse used for the evaluations made in this research were recorded between 15 and 45 days of the tomato crop cycle.
- The pH (important parameter for the nutrition and development of the plants) was maintained with adequate values in most of the vegetative cycle in the drained water, being between 6.5

and 8.5, except in the initial stage in which it reached a value of 8.8, attributed to the application of total nitrogen in the form of nitrate.

- The levels of salts of the drained water, reflected by the electrical conductivity, only registered values higher than the desired range reaching 7.3 dS/m, in the period between 42 and 73 days of the vegetative cycle, with adequate values that varied between 2.01 and 3.04 dS/m in the remaining period of the crop cycle.
- In the evaluations carried out during this research, where between two and four irrigations were applied per day, 29,701 liters of water per day per hectare of greenhouse were supplied in the first month of the cycle, 35,750.75 l/day/ha during the second month, and 39,172 l/day/ha in the third month of the cycle, with a level of water drainage from the greenhouse of 9.83 %, 9.55 % and 10.08 % of the volumes of water applied, respectively.
- The water used for irrigation contained 25.08 mg/l of nitrate (lower value than that established by FAO and WHO). After being used for the productive process in the greenhouse, there were times when the nitrate contents were higher in the drained waters with levels of 140.80 and 163.68 mg/l, approximately three times higher than that established for drinking water. This nitrate content in the volume of water drained makes it unfit for human consumption.
- Taking as reference parameter the level of nitrite allowed by the WHO in drinking water (0.5 mg/l), each liter of water drained from the greenhouse with content of 4.11 mg/l of nitrite can contaminate 8.06 liters of water, for a volume of 239.235 l/day/ha during the first month of the crop cycle.
- During the second month of the crop cycle, when the drained water contained 17.82 mg/l of nitrite, it had the potential to contaminate 35 liters of nitrite-free water from the source to where they were discharged, for a volume of 1,251, 276 l/day/ha of greenhouse.

Recommendations

- Carry out evaluations in the different planting areas under protected conditions, of the nitrate and nitrite levels of the drained water from the production structures and the possible contamination of the surface or underground water sources where they end.
- Establish monitoring points in water sources after receiving discharges from waters coming from areas with large greenhouse production areas.
- Optimize the use of water and fertilizers to reduce drained quantities coming from greenhouses.
- Perform periodic evaluations to determine nitrate and nitrite levels of those water sources that are used for human consumption, after receiving greenhouse waters.

5.1.1.4 Evaluation of different doses of nitrogen in the tomato crop (Lycopersicon esculentum Mill) (Figure 9).

Figure 9. Evaluation of different doses of nitrogen in the tomato crop

Results

The statistical analysis showed no significant differences (α = 0.05) for the variables fruit diameter, average fruit weight or Brix for the doses of N evaluated (Table 7).

When evaluating the yield, the treatment with 30 % increased N is significantly higher (α = 0.05) than the repetitions with 10 % increased, 30 % reduced, and the control, as shown in Table 7..

Table 7.- Performance components evaluated and tomato crop yield

Treatment	Fruit Diameter (mm)			Fruit Weight (g)	Brix %	Yield (kg/ha)
	maximum	minimum	average			
1 (+10%)	80.00	63.80	72.25	182.41	4.43	52,938.25 bc
2 (+20%)	82.90	59.82	74.70	201.25	4.40	61,543.83 ab
3 (+30%)	81.91	59.19	73.39	204.81	4.28	65,627.49 a
4 (-10%)	79.75	59.54	72.04	189.57	4.27	57,808.77 abc
5 (-20%)	81.10	58.52	73.53	186.66	4.17	60,677.29 abc
6 (-30%)	80.46	63.80	73.14	186.56	4.28	49,925.30 c
7 (Control)	80.91	61.85	72.41	179.37	4.26	50,732.07 bc

Conclusions

- The pH levels dropped from 8.3 in the substrate used, from alkaline to slightly acid, for all doses of nitrogen under study, with values between 5.7 and 6.2, which are within the adequate range to favor the availability of nutrients for the plants.
- The contents of salts represented by the electrical conductivity went from values lower than 0.75 dS/m in the substrate used to values between 0.90 and 2.15 dS/m in the final substrates of the different treatments, normal situation when fertigation is used in substrate or hydroponics, since the nutrients that are applied contain dissolved salts and for the tomato crop the conductivity can be higher than 2.15, mainly in the productive stage, without affecting the physiology of the plant, being recommended slightly saline levels to improve the quality of the fruits.
- The fertigation programs applied for the different doses of nitrogen, improved the nutrient contents of the substrates of the different experimental plots, except the calcium levels, which decreased in all the treatments compared, reaching levels below the desired ones.
- The levels of electrical conductivity of the drained water from the sowing beds, measured in the daily monitoring, showed a general average of 3.17 dS/m and variation between 1.30 and 7.66 dS/m, with values above 3.5 dS/m occasionally in some parcels, from the third fortnight. The high values of EC indicate the moments in which it is necessary to carry out a control measure of salts in the substrate, mainly washed by the applications of layers of water or application of irrigation without fertilizers or with reduced doses.
- The pH levels of the water drained from the beds with values between 6.09-8.07 are considered adequate for the balance and availability of the nutrients.
- The fruits obtained with the different doses of nitrogen submitted to the comparison study had an equatorial diameter between 58.52 and 82.90 millimeters, weighing 179.37 and 204.81 grams, and brix between 4.17 and 4.43 %. These values are within the ranges considered adequate for each of these characteristics in commercial tomato fruits.
- The total yield of the nitrogen dose increased by 30 %, 65,627.49 kg/ha, was the highest, exceeding the 49,925.30 kg/ha, 50,732.07 kg/ha and 52,938.25 kg/ha obtained with reduced nitrogen doses in 30 % of the control treatment and increased by 10 %, respectively, and at the same time statistically equal to the levels of yields with the nitrogen dose increased by 20 %, as well as to the yields of the doses reduced by 20 % and 10 %.
- The yield corresponding to the nitrogen dose increased by 20 % (61,543.83 kg/ha) was statistically higher than that obtained with the reduced dose in 30 %, 49.925.30 kg/ha and equal to all the others.
- The yield of the reduced nitrogen dose by 30 %, was found to be lower and statistically equal to those obtained with the increased doses in 10 %, as well as for those reduced in 10 and 20 % and to the performance of the control treatment, for α=0.05..

Recommendations

- Perform validation study to confirm the firmness of the results obtained.
- Evaluate the yields of the complete production cycle, and include economic analysis to define the levels of profitability of the different doses of nitrogen.
- Maintain continuous monitoring of pH and electrical conductivity of the nutrient solution and water drained from the seedbeds to maintain adequate levels of both, and make the necessary adjustments to ensure adequate conditions for the assimilation of nutrients and the development of plants.

*5.1.1.5 Evaluation of different doses of potassium in the tomato crop (*Lycopersicon esculentum* Mill.) (Figure 10).*

Figure 10. Evaluation of different doses of potassium in the tomato crop.

Results

The statistical analysis showed no significant differences for the variables fruit diameter, average fruit weight, Brix grade, or total yield for the N doses evaluated ($\alpha = 0.05$) (Table 8).

Table 8. Performance components evaluated and crop yield.

Treatment	Fruit Diameter (mm)			Fruit Weight (gr)	Brix %	Total Yield (kg/ha)
	maximum	minimum	average			
1 (+10%)	83.41	62.97	74.81	195.71	4.15	55,348.61
2 (+20%)	81.49	61.39	73.85	197.74	4.20	58,944.22
3 (+30%)	83.63	61.96	74.14	197.91	4.27	53,247.01
4 (-10%)	82.37	59.24	74.26	195.79	4.15	57,410.36
5 (-20%)	81.96	61.45	72.94	190.29	4.19	46,822.71
6 (-30%)	84.99	61.72	74.70	206.01	4.24	53,819.72
7 (Control)	83.03	63.37	74.44	200.40	4.21	54,721.12

Conclusions

- The chemical conditions of the substrates improved for all the treatments, with pH that went from alkaline between 8.1 and 8.3 to slightly acidic, oscillating between 6.2 and 6.7, adequate levels for the availability and absorption of nutrients.
- The conductivity levels of the drained water from the seedbeds varied between 1.27 and 4.24 dS/m and pH not higher than 8.5, with average values that are considered adequate for fertigation, in tomato planting on substrate.
- The fruits evaluated with diameters between 59.24 mm and 84.99 mm are classified among the sizes suitable for commercialization, and the degree brix with variation between 4.15 and 4.27 % are among the range considered suitable for the tomato fruit.
- Despite the increase and reduction, by up to 30 %, of the potassium dose recommended by PROMEFRIN for tomato cultivation under greenhouse conditions, no statistically significant differences were found for α of 0.05, in the evaluated yield components, nor in the yield of the tomato crop in the San Juan Valley.

