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# Production and profitability of zucchini with application of zeolite and chemical fertilizer

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## Abstract

The zucchini is used mainly for consumption in fresh fruit; it is rich in vitamins and minerals. For its production, high amounts of chemical fertilizers (CF) are applied, which increase production costs and cause ecological damage. In general, CF present low efficiency that could be increased with the use of products such as zeolite. As far as Apatzingan Michoacán, it was planted in zucchini field in December of 2017, to determine the effect of the application of zeolite (Z) as a percentage of the CF dose on production and economic profitability. The treatments were evaluated: 100CF, 25Z + 75CF, 50Z + 50CF, 75Z + 25CF, 100Z, 0Z + 0CF (the values represent percentages). It was found that the time to occur of the phenological stages was not modified by the treatments, the emergence occurred nine days after sowing (dds), flowering at 39 days, the first cut of fruits at 48 days and at 71 days the last cut. The supply of zeolite in mixtures with CF did not reduce plant height, stem diameter and number of leaves compared to the full dose of CF. The mixture that generated the highest yield of fresh fruit (37.8 t ha$^{-1}$) and gain per peso invested ($3.44) was 25Z + 75CF. So, in zucchini the application of zeolite allows to reduce the dose of CF with the consequent increase in yield and economic profitability.

**Keywords:** *Cucurbita pepo*, phenology, soil analysis.

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# Introduction

The cucurbitaceae family is one of the largest, with approximately 130 genera and 800 species that are grown in warm regions around the world, including crops of great economic importance such as zucchini (*Cucurbita pepo* L.), which has nutritional and medicinal benefits. It is used mainly for consumption in fresh fruit (tender) and mature; the seeds are commonly used for food purposes, while the flowers (generally the statized or masculine) and tender parts of the stems are used on a smaller scale as a vegetable (Aliu *et al*., 2012; Pérez, 2016).

The zucchini presented a high content of vitamins (A, $B_2$, C and E), β-carotene, flavonoids, amino acids and minerals, mainly potassium (Aliu *et al*., 2012; Martínez-Valdivieso *et al*., 2015). This crop is attributed anti-inflammatory, antiviral, analgesic, antidiabetic and antioxidant properties (Pérez, 2016).

In Mexico during 2016, 502 105 t of fresh fruit with a value of $2 527 million pesos were produced. The states with the highest production of zucchini are Sonora (153 0137 t), Puebla (63 561 t), Michoacan (40 869 t), Zacatecas (29,901 t) and Sinaloa (27 922 t), which mainly produce variety Gray Zucchini (SIAP, 2018).

For its production, it demands high levels of chemical fertilizers, which in this crop and in general represent approximately 50% of production costs, where nitrogen fertilizers are the most purchased (Obregón-Portocarreo *et al*., 2016). Soluble fertilizers, especially nitrogen fertilizers, when applied excessively reduce the percentage of the element recovered by the crop, which results in the accumulation in the soil and its consequent acidification; the nutritional imbalance is also favored. In addition, volatilization as ammonia, generates low efficiency of use mainly in tropical soils.

Likewise, high leaching in the form of nitrates represents an environmental risk, since it contaminates groundwater with serious consequences for human health such as the development of different types of cancer in people who consume water with nitrates (Zebarth *et al*., 1995; Compton *et al*., 2011). Nitrogen fertilizers have an efficiency of 50%, phosphates of 10% and potashes of 30% (Sanjuan and Moreno, 2010). Low efficiency has led to the search for alternatives that increase the efficiency of fertilization and reduce production costs.

In this sense, zeolite (clinoptilonite) has a porous structure that favors the exchange of ions (Obregón-Portocarrero *et al.*, 2016). The use of this mineral decreases the leaching and volatilization of elements, improves the colloidal structure of the soil and increases the efficiency of nutrients by increasing the availability of elements such as P. Zeolite mixtures and fertilizers have shown a positive effect on agricultural production, so this mineral could be an option as a complement to chemical fertilization (De Campos *et al*., 2013).

