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Variability study in medicinal and aromatic crop field experiments and yardstick there of

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ABSTRACT

The data on CV per cent for Medicinal and aromatic crop yield along with other details of 535 field experiments conducted during 1989-90 to 2011-12 at Main Research Station, Medicinal and Aromatic crop, Anand Agricultural University, Anand were collected and analyzed. Most of the experiments carried out in plant breeding (257) and Agronomy (216) disciplines. More than 80 % experiments carried out in RBD and about 23 % experiments of them have CV per cent higher than the fiducial limit (22.65 %). Treatments group 6-10, 11-15 and 16-20 showed lower CV per cent compared to overall average CV per cent. Plot size of the experiments 3 to 12 sq. mt. seems to be optimum plot size for medicinal and aromatic crops. Majority experiments were conducted with 3 and 4 replications in field experiments on Medicinal and Aromatic crops in which about 22 percent were having CV per cent > 22.65. The frequency distribution tables were prepared for various experimental factors. The upper fiducial limits (the yardstick) of CV per cent at 95% confidence based on non central't' distribution were worked out for accepting the results of Medicinal and aromatic crop experiments which emerged as 23%.

Key words : Fiducial limit, plot size, non central t distribution, experimental variability

Statistics are used to interpret data and sometimes to determine whether data are suspect. Most researchers are familiar with the use of the least significant difference (LSD) needed to separate two or more means. Another statistical measurement familiar to many scientists and taught in most basic statistics course is the coefficient of variation or the CV. This familiar measurement was created in the late 1800s as a measure of population variability. However, ever since it was tacitly promoted as a measure of experimental validity by (Snedecor and Cochran, 1967) its original purpose has been largely ignored. The experimental data provide information on controlled (treatment effect) and uncontrolled variation. The uncontrolled variation is expressed as experimental error, which could be quantified as an estimate called 'coefficient of variation (CV)'. In agricultural field experiments variation occurs due to uncontrolled factors such as soil heterogeneous, types of crop, climatic factors etc. and controlled factors such as field layout, treatments, replications, plot size etc. Therefore CV of field experiments varies with the situation. Lower magnitude of CV is the reflection of reliability (precision) of the experimental results. The acceptable range of CV advocated by various workers is based on the experience with very limited number of experiments. There need to develop a yardstick (critical value) for CV based on theory and also on a large number of experiments conducted under different situations. The present paper deals with this aspect. (Johnson and Welch, 1939) reported that for a normal distribution, the ratio of mean to standard deviation should be of the order of 3 or more. Further, they mentioned that 33% has often been stated as the permissible upper fiducial limit of CV. (Tyagi *et al.*,1973 and Patel *et al.*, 1978) pointed out that CV obtained for the crops under study was found to be considerably higher than those reported from the uniformity trials. They stated that the yardstick for accepting experimental results should be worked out using CV observed in the experiments rather than in the uniformity trials. (Bajpai and Nigam, 1980) suggested a working rule for deciding the value of *W2*

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(weight corresponds to precision of the experiment) and developed an index to evaluate agricultural field experiments statistically. (Gomez and Gomez, 1984) reported that CV varies greatly with the type of experiment, the crop grown and the character measured. They pointed out that the acceptable range of CV is 6 to 8 % for varietal trials, 10 to 12 % for fertilizer trials and 13 to 15% for insecticidal and herbicidal trials on rice. (Patel *et al.*, 2000), reported that the coefficient of variation in pulse experiments in RCBD exceeds 23 %, the experimental findings should not be considered for any purpose. (Snedecor and Cochran, 1967) they stated, "a knowledge of relative variation is valuable in evaluating experiments." They go on to say the coefficient of variation of the yield of hay is comparable to that of the yield of corn." Consequently, the CV has been used as a measure of validity for many types of agricultural experiments, from fertilizer experiments to crop performance trials. (Kendall and Stuart, 1977) they reported that CV was created as a measure of relative variability. (Aflakpui, 1995) states that "there is no such thing as a CV for an experiment, only for individual variates." However, a CV of 10 to 15% for yield in experiments is generally expected by most field crop researchers. (Cochran and Cox's, 1957) stated that "the coefficient of variation is often between 5% and 15%." The basis for the CV is the assumption that the variance increases as the size of the mean increases. (Allen *et al.*, 1978) reported a positive relationship for several crops, and (Gotoh and Osanai, 1959) reported a positive relationship for wheat. (Masood and Javed, 2003) reported based on the coefficients of variation the optimum plot sizes for maize trials were estimated to be (14.06 m^2) with square shape. (Khan and Mead, 1998) presented uniformity data from field trials for improving precision of agriculture field experiments in Pakistan. (Darji *et al.*, 2010), developed the yardstick of CV per cent for forage crop experiment at 95 % confidence based on non central 't' distribution were worked out for accepting the results of forage crop experiments which emerged as 14 %.