Recommendations

- Carry out a validation study of the potassium doses compared in this research work, making evaluations of the complete crop cycle, and include economic analysis in case there are significant statistical differences in yield..

5.2 Results of research in the open field

5.2.1. Effect of the separation of the laterals on the productivity and profitability of the onion crop in the San Juan Valley (Figure 11).

Figure 11. Effect of the separation of the laterals on the productivity and profitability of the onion crop in the San Juan Valley.

Results

When analyzing the equatorial perimeter of the bulbs and the weight of the same, no significant statistical differences were found (α = 0.05) between the treatments evaluated (Table 9).

When studying the yield (kg/ha), it was found that the lateral separations of 0.40 m and 0.50 m are statistically equal to each other, but significantly higher than the 0.70 m separation (α = 0.05). The 0.60 m separation was intermediate between the others (α = 0.05).

Table 9. Perimeters of the bulbs (cm), weight of the bulbs (gr) and yield (kg/ha), in onion culture (*Allium cepa* L.).

Lateral Separation (m)	Equatorial perimeters of the bulbs (cm)	Bulb weight (gr)	Yield kg/ha
0.40	13.95	36.91	23,229.17 A
0.50	15.15	43.95	22,500.00 A
0.60	16.36	56.75	18,958.33 AB
0.70	15.15	52.34	17,142.86 B

In the economic analysis it was determined that the costs varied between 76,728 and 111,286 pesos per hectare, and the net benefits varied between 820,297 and 1,107,129 pesos, with decreasing costs and benefits inversely proportional to the separation of the laterals (Table 10).
The marginal rates of returns corresponding to the different lateral separations evaluated varied between 1,529 and 173 %, with a higher rate of return for the lateral separation of 0.50 meters, corresponding the lowest rate of return to the lateral separation of 0.40 meters (Table 10 and Figure 12).

Table 10.- Variable cost, net profit and marginal rate of return of the different lateral separations in the onion crop.

Lateral Separation (m)	Variable Cost RD$/ha	Net Profit RDS/ha	Marginal Rate of Return %
0.70	76,728	820,297	-
0.60	82,364	906,492	1,529
0.50	93,116	1,075,665	1,573
0.40	111,286	1,107,129	173

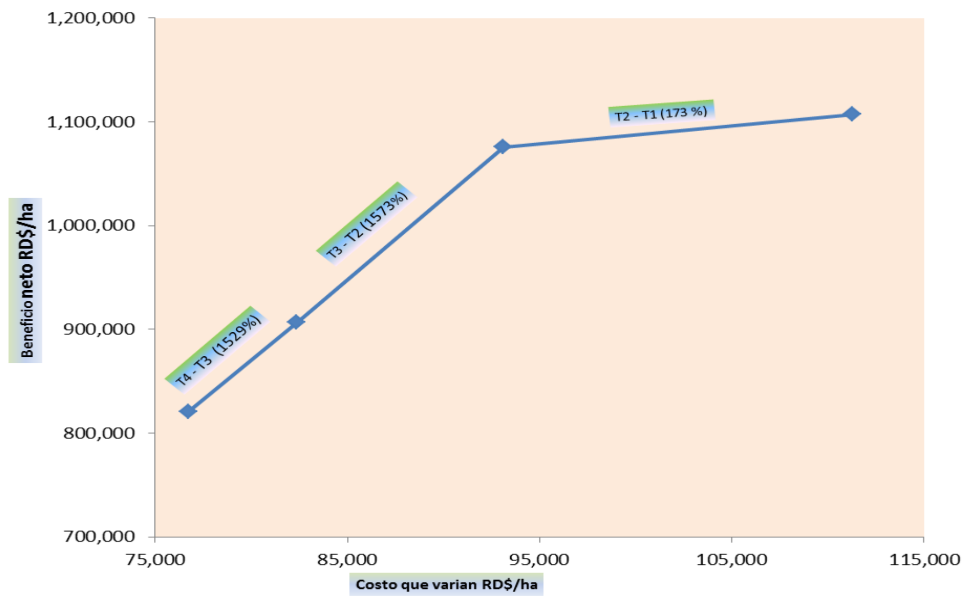

Figure 12. Marginal rate of return

Conclusions

- In the analyzes, no significant statistical differences were found between the equatorial perimeters of the bulbs, as well as for the bulb weights.
- The highest yields 23,229.17 kg/ha and 22,500 kg/ha corresponded to the separations between laterals of 0.40 meter and 0.50 meter, respectively, which were statistically higher than the 17,142.86 kg/ha obtained in the separation between laterals of 0.70 meter for an $\alpha = 0.05$.
- The yield of the lateral separation of 0.60 meters, 18,958.33 kg/ha, was statistically equal to all the others.
- The lower variable costs and net profit corresponded to the separation between laterals of 0.70 meters, with an increase inversely proportional to the lateral separations.
- The marginal rate of return when passing between lateral separation from 0.70 to 0.60 m was 1,529 %, which represents a return of 15.29 pesos for each peso invested by reducing the centimeters between laterals.
- By reducing the separation of the laterals from 0.60 meters to 0.50 meters, the rate of return reaches a value of 1,573 %, which indicates that for each peso invested an additional benefit of 15.73 pesos is obtained.
- When calculating the marginal rate of return for the reduction of lateral separation from 0.50 meters to 0.40 meters, a value of 173 % was obtained, which represents an additional return of 1.73 pesos for each peso invested to irrigate the onion crop.
- The highest yield of the onion crop was obtained with the separation between laterals of 0.40 meters, however, the higher marginal rate of return, 15.73 pesos for each additional Dominican peso invested in the tube with the emitters, corresponded to the separation between sides of 0.50 meters..

Recommendations

- Establish plots of technological validation at a commercial level, to compare the lateral separations.
- Based on the results obtained in this investigation, for commercial sowing of the onion crop with drip irrigation, it is recommended to place laterals separated from each other at 0.50 meters, with rows of plants separated at 0.25 meters, with which good yields and the higher rate of return of resources invested in drip hose and seeds are obtained

5.2.2. Effect of drip irrigation frequency on moisture tensions in the soil in the pepper crop (Figure 13).

Figure 13. Effect of drip irrigation frequency on moisture tensions in the soil.

Results

The average values of moisture tension in the soil, at 30 cm in depth, during the course of the month of December, varied between 7.9 and 20.4 centibars (cb), with the lowest value for the frequency of daily watering and the highest for the application of water every eight days. While the average values of the moisture tensions for the month of January ranged between 11.5 and 64.1 cb, with lower tension for daily water applications and higher for irrigation frequency of four days. The variations of the average tensions recorded in the month of February varied between 0 and 31.8 cb, with lower values for irrigation applications every 4 days and higher values for irrigation every eight days (Table 11).

The average values of tensions registered at depth of 60 cm, in the months of December and January were less than 20 cb for all the irrigation frequencies studied and average above 30 cb only for the irrigation frequencies of four and eight days, recorded in the month of February (Table 11).

Table 11. Soil moisture tensions recorded during the test. Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2018.

Month		Reading of the Tensiometers (30 cm) (cb/treatment)					Reading of the Tensiometers (60 cm) (cb/treatment)				
		T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
Dec	Average	7.9	14.6	23.7	8.2	20.4	10.4	15.6	10.8	15.0	15
	Minimum	3.0	4.0	2.0	2.0	7.0	6.0	10.0	8.0	2.0	10
	Maximum	20.0	20.0	-	17.0	46.0	17.0	17.0	13.0	19.0	18
Jan	Average	11.5	33.6	-	15.5	48.9	8.9	17.8	17.5	16.7	17.3
	Minimum	7.0	20.0	-	7.0	34.0	5.0	15.0	12.0	14.0	7
	Maximum	18.0	48.0	-	32.0	64.0	10.0	22.0	23.0	19.0	20
Feb	Average	8.8	8.5	-	28.0	31.8	1.8	18.4	50.3	28.8	34.1
	Minimum	0.0	2.0	-	0.0	12.0	0.0	14.0	46.0	18.0	15
	Maximum	18.0	12.0	-	52.0	58.0	8.0	24.0	56.0	48.0	47

The behavior of the climatic variables during the period of the experiment is shown in Table 12.

Table 12. Climatic information of the experiment period. Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2018.

Month	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Average Temperature(ºC)	Relative Humidity (%)	Wind Speed (km/day) *	ET (mm/day)
Dec	30.4	16.4	23.5	79.0	2.0	2.70
Jan	29.7	17.5	23.6	71.0	2.0	2.35
Feb	31.1	14.0	22.5	59.0	2.0	2.96
Mar	31.6	16.9	24.3	58.0	3.0	3.47

* Wind speed at 2 m above ground.
Source: Arroyo Loro Experimental Station

The number and weight of fruits (g), and yield (kg/ha) recorded for the five harvests made is shown in Tables 13, 14 and 15, respectively, for each irrigation frequency evaluated. The analysis of variance did not show significant differences between the irrigation frequencies studied ($P \leq 0.05$) for any of these variables.