The increase in agricultural yield due to the application of zeolite has been demonstrated in some crops, in this regard, in corn (*Zea mays* L.) grown in soils with medium texture and alkaline pH (González *et al*., 2012). In wheat (*Triticum aestivum* L.) with the application of urea mixed with zeolite in a calcissol with a sandy texture (Osuna-Ceja *et al*., 2012). In most studies' zeolite is used to reduce the dose of nitrogen fertilization, however, this mineral can also increase the efficiency of P and other nutrients (De campos *et al*., 2013), so it could reduce the amount that applies macronutrients and with this favor the economic profitability.

The agronomic response of the plants to the application of zeolite depends on the presentation of the zeolite, the type of soil, the applied dose and the crop (González *et al*., 2012; De campos *et al.*, 2013; Manikandan and Subramanian, 2016; Sosa-Núñez and Villarreal-Núñez, 2016). Therefore, in the various studies carried out, the recommended dose varies widely, which makes it necessary to delve more deeply into the subject in order to give more accurate recommendations.

At the present time, in zucchini under Apatzingan Valley conditions, studies are limited, so the objective of this study was to determine the effect of the mixture of different percentages of zeolite with chemical fertilizers on the time to occurrence of phenological stages, production, quality of production and economic profitability of pumpkin Gray Zucchini; as well as, in the changes in the physical and chemical properties of the soil.

## Materials and methods

### Description of the study site

The present study was developed in the experimental field in the Faculty of Agricultural Sciences of the Michoacán University of San Nicolas de Hidalgo, in Apatzingan, Michoacán at 19° 05’ 00” north latitude and 102° 22’ 17” west longitude and 314 m of altitude. The climate is $BS_1$ which corresponds to the drier climate of the BS (García, 2004).

### Crop management

Prior to sowing, a soil sampling of the experimental plot was carried out at a depth of 0-30 cm, to determine the physical and chemical properties. The analyzes were carried out in the Soil Analysis Laboratory of the Apatzingan Valley. The results indicate an alkaline pH, medium level in N and P, high content in K and high CIC according to the official Mexican standard NOM-021-SEMARNAT-2000. On December 19, 2017, Zucchini F1 gray zucchini was planted, prior preparation of soil, two seeds were placed per hit (mata) at a depth of 1.5 cm, the distance between plants was 0.6 m and between rows of 0.8 m, which generated a population density 4.2 plants $m^{-2}$.

A drip irrigation system was used, and the frequency and intensity were carried out according to the water needs of the crop. Weed control was done manually. During the growth of the crop the incidence of whitefly that was controlled with applications of Imidacloprid that was rotated with Flupyradifurone plus Spinetoram at the dose recommended by the manufacturer was presented.

From 15 days after sowing minor applications were applied by foliar sprays with a 15 L capacity pump and empty cone nozzle (hollow) foliar sprays were made up to drop point of a foliar fertilizer at the dose from 2 to 3 L $ha^{-1}$, composed of 3% humic acid; 6.25% gibberellic acid; 10% N, 5% $P_2O_5$ and 5% $K_2O$, plus 1.5, 0.25, 0.25, 0.6, 0.8, 0.4, 0.4, 0.01 and 0.01 g $L^{-1}$ of S, Ca, Mg, Fe, Zn, Mn, Cu, Mo and B, respectively, in total two applications were made at 15-day intervals.

**Treatments and experimental design**

Five treatments were evaluated: 100% chemical fertilizer (CF, 120 and 90 kg $ha^{-1}$ of N and $P_2O_5$, respectively), 25% zeolite + 75% CF, 50% zeolite + 50% CF, 75% zeolite + 25% CF, 100% zeolite and an absolute control (0% zeolite + 0% CF). It should be noted that the percentage of zeolite used was determined based on the weight of the fertilizers that completed the dose of chemical fertilization. The fertilizers used were urea (46N) and diammonium phosphate (18N + 46P), all $P_2O_5$, zeolite and half of N were applied at 15 days after sowing (dds) and the rest of N at 40 dds.

