Article

Study comparative of the characteristics agronomic and chemical of three cultivars of purple corn in Peru

Melissa Rabanal Atalaya[1§]
Alicia Medina Hoyos[2]

[1]Faculty of Chemistry and Chemical Engineering-Major National University of San Marcos. University Avenue s/n, Lima, Peru. ZC. 15081. [2]Baños del Inca Agrarian Experimental Station-Agrarian Technological Development-National Institute of Agrarian Innovation Jr. Wiracocha s/n, Baths of the Inca, Cajamarca, Peru. ZC. 06004.

[§]Corresponding author: mrabanala@unmsm.edu.pe.

Abstract

In Peru, due to the great geological and climatic diversity, there are different localities where agronomic and chemical research on purple corn has not yet been carried out. Therefore, the objective of the present research work was to evaluate yield, morphological and chemical characteristics of three varieties of purple corn, which were: INIA-601, an experimental variety called MM and Canteño, sown in five localities of the Departments of La Libertad and Cajamarca, located in northern Peru. Agronomic variables, yield and anthocyanin content in the cob and bracts were evaluated. The results showed that the best locality was Shaullo, with the cultivars of INIA-601 and Canteño, followed by MM, with yield values of 1.7, 1.6 and 1.6 t ha^{-1}, respectively, with averageable values of plant height of 1.7 m, ear height of 0.76 m, prolificacy about 1, amount of anthocyanins in the cob of 4.8 mg g^{-1} and in the bracts of 1.6 mg g^{-1}, and in ear rot, INIA-601 and Canteño obtained low and very close values of 5.9% and 5.4%, respectively; while MM, 9.6%.

Keywords: agronomic behavior, anthocyanins, cob.

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Introduction

Humans need oxygen for energy production; however, its excess is harmful due to the formation of reactive species. To remove these species, the body generates antioxidant molecules, which include enzymes, which are capable of subtracting an electron. When this is not compensated, oxidative stress is generated, which is the cause of different physiological processes such as aging and human diseases such as cancer, neurodegenerative, metabolic, digestive and cardiovascular disorders (Sánchez-Valle and Méndez-Sánchez, 2013). And in order to reduce these drawbacks, it is necessary to carry out agronomic and chemical studies that include antioxidant molecules such as anthocyanins from purple corn, which is consumed not only nationally but internationally.

The most important molecule within purple corn is anthocyanin, which, from the chemical point of view, is a glycosylated polyhydroxylated or polymethoxy molecule derived from 2-phenylbenzopyrylium, whose molecular weight is between 400 to 1 200 KDa. Anthocyanin is a glycosylated form and anthocyanidin is aglycone, which are grouped together, it is 3-hydroxyanthocyanidin, 3-deoxyanthocyanidins and O-methylanthocyanidins (Khoo *et al*., 2017). The most abundant molecule within anthocyanidins is cyanidin-3-glucoside, responsible for 70% of the color intensity, followed by pelargonidin and peonine (Castañeda *et al*., 2015; Medina-Hoyos, 2020).

Anthocyanins are widely used in a wide variety of industries such as food, cosmetics, textile fibers, medical industries and is also widely used in the pharmaceutical industry for its medicinal characteristics, being able to prevent degenerative diseases such as arteriosclerosis, diabetes, arthritis, reduces blood pressure and cholesterol in the blood, anti-Parkinson’s disease, antitumor (Somavat *et al*., 2016; Lao *et al*., 2017; Yoon-Mi *et al*., 2017; Roy and Jhon-Whang, 2020; Yazhen, 2020), anti-inflammatory (Zhang *et al*., 2019) and anticancer of the colon, chest, skin, prostate, among others (Lim *et al*., 2013; Tsai *et al*., 2014; Peiffer *et al*., 2014; Forester *et al*., 2014).

It should be noted that anthocyanins have been proven to have beneficial effects on different biological activities, especially on the high antioxidant power (Somavat *et al*., 2016; Tian *et al*., 2019), which are used in a wide range of food products such as soups, typical national drinks such as ‘chicha morada’ and in desserts (Pedraza *et al*., 2017; Cristianini, 2020).