Table 13. Number of harvested fruits. Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2018.

Irrigation frequency	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Total
Daily	33	73	109	45	69	329
Every 2 Days	28	86	70	60	55	299
Every 4 Days	38	71	122	58	58	347
Every 6 Days	42	88	105	56	73	364
Every 8 Days	40	84	89	58	64	335

Table 14. Fruit weight (g). Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2018.

Irrigation frequency	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Average
Daily	76.93	88.85	65.77	45.67	56.33	66.71
Every 2 Days	76.69	89.73	60.53	48.58	51.26	65.36
Every 4 Days	85.83	88.98	58.84	44.82	53.11	66.32
Every 6 Days	74.37	83.48	62.69	47.26	54.80	64.52
Every 8 Days	71.87	81.77	64.17	52.06	51.87	64.35

Table 15. Yield (kg/ha). Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2018.

Irrigation frequency	Treatments	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Total
Daily	**1**	2,123.75	5,374.50	6,006.50	1,677.25	3,201.25	18,383.25
Every 2 Days	**2**	1,789.75	6,378.50	3,597.00	2,433.50	2,350.75	16,549.50
Every 4 Days	**3**	2,386.00	5,244.75	5,876.50	2,155.50	2,557.25	18,220.00
Every 6 Days	**4**	2,693.25	6,018.75	5,350.75	2,309.25	3,278.00	19,656.00
Every 8 Days	**5**	2,433.00	5,676.00	4,742.50	2,403.75	2,575.00	17,830.25

Conclusions

- The monthly average values of humidity tensions varied between 7.9 and 48.9 centibars, with higher tensions for drip irrigation frequency of eight days and lower for daily irrigation applications.

- The variables number of fruits, fruit weight and crop yield evaluated for drip irrigation frequencies from daily up to 8 days for the cultivation of pepper (*Capsicum annuum* L.), in soil of clay texture, did not reflect significant statistical differences.

Recommendations

- Carry out a validation study of drip irrigation frequencies in soils with clay texture, to confirm the results and be able to make recommendations based on the information obtained in this research work.
- Conduct similar studies in different types of soil, areas and seasons of the year, for the cultivation of pepper.

5.2.3. Evaluation of different drip fertigation programs for the cultivation of pepper (*Capsicum annuum* L.) in the San Juan Valley (Figure 14).

Figure 14. Evaluation of different drip fertigation programs for the cultivation of pepper.

Results

For the number of harvested fruits, only significant statistical differences were found among the fertilization programs evaluated in the third cut (α = 0.05), as shown in Table 16. In said cut (harvest or collection), the fertilization program recommended by Transferagro (T4) was significantly superior to the granulated fertilization program based on soil analysis (T3). The water-soluble program based on soil analysis (T1) and water-soluble recommended by FERQUIDO (T2) were intermediate in that third cut. Differences were not found in the other harvests or in the total of fruits (Table 16).

Table 16.- Number of harvested fruits (unit). Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2018.

Fertilization Program	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Total
Water soluble according to soil analysis (T1)	44.50	96.00	107.25 AB	172.00	122.75	543
Water soluble FERQUIDO (T2)	47.75	90.25	131.00 AB	174.5	155.75	599
Granulated according to soil analysis (T3)	37.00	77.5	100.25 B	166.00	140.00	521
Transferagro (T4)	35.75	70.00	158.00 A	206.00	201.00	671

For the weight of harvested fruits, only significant statistical differences were found among the fertilization programs evaluated in the second harvest ($\alpha = 0.05$), as shown in Table 17. In said cut, the fertilization program recommended by Transferagro (T4) was significantly superior to the water-soluble fertilization program based on soil analysis (T1). Granulated program based on soil analysis (T3) and water-soluble recommended by FERQUIDO (T2) were intermediate in that second cut. In the other harvests, no differences were found in the average fruit weight (Table 17).

Table 17. Fruit weight (g). Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2018.

Fertilization Program	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Average
Water soluble according to soil analysis (T1)	58.80	68.97 B	68.29	56.27	59.66	62.40
Water soluble FERQUIDO (T2)	64.31	70.16 AB	68.98	54.69	57.34	63.10
Granulated according to soil analysis (T3)	64.76	76.29 AB	76.26	60.81	63.34	68.29
Transferagro (T4)	62.75	84.05 A	76.53	62.83	55.34	68.30

Regarding the fruit yield variable (kg/ha), no significant statistical differences were found in the first four harvests ($\alpha = 0.05$). However, for the yield of the fifth cut and for the total yield, significant statistical differences were found between the fertilization programs at the same probability level (Table 18). In the fifth harvest, the program recommended by Transferagro was significantly superior to the water-soluble according to soil analysis. The other two programs were intermediate and equal to each other (Table 18). In the case of total yield, the program recommended by Transferagro was significantly superior to the granulated program according to soil analysis. The other two programs were intermediate and equal to each other (Table 18).

Table 18. Yield (kg/ha). Arroyo Loro Experimental Station, San Juan de la Maguana, DR, 2018.

Fertilization Program	Harvest 1	Harvest 2	Harvest 3	Harvest 4	Harvest 5	Total
Water soluble according to soil analysis (T1)	3275.23	8460.08	9376.94	11918.02	9051.38 B	42081.48 AB
Water soluble FERQUIDO (T2)	4087.06	7671.58	11213.77	11442.77	11605.71 AB	46020.48 AB
Granulated according to soil analysis (T3)	2571.98	6898.08	9242.19	11900.44	10805.63 AB	41417.90 B
Transferagro (T4)	2950.50	7309.25	14706.50	13634.75	15069.50 A	53670.50 A

In the economic analysis, variable costs were determined between RD$17,726.45 and RD$69,060.92 pesos per hectare. The lowest cost was obtained by T3, application of granulated fertilizers, and the higher cost for the water-soluble fertilization program T4, using Ultra Soles fertilizers (Table 19).

Net benefits ranged between RD$414,968.08 and RD$522,545.12 pesos per hectare, with the lowest benefit corresponding to T1, with applications of water-soluble fertilizers, recommended by the results of the chemical soil analysis and greater net benefit for the T4 treatment (Table 19).

The marginal rates of returns were between 4,943 and 38,513 %, with a higher rate of return for the water-soluble treatment T4 and lower for the T2 treatment, registering a decrease in the net benefit when switching from granulated fertilizer applications to T1 (Table 19 and Figure 15).

Table 19. Variable cost, net benefit and marginal rate of return of the different lateral separations in the pepper culture (*Capsicum annuum*** L.)**

Fertilization program	Variable costs RD$/ha	Net Benefit RD$/ha	Marginal Rate of Return %
T3	17,726.45	438,893.07	-
T1	48,893.03	414,968.08	-
T2	51,678.79	455,601.63	4,943%
T4	69,060.92	522,545.12	38,513%

