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Upper Limit of Coefficient of Variation for Improving Efficiency in Sugarcane Field Experiments in India

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SUMMARY

Coefficient of variation (CV) is used to measure theheterogeneity of the experimental field in the context of agricultural research including sugarcane experiments.Smaller the CV value of cane yield, higher is the reliability of the experiment.In all the zones of All India Coordinated Research Project on Sugarcane - AICRP(S), upper limit of CV for cane yield is higher for early varietal trials in comparison tothe mid to late varietal trials of sugarcane in India. Similar trend was also found for upperlimit of CV for sucrose (%). Upper limit of CV (%) for cane yield was found highest in Peninsular zone as around 10% in early varietal trial followed by North central Zone. It is also observed as lowest in North West Zone, which is around 8.5 % both for early and mid-late varietal trials. Same trend was also observed for sucrose, which around 3% at 1%, 5% and 10% level of significance. Overall for all the trial of cane yield, it is estimated as 9% for cane yield in the country at all the three level of significance. For plant crop, it is estimated as 9% at all level of significance. For ratoon crop, it is estimated as 10% at all level of significance.

Keywords: Coefficient of variation, Randomized block design, Upper limit, AICRP(S).

1. INTRODUCTION

The coefficient of variation (CV) is a helpful quantity to describe the variation in evaluating results from different populations. There are many papers discussing methods of constructing confidence intervals for a single CV, such as exact method and approximation methods for CV when the underlying distribution is a normal distribution (Liu, 2012). He proposed a new para- metric interval and two non-parametric intervals for CV under the normality assumption.

In a field experiment, the coefficient of variation (CV) is a measure of the dispersion of a data set around the mean. It is calculated as the standard deviation of the data set divided by the mean, and is usually expressed as a percentage. The CV can be used to assess the reliability of the data obtained in a field experiment. A low CV indicates that the data are relatively consistent, while a high CV indicates that the data are more variable. This can be important when assessing the statistical significance of the results of the experiment, as well as when deciding whether the experiment should be repeated to obtain more reliable data. In general, the larger the number of replicates, the lower the CV will be, as more replicates will provide a better estimate of the mean of the data set.

In the design of experiments, the coefficient of variation (CV) can be used to assess the precision of the data obtained from the experiment. The CV can be used to determine the sample size needed for the experiment, as well as to assess the statistical power of the experiment. The CV can also be used to compare the precision of different experimental treatments. Coefficient of variation is a function of square root of mean square (S) and mean ($\bar{X}$). The distribution of $\bar{X}$ and S have simple forms and Student t distribution provides complete solution for testing the hypothesis or estimating fiducial limits relation to either mean or mean square singly.

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Patel *et al.* (2001) suggested upper fiducial limit of CV (%) based on truncated t-distribution and the theory of probability and it was recommended for further use as a yard stick for CV of field experiment. In this paper,plot yield was collected for 906 experiments on pulse crop and were subjected to statistical analysis and CV was calculated for individual experiments. After Patel *et al.* (2001) paper, several attempts were made in Gujarat to estimate the upper limit of CV for different crops. Motaka *et al.* (2019) suggested that about 17 percent CV should recommended as a yard stick for sorgum crop. For forage crop, Darji *et al.* (2010) suggested 14 percent CV is the yardstick for accepting or rejecting the results of field experiments under Gujarat condition. According to Motaka *et al.* (2016) upper fiducial limit of CV (%) at 95% percent confidence level of CV (%) was worked out to be 22.39 %. It was also suggested that about 23 % CV should be considered as a yardstick for Medicinal and Aromatic Crop field experiments. Motaka *et al.* (2016) also calculated that 22 percent CV should be considered as a yardstick for Ashwagandha crop field experiments. Similarly, Motaka *et al.* (2016) also worked out 21 % CV should be considered as yard stick for cotton crop.