In Peru, purple corn production takes place in the Departments of Cajamarca, Ayacucho, Ancash, Lima and Arequipa (Ccaccya *et al*., 2019) and to contribute to the knowledge of the behavior of its production, in the present study, agronomic and chemical tests are developed in three cultivars of purple corn: INIA-601, MM, Canteño, sown in five localities belonging to the Departments of La Libertad and Cajamarca, in order to know their adaptation and response in the content of anthocyanins both in the cob and in the bracts.

Materials and methods

The agricultural campaign was carried out from October to April 2017-2018 in five localities of the Departments of Cajamarca and La Libertad in Peru, whose details of geographical coordinates, altitude, average temperature and relative humidity are detailed in Table 1.

Table 1. Location and climatic characteristics in the localities studied in purple corn.

Department	Localities	Geographical coordinates	Altitude (m)	Average temperature	Relative humidity	Source
Cajamarca	Cajabamba	7°37’25” S, 78°2’49” O	2648	8.1 to 19.9°C	39.8 to 90%	Weather Underground (2020)
	Namora	7°12’6” S, 78°19’29” O	2743			
	Shaullo chico	7°10’24” S, 78°26’33” O	2789			
La Libertad	Uchuy	7°39’17.9 S, 77°49’6.7” O	2714			
	Vista Florida	8°12’49.6” S, 77°27’52.9” O	2809			

The analyses of the physicochemical characteristics of the soil in the different places studied are shown in Table 2, which were considered for fertilization, the amount of N-P-K used in the form of N, P_2O_5 and K_2O were in Vista Florida (145-65-45), Uchuy (120-65-55), Shaullo (120-60-50), Namora (120-50-45) and Cajabamba (120-60-50) kg ha^{-1}, respectively. The fertilization was carried out with island guano twice, the first application was at the sowing and the second at the hilling.

Table 2. Physicochemical characteristics of the soil in the five localities.

Department	Localities	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
La Libertad	Vista Florida	145	65	45
	Uchuy	120	65	55
Cajamarca	Shaullo	120	60	50
	Namora	120	50	45
	Cajabamba	120	60	50

Experimental design and statistical analysis

The study was conducted under the completely randomized block design, using the sowing density of 50 000 plants ha^{-1}, sown in five furrows 5.5 m long, 80 cm between furrows, 50 cm between holes, two seeds per hole with four repetitions, performing the evaluation in the three central furrows. The following cultivars were evaluated: INIA-601, morado mejorado called MM and Canteño, which are described below.

INIA-601. Cultivar formed by the National Institute of Agricultural Innovation, in the Agricultural Experimental Station (EEA, for its acronym in Spanish) of Cajabamba in Cajamarca, formed by 256 progenies, of which 108 progenies correspond to the cultivar ‘Morado de Caraz’ and the remaining 148 progenies to the ‘Negro de Parubamba’ (Pedraza *et al*., 2017; Medina-Hoyos *et al*., 2020).

Morado Mejorado. Cultivar in experimentation from the EEA of Agraria Baños del Inca in Cajamarca, which is derived from INIA-601 through the use of progenies S_1 (Medina-Hoyos *et al*., 2020).

Canteño. Early cultivar whose cultivation occurs in the upper parts of the valley of the River Chillón, in the Department of Lima between 1 800 to 2 500 m. It is characterized by having large grains arranged on ears with well-defined rows (Quevedo, 2013).

Data collection

The field weight, % shelling and area factor were determined. Ten plants per treatment were randomly selected to determine days at 50% of male flowering (MF), days at 50% of female flowering (FF), plant height (PH), ear height (EH), prolificacy (Number of ears/plant), ear rot (ER). The yield (t ha^{-1}) was calculated considering the moisture content of the seed at 14%, using the following formula: $GNY= FW^* \left(\frac{10}{EAP} * \frac{(100\text{-}\%M)}{86}\right) {}^*S$. Where: GNY is the grain yield corrected at 14% moisture in t ha^{-1}; FW is the field weight; %M is the percentage of moisture of the grain, (100 - %M) is the coefficient of percentage of dry matter; 86 is the moisture correction coefficient at 14%; (10/EAP) is the correction factor for transforming kg plot^{-1} into t ha^{-1}; EAP is the effective area of the plot, equal to 4.4 m^2 and S is the percentage of shelling equivalent to 80.

