

Rank-ordering coefficients of variation for popping expansion

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ABSTRACT. The coefficient of variation (CV) has been the most important statistic to determine the precision of experimental errors, but an even classification for guiding popcorn breeders is still lacking for popping expansion. The normality of data from 50 CVs was tested through the Shapiro-Wilk test, and the mean (m), median, standard deviation (SD), maximum and minimum values, asymmetry and kurtosis were all determined using the momentum method. The CVs were ranked as low [$CV \leq (m - 1 SD)$], moderate [$(m - 1 SD) < CV \leq (m + 1 SD)$], high [$(m + 1 SD) < CV \leq (m + 2 SD)$] and very high [$CV > (m + 2 SD)$]. In summary, these data were close to the normality because the slight and flattened curve was skewed to the right. The CV's mean was 11.08, the median was 11.94 and the standard deviation was 5.13%. Accordingly, values of $CV \leq 5.95\%$ are low, $5.95 < CV \leq 15.21\%$ are moderate, $15.21 < CV \leq 20.34\%$ are high, and $CV > 20.34\%$ are very high.

Keywords: *Zea mays*, dispersion measurement, genetic improvement, precision, accuracy.

RESUMO. Classificação de coeficientes de variação para capacidade de expansão. O coeficiente de variação (CV) tem sido o parâmetro estatístico mais importante para determinar a precisão de erros experimentais, sendo necessária uma classificação para orientar os pesquisadores de milho-pipoca para a capacidade de expansão. Assim, a normalidade de 50 CVs foi avaliada por meio do teste de Shapiro-Wilk; a média (m), mediana, desvio padrão (DP), valores máximos e mínimos, assimetria e curtose foram estimados utilizando o método dos momentos. Os CVs foram classificados como baixo [$CV < (m - 1 DP)$], moderado [$(m - 1 DP) < CV < (m + 1 DP)$], alto [$(m + 1 DP) < CV < (m + 2 DP)$] e muito alto [$CV > (m + 2 DP)$]. Em resumo, os dados aproximaram à normalidade e a curva normal foi desviada para a direita e ficou ligeiramente achatada. A média dos CVs foi de 11,08, a mediana foi de 11,94 e o desvio padrão foi de 5,13%. Assim, valores de $CV \leq 5,95\%$ devem ser classificados como baixos, $5,95 < CV \leq 15,21\%$ são moderados, $15,21 < CV \leq 20,34\%$ são elevados e $CV > 20,34\%$ são muito elevados.

Palavras-chave: *Zea mays*, medidas de dispersão, melhoramento genético, precisão, acurácia.

Introduction

In Brazil, popcorn growers have been requiring new cultivars to increase the crop productivity and the grain quality. Otherwise, as the number of breeding experiments with popcorn plants has been increasing all over the country (ARNHOLD; VIANA, 2007; ARNHOLD et al., 2009; MORA; ARNHOLD, 2006; PINTO et al., 2007a and b; SANTOS et al., 2008; SCAPIM et al., 2006a and b; SEIFERT et al., 2006; VIANA, 2007; VIEIRA et al., 2009), parameters indicating the precision of the experimental errors need still be rank-ordered to permit the recommendation of more uniform elite cultivars.

The Gaussian curve is the most important statistical distribution to describe quantitative random variables. This distribution is usually described by its mean and standard deviation. Skewness and kurtosis indicate the symmetry and

the clustering of data towards the center of a distribution. Both statistics accurately represent the observed data, and have also been used to describe the distribution shape, test the normality of the data, and study the robustness to the normal theory (JOANES; GILL, 1998). The normal distribution is mesokurtic when the kurtosis is equal to 3 because the values are close to the central value. The distribution is leptokurtic when the kurtosis is above 3 and, otherwise, it is classified as platykurtic (FERREIRA, 2005).

Moreover, research methods in which quantitative data obey the normal distribution, the CV has been the most important statistic to describe the precision of the experimental error. This error is evaluated for specific traits, and gives a general indication of the levels of variation within a population using the standard deviation as a fraction of the mean (BOWMAN; WATSON, 1997).

