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**Original article**

# Effect of agroecological practices on the production of corn (*Zea mays* L.) in cold seasons in Granma province

## Efecto de prácticas agroecológicas en la producción de maíz (*Zea mays* L.) en campañas de frío, provincia Granma

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**ABSTRACT:** In Cuba, corn is grown in all provinces, but yields are low, which is why the country has to import large quantities of this product. For this reason, the objective of this work was to evaluate the effect of some agroecological practices on the agronomic response of this crop in cold seasons. The experiment was developed in the 2021-2022 campaign in a mellow Fluvisol soil in the José Marti Credit and Services Cooperative, in Bayamo municipality, Granma province. Three agroecological factors were evaluated: genotypes, distances between plants and application of pyroligneous acid, with two levels each, for a total of eight treatments. Plots of 18 $m^2$ were used in a randomized block design with four replications. The data were processed using principal components analysis, three-factor analysis of variance and the multiple comparisons of means was performed using the Tukey test for $p \leq 0.05$. The values expressed by the Seed Plus in cob diameter, seed weight per cob and weight of 100 seeds were higher than those achieved by the Local Variety. The distances between plants evaluated did not influence the response of the variables seed mass per plant and yield in any of the genotypes, but the values expressed by the Plus seed were higher than those achieved by the Local Variety in both distances and the variables evaluated did not show responses to the dose of pyroligneous acid applied.

**Key words:** cultivation, yield, feeding, varieties.

**RESUMEN:** En Cuba el maíz se cultiva en todas las provincias, pero los rendimientos son bajos, por lo cual el país tiene que importar grandes cantidades de este producto. Por tal razón el objetivo de este trabajo fue evaluar el efecto de algunas prácticas agroecológicas en la respuesta agronómica de este cultivo en campañas de frío. El experimento se desarrolló en la campaña 2021-2022 en un suelo Fluvisol mullido en la Cooperativa de Créditos y Servicios José Martí, en el municipio Bayamo, provincia Granma. Se evaluaron tres factores agroecológicos: genotipos, distancias entre plantas y aplicación de ácido piroleñoso, con dos niveles cada uno, para un total de ocho tratamientos. Se utilizaron parcelas de 18 $m^2$ en un diseño de bloques al azar con cuatro réplicas. Los datos se procesaron mediante análisis de componentes principales, análisis de varianza trifactorial y la comparación múltiple de medias se realizó por la prueba de Tukey para $p \leq 0,05$. Los valores expresados por la semilla plus en el diámetro de la mazorca, masa de semilla por mazorca y masa de 100 semillas fueron superiores a los alcanzados por la variedad local; las distancias entre plantas evaluadas no influyeron en la respuesta de las variables masa de semillas por planta y el rendimiento en ninguno de los genotipos, pero los valores expresados por la semilla plus fueron superiores a los alcanzados por la variedad local en ambas distancias y las variables evaluadas no mostraron respuestas a la dosis de ácido piroleñoso aplicada.

**Palabras clave:** cultivo, rendimiento, alimentación, variedades.

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## INTRODUCTION

Maize is an important component of human and animal food. It is grown in the most diverse soil and ecological conditions due to its high plasticity, production and consumption worldwide (1). It is grown in more than 70 countries and covers an area of more than 120 million hectares (2). It is a cereal of great preference and high consumption in the world, both as a fresh and processed product, due to its nutritional properties. It contains many carbohydrates and due to its extreme adaptability, it has become the most produced food worldwide (3).

In Cuba, it is grown in all provinces of the national territory, but the production of dry corn is low, with an average of 1.93 t $ha^{-1}$ (4). In spite of the efforts made by agriculture to increase yields in the crop, these present a national average of 2.25 t $ha^{-1}$, far from the world average, with values around 4.5 t $ha^{-1}$ (5).

To guarantee the animal protein required from the production of poultry, pigs and fish, mainly, the country demands around 800,000 tons of dry corn (13 % humidity) and in 2020 only 257.208 tons were produced (6). If we compare the country's demand with the production reported by ONEI in 2020, it can see that only 32 % of this demand was met. This highlights the need to work quickly to increase national production of this vital item.

