



A NEW CLASSIFICATION PROPOSAL OF COEFFICIENTS OF VARIATION FOR MORPHO-AGRONOMIC TRAITS IN SNAP BEANS

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Abstract: The aim of this study was to present a classification proposal for coefficients of variation (CV) of morpho-agronomic traits in snap bean. The CV values were obtained from 53 studies related with snap beans published between 1987 and 2018, yielding a total of 372 data. The following traits were assessed: commercial pod yield, total pods yield, pod length, pod diameter, mean pod weight, number of pods per plant, number of seeds per pod and fiber pod content. Since verified the normal distribution of data, the CV were classified by values of mean (m) and standard deviation (sd) as: low [$\leq (m - 1sd)$]; medium [$(m - 1sd) < CV \leq (m + 1sd)$]; high [$(m + 1sd) < CV \leq (m + 2sd)$] and very high [$> (m + 2sd)$]. The results indicated that the pod diameter, pod length, mean pod weight and number of seeds per pods are variables weakly influenced by the environment. In contrast, the other traits related had the highest range of CV. The classification proposed in the present study provides a useful tool for researchers interested in estimating the accuracy of their experiments.

Keywords: accuracy, experimental error, experimental precision, green beans, *Phaseolus vulgaris* L.

Introduction

Snap bean (*Phaseolus vulgaris* L.) is an important vegetable worldwide, with estimated world production at around 21 million tons (FAO, 2019). The consumption of snap beans may be in form of seeds or immature pods, considered an excellent food source of fibers, vitamins, minerals, carbohydrates and proteins (Yuan et al., 2017; Fukuji et al., 2019). Due to the great importance of snap beans as human food, becomes relevant the confidence in the precision of agricultural experiments, such as development of new cultivars, resistance or tolerance to the crop pests and diseases, adaptation and stability in crop areas, beyond genotypes acceptance by bean consumers.

The proper estimation of experimental precision is a common aim among researchers, contributing to decrease experimental error (Ribeiro et al., 2017). The coefficient of variation (CV) has been used by researchers to describe the accuracy of their experiments (Kuehl and Kuehl, 2000), since it gives a general indication of the variation levels using the standard deviation as a fraction of the mean. In the sense, Pimentel-Gomes (2009) proposed a classification of the CV's obtained from agricultural studies, which were classified as low for values lower than 10%, moderate for values from 10 to 20%, high for values higher than 20 up to 30% and very high for values higher than 30%.

Despite it is commonly used, the classification proposed by Pimentel-Gomes (2009) is considered very wide, besides disregard the intrinsic factors of each crop and their traits evaluated. In the sense, aiming to classify the specific CV's for each crop, Garcia (1989) proposed a new classification methodology based on data from previous experiments. To do so, Garcia (1989) used the CV's from 146 experiments of different species of Eucalyptus, classifying them based on their mean values (m) and standard deviation (sd) as: low [$\leq (m - 1sd)$]; medium [$(m - 1sd) < CV \leq (m + 1sd)$]; high [$(m + 1sd) < CV \leq (m + 2sd)$] and very high [$> (m + 2sd)$].

In the sense, based on Garcia (1989) method, several studies have been performed to

investigate the classification of CV's in corn (Fritsche-Neto et al., 2012), rice (Costa et al., 2002), papaya (Ferreira et al., 2016), sugarcane (Couto et al., 2013) and eucalyptus (Mora and Arriagada, 2016). The aim of this study was to present a classification for coefficient of variation in snap bean traits, since there is not yet a specific proposal for this crop.

Material and methods

Data collection and evaluated traits

The CV values were obtained from 53 studies related with snap beans published between 1987 and 2018, yielding a total of 372 data. In these studies, different snap bean genotypes were used in experimental designs completely randomized or randomized blocks, using between three and five replicates. The following traits were assessed: commercial pod yield (CPY), total pods yield (TPY), pod length (PL), pod diameter (PD), mean pod weight (MPW), number of pods per plant (NPP), number of seeds per pod (NSP) and fiber pod content (FPC).