Method of analysis for the determination of anthocyanins

Ten plants per treatment were randomly selected to determine the anthocyanin content in the cob and bracts in cultivars INIA-601, MM and Canteño in the five localities where the experiment was developed. To 1 g of cob or bracts, previously dried and ground, 20 ml of a 20% ethanol solution at a pH of 2 was added for 60 min with constant stirring at 90 °C in bain-marie, the extract obtained was filtered through Whatman paper num. 1. An aliquot of the extract was diluted in a 25 ml flask with buffer solutions of potassium chloride at a pH of 1 and sodium acetate at a pH of 4.5, measuring the anthocyanin content according to the differential pH method described by Giusti and Wrosltad (2001).

The absorbances were read on the spectrophotometer in the visible range at wavelengths of 510 and 700 nm, in the range of 20 to 50 min, after preparation. Its content was expressed as cyanidin-3-glucoside, according to the following expression: $A= (A_{510\ nm} - A_{700\ nm})_{pH\ 1} - (A_{510\ nm} - A_{700\ nm})_{pH\ 4.5}$. Total anthocyanins $\left(\frac{mg}{g}\right)=\frac{Ax\ MW\ x\ DF\ x\ V}{\varepsilon\ x\ l\ x\ W}$, where: MW is the molecular weight of cyanidin-3-glucoside of 449.2 g mol^{-1}; DF is the dilution factor; l is the cell step length in cm; ε is the molar extinction coefficient of 26 900; V is the volume in ml of the extraction solvent; A is the absorbance and W is the weight of the sample in g. The analyses were performed in triplicate.

Data analysis

The data on yield, morphological and chemical variables obtained in the different localities were analyzed, the means by locality, genotypes and by genotype∗locality were calculated and compared based on the significant difference test with LSD 0.05, both in the statistical software InfoStat, version 2020 (Rienzo *et al*., 2020).

Results and discussion

The statistical analyses are shown in Table 3, which shows the sources of interaction with the agronomic and chemical variables used in the study of purple corn.

Table 3. It shows the values of the mean square of the analysis of variance of the different variables used in the study of purple corn cultivars.

Source of variation	DF	GNY	FF	MF	PH	EH	Prolif	ER	CAC	CAB
Locality	4	5.36	6629.85	5487.19	1.72	3.2	7.45	273.16	9.85	0.85
Genotype	2	0.49	9.32	9.22	0.01	0.0008	1	59.73	5.86	6.84
Blocks	3	0.03	11.08	7.2	0.01	0.0015	0.02	0.73	0.01	0.02
Locality x genotype	8	0.14	22.59	45.28	0.01	0.03	0.25	91.14	3.23	0.73
Error	42	0.07	15.02	8	0.01	0.0036	0.02	1.61	0.01	0.01
Total	59	-	-	-	-	-	-	-	-	-
CV	-	16.68	3.31	2.5	3.89	4.72	9.84	10.51	3.11	5.59

DF= degrees of freedom; GNY= yield; FF= female flowering; MF= male flowering; PH= plant height; EH= ear height; Prolif= prolificacy; ER= ear rot; CAC= content of anthocyanin in the cob; CAB= content of anthocyanin in the bracts and CV= coefficient of variation.