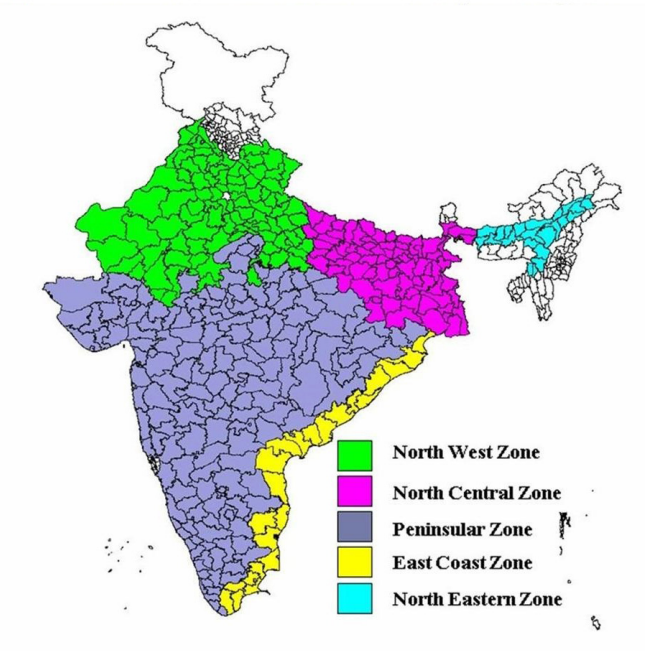
In sugarcane experimentation under RCBD, CV varies from 0.07 to 66.58 %. It is very difficult for planers to included results of experiment of particular centre for pooled analysis of zone when CV is high, for promoting varieties to next level of trial or identification of variety for release. The present investigation was carried out with the objectives to study control an uncontrol factors responsible for variability and to develop yardstick for reliability of the experimental results of sugarcane crop experiments conducted under Crop Improvement programme of All India Coordinated Research Project on Sugarcane. In this paper, an attempt has been made to estimate the upper limit of the confidence interval, called here, the upper limit, for the CV(%) for sugarcane experimentation for plant, ratoon, early, mid-late crop at zonal level under AICRP on Sugarcane which will useful for reliability of the experimental results of sugarcane crop in India.

2. MATERIAL AND METHODS

During 1991 to 2020, a large number sugarcane experiments (5265) were conducted in five sugarcane zones (Map 1) with five different agro-ecological conditions under Crop Improvement programme of All India Coordinated Research Project on Sugarcane - AICRP(S). The trials were conducted in Randomized Complete Block Design (RCBD) at nearly 35-40 locations in the sugarcane growing zones of the country (Map 1). Number of replications were three for nearly 98 % of the experiments. The present study was undertaken with the objective to know the extent of variability in experiments in different zones. For this, the data on standard error, coefficient of variation (CV) and critical difference (CD) of each experiment were collected for cane yield and sucrose (%) from Principal Investigator (Varietal Improvement Programme) reports (1991-2020), AICRP(S), ICAR - Sugarcane Breeding Institute, Coimbatore, Tamil Nadu. For cane yield, CV varies from 0.07 to 66.58 %. The plot-wise yield data of completely randomized block design were subjected to statistical analysis and CV was estimated individual experiments. The same was assumed as random variable in further analysis.

$$CV = \frac{s}{\bar{x}}$$

CV is a function of square root of mean square (S) and mean ($\bar{X}$). The distribution of $\bar{X}$ and S have simple forms and Student t distribution provides complete solution for testing the hypothesis or estimating fiducial limits relation to either $\bar{x}$ or s, singly. But t



Map 1- Zones of All India Coordinated Research Project on Sugarcane

distribution cannot be used for CV. Mckay (1932) used non-central t-distribution for providing fiducial limits of CV. In most of the paper, the method used is based on average CV of all the experiments. Where as in this study, Bootstrap sampling technique was used to calculate the confidence intervals of CV for early, mid-late, plant, ratoon crops at 90%, 95% and 99% confidence intervals. For overall crop of sugarcane, confidence intervals of CV was also measured. In this technique, all the units of CV was used to calculate the confidence intervals of CV.

