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Short article

Rooting young stem cuttings of *Solanum tuberosum* L. var. *yungay* using 2,4-dichlorophenoxyacetic acid

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Abstract

For the propagation of *Solanum tuberosum,* tubers as seeds are the most commonly used method in most agroecological areas. The use of young stem cuttings is an exclusive practice of nurseries and agricultural companies, which employ rooting hormones that are inaccessible to small farmers. Reportedly, synthetic auxin 2,4-dichlorophenoxyacetic acid (2,4-D) at a very low concentration induces the rooting of cuttings and can be an accessible alternative for small-scale agriculture. Given the need for broader knowledge, this research aims to evaluate the rooting effect of 2,4-D in young stem cuttings of *S. tuberosum* var. *yungay*. The experimental phase took place in the greenhouse of the Institute for Potato and Andean Crops, Universidad Nacional de Trujillo, Peru, with seedlings from the same Institute. These seedlings became mother plant donors of young stem cuttings, which were sown in a rooting bed with different 2,4-D concentrations. When analyzed statistically, the results obtained show that the 0.3 % concentration caused a higher average in the number of roots (6.52), root length (5.31 cm), and seedling height (2.63 cm). In conclusion, 2,4-D at a 0.3 % concentration produces the better rooting of young stem cuttings of *S. tuberosum* var. *yungay*.

Keywords: auxins, cuttings, plant growth substances, potatoes, vegetative propagation

Enraizamiento de esquejes de tallo juvenil de *Solanum tuberosum* L. var. *yungay* mediante la aplicación del ácido 2,4-diclorofenoxiacético

Resumen

Para la propagación de *Solanum tuberosum*, los tubérculos son la forma más empleada en la mayoría de las zonas agroecológicas. El empleo de esquejes de tallo juvenil es una práctica exclusiva de viveros y empresas agrícolas que hacen uso de hormonas enraizantes, inaccesibles para los pequeños agricultores por su alto costo. Se ha reportado que la auxina sintética 2,4-diclorofenoxiacético (2,4-D) a muy baja concentración induce al enraizamiento de esquejes y puede ser una alternativa viable para la agricultura a pequeña escala. Ante la necesidad de un mayor conocimiento, se propuso como objetivo de investigación evaluar el efecto enraizante del 2,4-D en esquejes de tallo juvenil de *S. tuberosum* var. *yungay*. La fase experimental se desarrolló en el invernadero del Instituto de la Papa y Cultivos Andinos de la Universidad Nacional de Trujillo (Perú), con plántulas procedentes del mismo instituto que se convirtieron en plantas madre donadoras de esquejes de tallo juvenil, los cuales fueron sembrados en cama de enraizamiento con diferentes concentraciones de 2,4-D. El análisis estadístico de los resultados demostró que la concentración de 0,3 % generó un promedio mayor en número de raíces (6,52), longitud de raíces (5,31 cm) y altura de plántula (2,63 cm). Se concluyó que el 2,4-D en concentración del 0,3 % produce un mejor enraizamiento de esquejes de tallo juvenil de *S. tuberosum* var. *yungay*.

Palabras clave: auxinas, esquejes, papas, propagación vegetativa, sustancias de crecimiento vegetal

Introduction

The northern area of Lake Titicaca is one of the centers of origin and diversity of *Solanum tuberosum* L. In this place, wild species such as *Solanum bukasovii* Juz. and *Solanum bukasovii* var. *multidissectum* (Hawkes) Ochoa gave rise to *Solanum stenotomum* Juz. et Buk., listed as the first domesticated potato. *Solanum stenotomum* originated *Solanum andigenum* Juz. et Buk., which by polyploidization and interspecific hybridization processes resulted in a great diversity of potatoes. Ancient Peruvians were responsible for scattering them across the center, south, and north of Peru. Then, the Spanish colonizers spread them throughout Europe and the world (Centro Internacional de la Papa & Federación Departamental de Comunidades Campesinas, 2006; Gil-Rivero et al., 2019; Gómez et al., 2012; Rodríguez, 2010).

