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Evaluation of the Optimal Dose of Gibberellic Acid (Full Gib) in the Induction of Sprouting of Yungay Potato Variety Tuber (*Solanum tuberosum* L.)

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Abstract: This research was carried out in the district of Luya, province of Chachapoyas, Amazonas, with the objective of evaluating the optimal dose of gibberellic acid (Full Gib) in the induction of sprouting of potato tubers (*Solanum tuberosum* L.) Yungay variety. A Completely Randomized Design (CRD) with two factors three replications and seven treatments was used. Minitat 17 statistical software, ANOVA, and the Tukey mean comparison test at 5% were used for data analysis. The treatments were: Nothing was applied (T_1), 7.5 mL of Full Gib in 20 L of water, for 15 min (T_2), 7.5 mL of Full Gib in 20 L of water, for 20 min (T_3), 10 mL of full Gib in 20 L of water, for 15 min (T_4), 10 mL of full Gib in 20 L of water, for 20 min (T_5), 12. 5 mL of full Gib in 20 L of water, for 15 min (T_6), 12.5 mL of full Gib in 20 L of water, for 20 min (T_7). The variables evaluated were: Sprouting percentage, number of sprouts, sprout length, and sprout diameter per tuber. According to the results obtained, it can be observed that treatments 5 and 3 obtained the highest germination percentages with 86.17 and 85.67%, respectively, surpassing the other treatments; there were no significant differences between treatments in the number of sprouts per tuber. Treatments 5, 3, and 4 were better, with results of 8.93, 8.83, and 8.68, respectively; on the other hand, the variable shoot length obtained the best results in treatments 5 and 3 with 7.69 and 7.50 cm, respectively. Similarly, the shoot diameter variable had positive results in treatments 3 and 5 with 6.0 and 5.9 mm, respectively.

Keywords: Optimal Dose, Gibberellic Acid, *Solanum tuberosum* L., Yungay Potato

Introduction

There are various methods and products used to promote or delay the sprouting of tubers. These include growth regulators that delay sprout formation by inhibiting gibberellin synthesis. Abscisic Acid (ABA) and ethylene are considered Sprout Growth Inhibitors (SGI). Their use varies significantly and is influenced by factors such as variety, environmental conditions during storage, the physiological state of the harvested plant, the presence of phenolic compounds, and sugar metabolism (Rodriguez and Moreno, 2010). Additionally, the quantity and frequency of product applications for sprout control play a role (Daniels-Lake, 2013).

Among the substances used to break dormancy are gibberellins, which are natural compounds that act as endogenous regulators of growth and development in higher plants.

Numerous studies have shown that the application of GA3 to seed potato tubers can break the dormancy period and accelerate sprouting (Alexopoulos *et al*., 2008; Huamán *et al*., 2017; Wróbel *et al*., 2017; Mustefa *et al*., 2017; Chindi and Tsegaw, 2019; Lizarazo-Peña *et al*., 2020; Deligios *et al*., 2019).

The objective of this research was to evaluate the effects of different doses and immersion times of gibberellic acid (Full Gib) on sprouting, the number of sprouts, and the length and diameter of sprouts per tuber of Yungay potato variety (*Solanum tuberosum* L.).

Materials and Methods

Experiment Location

The experiment was conducted in the province of Luya. This locality is one of the seven provinces that make up the Amazonas region, located in the northeastern part of Peru. It represents 8.25% of the total surface area of the Amazonas region. The capital of the province of Luya is the city of Lamud, situated at an elevation of 2,307 meters above sea level. Luya covers an area of 3,236.68 square kilometers. The province of Luya is composed of 23 districts and its territory stretches between the Marañón and Luya rivers. It is characterized by its rugged terrain with various altitude levels ranging from 500-3,800 m above sea level, corresponding to the high jungle ecoregion according to the classification of Antonio Brack (Comeca Chuquipul, 2015). The territory of Luya encompasses three natural regions: (a) Suni or jalca, (b) Quechua, and (c) Yunga fluvial or temple, which endows the province of Luya with significant natural and cultural resources (Instituto Nacional de Estadística e Informática, 2017).