Bootstrapping is a method for deriving robust estimates of standard errors and confidence intervals for estimates such as the mean, median, proportion, odds ratio, correlation coefficient or regression coefficient. It may also be used for constructing hypothesis tests. Bootstrapping is most useful as an alternative to parametric estimates when the assumptions of those methods are in doubt (as in the case of regression models with heteroscedastic residuals fit to small samples), or where parametric inference is impossible or requires very complicated formulas for the calculation of standard errors (as in the case of computing confidence intervals for the median, quartiles, and other percentiles). **BCa bootstrap** or Bias Corrected Accelerated use percentile limits with bias correction and estimate acceleration coefficient corrects the limit and find the class interval or upper limit of CV (%). The iteration times (number of samples) R = 10000 were chosen for calculating **BCa bootstrap** intervals of CV(%) with bootstrap method. Data was analysis with the help of SPSS and trial version of XLSTAT.

3. BOOTSTRAP ESTIMATES (BOOTSTRAPPING ALGORITHMS)

Bias

Let us consider T is CV(5) and the bias of statistic T can be estimated by the following equation

$$\text{Bias}\ (T) = B^{-1}\sum_{b=1}^{B} T_b^* - T$$

Standard error

The standard error of statistic T can be estimated by the standard deviation of the bootstrap values with the following equation

$$SE \approx \sqrt{\frac{1}{B-1}\sum_{b=1}^{B}\left(T_b^* - B^{-1}\sum_{b=1}^{B} T_b^*\right)^2}$$

BCa confidence interval

The influence value of the k_s th record in the sth stratum is approximated by

$$l_{jack,sk_s} = (N_s - 1)(T - T_{-sk_s})$$

Where T_{-sk_s} is the estimate calculated from the original data but with the frequency $f_{sk_s} - 1$ for the k_s th record in the sth stratum. It is reasonable to assume the empirical influence values l_{sk_s}

$$l_{jack,sk_s}$$

Defining $\tilde{l}_{sks} = l_{sks} N / N_s$, the BCa confidence interval is given as

$$\hat{\theta}\alpha = T^*((B+1)_{\tilde{\alpha}})'\hat{\theta}1-\alpha = T^*((B+1)(1-\tilde{\alpha}))$$

Where

$$\tilde{\alpha} = \Phi\left(w + \frac{w+z_\alpha}{1-a(w+z_\alpha}\right),$$

$$z_\alpha = \Phi^{-1}(\alpha),$$

$$w = \Phi^{-1}\left(\frac{\left|\left\{T_b^* \le t\right\}\right|}{B+1}\right),$$

$$a = \frac{1}{6}\frac{\Sigma_{s,k_s} f_{sk_s}\tilde{l}3_{sk_s}}{(\Sigma_{s,k_s} f_{sk_s}\tilde{l}2_{sk_s})^{3/2}}$$

Interpolation will be used as in the Percentile confidence interval.

4. RESULTS AND DISCUSSION

Sugarcane is large duration crop. In sugarcane field experiments, variation occurs due to uncontrolled factors such as soil fertility, climatic factors and pests and diseases etc. and control factors such as treatments, replication, field layout, block size and plot size etc. Such factors play an important role in the precision of the experimental results.

4.1 Upper limit of CV(%) for cane yield in sugarcane experimentation

For this upper limit of CV, the data on standard error, coefficient of variation (CV) and critical difference (CD) of each experiment were collected for cane yield and sucrose (%) from Principal Investigator (Varietal Improvement Programme) report (191-2020) of AICRP(S), ICAR - Sugarcane Breeding Institute,

Coimbatore, Tamil Nadu. For cane yield, CV varied from 0.07 to 66.58%. Similarly for sucrose (%), CV varied from 0.02 to 27.53 %. Out of 5265 sugarcane experiments, significant results were found in 91.23 % experiments for cane yield. Distribution of CV is presented in Table 2. It indicated that 86.67% of experiments had CV in between 2.5 to 15.00 %. Whereas in case of plant, ratoon, early and mid-late trials, it ranged in between 84.09 to 86.60 % of experiments. Below 2.5 % CV, it had around 3.0 to 4.0 % of the experiments (Graph 1). It can be inferred that majority of experiments had CV below 15 %. For medium sized CV of the samples (50<n<300), Fisher Z test was applied to test the normality of CV for all the five cases at 1 %, 5 % and 10 % level of significance (Table 2 to 5). Fisher Z test value was found more than 3.29 for skewness and kurtosis of CV in all the four cases at 1 %, 5 % and 10 % level of significance, reject the null hypothesis conclude that the distribution is non-normal (Table 1 and Graph 1). Data of CV (%) substantial departure from normality (Graph 1), a nonparametric method such that Bootstrap method is used to calculate the upper limit of CV(%), when normality assumption is not required.

