International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 23s,2025
https://theaspd.com/index.php

Comparison Of Application Of Mycorrhizae And Chemical Fertilizers In Corn Cultivation: A Commitment To Conservation

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Summary
The purpose of this study is to compare the effect of the application of mycorrhizae with the use of chemical fertilizers in corn cultivation, thus provoking a commitment to sustainable production. The research was carried out in La Punta, a cultivation area of the village of La Pacha, located in the township of San Sebastián, in the department of Magdalena. As a differential element within the methodology, psychosocial accompaniment was provided to the participating families. A randomized experimental design was used with four treatments and three replications. Starting in August 2024 and culminating in January 2025. The first consisted of applying triple super phosphate and ammonium nitrate. The second was inoculation with the mycorrhizal fungus Glomus intraradices. The third treatment added mycorrhizal inoculation plus 50% chemical fertilizer. Finally, a control treatment without any application. The comparison consisted of determining the growth of the plant (height and diameter of the stem, leaves and leaf area), the grain yield of maize (kg per row and yield of ton per hectare) and the soil chemistry (Phosphorus (P), Potassium (K), Magnesium (Mg), Calcium (Ca), Sodium (Na), organic matter and nitrogen). The conclusion of the research points out that the application of mycorrhizae can replace the application of mineral fertilizers, as they improve the chemical properties of the soil, plant growth and grain yield, translating into economic savings for the producer and at the same time contributing to the development of sustainable agriculture.

1. INTRODUCTION

Undoubtedly, corn is one of the basic products for Mexican society, since it becomes one of the most important foods for different social classes. For this reason, a myriad of fertilizers and biofertilizers are used for its production, such as mycorrhizae and chemical fertilizers, which belong to different groups. With the purpose of improving corn yield, the application of mycorrhizae is a commitment to conservation, and represents an alternative. The excessive use of chemical fertilizers has a very high environmental cost, therefore, it is necessary to direct production towards a sustainable cycle to reduce the impact and conserve the ecosystem.

The research and experimentation work was carried out during the spring-summer cycle of 2024. The objective was to compare the application of mycorrhizae and chemical fertilizers in corn cultivation to determine which option represents a commitment to conservation. In the experimental design, a control treatment, a treatment with mycorrhizae, another with chemical fertilizers and one more with mycorrhizae and combined fertilizers were considered. Variables related to maize growth, grain yield and soil quality were evaluated. The results obtained made it possible to make recommendations to producers on the use of fertilizers based on their polluting effects.

2. THEORETICAL FRAMEWORK

The genus Glomus is among the most common in the Mesoamerican habitat, to establish a good inoculation of the plants grown in the laboratory. Glomeromycota is a division of the kingdom Fungi.

It currently includes only one order: Glomales. This division comprises a group of fungi associated with most terrestrial plants, resulting in beneficial symbiosis through the formation of arbuscular mycorrhizae. This type of symbiotic association is a natural phenomenon that favors the growth, development and better production of many plant species of economic interest. They are a group of fungi of the phyla Glomeromycota and are considered one of the most important biological organisms for the environment; They have the ability to establish associations with most terrestrial plants and can improve plant growth and their resistance to a large number of biological and abiotic stress conditions. In general, it improves the growth of host plants by increasing the uptake of nutrients from the soil, particularly phosphates, nitrogen, potassium, calcium and other elements. Among the phytopathogenic fungi against which mycorrhizae can protect themselves are Rhizoctonia sp., Sclerotium sp., Fusarium sp., and Pythium sp. Adverse conditions include drought and dwarfism, or salinity and heavy metals.

2.1. Definition of Mycorrhizae

According to Silva and Montoya, (2022), mycorrhizae are microsymbiotic fungi that coexist in plant roots. A mycorrhiza is therefore the symbiotic association between certain types of fungi and plant roots, where fungal hyphae develop along with roots. Mycorrhizae increase the longevity of the roots, and also provide more easily absorbable nutrients, water, and minerals. As for other ecosystem services, these partnerships also provide protection to the roots against diseases of certain nematodes, fungi, bacteria and also provide anchoring support for the plant in states of drought or soil contamination (Rukavina, 2024). In cultivation systems, especially those that require the application of large amounts of chemical fertilizers, the activity of mycorrhizal fungi decreases considerably, since the soil environment is transformed, thus affecting its development (Sánchez López & Villanueva Fernández, 2022). In recent years, the properties of the mycorrhizal fungus have been widely studied to try to reduce the impacts generated by the indiscriminate use of chemical fertilizers, using sustainable agriculture, which aims to obtain a better yield with minimal investment and contributing to the conservation of natural resources (Figueroa Romero, 2023).