Weather Conditions

In the province of Luya, summers are short, comfortable, and dry, while winters are long and cool and it remains mostly cloudy throughout the year. Over the course of the year, the temperature typically varies from 8-23°C, rarely dropping below 6°C or rising above

25°C. The warm season lasts for 1.6 months, from August 22 to October 9, with a daily average high temperature above 22°C. The hottest month of the year in Luya is October, with an average high temperature of 22°C and a low of 11°C. The cool season spans 5.7 months, from January 20 to July 11, with a daily average high temperature below 21°C. The coldest month of the year in Luya is July, with an average low temperature of 8°C and a high of 21°C (Municipalidad de Luya, 2017).

Materials and Equipment Used

The materials used in this research were:

- ✓ 07 foam trays
- ✓ ½ liter of gibberellic acid (Full Gib)
- ✓ 05 masks
- ✓ 05 pairs of surgical gloves
- ✓ 01 roll of toilet paper
- ✓ Black plastic, measuring 5×5 m
- ✓ 105 tubers of Yungay potato variety, approximately 30 grams each
- ✓ Fungicide vitarax
- ✓ Office supplies

The equipment used in this research included:

- ✓ 01 digital scale
- ✓ 01 electronic vernier caliper
- ✓ 01 camera
- ✓ 01 computer

Experimental Design

In Table 2, a Completely Randomized Design (CRD) with two factors three (3) replications and seven treatments was used:

- Factors under study
- Gibberellic acid (full Gib) dosage (A)

  - D1 = 7.5 mL
  - D2 = 10.0 mL
  - D3 = 12.5 mL

- Immersion time (B)

  - T_1 = 15 min
  - T_2 = 20 min

Treatments

The treatments included seven variations, subject to the analysis of the interaction between doses and times, as shown in Table 1.

Table 1: Gibberellin treatments under study on the tubers

Treatment	Description
T_1	No treatment applied
T_2	7.5* mL of full Gib for 15 min of immersion
T_3	7.5* mL of full Gib for 20 min of immersion
T_4	10* mL of full Gib for 15 min of immersion
T_5	10* mL of full Gib for 20 min of immersion
T_6	12.5* mL of full Gib for 15 min of immersion
T_7	12.5* mL of full Gib for 20 min of immersion

*Dose for 20 liters of water

Table 2: Experimental unit layout

Treatments	Experimental unit Number of tubers	Repetition	Total tubers
T_1	3	5	15
T_2	3	5	15
T_3	3	5	15
T_4	3	5	15
T_5	3	5	15
T_6	3	5	15
T_7	3	5	15
Total			105

Experimental Unit

An experimental unit consisted of a foam plate with three tubers weighing approximately 30-60 g each, from the Yungay variety, harvested three days after being dug up.

Variables Evaluated

In this research, the following variables were assessed:

- Percentage of tuber sprouting: This data was collected on the seventh and fourteenth days from all 15 tubers in each treatment and repetition, calculating the percentage of sprouting
- Number of sprouts per tuber: Three tubers from the net area of the bucket were selected and the count of sprouts per tuber was done on the 7 and 14^{th} days. Only well-defined sprouts were recorded
- Sprout length per tuber: Using a ruler, the length of sprouts from the net area (three tubers) in each treatment and repetition was measured on the seventh and fourteenth days, from the base to the terminal end of the sprout. The data was expressed in centimeters
- Sprout diameter per tuber: With the help of a caliper, the diameter of the sprout from the net area (three tubers) in each treatment and repetition was measured on the seventh and fourteenth days, at the base of the sprout. The data was expressed in millimeters (mm)

Experimental Management

Obtaining Seed Tubers and Disinfection

Seed tubers were obtained from the Cuemal village, acquiring 150 Yungay potato tubers that met quality

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parameters, including healthy and uniform tubers with average weights ranging from 30-60 g. Subsequently, 105 healthy and uniform tubers were selected to form the 35 experimental units. The tubers were then transported to the Luya district, specifically to the Luya agricultural agency, where the research work took place. The tubers underwent a thorough cleaning process by immersing them in water and gently scrubbing them with a brush to remove impurities from the harvest. They were then disinfected using Vitarax (Carboxin + Captan).