The treatments were distributed in a design of complete blocks at random with four repetitions, this generated 24 experimental units, each experimental unit, was formed by three rows of 3 m in length.

**Response variables**

In the fruiting period (60 dds) in five plants of the central groove of each experimental unit, the height of the plant, the stem diameter and the number of leaves were recorded. In total eight fruit slices were made one every third day. The fruits were harvested when they had a length greater than 15 cm. In each one, the total weight, the number of fruits per plant, the length and the diameter of the fruits were determined. By means of the sum of the cuts, the number of fruits per plant, average weight of fruits, length and average diameter of fruits was determined. The yield of fresh fruit in t $ha^{-1}$ was calculated considering the population density.

During the development of the crop the maximum temperature (°C) and minimum (°C) and daily rainfall (mm) were registered, as well as the time to the occurrence of the phenological stages: days to emergence, days at the beginning of flowering, days to first cut of fruit and days to last cut of fruit.

**Analysis of soil at the end of the crop**

After finishing the study and with the purpose of knowing the soil modifications due to the evaluated treatments, the physical-chemical analysis was carried out in the Soil Analysis Laboratory of the Apatzingan Valley.

**Statistical analysis**

The data of the variables were subjected to an analysis of variance and comparison test of means between treatments (Tukey, $p \leq 0.05$), both with the Statistical Analysis System package (SAS, 2002). An economic analysis was also applied to each treatment, with the equation: IN= YPy-($\sum$XiPi + CF) (Volke, 1982). Where IN= net income; Y= yield (kg $ha^{-1}$); Py= price per kg; $\sum$XiPi= sum of variable costs (fertilizer, wages for harvest, freight, etc.); and CF= fixed costs (land preparation, seed and wages for crop management). The sale price considered per kilogram was $10.00 pesos.

# Results and discussion

## Elements of climate and phenology

In Figure 1, which shows the maximum and minimum temperatures (half-decade), it was observed that on average during cultivation the maximum temperature ranged between 32 and 39.4 °C and the minimum temperature between 15 and 19.3 °C (Figure 1). In general, temperatures tended to increase as the crop cycle progressed and were higher than those required by this crop, which according to Maroto (2002) must be between 18 and 35 ºC, a situation that could limit the productive response of this crop.

In terms of rainfall, only two rains occurred, one on January 25 and the other on January 26 that added 43 mm. However, the remaining water requirement was provided by drip irrigation. The time to occur of the phenological stages of the zucchini was not modified by the effect of the treatments, thus, the emergency occurred nine days after sowing (dds), flowering at 39 dds, the first cut of fruits 48 dds and at 71 dds the last cut (Figure 1). While in the cultivation of banana the application of zeolite reduced the time to harvest (Soca-Núñez and Villarreal-Núñez, 2016), so the response varies according to the crop.