Currently, more than 5,000 varieties of potato are known in Peru, including wild, native, and commercial varieties. Potato is considered the world's fourth food staple of the human diet due to its nutritional and culinary characteristics (Gómez et al., 2012; Kramm, 2017). In the culinary field, potato can be eaten in various preparations such as soups, mashed potatoes, French fries, dried potatoes, *chuño*, and *tocosh*. The last two are the most important ethnomedicinally for the Andean populations due to their content of natural antibiotics (Álvarez, 2001; Centro Internacional de la Papa, Asociación Pataz, & Instituto Nacional de Innovacion Agraria, 2015; Pesantes, 2015).

Solanum tuberosum is propagated vegetatively using cuttings, tubers, and *in vitro* cultures, and sexually through botanical seeds, which are the most used form because it preserves the agronomic attributes of the species. According to the principle of cell totipotential, plants retain the ability to regenerate and rebuild their tissues until they become once again whole plants with the same genotype (Araújo et al., 2009; Hartmann & Kester, 1995; Rojas et al., 2004). Therefore, farmers use seed tubers to obtain plants identical to the mother plant, although this method allows the transmission of diseases that, together with poor agricultural practices and genetic potential, reduce yields.

This problem resulted in the implementation of new propagation alternatives in production systems, such as *in vitro* plant tissue cultures. Meristem culture, somatic embryogenesis, and *in vitro* tuberization are the most common techniques in plant biotechnology since they ensure better genetic and phytosanitary quality of the crop due to a lower viral and bacterial load. Thus, the production and profitability of crops are maximized (Araque et al., 2018; Hernández & Díaz, 2019; Tacoronte et al., 2017).

Propagation by young stem cuttings is useful in pre-basic and basic seed programs. This technique lies in selecting young greenhouse plants that contain between five and six nodes and cutting them at the base of the shoot, leaving a basal leaf with its bud. Then, the apical bud is removed, and portions of the stem

are sectioned to obtain cuttings consisting of a leaf and its axillary bud, which will induce rooting when treated with hormones and sown in the sand (Cotes & Ñustez, 2001; Ramírez et al., 2011b).

The rooting of any cutting requires the right hormonal balance of phytohormones or phytoregulators. In agriculture, the most widely used phytohormone is indole-3-butyric acid (IBA), and the most widely used phytoregulator is 1-naphthaleneacetic acid (ANA); these compounds are not affordable for small and medium farmers and agricultural technicians (García et al., 2001; Moreno et al., 2009; Uribe et al., 2012). Although it is known that 2,4-dichlorophenoxyacetic acid (2,4-D) is the most used synthetic auxin herbicide in agriculture to control weeds because it is cheap and easy to buy, it reportedly induces the rooting of cuttings at low concentrations (De la Cruz et al., 2014). Then, the aim of this research is to evaluate the rooting of young stem cuttings of *S. tuberosum* var. *yungay* by applying different 2,4-D concentrations.

Materials and methods

We selected *Solanum tuberosum* var. *yungay* (Solanaceae) plants with five to six nodes from the Biotechnology Laboratory of the Institute for Potato and Andean Crops, Universidad Nacional de Trujillo, and cultivated them in pots of 10 cm in diameter with a substrate consisting of a mixture of sand, humus, and moss in a 1:1:1 ratio under greenhouse conditions.

Seedbed preparation

In the greenhouse, we prepared a seedbed consisting of two layers of sand: the first, 4 cm thick with coarse sand of 1 cm in diameter at the bottom, and the second, 10 cm thick with fine sand of 0.05 cm in diameter on the top. This substrate was previously disinfected with 2 % sodium hypochlorite for 24 hours and solarization for one week.

Sowing cuttings of *Solanum tuberosum* var. *yungay*

When the mother plants were able to acclimatize and had between five and six leaves, young stem cuttings consisting of a shoot and its leaf were sectioned (figure 1). The method was to moisten the basal part of the cuttings with water and then impregnating them with the 2,4-D hormone powder according to the indicated treatments: T1: 0 %; T2: 0.3 %; T3: 0.5 %; and T4: 0.8 %.