MATERIALS AND METHODS

The secondary data of CV per cent for yield character was compiled on Medicinal and aromatic crop of 535 field experiments conducted at Main Research Station, Medicinal and Aromatic crop, Anand Agricultural University, Anand during 1989-90 to 2011-12 in plant breeding, agronomy, plant protection, plant physiology and plant pathology disciplines on different Medicinal and aromatic crops viz. Aloe (1), Asalio (1), Ashwagandha (106), Basil (7), Bhumi amali (3), Cress (9), Dodi (21), Glycyrhiza (7), Isabgul (159), Kalmegh (34), Liquorice (19), Madhunashi (3), Periwinkle (10), Safed musali (99), Senna (44), Shankhpushpi (11) crops were utilized for the variability study. Information on plot size, number of treatments, replications, experimental design and disciplines were collected for each experiment.

The plot-wise yield data were subjected to statistical analysis and CV was estimated for individual experiment. The same was assumed as random variable in further analysis. CV is a function of square root of mean square (S) and mean ($\bar{X}$).

$$CV = \frac{S}{\bar{X}} \qquad (1)$$

The distributions of $\bar{X}$ and S have simple forms and Student's t distribution provides complete solution for testing the hypothesis or estimating fiducial limits relating to either m or s, singly. But t distribution cannot be used for $CV = \frac{s}{\bar{x}}$. (Mckay, 1932) used non-central t-distribution for providing fiducial limits of CV.

Let z be a quantity distributed normally about zero mean with unit standard deviation and let w be a quantity distributed independently as x^2, with degrees of freedom of x^2. Then, if t is defined by the equation:

$$t = \frac{Z + \delta}{\sqrt{W}} \qquad (2)$$

Where d is some constant, then t is distributed in a manner depending only on d and f. This distribution is a non central t-distribution. When d equals zero, the distribution is the familiar Student's t.

Let an estimate of V be $v = S/\bar{X}$ the sample coefficient of variation.

Now, one may write

$$\frac{\sqrt{n}}{v} = \frac{\sqrt{n}\bar{X}}{S} = \frac{\sqrt{n}(\bar{X} - \mu)}{\sigma} + \frac{\sqrt{n}\mu}{\sigma} + \frac{S}{\sigma} \qquad (3)$$

It appears from comparison with eq. (2) that $\frac{\sqrt{n}}{V}$ is distributed as non-central t with $f = (n-1)$ and $\frac{\sigma\sqrt{n}}{V}$. This distribution can be used for test of significance and for providing fiducial limits of V (*i.e.*, CV), as is done for μ. Since the objective was to work out the yardstick based on CV, the upper fiducial limit of CV using non-central t-distribution was estimated following the procedure given by (Johnson and Welch, 1939).

The procedure is briefly explained below. Let,

(1) $$CV = \frac{\sqrt{Error\ mean\ square}}{General\ mean}$$

n = number of treatments × number of replications in a given experiment, $f = n-1$ degrees of freedom.

Now, the upper fiducial limit of CV is,

$$CV_{UL} = \frac{\sqrt{n}}{\delta}(f,\ t_o\ \varepsilon)$$

Where, $$t_o = \frac{\sqrt{n}}{CV}$$

(2) Find $$Y = \left[1 + \frac{t_0^2}{2f}\right]^{-1/2}$$

or

$$Y' = \frac{t_0}{\sqrt{2f}}\left[1 + \frac{t_0^2}{2f}\right]^{-1/2}$$

According to whether $\frac{t_0}{\sqrt{2f}}$ is greater than or less than 0.75. Consider Y', if $\frac{t_0}{\sqrt{2f}}$ lies between – 0.75 and 0.75, otherwise consider Y.

(iii) If $f > 9$, calculate $\frac{12}{\sqrt{f}}$

(iv) Select desired probability level of confidence, *i.e.*, and obtain $\lambda(f, t_0, \varepsilon)$ from the table in (Johnson and Welch, 1939) interpolating with respect to the quantities obtained in (ii) and (iii).

(v) Calculate

$$\delta(f, t_0, \varepsilon) = t_0 - \lambda\left[1 + \frac{t_0^2}{2f}\right]^{-1/2}$$

In the present investigation, the yardstick of CV for field experiments was worked out using two concepts: (i) average upper fiducial limit of CV for each of the 535 medicinal and aromatic crops field experiments was worked out separately and then average of these upper fiducial limits was computed, and (ii) upper fiducial limit of CV based on average size of experiments, i.e., degree of freedom. The upper fiducial limit of 95 % and 90 % worked out using the theory of truncated t distribution as described by (Johnson and Welch, 1939).