The Installation Process of the Experiment

The installation process was carried out during the first week of March 2023. It began with the distribution of 35 experimental units (egg cartons). Subsequently, the doses were prepared. Likewise, the tubers were immersed in the different durations and doses of gibberellic acid. After draining, the tubers were placed in foam trays for approximately 1 h to dry in the shade at room temperature. Then, 15 tubers were distributed in each egg carton, which prevented moisture accumulation and allowed for free air circulation, facilitating various physiological changes in the seed tubers.

As a protective measure against pest attacks, the potatoes were exposed to diffused light for one week to promote greening, making them slightly bitter and less appetizing to insects. Subsequently, they were covered with a black blanket for one week to simulate a closed environment, which facilitated rapid sprouting and dormancy breakage. Additionally, records were taken at seven-day intervals until all the tubers completed the sprouting process.

During this stage, the following aspects were evaluated: Sprouting percentage, number of sprouts, sprout length, and tuber diameter. These measurements were taken using a ruler and a vernier on the sample tubers. Data organization and analysis were conducted using Microsoft Excel, while variance analysis and multiple comparisons were performed using Minitab 17 software.

Results

Percentage of Tuber Sprouting

For the variable percentage of sprouting in Table 3, according to the Tukey statistical test, the analysis of variance has determined highly significant differences ($p<0.05$) between the treatments for tuber sprouting percentage.

The Tukey multiple comparisons (Fig. 1) show significant differences in terms of tuber sprouting percentage among the treatments. According to the results, treatment 5 has the highest sprouting percentage, followed by treatment 3 and treatment 4. On the other hand, treatment 1 and treatment 6 have the lowest sprouting percentages. Therefore, we can conclude that treatments T_5 and T_3 are the most effective in accelerating sprouting in potatoes, while treatment T_1 is the least effective. Treatments T_4 and T_2 fall in between and treatments T_7 and T_6 are less effective than treatments A and *B*, but more effective than treatment T_1.

Number of Shoots

Table 4 indicates analysis of variance has determined there are highly significant differences ($p<0.05$) between treatments in terms of the number of shoots. In Fig. 2, it can be observed that treatments 5, 3, and 4 had the highest averages for the number of shoots with 8.93, 8.83, and 8.68, respectively, surpassing the other treatments evaluated.

Table 3: Tukey Means comparison test for the variable percentage of tuber sprouting

Treatment	Mean	Range
T_5	86.17	A
T_3	85.67	A
T_4	84.96	AB
T_2	82.54	BC
T_7	81.21	CD
T_6	79.73	DE
T_1	69.94	E

Table 4: Mean comparison test for the variable number of shoots

Treatment	Mean	Range
T_5	8.93	ABC
T_3	8.83	ABC
T_4	8.68	ABC
T_2	8.33	AB
T_7	7.95	A
T_6	7.90	A
T_1	7.81	A

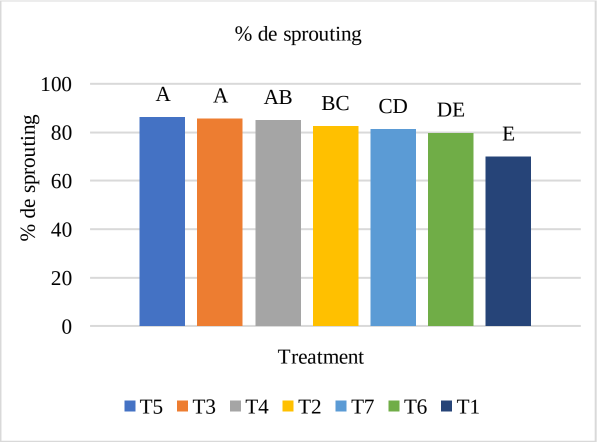

Fig. 1: Tukey means comparison test for the variable percentage of tuber sprouting

Shoot Length

For the variable shoot length, according to the analysis of variance, there are highly significant differences ($p<0.05$) among the treatments for shoot length (Table 5).

