Original Article

PRODUCTIVE AND PHYSICAL QUALITY PARAMETERS OF INTERCLONAL COCOA PROGENIES (THEOBROMA CACAO L.)

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Abstract

This research was carried out at the Experimental Farm "La Represa", during the years 2012 to 2014. The behavior of 21 improved progenies of cocoa T. Nacional type was evaluated, including control of Trinitario origin (JHVH-10), a completely randomized block design was used within a bi-factorial, with four replications, using the Tukey multiple range test ($P \leq 0.05$). The following variables were evaluated: number of vegetative witches' brooms, percentage of diseased ears, number of healthy fruits, as well as estimated yield, and seed and ear index. The outstanding cross was DICYT-H-253, which presented the best yield kg/ha/year; DICYT-H-270 stood out as the progeny with the highest number of healthy ears, while DICYT-H-258 presented the highest number of ears with witches' broom. However, in the quality indexes, the crosses in terms of the cob index were DICYT-H-267 and DICYT-H-268. In the same way, DICYT-H-257 and DICYT-H-260 presented the highest seed index in terms of the number of kernels in 100 g, proving the productivity and quality of the central zone of the Ecuadorian coast.

Keywords: Cocoa, progenies, yield, kernel quality.

Introduction

Cocoa (Theobroma cacao L,) belongs to the Sterculiaceae family, characterized by developing in specifically tropical geographical areas and extending 20° latitude towards the northern and southern hemispheres (Cuellar et al., 2012), being Ecuador a privileged country due to its natural conditions, in addition to agroecological characteristics in climate and humidity, standing out as one of the best producers in Latin America and the world (Tirado et al., 2016).

In the area of Los Rios, the humid tropical climatic conditions allow diseases caused by fungi to develop easily, including witches' broom (Moniliophtora perniciosa Cif and Par), causing infection in young shoots, flower buds, vegetative buds and young fruit; combined with other diseases, they cause annual losses that sometimes exceed 50% of total annual losses (Quintero et al., 2010).

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Access this article online

Quick Response Code:

Website: www.pnrjournal.com

DOI: 10.47750/pnr.2022.13.03.069

How to cite this article: Jaime Fabian Vera Chang, Fernando David Sánchez Mora, Gregorio Humberto Vásconez Montufar, Leonela Alexandra Álvarez Coello, PRODUCTIVE AND PHYSICAL QUALITY PARAMETERS OF INTERCLONAL COCOAO PROGENIES (Theobroma cacao L,), J PHARM NEGATIVE RESULTS 2022;13:450-454.

Likewise, causing infection in young shoots, floral bearings, vegetative buds and young fruit, combined with other diseases, cause annual losses that sometimes exceed 50% of the total fruit produced; therefore, obtaining varieties with greater economic value depends on genetic improvement processes (Tarqui et al., 2017).

It is partly related to physical and chemical factors of the soil, crop management, light interception, photosynthesis rate, respiration, and fruit morphology (Puentes et al., 2014), Consequently, farmers have opted to replace the traditional variety with more productive and disease tolerant materials of Trinitario origin, causing an improvement of materials, mainly of genes related to quality (Sánchez et al., 2014).

Cocoa (Theobroma cacao L.) generally has considerable genotypic variability in morphological and physiological traits associated with yield, (Portela et al., 2011) by developing research on genetic improvement, the possibility of obtaining excellent yields or dry kernel production by achieving high-quality genotypes, healthy bean production and large cob size is increased (Daymond & Hadley, 2002).

It is estimated that Ecuador exports 260 thousand metric tons of cocoa beans, according to projections for 2016 production and exports will increase to 300 thousand tons of cocoa, destined for the European market such as Switzerland, Belgium, and France, representing 60% of the demand, generating income of about 167 million dollars, constituting a source of employment and an important item for the country (Vera et al., 2016).

The objective of this study was to evaluate products and quality parameters of twenty-one cocoa (Theobroma cacao L) progenies for three years from 2012 to 2014, located in the Experimental Farm "La Represa", property of the State Technical University of Quevedo (UTEQ), Republic of Ecuador, through the Scientific and Technological Research Unit (UICYT) in the Cocoa area.

Materials and methods

The experiment was conducted at the "La Represa" Experimental Farm. Its geographical location is 1° 03' 18" South latitude and 79° 25' 24" West longitude at an altitude of 90 meters above sea level, with ¬characteristics of humid-tropical forest (bh-T), irregular topography, inceptisol type soil, texture, clay loam ¬and pH 5.9.

