Categorizing coefficients of variation in sunflower trials

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ABSTRACT

This study was carried out to categorize coefficients of variation (CV's) associated with important traits of routine use in the sunflower breeding programs. Separate categories were obtained for the August/September and February/March sowings. Data were used from the intermediate and final sunflower experiments carried out by Embrapa Soybean and other collaborator institutions of the Network of Official Sunflower Trials. Taking into account the mean and the standard deviation of the CV's obtained from the analyses of variance of the experiments, they were fitted into the low, medium, high and very high categories. An additional classification was made using the median and pseudo-sigma, in place of the mean and standard deviation, respectively. In this study it was ascertained that the CV's categorization depended on the trait studied. Sowing date effects were more pronounced for seed and oil yield and plant height. For all assessed traits in February/March, the methodologies adopted were similar (regardless of the CV's distribution) and satisfactory to assess the experimental accuracy of the trials. In the August/September trials there was good agreement between the results of the methodologies adopted and that of Gomes (1985) for seed and oil yield. For the other traits, the former methodologies were shown to be more adequate. The proposed CV's categorizations for the sunflower traits use as maximum acceptable limits the values of 23.5% (August/September sowing) and 31.5% (February/March sowing) for seed and oil yield, 6.0% for oil content (August/September and February/March) and plant height (August/September), 9.5% for plant height (February/March) and 4.5% for flowering and physiological maturity (August/September and February/March).

KEY WORDS: Yield components, *Helianthus annuus*, experimental accuracy.

INTRODUCTION

The coefficient of variation (CV) obtained from the analysis of variance of an experimental trait indicates the degree of precision of this experiment. Based on the CV's, regularly estimated in agricultural field trials, Gomes (1985) categorized them as low, when less than 10%; average, when from 10% to 20%; high, when from 20% to 30% and very high, when greater than 30%. However, this categorization is very wide and does not take into consideration the peculiarities of the studied crop, and, especially, does not make a distinction of the nature of the trait assessed (Garcia, 1989; Scapim et al., 1995; Costa et al., 2002). Furthermore, the categories may vary depending on the soil-climatic conditions or sowing dates of the crop (Scapim et al., 1995).

Assuming normal distribution and considering the mean (**m**) and the standard deviation (**DP**) of the CV's estimated in the analyses of variance of experimental trials for the Eucalyptus and Pines species, Garcia (1989) proposed new categories of CV's that are specific to the forest reality. For a given trait, the CV's were categorized as low [CV ≤ (**m** – 1 DP)], medium [(**m** – 1 DP) < CV ≤ (**m** + 1 DP)], high [(**m** + 1 DP) < CV ≤ (**m** + 2 DP)] and very high [CV > (**m** + 2 DP)]. These criteria were also used on maize by Scapim et al. (1995). When the CV's did not present normal distribution, Costa et al. (2002) suggested the use of the **Md** and **PS** statistics instead of the mean and the standard deviation, respectively. According to these authors, these two methodologies are equivalent under normality.

In a crop genetic breeding program, CV categorization can be used to provide information on the experimental quality of the trials. In these trials, a set of traits is measured to help the breeder in the description and recommendation of new cultivars. The following attributes are desirable and generally evaluated in sunflower (*Helianthus annuus*) breeding programs: a) high seed yield, to make the crop competitive, considering the high production costs in Brazil; b) high oil content, as the commercialization policy provides a bonus for contents higher than a certain value (currently 40%), bound to increase as the crop becomes more widespread in the country; c) early to medium maturity cycle, for perfect integration in the different production systems; d) short and uniform plant height and uniform flowering to facilitate harvesting; and, e) disease resistance, to ensure better production stability (Castiglioni and Oliveira, 1999).

This study used the methodologies proposed by Garcia (1989) and Costa et al. (2001) to categorize the CV's associated to important traits of routine use in sunflower breeding programs. Distinct categories were provided for the August/September and February/March sowings. The results were compared based on the obtained CV's distributions.