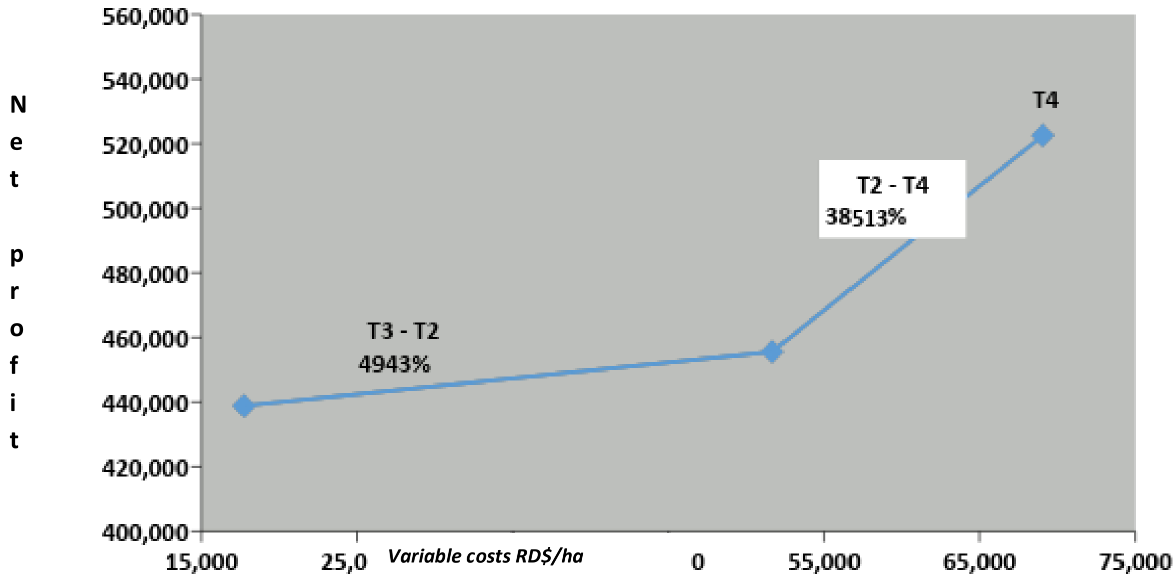

Figure 15. Marginal rate of return

Conclusions

- When evaluating the numbers of fruits per harvest and totals, only significant statistical differences were recorded in the third cut, with numbers that varied between 166 and 206 units, resulting in an increase in the number of fruits harvested with the T4 treatment, with Ultra Soles fertilizers.
- In the weight of fruits and average, only significant statistical differences were found in the second harvest, with fruits that weighed between 68.29 and 84.05 grams, exceeding the weight of the fruits of T4 those of T1, resulting in the weights of fruits of the treatments 2 and 3 statistically equal to each other and to the other fertilization programs.
- The yields obtained by harvest only showed significant statistical differences for $\alpha = 0.05$ in the fifth cut, with yields that varied between 9,051.38 and 15,069.50 kg/ha, with higher yield for T4, which was higher than the yield obtained with T1.
- The total yields of the different fertilization programs ranged between 41,417.90 and 53,670.50 kg/ha, with a higher yield for the water-soluble fertilizer applications T4, which was statistically superior to the yield obtained with the applications of T3 granulated fertilizers.
- The lowest investment in fertilization (17,626.45 RD$/ha) corresponded to granulated fertilizer applications (T1), with a higher fertilization cost (69,060.92 RD$/ha), for the water-soluble fertilization program T4.
- The lowest net benefits are obtained by moving from granulated fertilizer applications to water-soluble fertilizers recommended by soil analysis results, while the greatest benefit was the change from the water-soluble fertilization program T2 to the water-soluble program T4.
- The T2, requiring more investment in fertilizer than T3 and providing lower benefits than this, was dominated by T1.

- The marginal rate of return when passing from granulated fertilizer applications, T3, to the water-soluble fertilizer program, T2, was 4.943 %, contributing 49.43 pesos for each peso invested in fertilizers.
- The highest marginal rate of return (38.513 %) was obtained by changing from the water-soluble fertilization program T2 to the water-soluble program T4, obtaining a return of 385.13 pesos for each peso invested when changing from T2 to T4.

Recommendations

- Establish a plot of technological validation at commercial level for the verification of the results obtained in this research work.
- In drip irrigation systems, make post-sowing applications through fertigation, as it is less tedious and provides additional benefits.
- In granulated fertilizer applications, incorporate it into the soil next to the rows of plants or in a circle.
- Perform soil chemical analysis to define the nutrients and levels that should be applied to crops.

5.3 Dissemination and training activities (Courses, seminars, workshops, meetings, reports and others)

5.3.1 Preparation of quarterly and annual reports on the activities carried out within the framework of the project.

5.3.2 Realization of seven work meetings with the participation of the research management, the planning and monitoring unit of the IDIAF, the management and administration of the South Center and project technicians, with the purpose of defining strategies for technical management of the project. (Figure 16).

Figure 16. View of the participants in a work meeting about the project.

5.3.3 Realization of the seminar: Introduction of the Vegetable Industry of Korea and the Production of Vegetables under Protected Environment, with the presentations of PhD technicians of the Republic of South Korea. Held at Arroyo Loro Experimental Station, South Center, IDIAF, San Juan de la Maguana, DR.

5.3.3.1. Conferences/Seminars on the KOPIA/IDIAF research project.

5.3.3.2. Seminar: Korea Horticultural Industry and Greenhouse Vegetable Production Techniques (Figure 17).

Figure 17. View of the seminar participants "Korea Horticultural Industry and Greenhouse Vegetable Production Techniques".

5.3.4. Consultation meeting of the KOPIA Cooperation project, with the participation of IDIAF technicians and the Korea Commission (Figure 18).

Figure 18. View of the KOPIA Cooperation Project Commission.

5.3.5. Presentations of experiments established in the greenhouse of the Arroyo Loro Experimental Station to visitors of the KOPIA Center, DR.

5.3.6 Field day "Presentation of project progress and work in progress to authorities of the agricultural sector, representatives of KOPIA DR Center, technicians and producers" (Figure 19).

Figure 19. View of the activities developed in the field day.

5.3.7 Presentation on the progress of the project to a visiting commission from South Korea, representatives of the KOPIA Dominican Republic Center, and representatives from the IDIAF (Figure 20).

Figure 20. View of presentations made about the project progress.

5.3.8 Visit to South Korea of technicians involved in the project to participate in training on post-harvest management of horticultural crops, held in Jeonju from June 13 to 16, 2016 (Figure 21).

Figure 21. View of participants in training and exchange in South Korea.

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DOMINICAN INSTITUTE OF AGRICULTURAL
AND FORESTRY RESEARCH
(IDIAF)
South Center

Final Report of Component II

Dr. Graciela Godoy de Lutz
Principal Investigator, IDIAF

Project:

Development of Precision Fertilization and Disease Control Technology in Greenhouse Cultivation in San Juan, Dominican Republic., with the sponsorship of the Technical Cooperation -TCP / KOPIA

October, 2018

KOPIA Project Final Report

Project Title	Development of Precision Fertilization and Disease Control Technology in Greenhouse Cultivation in San Juan, Dominican Republic. Component II.		
Cooperative Institute	Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF)	**Principal Investigator**	*Dr. Graciela Godoy de Lutz. Component II*
RDA/KOPIA counterpart Institute	Protected Horticulture Research Institute, National Institute of Horticulture and Herbal Science (NIHHS)	**Collaborator**	*Dr. Ju Hyeon Choi*
Project Duration	Aug. 2014. ~ Jul. 2017 (3 years)		
Budget	2014	USD 40,000	
	2015	USD 40,000	
	2016	USD 40,000	
	Total amount	USD 120,000	

Contenido

1. Summary

The aim of component II of this project focused on identifying diseases and their causal agents affecting newly introduced horticultural crops in the San Juan and Elias Pina provinces, located in the southwest region of the Dominican Republic. Recently, as a result of an import ban to vegetables grown in the Dominican Republic by United States due to the introduction of the Mediterranean flruit fly *Ceratitis capitata* (Wiedemann),vegetable exports plummeted and producers losses led to many bankruptcies and mounting debts. After the pest was eradicated in 2016 there is a renewed interest in growing more horticultural crops for export to substitute low cash crops that are traditionally grown in San Juan and Elias Pina. Traditional farmers are facing the new challenges of learning to grow these crops and to manage pest and diseases unknown in the region, without recurring to excessive use of pesticides. The San Juan and Elias Pina provinces located in the southwest of the Dominican Republic have the potential to diversify its agriculture and to expand to other export crops such as tomato, bell and habanero pepper among others grown under greenhouse or open field conditions for local and export markets In San Juan there are more than 30,000 growers with less the than 3 hectares who produce legume, rice, sweet potato and corn crops which are important for food security but of low cash value in the local market. To increase farmers income through planting of high cash crops in greenhouses and open fields, Dominican government institutions such as the Ministry of Agriculture and IDIAF have launched programs dealing with studies on marketing and adaptation of oriental vegetables to the southwest environment and cropping system, and handling and packing vegetable for exports. This project can contribute with information on pest and diseases for risk assessment analysis for establishing new crops in an area where traditional legume and solanaceous vegetable crops have been grown for decades. The adaptation or emergence of new insect pests and diseases can occur and cause yield and quality losses. Neither San Juan or the neighboring provinces have trained agronomy personnel specialized in crop protection except for IDIAF personnel working at the only crop protection diagnostic laboratory in the Southwest part of the country. The laboratory lacks equipment and reagents to address emergence of problems especially those that cannot be identified by microscopic examination such as virus which requires serological or molecular techniques for accurate identification. During the length of this project we had funds available to purchase basic equipment, materials and serological kits which contributed to identified virus and insect newly introduced that were prevented to spread and contained with measures within the guidelines of Good Agricultural Practices Scheme and Food Safety protocols that were implemented by the growers. The economic importance of this project relied on giving technical support and conducting basic research that prevented major losses of vegetable for export. By providing accurate pest/disease diagnosis growers were able to maintain their export business, therefore protected their investments closed to US $ 1,000,000 in trickle irrigation systems and packing warehouse in Las Matas, also a US $ 35 million- investment in greenhouse technology for vegetable crops with potential for exporting up to US $ 98 million in vegetables to USA and European markets that could be jeopardized if important plant pathogens such as viruses are introduced from old infested to clean new growing areas.

- Goal

To identify and monitor endemic or emerging pest and diseases that threatens vegetable production in San Juan and Elias Pina to prevent their spread or yield and market losses by providing accurate recommendations to local growers.