The means by genotypes and by localities of the different agronomic and chemical variables used for purple maize are shown in Tables 4 and 5, respectively. Table 6 shows the means by genotype∗locality of yield, plant and ear height of the three cultivars used in the five localities of purple corn, which show that the means by genotype indicate that the cultivars that stand out are Canteño and INIA-601, showing an equal statistical value of 1.5 t ha^{-1} and the means by localities indicate that Cajabamba had the highest yield with 2.4 t ha^{-1} , in addition, when the analysis genotype∗locality is carried out, it shows that the cultivars with the highest yield occurred in Cajabamba, which was Canteño with 2.8 t ha^{-1}, followed by INIA-601 with 2.3 t ha^{-1} and MM with 2.1 t ha^{-1}, then followed by the locality of Shaullo, whose values were 1.7, 1.6 and 1.6 t ha^{-1}, values only slightly higher than those obtained in Vista Florida with 1.5, 1 and 1.3 t ha^{-1} for Canteño, INIA-601 and MM, respectively; however, in Uchuy and Namora, the values in the three cultivars were low, suggesting a higher requirement for fertilizers and water resources.

Table 4. Mean values by genotypes of the different variables used in the agronomic and chemical development of purple corn.

Genotype	GNY (t ha^{-1})	FF (days)	MF (days)	PH (m)	EH (m)	Prolif	ER (%)	CAC (mg g^{-1})	CAB (mg g^{-1})
Canteño	1.5 a	117.3 a	113.6 a	1.84 a	1.28 a	1.9 a	12.2 b	2.8 c	0.8 c
MMM	1.2 b	117.8 a	113.5 a	1.82 a	1.27 a	1.5 b	13.8 a	3.8 a	1.5 b
INIA-601	1.5 a	116.5 a	112.4 a	1.8 a	1.28 a	1.5 b	10.3 c	3 b	1.9 a

GNY= yield; FF= female flowering; MF= male flowering; PH= plant height; EH= ear height; Prolif.= prolificacy; ER= ear rot; CAC= content of anthocyanin in the cob; CAB= content of anthocyanin in the bracts.

Table 5. Mean values by locality of the different variables used in the agronomic and chemical development of purple corn.

Locality	GNY (t ha^{-1})	FF (days)	MF (days)	PH (m)	EH (m)	Prolif	ER (%)	CAC (mg g^{-1})	CAB (mg g^{-1})
Uchuy	1 d	153.3 a	147.1 a	1.5 d	1.12 c	2.8 a	16.4 a	2.9 c	1.2 b
Shaullo	1.6 b	128.9 b	121.7 b	1.66 c	0.76 d	0.8 e	7 c	4.8 a	1.6 a
Vista Florida	1.3 c	101.7 c	99.3 c	2.28 a	1.31 b	1.5 c	9 b	3 b	1 c
Cajabamba	2.4 a	101.7 c	99.8 c	2.17 b	2.13 a	2 b	10.2 b	2.7 d	1.5 a
Namora	0.6 e	100.3 c	97.8 c	1.48 d	1.07 c	1 d	17.8 a	2.6 d	1.6 a

GNY= yield; FF= female flowering; MF= male flowering; PH= plant height; EH= ear height; Prolif.= prolificacy; ER= ear rot; CAC= content of anthocyanin in the cob; CAB= content of anthocyanin in the bracts.

Table 6. Values of yield, plant and ear height in the five localities in the three cultivars used in purple corn.

Locality	Grain yield			Plant height			Ear height		
	INIA-601	MMM	Canteño	INIA-601	MMM	Canteño	INIA-601	MMM	Canteño
	(t ha^{-1})			(m)			(m)		
Vista Florida	1.54 bc	0.98 c	1.3 bc	2.32 a	2.27 a	2.26 a	1.39 b	1.34 b	1.2 b
Uchuy	1.13 c	0.88 c	0.8 c	1.46 d	1.51 bc	1.53 c	1.19 c	1.04 c	1.13 bc
Shaullo	1.71 b	1.59 b	1.6 b	1.66 c	1.61 b	1.73 b	0.76 d	0.68 d	0.84 d
Namora	0.63 d	0.45 d	0.8 c	1.45 d	1.47 c	1.53 c	1.03 c	1.08 c	1.09 c
Cajabamba	2.29 a	2.07 a	2.8 a	2.11 b	2.22 a	2.18 a	2.05 a	2.22 a	2.13 a
LSD	0.5	0.4	0.7	0.2	0.1	0.2	0.2	0.1	0.1
CV	15.41	15.01	22.36	4.6	3.3	3.82	6.6	2.54	3.7

Differences in letters indicate that they are significant at a level of ($p \leq 0.05$).