2.2. Use of Chemical Fertilizers

These chemical fertilizers, made with physical and chemical means that contain different amounts of elements, can be harmful to plants; however, its use is very widespread in agriculture. These maize evolution, small producers use these do not adjust to production needs, which causes deficiencies in maize growth. During germination, the roots are the first in contact with fertilizers or inoculation with mycorrhizae for their development, so it is considered important to first analyze phytodevelopment during this stage. The yield of the grain in terms of fresh mass and dry mass is also a parameter of comparison. After the agronomic analysis, an analysis of the physical and chemical properties of the soil is carried out to determine if there is any change in fertility when applying sustainable agriculture.

The excessive use of these products can generate ecotoxic effects in humans, such as acute kidney damage, anemia, respiratory problems, damage to the nervous system, and cancer (Alvario Maldonado, 2025). Manrique Tello (2024) mentions that one of the most worrying consequences of the indiscriminate use of chemical fertilizers is water pollution. Against this backdrop, the use of tree mycorrhizae will favor sustainable agriculture, as they help conserve the soil, maintain its physical and chemical properties, such as pH balance, organic matter and phosphorus content, improve water quality and have the ability to establish associations with different crops, including corn.

2.3. Benefits of Sustainable Agriculture

Sustainable agriculture emphasizes the responsible use of resources to ensure appropriate agricultural yields and the rational use of fertilizers and pesticides, with the aim of conserving the soil and maintaining its physical, chemical, and biological properties. In the region of Chiapas, Mexico, the predominant use of chemical fertilizers in agriculture is ammonium nitrate (NH4NO3), due to its richness in nitrogen, although other fertilizers with phosphorus, potassium, zinc, calcium, magnesium content, among others, are also used. These chemical fertilizers are, for the most part,

chemically synthesized and are produced by highly polluting processes, which also, during their degradation, generate a series of pollutants.

In contrast, there are environmentally friendly microorganisms, such as mycorrhizae, which have proven to be an elegant alternative to feed plants. Recent research indicates that the combination of chemical fertilizers with mycorrhizae may be the solution for sustainable agriculture, by reducing the dose of fertilizer and generating less pollution. On the other hand, a study carried out in the Tapalpa Bicentennial Reserve, Jalisco, Mexico, highlighted a significant increase in the pH and concentration of irrigated potassium, in addition to an increase in the yield of corn grain, derived from the growth of the crop inoculated with mycorrhizae.

3. METHODOLOGY

This experimental work aimed to compare the effect of the application of mycorrhizae and chemical fertilizers on the growth of maize (Zea mays) both in height and in number of ears, in addition to evaluating soil parameters to analyze the detrimental or beneficial impact of both on nature. The information for this research was obtained through field experiments, where variables such as plant height, grain yield per plant, and soil chemical levels (nitrogen, phosphorus, potassium, and organic matter) were recorded. In order to interpret the results and obtain well-founded conclusions, appropriate statistical methods were applied to establish the presence of significant differences for the variables studied.

The implementation of the statistical analysis had two main objectives: the evaluation of the effect on maize yield through the height and number of ears, and the interpretation of the impact of the application of mycorrhizae and chemical fertilizers on the soil, establishing significant differences through tests such as analysis of variance. Finally, the discussion contrasted the two treatments based on their influence on nature and advised organic producers to move away from the use of chemical fertilizers in favor of more sustainable agriculture.

3.1. Experimental Design

The following experimental proposal aims to establish a method as a means of comparison about the use of mycorrhizae and synthetic fertilizers and to verify which of them promotes greater growth and development during the complete cycle in corn cultivation. It is important to mention that conventional agriculture based on chemicals that do not guarantee a good condition to the crop and even such products that are used to improve the crop in some aspect, are harmful to nature. Currently, the use of chemical fertilizers and pesticides is increasing, which has negative repercussions on the environment and contamination of water sources, deterioration of soil quality and diseases for humans and animals. This reflects the need to resort to agroecological alternatives that are as natural as possible.

According to Manrique (2024), the term sustainability first appeared in the book: "Ecoeconomy. Principles and applications". Based on this, economic agriculture produces through an optimal combination of productive factors the greatest possible amount of food for present and future generations. In this context, there is a category of organisms that establishes a symbiotic relationship with plants and crops, known as mycorrhizal fungi; These improve nutrient uptake, plant growth and development, as well as protecting them by inducing greater tolerance against pathogenic organisms. Given this background, the objective was to compare the effect of the use of chemical fertilizers and mycorrhizal fungi on vegetative growth during the flowering stage of the corn crop, using a non-parametric randomized experimental design.

3.2. Data Collection

Data collection is the stage in which the proposal is executed, integrating with the monitoring process. This phase includes visible observations of maize growth during all phenological stages and triplicate analysis of grain yield at the end of the crop cycle at each treatment. Likewise, the two treatments —Mycorrhizae and Chemical Fertilizer—, the cultivated soil and the corn roots are analyzed.