The iteration times (number of samples) R = 10000 chosen for calculating **BCa bootstrap** intervals of CV(%) with bootstrap method,

Upper fiducial limit of CV (%) for plant crop of sugarcane was estimated as 9.00, 8.95 and 8.92 at 1

Graph 1 - Distribution of CV for cane yield in sugarcane experiments

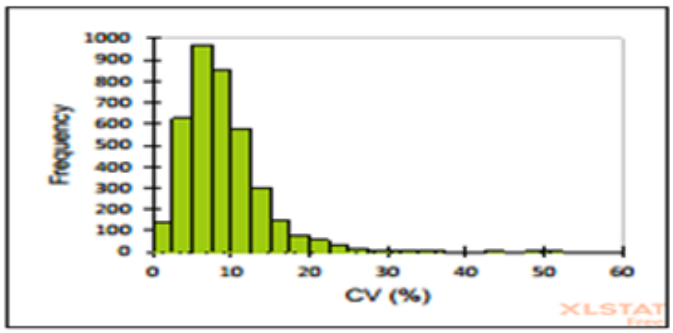


Fig. 1. Histogram of CV (%) for plant Crop of Sugarcane

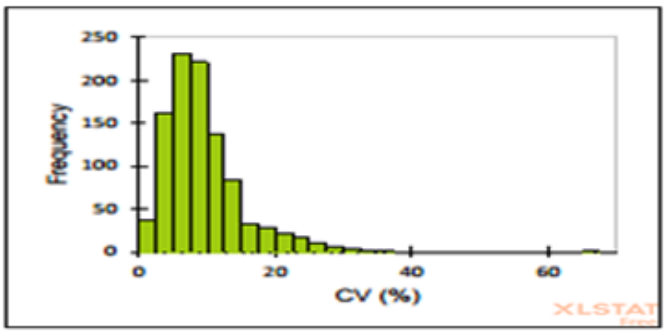


Fig. 2. Histogram of CV (%) for Ratoon Crop of Sugarcane

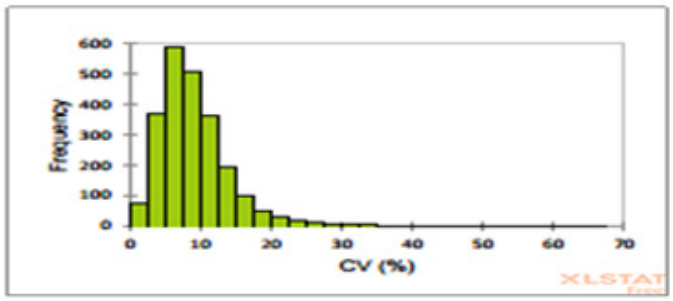


Fig. 3. Histogram of CV (%) for Early Crop of Sugarcane

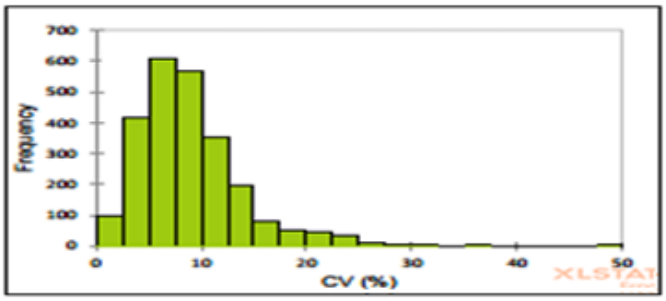


Fig. 4. Histogram of CV (%) for Mid-late Crop of Sugarcane

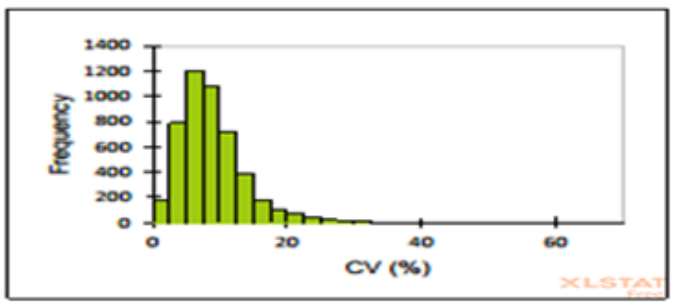


Fig. 5. Histogram of CV (%) for Sugarcane Crop (All Units)