A completely randomized with the bifactorial arrangement was used to detect differences, 21 progenies of improved T. cacao Trinitario and Nacional varieties previously selected for high productivity will be considered as treatments, plus a commercial control JHVH-10 (Nacional type) grown at the research site, with four replications, each experimental unit will consist of ten seedlings in Tukey's test with $p \leq 0.05$ (Pedroza et al., 2016). It was used to compare mean values and significance was detected. Statistical analyses were performed using InfoStat software version 2018.

For the production and physical quality measurements in this study, they were coded by the Cocoa Program of the Scientific and Technological Research Unit (UICYT) of the UTEQ: T251, T252, T253, T254, T255, T256, T257, T258, T259, T260, T261, T262, T263, T264, T265, T266, T267, T268, T269, T270, and T271 according to disease tolerance, evaluating parameters such as number of vegetative witches' brooms, percentage of diseased cobs, number of healthy ones, as well as the estimated yield Kg/ha/year, in addition to the seed and cob index, During the years 2012, 2013 and 2014, meteorological parameters such as Temperature, Heliophonia hours/ light/ months, humidity and precipitation were also considered.

Twenty-one progenies and one commercial cocoa control with outstanding production characteristics, tolerance to the main diseases, and quality, belonging to the Cocoa Program of the Scientific and Technological Research Unit (UICYT) were used. Crosses were made between Trinitario and Nacional to produce the progenies and 10 plants were transplanted in the field for each interclonal cross.

The variables to be evaluated were: Number of healthy ears (#), for which, the data record was obtained when harvesting and counting the number of healthy ears per tree of each treatment; Number of healthy cobs (#), for which, the data record was obtained by harvesting and counting the number of healthy cobs per tree for each treatment. The number of diseased ears (#), data recording for this descriptor was carried out at the same time as the variable number of healthy ears by counting the number of diseased ears per tree. The yield (kg/ha/year) was also analyzed. The dry cocoa yield per year (kg-1 ha) was estimated with the dry weight in grams of each treatment, and this result was transformed into kilograms per hectare per year. Another variable analyzed was the number of sick ears with witches' brooms (#). This variable was recorded monthly, the data was taken by counting the number of witches' brooms obtained by the plant. Subsequently, the Index of seeds (#) and cobs (#) was made, from the cobs collected to determine the SI, 100 fermented and dried seeds were taken correctly, and it was calculated by the following operation: SI=weight in grams of 100 fermented and dried seeds divided by the number of seeds.

The cob index refers to the number of cobs needed (20-22 cobs) to obtain one kilogram of dry cocoa and was collected from mature and healthy cobs and determined by this formula: MI= number of cobs/weight in grams of the dried beans in the cobs.

Organoleptic variables, to determine the organoleptic characteristics, samples of fermented and dried almonds were taken from the progenies, individually and using the senses of smell and taste, in the three flavor profiles (basic, specific, and acquired), the tasting of the cocoa liquor was rated using an international scale of 0 to 10 points.

RESULTS

The effects of precipitation on the number of healthy and diseased ears in the years 2012-2014 can be observed, with the months of October, November and December being those with the highest presence of healthy ears and production peaks, low incidence of diseased ears is evidenced, while in yield they exceed 400 kg-1 ha, despite the low precipitation and temperatures recorded, indicating a possible tolerance to drought and diseases, expressing their productive potential in the third year of establishment in the field. Tolerance to diseases and where the effect of rainfall influences the yield of the progenies is evident in each graph.

Number of healthy ears

According to the Tukey test ($p \geq 0.05$), no significant differences were found among healthy cobs in the three years of evaluation, in which the treatment DICYT-H- 258 registered the highest average in 2012 and 2014 with 19.58 and 25.42 respectively, while in 2013 it was DICYT-H-257 with 27.18 and the lowest values are expressed in DICYT-H- 269 with 4.00 in 2012, in the following year JHVH-10 (Control) DICYT-H- 271 obtaining 1.55 and in 2014 the DICYT-H- 255 with a statistical average of 9.14.

Number of diseased ears

In the analysis of Variance, significant differences were evident in the year 2014 for the other years, being the treatment DICYT-H-271 which registered the highest number (8.00 brooms, 2014) and DICYT-H-258 (3.25, brooms, 2014), while in the years 2012 and 2013 the ANOVA did not evidence significant differences, where the treatment that obtained high presence of diseases was DICYT-H-251 with 3.83 in 2012 and 2013 DICYT-H-262 presented 2.60. The lower values were manifested in DICYT-H- 269 and 268 with 0.00 in 2012, in 2013 DICYT-H-271 with an average of 0.55 and DICYT-H-254 that registered 0.92, in the last year of evaluation lower values were presented in the treatment DICYT-H- 268 (0.67) and DICYT-H-254 (0.92,).