In a study conducted in 28 environments and using six cultivars of purple corn in the locality of San Marcos in the Department of Cajamarca. yields of cultivars INIA-601 (2.77 t ha^{-1}), MM (2.5 t ha^{-1}) and Canteño (1.9 t ha^{-1}) were reported, with the value of Canteño being lower than that found in the present research work and cultivars INIA-601 and MM only slightly higher (Medina-Hoyos *et al*., 2020).

The means by genotypes show that the values of plant and ear height are statistically equal to 1.8 m and 1.2 m, respectively, and the means by localities indicate that Vista Florida stands out with the highest plant height with 2.28 m. The means by locality∗genotype of plant height show that Cajabamba and Vista Florida had the highest values, in the three genotypes with plant height means greater than 2 m, while the means of locality∗genotype of ear height show that Cajabamba has high heights greater than 2 m, and in Vista Florida it presents on average 1.3 m in the three genotypes, while in the localities of Uchuy, Shaullo and Namora, the values of plant and ear heights were lower than the previous ones and very similar, whose average of plant height was 1.5 m and of ear height of 0.9 m in the three cultivars.

Pedraza *et al*. (2017) reported that the plant height for the INIA-601 variety was 2.16 m, whose trial was carried out in the Amazon region at 2 820 m, whose value is lower than that reported in Vista Florida with 2.32 m and similar to that found in Cajabamba with 2.11 m; however, it is higher than those found in Uchuy, Shaullo and Namora with 1.46, 1.66 and 1.45 m, respectively, while the value obtained of ear height was 1.24 m, a value similar to that obtained in Vista Florida and Uchuy, higher than those obtained in Cajabamba and Namora and much lower than that found in Cajabamba.

The means by genotypes of FF and MF show that there is no significant difference between genotypes, with FF being on average 117 days and MF 113 days. The means by localities indicate that the earliest was carried out in Namora, with an FF of 100 days and its MF of 97.8 days, followed by Vista Florida and Cajabamba, whose values of FF were very similar with an average value of 101 days and their MF with 99 days. Analyses of genotype∗locality show that, in the locality of Namora, the genotypes stood out, being the earliest in both FF and MF, being for the cultivar INIA-601 (96.8 and 95.5 d), MM (102.8 and 101 d) and Canteño (101.5 and 97 d), respectively, as shown in Table 7.

Table 7. Values of female and male flowering in the three cultivars of purple corn.

Locality	Female flowering (days)			Male flowering (days)		
	INIA-601	MMM	Canteño	INIA-601	MMM	Canteño
Vista Florida	101 c	102 c	102 c	99.5 c	102 c	96.5 c
Uchuy	155 a	151.3 a	153.8 a	150 a	143 a	148.3 a
Shaullo	130.2 b	130.5 b	126 b	121 b	119.5 b	124.5 b
Namora	96.8 c	102.8 c	101.5 c	95.5 c	101 c	97 c
Cajabamba	99.3 c	102.5 c	103.3 c	95.8 c	102 c	101.5 c
LSD	4.9	12.4	5.8	4.5	4.3	8.7
CV	1.94	4.82	2.25	1.82	1.75	3.49

Differences in letters indicate that they are significant at a level of ($p \leq 0.05$).

Virgen-Vargas *et al*. (2014) says that there is a period of five days to remove the spike of the female parent, to preserve genetic quality and avoid self-fertilization. The genotypes under study, in a general way, both in the early and late lines had a synchrony between male and female flowering of 2 to 8 days, in both cases the data indicate the ease or difficulty to perform the detasseling if the lines are used as a female. It should be noted that the days of flowering are influenced by the environment depending on the height above sea level and temperature, there are materials that due to their tropical origin reduce their days to flowering in warm places and at a higher altitude. Therefore, before defining where the hybrid seed is going to be produced, the genotype, the environment and their interaction must be known (Virgen-Vargas *et al*., 2014).