Table 1. Different statistical parameters of CV(%) for sugarcane yield

Statistic	All Units	Ratoon Crop	PlantCrop	Early (Combined)	Mid-late (Combined)
Number of observation	4803	993	3810	2324	2479
Minimum	0.13	0.14	0.13	0.66	0.13
Maximum	66.58	66.58	52.49	66.58	48.91
Mean	8.92	9.39	8.79	9.02	8.82
Variance	26.17	33.88	24.09	26.64	25.71
Standard deviation	5.12	5.82	4.91	5.16	5.07
Variation coefficient	0.57	0.62	0.56	0.57	0.57
Skewness (Fisher)	1.97	2.19	1.83	2.17	1.76
Kurtosis (Fisher)	9.05	11.09	7.49	11.66	6.41
Z-Skewness (Fisher)	55.63*	28.15*	46.04*	42.73*	35.88*
Z-Kurtosis (Fisher)	128.13*	71.49*	94.46*	114.87*	65.24*
Mean absolute deviation	3.70	4.15	3.58	3.72	3.68

Table 2. Bootstrap statistic and Upper fiducial limit of CV (%) of cane yield for plant and ratoon crop of Sugarcane

Statistics	Plant Crop (All Units)			Ratoon Crop (All Units)		
No. of experiments	3810	3810	3810	993	993	993
Level of Significance (%)	10	5	1	10	5	1
CV (%)	8.79	8.79	8.79	9.39	9.39	9.39
Bias	-0.0005	-0.0001	0.0007	0.001691	0.001224	0.001599
Std. Error	0.08	0.08	0.08	0.18	0.19	0.19
Upper	8.92	8.95	9.00	9.70	9.76	9.88
Z test	111.6*	110.5*	110.7*	51.0*	50.7*	50.8*

Table 3. Bootstrap statistic and Upper fiducial limit of CV (%) of cane yield for early and midlate crop of sugarcane

Statistics	Early (All Units)			Midlate (All Units)		
Total Samples	2324	2324	2324	2479	2479	2479
Level of Significance (%)	10	5	1	10	5	1
CV (%)	9.02	9.02	9.02	8.82	8.82	8.82
Bias	-0.0001809	0.0003242	0.0011162	-0.00161338	0.00106677	-0.000038029
Std. Error	0.106	0.108	0.107	0.101	0.102	0.101
Upper	9.190	9.234	9.302	8.980	9.017	9.072
Z test	85.193*	83.728*	84.695*	87.215*	86.799*	87.008*

%, 5 % and 10 % level of significance respectively. Similarly, Upper fiducial limit of CV (%) for ratoon crop of sugarcane was estimated as 9.88, 9.76 and 9.70 at 1 %, 5 % and 10 % level of significance respectively (Table 2). It is inferred that upper limit of CV is more in ratoon crop than the plant crop. These limits are for cane yield to get the consistent and reliable results in varietal trails conducted in randomized complete block design. Upper fiducial limit of CV (%) for early crop of sugarcane was estimated as 9.302, 9.234 and 9.190 at 1 %, 5 % and 10 % level of significance respectively. Similarly, Upper fiducial limit of CV (%) for mid-late crop of sugarcane was estimated as 9.072, 9.017 and 8.98 at 1 %, 5 % and 10 % level of significance respectively (Table 3). It is inferred that upper limit of CV is more in early crop than the mid-late.

Bootstrap bias is negligible for all the crop of sugarcane (Table 2-4). As level of significance increases, the upper limit of CV (%) decreases. It is inferred that upper limit of CV (%) is more in ratoon crop than the plant crop because the gaps in sugarcane field is more in comparison to plant crop. Gaps occur due to death of clumps (plants) from pests and diseases.