Results and major achievements

The overall results and major achievements of this project's component were the following:

1. Identification of two major economically important diseases, never reported in the southwest, known as Downy Mildew caused by the fungus *Pseudoperonospora cubensis* (Berk. & Curt.) Rost and Tomato Spotted Wilt Virus (TSWV) caused by a tospovirus (genus *Tospovirus*; family *Bunyaviridae*) (TSWV). Downy mildew caused economic yield losses in export melons in 2016 Las Matas and TSWV affecting yields and the quality of the peppers, tomatoes, eggplant and bitter squash in open fields and greenhouses in Las Matas, San Juan and Elias Pina from 2015 to 2017. A third pathogen *Pythium aphanidermatum* (Edson) Fitzp. was found to cause seedling death in seedbeds purchased by the growers from the same company where TSWV-contaminated seedlings were detected in 2015.
2. Identification of the source of the TSWV epidemic as originated from infected seedlings transported from heavily infested locations in the mountains of San Jose de Ocoa. We recommended management practices, such as local preparation of seedbed in the greenhouse instead of purchasing seedlings from companies that produce vegetable nurseries in highly infested areas in other provinces. In addition, we located and mapped hot spots where the virus caused severe yield losses.
3. By serology with ImunoStrip® and InmunoComb® we detected the presence of TSWV and other viruses such as Tobacco Mosaic Virus, Cucumber Mosaic Virus and an unknown Potyvirus were also recorded in Pedro Corto and Escondido associated to tomato, chili and table pepper. The confirmation of the species and strains of the viruses need to be confirmed by RT-PCR. At the end on this project, outbreaks of TSWV have been contained beyond the hot spot locations because the most of the vegetable seedbeds are produced locally reducing the chances of incoming infested plant material. Since other virus detected during the survey might be seed transmitted also, we recommended the growers to obtain vegetable seed from reputable companies.
4. We conducted two workshops for the vegetable growers to share research results and provide guidelines and recommendations to grow healthy and high quality vegetables for exports. The first workshop was held in February 2015 in Las Matas, San Juan and the second at the Arroyo Loro Station in San Juan in 2017.
5. Through our visits to growers and workshops, the vegetable growers in San Juan were made aware of the pest and diseases affecting their crops, especially the presence of TSWV and other potentially damaging viruses and agronomic practices to prevent the spread of the pathogens between farms.
6. Visit to South Korea by component II research collaborators.

Plan for the next year

Because the project ended in July 2017 we will attempt to submit a new project dealing training the growers on the applications of good agronomic practices aim at reducing the use of pesticides in export vegetables. Also we plan to contact Korean researchers to aid identified multiple virus and their biotypes or strains found in San Juan.

2. Introduction and importance of this project

The Dominican Republic is emerging as one of the Caribbean island with potential for increasing traditional and oriental vegetable exports to United States, Europe and other islands in the Caribbean. The growth of export vegetables whether in open fields or greenhouse has been limited to the Cibao Valley and Costanza and Jarabacoa in the North and San Jose de Ocoa in the South. However the need to increase exports and substitute low for high cash crops in the southwest has prompted the Dominican government though the Ministry of Agriculture and other related agencies to draw private as well as government investments in greenhouse, trickle irrigation systems and packing facilities in the region and to facilitate loans for diversifying the agriculture system and growing high cash crops under greenhouse systems. The San Juan province has the agro climatic conditions for growing crops under greenhouse system and the availability of fertile land and low annual rainfall adequate for vegetable growth. Due to the slow economic development in the southwest region of the country, there is a need for expanding their traditional agriculture into a more dynamic agribusiness for export, therefore to improve the livelihood of more than 30,000 growers who traditionally grow legumes, rice, sweet potato and corn, crops which are important for food security but have low cash value in the local market.

Due to a lack of a formal seed certification system, a well-equipped crop protection laboratory and research and technology transfer funds there has been an emergence and spread of diseases transmitted by either seed or insect pests. Important economic diseases such as those caused by the potyvirus Bean Common Mosaic Necrotic Virus (BCMNV) (ICTVdB, 2006a). This disease alone caused total yield losses in farms in the San Juan Valley and San Rafael del Yuma in the eastern part of the country over ten years ago (Arias et al. 2003).

Most viruses (begomovirus and potyvirus) that affect legumes and also pathogenic to *Solanaceae* crops such as tomato (*Lycopersicon esculentum* Mill) and pepper (*Capsicum annuum* L.) (Brunt et al. 1996) which are the main vegetable crops grown in greenhouses for export. The threat of the introduction of Tomato Spotted Wilt Virus (TSWV) and Tomato Yellow Leaf Curl Virus (TYLC) (ICTVdB, 2006b; 2006c) to the San Juan Valley and the rest of the Southwest could be a major setback for government projects aimed at diversifying the agriculture in San Juan with vegetable crops.

TYLC, another yield limiting virus caused severe losses to up to US $50 million in tomato fields in Azua during 1989-1995 (Polston and Anderson, 1997). TYLC is a begomovirus transmitted by the adult whitefly *Bemisia tabaci* Gennadius. TSWV is a tospovirus transmitted by larvae and adult of about 20 species of thrips. Neither TYLC nor TSWV are seed transmitted. (Maule and Wang, 1996) TSWV was reported by Martinez et al. 2014 infecting pepper and tomato grown in greenhouses in Jarabacoa, Constanza and San Jose de Ocoa. Even though the virus caused extensive damage to greenhouse vegetable production, no yield loss data was provided. The presence of new pathogens associated to vegetable crops grown in the greenhouse or open fields and the endemic pathogens present in San Juan, which also have the capacity to become infectious to most vegetable crops, poses a threat to halt development or expansion of vegetable export crops in San Juan.

In spite of the planning and investments for growing vegetable for export, there is a lack of personnel and infrastructure to give support to growers and the challenges they face when new crops are introduced to new areas. There is a risk for the emergence of new insect pest and diseases that can occur and cause drawbacks in their development and production of exportable vegetables. In San Juan there is a lack of trained personnel on crop protection except for IDIAF personnel working at the only crop protection diagnostic laboratory in that part of the country. The laboratory lacks equipment and reagents to address emergence of problems especially those that cannot be identified by microscopic examination such as viruses and would require serological or molecular techniques to be accurately identified.

With the support of the Kopia-DR project funds the IDIAF crop protection personnel started planned surveys to detect, identify and monitor for the presence and means of spread of economically important insect pest and pathogens and to make farmers aware of the risks therefore to prevent their introduction and to deploy practices based on good agricultural practices (GAP) designed to reduce yield losses, minimize the application of pesticides for food safety and maximize the use of nutrients and water.

3. Specific objectives of component II

- To identify and monitor insect pest and diseases that threatens vegetable production in San Juan and to prevent their spread and also to provide the appropriate guidelines to prevent yield and market losses.
- To transfer research results to vegetable growers in the San Juan province by workshops, field and greenhouse visits
- To visit important research centers in South Korea

4. Materials and methods

Samples of symptomatic plants were collected from January 2015 up to March 2017 from vegetable farms or greenhouses located in the San Juan province. Samples of either leaves, stems or fruits from tomatoes, peppers, melon, bitter melon, okra, cucurbits and weeds showing yellowing, deformations, dwarfing, blotches and watersoaking, among others, were collected and bagged in plastic ziploc bags and transported to the laboratory in an ice cooler. Upon arrival, plant materials were washed in running tap water to removed debris or soil, blotted on paper towels, portions of plant tissue up to 2.5 cm2 were ground and homogenized in 1:20 (w/v) ratio with extraction buffer in plastic extraction bags provided in the InmunoComb® and Inmuno Strips® serology kits (Agdia Inc Elkhart,IN, USA). InmunoComb® or InmunoStrips® were submerged into the bags with the plant tissue sample and allowed to remained up to 10 min and then removed. Positive results were recorded if two lines or bands, control and test lines were visible (pink or purple) at any intensity (Fig. 7). Negative results were recorded if only the control line was visible. We tested two sets of InmunoCombs® with capture monoclonal antibodies for Pepper Mild Mottle Virus, Arabis Mosaic Virus, Cucumber Mosaic Virus, Impatiens Necrotic Spot Virus, Tobacco Mosaic Virus, Tomato Spotted Wilt Virus. The Inmuno Strips® with capture monocloanal antibodies for Tomato Spotted Wilt Virus, Potivirus y *Phytophthora* tested individually for each pathogen.

Sections of the remaining of the plant tissue sample with necrotic or watersoaked lesions were examined under the microscope for signs of fungi (conidia, conidiophore, mycelia, sac-like structures etc.) or bacterial ooze. For culture growth, small sections of diseased tissue were surface sterilized by immersing 2-4 mm portions in 10% v/v NaOCL/water for 15 - 30 sec, transferring to 70% alcohol for 15 - 30 s, and finally to distilled water for 1 to 2 min. The segments were then blotted on paper towel to air dry, then plated using sterile forceps onto 2% water agar (WA) in a disposable polystyrene Petri plate. Once the hyphal tips of the developing fungal colonies reached about 4 mm in length they were transferred onto potato dextrose agar (PDA) (39 g/L) for growth. Within 4-7 days, plates were examined and culture surface scrape off were transferred onto a drop of lactophenol-cotton blue on a glass slides for microscopic observations. Genus or species of fungi/oomycetes was tentatively identified according to several online identification keys.

