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Benefit-cost analysis of the optimum level of giberellic acid as an inductor of the germination of chiltepín chili (*Capsicuum annuum* var. *aviculare*) cultivated in backyard

Análisis beneficio-costo del nivel óptimo de ácido Giberélico como inductor de la germinación de chile chiltepín (*Capsicuum annuum* var. *aviculare)* cultivado en traspatio

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Abstract

The gastronomic culture of Mexico is linked to various vegetables, to certain species and, in particular, chili. It is clear that chilies are plant species that have great importance in the identity of the people of Mexico. The objective of this research was to analyze the cost-benefit of sowing chiltepin-type chili in the backyard using the optimal level of applying gibberellic acid as a germination inducer. Prior to the cost-benefit analysis, seven treatments were evaluated to select the best one to induce chiltepín germination. The treatments were supported by the application of gibberellic acid in different percentages, plus a control (T1-no application). The results showed that the optimal level of germination was obtained with the application of substrate, perlite, vermiculite and 5% gibberellic acid. With this treatment, a greater number of plants and 95% rooting were obtained, compared to the control treatment (T1) as well as a greater yield of chili (171 g plant-1) compared to the control (128 g plant-1). A cost-benefit ratio of 1.33 was calculated for the best biological treatment, so it is concluded that it is possible to improve family income through the production of chiltepin-type chili under backyard conditions.

Evaluation, Production, Alternative cultivation

Resumen

La cultura gastronómica de México está ligada a diversos vegetales, ciertas especies y en lo particular al chile. Es claro que los chiles son especies vegetales que tienen gran trascendencia en la identidad del pueblo de México. El objetivo de esta investigación fue analizar el costo-beneficio al sembrar el chile tipo chiltepín en traspatio utilizando el nivel óptimo de aplicar ácido giberélico como inductor de la germinación. Previo al análisis costo-beneficio se evaluaron siete tratamientos para seleccionar el mejor para inducir la germinación del chiltepín. Los tratamientos se sustentaban con la aplicación de ácido giberélico en diferentes porcentajes, más un testigo (T1-sin aplicación). Los resultados mostraron que el nivel óptimo de germinación se obtuvo con la aplicación de sustrato, perlita, vermiculita y ácido giberélico al 5%. Con este tratamiento se obtuvo un mayor número de plantas y un 95% de enraizamiento, en comparación con el tratamiento testigo (T1) así como un mayor rendimiento de chile (171 g planta-1) en comparación al testigo (128 g planta-1). Se calculó una relación de b/c de 1.33 para el mejor tratamiento biológico por lo que se concluye que es posible mejorar el ingreso de las familias mediante la producción de chile tipo chiltepín bajo condiciones de traspatio.

Evaluación, Producción, Cultivo alternativo

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Introduction

Chilli peppers are a plant species of particular importance in Mexican culture and identity. The chiltepín chilli (*Capsicum annuum* L. var. *glabriusculum* (Dunal) Heiser & Pickers- gilles) also known as quipi, pikin or ají pajarito is native to tropical areas, being found from the south of the United States of America, in various regions of Mexico (Rueda, *et al*., 2010) and in Central America (Castro, 2020). The word chiltepín is believed to come from the Nahuatl word meaning "flea". In Mexico, the main producers, and consumers of chiltepín are the states of Sonora and Sinaloa. In Sonora it is known as the red gold, due to its high cost as an exotic chilli (Camarena, 2016). The wild chiltepín from the Sierra de Sonora occupies a significant place in the culture of Sonorans. However, studies on this species are scarce and one-dimensional (Bañuelos, *et al*., 2008). Chiltepín is mainly collected by women and children in the various ecoregions of the country, which is why this activity represents a source of extra income for rural municipalities and, therefore, is a factor of socio-economic development for the region.