Table 4. Bootstrap statistic and Upper fiducial limit of CV (%) for cane yield of Zonal level of All India Coordinated Research Project on Sugarcane

Statistic	Peninsular Zone					
	Early (PS)			Midlate (PS)		
N	1067	1067	1067	1427	1427	1427
Level of Significance (%)	10	5	1	10	5	1
Statistics	9.54	9.54	9.54	9.27	9.27	9.27
Bias	0.000189	-0.000093	0.000702	-0.001018	0.002232	-0.001588
Std. Error	0.18	0.18	0.18	0.17	0.17	0.17
Upper Limit	9.836	9.894	10.018	9.537	9.607	9.699
Z test	53.28*	52.52*	53.03*	55.20*	54.45*	55.31*
	East Coast Zone					
Statistics	Early (ECZ)			Midlate (ECZ)		
N	323	323	323	200	200	200
Level of Significance (%)	10	5	1	10	5	1
Statistic	8.63	8.63	8.63	8.12	8.12	8.12
Bias	-0.00266	-0.00303	0.00439	-0.00128	-0.00083	0.00144
Std. Error	0.28	0.27	0.27	0.30	0.30	0.29
Upper	9.068	9.154	9.346	8.613	8.699	8.906
Z test	31.26*	31.69*	31.38*	27.20*	27.43*	27.56*
	North West Zone					
Statistics	Early (NWZ)			Midlate (NWZ)		
N	593	593	593	726	726	726
Level of Significance (%)	10	5	1	10	5	1
Statistic	8.22	8.22	8.22	8.13	8.13	8.13
Bias	-0.000358	0.0024688	0.0002342	0.000259	0.000272	0.000285
Std. Error	0.16	0.16	0.16	0.15	0.15	0.15
Upper Limit	8.490	8.545	8.639	8.369	8.402	8.521
Z test	50.97*	51.31*	51.53*	55.15*	55.74*	55.60*
	North Central Zone					
Statistics	Early (NCZ)			Midlate (NCZ)		
N	330	330	330	400	400	400
Level of Significance (%)	10	5	1	10	5	1
Statistic	9.22	9.22	9.22	8.81	8.81	8.81
Bias	0.000310	0.000323	0.000335	0.000360	0.000373	0.000386
Std. Error	0.28	0.28	0.28	0.24	0.24	0.24
Upper Limit	9.676	9.767	9.950	9.190	9.268	9.427
Z test	33.27*	32.73*	33.15*	37.22*	37.27*	37.15*

Table 5. Bootstrap statistic and Upper fiducial limit of sucrose of CV (%) for plant and ratoon crop of sugarcane based on all units

Statistics	Plant Crop (All Units)			Ratoon Crop (All Units)		
No. of experiments	3723	3723	3723	980	980	980
Level of Significance (%)	10	5	1	10	5	1
CV (%)	3.6971	3.6971	3.6971	3.6545	3.6545	3.6545
Bias	0.0007	-0.0006	-0.0007	0.0015	-0.0016	-0.0032
Upper limit	3.7692	3.778	3.8041	3.825	3.8205	3.8452
Z test Fisher)	86.99*	87.40*	85.77	45.22	43.87	44.35

Table 6. Bootstrap statistic and Upper fiducial limit of sucrose of CV (%) for Early and Mid-late crop of sugarcane based on all units

Statistics	Early (All Units)			Midlate (All Units)		
No. of experiments	2266	2266	2266	2437	2437	2437
Level of Significance (%)	10	5	1	10	5	1
CV (%)	3.7657	3.7657	3.7657	3.6162	3.6162	3.6162
Bias	-0.0008	0.0014	0.0004	-0.0009	0.0009	-0.0014
Upper limit	3.8591	3.8824	3.923	3.6907	3.712	3.7492
Z test Fisher)	65.49*	64.70*	66.41*	75.97*	76.29*	75.49*

*Significant at 5% level of significance (Table 2 to 7)