MATERIAL AND METHODS

Data were used from the intermediate and final sunflower trials conducted by Embrapa Soybean and other institutions involved in the Network of Official Sunflower Trials carried out between 1992 and 2000. The genetic material assessed were single and double hybrids and open pollinated varieties.

The trials were sown in two different dates: August/September and February/March. Randomized complete block design experiments with three replications in the intermediary trials and four replication in the final trials were used. Each plot consisted of four 6m rows spaced at 0.80m. Only the two central rows were harvested in each plot, disregarding 0.5m from each end that resulted in an 8m^2 useful area. The plant density established was approximately five plants/m^2. Fertilization, pest and disease control, hoeing and other crop management practices were carried out to keep plants under optimum growth and development conditions.

In August/September, the sunflower trial network included locations in the states of Rio Grande do Sul, Paraná and São Paulo. In February/March, the trials were conducted in the states of Mato Grosso, Mato Grosso do Sul, Goiás, Distrito Federal, Minas Gerais, São Paulo, Piauí and Maranhão.

The assessed traits were seed yield (kg/ha), oil content (%), oil yield (kg/ha), plant height (m), flowering (emergence to flowering onset in days) and physiological maturity (days). Analyses of variance were performed on the traits based on the mean of the plants in the plot. The CV's for each trait, obtained from the analyses of variance, were estimated based on Gomes (1985) and categorized according to the methodologies proposed by Garcia (1989) and Costa et al. (2002). Table 1 shows the number of trials used in this study. The normal distribution of the CV's was ascertained by the Shapiro-Wilk test (SAS Institute, 1985).

Based on the mean (**m**) and the standard deviation (**DP**) of the CV's obtained in the analyses of variance, they were categorized by Garcia (1989) as low [CV $\leq$ (**m** – 1 DP)], medium [(**m** – 1 DP) < CV $\leq$ (**m** + 1 DP)], high [(**m** + 1 DP) < CV $\leq$ (**m** + 2 DP)] and very high [CV > (**m** + 2 DP)]. In the methodology proposed by Costa et al. (2002), the category intervals are defined similarly to those of Garcia (1989). However, **m** and **DP** are substituted, respectively, by the median (**Md**) and pseudo-sigma (**PS**) where,

Md = $(Q_1 + Q_3)/2$ is the median of the coefficients of variation for the first and third quartile, respectively, that delimit 25% of each tail of the distribution and,

PS = AI/1.35 is the pseudo-sigma (Tukey, 1977; Hoaglin et al., 1983) for the inter-quartile amplitude (AI), which indicates the distance between the data and the median. According to Costa et al. (2002), the pseudo-sigma would be the standard deviation that a normal distribution would need to have to produce the same inter-quartile amplitude in the distribution of the sampled data. The value 1.35 corresponds to the distance between Q1 and Q3 of the normal distribution (N~(0,1)).

The CV's were categorized for each trait and sowing date. To test the significance of the trait effects [i = 1 (seed yield); 2 (oil content); 3 (oil yield); 4 (plant height); 5 (flowering onset); and, 6 (physiological maturity)] and sowing date [j = 1 (August/September) and j = February/March)] a t test was applied (Gomes, 1985). The differences among CV means ($\mathbf{m}_{ij}$ - $\mathbf{m}_{i'j}$) within a single sowing date were used to test the effect of trait. To test the effect of sowing period, differences among CV means ($\mathbf{m}_{ij}$ - $\mathbf{m}_{ij'}$) of the two sowing periods within trait obtained were used. Due to the large number of contrasts tested (especially for trait effect), the significance levels for testing traits and sowing dates means were set at the 0.1% level of probability.

The statistical analyses were made using the procedures 'PROC UNIVARIATE′ and 'PROC GLM′ of the SAS statistical package (SAS Institute, 1985).

Table 1. Normality test and descriptive statistics of the coefficient of variation obtained in sunflower regional yield trials carried out by Embrapa and associates from 1992 to 2000 in Aug/Set and Feb/March sowings.