5. Results and major achievements

Between January 2015 and March 2017 we collected a total of 258 symptomatic plants samples from 8 vegetable open fields and 3 greenhouses. From the collected samples, 53% showed the presence of one or more pathogens detected by microscopy, culture media or serology, the remaining 47% did not evidenced any signs of fungal (spores/conidia, conidiophores, mycelia) or bacterial (bacterial ooze) pathogens in dissected tissue for microscopic visuals or reacted positive for pathogens embedded in InmunoComb® or InmunoStrips®. The plant samples were collected from fields in La Piedra, Escondido, Carrera Yegua in Las Matas and Pedro Corto, Yabonico, km 11. Each field was sampled at least four times during the two year sampling due to continuous cropping and harvesting. The greenhouses visited were mostly planted with tomatoes for export and located in Pedro Corto, Yabonico and km 5, the latter greenhouse was planted with tomatoes and poblano chile pepper. All samplings were conducted in the San Juan province. The symptoms more frequently associated with diseased plants were yellowing, mottling, leaf deformation, plant tip necrosis, fruit peduncle necrosis, leaf water soaking and/or necrosis (Figs 2-3). Summaries of disease causal agents on different crops are presented in figure 1. Virus were the pathogens most frequently detected during the two year sampling. The higher frequency of occurrence in samples were recorded with 72% of total positive samples for Tomato Spotted Wilt Virus (TSWV) affecting all market types of pepper and tomato (Fig.1). TSWV was found in all open fields crops sampled except in greenhouses in Yabonico and Pedro Corto. The greenhouse located in km 5 at the Arroyo Loro Experimental Station was severely affected by TSWV in 2015 and 2016, the outbreaks were attributed to infected seedlings transported from San Jose de Ocoa. The second most pathogenic virus was a collective of potyvirus with 27% of total positive samples. This type of virus was found in Habanero and Thai Chile peppers planted in open fields in La Piedra, Pedro Corto, Yabonico and Escondido. Tobacco Mosaic virus and Cucumber Mosaic virus were detected simultaneously co ocurring with potyvirus and TSWV in 4 samples of Thai Chile pepper from Escondido and 6 samples of Habanero peppers from Pedro Corto. Two of the three grenhouses sampled were free from either fungi or virus diseases, Tamara Industrial in Pedro Corto and Lidor S.R.L in Yabonico, enforced strict protocols to conform to Good Agricultural Practices for product safety.

Even though the majority of problems identified were related to insect or seedborne transmitted viruses few fungi of economic importance were detected during the 2 year survey.

Initial samplings were conducted on seedlings in 20 seedbeds recently purchased by the growers and kept in a screenhouse in a farm in Escondido, Las Matas. Seedlings sampled belonged to the following crops: *Momordica charantia* (Chinese cucumber), *Solanum melongena* (eggplant), *Cucurbita* spp. (Kaboche pumpkin) and hot pepper (*Capsicum* spp). Most seedlings displayed various symptoms but the most common was wilting and stem necrosis. Eggplant had more than 50% of dead seedlings (Fig.4). The causal agents associated with diseased seedlings were the fungus *Rhizoctonia solani* Kuhn and the Oomycete *Pythium aphanidermatum* (Edson) Fitzp . Other fungi identified were *Alternaria* spp causing leaf spots on Chinese cucumber and

Pseudoperonospora cubensis (Berkeley & Curtis) Rostovtsev causing severe leaf necrosis and defoliation of (*Cucumis melo* L.) cantaloupe in a farm in Escondido, Las Matas (Fig.5-6). Other fungus identified in tomatoes in the greenhouse was powdery mildew caused by *Oidium neolycopersici* L. Kiss, sp. nov which destroyed foliage and reduced fruit size and harvest. The fungus was only found once in the greenhouse located at the Arroyo Loro Experimental Station.

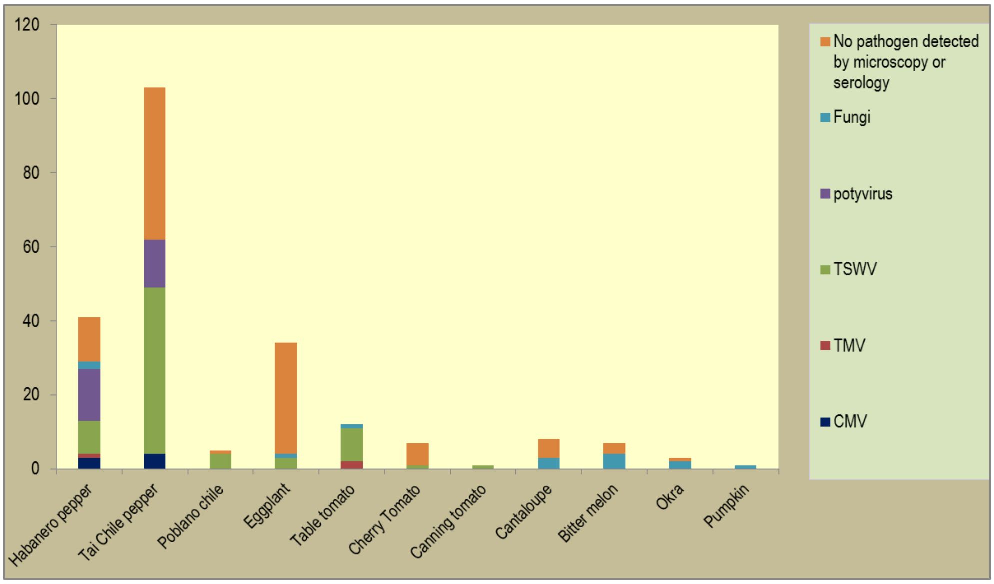

Figure.1. Data represent frequency of occurrence of virus types and fungi detected in samples of vegetables collected from January 2015 to March 2017 in the San Juan province

Figure. 2. Different symptoms observed at a Habanero pepper farm in Pedro Corto, San Juan. Some of the samples were positive for up to four viruses.

Figure 3. Fruit lesions on pepper fruits from plants that reacted positive for TSWV and CMV.

Figure 3. Bell pepper plant showing symptoms caused by TSWV in the greenhouse at the Arroyo Loro Station.

Figure 4. Diseased *Solanum melongena* seedlings caused by *Pythium aphanidermatum*.

Figure 5 Melon crop infected by downy mildew at Carrera Yegua, San Juan.

Figure 6 Spores and sporophores of *Pseudoperonospora cubensis* (Berk. & Curt.) Rost and profuse growth in the underleaf.

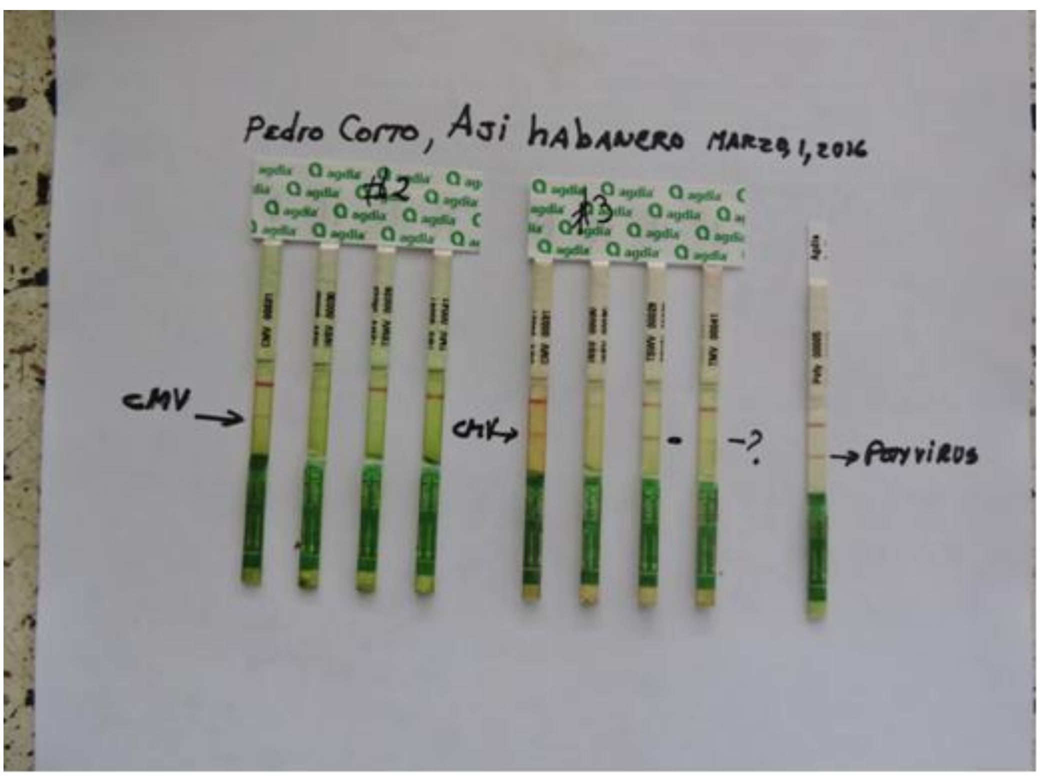

Figure 7. InmunoStrips display positive reaction to CMV, TSWV and potyvirus group, all three in the same sample.

