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Morphoagronomic characterization and production gain after two mass selection cycles in Nawa Sheki landraces maize originated from the Western Brazilian Amazon

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Abstract

Intensive breeding and artificial selection of the desired traits in maize landraces through domestication have created modern maize, which needs a great technological contribution for optimal productive development. However, the narrowing of the genetic bases of maize made it difficult for traditional farmers to access productive genetic material that maintains the genotypic and phenotypic diversity capable of ensuring productive sustainability. Thus, objective of the study was to evaluate the variability and production gain in morphoagronomic characters of Nawa Sheki landraces maize after two mass selection cycles. The work was carried out in the experimental area of the Federal University of Acre, where two cycles of mass selection were applied on variety Nawa Sheki, in periods 2018/2019 and 2019/2020. The characteristics evaluated were: plant height, ear insertion height, ear length, ear diameter, number of rows of grains, number of grains per row, ear mass and grain mass. Data were submitted to descriptive analysis, with presentation of the histogram of frequency, asymmetry, kurtosis and Shapiro-Wilk test for the general population in both cycles. For the selected population, the following were obtained: mean, coefficient of variation, amplitude, minimum and maximum values and population variance in each cycle. The genetic parameters were selection differential for both cycles, production gain with selection and realized heritability of the first cycle. The choice of individuals in both cycles of mass selection was based on the ranking of the best values of the evaluated characteristics. The two cycles of mass selection provided high variability in the traits with the presence of superior phenotypes. Still, mass selection stabilized values for plant height, ear insertion height, followed by production gains for number of grains per row and ear mass.

Keywords: Maize; genetic variability; plant breeding

Abbreviations: As_asymmetry; Kt_kurtosis; W_Shapiro Wilk test; Normal dist._normality curve; PH_plant height ; EIH_ear insertion height, NRG_number of rows of grains, NGR_number of grains per row; EL_ear length; ED_ear diameter, EM_ear mass; GM_grain mass; $MGP_{0 \text{ and } 1}$_mean of the population in the 1st and 2nd cycle of mass selection, respectively; $SPM_{0 \text{ and } 1}$_mean of the population selected in the 1st and 2nd cycle of mass selection, respectively; $SD_{0 \text{ and } 1}$_selection differential in the 1st and 2nd cycle of mass selection, respectively; h^2_0_realized heritability.

Introduction

Maize (*Zea mays* L.) has high genetic diversity and is among the most cultivated crops in the world, having great economic value and potential to generate income for many families, especially small producer (Guimarães et al., 2019). In Brazil, maize is present throughout the national territory due to its ability to adapt to different environmental conditions, but grain yield is quite diversified depending on the level of adopted technology among the corn crops (Conab, 2021).

In economically developed regions, most crops are intended for the cultivation of hybrid and transgenic maize, while in regions where agriculture family predominates, the main type of maize cultivated is landraces varieties (Langner et al., 2019). Thus, these landrace seeds are obtained by several generations of cultivation at a low technological level, which allows the producer's independence in relation to the need to acquire the seeds, rescuing them annually (Campos et al., 2018).

Hybrid cultivars have higher productivity than landrace varieties. However, these traditional varieties can exhibit similar or superior performance to hybrids in crops that use low technological level due to their broad genetic base (Alves et al., 2020). In the domestication process, landrace varieties have accumulated great genetic variability, which gives them stability in long-term grain production, in addition to displaying favorable gene for genetic response of resistance to biotic and abiotic factors that can be exploited in plant breeding program (Dwivedi et al., 2016).

Maize was probably found in nature by traditional peoples and selected successively, although it has undergone previous natural selection (Kistler et al., 2018). This strategy, known in genetic improvement as mass selection, consists of evaluating and selecting plants based on their phenotype, favoring a gradual and continuous increase in the average of the character under selection, in addition to favorable alleles, but without reducing variability (Rutkoski, 2019).

Above all, it is essential to follow the evolution of production gain and the variation of genetic parameters of the population during the selection cycles, in order to continue establishing correct selection strategies, which make it possible to obtain superior populations in breeding program (Moraes Júnior et al., 2017). Therefore, the objective of this research was to evaluate the variability and yield gain in morphoagronomic characters of a maize landraces during two cycles of mass selection.