Sowing date	Yield components	Number of Trials	Normality test	Coefficient of variation					
				Mean	Standard deviation	Median	Pseudo-sigma	Minimum	Maximum
August/September	Seed yield	84	$0.95^{1/}$	15.44	5.51	14.89	5.22	4.43	34.9
	Oil content	50	$0.91^{1/}$	3.73	1.42	3.70	1.25	1.66	7.39
	Oil yield	48	0.96^{ns}	17.82	5.56	17.40	5.42	8.40	33.94
	Plant height	59	$0.94^{1/}$	4.62	1.41	4.51	1.41	2.30	8.33
	Flowering onset	50	$0.88^{1/}$	2.57	1.44	2.51	1.50	0.65	6.40
	Physiological maturity	41	$0.83^{1/}$	2.30	1.27	2.17	1.14	0.63	6.05
February/March	Seed yield	156	$0.94^{1/}$	20.85	7.11	20.31	6.66	7.99	41.68
	Oil content	106	$0.89^{1/}$	4.20	2.05	3.98	1.61	0.77	11.55
	Oil yield	92	$0.945^{1/}$	23.22	8.20	23.46	7.82	8.26	42.41
	Plant height	144	$0.96^{1/}$	6.92	2.69	6.82	2.53	1.34	15.36
	Flowering onset	90	$0.84^{1/}$	2.97	1.56	2.77	1.07	0.91	7.82
	Physiological maturity	64	$0.91^{1/}$	2.70	1.43	2.62	1.37	0.44	7.36

^{ns} and $^{1/}$ indicate non-significance and significance at the 5% and 1% level of probability, respectively, by the Shapiro-Wilk test.

RESULTS AND DISCUSSION

Except for flowering vs. physiological maturity and for seed yield vs. oil yield, both in August/September and February/March sowings and for oil content vs. plant height in August/September sowing, significant differences at the 0.1% level of probability were obtained between trait CV means ($\mathbf{m}_{ij}$ - $\mathbf{m}_{i'j}$), which indicated trait influence on the CV's magnitude (Tables 1 and 2). In the two sowing dates, the lowest estimated CV value for oil yield, for example, was superior to the largest CV obtained for flowering and physiological maturity. On average, the largest CV was obtained for oil or seed yield followed by plant height, oil content, flowering and physiological maturity. The sowing date effect ($\mathbf{m}_{ij}$ - $\mathbf{m}_{ij'}$) was not significant at the 5% level of probability, for oil content, flowering and physiological maturity (Tables 1 and 3). For the other traits, the CV's tended to be larger in the February/March sowing.

In Garcia's classification (1989), the CV's standard deviation should also be considered. In the August/September and February/March sowings, the differences in magnitude of the trait standard deviations were small or similar to the performance detected for **m** (Table 1). Similarly to **m**, the **DP** for the oil content, flowering and physiological maturity traits tended not to vary greatly in function of the sowing date. However, the sowing date affected the **DP** of the other traits. These results justify the definition of different categories for traits and sowing dates of sunflower (Table 4), except for flowering and physiological maturity (classification not different in both sowings), for seed and oil yields (classification not different within sowing dates) and for oil content and plant height (classification not different in both sowings for oil content and August/September for plant height).

Except for oil content in August/September sowing, the sunflower coefficients of variation assessed in the two sowings did not present normal distribution for any trait (Table 1). Under these conditions, Costa et al. (2002) reported that the **Md** and the **PS** are more robust statistics than **m** and **DP**, respectively. According to these authors, another advantage of the use of these parameters is that the category intervals do not depend on the CV's distribution. However, in this study, there were no large differences between the methodologies of Garcia (1989) and Costa et al. (2002) in setting the intervals of each category (Tables 4 and 5) and in the frequency with which the CV's fitted in the classes defined by these two classifications (Table 6), even under situations of CV distribution non-normality (Table 1). Consequently, the importance of the trait and sowing effects tended to remain with the substitution of **m** and **DP** by **Md** and **PS** (Tables 1, 4 and 5).