In the same way, the research method is contemplated, which is based on a completely random design. The addition of these elements makes it possible to evaluate and compare the responses of maize crops to the use of mycorrhizae and chemical fertilizer. The purpose is to issue recommendations for those who, at present, opt for environmental conservation.

3.3. Statistical Analysis

To perform the statistical analysis, a completely randomized experimental design with four treatments and three replications was used. As factors of agronomic quality, plant growth and grain production were determined, and for the chemical quality of the soil, the amount of total nitrogen. The variables were analyzed on mean and standard error, and then the Tukey test was performed with a significance level of 95%.

Maize yields and growth matrices are not only the result of chemical analysis and soil correlation, but atmospheric composition and climate also influence. Maize is a plant that is very sensitive to any change in the environment, which is why it has been chosen for this analysis. The plants in the plots with mycorrhizae outperformed those chemically fertilized in height and yield, while the amount of total nitrogen in the soil was higher in the chemically fertilized one, despite the fact that the C/N ratio is almost equal, indicating that the total amount does not prove that the soil is fertile.

4. RESULTS

The comparison between the application of mycorrhizae and chemical fertilizers in maize cultivation was made based on growth parameters, grain yield and chemical characterization of the soil. The results show that plants associated with mycorrhizae show a growth similar to those treated with chemical fertilizers. However, differences in final grain yield were observed, attributable to changes in the nutritional composition of the soil. These findings indicate that, from a conservationist point of view, the use of mycorrhizae constitutes a viable alternative for degraded soils.

Mycorrhizae establish an extension of the root system that improves the uptake of water and nutrients, increases plant growth and reduces damage due to biological stress, as well as the incidence of diseases. Although the application of chemical fertilizers has been a traditional method to increase yields in production systems, their excessive use affects soil quality and contamination. In this context, sustainable and careful agriculture represents the best solution to balance food supply with demand.

4.1. Growth of Corn

To estimate the optimal treatment necessary for maize production, the growth of doses of mycorrhiza, chemical fertilizer and a control were measured, with 10 replicates of five seeds sown in pots. The criterion assigned was the measurement of the distance between the surface of the substrate to the base of the stem, and subsequently the measurement of approximately 2 cm from the base of the stem to the top. To determine differentiated development, measurements were made every 4 days for one month. The values obtained were integrated into a table to determine if there was a difference between treatments and measurement days. To define the difference, a statistical analysis was performed under a Completely Randomized Design (ABI), considering a 95% confidence level and a sampling of nine samples per treatment and day of measurement.

Since maize growing distance values over time are statistical variables, it is important to determine whether there is a significant difference between the growing distances recorded per day for each treatment. This makes it possible to define whether the difference in growth is statistically significant or simply varies without a defined pattern. When there is a significant difference in the analysis, the corn gradually develops to its maximum size. On the other hand, when there is no significant difference, it indicates that the corn does not grow in the following days.

4.2. Grain Yield

In all treatments with chemical fertilizers, the plants grew more in height; they are more robust plants and the ligules are more developed. The roots appear whiter and less rusty. The highest grain yield was 104.87 tons per hectare using chemical fertilizers. In contrast, the use of mycorrhizae helps the growth of the corn plant, favors its development, but the agricultural yield resulted in 72.73 tons per

hectare. These data indicate that, although organic fertilizer sources conserve soils, the excessive use of chemical fertilizers causes environmental pollution.

The respective analysis determined that the chemical fertilizer increases grain yield, while mycorrhiza improves corn structure and soil characteristics. From the perspective of sustainable agriculture, soil type can define the use of living organisms as a source of nutrition for widespread plants.

4.3. Soil Analysis

Generally, the soils used for maize cultivation are characterized by having 50% mineral materials, 50% pores, air and water, and 5% organic matter and nutrients. The results of growth and grain production were used to perform a soil analysis; due to the concentration of phosphorus in the soil, it was observed that the maximum dose corresponds to treatment with Fungimycorrhiza at 60 g; as for the nitrogen analysis, it was observed, at the high level, less content, in the soil of the control (Table 11). Chemical fertilizers are compounds used to accelerate or increase plant growth. Because plants require various nutrients for their development, the chemical composition varies, including macro and micronutrients, although they exceed the amounts and nutrients presented in the soil, which is why it is important to know the concentration and reaction of the soil. Precautions must be taken in their application, since exceeding adequate amounts can negatively impact the development of the plant, and even human health. On the other hand, mycorrhizae maintain a balance with the roots and soil, so their applications are considered harmless to humans and the environment.