Principal component analysis (PCA) of production variables 2012-2014

For the quality parameters, the first two principal components explained 61.80% of the total variability. The yield and seed index are located to the left of the axis representing the second component, which explains 27.2% of the total variance of the original data matrix.

The number of total healthy ears in the three years of the evaluation showed significant differences, the highest averages per treatment were presented in the progenies DICYT-H-270 and DICYT-H-253 with 272.67 and 263.67 ears, respectively. The lowest values were presented for the hybrids DICYT-H-260 and DICYT-H-263 with 78.67 and 95.67 ears. The overall average was 162.03 and a coefficient of variation of 33.49 %.

In the number of diseased ears, the analysis of variance did not reveal statistical significance, the highest average were the treatments DICYT-H-253 with 25.00, DICYT-H-256 which recorded 24.67 and DICYT-H-251 reflected 21.00 ears, a coefficient of variation of 35.76 % and an overall average of 13.87.

The highest cocoa yield averages were presented in treatments DICYT-H-258 and DICYT-H-259, with 2251.63 kg-1 ha and 2167.68 kg-1 ha, respectively, with totals that differed statistically from the remaining progenies. The treatments that reported lower averages were DICYT-H-267 with a yield of 214.05 kg ha-1, DICYT-H-268 with 580.20 kg ha-1 and DICYT-H-271 with 876.70 kg ha-1.

The analysis of the variance of the variable number of diseased ears revealed statistical significance. The highest number of diseased ears was for T1, DICYT-H-272 with 6.33 ears, the minimum values were reflected in T30, DICYT-H-301, with 0.33 diseased ears, with a coefficient of variation of 32.64% and an overall average of 2.20 (Espin, 2017).

Quality parameters

The effects of crosses, treatment and the interaction crosses x treatment were not significant ($P<0.05$) for the disease witches' broom number (NEB- Número de Escoba de Bruja), seed index (SI) and ear index (MI). The NEB variable showed a higher presence in DICYT-H-259 with 32.33 and a lower average in DICYT-H-270 with 1.50, with an overall average of 13.68 and a coefficient of variation of 49.46.

The highest SI (seed index) occurred in the crosses DICYT-H-257 (1.25) and DICYT-H-260 (1.25). Consequently, lower SI values were recorded in the progenies DICYT-H-267 (1.02), DICYT-H-268 (1.03) and DICYT-H-266 (1.07). The overall average is 1.16 g with a coefficient of variation of 9.67 %.

The best MI (cob index) was presented by the cross DICYT-H-267 (32.83), followed by the cross DICYT-H-268 (32.83), DICYT-H-253 (30.14) while the lowest MI was presented by the crosses DICYT-H-259 (21.65), DICYT-H-258 (21.67) and DICYT-H-262 (22.11). The overall average is 26.17 g with a coefficient of variation of 20.02 %.

Organoleptic analysis of the 21 cocoa progenies.

It was evidenced that the astringent flavor was highly significant with bitterness, due to the content of polyphenols contained in the almond, as well as cocoa, up and fruity flavors, being of high statistical significance.

Discussion

In their study, Vera and Goya (2015) evaluated 21 cocoa crosses registering few differences in agronomic behavior number of healthy ears, where the highest averages per treatment were presented in the hybrids DICYT-H-259 and DICYT-H-263 with 15 and 14 ears: The lowest averages were obtained by DICYT-H-253 and JHVH-10 (control) with 6

and 3 ears, respectively.

In terms of the number of healthy pods, lower values were presented compared with (Sánchez et al., 2015). When evaluating 140 cocoa accessions in Rondônia, Brazil, observed that clone CAB383 did not manifest witches' broom while clone CAB261 presented 20.5 infected branches.

According to Espín (2017) in his analysis of variance of the factor under study number of healthy ears revealed statistical significance, indicating the highest value for T22, DICYT-H-293 with 17.33 healthy ears, while the minimum values reside on T6, DICYT-H-297 and T11, DICYT-H-282 respectively, with values of 10 healthy ears per treatment, the overall average was 12.26 and a coefficient of variation of 19.80 %.