In the August/September sowing, the classifications based on the criteria of Garcia (1989) and Costa et al. (2002) for seed and oil yield were fairly similar to those of Gomes (1985) (Table 4 and 5). This was not observed for the other traits. In this case, Gomes' classification (1985) was shown to be slightly conservative, because all CV's were classified as low (Table 6). On the other hand, based on **m** and **DP** (or **Md** and **PS**), non-nil CV's frequencies were observed

Table 2. Comparing means of the coefficients of variation obtained in analyses of variance of several sunflower traits assessed in experiments sowed in the Aug/Sept and Feb/March sowings.

Comparison	t value	
	August/September	February/March
Seed yield vs Oil content	18.5 $^{3/}$	27.6 $^{3/}$
Seed yield vs Oil yield	-2.4 $^{1/}$	-2.3 $^{1/}$
Seed yield vs Plant height	17.2 $^{3/}$	22.8 $^{3/}$
Seed yield vs Flowering onset	20.3 $^{3/}$	30.2 $^{3/}$
Seed yield vs Physiological maturity	20.8 $^{3/}$	30.5 $^{3/}$
Oil content vs Oil yield	-17.0 $^{3/}$	-22.7 $^{3/}$
Oil content vs Plant height	-3.3 $^{2/}$	-9.1 $^{3/}$
Oil content vs Flowering onset	4.1 $^{3/}$	4.8 $^{3/}$
Oil content vs Physiological maturity	5.1 $^{3/}$	5.6 $^{3/}$
Oil yield vs Plant height	16.0 $^{3/}$	18.5 $^{3/}$
Oil yield vs Flowering onset	18.4 $^{3/}$	23.3 $^{3/}$
Oil yield vs Physiological maturity	18.8 $^{3/}$	23.5 $^{3/}$
Plant height vs Flowering onset	7.5 $^{3/}$	14.2 $^{3/}$
Plant height vs Physiological maturity	8.7 $^{3/}$	14.7 $^{3/}$
Flowering onset vs Physiological maturity	1.0 ^{ns}	1.1 ^{ns}

^{ns}, $^{1/}$, $^{2/}$ and $^{3/}$ indicate non-significance and significance at the 5%, 1% and 0.1% level of probability, respectively, by the t test.

for the low, medium, high and very high categories. These results are similar to those obtained in maize (Scapim et al., 1995).

Similar to the August/September sowing, no CV associated with oil content, plant height, flowering or physiological maturity was considered high or very high in the February/March sowing, according to Gomes (1985) (Table 6). However, based on **m** and **DP** (or **Md** and **PS**), a non-nil CV frequency was detected in all categories. Unlike the August/September sowing, the February/March sowing showed no agreement between the categories proposed by the studied methodologies and that of Gomes (1985) for seed and oil yields. A high frequency of experiments with high CV's were obtained based on Gomes (1985).

Table 3. Comparing the Aug/Sept and Feb/March trait means of the coefficients of variation obtained in analyses of variance of several sunflower field experiments.

Trait	t value
Seed yield	-6.6 $^{1/}$
Oil content	-1.7 ^{ns}
Oil yield	-4.6 $^{1/}$
Plant height	-8.0 $^{1/}$
Flowering onset	-1.5 ^{ns}
Physiological maturity	-1.5 ^{ns}

^{ns}, and $^{1/}$ indicate non-significance and significance at the 0.1% level of probability, respectively, by the t test.

Generally, in spite of the different numbers of observations analyzed to obtain the CV classification for the sunflower traits (Table 1), the frequencies of the low, medium, high and very high CV categories were relatively similar in the classifications of the different yield components (Table 6). These frequencies were also similar to those reported in forest species (Garcia, 1989) and in maize (Scapim et al., 1995). A more even distribution of the CV's in the different categories, observed when **m** and **DP** are used, was considered by Scapim et al. (1995) an indication of superiority of this method compared to that of Gomes (1985).