The objective of this study was to evaluate the effect of some agroecological practices on the agronomic responses in the maize crop.

## MATERIALS AND METHODS

During the 2021-2022 cold season, an experiment was carried out in MELLOW Fluvisol soil (7), belonging to the José Martí Credit and Service Cooperative, located in the Barranca Popular Council in Bayamo municipality, Granma province. Soil preparation was carried out with oxen using the traditional method. Planting was carried out on September 27, 2021 in furrows separated at a distance of 0.90 m.

Plots formed by four furrows five meters long for a total area of 18 $m^2$ were used, distributed in a randomized block design with eight treatments and four replications.

The following treatments were used:

**T1:** VL-DT, **T2:** VL-DT +AP, **T3:** VL-D20, **T4:** VL-D20+AP, **T5:** Plus-DT, **T6:** Plus-DT+AP, **T7:** Plus-D20 and T8: Plus-D20+AP,

where:

VL: seed of the local variety (Tayuyo).

Plus: seed obtained from free pollination of four commercial varieties (Tusón, T-7928, Dorado and Maig).

DT: traditional distance of 0.25 m between plants by the traditional method (two seeds per nest).

D20: distance of 0.20 m between plants.

AP: pyroligneous acid obtained by pyrolysis of marabú wood, chemically characterized at the Chemical Engineering and Research Center, showing the following composition: p-cresol, 2-4 dimethyl-phenol, 3-4 dimethyl-phenol, cresol, 2-ethyl-4-methyl-phenol, 4-ethyl-2-methoxy-phenol, 2-6-dimethoxy-phenol, 2-methoxy-4-propyl-phenol and 1,2,3-dimethoxy-5-methyl-benzene. This was applied at a dose of one liter per hectare, every 10 days from germination until plot closure.

Before sowing, a background fertilization with earthworm humus was carried out at a rate of 5 t $ha^{-1}$ (8).

Cultural attentions were carried out according to the Technical Instructions for the cultivation of corn (9).

After germination, 10 plants were randomly selected in the calculation area of each plot, and the following variables were evaluated: flowering(days), fruiting (days), stalk length (cm), stalk diameter (cm), number of ears per plant, number of seeds per cob, cob length (cm), ear diameter (cm), seed mass per plant (g), 100-seed mass (g), and dry grain yield (t $ha^{-1}$), which was determined on the basis of the calculation area of each plot.

Stem and cob length were measured with a tape measure; a caliper was used to measure stem and cob diameter, while seed mass per plant and 100-seed mass were obtained using a digital analytical balance.

The data obtained were processed using Statgraphics (10). A Principal Component analysis was applied to determine the variables that contributed most to the total phenotypic variance. A 2x2x2 trifactorial analysis of variance (genotypes: two levels, sowing distance: two levels, PA application: two levels) was performed on the variables that contributed the most, and the multiple comparison of means was performed by Tukey's test for $p \leq 0.05$.

## RESULTS AND DISCUSSION

Principal component analysis (Table 1) showed that the first three components explained 81.25 % of the total phenotypic variance. Component C1 had a contribution of 39.5 % and was characterized by the variables cob diameter, seed mass per cob, seed mass per plant, 100-seed mass and yield. The C2 component contributed 24.87 % and was characterized by the variables number of seeds per cob and number of seeds per plant, while the C3 component showed a contribution of 16.88 %, characterized by the variable days to fruiting. In each component, the variables with the highest contribution showed the same sign, indicating that they were positively related.

The variables that are more correlated with the first components are the most important to explain the total variability of the basic matrix of original data and the variables of little contribution can be eliminated to simplify the analysis (11).

The variables days to flowering, plant height, height to cob, stem diameter, number of ears per plant, cob length and number of lines per cob only contributed 18.75 % to the total variance, therefore they are excluded from this study because of their low contributions.

The analysis of variance for the variables with the greatest contribution (Table 2) showed significant differences in cob diameter, seed mass per cob, seed mass per plant, 100-seed mass and yield. The variables days to flowering, number of seeds per cob and number of seeds per plant showed no significant differences in any source of variation.