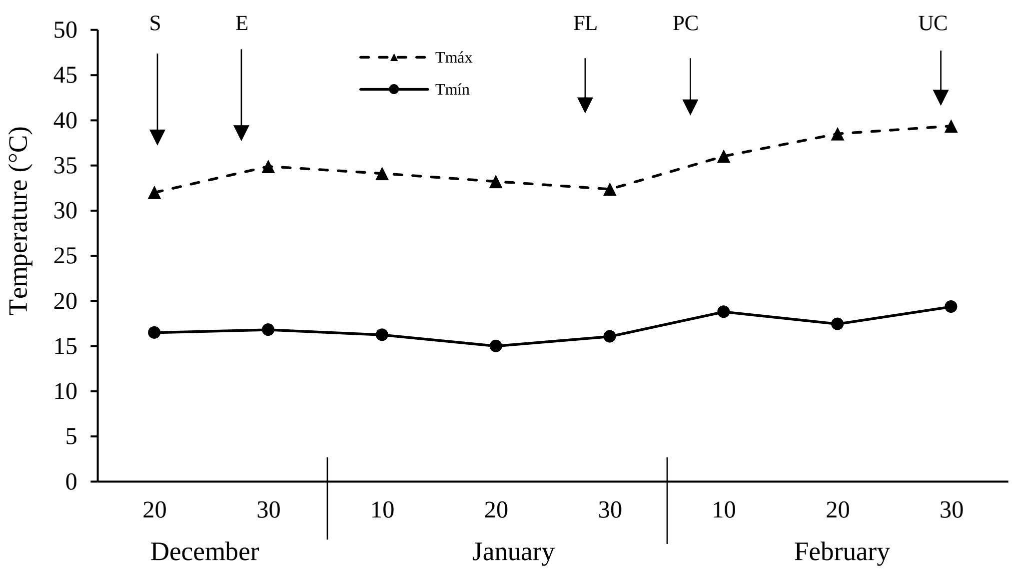


**Figure 1. Distribution of the maximum and minimum temperature (half-decade) during the development of zucchini cultivation. S= sowing; E= emergency; FL= flowering; PC= first cut of fruits; and UC= last cut of fruits.**

## Height of the plant, diameter of the stem and number of leaves

The height of the plant, the diameter of the stem and the number of leaves of the zucchini showed highly significant changes ($p \leq 0.01$) due to the treatments (Table 1).

**Table 1. Level of significance and comparison test of plant height (AP), stem diameter (DT) and number of leaves (NH) of zucchini plants based on the combination of zeolite and chemical fertilizer.**

| Treatment | AP (cm) | DT (cm) | NH (number plant$^{-1}$) |
|---|---|---|---|
| 100CF | 37.2 a¶ | 1.95 ab | 27.33 ab |
| 100Z | 32.6 b | 1.6 b | 27.5 ab |
| 25Z+75CF | 38.1 a | 2.1 a | 27.5 ab |
| 50Z+50CF | 37.5 a | 1.81 ab | 27.5 ab |
| 75Z+25CF | 35 ab | 1.79 ab | 31.92 a |
| 0Z+0CF | 33.9 ab | 1.72 b | 23.25 b |
| General mean | 35.69 | 1.83 | 27.5 |
| Probability F | ** | ** | ** |
| $DMSH_{0.05}$ | 4.26 | 0.37 | 5.61 |
| Coefficient of variation % | 5.2 | 8.82 | 8.88 |

¶= means with equal letters within each column do not differ statistically (Tukey, $p\leq$ 0.05). *, ** $p\leq$ 0.01 and 0.05, respectively; ns= not significant ($p\geq$ 0.05); $DMSH_{0.05}$= honest minimum significant difference; Z= zeolite; CF= chemical fertilizer.

The plants that statistically had the highest height were with 25% zeolite + 75% chemical fertilizer, 50% zeolite + 50% chemical fertilizer and with 100% chemical fertilizer.

Those that were only supplied with zeolite had the lowest height. Similar results were found in stem diameter, where plants with smaller stem diameter were those of 100% zeolite treatment and the control that were statistically similar and lower in 18 and 23%, respectively compared to plants with 25% zeolite + 75% chemical fertilizer.

For the number of leaves, the application of 75% zeolite and 25% of chemical fertilizer was highlighted as the treatment that generated the highest values, although statistically they were similar to the other treatments with zeolite and with 100% of chemical fertilizer. All of them surpassed the absolute witness without application (Table 1).

The positive response of the application of zeolite in combination with chemical fertilizer on the height of the plant, stem diameter and number of leaves can be attributed to the fact that zeolite improves the absorption of nutrients such as nitrogen (Aghaalikhani *et al*., 2012); so, in this study, the reduction in chemical fertilizer amounts does not decrease the size of the plant.

