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## Study on Variability in Field Experiments of Bhal and Coastal Zone Crops and Development Yardstick

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### Abstract

The data on CV % for Bhal and coastal zone of Gujarat crops yield along with other details of 1117 field experiments conducted during 1989–90 to 2014–15 at Agriculture research station, Anand Agricultural University, Arnej and Dhandhuka center were collected and analyzed using BASIC programme. Most of the experiments carried out in plant breeding discipline (837) among the 21% experiments had greater than 18% CV followed by Agronomy (170) among 24% experiments had greater than 18% CV. More than 88% experiments carried out in RBD and about 23% experiments of them have CV % higher than the fiducial limit. According to different treatment, Treatments group 6–10, 16–20, 21–25 and 26–30 showed lower CV % compared to overall average CV %. Plot size and shape also play an important role in the precision of the experiment results. Therefore, plot size of the experiments 3 to 9 m<sup>2</sup> seems to be optimum plot size of bhal and coastal zone crops. All the experiments conducted in these regions had 2 to 6 replications. Out of them, most of experiments were conducted with 2 to 4 replications and Most of the experiments were conducted with 2, 3 and 4 replications. The experiments with 5 replications had high variability. The upper fiducial limits (the yardstick) of CV % at 95% confidence based on non-central 't' distribution were worked out for accepting the results of Bhal and coastal zone crops experiments which emerged as 18%.

**Keywords:** Experimental variability, crops, yardstick, CV %, fiducial limit

### 1. Introduction

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)'. Besides, fertility variation among experimental units (plots), the factors contributing toward uncontrolled variation are climatic and experimental. 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 is a 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; 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  $W_2$  (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 opined 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. No other information (except reviewed and reported here), is available in the literature on the yardstick of CV for field experiments on crops. (Patel et al., 2000), reported that the when 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, 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. The CV was created as a measure of relative variability by (Kendall and Stuart, 1977). (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. This expectation probably originated from (Cochran and Cox's, 1957) statement 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<sup>2</sup>) with square shape. (Khan and Mead, 1998) presented uniformity data from field trials for improving precision of agriculture field experiments in Pakistan. (Darjiet al., 2010), developed the yardstick of CV % 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%.

## 2. Materials and Methods

The secondary data on bhal and coastal zone crops yield of 1117 field experiments conducted at Agriculture research station, Anand Agricultural University, Arnej and Dhandhuka center during 1989–90 to 2014–15 in plant breeding, agronomy, entomology and soil science disciplines on different bhal and coastal zone crops viz. Dill seed (14), Paddy (2), Sun flower (4), Castor (7), Cotton (224), Cumin (12), Gram (188), Mustard (36), Pigeonpea (9), Safflower (116), Sesame (37), Sorghum (87), Spices (2), Vegetable (5) and Wheat (374) crops were utilized for the variability study. Information on plot size, number of treatments, replications, experimental design and disciplines was collected for each experiment. The plot-wise yield data were subjected to statistical analysis and CV was estimated for individual experiments. The same was assumed as random variable in further analysis. CV is a function of square root of mean square (S) and mean ( $\bar{X}$ ).

$$CV = \frac{S}{\bar{X}} \dots \dots \dots 1$$

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  $\chi^2$ , with degrees of freedom of  $\chi^2$ . Then, if  $t$  is defined by the equation:

$$t = \frac{Z + d}{\sqrt{w}} \dots \dots \dots 2$$

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  $v = S/$  the sample coefficient of variation.

Now, one may write

$$\frac{\sqrt{vn}}{v} = \frac{\sqrt{vn}\bar{X}}{v} = \frac{\sqrt{vn}(\bar{X} - \mu)}{\sigma} + \frac{\sqrt{vn}\mu}{\sigma} + \frac{s}{\sigma} \dots \dots \dots 3$$

It appears from comparison with eq. (2) that  $\frac{\sqrt{vn}}{v}$  is distributed as non-central  $t$  with  $f = (n-1)$  and  $\sigma \frac{\sqrt{vn}}{v}$ . This distribution can be used for test of significance and for providing fiducial limits of  $V$  (i.e. CV), as is done for  $\mu$ . 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,

(i)  $CV = \frac{\text{Error mean square}}{\text{General mean}}$

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

Now, the upper fiducial limit of CV is,

$$CV_{UL} = \frac{\sqrt{vn}}{\delta} (f, t_o, \epsilon)$$

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

$$\text{ii) Find } Y = \left[ 1 + \frac{t_o^2}{2f} \right]^{-1/2} \text{ or } Y = \frac{t_o^2}{\sqrt{2f}} + 1 + \frac{t_o^2}{2f}$$

According to whether  $\frac{t_o^2}{\sqrt{2f}}$  is greater than or less than 0.75.

Consider  $Y'$ , if  $\frac{t_o^2}{\sqrt{2f}}$  lies between  $-0.75$  and  $0.75$ , otherwise consider  $Y$ .