In Fig. 3, it is evident that treatments 5 and 3 have shown the highest average shoot lengths with 7.69 and 7.50 cm, respectively. Conversely, the shortest shoot lengths were observed in treatments 4, 2, 7, 6, and 1, with values of 7.32, 7.19, 6.69, 6.59, and 5.54 cm, respectively.

Shoot Diameter

According to the analysis of variance using the Tukey test, there are significant differences ($p<0.05$) among the treatments in shoot diameter (Table 6).

In Fig. 4, it can be observed that treatments 3 and 5 obtained the highest average shoot diameter with 6.00 and 5.90 mm, respectively. They were followed by treatments 4 and 2, which had results of 5.55 and 5.54 mm, respectively. Treatments 7 and 6 performed with lower results, averaging 5.39 and 5.37 mm, respectively, and finally, the control treatment had the lowest shoot diameter at 4.47 mm.

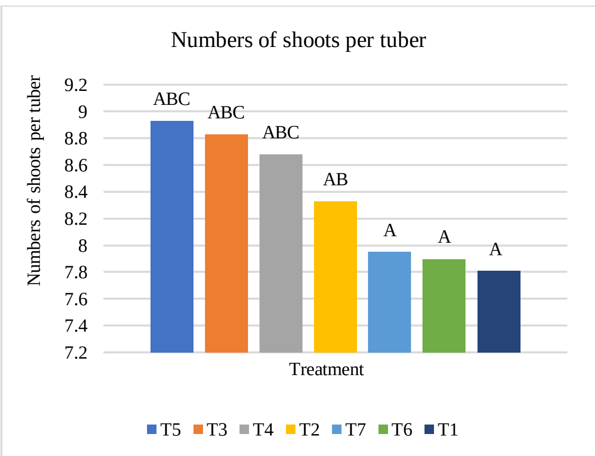

Fig. 2: Number of shoots

Table 5: Means test for shoot length

Treatments	Mean	Range
T_5	7.69	A
T_3	7.50	A
T_4	7.32	B
T_2	7.19	B
T_7	6.69	C
T_6	6.59	C
T_1	5.54	D

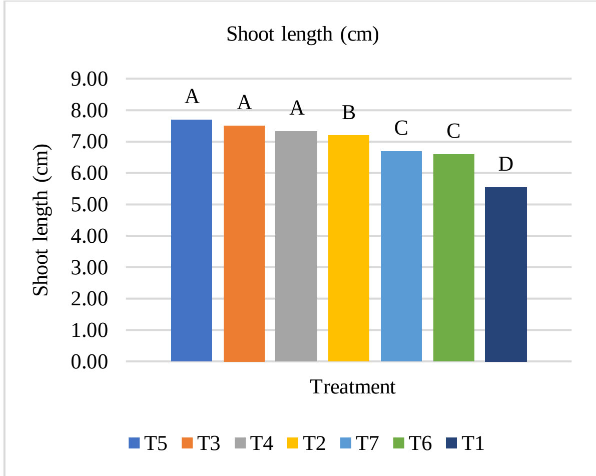

Fig. 3: Shoot length

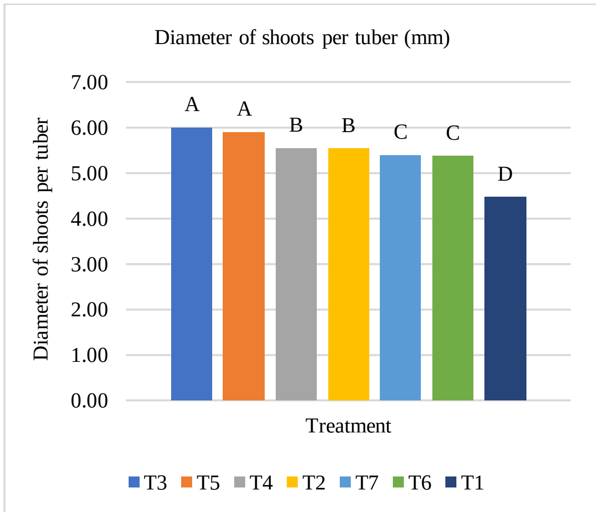

Fig. 4: Diameter of shoots per tuber

Table 6: Mean comparison test for the shoot diameter variable

Treatment	Mean	Range
T_3	6.00	A
T_5	5.90	A
T_4	5.55	B
T_2	5.54	B
T_7	5.39	C
T_6	5.37	C
T_1	4.47	D