**Fresh fruit yield and yield components**

The yield of fresh fruit, number of fruits and length of fruits showed highly significant changes ($p\leq$ 0.01) due to the treatments studied. The average fruit weight and fruit diameter were similar between treatments (Table 2 and Figure 2).

**Table 2. Level of significance and comparison test of means of the number of fruits per plant (NF), average fruit weight (PPF), length (LF) and fruit diameter (DF) in zucchini depending on the combination of zeolite and chemical fertilizer.**

| Treatment | NF (number plant$^{-1}$) | PPF (g) | LF (cm) | DF (cm) |
|---|---|---|---|---|
| 100CF | 5.85 b[¶] | 162.21 a | 15.4 b | 5.34 a |
| 100Z | 2.28 c | 233.83 a | 17.85 a | 5.85 a |
| 25Z+75CF | 8.5 a | 177.82 a | 16.08 ab | 5.52 a |
| 50Z+50CF | 4.88 b | 189.13 a | 16.28 ab | 5.68 a |
| 75Z+25CF | 4.23 b | 217.2 a | 18.5 a | 5.41 a |
| 0Z+0CF | 2.28 c | 226.25 a | 17.96 a | 5.4 a |
| General mean | 4-67 | 201.07 | 17.01 | 5.53 |
| Probability F | ** | ns | ** | ns |
| $DMSH_{0.05}$ | 1.8 | 88.72 | 2.51 | 0.92 |
| Coefficient of variation (%) | 16.82 | 19.2 | 6.4 | 7.23 |

[¶]= means with equal letters within each column do not differ statistically (Tukey, $p \leq 0.05$). [*, **]$p \leq 0.01$ and 0.05, respectively; ns= not significant ($p \geq 0.05$); $DMSH_{0.05}$= honest minimum significant difference; Z= zeolite; CF= chemical fertilizer.

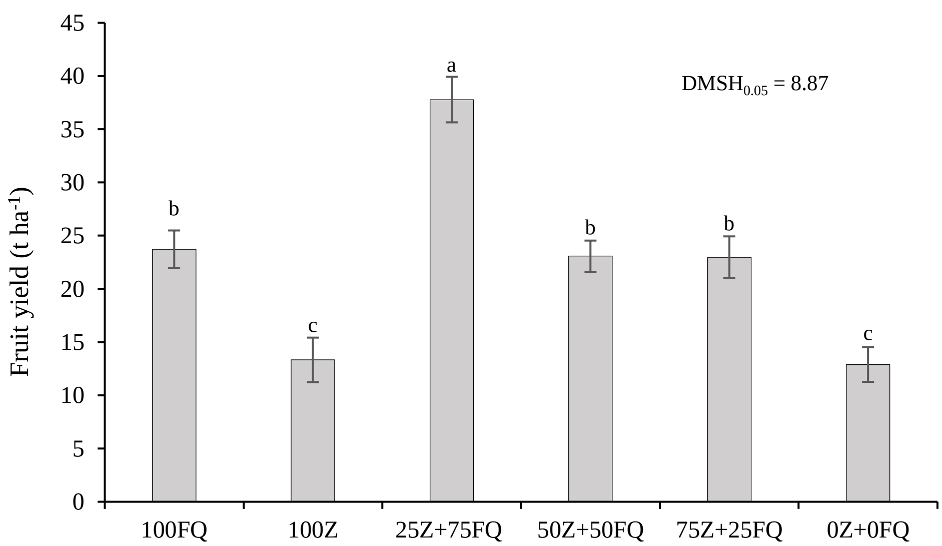


**Figure 2. Performance of zucchini depending on the combination of zeolite and chemical fertilizer.** $DMSH_{0.05}$= honest significant minimum difference; Z= zeolite; CF= chemical fertilizer.

According to the results obtained, the greatest amount of fruits harvested per plant was registered in plants with application of 25% zeolite + 75% chemical fertilizer, 45% higher than plants fertilized with 100% chemical fertilizer. The lowest number of fruits was present in the plants with 100% zeolite and with the absolute control, which showed statistically similar values. As for the length of fruits, the shortest were harvested in plants with 100% chemical fertilization (Table 2).