Results and discussion

First cycle of mass selection

The base population showed a normal distribution for plant height (Figure 1A), ear insertion height (Figure 1B) and ear diameter (Figure 1D). In these characters kurtosis (PH = 2.89; EIH = 3.40; ED = 3.12) and asymmetry (PH = - 0.24; EIH = 0.01; ED = - 0.18), favor the occurrence of extreme values related to the mean and distribution normal in the population studied. On the other hand, ear length (Figure 1C) did not show a normal distribution ($p<0.05$), indicating variations between plants in the base population.

In this population, 84.64% of the individuals had a plant height between 2.52 m and 3.38 m, while 7.42% had a height from 2.00 m to 2.35 m. For ear insertion height, the extremes observed were 1.00 m and 3.10 m, where 61.88% of the plants reached EIH between 1.76 m and 2.15 m. This discrepancy for PH and EIH demonstrates a very favorable situation for the selection of individuals aiming at the improvement of these characteristics, since the heterogeneity in the characters indicates the possibility of success in the genetic progress, as stated by Allier et al. (2019).

Regarding the ear length (Figure 1C), we can observe that 38.60% of the individuals in the population presented values below 11.91 cm, while 61.39% of the plants presented ears with 13.55 cm up to the limit of 25 cm long. As for the ear diameter (Figure 1D), a variation from 26.49 mm to 52.56 mm was observed between the ears of the base population. These results reflect the variability in the expression of these characters at initial moments of mass selection in the studied maize variety. Overall, this variability is essential to make progress in maize breeding programs, as it favors the choice of superior genotypes (Ramalho et al., 2012).

The characteristics number of rows of grains (Figure 2A) and grains in the row (Figure 2B), as well as ear mass (Figure 2C) and grain mass (Figure 2D) of the base population in the first mass selection cycle did not present normal distribution ($p<0.05$), indicating variations between plants in the population.

In the evaluation of the ear, the predominance of classes of 6, 8, 10, 12, 14 and 16 for NRG was observed, where 44.55% of the individuals presented the amount of 12 rows per ear (Figure 2A). As for the NGR, the variation found was from 10 to 47, with 34.65% of the ears of the plant population showing between 23.45 and 26.82 grains in the row (Figure 2B). The differences between the classes found for the NRG and NGR traits portray the heterogeneity in the base population of the maize landraces. Thereby, the genetic progress of these traits in a breeding program is possible, since the improvement is highly dependent and influenced by the variability found within the population (Al-Naggar et al., 2020).

In the ear mass (Figure 2C) the minimum and maximum values observed in the base population of maize landraces were in the class of 28 to 260 g, respectively, but a higher relative proportion of individuals (65.12%) were found with EM equal to or higher than 112 g up to the maximum limit of the evaluated characteristic. According to Pinheiro et al. (2021) EM is considered one of the essential components of yield, as heavier ears have a high potential for high yields. Then, the presence of high coefficients of variability for the trait portrays a high possibility of selecting individuals with superiority in grain production (Chavan et al., 2020).

With regard to grain mass (Figure 2D), the base population presented class values that ranged from 7 to 239 g. The expression of this character is dependent on the genotypes used, since some varieties have grains with smaller and lighter nuclei, which consequently reduces the productive potential per plant. Thus, the selection of genotypes with higher grain mass is essential to obtain production gains in a maize breeding program (Li et al., 2015).

Second cycle of mass selection

In the mass selection cycle conducted in the 2019-2020 season, the general population showed high dispersion of values for the characteristics PH, EIH, EL and ED (Figure 3). The data for these characteristics do not follow a normal distribution ($p<0.05$), while the observed relative frequencies were distributed in different classes, showing, through As and Kt, where a dispersion of the values observed in the population.

In the second mass selection cycle, the minimum value for the plant height class (Figure 3A) was 1.50 m, reaching a maximum of 4.40 m, to the point that 68.92% of the plants presented height above 3.16 m to the observed upper limit. Regarding the ear insertion height (Figure 3B), only 2.36% of the plants had ears between 0.80 m and 1.76 m in height, which facilitates the manual harvesting of these ears. According to Baretta et al. (2016), the maize landraces have high plant height, where above 3.00 m is not desirable for farmers because it is often associated with greater plant lodging and breakage. They also reinforce that maize landraces ear above 2.00 meters in height making manual harvesting difficult.