Table 7. Zone wise Upper fiducial limit of CV (%) for sucrose (%) by Bootstrap method

Statistics	Early (PZ)			Midlate (PZ)		
No. of experiments	1017	1017	1017	1102	1102	1102
Level of Significance (%)	10	5	1	10	5	1
Upper limit	4.6884	4.7056	4.7704	4.4646	4.4814	4.5235
Statistics	Early (ECZ)			Midlate (ECZ)		
No. of experiments	341	341	341	212	212	212
Level of Significance (%)	10	5	1	10	5	1
Upper limit	3.2829	3.3273	3.4217	3.7061	3.7389	3.8127
Statistics	Early (NWZ)			Midlate (NWZ)		
No. of experiments	589	589	589	723	723	723
Level of Significance (%)	10	5	1	10	5	1
Upper limit	2.8722	2.8852	2.9149	2.9384	2.945	3.0036
Statistics	Early (NCZ)			Midlate (NCZ)		
No. of experiments	318	318	318	400	400	400
Level of Significance (%)	90	95	99	90	95	99
Upper limit	3.7344	3.7784	3.8937	3.5586	3.5895	3.6827

It also indicated that upper limit of CV (%) is more in early crop than the mid-late. It may be due to the plot size of experiment. Plot size of mid-late trials are more than the early trials in sugarcane crop. In case overall experiments, Upper fiducial limit of CV (%) for sugarcane was estimated as 9.110, 9.061 and 9.037 at 1 %, 5 % and 10 % level of significance respectively (Table 5). At 5 % of level of significance, upper limit of CV(%) for early crop is 9.24, mid-late crop is 9.02%, plant crop 8.95% and ratoon crop is 9.76%. These limits are for cane yield to get the consistent and reliable results in varietal trails conducted in complete randomized block design under All India Coordinated Research Project on Sugarcane in both tropical and sub-tropical India. It is a good measure of the reliability of the experiment, which is, the smaller the CV values, the higher is the reliability of experiment (Gomez and Gomez, 1984; Steel and Torrie, 1980). Hence, CV is frequently provided by researchers, especially those in agricultural fields, in major publications. These results will be helpful for deciding to included the findings of experiments in recommendation of treatment for particular zone.

4.2 Upper limit of CV(%) for sucrose (%) in sugarcane experimentation

The present study was undertaken with the objective to know the extent of variability of sucrose (%) in experiments in different zones.For this, the data on standard error, coefficient of variation (CV) and critical difference (CD) of each experiment were collected for sucrose (%). Data of CV (%) of sucrose substantial departure from normality, a nonparametric method such that Bootstrap method was used to calculate the upper limit of CV(%), when normality assumption is not required.

Bootstrap bias is negligible for all the crop of sugarcane. As level of significance increases, the upper limit of CV (%) of sucrose decreases. It is inferred that

upper limit of CV (%) is more in ratoon crop than the plant crop because the gaps in sugarcane field is more in comparison to plant crop. Gaps occur due to death of clumps (plants) from pests and diseases. It also indicated that upper limit of CV (%) is more in early crop than the mid-late. It may be due to the plot size of experiment. Plot size of mid-late trials are more than the early trials in sugarcane crop. Upper fiducial limit of CV (%) for sucrose (%) of plant crop at 1 %, 5 % and 10 is around 3.6% of CV for all the three level of significance. Similarly for ratoon crop, it is around 3.5 at all the three level of significance (Table 5). In case overall experiments, Upper fiducial limit of CV (%) for sucrose (%) in sugarcane was estimated around 3.5 to 3.7 at 1 %, 5 % and 10 % level of significance respectively for both early and midlate crop. Upper limit of CV(%) for early crop and mid-late crop in Peninsular Zone is 4.7 and 4.48 at 5 % level of significance (Table 7). In case of East Coast Zone, upper limit of CV(%) of sucrose for early crop and mid-late crop is 3.73 and 3.33 at 5 % level of significance (Table 7). In case of North West Zone, upper limit of CV(%) of sucrose for early crop and mid-late crop is 2.88 and 2.95 at 5 % level of significance (Table 7). In case of North Central Zone, upper limit of CV(%) of sucrose for early crop and mid-late crop is 3.78 and 3.59 at 5 % level of significance (Table 7). These limits of CV(%) are for sucrose (%) to get the consistent and reliable results in varietal trails conducted in complete randomized block design under All India Coordinated Research Project on Sugarcane in both tropical and sub-tropical India. It is a good measure of the reliability of the experiment, which is, the smaller the CV values of CV, the higher is the reliability of experiment.