Classification of coefficients of variation

The Kolmogorov-Smirnov test modified by Lilliefors (1967) was used to verify the adherence of the data to the normal distribution. The arithmetic mean (m), standard deviation (sd) and maximum and minimum values from the review were evaluated for the present study proposal based on Garcia (1989) method, classifying the CV range as low [$CV \leq (m - 1sd)$]; medium [$(m - 1sd) < CV \leq (m + 1sd)$]; high [$(m + 1sd) < CV \leq (m + 2sd)$] and very high [$CV > (m + 2sd)$].

Expected and observed frequencies

The expected and observed frequencies of CV's were verified, besides the frequencies observed by Pimentel-Gomes (2009). Within normal distribution of the data, 68.27% of the CV's are included between $m \pm 1sd$; 95.45% of CV's between $m \pm 2sd$ and 99.73% of CV's between $m \pm 3sd$. Thus, the expected CV's frequencies that correspond to the ranges of classification are 15.86, 68.27, 13.59 and 2.28%, respectively.

Statistical analyses

Statistical analyses were carried using the software R (R Core Team, 2019) through `norstest` (Gross and Ligges, 2012) and `ggplot2` (Wickham, 2016) packages.

Results and discussion

Normality and amplitude of the data

All traits presented normal distribution by Lilliefors test (1967) at a significance level of 5%

(Figure 1). The verification of the normal distribution of the data is important, since it is required according to the classification criteria of Garcia (1989). When data has not been normally distributed, Costa et al. (2002) suggested the use of median and pseudo-sigma statistics instead of the mean and standard deviation, respectively. Furthermore, these authors verified that when there is normal distribution of the data, both methodologies provide equivalent classification.