According to the classification proposed for the sunflower traits, the maximum acceptable limits for the coefficients of variation were: 23.5% (August/September sowing period) and 31.5% (February/March sowing) for seed and oil yields; 6.0% for oil content (August/September and February/March sowings) and plant height (August/September sowing); 9.5% for plant height (February/March sowing); and, 4.5% for flowering and physiological maturity (August/September and February/March sowings).

Table 4. Garcia (1989) classification intervals for the coefficients of variation obtained for sunflower yield components assessed in regional yield trials sowed in Aug/Sept/ and Feb/March carried out by Embrapa Soybean and associates from 1992 to 2000.

Sowing date	Coefficients of variation classification intervals	Intervals (%)					
		Seed yield	Oil content (%)	Oil yield	Plant height	Flowering onset	Physiological maturity
August/September	Low	≤ 10.0	≤ 2.5	≤ 12.0	≤ 3.0	≤ 1.0	≤ 1.0
	Medium	10.0 - 21.0	2.5 - 5.0	12.0 - 23.5	3.0 - 6.0	1.0 - 4.0	1.0 - 3.5
	High	21.0 - 26.5	5.0 - 6.5	23.5 - 29.0	6.0 - 7.5	4.0 - 5.5	3.5 - 5.0
	Very high	> 26.5	> 6.5	> 29.0	> 7.5	> 5.5	> 5.0
February/March	Low	≤ 13.5	≤ 2.0	≤ 15.0	≤ 4.0	≤ 1.5	≤ 1.0
	Medium	13.5 - 28.0	2.0 - 6.0	15.0 - 31.5	4.0 - 9.5	1.5 - 4.5	1.0 - 4.0
	High	28.0 - 35.0	6.0 - 8.5	31.5 - 39.5	9.5 - 12.5	4.5 - 6.0	4.0 - 5.5
	Very high	> 35.0	> 8.5	> 39.5	> 12.5	> 6.0	> 5.5

Table 5. Costa et al. (2002) classification intervals for the coefficients of variation obtained for sunflower yield components assessed in regional yield trials sowed in Aug/Sept/ and Feb/March carried out by Embrapa Soybean and associates from 1992 to 2000.

Sowing date	Coefficients of variation classification intervals	Intervals (%)					
		Seed yield	Oil content (%)	Oil yield	Plant height	Flowering onset	Physiological maturity
August/September	Low	≤ 9.5	≤ 2.5	≤ 12.0	≤ 3.0	≤ 1.0	≤ 1.0
	Medium	9.5 - 20.0	2.5 - 5.0	12.0 - 23.0	3.0 - 6.0	1.0 - 4.0	1.0 - 3.5
	High	20.0 - 25.5	5.0 - 6.0	23.0 - 28.0	6.0 - 7.5	4.0 - 5.5	3.5 - 4.5
	Very high	> 25.5	> 6.0	> 28.0	> 7.5	> 5.5	> 4.5
February/March	Low	≤ 13.5	≤ 2.5	≤ 15.0	≤ 4.5	≤ 1.5	≤ 1.0
	Medium	13.5 - 27.0	2.5 - 5.5	15.0 - 31.5	4.5 - 9.5	1.5 - 4.0	1.0 - 4.0
	High	27.0 - 33.5	5.5 - 7.0	31.5 - 39.0	9.5 - 12.0	4.5 - 5.0	4.0 - 5.5
	Very high	> 33.5	> 7.0	> 39.0	> 12.0	> 5.0	> 5.5

It is emphasized that besides trait, the crop factor must be taken into account to determine the experimental accuracy. For example, maize plant height assessed at harvesting is considered of low experimental accuracy with high or very high CV experiments, usually above 13% (Scapim et al., 1995). This value is more than double the value found for sunflower. On the other hand, seed yield CV's above 22% are considered high or very high for maize or sunflower August/September experiments.

