Automated Temporary Immersion System for Blueberry and Pineapple

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***Abstract*—In this work, an automated temporary immersion system was implemented, where blueberry and pineapple were used as test crops, achieving an economic and simple handling system compared to the existing ones. After the corresponding tests, multiplication rates of the explants between 2 and 8 were obtained, reaching a number of sprouts above 100 units, demonstrating the efficiency of the system.**

***Index Terms*—temporary immersion system, crop, biotechnology, micropropagation, artificial liquid medium**

I. Introduction

Peru between 2011 and 2014 has grown its agriculture by an average of 3.2% per year, becoming one of the main economic activities that promote its development, generating formal rural employment and foreign exchange.

The export of fresh fruits and vegetables to distant places is a sophisticated activity with a high content of technology and added value. One of the pioneers in this field was Chile in the 1990s. In Fig. 1 shows the exponential growth of blueberry exports in Peru. Many consider that this sector in our country has so much potential that technological advances could be taken advantage of to change the agro-industrial industry and future trends [1].

Currently, Peruvian blueberries are exported to many countries, among them the United States, the Netherlands, China, Hong Kong and Canada that stand out for the quantity of their exports [2].

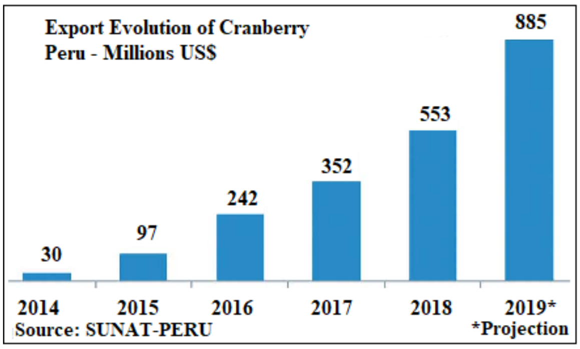

Figure 1. Export evolution of blueberry (Peru in million US$).

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In Peru regarding pineapple, the creole jungle variety and the Golden MD-2 are produced in greater quantity, especially in the Junin Region, in the province of Chanchamayo. The respective information is shown in Table I.

TABLE I. Demand and Harvest of Pineapple in Peru (Reference 2015 to 2019)

Jan. – Mar.	Apr. – May	Jun.– Sep.	Oct. – Dec.
Better harvests and higher demands	Moderate harvest and demand	Low demand for winter	Better harvests and higher demands

The national industry of micro-propagation of crops does not develop Temporary Immersion Systems (TIS), especially at the research level. There are works on the subject, but mostly oriented to the field of biology and chemistry.

The Temporary Immersion System (TIS) involves subjecting the plants to an immersion regime, controlling the time that the plants will be in contact with the crops medium, and the frequency with which these immersions are given [3].

There are three types of media in which an in vitro crop can be performed: semi-solid, liquid and in temporary immersion systems [4].

Maintaining a crop in a TIS implies:

- Greater contact between the plant biomass and the medium.
- Lack of restrictions on gas exchange.
- Possibility of controlling the composition of the medium and that of the atmosphere inside the bioreactor.

Subjecting plants to this type of growth and multiplication process in controlled systems implies increasing multiplication rates, as well as obtaining a better development of the explants.

It should also be mentioned that it is possible to protect them from the attack of parasites and diseases to which they are exposed when the process occurs in open and exposed environments.

II. Design and Implementation of the System

A. Crops Selected for the System

Blueberry: The scientific name of which is Vaccinium myrtillus shown in Fig. 2(a), is a bluish-black, globose

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fruit measuring about 6 mm in diameter. In addition, its positioning in the market is due to being some food rich in vitamins and with little contribution of calories.

Pineapple: Tropical fruit whose scientific name is Anana Comosus, Fig. 2(b) shows one of the variations that predominate in the production of this fruit in Peru [5]. Its consumption is highly appreciated because apart from its pleasant taste, many benefits are attributed to it.