Figure 1. Young stem cutting of *Solanum tuberosum* var. *yungay*.
Photo: Segundo Eloy López Medina

Finally, the plants were sown in rooting beds at field capacity and watered twice a week with sterile water added with liquid NPK-based fertilizer (12-14-12) at a rate of 5 g/L. The greenhouse was kept at an average temperature of 25 °C ± 2 °C, relative humidity of 80 %, and a photoperiod of 16 hours of light and 8 hours of darkness.

Statistical design

A completely randomized design was used, consisting of 4 treatments, 24 repetitions, and 96 experimental units. Twenty days after sowing, the number of roots, their length, and seedling height were measured. The recorded data were analyzed with the RStudio integrated development environment, version 1.2.5033. The presence of statistically significant differences was evaluated using Welch's Anova test because no variable met the homoscedasticity, and the Games-Howell *post hoc* test, with a 5 % significance level, for selecting the best treatment.

Results and discussion

The number of roots, the maximum root length, and the seedling height produced by the different 2,4-D concentrations 20 days after sowing clearly show the action of synthetic auxin, with significant differences between treatments and evaluated parameters (table 1). Ramírez et al. (2011a) have shown

that, in Solanaceae, it is necessary to use auxins for the rooting of young cuttings, while in other plant species, they are not essential since water is enough to induce rooting. However, it is crucial to consider that the type of substrate used influences the quality and quantity of roots formed due to more aeration and water retention (López et al., 2008). For their part, Ludwig-Müller and Cohen (2002) reported that auxins regulate plant development, including rooting, since the hormone concentration used is responsible for inducing or inhibiting radical development of future plants.

Table 1. Average values of the variables measured for each treatment

Treatment	Number of roots $\bar{x} \pm e$	Maximum root length (cm) $\bar{x} \pm e$	Seedling height (cm) $\bar{x} \pm e$
T1	0.63 ± 0.39	1.62 ± 0.96	0.39 ± 0.22
T2	6.52 ± 0.91	5.31 ± 0.67	2.63 ± 1.41
T3	5.33 ± 1.23	4.89 ± 1.17	2.53 ± 1.31
T4	4.29 ± 1.30	4.52 ± 1.23	1.66 ± 1.11

Note: $\bar{x} \pm e$: mean estimate

Source: Elaborated by the authors

When 0.3 % 2,4-D was used, better results were obtained in terms of the number of roots, maximum root length, and seedling height (table 1). When analyzing the Games-Howell *post hoc* test (table 2), we noted that the T2 treatment is the best as it achieved a more significant number of cell divisions that promoted root growth (figure 2). De la Cruz et al. (2014) corroborate this finding by stating that the 0.3 % concentration of 2,4-D exerts a positive effect on the rooting of young cuttings of *Rosa canina* L. (Rosaceae).

Table 2. Homogeneous subsets obtained from the Games-Howell test for each treatment according to the variables analyzed

Treatment	Average number of roots	Average maximum root length	Average seedling height
T2: 0.3 % concentration	a	a	a
T3: 0.5 % concentration	ab	a	a
T4: 0.8 % concentration	b	a	ab
T1: 0 % concentration	c	b	b

Note: Distinct letters in subsets have a significant difference at 95 % confidence.