RESULTS AND DISCUSSION

The results presented in (Table 1) revealed that mean CV per cent (17.28) and upper fiducial limit (22.65) of average value of all the discipline except for plant physiology and plant protection discipline, were below the average CV per cent. The experiments on plant protection and plant physiology showed large variation (average CV = 26.32 % and 32.51 %) respectively showed poor precision may be because of experimental requirements such as sample size, natural population of pests and diseases. Use of proper statistical tools may help to improve the precision of the results. More than 50% experiments of this disciplines had more than 22.65%.

The results presented in (Table 2) indicated that most of the experiments were carried out in RBD and FRBD and about 20 % of them had CV per cent higher than the fiducial limit worked out. This proportion was about 40 % in other designs (Except RBD and SPT).

Influence of number of treatments was also examined and results are given in (Table 3) according to different treatments group. More than 20 treatments in an experiment showed higher CV per cent than the overall average (17.28%).

Generally increased number of treatments in the experiments increases blocks (replication) size which increases error variance, affecting the precision of the results. Therefore, it is advisable to use such experimental designs (when treatment exceeds 16) which can help in controlling within block variation. Other means such as optimum plot size, more number of replications, proper site of the experiment etc. need to be considered. About 23 to 57 percent experiments showed higher CV per cent compared to the overall average CV per cent except the treatment group 11-15.

Table 1 Upper fiducial limit of CV per cent of experiments for different disciplines

Discipline	No. of experiments	Average C.V. %	Upper limit		Range		C.V. % > 22.65	
			(0.05)	(0.10)	(0.05)	(0.10)	No.of exp.	Proportion
Agronomy	216	16.81	22.04	20.69	5.23	3.88	45	0.20
Plant Breeding	257	16.31	21.24	19.97	4.93	3.66	53	0.20
Plant Physiology	15	26.32	37.55	34.50	11.23	8.18	8	0.53
Plant Protection	18	32.51	42.07	39.64	9.56	7.13	12	0.67
Plant Pathology	29	16.43	21.39	21.13	4.97	3.70	2	0.06
Average	535	17.28	22.65	21.26	-	-	-	-

Table 2 Upper fiducial limit of CV per cent of experiments for different design

Design name	No. of experiments	Average C.V. %	Upper limit		Range		C.V. % > 22.65	
			(0.05)	(0.10)	(0.05)	(0.10)	No.of exp.	Proportion
FRBD	89	16.56	20.40	19.46	3.84	2.90	17	0.19
RBD	427	17.46	23.21	21.71	5.75	4.25	100	0.23
SPT	14	16.51	20.34	19.41	3.84	2.90	2	0.14
Other	5	21.96	26.81	25.63	4.85	3.67	2	0.40
Average	535	17.28	22.65	21.26	-	-	-	-

Table 3 Upper fiducial limit of CV per cent of experiments for different treatments

Treatments	No. of experiments	Average C.V. %	Upper limit		Range		C.V. % > 22.65	
			(0.05)	(0.10)	(0.05)	(0.10)	No.of exp.	Proportion
Up to 5	129	17.38	24.25	24.41	6.87	5.03	30	0.23
6-10	221	17.22	22.93	21.45	5.71	4.23	52	0.23
11-15	116	16.97	21.13	20.11	4.16	3.14	19	0.16
16-20	56	16.99	20.52	19.67	3.53	2.68	14	0.25
21-25	00	–	–	–			0	00
26-30	7	24.11	27.84	26.99	3.74	2.88	4	0.57
>30	6	18.57	21.13	20.55	2.56	1.99	2	0.33
Average	535	17.28	22.65	21.26	-	-	-	-

The results presented in (Table 4) indicated that the average CV per cent for different plot size experiments were below the average CV per cent (17.28) in plot size 3 to 12 sq.mt. Beyond 12 sq.mt. plot size the proportion of CV per cent having higher CV per cent increased from 0.34 to 1.0. Therefore, plot size of 6 to 12 sq.mt. seems to be an optimum plot size for medicinal and aromatic crops. Therefore, this needs to be confirmed by plot technique study for different locations and crops.