Mexico has been classified as a high producer and consumer of chilli. For this reason, several types of species are consumed, depending on the region and the type of vegetation, but one of the most important is the Chiltepín type chilli. Mexico stands out for the importance of the origin and diversity of the most representative chilli species, which includes Capsicum annuum among the more than 100 varieties of chillies consumed worldwide (Gallardo, 2017). Chilli is a relevant element in the national culture for the preparation of dishes and traditional medicine and is undoubtedly a source of income for rural communities where it is naturally produced.

It is well documented that Mexico has been classified as a high consumer of spicy products. Thus, consumers identify several types of chilli, depending on the region, the environment, and the type of vegetation. In the case of chiltepín, it should be mentioned that this species is consumed in the communities surrounding the production areas and, it is believed, that its harvesting has not endangered the survival of this species; that is to say, its cultivation has taken place under sustainable conditions.

In addition, it should be mentioned that consumption has increased in recent years as a result of their display in US supermarkets, promoted as exotic chillies (Camarena, 2016). However, in some regions of Mexico (i.e., in the region of Chínipas in the state of Chihuahua), this species is intensively harvested in the wild, deteriorating its habitat and participating in the gradual extinction of this species (Oviedo, *et al*., 2017).

Chiltepín is produced seasonally and at a specific time; consequently, it is necessary to practice adequate management of the plant in order to have a product all year round. For this reason, it is necessary to generate clonal lines by selecting plants with the required characteristics, such as size, shape, fruit colour, quantity and quality of modern crops (González, 2016).

Once a line has been generated, cuttings can be taken from the plant, i.e. stems cut lengthwise to which hormones are added in substrate during the period when the plant is not differentiating, flowering or bearing fruit. Finally, the plant is properly managed until it is big enough to be transferred to soil or hydroponic cultivation. Ibid.

The objective of this study was to perform a benefit-cost (b/c) analysis of the investment made by producers in the municipality of Rosales, Chihuahua, Mexico in the production of chiltepín chilli under backyard conditions. The results will reduce the costs associated with the purchase of chili peppers for daily consumption by participating families and increase their financial indicators. We hypothesised that growth in the agricultural sector plays an important role in reducing poverty in communities, as some estimates have determined that such growth is three to four times more effective than growth in other non-agricultural sectors (Christensen, 2018).

Methodology to be developed

The study was carried out from February 2022 to June 2023 in the town of Ortiz, in the municipality of Rosales, Chihuahua, Mexico. This community is located at the coordinates Latitude 28,1833, Longitude-105.467 28° 10`60" North, 105° 28`1" West. Figure 1 and Figure 2 show the location of the study.

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The area has an extreme semi-arid climate, the average annual temperature is 18.6 ºC, the maximum temperature is 42 ºC and the minimum temperature is -13º C. The average annual rainfall is 294.7 mm, with an annual average of 82 days of rain and a relative humidity of 45%. There are an estimated 60 days of rain and 2 days of hail. The number of frost days is 110 and there are 3 d of early frosts (October) and 4 d of late frosts (April). The prevailing winds come from the southwest (INAFED, 2021).

In a first stage, an experiment was established under backyard conditions with the objective of identifying the optimum level of gibberellic acid application to obtain good chiltepín seed germination. The following eight treatments with additions of substrate, perlite, vermiculite and gibberellic acid were evaluated; the control treatment (T1), application of substrate, perlite, vermiculite and gibberellic acid at 3% (T2), application of substrate, perlite, vermiculite and gibberellic acid at 4% (T3), application of substrate, perlite, vermiculite and gibberellic acid at 5% (T4), application of substrate, perlite, vermiculite and gibberellic acid at 6% (T5), application of substrate, perlite, vermiculite and gibberellic acid at 7% (T6) and application of substrate, perlite, vermiculite and gibberellic acid at 8% (T7). The treatments were established in soil with a plant spacing of 2x2 m.