Regarding the general population of the second mass selection cycle, the highest percentage of individuals (66.71%) had ears in the pattern of 11.38 cm up to the maximum limit of 20.00 cm in length; while others showed ear size of ears between 4.00 to 10.15 cm (Figure 3C). For the ED, the class values ranged from 10.00 mm to 50.00 mm (Figure 3D), where this difference facilitates the selection of individuals with higher values when high selection intensity is applied, even more than 80.72% of the individuals showed ears above 30.00 mm in diameter.

In maize landrace populations, ear length and diameter are influenced by environmental factors and the genotype, resulting in greater variability. According to Kizilgeci et al. (2018) ear lengths ranging from 6.21 cm to 25.38 cm and diameters ranging from 14.13 mm to 48.92 mm were recorded in maize landraces, which are similar to the population of the second selection cycle of this maize study. However, the heterogeneity observed in the plant population favors the exclusion of individuals with low values for the conduction of subsequent cycles, which increases the chance of success in genetic gain with the selection for establishment of the next generations (Resende et al., 2021).

The data from the general population of the second mass selection cycle did not follow a normal distribution for characteristics such as number of grain rows, number of grains in the row, ear mass and grain mass (Figure 4). They were associated with As values different from zero, positively or negatively, followed by a kurtosis coefficient greater than or equal to 3 (Kt ≥ 3), indicating the existence of intrapopulation variability among the evaluated individuals (Benítez et al., 2020).

The extremes observed for the NRG were the presence of individuals in the minimum class of 4 and maximum of 18 rows per ear. However, 33.85% of the plants were concentrated with 11.54 rows (Figure 4A). As for the number of grains in the row, the individuals were distributed among 14 classes with their proper proportions (Figure 4B), where the ears with 20, 23, 26, 29 and 32 grains per row presented a concentration of 59.86% of the individuals of the population. Similar results were observed by Stephen et al. (2016), were the number of rows of grains ranged from 9.60 to 16.92, while the number of grains per row ranged from 21.33 to 36.85, representing a diversity that can be explored efficiently in breeding programs.

For EM, intrapopulation variation was observed (Figure 4C), since the class values ranged from 16.40 to 299 g, where most individuals (73.53%) had a mass greater than 81.00 g up to the maximum limit. Thus, one of the main factors that demonstrate response to selection in breeding programs is intrapopulation variability (Allier et al., 2019). In this context, our results reveal individuals subject to selection, because in the variability present for EM, the population exposes the presence of plants with heavier ears. Thereby, in maize landraces, plants with ears of greater mass have high potential to express high yields (Fontinele et al., 2021).

As for the grain mass, we found that the general population of the second cycle of mass selection presented high amplitude, with a variation from 10.61 g to 243.75 g (Figure 4D), but only 33.57% of the individuals presented value greater than 100 g. Under these conditions, the results allow the selection of superior individuals for the trait, as plants with lower grain mass are related to low yield potential, since they have smaller and lighter grains (Nascimento et al., 2019).

Genetic parameters

Among the characteristics evaluated in the two mass selection cycles, the parameters of mean of the base population (MGP_0) and of the general population of the second cycle (MGP_1), mean of the selected population of the first (SPM_0) and of the second cycle (SPM_1), selection differential of the first (SD_0) and second cycle (SD_1), selection gain of the first cycle (GS_0), realized heritability (h^2_0) and coefficient of variation of the first (CV_0) and second cycle (CV_1) of the maize landraces population, are shown in Table 1.

The realized heritability did not show expected intervals for the characters of NRG, EL, ED and GM, as negative values smaller than $h^2 = 0.01$ were observed, indicating that there are changes in the characteristics below the levels selected as stated by Yoo et al. (2020). According to these authors, h^2 with negative values for the characters are not related to the selection of individuals, as they are the result of the incorporation of annual variation, inbreeding depression, random genetic drift or incidental environmental effects on the base population, which may explain the results found here.

For the number of row of grains the realized heritability was 0.86, while for ear mass, h^2_0 was 0.14. According to Saha et al. (2019) h^2 values greater than 0.70 are considered high, but they vary according to the studied character and thus help in the effective selection of traits based on phenotypic expression, helping to adopt a simple selection method focused on genetic improvement.