Table 4 Upper fiducial limit of CV per cent of experiments for different plot size

Plot size (m^2)	No. of experiments	Average C.V. %	Upper limit		Range		C.V. % > 22.65	
			(0.05)	(0.10)	(0.05)	(0.10)	No.of exp.	Proportion
<3	35	18.91	24.70	23.20	5.78	4.29	13	0.37
3-6	169	15.61	20.37	19.15	4.76	3.54	26	0.15
6-9	138	16.81	22.13	20.76	5.33	3.96	32	0.23
9-12	128	16.67	21.60	20.33	4.93	3.65	26	0.20
12-15	23	21.00	27.97	26.16	6.97	5.16	8	0.34
15-18	38	23.57	31.15	29.19	7.58	5.62	14	0.36
18-21	2	15.47	18.34	17.63	2.86	2.17	0	00
21-24	0	–	–	–	–	–	0	00
>-24	2	42.08	63.84	57.66	21.76	15.58	2	1.00
Average	535	17.28	22.65	21.26	–	–	–	–

Table 5 Upper fiducial limit of CV per cent of experiments for different replications

Replication	No. of experiments	Average C.V. %	Upper limit		Range		C.V. % > 22.65	
			(0.05)	(0.10)	(0.05)	(0.10)	No.of exp.	Proportion
2	7	15.91	20.38	19.25	4.46	3.33	1	0.14
3	244	17.29	22.40	21.09	5.11	3.80	56	0.22
4	192	17.17	22.61	21.20	5.44	4.02	43	0.22
5	12	19.47	25.71	24.10	6.24	4.63	4	0.33
6	7	15.90	21.64	20.14	5.74	4.24	0	00
8	39	20.01	27.05	25.23	7.05	5.22	12	0.30
11	6	16.23	20.96	19.79	4.73	3.55	0	00
13	27	14.75	19.54	18.31	4.79	3.56	5	0.18
Average	535	17.28	22.65	21.26	–	–	–	–

As far as replications are concerned, the experiments conducted with 5 and 8 replications showed large variation and 33 and 30 per cent experiments showed CV > 22.65 respectively (Table 5). Analysis showed that majority experiments were conducted with 3 and 4 replications in field experiments on Medicinal and Aromatic crops in which about 22 percent were having CV per cent > 22.65.

Table 6 The average upper fiducial limit and yardstick for CV per cent for the experiments of Medicinal and Aromatic crops

Name of Crops	No. of experiments	Average C.V. %	Upper fiducial limit of C.V. %		Overall yardstick of C.V.%
			0.95	0.90	
Medicinal and Aromatic crop	535	17.28	22.65	21.26	23 %

The CV per cent data of 535 field experiments were used to fit non central 't' distribution to work out upper confidence limit of CV at 0.05 level of probability (Table 6). According to the upper fiducial limit of CV per cent at 95 percent confidence level of CV per cent was worked out to be 22.65 per cent. Thus the results suggested that about 23 percent CV per cent should be considered as a yard stick for Medicinal and Aromatic crop field experiments. These having CV per cent > 23 should be rejected for drawing valid scientific conclusion.

Table 7 Power of F-test as influence by CV per cent

Class C.V.%	No. of experiments	F-test		
		Significant	Not-Significant	Ratio
3.35-8.35	73	41	32	0.78
8.35-13.35	129	56	73	1.30
13.35-18.35	133	70	63	0.90
18.35-23.35	74	34	40	1.18
23.35-28.35	47	24	23	0.96
28.35-33.35	26	17	9	0.53
33.35-38.35	16	4	12	3.00
38.35-43.35	8	4	4	1.00
43.35-48.35	2	0	2	0.00
48.35-53.35	6	1	5	5.00
53.35-58.35	1	0	1	0.00
73.35-78.35	1	0	1	0.00
Total	516	251	265	1.06

The power of F test was examined with the not significant/ significant ratio of experiments (Table 7). The results revealed that the ratio consistently increased with the increase in CV of the experiments. It also indicated that the efficiency (of detecting difference in treatment means) of F-test decreased with the increase in CV of experiments. The average ratio was observed to be 1.06. The ratio for the class 13.35-18.35 % was almost equal to the average ratio which included 17.28 %, the average CV of all experiments results clearly showed that when the coefficient of variation in Medicinal and Aromatic crop field experiments exceeds 23 %, the experimental finding should not be considered for scientific purpose.

CONCLUSION

All the experiment results clearly showed that most of the Medicinal and Aromatic crops experiment carried out in plant breeding and agronomy disciplines, more than 80 % experiments conducted in RBD and, 6-10, 11-15 and 16-20 treatments group shows lower CV per cent as compared to overall average CV per cent. 3 to 12 sq.mt plot size seems to be optimum plot size and most of the experiments conducted with the 3 and 4 replications. When the coefficient of variation in Medicinal and Aromatic crops field experiments exceeds 23 %, the experimental finding should not be considered for any scientific purpose.

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