5. DISCUSSION

The excessive use of chemical fertilizers has caused an imbalance in the ecosystem. Important data show that 60% of the CO2 in the atmosphere is the product of industrial activities carried out by human beings. It is estimated that 70 million tons of nitrogen fertilizers are applied annually worldwide, a value that is increasing in line with the expansion of intensive agriculture. Agriculture is a significant source of greenhouse gases and contributes to climate change, since to guarantee the required production, they resort to polluting inputs, but in return it decreases due to these. With the use of mycorrhizae, it is observed that they do not have a negative impact or damage on ecosystems, since they are a natural means to recover soils. On the other hand, the climatic conditions in which they favor and continue the application of chemical fertilizers and the plant material that is obtained are very established and controlled. Therefore, by applying mycorrhizae to crops (fertile land), the production obtained is very similar to that of farmers who apply chemical materials.

Today, producers pollute their land using large amounts of chemicals. However, the benefit of growing with mycorrhizae compared to using these conventional materials is evaluated. When evaluating the growth results mentioned above, it applies to obtain the grain yield; As it does not require large amounts of water and therefore less food for the plant, the ear is smaller, which implies that the amount of cobs obtained is greater in the corn crop where the micronutrients were tested than in the world crop, but with a shorter length."

5.1. Comparison of Effects

Corn (Zea mays L.) is positioned as the most consumed agricultural product worldwide, because in addition to being used for self-consumption and animal feed, it is also the basis for other important productions for humans, including gasoline. Sustainable agriculture allows the development of agricultural activities that properly manage agroecosystems by optimizing resources using products that are harmless to health and the environment. Its objective is to obtain a highly efficient agricultural system from the economic and environmental point of view. Moreover, with the valuation of natural resources and their processes in the field, production costs can be reduced and the efficiency of productive activity increased.

Chemical fertilizers, despite being relatively cheap, have been used frequently and for various reasons in agriculture. But the continuous use of high doses of the product can cause damage to the soil and the environment in general. In response, agriculture created from new techniques makes it possible to recover soil fertility and structure and guarantee production.

The experimental design used is completely randomized; For data collection, production was obtained at the end of the crop, when maize has a high solid content in the grain. Finally, the data analysis was carried out with the comparison of means (Tukey alpha 0.05), a statistic that allows determining that both techniques (mycorrhizae and chemical fertilizers) have similar effects on plant development and grain yield, but with the difference that mycorrhizae contribute to soil conservation and environmental improvement.

5.2. Environmental Implications

Conventional agriculture has had a negative impact on the environment due to the application of fertilizers and pesticides that damage the land and pollute water and air. Therefore, the study compared the application of mycorrhizae and chemical fertilizers in corn cultivation to favor the producer and their families through sustainable production. A completely randomized experimental design was used; Data were collected during the plant's growth cycle and subsequently analyzed. The development and yield of maize was evaluated along with soil analysis in response to the different treatments applied. The results indicated that mycorrhizae promoted the development and productivity of maize, proposing them as a conservation alternative for the crop.

Plants establish various associations to increase their chances of survival, with the mycorrhizal association being one of the most common. This is a beneficial situation between the soil fungus and the roots of the plants, through which both organisms receive nutrients. Although chemical fertilizers are the most common method of ensuring satisfactory agricultural production when nutrients in the soil are limited, they cause damage to the environment and biodiversity. Sustainable agriculture considers that the introduction of mycorrhizal fungi helps to optimize the management of crop areas, making fertilization possible with lower amounts of chemical fertilizers.

5.3. Recommendations for Producers

The symbiotic relationship that plants establish with some soil microorganisms makes them grow faster and protects against pathogens and pests, thus also protecting the environment and human health, thus providing healthy food. We can deduce that the application of mycorrhizae increases corn growth and decreases pest infestation, with an acceptable grain production; In addition, these causes also play an important role in soil conservation. Mycorrhizae improve the physical condition of the patient, thus avoiding erosive phenomena. On the other hand, chemical fertilizers induce more growth in the crop, but they become dangerous to health and, according to the soil conditions, considerably increase grain production, which can be attractive to the producer; however, if this practice is continued, due to the excessive use of applied nutrients, salinization can occur in the soil.

6. CONCLUSIONS

The use of nitrogen fertilizers for corn cultivation affects the properties of the soil, polluting the environment. Therefore, mycorrhizae represent a renewable alternative capable of stimulating the growth of both corn and other crops. Sustainable agriculture seeks to maximize production by minimizing pollution in order to preserve natural resources without depleting or damaging them.

The analysis of the data obtained shows that, during the growth phase of the crop, treatment with mycorrhizae was not sufficient to achieve optimal development. According to the results regarding grain production and soil analysis, mycorrhizae contribute to the conservation and improvement of soil quality, constituting a productive option for farmers

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