The prolificacy is the number of ears plants^{-1}, it is important because, according to the number of ears per plant and this multiplied by the number of plants produced in a hectare, the total number of ears per hectare is obtained, which is important to know since the price of dry purple grain is \$2.00 k^{-1}g and the price of dried cobs or bracts is \$20 kg^{-1}. Therefore, the 700 kg of dried and chopped cobs and bracts generate an income of $14 000.00. This means that, by producing on one hectare 2 500 kg of grain at 14% moisture and 700 kg of dried and chopped cobs and bracts, the farmer could obtain a gross income of $19 000.00. Discounting the cost of production that approaches $8 000.00 ha^{-1} (MINAGRI, 2017), the net profit would be $11 000.00 ha^{-1}.

The means by genotypes indicate that the highest prolificacy value occurs in Canteño and the means by locality indicate that the most outstanding values occur in Uchuy and Cajabamba with 2.8 and 2, respectively. The means of genotypes∗localities indicate that the highest values of prolificacy occur in Uchuy with 2.3, 2.5 and 3.4 for the genotypes INIA-601, MM and Canteño, respectively.

The means by genotype of ER indicate that the cultivar INIA-601 had the lowest value of 10.3% and the means by locality show that Shaullo has the lowest value of 7%. The means of genotypes∗localities of ER show that in the locality of Shaullo, it showed the lowest values in the three cultivars INIA-601 (5.9%), MM (9.6%) and Canteño (5.4%), in Vista Florida, the cultivars Canteño and INIA-601 showed very similar averageable values of 9.5% and the MM with the lowest value of 7.9%. In Cajabamba, genotypes ranged from 7 to 10%, while the highest ear rot values were in Namora and Uchuy, which ranged from 9.7% to 25.3%.

Medina-Hoyos *et al*. (2020) indicates that ER is mainly caused by fungi of the genus *Fusarirum* sp., by the damage of birds, which increases the damage of fungi, by the mosquito *Euxesta* sp., which attacks the ear from the formation of the pistils and continues during the development of the grain producing at the apex of the ear a wet area that facilitates the proliferation of fungi and consequently ear rot, whose impact depends on the genotype or variety and the environmental factors in which the crop develops (Table 8).

Table 8. Values of prolificacy and ear rot in purple corn cultivars.

Locality	Prolificacy			Ear rot (%)		
	INIA-601	MMM	Canteño	INIA-601	MMM	Canteño
Vista Florida	1.5 b	1.3 c	1.7 c	9.5 b	7.9 d	9.4 c
Uchuy	2.3 a	2.5 a	3.4 a	9.7 b	14.3 b	25.3 a
Shaullo	0.7 d	0.9 d	0.8 d	5.9 c	9.6 cd	5.4 e
Namora	1 c	0.9 d	1.1 d	17 a	23.4 a	13.1 b
Cajabamba	1.7 b	1.9 b	2.3 b	9.4 b	13.6 bc	7.7 d
LSD	0.3	0.3	0.5	1.2	4.5	0.9
CV	8.8	7.8	11.2	5.6	14.8	3.4

Differences in letters indicate that they are significant at a level of ($p \leq 0.05$).

The means by genotype of CAC show that the genotype that stands out is MM with 3.8 mg g^{-1}, followed by INIA-601 with 3 mg g^{-1}, and in the means by genotype of CAB, they show that INIA-601 showed the highest value of 1.9 mg g^{-1} followed by MM with 1.5 mg g^{-1}. The means by locality show that, in CAC, the locality that stood out the most was Shaullo with 4.8 mg g^{-1} and in CAB, in all cases they showed small variations between 1 to 1.6 mg g^{-1}. The means of genotype∗locality of the quantity of anthocyanins in the cob and bracts are shown in Table 9. The analyses of CAC show that in Shaullo all the cultivars showed the highest values, being for INIA-601 (4.6), MM (4.9) and Canteño (5) mg g^{-1}. The MM cultivar also stands out with similar and averageable values of 4.6 mg g^{-1} in both Uchuy and Vista Florida, all other cultivars showed values only slightly lower than 3 mg g^{-1} in the five places; while CAB in all cases, they were lower than that of the cob, with INIA-601 standing out with 2.3 mg g^{-1} in Uchuy, followed by cultivars INIA-601 and MM with an averageable value of 2 mg g^{-1} in Namora.