RESUMO

Uma proposta de classificação dos coeficientes de variação para a cultura do girassol

Este trabalho teve como objetivo apresentar classificações de coeficientes de variação (CV's) associados a caracteres importantes e de uso rotineiro nos programas de melhoramento do girassol. Classificações distintas foram feitas para as semeaduras de agosto/setembro e fevereiro/março. Foram utilizados dados dos ensaios intermediários e finais do girassol, conduzidos pela Embrapa Soja e outras instituições da Rede de Ensaios Oficiais do Girassol. Considerando-se a média e o desvio padrão dos coeficientes de variação obtidos das análises de variância dos ensaios, estes foram classificados como baixo, médio, alto e muito alto. Uma classificação adicional foi feita utilizando a mediana e o pseudo-sigma, em substituição à média e ao desvio padrão, respectivamente. Nesse estudo verificou-se que a classificação dos CV's dependeu do caráter estudado. O efeito época de semeadura foi mais pronunciado para caracteres rendimento de grãos e de óleo e altura de planta. Para todos os caracteres avaliados na semeadura de fevereiro/março, as metodologias

Table 6. Frequencies of the coefficients of variation obtained for sunflower yield components assessed in regional yield trials sowed in Aug/Sept and Feb/March in the low, average, high and very high categories according to Garcia (1989), Costa et al. (2002) and Gomes (1985) methodologies.

Sowing date	Methodology	Coefficients of variation classification	Observed frequency (%)					
			Seed yield	Oil content (%)	Oil yield	Plant height	Flowering onset	Physiological maturity
August/September	Garcia (1989) method	Low	10.71	14.00	12.50	8.47	8.00	2.44
		Medium	72.62	70.00	70.83	74.58	76.00	82.92
		High	14.29	8.00	12.50	11.87	10.00	7.32
		Very high	2.38	8.00	4.17	5.08	6.00	7.32
	Costa (2002) method	Low	10.71	14.00	12.50	8.47	8.00	2.44
		Medium	71.43	70.00	66.67	74.58	76.00	82.92
		High	13.10	4.00	14.58	11.87	10.00	4.88
		Very high	4.76	12.00	6.25	5.08	6.00	9.76
	Gomes (1985) method	Low	10.71	100.00	8.33	100.00	100.00	100.00
		Medium	71.43	0.00	60.42	0.00	0.00	0.00
		High	15.48	0.00	29.17	0.00	0.00	0.00
		Very high	2.38	0.00	2.08	0.00	0.00	0.00
February/March	Garcia (1989) method	Low	12.82	7.55	15.22	11.11	10.00	4.68
		Medium	69.87	76.42	66.30	71.53	75.56	78.13
		High	12.82	10.37	13.04	14.58	3.33	10.94
		Very high	4.49	5.66	5.44	2.78	11.11	6.25
	Costa (2002) method	Low	12.82	16.98	15.22	21.53	10.00	4.68
		Medium	67.95	63.21	66.30	60.42	70.00	78.13
		High	13.46	9.43	13.04	11.80	10.00	10.94
		Very high	5.7	10.38	5.44	6.25	10.00	6.25
	Gomes (1985) method	Low	2.56	98.11	3.26	87.5	100.00	100.00
		Medium	50.00	1.89	39.13	12.5	0.00	0.00
		High	35.26	0.00	35.87	0.00	0.00	0.00
		Very high	12.18	0.00	21.74	0.00	0.00	0.00

adotadas foram similares (independente da distribuição dos CV's) e satisfatórias para avaliar a precisão experimental dos ensaios. Na semeadura de agosto/setembro, houve boa concordância entre as metodologias usadas e a de Gomes (1985), em relação a rendimentos de grãos e de óleo de girassol; para os demais caracteres, aquelas metodologias mostraram mais adequadas. De acordo com as classificações propostas para os caracteres do girassol, os limites máximos de coeficientes de variação aceitáveis são: 23,5% (semeadura de agosto/setembro) e 31,5% (semeadura de fevereiro/março) para rendimentos de grãos e de óleo, 6,0% para teor de óleo (semeadura de agosto/setembro e de fevereiro/março) e altura de planta (semeadura de agosto/setembro), 9,5% para altura de planta na semeadura de fevereiro/março e 4,5% para floração inicial e maturação fisiológica, independente da época de semeadura.

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