Properties
Antibacterialand
Antioxidant
Improve eye health
Prevents infections
Stimulates digestion
Improves immune response

(a) Blueberry fruits

Properties
Regulates sugar level
Diuretic
Improves circulation
High in vitamin C
Regulates cholesterol
Help iron absorption

(b) Pineapple

Figure 2. Fruits of plants used.

B. *Methodology Used*

A mechanical system with grids as support of the system was developed. The separation of the liquid medium from the explants, seeds and buds was carried out by heat sealing the center of the bags, which were previously filled halfway with the liquid medium and the seeds, leaving a small channel through which only the liquid medium passes.

Due to the acceleration of gravity, as the bag rotates, the liquid medium moves to the other half of the bag, leaving the seeds in the first half of the bag dry.

As shown in Fig. 3, to build the system, it began with the development of its design and the parts that comprise it. The implementation began with the mechanical module, and then continued with the electronic part, which includes programming, ending with the respective tests and documentation.

C. *Mechanical System*

The structure was built using grooved angles as structural support material. Later stops were added to limit the rotation of the grids that serve as support for the explants, in the direction of their axis [6]. This implementation can be seen in Fig. 4(a). In Fig. 4(b) you can see the mechanism that allows transmitting the movement to the entire platform.

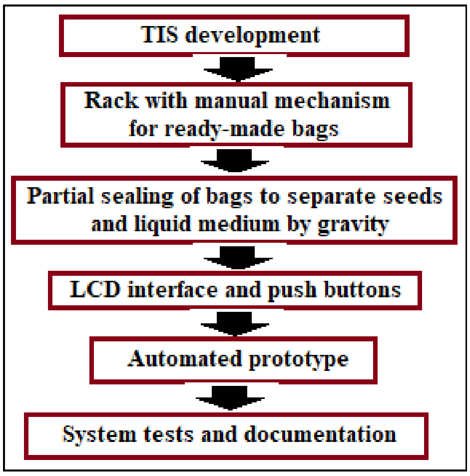

Figure 3. Scheme implementation of TIS.

(a) Mechanical structure.

(b) Transmission mechanism.

Figure 4. Mechanical structure of the system.

D. *Actuator Selection*

A direct current servomotor was used with a gearbox to reduce the speed of rotation and increase the torque in its drive shaft, together with a control circuit that uses Pulse Width Modulation (PWM) [7] and an H-bridge for turning change

E. *Electronic System*

The Arduino Pro Mini microcontroller was used, which is shown in Fig. 5, its choice was due to its low cost and ease of programming, in addition to the small space it occupies, which contributes to the design of the system.

Figure 5. N Arduino Pro mini microcontroller.

To interface with the user, a 2×16 LCD screen was used for visualization, as can be seen in Fig. 6, there the configuration options of cycles and immersion times are shown. You can also see the number of cycles the system has already run.

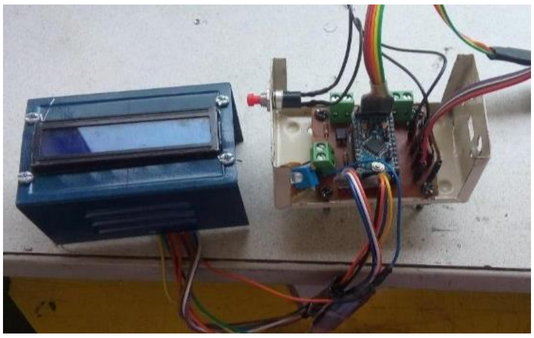

Figure 6. Electronic programming and display module.

F. *Crop Lighting*

It was thought to use 40W fluorescent per 1.20 m tube length for lighting and to generate heat. In this case, the shelves generate more heat, as can be seen in Table II, being necessary to move the ballasts towards it or separate the floors.

Finally, we opted for 5050 LED lighting [8] in strips, which cover the entire surface of each floor with a consumption of 15W per 1.00 m of strip length. With two strips of 1.50 m in length we will have a total 3.00m with a total consumption per floor of 30W. The lighting is more efficient, because; LED strips can be cut and conditioned to exact size.