Discussion

The latency in potato tubers can be broken or accelerated through physical and phytohormonal treatments, in which the application of gibberellins, cytokinins, and auxins disrupts tuber dormancy (Geldres and Skrabonja, 2014). The results obtained in this study indicate that tubers treated with gibberellic acid broke dormancy in less time. Similarly, it has been demonstrated that cropping systems influence the quality parameters of tubers, such as starch content and dry matter (Roinila *et al*., 2003).

This is evident in this study, where 30 days after the administration of gibberellin began, a germination rate of 86.17% was achieved with treatment T_5, which involved a dose of 10 mL of full Gib for 20 min of immersion. Similar results were obtained in a study by Veliz Galarza (2013), which mentioned that the best results were achieved by immersing 8 g of 10% new Gibb in water for 15 min.

The information obtained significantly differs from the recommendation in the Ryzup prospectus, which suggests that the ideal dose for immediate germination is 2.5 mL soaked in water for 15 min.

The number of shoots per tuber does not have a direct correlation with the germination percentage. Therefore, T_5 (10 mL of full Gib for 20 min of immersion) stood out more than treatment T_7, despite having a different dose and time. It's worth mentioning that Dragićević *et al*. (2008) reported similar evidence in a study of potato stem and its growth induced by gibberellins. GA3 promotes the accelerated emergence of multiple shoots per tuber seed, as seen in our results in Fig. 2, where treatments containing GA3 outperformed the control. In comparison with Salimi *et al*. (2010), these results are consistent with the shortened latency time and the emergence of tubers treated with GA3. Regarding the length of shoots per tuber, the results show a significant effect, reflecting the efficacy of GA3. Similar results were again obtained by Salimi *et al*. (2010), who treated potato micro tubers with gibberellic acid and carbon disulfide and determined that the length of shoots after treatment with CS2 and GA3 was significantly greater than the controls or untreated samples. The microtubers treated with GA3 had a significantly greater shoot length than those treated with CS2. On the other hand, Geldres and Skrabonja (2014) evaluated variables such as shoot length and shoot diameter per tuber and found that seed tubers of the Canchán variety had apical shoots of 32 mm after 90 days of storage. These results are comparable to the results of treatments T_5 and T_3 in this study, which clearly highlight the importance of Gibberellic Acid (GA) applications in increasing RNA and DNA synthesis (Rodriguez and Moreno, 2010). These increases precede cell division, allowing the dominant apical period to end and multiple sprouting to begin, meaning that lower buds and apical buds begin to grow. This indicates that the multiple germination period is ideal for planting seed tubers (Yang *et al*., 2010). Authors like Alexopoulos *et al*. (2007); Salimi *et al*. (2010) found that shoots of tubers treated with GA3 tended to be long, slender, fragile, and susceptible to breakage during handling and planting. This can limit the commercial use of GA3. However, this differs from our results, which may be related to the diffuse light conditions they were exposed to when the first shoots emerged.

Conclusion

The best results obtained in the tuber sprouting percentage were in treatments 5 and 3, reaching averages of 86.17% and 85.67%, respectively, surpassing the other treatments. There were no significant differences between treatments in the number of shoots per tuber. The best treatments for this variable were 5, 3, and 4, with results of 8.93, 8.83 and 8.68, respectively. Additionally, the variable shoot length achieved the best results in treatments 5 and 3, with measurements of 7.69 and 7.50 cm, respectively. Similarly, the shoot diameter variable yielded positive results in treatments 3 and 5, with measurements of 6.0 and 5.9 mm, respectively.

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Author's Contributions

Wilfredo Ruiz Camacho and Danny Villegas-Rivas: Participated in all experiments, coordinated the data analysis and contributed to the written of the manuscript.

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Ethics

All the protocols of ethical research conduct were strictly adhered to throughout the study and there are no conflicts of interest to report.

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