The increase in the number of fruits in plants with 25% of zeolite + 75% favored the yield of fresh fruits, since it was also with this treatment that the highest production was achieved, 58% more yield than with the full dose of chemical fertilization, and three times more than with 100% zeolite and the control. In the present study, the application of 25% zeolite + 75% chemical fertilizer increased the content of P, Mg, Fe and B. Likewise, in most of the treatments with zeolite the CIC was increased, all this could favor the fresh yield (Table 3).

These results are similar to those found by Soca-Nuñez and Villarreal-Núñez (2016) who in plantain and sugarcane grown in a pot found that the application of zeolite increased the CIC of the soils used as substrates.

**Table 3. Physical-chemical characteristics of the soil at the end of the experiment.**

| Characteristic | Units | 100CF | 100Z | 25Z+75CF | 50Z+50Z | 75Z+25CF | 0Z+0CF |
|---|---|---|---|---|---|---|---|
| Soil pH | | 6.9 | 7.73 | 7.16 | 7.15 | 7.77 | 7.77 |
| Organic material | (%) | 3.09 | 2.82 | 2.96 | 3.09 | 2.82 | 3.23 |
| $NO_3$, $NH_4$ | (mg $kg^{-1}$) | 107.5 | 33.5 | 83.1 | 52.8 | 25.7 | 21.9 |
| Phosphorus | (mg $kg^{-1}$) | 68.6 | 20 | 73.7 | 44.3 | 21.7 | 18.6 |
| Potassium | (mg $kg^{-1}$) | 1 054 | 1 050 | 728 | 1 023 | 896 | 976 |
| Calcium | (mg $kg^{-1}$) | 5 690 | 5 692 | 5 932 | 5 450 | 6 252 | 5 454 |
| Magnesium | (mg $kg^{-1}$) | 1 862 | 1 894 | 2 048 | 1 898 | 1 818 | 1 854 |
| Iron | (mg $kg^{-1}$) | 7.98 | 5.29 | 6.8 | 6.4 | 4.44 | 4.2 |
| Copper | (mg $kg^{-1}$) | 2.17 | 1.82 | 1.82 | 2.1 | 1.69 | 1.83 |
| Zinc | (mg $kg^{-1}$) | 0.86 | 0.73 | 0.8 | 0.84 | 0.68 | 0.67 |
| Manganese | (mg $kg^{-1}$) | 28.9 | 9.46 | 15.4 | 14.3 | 8.33 | 9.01 |
| Boron | (mg $kg^{-1}$) | 1.24 | 0.73 | 1.4 | 1.09 | 0.73 | 0.73 |
| CIC | Cmol $kg^{-1}$ | 46 | 47 | 48 | 45 | 48 | 45 |
| Apparent density | (t $m^{-3}$) | 1.11 | 1.09 | 1.11 | 11.1 | 1.11 | 1.12 |
| Sodium | (mg $kg^{-1}$) | 120 | 115 | 122 | 120 | 110 | 112 |

The results found in the present study are similar to those reported in wheat by Osuna-Ceja *et al*. (2012) who with the application of urea mixed with zeolite in a sandy texture calciol significantly increased the yield of grain and biomass.

Also, in the cultivation of corn grown in different regions of the state of Guerrero, an increase in grain yield was found, although only in soils with medium texture and alkaline pH (González *et al*., 2012), conditions similar to those of the experimental site of the present study. The positive effect of the application of zeolite on the yield can be attributed to the fact that it improves the efficiency in the use of fertilizer, mainly nitrogenous, since this mineral reduces the leaching of the fertilizer as reported in canola (*Brassica napus* L.) by Aghaalikhani *et al*. (2012).