Observing the population parameters of mass selection (Table 1), a balance in the coefficient of variation (CV_0 and CV_1) can be seen in the plant height and ear insertion, indicating that there was stabilization of intrapopulation variability with the selection cycles. Regarding the gains with selection in the first cycle (GS_0), these characters did not respond as expected, presenting a larger plant in the second cycle compared to the previous cycle. These results are not favorable in a corn improvement process whose objective is grain yield, since larger plants have a greater tendency to lodging, thus reducing the number of productive plants in the population (Bianchetto et al., 2017).

The characteristics of NRG, EL, ED and GM of the maize landraces population did not respond positively to mass selection applied to the base population, as the population of the second cycle showed a reduction in values for the highlighted characters. These results can be explained by the wide variability observed in the general population of the second cycle, which influenced the decrease of the average values for the analyzed characters, allowing negative gains in relation to the previous cycle.

As maize landraces have high intrinsic variability, they are a valuable source of potentially useful traits in breeding programs, and there is a need to properly characterize them and identify superior genotypes (Costa et al., 2021). However, it is natural that maize landraces populations have a low average estimate in their characters, as the variability present within the population provides great differences between the values, favoring its decrease (Olaniyan, 2015). Above all, the amplitude observed in the phenotypic diversity of the population helps to obtain genotypes with superior characteristics within the collectivity of plants evaluated in a breeding program (Resende et al., 2021).

According to the selection differential (SD_1), the families selected in the second cycle of mass selection showed a higher average value than the population of the first cycle in all observed characteristics. These results prove that the selection of individuals provides homogenization and elevation of the mean values of the characteristics compared to the base population with high heterogeneity (Shelton and Tracy, 2015).

Table 1: Genetic parameters of mass selection in a maize landraces for the characters plant height (in cm, PH), ear insertion height (in cm, EIH), number of rows of grains (NRG), number of grains per row (NGR), ear length (in cm, EL), ear diameter (in mm, ED), ear mass (in g, EM) and grain mass (in g, GM).

Parameters	Characters							
	PH	EIH	NRG	NGR	EL	ED	EM	GM
MGP_0	2.95	1.93	11.93	25.52	13.53	39.77	121.83	100.83
SPM_0	2.95	1.92	12.22	26.70	13.93	40.54	138.86	117.86
SD_0	0.00	-0.01	0.30	1.17	0.40	0.77	17.03	17.03
GS_0	0.49	0.17	-1.28	1.01	-0.55	-3.77	2.42	-15.96
h^2_0	-	-	-4.27	0.86	-1.38	-4.89	0.14	-0.93
CV_0	12.76	17.64	17.54	28.72	19.25	10.54	38.26	46.23
MGP_1	3.44	2.10	10.65	26.53	12.98	36.45	124.25	84.87
SPM_1	3.68	2.24	13.02	33.20	13.70	40.67	164.98	133.89
SD_1	0.24	0.14	2.38	6.68	0.73	4.22	40.73	49.02
CV_1	14.15	17.34	21.97	29.84	29.77	14.21	37.74	51.27

Note: $MGP_{0 \text{ and } 1}$_mean of the population in the 1st and 2nd cycle of mass selection, respectively; $SPM_{0 \text{ and } 1}$_mean of the population selected in the 1st and 2nd cycle of mass selection, respectively; $SD_{0 \text{ and } 1}$_selection differential in the 1st and 2nd cycle of mass selection, respectively; h^2_0_realized heritability.