TABLE II. FLUORESCENT VERSUS LED'S

Parameter	Fluorecent	LED
Heavy materials	YES	NO
Primer	YES/ NO	NO
Ballast	YES	NO
Reactive energy	YES	NO
With cast tube	YES	NO
P tube 60cms	18W	9W
P tube 120cms	36W	18W
P tube 150cms	58W	22W
Ballast / driver consumption 60cms	3W-7W	1W
Ballast / driver consumption 120cms	5W-7W	2W
Ballast / driver consumption 150cms	7W-11W	3W
Emits ultraviolet	YES	NO
Emits infrared	YES	NO
Work temperature	80º	40º
Surface temperature	5º to 45º	-20º to 60º
Danger of breaking	YES	NO
Work tension	240V	12V
Electrical risk	YES	NO
Useful life	6000/17000H	50000H
Half life	8000/19000H	80000H
Discolored ceiling	YES	NO
Flashes	YES	NO
Instant on at	NO	YES
Full light	NO	YES
Consumption by multiple ignitions	YES	NO
Light degradation	30%	2%

III. RESULTS

The Table III and Table IV show the results obtained when using the temporary immersion system, varying different parameters in the process. Since the system was designed to work in the blueberry and pineapple sector, then plants of said product were used to collect information and evaluate the efficiency of the system.

TABLE III. TEMPORARY IMMERSION TESTS WITH BLUEBERRY

TEMPORARY IMMERSION TEST 1 Crop: **Blueberry** Growth of microplants in TIS: **35 to 45 days** **Number of sprouts installed per container: 50**		
Cycles Immersion	Rate Multiplication	Nº sprouts obtained per explant
2 cycles - 12 hrs.	3.0	150
TEMPORARY IMMERSION TEST 2 Cultivation: **Blueberry** Growth microplants in TIS: **35 to 45 days** **Number of sprouts installed per container: 50**		
Cycles Immersion	Rate Multiplication	Nº sprouts obtained per explant
3 cycles - 8 hrs.	4.5	225
TEMPORARY IMMERSION TEST 3 Crop: **Blueberry** Growth of microplants in TIS: **35 to 45 days** **Number of sprouts installed per container: 50**		
Cycles Immersion	Rate Multiplication	Nº sprouts obtained per explant
5 cycles - 5 hrs.	2.6	130
TEMPORARY IMMERSION TEST 4 Cultivation: **Blueberry** Growth microplants in TIS: **35 to 45 days** **Number of buds installed container: 50**		
Cycles Immersion	Rate Multiplication	Nº sprouts obtained per explant
6 cycles - 4 hrs.	2.1	105

TABLE IV. TEMPORARY IMMERSION TESTS WITH PINEAPPLE

TEMPORARY IMMERSION TEST 1 Crop: **Pineapple** Growth of microplants in TIS: **30 to 40 days** **Number of sprouts installed per container: 20**		
Cycles Immersion	Rate Multiplication	Nº sprouts obtained per explant
2 cycles - 12 hrs.	3.4	69
TEMPORARY IMMERSION TEST 2 Cultivation: **Pineapple** Growth microplants in TIS: **30 to 40 days** **Number of buds installed container: 20**		
Cycles Immersion	Rate Multiplication	Nº shoots obtained per explant
3 cycles - 8 hrs.	8.0	160
TEMPORARY IMMERSION TEST 3 Crop: **Pineapple** Growth of microplants in TIS: **30 to 40 days** **Number of sprouts installed per container: 20**		
Cycles Inmersion	Rate Multiplication	Nº sprouts obtained per explant
5 cycles - 5 hrs.	2.2	44
TEMPORARY IMMERSION TEST 4 Crop: **Pineapple** Growth of microplants in TIS: **30 to 40 days** **Number of sprouts installed per container: 20**		
Cycles Inmersion	Rate Multiplication	Nº sprouts obtained per explant
6 cycles - 4 hrs.	1.6	32

A. Immersion Tests with Blueberry

In the case of blueberries, each propagation cycle can last from 35 to 45 days, having a better multiplication rate in 3 immersion cycles every 8 hours, where each immersion should last 3 minutes. These results can be seen in Table V, concerning blueberries.

The placed explants formed new elongated shoots approximately 4 cm high, obtaining a multiplication rate of 4.5 new explants on average.