In field conditions, values of $CV \leq 10\%$ are usually low, $10 < CV \leq 20\%$ are moderate, $20 < CV \leq 30\%$ are high, and $CV > 30\%$ are very high (PIMENTEL GOMES, 1985). This general classification, however, does not consider agronomic aspects, traits under investigation, weather conditions and growing cycles (SCAPIM et al., 1995). In some specific traits, the comparison of experimental responses based on the CV must consider the different conditions in which these experiments were carried out, the crop species, traits under investigation, necessity of data transformation, environmental heterogeneity, plot size and number of replications. All these variables reinforce the necessity of precise references based on the nature of a specific trait (LANA et al., 2006).

The importance of specific evaluation for every crop and trait can be seen in recent reports in which these coefficients were rank-ordered (AMARAL et al., 1997; CARVALHO et al., 2003; COSTA et al., 2002; JUDICE et al., 1999; LANA et al., 2006; OLIVEIRA et al., 2009; SANTOS et al., 1998; SCAPIM et al., 1995). Although the rank reported by Scapim et al. (1995) can be recommended for popcorn, it has not yet been precisely determined for popping expansion. Thus, the objective of the present experiment was to rank the order of these coefficients of variation.

Material and methods

Fifty CVs describing the experimental errors from popping expansion were collected from 32 national experiments reported in numerous national and international research magazines published from 1998 to 2009 (Table 1).

Table 1. The origin and values of the coefficients of variation for popping expansion collected from 50 national experiments reported in research magazines from 1998 to 2009.

Source	CV (%)	Source	CV (%)
Pacheco et al. (1998)	14.70	Daros et al. (2004)	17.68
Pacheco et al. (1998)	15.10	Pacheco et al. (2005)	6.57
Sawazaki et al. (2000)	3.58	Luz et al. (2005)	4.75
Sawazaki et al. (2000)	4.13	Carpentieri-Pipolo et al. (2005)	10.78
Sawazaki et al. (2000)	5.44	Scapim et al. (2006a)	13.20
Sawazaki et al. (2000)	4.72	Scapim et al. (2006a)	12.80
Nobre et al. (2000)	10.41	Mora and Arnhold (2006)	11.00
Vendruscolo et al. (2001)	13.83	Seifert et al. (2006)	7.17
Pereira and Amaral Júnior (2001)	11.87	Seifert et al. (2006)	12.41
Daros et al. (2002)	13.68	Scapim et al. (2006b)	5.20
Coimbra et al. (2002)	12.80	Scapim et al. (2006b)	5.76
Scapim et al. (2002)	12.50	Arnhold and Viana (2007)	7.70
Scapim et al. (2002)	13.80	Pinto et al. (2007b)	16.00
Granate et al. (2002)	10.65	Pinto et al. (2007a)	3.10
Carpentieri-Pipolo et al. (2002)	21.11	Pinto et al. (2007a)	3.10
Matta and Viana (2003)	16.14	Pinto et al. (2007a)	3.00
Vilarinho et al. (2003)	16.38	Viana (2007)	16.10
Vilarinho et al. (2003)	14.91	Viana (2007)	9.60
Miranda et al. (2003)	15.00	Viana (2007)	9.70
Von Pinho et al. (2006)	19.01	Viana (2007)	7.60
Sawazaki et al. (2003)	3.91	Santos et al. (2008)	12.62
Sawazaki et al. (2003)	2.93	Arnhold et al. (2009)	12.00
Santos et al. (2004)	19.21	Arnhold et al. (2009)	13.00
Simon et al. (2004)	9.68	Arnhold et al. (2009)	17.00
Simon et al. (2004)	9.07	Vieira et al. (2009)	21.75

The normality of these data was evaluated by the Shapiro-Wilk test. The mean (m), median, standard deviation (SD), maximum and minimum values, asymmetry and kurtosis were evaluated by the method of the momentum. The estimators for the sample moment of order r (m_r) is calculate by:

$$m_r = \frac{\sum_{i=1}^n (X_i - \bar{X})^r}{n},$$

the asymmetry coefficient is:

$$\sqrt{b_1} = \frac{m_3}{(m_2)^{3/2}},$$

and the kurtosis coefficient is:

$$b_2 = \frac{m_4}{(m_2)^2} \text{ (FERREIRA, 2005).}$$

These CVs were rank-ordered according to Scapim et al. (1995), who used the classification proposed by Garcia (1989) in which the values were reported as low [$CV \leq (m - 1 \text{ SD})$], moderate [$(m - 1 \text{ SD}) < CV \leq (m + 1 \text{ SD})$], high [$(m + 1 \text{ SD}) < CV \leq (m + 2 \text{ SD})$] and very high [$CV > (m + 2 \text{ SD})$].