Ruales et al. (2011), in their research materials in cocoa hybrid, studies observed a total of 37.47 cobs obtained, of which, 24.3 healthy cobs and 4.81 cobs were attacked by S. Vulgaris. For clone CAP-34, a total of 22.36 cobs were obtained, of which, 4.27 were attacked by Monilia (Moniliophthota roreri Cif, and Par).

According to Hernandez (2016), described in terms of yields the measurements made also indicate that the agroecological management of witches' brooms in the plantations considered has an impact on that variable, it has been shown that fungal diseases, poor management, non-optimal genetic material and little use of inputs in production. Quiroz and Amores (2002) cite that Ecuador is one of the main cocoa producers in Latin America, with an estimated average commercial yield of 300 kg-ha-1 per year.

For this variable (Espín, 2017), the ANOVA indicates that there is a statistical difference, where the highest value reflected on T10, DICYT-H-281 with 818.67 kg/ha/year, different from T30, DICYT-H-293 with a yield of 485.37 kilograms per hectare per year, the Coefficient of Variation was 15.82 and an overall average of 648.26 kg/ha/year.

Quality parameters

Sanchez et al. (2015) obtained the number of vegetative witches' brooms and the percentage of diseased ears, the interactions between ¬clones x locations ($P<0.05$) and locations x years ($P < 0.01$) were significant in the Clones L11-H19, L18-H58, L21-H43, L26-H64, L46-H57, L46-H75, L46-H88, and CCN-51 presented lower ¬values of witches' broom in Quevedo.

Hernández (2016) describes those factors such as high temperature, high precipitation, and relative humidity, together with the high density of cocoa plants in the agroecosystems evaluated, favor the development of witches' broom.

According to a study by Vera and Goya (2015), the highest averages of Seed Index (SI) were DICYT-H-261 and DICYT-H-264 with 1.37 and 1.33 grams, respectively, describing that SI is an important indicator for yield in breeding studies and is influenced by factors such as the environment and the genetic conformation of the parents (Vera et al., 2014), who indicates that the samples have values with amplitude varying between 0.76 and 1.89, with an average value of 1.32 g.

Similar values were presented by Vera & Goya (2015), who obtained average Cob Index (MI) in hybrids DICYT-H-269 and DICYT-H-268 with 30.25 and 26.25 cobs, respectively. On the other hand, cultivars represented averages that varied between 16.75 (DICYT-H- 266) and 25.05 (DICYT-H-263). This is acceptable for marketing and industry, explaining that to produce 1 kg of dry grain, a greater number of cobs is necessary to produce 1 kg of dry grain (Puentes et al, 2014).

In addition, Mendoza (2013) recorded indices in CCN-51 of 15.99 cobs and ETT-544 of 23.11 cobs, and Ortiz (2002), who evaluated the cob index in the three types of cocoa, projecting an average of 13.85 to 30.77 cobs in criollos, 11.23 to 30.46 cobs in Forasteros and 8.69 to 24.10 cobs in Trinitarios.

Sensory analysis

A study by Cuellar et al. (2018), explains that post-harvest practices influence the quality of the product, one of them fermentation if interrupted, the chemical processes will be affected. This in turn influences the high values of acidity and bitterness found during the tasting, its quality is classified as acceptable found with attributes such as specific tastes of nuts, flowers, and fruits.

According to Rivera et al. (2012), astringency is more than a taste it is a sensation or perception that causes a contraction of the mucosal surface of the mouth due to poor fermentation.

According to Vera & Goya (2015), their sensory analysis of cocoa hybrids showed wide sensory variability, due to the different genetic constitutions of the trees. Being the materials DIRCYT- H- 255, DIRCYT- H- 257, DIRCYT- H-261, and DIRCYT- H- 270, including the control JHVH-10 registered cocoa flavors above (organoleptic profiles 5, 6, 7) and of these the materials DIRCYT- H- 255 and DIRCYT-H- 270 presented a higher intensity fruity and nutty flavor.

Conclusions

When analyzing the productive parameters, DICYT-H-270 stood out among the other treatments in terms of healthy ears, and DICYT-H-258 presented the best yield kg -1ha-1year. The treatment with the lowest number of ears with witches' broom was DICYT-H-270.

The treatments DICYT-H-267 and DICYT-H-268 showed the highest seed index in terms of the number of kernels per 100 g in the cob indexes.

In the sensory analysis, the progenies showed cocoa, up and fruity flavors with high statistical significance, as well as astringent flavor and bitterness, due to the polyphenol content of the almond.

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