**Table 1.** Results of the Principal Component Analysis

| Main axes | C1 | C2 | C3 |
|---|---|---|---|
| Eigenvalues | 5.32 | 3.13 | 1.93 |
| Contribution to total variation | 39.50 | 24.87 | 16.88 |
| Cumulative | 39.50 | 64.37 | 81.25 |
| Eigenvectors | | | |
| Days to flowering | 0.400976 | 0.071458 | 0.635076 |
| Days to fruiting | 0.314078 | -0.183290 | **0.731858** |
| Plant height | 0.545397 | -0.429888 | -0.248543 |
| Height to cob | 0.675412 | -0.515728 | -0.248720 |
| Stem diameter | -0.097176 | -0.277217 | -0.403641 |
| No. of ears per plant | 0.008265 | -0.614415 | -0.390063 |
| Cob length | 0.345299 | -0.533684 | 0.494722 |
| Cob diameter | **-0.801124** | -0.207832 | 0.044208 |
| No. of rows per cob | -0.444457 | -0.327754 | -0.261563 |
| No. seeds per cob | -0.023731 | **-0.785719** | 0.381240 |
| Seed mass per cob | **-0.917415** | -0.197957 | 0.261418 |
| Number of seeds per plant | 0.002673 | **-0.927012** | -0.059543 |
| Seed mass per plant | **-0.854434** | -0.447202 | 0.046195 |
| Mass of 100 seeds | **-0.936373** | 0.181434 | 0.071221 |
| Yield | **-0.945630** | -0.054948 | 0.119960 |

**Table 2.** Results of the factorial analysis of variance in the variables with the highest contribution (%) to the total phenotypic variation in the maize crop

| Sources of Variation | Mean squares | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | DF | DC | SMC | SMP | NSC | NSP | P100s | Y |
| Genotypes (G) | 1.62 ns | 1.3654 * | 9010.9 * | 9017.9 * | 1162 ns | 5607 ns | 420.50 * | 11.968 * |
| Distances (D) | 1.81 ns | 0.1024 ns | 22.1 ns | 190.0 ns | 343 ns | 2521 ns | 0.03 ns | 0.019 ns |
| AP | 0.78 ns | 0.0001 ns | 3.1 ns | 138.0 ns | 559 ns | 5503 ns | 0.02 ns | 0.027 ns |
| G X D | 0.21 ns | 0.1001 ns | 369.4 ns | 908.8 * | 5025 ns | 12102 ns | 0.36 ns | 0.213 * |
| G X AP | 0.50 ns | 0.0004 ns | 38.5 ns | 327.4 ns | 1142 ns | 8056 ns | 0.32 ns | 0.057 ns |
| D X AP | 0.60 ns | 0.0034 ns | 36.8 ns | 703.2 ns | 541 ns | 12903 ns | 0.01 ns | 0.004 ns |
| G X D X AP | 0.01 ns | 0.0259 ns | 66.9 ns | 328.4ns | 540 ns | 5724 ns | 0.66 ns | 0.066 ns |
| Error | 0.54 | 0.0384 | 97.2 | 179.5 | 1129 | 2572 | 1.30 ns | 0.033 |

DF: Days to flowering, DC: Diameter of cob, SMC: Seed mass per cob, SMP: Seed mass per plant, NSC: Number of seeds per cob, NSP: Number of seeds per plant, P100s: 100-seed mass, Y: Yield

This indicates that the responses of these last variables were not influenced by the effect of the treatments evaluated.

The results show that there were no responses to the application of pyroligneous acid in any of the variables evaluated, which may be due to the fact that the dose used was not sufficient. Similar results were observed in the distances between plants, since it only showed significant effects in the interaction with genotypes on the mass of seeds per plant and yield, which has certain coincidence with other authors (12) who indicated that corn differed in its response to population density as a function of genotype and environmental conditions.

The multiple comparison of means (Table 3) showed that the plus seed significantly outperformed the local variety in the variables cob diameter, seed mass per cob and 100-seed mass. An increase of 10.0, 33.6 and 33.8 % was observed, respectively.