Source: Elaborated by the authors

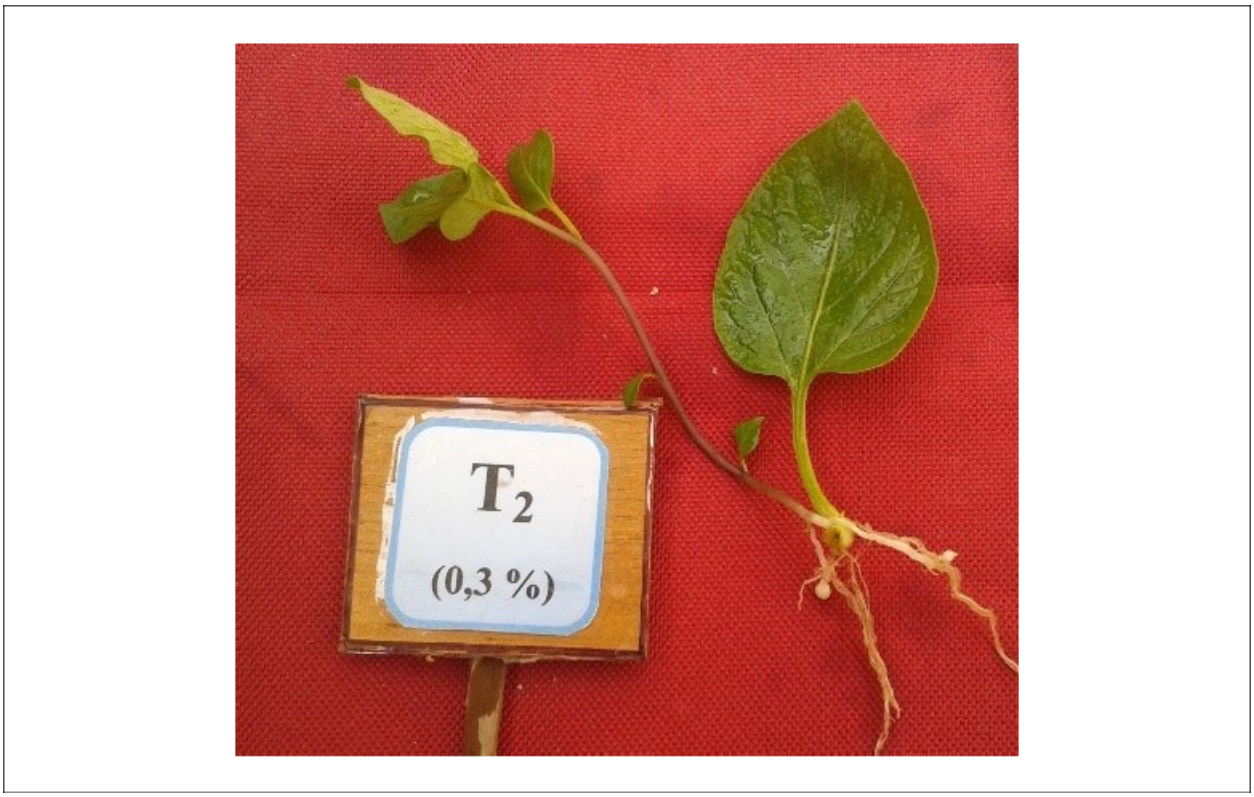

Figure 2. Rooted seedling of *S. tuberosum* var. *yungay* obtained from young stem cuttings with 2,4-D application 20 days after sowing.
Photo: Segundo Eloy López Medina

Moreover, we observed that, when increasing the 2,4-D dose from 0.3 % to 0.5 % and 0.8 %, there was no rise in the number of roots, maximum root length, and seedling height that exceeded the results of the T2 treatment. It can be inferred that a higher 2,4-D concentration causes a hormonal imbalance that ends up inhibiting rooting. Hartmann and Kester (1995) reported that volumes of growth regulators should be optimal to induce rooting. Also, Moreno et al. (2004) argued that by using ANA, good results are obtained in rooting potato cuttings. Ramírez et al. (2011a) reported that the use of ANA at a 0.4 % concentration induces 100 % rooting and survival of cuttings. For their part, López et al. (2016) indicated that IBA at a 0.0001 % concentration has a positive effect on the rooting of cuttings.

As a result of good root development, a more significant increase in the length of the plants was observed (table 1, figure 2). Likewise, the action of auxins, which improves the plasticity of the cell wall, generated a greater deposit of cellulose, which promotes longitudinal growth (Hager, 2003; Henríquez, 2004). Giraldo et al. (2009) reported that the presence of auxins induces the synthesis of gibberellins, which are the hormones responsible for cell elongation.

Conclusions

The use of 2,4-D at a 0.3 % concentration produces the better rooting of young stem cuttings in *S. tuberosum* var. *yungay* and is an efficient alternative for the propagation of *S. tuberosum* by small farmers.

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Disclaimers

The authors made significant contributions to this document, agree with its publication, and state that there are no conflicts of interest in this study.

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