Table 9. Values of anthocyanins in the cob and bracts in purple corn cultivars.

Locality	Content of anthocyanins in the cob			Content of anthocyanins in the bracts		
	INIA-601	MMM	Canteño	INIA-601	MMM	Canteño
		($mg\ g^{-1}$)			($mg\ g^{-1}$)	
Vista Florida	2 e	4.7 b	2.5 c	1.6 d	0.6 d	0.8 b
Uchuy	2.4 d	4.5 c	1.9 d	2.3 a	1.2 c	0.1 c
Shaullo	4.6 a	4.9 a	5 a	1.8 cd	1.9 ab	1.1 a
Namora	3.3 b	2.8 d	1.8 d	2.1 b	2 a	0.7 b
Cajabamba	2.9 c	2.4 e	2.9 b	1.8 c	1.8 b	1.1 a
LSD	0.2	0.2	0.3	0.2	0.2	0.1
CV	3.1	2.1	4.5	3.8	7	8.8

Differences in letters indicate that they are significant at a level of ($p\leq 0.05$).

When comparing the results obtained in the interaction of genotype∗locality of yield, plant and ear height, prolificacy and rot, it is observed that, in the average yield of genotypes, in the locality of Cajabamba, it presents greater yield of 2.4 t ha^{-1} than Shaullo with 1.7 t ha^{-1}; however, Cajabamba shows greater ear rot, ranging from 7.7% to 13.6% and in Shaullo, it ranges from 5.4% to 9.6%. The plant and ear height in Cajabamba has values higher than 2 m, which makes it difficult for the producer to collect the cob, while, in Shaullo, the plant height is 1.7 m and the ear height is 0.76 m. On the other hand, the content of anthocyanins in the cob of Shaullo is higher than in Cajabamba, with an average of 4.8 mg g^{-1} and 2.7 mg g^{-1} and it has very similar values in the content of anthocyanins in the bracts, which is why it is suggested that the best locality to produce purple corn is Shaullo, highlighting the cultivars INIA-601 and Canteño, followed by MM.

The anthocyanins in purple corn, as indicated by Li *et al*. (2008); Fernández-Aulis *et al*. (2019), are produced throughout the plant, especially in the bracts and in the cob, although their quantities vary significantly between them according to the phenotype and the type of chemical extraction used, either classic techniques such as solid-liquid extraction in aqueous solutions and maceration (Doroteo *et al*., 2013; Ccaccya *et al*., 2019) or emerging techniques such as ultrasound, ohmic heating, microwaves, supercritical fluid and high isostatic pressure (Monroy *et al*., 2016; Muangrat *et al*., 2017; Itthisoponkul *et al*., 2018).

In a study reported by Medina-Hoyos, 2020, in the locality of San Marcos in Cajamarca, it shows that the quantity of anthocyanins in the cob and bracts was for INIA (6.12 and 3.18), MM (5.63 and 1.76) and Canteño (4.66 and 0.63) mg g^{-1}, these being some results with characteristics similar to those reported in the present study.

Conclusions

The evaluations of the different agronomic variables, yield and the content of anthocyanins in the three cultivars of purple corn in the five localities belonging to the departments of La Libertad and Cajamarca show that the best locality was Shaullo, whose yields of the cultivars INIA-601, Canteño and MM were, 1.7, 1.6 and 1.6 t ha^{-1} , respectively, with averageable values of plant height of 1.7 m, ear height of 0.76 m, prolificacy about 1, amount of anthocyanins in the cob of 4.8 mg g^{-1} and in the bracts of 1.6 mg g^{-1}. However, in ear rot, INIA-601 and Canteño obtained low and very close values of 5.9% and 5.4%, respectively; while MM, 9.6%, which is why the priority choice of INIA-601 and Canteño cultivars is recommended. It is suggested that anthocyanin content be tested with other classic or emerging extraction techniques both at harvest and at different times of post-harvest.

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