(iii) If  $f > 9$ , calculate

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

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

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 1117 bhal and coastal zone 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).

### 3. Results and Discussion

The results presented in Table 2 revealed that mean CV % (14.31%) and upper fiducial limit (17.83%) of average value

Crop/Location	Scientific name	Arnej	Dhandhuka	Average
Dill seed	( <i>Anethum graveolens</i> L.)	12.30 (12)	13.09 (2)	12.41 (14)
Paddy	( <i>Oryza sativa</i> L.)	8.90 (2)	-	8.90 (2)
Sun flower	( <i>Helianthus annuus</i> L.)	30.90 (1)	12.04 (3)	16.75 (4)
Castor	( <i>Ricinus communis</i> L.)	12.59 (7)	-	12.59 (7)
Cotton	( <i>Gossypium herbaceum</i> L.)	15.17 (59)	16.53 (165)	16.17 (224)
Cumin	( <i>Cuminum cyminum</i> L.)	13.16 (12)	-	13.16 (12)
Gram	( <i>Cicer arietinum</i> L.)	14.52 (131)	14.31 (57)	14.46 (188)
Mustard	( <i>Brassica juncea</i> L.)	16.14 (17)	17.10 (19)	16.65 (36)
Pigeon pea	( <i>Cajanus cajan</i> L.)	18.52 (9)	-	18.52 (9)
Safflower	( <i>Carthamus tinctorius</i> L.)	19.71 (61)	17.82 (55)	18.81 (116)
Sesame	( <i>Sesamum indicum</i> L.)	15.43 (8)	12.86 (29)	13.42 (37)
Sorghum	( <i>Sorghum bicolor</i> L.)	14.52 (48)	10.85 (39)	12.88 (87)
Spices	-	13.11 (2)	-	13.11 (2)
Vegetable	-	32.16 (5)	-	31.16(5)
Wheat	( <i>Triticum durum</i> L.)	14.11 (137)	10.34 (237)	11.72 (374)
Average		15.32 (511)	13.46 (606)	14.31 (1117)

Table 2: Upper fiducial limit of CV % for different disciplines of Bhal and Coastal zone crops

Discipline	No. of expt.	CV %	UL		Range		CV % >17.83	
			(0.05)	(0.10)	(0.05)	(0.10)	No. of expt.	Propo-rtion
Agronomy	170	15.14	18.94	17.98	3.81	2.85	42	0.24
Entomology	70	16.78	23.86	21.86	7.09	5.08	19	0.27
Pl.Breeding	837	13.93	17.12	16.34	3.19	2.40	184	0.21
Soil Science	40	14.50	17.44	16.72	2.94	2.22	10	0.25
Average	1117	14.31	17.83	16.95				

of all the discipline except for agronomy and entomology disciplines, were below the mean CV %. The experiments on agronomy and entomology showed large variation (average CV=15.14% and 16.78% 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 24% to 27% experiments of this disciplines had more than 17.83%.

The results presented in Table 3 indicated that most of the experiments were carried out in RBD and about 23% of them had CV % higher than the fiducial limit worked out. The proportion showed 0.15 to 0.27 in split plot and FRBD.

Influence of number of treatments was also examined and results are given in (Table 4). According to different treatments

group. <6, 11–15 and >30 treatments in an experiment showed higher CV % than the overall average (14.31%).

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 30) 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 28 to 39% experiments showed higher CV % compared to the overall average CV % except the treatment group 6–20, 16–20, 21–25 and 25–30.

The results presented in (Table 5) indicated that the average CV % for different plot size experiments were below the average CV % (14.31) in plot size <3, 3–6, 6–9, 12–15 and >31

Table 3 : Upper fiducial limit of CV % for different design Bhal and Coastal zone crops

Design	No. of expt.	CV %	UL		Range		CV % >17.83	
			(0.05)	(0.10)	(0.05)	(0.10)	No. of expt.	Propo-rtion
CRD	10	10.00	12.91	12.18	2.92	2.18	0	00
FRBD	47	15.96	19.42	18.59	3.46	2.62	13	0.27
RBD	989	14.36	18.00	17.08	3.64	2.72	231	0.23
Split plot	71	13.24	15.12	14.68	1.88	1.44	11	0.15
Average	1117	14.31	17.83	16.95				

Table 4: Upper fiducial limit of CV % for different treatments of Bhal and Coastal zone crops

Treatments	No. of expt.	CV %	UL		Range		CV % >17.83	
			(0.05)	(0.10)	(0.05)	(0.10)	No. of expt.	Propo-rtion
<6	51	20.28	30.20	27.34	9.93	7.07	20	0.39
6–10	299	13.31	17.37	16.33	4.06	3.02	58	0.19
11–15	314	14.92	18.27	17.45	3.35	2.53	88	0.28
16–20	199	13.86	16.60	15.95	2.74	2.08	48	0.24
21–25	112	13.26	15.69	15.11	2.43	1.86	19	0.16
26–30	124	14.12	16.49	15.93	2.37	1.82	16	0.12
>30	18	16.46	18.89	18.33	2.43	1.87	6	0.33
Average	1117	14.31	17.83	16.95				