In yellow corn varieties, of high production for the Caribbean region of Colombia, values between 30.3 - 39.0 g are indicated for the mass of 100 seeds (13). On the other

**Table 3.** Results of the multiple comparison of means for the variables ear diameter, seed mass per cob and 100-seed mass in the maize crop

| Genotypes | cob diameter (cm) | mass of seeds per cob (g) | mass of hundred seeds (g) |
|---|---|---|---|
| Local variety | 4.11 b | 99.87 b | 21.6 b |
| Seed plus | 4.52 a | 133.43 a | 28.9 a |
| SE.x | 0.03 | 1.74 | 0.20 |
| Significance | p≥0.000 | p≥0.000 | p≥0.000 |

Means with unequal letters in the same column show significant differences between genotypes according to Tukey's test for p≤ 0,05 hand, in a study of the characteristics and properties of 12 accessions of Criollo maize grown in Aguas Calientes, Mexico, values between 28.5 and 46.3 g were recorded for the mass of 100 seeds (14). It is observed that the average achieved by the plus seed is close to the first interval and within the range indicated by the other authors.

On the other hand, in the evaluation of 12 maize introductions from the Working Collection of the Neotropical Genetic Resources Research Group of the National University of Colombia, an average of 17.4 g was recorded in the mass of 100 kernels (15). Such variability in this character may be due to the fact that it is related to grain size.

In the combined effect of genotypes and distances between plants on the variables seed mass per plant and yield, there were no significant differences between the distances evaluated (Table 4), but the values achieved by the plus seed were higher than those achieved by the local variety in both variables. The relationship between grain yield and population density is complex (16), since the best response in grain yield varies according to soil conditions, climate, cultural practices and genotype.

In seed mass per plant, the plus seed outperformed the local variety at the traditional distance by 20 % and at 0.20 m by 40.8 %, while the yield of the plus seed, at the traditional distance and at 0.20 m between plants was higher than the local variety by 20.9 and 27.9 %, respectively. This is equivalent to an increase of 1.06 t $ha^{-1}$ at the traditional planting and 1.38 t $ha^{-1}$ at the 0.20 m plant spacing. These results indicate that the hybrid vigor achieved by the plus seed, due to the free pollination of the varieties used, translates into a significant increase in grain yield.

The average yield of the local variety (Tayuyo) was 5 t $ha^{-1}$, slightly higher than 4.68 t $ha^{-1}$ obtained in a study carried out with the variety T-7928 in Mayabeque province (3). This yield indicated by these authors is 25 % lower than those expressed by the plus seed.

The yields of the plus seed were similar to those achieved in 2018 worldwide and in Argentina, where average values of 5.89 and 6.0 t $ha^{-1}$ were recorded, respectively (17).

## CONCLUSIONS

- The values expressed by the plus seed for ear diameter, seed mass per ear and 100-seed mass were higher than those achieved by the local variety.
- The distances between plants evaluated did not influence the response of the variables seed mass per plant and yield in any of the genotypes, but the values expressed by the plus seed were higher than those achieved by the local variety in both distances.
- The variables evaluated showed no response to the applied dose of pyroligneous acid.

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**Table 4.** Response of the variables seed mass per plant and yield to the combined effect of genotypes and distances between maize plants

| Genotypes | Distances between plants | | | |
|---|---|---|---|---|
| | Seed mass per plant (g) | | Yield (t $ha^{-1}$) | |
| | Traditional | 0.20 m | Traditional | 0.20 m |
| Local variety | 114.3 b | 108.5 b | 5.06 b | 4.95 b |
| Seed plus | 137.2 a | 152.8 a | 6.12 a | 6.33 a |
| Esx | 2.37 | | 0.03 | |
| Significance | P≥ 0.03 | | P≥ 0.01 | |

Means with unequal letters in the same column show significant differences between genotypes according to Tukey's test for p≤ 0.05.
Medias con letras desiguales en la misma columna muestra diferencias significativas entre los genotipos según prueba de Tukey para p≤ 0,05

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