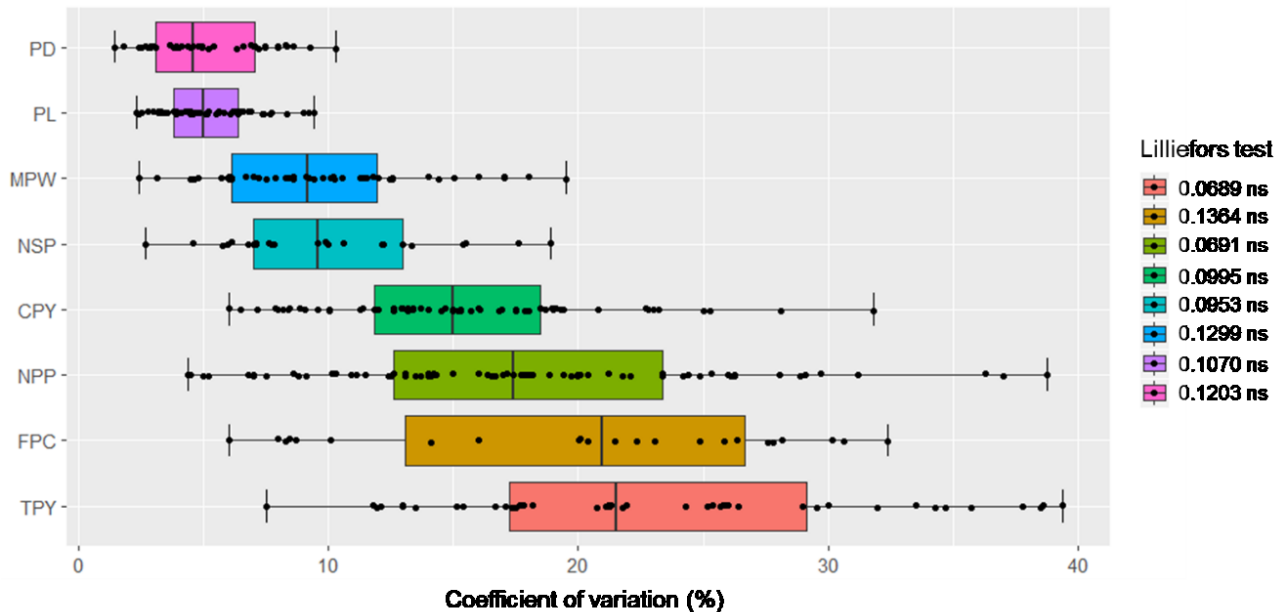


Figure 1. Box plot and Lilliefors test (1967) of the coefficients of variation for eight traits obtained from snap beans (*Phaseolus vulgaris* L.) studies. Commercial pod yield (CPY), total pod yield (TPY), pod length (PL), number of seeds per pod (NSP), number of pods per plant (NPP), mean pod weight (MPW), pod diameter (PD) and fiber pod content (FPC). ns = not significant at the 5% level by Lilliefors test.

Based on the maximum and minimum values (Figure 1), wide amplitude of the data was observed both among and within the traits, indicating the influence of environmental factors on the evaluated traits. It should be noted that the CV values were determined based on field trials where the treatments were of different natures such as types and rates of fertilizer (Gomes et al., 2017) and assessments applied to genetic improvement (Sousa et al., 2017). Thus, the classification of CV for each trait is necessary to promote a proper precision evaluation of these experiments. Similar results were observed in the determination of classification ranges of CV's in plants species (Mora and Arrigada, 2016; Ferreira et al., 2016).

Ranges of classification

The studied traits had specific ranges of classification (Table 1), different from those

proposed by Pimentel-Gomes (2009), except for the traits CPY and NPP, which were similar for both classification proposals. The frequencies expected and observed, according to the criteria proposed by Garcia (1989) and Pimentel-Gomes (2009) (Table 2), were estimated considering that the CV data had normal distribution. Hence, it is expected that most values are distributed close to the mean, and low frequency of extreme values.

The TPY presented the ranges of classification for CV higher than for the CPY (Table 2), indicating a great environment influence on the TPY. These results can be justified due to the pods selection according to the commercial standard, with discard the non-standard pods, which promote a high homogeneity of pods and, consequently, lower CV values (Myers and Baggett, 2013).

Table 1. Classification of coefficient of variation (CV) for eight traits obtained from snap beans (*Phaseolus vulgaris* L.) studies.

Traits ¹	Coefficient of variation (%) ²			
	Low	Medium	High	Very high
CPY	≤ 9.7	9.7 < CV ≤ 20.8	20.8 < CV ≤ 26.3	> 26.3
TPY	≤ 14.8	14.8 < CV ≤ 31.6	31.6 < CV ≤ 40.0	> 40.0
PL	≤ 3.3	3.3 < CV ≤ 7.0	7.0 < CV ≤ 8.8	> 8.8
NSP	≤ 5.7	5.7 < CV ≤ 14.0	14.0 < CV ≤ 18.2	> 18.2
NPP	≤ 9.9	9.9 < CV ≤ 25.5	25.5 < CV ≤ 33.3	> 33.3
MPW	≤ 5.5	5.5 < CV ≤ 13.6	13.6 < CV ≤ 17.7	> 17.7
PD	≤ 2.8	2.8 < CV ≤ 7.4	7.4 < CV ≤ 9.7	> 9.7
FPC	≤ 11.8	11.8 < CV ≤ 28.7	28.7 < CV ≤ 36.4	> 36.4

¹ CPY: commercial pod yield, TPY: total pod yield, PL: pod length, NSP: number of seeds per pod, NPP: number of pods per plant, MPW: mean pod weight, PD: pod diameter and FPC: fiber pod content.

² The CV's were classified by values of mean (m) and standard deviation (sd) as: low [$\leq (m - 1sd)$]; medium [$(m - 1sd) < CV \leq (m + 1sd)$]; high [$(m + 1sd) < CV \leq (m + 2sd)$] and very high [$> (m + 2sd)$].