Visit to South Korea by IDIAF - Arroyo Loro Experimental Station researchers.

1. Visit to the Research Institute Protected Horticulture (Protected Horticulture Research Institute (PHRI)

Dr. Graciela Godoy Lutz and Ing. Yony Segura, senior and assistant researcher, respectively of the Dominican Institute of Agricultural and Forestry Research (IDIAF) and both working in the crop protection laboratory at the Arroyo Loro Station visited South Korea from October 10-22, 2015. The purpose of their trip was to observe technological advances in agriculture in South Korea. They were hosted by Dr. Han-Cheol Lhee, senior researcher at the Research Institute Protected Horticulture (Protected Horticulture Research Institute (PHRI) located in Haman, in southwestern Korea, which is one of eight centers research within the National Institute of Horticultural and Herbal Science dependent on the Rural Development Administration (RDA), a government agency responsible for agriculture in South Korea which invest more than $100 billion annually for agricultural research and development.

At the PHRI, where the researchers remained for a week, they were exposed to the greenhouse operations and were given technical explanations by Dr. Lhee and other technical staff regarding research in greenhouse management for energy efficiency, automation and ecofriendly vegetable production. IDIAF researchers learned about the latest advances in hydroponics which helps to increase production of many vegetables and reduce losses due to insect pests and diseases and therefore reduces the need for pesticides. Hydroponics is the use of organic and inert substrates (moss, organic compounds, perlite and mineral wool) instead of soil for an efficient use of water, fertilizers and further development of the healthy crop that can last up to a year performing multiple cuts. This technology together with the development of intelligent greenhouses through the convergence and integration of ICT (information and communication technologies) has placed South Korea as a leader in the use of high technology in agriculture.

The availability of ICT for producers and exporters allows precise control of the microenvironment and water and nutritional requirements according to the physiology of the plant by remote control via mobile devices. Another innovative technologies under investigation at the PHRI is the the plant factory also known as the sixth industry which consists of vertical structures with automated systems that enable the production of high quality vegetables with controlled environment and recycling water nutrients and sunlight using LED or the sun as energy. The plant factory is a futuristic concept with applications for urban areas, ocean platforms, deserts and space travel.

IDIAF researchers also visited the Center for Agricultural Research and Extension Services Gyeongsangnam-do where they observed greenhouses for farmers training and high-tech laboratories. The center provides the technology transfer to more than one million farmers in the region, other areas of research deal with rice biotechnology, cucurbits and greenhouse crops for export and the promotion of bioindustry and e-commerce in the region. Dr. Godoy de Lutz and Ing. Segura visited farmer’s greenhouses near Busan and Haman and learned how the farmers fully apply the technologies developed by the research centers. The IDIAF researchers observed the greenhouse production of tomatoes and peppers and crops such as rice, cabbage, onions and fruits, in open fields grown under high standards for productivity, quality and food safety.

Most of the growers have small greenhouse areas from 0.5 to 1.5 ha but they are operated with efficiency by using hydroponic systems and microenvironment control technology handled from their mobile devices. Small greenhouse producers supply the local market and also export mainly to

Japan, China, United States and the Arab countries where Korean products are highly demanded for their high quality and safety. The feasibility of applying part of the observed technologies and their applications to local conditions was shared with local farmers at a workshop held in April, 21, 2017 at the Arroyo Loro Experimental Station in San Juan, Dominican Republic. The trip of the IDIAF researchers was coordinated and funded by the TCP/Kopia-RD project based at the Agricultural Technology Center CENTA located in Pantoja, Santo Domingo.

2. Visit to the Asian Postharvest Research Center, National Institute of Horticultural and Herbal Science

Ing. Martin Frias and Ing. Juan Arias, both researchers at the Dominican Institute of Agricultural and Forestry Research (IDIAF) and working for the Kopia/RDA project visited South Korea from June 11 to June,19, 2016 . The purpose of the trip was a technical exchange to visit research centers specialized in post-harvest technologies of fruits and vegetables. The visit was hosted by Dr. Lin a researcher and project leader at the Asian Postharvest Research Center, National Institute of Horticultural and Herbal Science, under the Rural Development Administration located in Jeonju. On Monday 13 they visited the above mentioned center where they were introduced to the technical staff and received information about current research conducted on post-harvest management of types of pepper, tomato, mango, banana, pear, melon, strawberry, onions among others. At the center, they participated in a workshop that extended until Tuesday where six talks were presented giving details and protocols for handling harvested fruits and vegetable. On Wednesday 15 they visited Piond Sand and observed first-hand the structure and system operations of the onion growers association established in that locality. The association own cold storage rooms where harvested onion bulbs can be stored for over a year without losing freshness weight and quality. The same day they visited a flower processing plant known as Rosepia where we observed directly and by video presentation the complexity of the labor and processes regarding packing for export to Japan. According to their market statistics Rosepia send 8-10 thousands packages to Japan daily.

They also visited another company that process table pepper or paprika Nongsan (Agriculture Corporation Company), where we also observed the packing process and their greenhouses.

On Thursday June 16 they visited Anseong where is located one of the most important vegetable packing and export Company of South Korea known as NH NongHyup (Agrifood Distribution Center). At the company grounds, they observed the massive operation of their packing and shipping to other countries. They also have branches in six of the seven Korean provinces and have the main task of distributing vegetables to markets and supermarkets. In addition to vegetables they process most fresh juices and carbonated drinks sold in South Korea. To top the visit to important processing plants, on Friday they attended a presentation by Dr. Ji-Weon Choi about their research on edible mushrooms and the long term preservation for freshness. Currently Dr. Choi is working with two types of mushroom known as king oyster and oyster. On Saturday they were taken for sighting the city of Seoul and its attractions and by Sunday were on their way to the Dominican Republic.

First workshop on crop protection and soils on oriental vegetables in Las Matas de Farfán

Venue: Club Coopcentral. Las Matas, San Juan

Date: February, 25, 2015

The purpose of the workshop was to train farmers, associated to AgroExsur, on crop protection and soil management to increase productivity and reduce yield and quality losses on their vegetable farming systems. The welcoming words were given by Ing. Manuel Encarnación, Arroyo Loro Station director and Mr. Guillermo Rodríguez, AgroExsur executive director. The speakers were: Dr. Graciela Godoy Lutz, PI Component II Kopia-RD and plant pathologist at the Arroyo Loro Station, Ing. Miguel Martínez, nematologist and Ing. Melvin Mejía, soil researcher, both researchers at CENTA, Pantoja. Dr. Godoy de Lutz started the workshop and presented a talk entitled: Diagnosis of important diseases of export vegetables in San Juan. During the presentation she pointed out the need to prevent pathogen introductions to Las Matas from other locations where diseases are widespread among different vegetable crops and are already causing losses in greenhouse or open field production.

On the other hand, Ing. Miguel Martinez presented a talk entitled: Survey on Bangaña nematodes, which dealt with important nematode, symptoms and management of this and other Oriental vegetables. In his talk, Ing. Martínez covered basic information about nematodes in general with emphasis on control with nematicides of low toxicity and bionematicides.

Ing. Melvin Mejía, who is currently the head of the CENTA soil laboratory, presented the third talk entitled: Soil fertility analysis and Global Positioning System and its application in agriculture. The topics were basic information on soil characteristics and fertility and mapping by GPS technology. After his presentation, there was a section for questions and answers with the three speakers. The farmers were interested in knowing more information on how to reduce the use of chemical pesticides, how to prevent damage by insect-pest and diseases and deployment of eco-friendly control practices. The AgroExsur farmers were grateful to IDIAF-Kopia-DR project for holding such a workshop, the first of his kind in Las Matas.

Second workshop on crop protection, greenhouse fertigation, visit to South Korea and Korean vegetable adaptation to Dominican enviaronment

Venue: Estacion Experimental de Arroyo Loro, Km 5, Carretera San Juan- las Matas

Date: April, 17, 2017

The purpose of the second workshop was to update research results from components I and II to San Juan and Las Matas (Agro-Exsur) farmers, regarding best fertilizer formulas and application timing for tomatoes and pepper under greenhouse conditions and how to prevent the spread of diseases under open fields and greenhouse. A group of researchers from the North Center led by Dr. Pedro Nunez presented their results on Korean vegetable adaptation to the Dominican Republic. The welcoming words for the guests were given by Ing. Rafael Perez Duvergé, IDIAF Executive Director who pointed out the outstanding support by RDA/Kopia in the Dominican Republic and their contributions to promote the growth of vegetable following quality and safety protocols under greenhouse conditions. The speakers and their presentations were in the following order: 1. Ing.