In this regard, it is mentioned that zeolite has been used as a soil improver, to restrict the loss of fertilizers by leaching and neutralize the pH of the soil, has high cation exchange capacity and affinity for $NH_4^+$ ions. Zeolite is also considered to function as a slow-release fertilizer by capturing $NH_4^+$ in its structural channels, thus avoiding its oxidation to $NO_3^-$ (Aghaalikhani *et al*., 2012; Li *et al*., 2013).

The yield of fresh fruit obtained in the present study is lower than that recorded by Sedano-Castro *et al*. (2011) in zucchini cv Tala (Seminis®), who when applying 330 kg N ha$^{-1}$ managed to harvest 68 t ha$^{-1}$ of fresh zucchini; it should be noted that in our study we only applied 120 kg N ha$^{-1}$. On the other hand, the maximum temperatures that occurred during the crop cycle were higher than 35 °C that are higher than those required by the crop, it is mentioned that the thermal interval to germinate the seed is between 21 and 35 ºC and the Growth temperature can be between 18 and 35 ºC (Maroto, 2002), which could reduce the productive response of this crop.

## Economic profitability analysis

In Table 4 it was observed that the highest variable and total costs were generated with the treatment 25% zeolite + 75% chemical fertilizer despite the reduction in the cost of chemical fertilization, since zeolite is a low cost mineral ($2.00 kg$^{-1}$); however, the high yield generated caused the highest costs for harvesting and marketing.

**Table 4. Costs of production and profitability of zucchini cultivation based on the combination of zeolite and chemical fertilizer.**

| Treatments | Yield (kg ha$^{-1}$) | IT ($ MXN) | CF ($ MXN) | CV ($ MXN) | CT ($ MXN) | IN ($ MXN) | GPI ($ MXN) |
|---|---|---|---|---|---|---|---|
| 100Q | 23 723 | 237 230 | 37 404 | 45 295 | 82 699 | 154 531 | 1.87 |
| 100Z | 13 328 | 133 280 | 37 404 | 21 036 | 58 440 | 74 840 | 1.28 |
| 25Z+75CF | 37 787 | 377 870 | 37 404 | 47 708 | 85 112 | 292 758 | 3.44 |
| 50Z+50CF | 23 074 | 230 740 | 37 404 | 40 962 | 78 366 | 152 374 | 1.94 |
| 75Z+25CF | 22 969 | 229 690 | 37 404 | 38 652 | 76 056 | 153634 | 2.02 |
| 0Z+0CF | 12 896 | 128 960 | 37 404 | 17 808 | 55 212 | 73 748 | 1.34 |

Total income (IT)= performance$*$price per kg ($10.00); fixed cost (CF)= includes land preparation costs, installation of the irrigation system, cost of water, seed, wages for crop management; variable costs (CV)= include the cost of fertilizer, wages for fertilizer application, harvest and freight; Total cost (TC)= fixed cost + variable cost; net income (IN)= total income-total cost; GPI= profit per peso invested.

Despite this, it was the treatment that achieved the highest total income, net income and profit per peso invested. With 50% zeolite + 50% chemical fertilizer and 75% zeolite + 25% chemical fertilizer the gain per invested weight was higher than the value obtained with 100% chemical fertilizer, 100% zeolite and the control. So, the application of zeolite without chemical fertilizer does not favor the yield or economic gain.

## Conclusions

The application of zeolite as a complement to chemical fertilization did not modify the time to occurrence of the phenological stages in the zucchini cultivation.

The supply of zeolite in mixtures with chemical fertilizer did not reduce the height of the plant, diameter of the stem and the number of leaves in comparison with the complete dose of chemical fertilization.

The mixture with greater effectiveness on the yield of fresh fruit of pumpkin was with 25% of zeolite plus 75% of chemical fertilizer with which the number of fruits per plant was increased. With this treatment the greatest economic gain was also achieved.

The application of zeolite increased the content of P, Mg, Fe and B and increased the cation exchange capacity of the experimental soil.

In zucchini the application of zeolite allows reducing the dose of CF with the consequent increase in yield and economic gain.

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