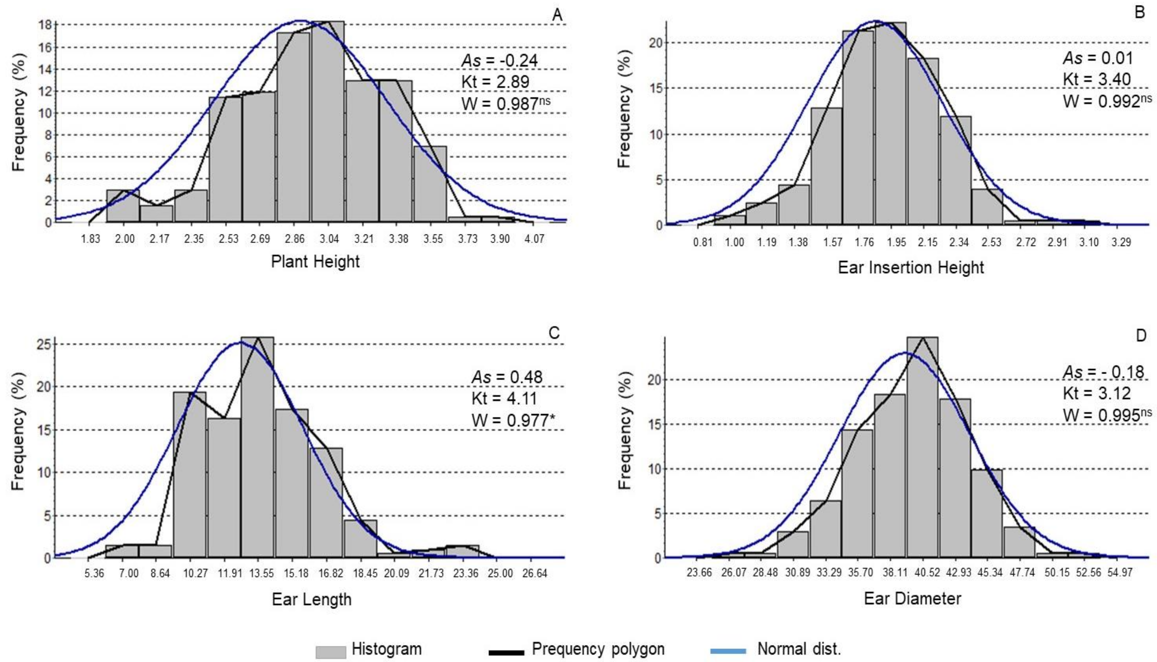
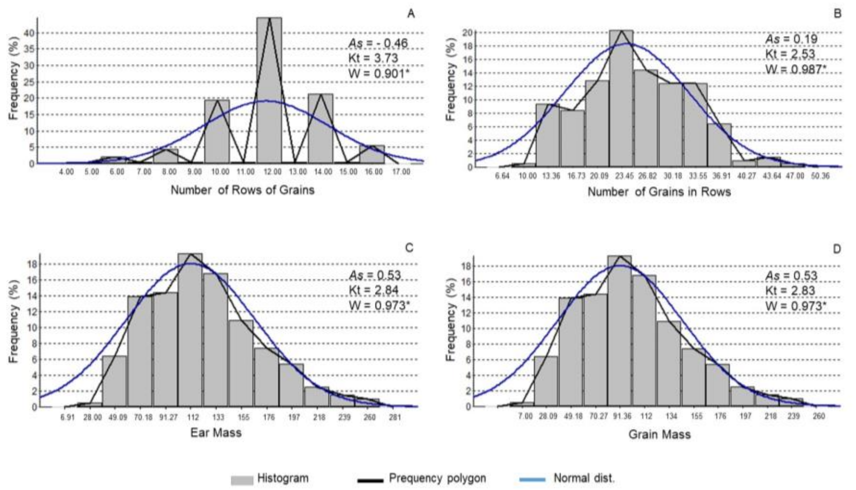


Fig 1. Frequency histogram and normality curve for the characters plant height (A), ear insertion height (B), ear length (C) and ear diameter (D) of the maize landraces population in the first selection cycle mass. Note: *As*_asymmetry; Kt_kurtosis; W_Shapiro Wilk test; Normal dist._normality curve.



Note: *As*_asymmetry; Kt_kurtosis; W_Shapiro Wilk test; Normal dist._normality curve.

Fig 2. Frequency histogram and normality curve for the characters number of rows of grains (A), number of grains in rows (B), ear mass (C) and grain mass (D) of the maize landraces populations in the first cycle of mass selection.