Yony Segura presented an update on seedborne and insect transmitted virus diseases on tomatoes, pepper, eggplant and members of *Cucurbitaceae*, their sources and how to prevent their introduction and spread of the pathogens in the greenhouse without recurring to pesticides applications.2. Ing. Martin Frias, expert in soil and water management presented data referring to water requirements, salts, pH, evapotranspiration, water drainage and the underground accumulation of nitrates and nitrites, optimal dosage of nitrogen for tomato and pepper growth in the greenhouse. His presentation pointed out the excessive use of fertilizer when growers applied commercial formulas not previously tested under greenhouse conditions. 3. Dr. Pedro Nunez presented information on the scope of the Kopia project in the North Centern and general results of the studies on the adaptation capacity of Korean vegetables to different agro-ecosystems in the Dominican Republic whereas Ings. Leocadia Sanchez, Jose R. Rodriguez and Roque Bathel presented results of experiments conducted in La Vega, Constanza and San Jose de Ocoa, 4. Dr. Graciela Godoy de Lutz presented her experiences and observations during her visit to the Research Institute Protected Horticulture (Protected Horticulture Research Institute (PHRI) in Haman, South Korea. She focused her presentation on new technologies such as hydroponic crops, plant factories and advances in mechanical engineer applied to agriculture. She highlighted the ample diversity of vegetables grown, their byproducts use in the food industry and their and importance in the Korean diet.

Among the attendants, in addition to growers and the Ministerio de Agricultura staff, the Kopia technical staff led by Dr. Choi Ju Hyeon participated in the workshop

6. Discussion including problems, solutions, and economical analysis

The detection of important viruses such as Tomato Spotted Wilt Virus (TSWV) at high levels of incidence during the 2- year survey in the San Juan province indicates the need for implementation of good agronomic practices, pest and pathogen surveillance and training for growers who have been traditionally growing legumes, rice or root crops. Since 47% of the symptomatic plant samples collected did not react with InmunoComb ® or InmunoStrips ® with monoclonal antibodies for seven viruses or *Phytophthora*, and no other causal agent was evidenced by microscopy, may suggest the presence of other potential pathogens such as other viruses of economic importance which display similar symptomatology as the ones tested during this survey.

TSWV and potyvirus were the two most common viruses associated with all market types of tomato and pepper in at least six locations in the San Juan province. TSWV is known to be one of the most harmful viruses of vegetable and its widespread distribution around the world is mainly attributed to the western flower thrips (*Frankliniella occidentalis* Pergande), an efficient TSWV vector and which has certainly played an important role in its emergence (Kirk & Terry, 2003). Thrips in general are difficult to control with insecticides partly because of their mobility, feeding behavior and protected egg and pupal stages (Reitz, 2009) also thrips can become resistant to many insecticides (Jensen, 2000). There are commercial few tomatos (carrying the Sw-5 gene) and pepper (carrying the Tsw gene) varieties resistant to TSWV, the resistance to these genes, however have been overcome by numerous virulent biotypes in many parts of the world (Crescenzi et al. 2013; Aramburu and Marti 2003). Since we do not have detailed information on the biotypes or strains of TSWV occurring specifically in the San Juan province or other regions in the Dominican Republic, is difficult to predict if deployment of TSWV –resistant varieties, whose seed are more expensive than traditional commercial varieties, should be recommended as part of an integrated disease management for TSWV.

TSWV is reported for the first time in this survey associated to symptoms on tomato, pepper and eggplant in the San Juan province.

To contain the spread of TSWV to other vegetable growing farms or newly stablished greenhouses in San Juan is going to require a concerted effort by growers organizations and government institutions. According to reports from local growers on early planting losses the source of contaminations appears to be from infected seedlings. Even though most growers are no longer purchasing plant material from companies located in San Jose de Ocoa or Constanza where the TSWV is endemic and either produces their own vegetable nurseries or switched to other companies established in Bani where TSWV has not been found or reported. We need to continue monitoring hotspots locations in Pedro Corto and Escondido where TSWV has caused severe yield losses in habanero pepper and tomato in 2015 and 2016 . We collected weed samples around or within infected fields during the 2- year sampling but none reacted positive for TSWV or other viruses. The weed samples tested for viruses were: *Sida* spp, *Cassia dipfhylla*, *Ocimum gratisimum*, *Ocimum basilicum*, *Senna occidentalis*, *Bracharis* and *Euphorbia* spp. At least 16 weed families have been reported as TSWV reservoirs in vegetable fields in Hawai and Spain (Cho et al. 1986; Laviña et al. 1996) therefore weeds need to be monitored for symptoms in infested fields even if infected plants have been dispose of.

To avoid more outbreaks or the spread of TSWV in vegetable fields in San Juan growers need to prevent the introduction of infected plant materials from high risk areas, use of insect proof nets, yellow traps, silver mulch, insecticides, crop rotations, weed control, timing of planting and and monitor weather variables that promote higher thrips populations (Al-Ali et al. 2013; Momol et al. 2002). After identifying TSWV, as the main pathogen associated to loses in nurseries and harvests in open fields, farmers estimated yield and quality losses in habanero pepper and Thai chile pepper to up to US $20 million between 2013-2015 according to Mr. Guillermo Rodriguez, executive director of Agro-Exsur, a vegetable exporters association located in Las Matas, San Juan.

Other important group of pathogens was the members of the genus *Potyvirus* but were only found in Thai Chile and Habanero pepper causing leaf mottling and deformation. There are at least 11 species of potyvirus affecting pepper (Kenyon et al. 2014) and are transmitted very fast and efficiently by various aphid vectors in a non-circulative (non-persistent) manner (Whitefield et al.2015). Other means of dissemination are the seed, mechanical, graft and pollen (Kenyon et al. 2014). Potyvirus can have a significant impact on crop production including loss of yield, unmarketable product and regulatory impacts. The finding of potyvirus in pepper fields in the San Juan province poses a great risk for the growth of the peppers for export. The source of the virus are yet unknown but traditionally legume crops have been severely affected by recurrent potyvirus in the San Juan province (Arias et al.2003

Another important finding during the 2016 samplings was the positive reaction detected with InmunoComb and InmunoStrips serology kits to four unrelated virus simultaneously in numerous plants. The viruses detected were: Cucumber Mosaic Virus (CMV), Tobacco Mosaic Virus (TMV), Tomato Spotted Wilt Virus and unknown Potyvirus. Samples were either positive for two, three or four at the same time in plants of Habanero pepper in Pedro Corto and in table tomato table in Escondido. Martinez et al., 2014 reported the presence of each of these viruses in Jarabacoa, Constanza and San José de Ocoa, the latter locations was the source of the pepper and tomato nurseries used for planting in greenhouse and open field vegetables for export in San Juan in 2014 and 2015. The implications of this finding are manifold. The presence of multiple virus lead to in-host interactions and the possibilities of generating variants due to genetic recombination or component exchange and a possible increase in aggressiveness and transmissibility (Aramburu and Marti, 2003) . This is the first report of all four viruses occurring in the same plant simultaneously in fields in San Juan

The presence of fungi in seedbeds or fields as reported in this survey was traced back to contaminated seedlings in nurseries from infested areas. As part of the initials recommendations by the IDIAF crop protection team was to either produce the nurseries locally or purchased from reputable companies. Due to deployment of sanitation and other prevention practices no fungal outbreaks in nurseries were detected in 2016.

Based on the results in this survey we concluded that the simultaneous presence of multiple viruses poses a great risk for vegetable crops grown in open fields as well as it increases the chances of contamination in greenhouses unless strict sanitation and management of the crops are in placed before expanding this export industry.

7. Suggestion and future plan

An integrated and more pragmatic approach to prevent viral diseases needs to be deployed along with the construction of greenhouse for vegetable growth under more environmentally controlled scheme. There is a need for more in depth research on the types and strains of virus in the region and knowledge in their ecology and epidemiology. The deployment of cultural practices to reduce sources of virus inoculum and decrease the rate of spread of virus, the judicious used of synthetic insecticides, only at seedling stage when plants are susceptible to infection, the use of natural insecticides or biocontrol agents that alters behavior spread or development of vectors populations and, if available the use of vegetable varieties with multiple genes to assure more resistance durability.

We expect to continue collaboration with RDA/Kopia RD to contact Korean researchers who could assist us for future work.

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Final Report of Component I

Project: ***Development of Technologies for the Sustainable Management of Fertigation and Diagnosis of Diseases in the Vegetable Crops for Exportation in the Greenhouse Effect Environment in San Juan, DR, with the sponsorship of the Technical Cooperation -TCP / KOPIA***

Final Report of Component II

Project: ***Development of Precision Fertilization and Disease Control Technology in Greenhouse Cultivation in San Juan, Dominican Republic., with the sponsorship of the Technical Cooperation -TCP / KOPIA***