The statistical analysis was performed using R software (R DEVELOPMENT CORE TEAM, 2010). To estimate the asymmetry and kurtosis was used library fBasics.

Results and discussion

The distribution of these CVs for popping expansion was close to the normality, and the shape of this Gaussian curve was classified as platykurtic because of its flattered curvature (FERREIRA, 2005). The kurtosis was 2.038 because these data were less concentrated around the mean than usually they are when described by the Gaussian distribution. The mean CV was 11.08 and the median was 11.94%. The high median value indicated the presence of a slight and positive asymmetry which was 0.014 (Table 2) unlike stated by Ferreira (2005) who using the method of the momentum reported asymmetry equal to zero. Positive coefficients of asymmetry are higher than zero or, otherwise, they are negative.

Otherwise, the mean CV of 11.08% is an average value whether based on the classification of Pimentel Gomes (1985). If this mean had been less than 10%, it should be ranked as low. As this present mean is close to 10%, the popping expansion must be considered a characteristic relatively stable or

weakly affected by the environment. Factors such as fungus and insect attack, and mechanical damage to the grains can negatively affect the popping expansion. These factors in conjunction with the lack in the standardization of grain moisture and the popping temperature could lead to high CV values if the experiment is not properly controlled. In maize, otherwise, plant and ear height, and the weight of 100 grain had an average CV lower than the present responses, but the ear average weight, ear number, grain weight and prolificity had higher means (SCAPIM et al. 1995).

Table 2. Descriptive statistics, normality test and CV classification for popping expansion from 50 field experiments.

		P-value	Values	Intervals
Descriptive statistics	Minimum		2.93	
	Maximum		21.75	
	Mean		11.08	
	Median		11.94	
	Standard deviation		5.13	
	Asymmetry		0.014	
Normality test	Kurtosis		2.038	
	Shapiro-Wilk	0.1121		
CV ranks	Low			$CV \leq 5.95\%$
	Moderate			$5.95 < CV \leq 15.21\%$
	High			$15.21 < CV \leq 20.34\%$
	Very high			$CV > 20.34\%$

The standard deviation was 5.13% (Table 2). Plant and ear height, weight of 100 grain and prolificity had lower values than the ear and grain weight and the number of ears per plant (SCAPIM, et al., 1995). In the present experiment, the lowest CV was 2.93% reported by Sawasaki et al. (2003) and the highest was 21.75% reported by Vieira et al. (2009). This large amplitude shows the strong influence of genotypes, soil conditions, nutrients and insects on the estimates of popping expansion.

As the variables can be more or less influenced by several factors, the classification of CV for every trait is necessary. Therefore, we ranked the values as low for every $CV \leq 5.95\%$, moderate for $5.95 < CV \leq 15.21\%$, high for $15.21 < CV \leq 20.34\%$, and very high for $CV > 20.34\%$ (Table 2). In the classification of Garcia (1989), the 50 CVs for popping expansion (Table 1) were 24% (12) low, 56% (28) moderate, 16% (8) high and 4% (2) very high. Otherwise, the Pimentel Gomes (1985) classification ranked 40% of the CVs (20) as low, 56% (28) as moderate, 4% (2) as high, and none of them was classified as very high. Therefore, the methods were discrepant for ranking these values (SCAPIM et al., 1995). As every variable has specific stability, some traits have lower variation than others which are naturally unstable. The present

classification can be safely recommended for making precise decisions about popping expansion.

Conclusion

The CVs for popping expansion were close to the normality because the data distribution was slightly flattered and skewed to the right. The average CV for popping expansion was 11.08, the median was 11.94, and the standard deviation was 5.13%. The CV ranks for popping expansion must be recorded as low for $CV \leq 5.95\%$, moderate for $5.95 < CV \leq 15.21\%$, high for $15.21 < CV \leq 20.34\%$ and very high for $CV > 20.34\%$.

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