Statistical analysis of biological response

Differences between treatments were analysed by analysis of variance (ANOVA) considering an unstructured arrangement of treatments (Rubio and Jiménez, 2012). The statistical package SAS (Statistical Analysis System) was used for the analysis. When the F value was significant, a mean comparison test was used with Tukey's method. The statistical analyses considered a significance value of 95%, i.e. $\alpha=0.05$ in all cases.

Cost-benefit analysis

Once the best evaluated treatment of gibberellic acid application was determined from the biological point of view, a cost-benefit analysis was carried out. The simplest formula was used for this analysis, i.e., the b/c ratio was calculated, where b represents the benefit and c the cost.

The benefit is determined as a percentage and its interpretation is: if the result is greater than 1, it is acceptable or profitable; if the result is equal to 1, there is no profit or loss; and if the result is less than 1, it is not profitable, so the treatment or project is rejected. Its formula:

$$\text{Benefit Cost} = \left(\frac{\text{Net income}}{Net\ cost}\right) \times 100$$

Results and discussion

The ANOVA results for the percentage of gibberellic acid applied to chiltepin chili seed showed differences between treatments in rooting, seedling development and yield ($P<0.05$). A detailed analysis of these results is not shown as it was not the objective of this study. Of the evaluated treatments, the one that presented a higher growth and a better rooting of the chiltepin chili seedling under backyard conditions was T4; that is to say, with the application of substrate, perlite, vermiculite and gibberellic acid in 5%. It was noted that this treatment had a positive effect favouring a better development of the plant. With this treatment, a greater number of plants were obtained (17 plants), which greatly surpassed the control (T1), where 8 plants were observed. With respect to yield, in T4 171 g of fresh red fruit per plant were harvested, while in the control treatment 128 g were harvested.

Agronomic results show evidence that this plant is highly adaptable to different environments and soil types (Cano *et al*., 2015; Rueda *et al*., 2010). In a recent work developed by Alcalá, e*t al*. (2019), where they evaluated 11 germination treatments in chiltepín, they found that the application of gibberellic acid to the seed with a scarification process improved the germination percentage, germination index and germination speed and reduced seed death. Koornneef and Bentsink (2002) reported that gibberellic acid offered an excellent way to improve plant germination. Similarly, Quintero *et al*. (2018) found that gibberellic acid treatments had a positive effect on germination compared to the control group.

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Our results are interesting because there is a marked interest in domesticating this plant and, in this way, making it possible for families to harvest their chilli needs, in this case chiltepín. However, little has been studied about the dormancy mechanism of this particular species, which has allowed it to overcome adverse climatic conditions or to resist light, water and nutrients with special competitiveness (Finkelstein *et al.*, 2008). It is traditional for Mexican families to collect chiltepín fruits in the wild (Guerrero, 2015) and little has been done to domesticate this plant in backyard plots, although several studies have shown that chili seed production is a highly profitable market (Tigari and Swathi, 2019). Major problems in domestication include variation among genotypes, low and erratic germination rates, morphological and physiological information among other factors.

The benefit-cost analysis found a value of 1.33, i.e. it is possible to support the sowing of chiltepín type chilli under backyard conditions, as this crop is profitable and without any visible risk. It is desired that the producer adopts an innovation or alternative that will improve his standard of living and, consequently, increase his income. It is not common to find benefit-cost analyses on agricultural and livestock products; however, some researchers have conducted such analyses to motivate the planting and promotion of a certain type of crop. For example, researcher Avila (1997) conducted a study to determine the benefit-cost of several important crops in the northwest region of the state of Chihuahua and concluded that oats were the most suitable crop for producers because of their 63.41% profitability including land costs.

The advantage of producing one's own type of chilli under backyard conditions by a Mexican family is truly innovative, as it is well documented that the price of this product, which is consumed in practically every meal, increases significantly in local markets. For example, in India 90% of chillies sold are produced in other regions and only 10% is a local product, which increases the price of the products significantly (Srikala, *et al*., 2016).

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