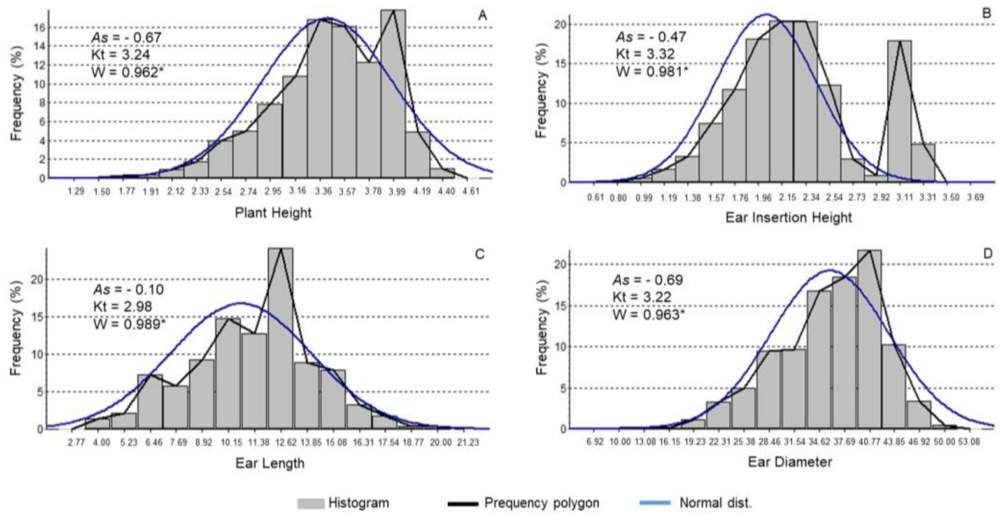


Fig 3. Frequency histogram and normality curve for the characters plant height (A), ear insertion height (B), ear length (C) and ear diameter (D) of the maize landraces populations of the second cycle of mass selection. Note: *As*_asymmetry; Kt_kurtosis; W_Shapiro Wilk test; Normal dist._normality curve.

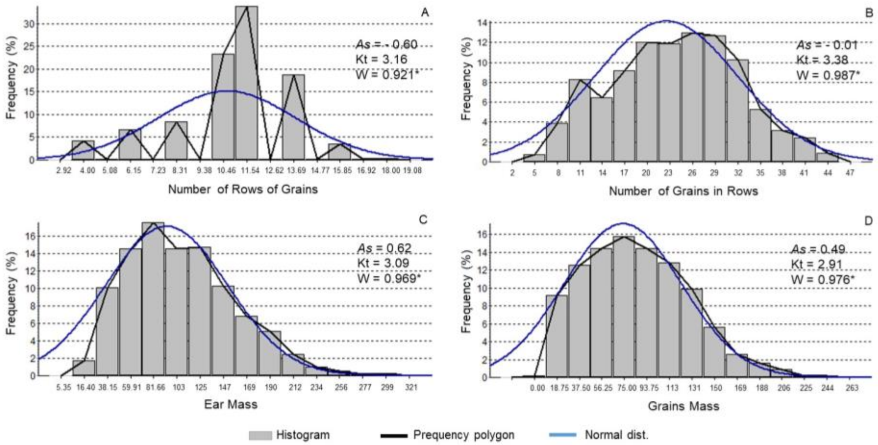


Fig 4. Frequency histogram and normality curve for the characters number of rows of grains (A), number of grains per row (B), ear mass (C) and mass of grains (D) of the maize landraces populations of the second cycle of mass selection. Note: *As*_asymmetry; Kt_kurtosis; W_Shapiro Wilk test; Normal dist._normality curve.

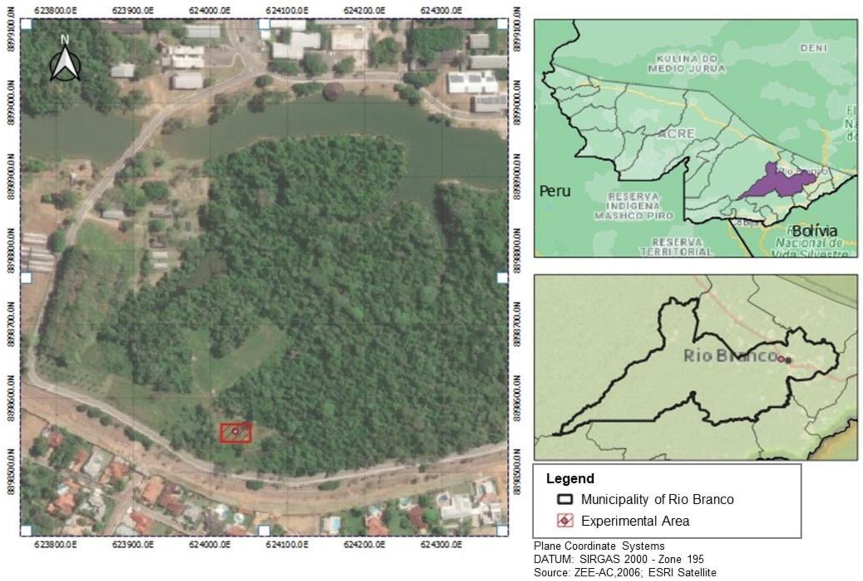


Fig 5. Location of the experimental area of the Federal University of Acre Campus cede, Rio Branco, Acre.