Table 5: Upper fiducial limit of CV % for different plot size of Bhal and Coastal zone crops

Plot size (m <sup>2</sup> )	No. of expt.	CV %	UL		Range		CV % >17.83	
			(0.05)	(0.10)	(0.05)	(0.10)	No. of expt.	Propo-rtion
<3	4	13.26	15.75	15.15	2.49	1.89	1	0.25
3–6	89	13.96	17.20	16.40	3.24	2.44	18	0.20
6–9	397	13.58	16.42	15.74	2.85	2.16	82	0.20
9–12	223	14.74	18.59	17.62	3.85	2.88	52	0.23
12–15	136	13.96	17.22	16.42	3.26	2.46	29	0.21
15–18	120	15.11	19.87	18.58	4.76	3.47	30	0.25
18–21	127	15.81	20.03	18.96	4.22	3.15	40	0.31
24–31	14	16.30	21.10	19.89	4.80	3.59	3	0.21
>31	7	9.84	13.04	12.21	3.20	2.37	0	00
Average	1117	14.31	17.83	16.95				

sq.mt. The average CV % for different plot size experiments were higher the average CV % (14.31) in plot size 9–12, 15–18, 18–21 and 24–31 m<sup>2</sup>. The proportion of CV % having higher CV % increased from 0.23 to 0.31 therefore, plot size of 3 to 9 m<sup>2</sup> seems to be an optimum plot size for Bhal and coastal zone crops. Therefore, this needs to be confirmed by plot technique study for different locations.

As far as replications are concerned the most of the experiments conducted with 2, 3 and 4 replications. Among the experiments conducted with 3, 4 and 5 replications

showed large variation 23, 24 and 41% experiments showed CV >14.31% respectively (Table 6).

The CV % data of 1117 field experiments were used to fit non central 't' distribution and to work out upper confidence limit of CV at 0.05 level of probability. According the upper fiducial limit of CV % at 95% confidence level of CV % was worked out to be 17.83%. Thus the results suggested that about 18 percent CV % should be considered as a yard stick for Bhal and coastal zone crop field experiments. These having CV % >18 should be rejected for drawing scientific conclusion (Table 7).

Table 6: Upper fiducial limit of CV % for different replications of Bhal and Coastal zone crops

Replication	No. of expt.	CV %	UL		Range		CV % >17.83	
			(0.05)	(0.10)	(0.05)	(0.10)	No. of expt.	Proportion
2	204	12.36	15.43	14.67	3.07	2.30	32	0.15
3	385	14.70	18.18	17.32	2.48	2.63	92	0.23
4	499	14.52	17.83	17.01	3.32	2.50	124	0.24
5	12	31.97	52.16	45.96	20.20	13.99	5	0.41
6	24	11.80	15.35	14.45	3.55	2.64	9	0.37
Mean	1117	14.31	17.83	16.95				

Table 7: The average upper fiducial limit and yardstick for CV % for the experiments of Bhal and Coastal zone crops

Name of crop	No. of expt.	Mean CV %	Upper fiducial limit of CV %		Overall yardstick of CV%
			0.95	0.90	
Bhal and coastal zone crops	1117	14.31	17.83	16.95	18 %

The power of F test was examined with the non significant/significant ratio of experiments (Table 8). 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

Table 8: Power of F-test as influence by CV %

Classes CV %	No. of Exp.	F-test		
		Significant	Non-significant	Ratio
1.0–10.0	408	369	39	0.11
11.0–21.0	545	400	145	0.36
21.0–31.0	122	56	66	1.18
31.0–41.0	35	12	23	1.92
41.0–51.0	3	0	3	0.00
51.0–61.0	2	1	1	1.00
61.0–71.0	0	0	0	0.00
71.0–81.0	0	0	0	0.00
81.0–91.0	0	0	0	0.00
91.0–100	2	0	2	0.00
Total	1117	838	279	0.33

observed to be 0.33. The ratio for the class 11.0–21.0% was almost equal to the average ratio which included 14.3%, the mean CV of all experiments.

#### 4. Conclusion

Most of experiments of plant breeding discipline were

conducted in RBD. Number of treatments 6–10, 16–20 and 21–25 showed lower CV % as compared to overall average CV %. Size of plot 3 to 9 m<sup>2</sup> seems to be optimum plot size and most of the experiments conducted with the 3, 4 and 5 replications. When the coefficient of variation in Bhal and coastal zone crops field experiments exceeds 18%, the experimental finding should not be considered for any scientific purpose.

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