5. CONCLUSION

- Out of 5265 experiments, 91.23% had significant results.
- For cane yield, at 5 % of level of significance, upper limit of CV(%) for early crop is 9.24, mid-late crop is 9.02%, plant crop 8.95% and ratoon crop is 9.76%.
- Upper limits for CV in sugarcane experimentation is in between 3.5 to 4.5 % for sucrose (%) in sugarcane experimentation.
- It is inferred that upper limit of CV (%) is more in ratoon crop than the plant crop because the gaps in sugarcane field is more in comparison to plant crop. Gaps occurs in ratoon crop due to mortality of clumps (plants) from pests and diseases, imbalance of nutrient and negligible attitude towards ratoon crop.
- It also indicated that upper limit of CV (%) is more in early crop than the mid-late. It may be due to the plot size of experiment. Plot size of mid-late trials are more than the early trials in sugarcane crop. In case overall experiments.
- Upper limit of CV(%) for cane yield is also discussed at zonal level of All India Coordinated Research Project on Sugarcane.
- These limits are for cane yield and sucrose to get the consistent and reliable results in varietal trails conducted in complete randomized block design under All India Coordinated Research Project on Sugarcane in both tropical and sub-tropical India.

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REFERENCES

Darji, V.B., Bhatt, B.K. and Dixit, S.K. (2010). Variability in forage crop field experiments and yardstick thereof. *Agric. Sci. Digest*. **30**(4), 266-269.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. 2nd ed. New York: John Wiley and Sons, Inc.

Gupta, S.C. and Kapoor, V.K. (1986) : Fundamentals of Mathematical Statistics, Sultan Chand & Sons, New Delhi.

Liu, S. (2012). Confidenceintervalestimationforcoefficientofvariation. Master of Science (MS) Thesis, Department of Mathematics and Statistics at ScholarWorks @ Georgia State University

McKay, A.T.(1932). Distribution of the coefficient of variation and the extended t-distribution. *J. Roy. Statist. Soc.* B **95**, 695-698.

Motaka, G.N., Parmar, D.J. and Kalola, A.D. (2019). Variability study in Sorghum (Bhal and Costal Zone crop) field experiments and yardstick thereof. *GAU Research Journal,* **44**(3), 150-155.

Motaka, G.N., Darji, V.B., Parmar, D.J., Kalola, A.D. and Vaishnav, P.R. (2016). Variability study in medicinal and aromatic crop field experiments and yardstick thereof. *GAU Research Journal*, **41**(2), 103-109.

Motaka, G.N., Parmar, D.J. and Kalola, A.D. (2019). Variability study in Sorghum (Bhal and Costal Zone crop) field experiments and yardstick thereof. *GAU Research Journal*, **44**(3), 150-155, 2019.

Motaka, G.N., Parmar, D.J., Kalola, A.D., Darji, V.B. and Vaishnav, P.R. 2016. Study on variability in field experiments of Isabgul crop. *International Journal of Current Research*, **8**(3), 27195-27197.

Motaka, G.N., Darji, V.B., Parmar, D.J., Kalola, A.D. and Vaishnav, P.R. (2016) :). Study on Variability study in field experiments of Cotton Crop (Bhal and Costal Zone crop). *International Journal of Agricultural Science and Research*, **6**(3), 295-300.

Pearson, K. (1857-1936) - Biography - MacTutor History of Mathematics.

Patel, J.K., Patel, N.M. and Shiyani, R.L. (2001). Coefficient of variation in field experiments and yardstick thereof- An empirical study. *Current Science*. 81(9), 1163-1164.

Steel, R.G.D. and Torrie, J.H. (1980). Principles and Procedures of Statistics, 2nd ed. New York: McGraw-Hill.