For the characters NGR and EM, mass selection provided increases in production, where at the end of the process, the ears showed higher average mass and number of grains in the row. It is noteworthy that even observing the presence of intrapopulation variability, the GS_0 was 1.01 for NGR and 2.42 for EM for the selection cycles performed. In this case, it is expected that the selected families will be able to produce a greater amount of grain and an increase in ear mass, with a tendency to increase the productivity of the maize landraces population.
In general, the ultimate goal of any breeding program is to develop outstanding genotypes in terms of productivity, adaptation, resistance to and abiotic stresses, with greater yield gain (Tadesse et al., 2019). The mass selection can be usually used by small producers, mainly, due to its ease of application, guaranteeing better grain production in each generation (Yong et al., 2020). Therefore, mass selection was efficient, as it provided considerable selection gain for ear mass and number of rows of grains in the maize landraces subjected to selection cycles.

Materials and methods

Characterization of area
The work was carried out in the experimental area of the Federal University of Acre, located in the municipality of Rio Branco in the state of Acre (67º 52' 6.53'' W and 09º 57' 43.93'' S in WGS84 datum) in the harvest period 2018/2019 and 2019/2020. The area is reserved for conducting a corn improvement experiment, as it is far from other plantations of the same species, so that there is no crossing of other varieties with the genetic material worked on (Figure 5).
According to the international classification of Köppen, the climate of the region is of the type Am, characterized as hot and humid, with maximum temperatures that vary from 29.7°C to 32.8°C and minimum of 16.1°C at 21.8°C, precipitation 1,994 mm per year and relative humidity between 80.5% and 87.9% throughout the year (Climate-data.org, 2021).

Plant material
The base population in which the two mass selection cycles were applied is a maize landraces from the Kaxinawá Indigenous Land of Nova Olinda (TIKNO), located in the Alto Envira region, in the municipality of Feijó, Acre. The maize seeds of this traditional variety are registered in the National System of Genetic Heritage and Associated Traditional Knowledge (SisGen), under number A6A46CC and registered with the Genetic Heritage Management Council (CGen) with number 201/2014.

Experimental characterization
In the maize landraces, two cycles of mass selection were applied, the first being carried out in the 2018/2019 harvest and the second in the 2019/2020 harvest. The conduction of the first mass selection cycle was carried out in an area of 20 x 20 m, composed of 22 lines of 20 meters in length each, with a spacing of 0.80 m between lines and 0.20 m between plants, totaling 2200 plants. Sowing was carried out manually with one seed per hole on october 19, 2018, later replanting was carried out on october 26 and november 2, 2018.
In both the first and second mass selection cycles, with the physiological maturation of the ears and before harvesting, the following characteristics were measured in all individuals in the population: plant height (PH): measured with the aid of a graduated ruler (m) on all plants, considering the distance from the ground level to the last fully expanded leaf; Ear insertion height (EIH): measured with the aid of a graduated ruler (m), considering the distance between the soil surface and the insertion of the first ear.
At the time of harvest, which in the first cycle was carried out on March 5, 2019 manually, the ears were bagged and individually identified according to the characteristics of the mother plant, which were later placed in an open environment for air drying.
Subsequently, the characteristics evaluated were: ear length (EL): with the aid of a graduated ruler (cm), the measurement was performed from the basal end to the apical end of the ears without the presence of straw; ear diameter (ED): measured in the middle third of the ear harvested from each plant, using a manual caliper (mm); number of rows of grains (NRG): the number of rows of grains from the ear harvested for each individual was counted; number of grains per row (NGR): the number of grains in a row on the ear of each plant was counted; ear mass (EM): individually measured the mass in grams of the ear harvested from each individual, without the presence of straw, and using an digital analog scale; grain mass (GM): measured the mass of all the grains of the ear harvested for each plant, in g, using an digital analog scale.