Later these explants after being extracted from the container; the developed and cut shoots can be placed in another container to start the crop cycle again.

TABLE V. TEMPORARY IMMERSION TESTS WITH BLUEBERRY

Immersion cycles	**Multiplication rate**	**Number of sprouts obtained per explant**
2 cycles - 12hours	3.0	150
2 cycles - 8hours	4.5	225
2 cycles - 5hours	2.6	130
2 cycles - 4hours	2.1	105

B. Immersion Tests with Pineapple

In the case of pineapple, each multiplication cycle can last between 30 to 40 days, depending on the variety of the plant, and it was observed that the best multiplication rate was possible achieve with 3 immersion cycles each day, for periods of 8 hours; in 5 minutes intervals. This information can be seen in the data contained in Table VI.

It was then possible to observe that after placing explants in each container, new buds of different dimensions were formed from these, reaching an average of 3 cm in length. The most promising multiplication rate in this case was 8 buds per explant.

After controlled periods of immersion, the formed buds are separated and the larger ones are transferred to new containers for a new multiplication process.

A sample of the explants obtained from both blueberry and pineapple; can be seen in Fig. 7.

TABLE VI. TEMPORARY IMMERSION TESTS WITH PINEAPPLE

Immersion cycles	**Multiplication rate**	**Number of sprouts obtained per explant**
2 cycles - 12hours	3.4	69
2 cycles - 8hours	8.0	160
2 cycles - 5hours	2.2	44
2 cycles - 4hours	1.6	32

(a) Blueberry

(b) Pineapple

Figure 7. Explants obtained.

In addition to the quantitative results shown in the previous tables, Fig. 7 shows the qualitative characteristics of the explants obtained. Due to the care taken with the plant development environment and the control of pests and diseases carried out by the personnel in charge, very healthy explants are obtained which guarantees their subsequent growth.

C. Approximate Budget of the System

A temporary compressed air immersion system can cost US$ 8000.00 including accessories. But in this case a TIS can be obtained for a price accessible to the national market, both for export use and also in the field of production. The approximate budget of the propsed automated temporary immersion system is shown in Table VII.

TABLE VII. ESTIMATED BUDGET

APPROXIMATE BUDGET	
Automated Temporary Immersion System	
Mechanical part	150.00 USD
Electronic part	100.00 USD
Others	200.00 USD
TOTAL	**450.00 USD**

IV. CONCLUSION

The results obtained showed that the system works optimally, meeting the specifications established at the beginning of the development of this work, it can also be concluded that the system is able to efficiently separate the liquid medium from the explants. For this purpose, observations and needs of the qualified personnel working in the facilities were raised.

From the results obtained, we can also conclude:

- In the case of blueberry, each propagation cycle can last for 35 to 45 days with a better multiplication rate in 3 immersion cycles of 8 hours, where each immersion should last around 3 minutes. These parameters vary slightly, depending on the variety used in the test.
- In the case of pineapple, each multiplication cycle can last from 30 to 40 days depending, and the best multiplication rate can be achieved with 3 immersion cycles a day every 8 hours for 5 minutes. These parameters, as in blueberries; vary slightly depending on the variety.
- The use and programming by the staff do not present difficulties.

Recommendation

The system can be improvedusing more sensors and advanced programming techniques, order to give higher performance and autonomy, additionally it is recommended and at the same time the capacity of the mechanical structure can be expanded to be able to handle a greater number of bags with seeds and liquid medium, using the same electronic system, changing the power of the motors and adding lighting for a greater number of plants.

Additionally, it is recommended:

- Bioreactors currently used in the TIS industry can be used to increase the number of plants and their quality. It allows to preserve the airtightness and provides practicality for propagating plants.
- It would be convenient in the local environment to design temporary immersion systems based on other principles, as part of a policy of modernization of the agricultural industry.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Walter Corvacho Cardenas did the research part of the system, the implementation, testing and data collection. Freedy Sotelo Valer participated in the research part of the work, in the verification of the electronic system and in the writing of the article. Hugo Gamarra Chinchay participated in the evaluation of the mechanical part of the developed System.

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