Table 2. Observed (F_o) and expected frequencies (F_e) of coefficient of variation for eight traits obtained from snap beans (*Phaseolus vulgaris* L.) studies according to Garcia (1989) and Pimentel-Gomes (2009).

Method	Traits ¹	F_o (%)			
		Low	Medium	High	Very high
Garcia (1989)	CPY	18.46	67.69	12.31	1.54
	TPY	15.91	63.64	18.18	2.27
	PL	16.00	68.00	10.00	6.00
	NSP	12.00	72.00	12.00	4.00
	NPP	15.58	67.53	14.29	2.60
	MPW	10.87	71.74	13.04	4.35
	PD	17.07	63.41	17.07	2.44
	FPC	21.00	66.50	9.33	3.17
Pimentel-Gomes (2009)	CPY	18.46	66.15	10.77	1.54
	TPY	2.27	34.09	43.18	20.45
	PL	100.00	0.00	0.00	0.00
	NSP	60.00	40.00	0.00	0.00
	NPP	15.58	53.25	27.27	5.19
	MPW	56.52	43.48	0.00	0.00
	PD	97.56	2.44	0.00	0.00
	FPC	20.83	16.67	50.00	12.50
F_e (%)		15.86	68.27	13.59	2.28

¹ CPY: commercial pod yield, TPY: total pod yield, PL: pod length, NSP: number of seeds per pod, NPP: number of pods per plant, MPW: mean pod weight, PD: pod diameter and FPC: fiber pod content.

In relation to the PL, according to Pimentel-Gomes (2009) proposal, 100% of the CV would be considered low and none them would be classified as medium, high or very high (Table 2), therefore, it may generate a false indication of high experimental precision and, consequently, generating incorrect conclusions. Similar results were observed by Couto et al. (2013), Mora and Arrigada (2016) and Ferreira et al. (2016).

For the traits MPW, NSP and PD, none of the CV observed would be classified as high or very high by Pimentel-Gomes (2009) proposal

(Table 2). Therefore, the CV classification proposal by Pimentel-Gomes (2009) would not be the most proper for these traits due a low environment influence on precision of the experiments. In contrast, according to Pimentel-Gomes (2009) classification proposal, 50% of CV's should be classified as high and 12.5% as very high, underestimating the CV ranges for the FPC.

Oliveira et al. (2009) proposed a classification of the CV's in common bean. Comparing the ranges obtained by Oliveira et al. (2009) with the proposals of the present study,

similar ranges are observed for the NPP and NSP. These results can be explained by the fact that snap beans belong to the same botanical species of common bean (*Phaseolus vulgaris* L.), in which a great part of the distinguishing traits is related to the occurrence of mutations in loci that control quality traits of pods (Myers and Bagget, 2013).

In general, when there is not a classification for a particular species and traits, the researchers compare the CV values of their experiments with the ones suggested by Pimentel-Gomes (2009). Thus, as there is not a previous report for the traits of snap beans, the means of the CV's for PD (5.14%), PL (5.21%), MPW (9.63%) and NSP (9.89%) were considered low. This indicates most of the variables measured in snap bean are stable or weakly affected by the environment, except the CPY (15.29%), NPP (17.72%), FPC (20.05%) and TPY (23.27%), which was classified as moderate. Therefore, the present classification is recommended to guide researchers on the

validity of their results and may lead to correct conclusions in studies involving these variables in snap beans.

Conclusion

The proposal suggested in this study presents a more proper classification of coefficient of variation for snap bean traits, allowing an experimental precision approach specific for this crop. The ranges of values of the coefficient of variation differ among the different variables, showing wide variation, justifying the need to use specific evaluation range for each character. The proposed classification provides a useful tool for researchers interested in estimating the accuracy of their experiments involving snap beans traits.

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