Conducting the mass selection cycles
The selection of individuals in the first mass selection cycle was carried out taking into account the phenotypic characteristics for grain production, visually observing erect plants, yellow or orange grains and well-stuffed ears. Based on the values of the evaluated traits, a ranking was performed in descending order for all traits and the selected individuals were those that presented the highest value in all traits, except for plant height and ear insertion. Thus, in the first cycle, individuals were selected until reaching the intensity of 6% of selection.
Through the selection of these individuals, it underwent the second cycle of mass selection, which took place in the 2019-2020 harvest. The population of the second cycle of selection originated from the seeds of the plants of the individuals selected in the first cycle. In this case, the seeds were collected with a sample of equal numbers for each selected ear, which were later mixed and sown to form the population of the second mass selection cycle. Under these conditions the initial population was 1800 plants.
In conducting the second mass selection cycle, sowing was carried out on october 27, 2019, conducted in a similar way to the experiment of the previous cycle. The harvest took place on March 10, 2020, when the ears were in the final stage of maturation. So, the evaluations were carried out under the same conditions and characteristics of the first selection cycle.
The second cycle population was subjected to selection intensities of 8%, to obtain the superior half-sib families. The standards adopted for the selection of the best families were based on the values of the evaluated characteristics, where ranking was performed in descending order for all characters and the selected individuals were those that presented the highest value for EL, ED, NRG, NGR, EM and GM, which were selected until reaching the determined intensity.

Cultural treatments

Before the installation of the experiment for the first mass selection cycle, a chemical analysis of the soil of the experimental area was carried out in the layer of 0 - 20 cm, with pH = 5.09; P = 9.86 mg dm^{-3}; K = 35.19 mg dm^{-3}; MO = 12.05 g dm^{-3}; Al = 0.63 cmolc dm^{-3}; Ca = 1.31 cmolc dm^{-3} and Mg = 0.69 cmolc dm^{-3}. Soil preparation, carried out in the two mass selection cycles, took place thirty days before sowing with plowing and harrowing. Before the first selection cycle, agricultural lime at a rate of 2.0 t ha^{-1} was applied at the time of harrowing the area, based on soil chemical analysis.

For fertilization in each cycle, 60 kg P ha^{-1}, 80 kg K ha^{-1} and 120 kg N ha^{-1} were applied (20% at the base, 35% at the V4 stage and 35% at the V8 stage) adjusting the distribution of fertilizers per linear meter. For weed control, two manual weedings were carried out in both selection cycles between and within the planting lines, one at 30 days after sowing (DAS) and the other at 60 DAS.

Statistical analysis

The values of the individuals of the base population of the first cycle and of the general population of the second cycle of mass selection were used to construct the histogram, which was represented by a graph of distribution of classes for each characteristic of the population, with the presence of asymmetry (*As*), kurtosis (Kt) and Shapiro-Wilk normality test for population data. These analyzes and the production of graphs were carried out with the help of the SISVAR software (Ferreira, 2019).

With data from the first and second mass selection cycles, the selection differential (SD) for both cycles was calculated, according to Equation 1 (Nascimento et al., 2014).

$$SD_{0\ e\ 1} = SPM_{0\ and\ 1} - MGP_{0\ and\ 1} \qquad \text{Eq. 1}$$

Where, SD_0 and SD_1 is the selection differential of the first and second cycle, respectively; SPM_0 and SPM_1 is the selected population mean of the first and second cycles, respectively; MGP_0 and MGP_1 is the general mean of the base population of the first cycle and the general population of the second cycle, respectively.

Posteriorly, calculated the gain with the selection (GS) of the first selection cycle (Equation 2) for all evaluated characteristics.

$$GS = MGP_1 - MGP_0 \qquad \text{Eq. 2}$$

Where, the GS is gained with the first mass selection cycle of the maize landraces population; MGP_1 is the mean of the general population in the second mass selection cycle; MGP_0 is the mean of the base population of the first mass selection cycle.

The realized heritability values (h^2_0) were estimated for each trait only from the first mass selection cycle, being calculated by: $h^2_0 = GS / SD_0$, where GS is the selection gain of the first mass selection cycle, and SD_0 is the selection differential of the first mass selection cycle, according to Yong et al. (2020).

Conclusion

The ear length and diameter, number of grain rows and grain mass show greater variation after mass selection cycles. The selection of plants based on the phenotype through two cycles of mass selection in the maize landraces Nawa Sheki leads to homogenization and elevation of the average values, followed by genetic gains for the traits number of grains in the row and ear mass.

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