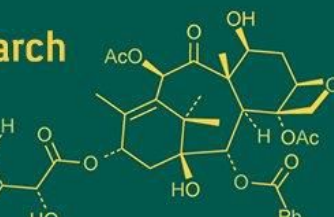
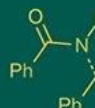
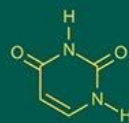


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Assessing the efficiency of variance balance design and row column design in comparison to randomized complete block design

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Abstract

Plant breeding programs rely on effective mating and environmental designs to achieve successful outcomes. The aim is to provide most suitable environmental design considering estimation accuracy, required replication levels, and experimental area requirements by comparing three environmental designs namely, RCBD, RCD and VBD. Fifteen diallel crosses were evaluated using the three designs, and observations were recorded for YPP, NFP, AFW, FL and FG. The results showed significant differences among the F₂ progeny for all traits across the three environmental designs, indicating substantial genotypic variation. The average relative efficiency of VBD over RCBD and RCD was 192.53% and 145.71%, respectively, while RCD showed a relative efficiency of 135.87% over RCBD. The results revealed that RCD and VBD were efficient designs compared to RCBD, with VBD showing the highest gain in efficiency. The significance of *gca/sca* estimates varied among the designs, suggesting that the choice of experimental design influenced the precision of the estimates. In conclusion, VBD proved to be the most suitable environmental design for diallel method-IV experiments in brinjal crops, offering improved estimation accuracy and requiring less experimental area compared to other designs. These findings contribute to enhancing the design and execution of plant breeding programs, leading to improved breeding outcomes.

Keywords: Efficiency comparison; variance balanced design; randomised complete block design; row column design, Diallel method-IV

Introduction

Plant breeding programmes rely on effective mating and environmental designs to achieve successful outcomes. Among environmental designs, Randomized Complete Block Design (RCBD) is widely used but assumes one-way soil fertility heterogeneity in experimental units. In diallel experiments with an increasing number of parents, two-way heterogeneity in soil fertility becomes a challenge, necessitating alternative approaches. In this context, Incomplete Block Designs offer potential solutions. Row Column Design, proposed by Gupta and Choi (1998) ^[4] and Varghese *et al.* (2015) ^[10], arranges crosses in a manner where each row and column contain the crosses at most once, enabling estimation of general combining ability (GCA) and specific combining ability (SCA) effects. However, this design requires a greater number of replications. On the other hand, Sharma and Fanta (2010) ^[9] proposed Variance Balanced Design, which requires less experimental area while also providing estimation for *gca* and *sca* effects.

This study compares three environmental designs: Randomized Complete Block Design, Row Column Design, and Variance Balanced Design, in evaluating the performance of the segregating generation (F₂) generated using diallel method-IV. Through this comparative analysis, we aim to provide insights into the most suitable environmental design for diallel method-IV experiments, considering factors such as estimation accuracy, required replication levels, and experimental area requirements. The findings of this research contribute to improving the design and execution of plant breeding programmes, ultimately enhancing the quality and efficiency of breeding outcomes.

Materials and Methods

The study was conducted at the Agronomy Farm, Anand Agricultural University, Anand during the Late *Kharif* season of 2021.

The F₁ crosses were generated at Main Vegetable Research Station (MVRS), AAU, Anand and subsequent selfing was performed to obtain F₂ populations at the Agronomy Farm, AAU, Anand, in the Late Kharif season of 2020. The generated material was then evaluated during the Late Kharif season of 2021 at the same location.

Fifteen diallel crosses were produced using the six brinjal genotypes, namely GOB1, JBGR1, KS331, AB 15-06, AB 17-17, and AB 17-28. The F₂ populations derived from these crosses were evaluated using three environmental designs, viz., Randomized Complete Block Design (RCBD), Row Column Design (RCD), and Variance Balanced Design (VBD). Each plot consisted of three rows, with eight plants in each row, spaced at 90 cm × 60 cm (inter-row × intra-row). The observations were recorded for yield per plant (YPP), number of fruits per plant (NFP), average fruit weight (AFW), fruit length (FL), and fruit girth (FG) from eight randomly selected F₂ plants in each plot. The data obtained from the field study were analyzed to assess the performance and variability of the F₂ populations derived from the diallel crosses.

Design	Crosses	Replication	Area Required
VBD	15	2	566.5 m ²
RCD	15	6	1614 m ²
RCBD	15	4	1048 m ²
# The mentioned area is for F ₂ population. For evaluation of F ₁ population required area can be three times lesser as it requires less population to be studied as compared to F ₂ population			

Statistical Analysis

Statistical analysis was performed on the data obtained from all three environmental designs using appropriate methods given below:

Design	Statistical Model	Reference
RCBD	$Y_{ijk} = \mu + r_k + c_{ij} + \varepsilon_{ijk}$	Griffing (1956) [13]
RCD	$Y_{kl(m)} = \mu + \tau_{ij(m)} + \alpha_k + \beta_l + \varepsilon_{kl(m)}$	Varghese <i>et al.</i> (2015) [10]
VBD	$y = \mu l + X\tau + D\beta + \varepsilon$	Sharma and Fanta (2010) [9]

Relative efficiency (RE) of Experimental Designs using Error mean Square (EMS) was calculated using formula Ghosh and Ahuja (2017) given below:

$$RE\% = \frac{V(\hat{\tau}_i - \hat{\tau}_j)_{\text{reference}}}{V(\hat{\tau}_i - \hat{\tau}_j)_{\text{test}}} \times 100$$

$$V(\hat{\tau}_i - \hat{\tau}_j)_{\text{RCBD}} = \frac{2}{r} \sigma_{\text{RCBD}}^2$$

$$V(\hat{\tau}_i - \hat{\tau}_j)_{\text{RCD}} = \frac{2}{r} \times \frac{\sigma_{\text{RCD}}^2}{\text{Efficiency factor}}$$

$$V(\hat{\tau}_i - \hat{\tau}_j)_{\text{VBD}} = \frac{2}{\theta} \sigma_{\text{VBD}}^2$$

$$\theta = \frac{n-b}{v-1} \quad [n = \text{number of observations, } v = \text{number of crosses, } b = \text{blocks}]$$

$$r = \text{Number of replications in randomized complete block design}$$

$$\sigma_{\text{RCBD}}^2, \sigma_{\text{RCD}}^2, \sigma_{\text{V}}^2 = \text{Error mean square of RCBD, RCD and VBD, respectively}$$

Relative Efficiency using SEM and CV was calculated by taking ratio of SEM and CV of reference design (RCBD) to test design (VBD and RCD). The gain in efficiency was computed using formula mentioned here:

$$\text{Gain in efficiency} = RE - 100$$

The Chi square (χ^2) test is used to test dependency of sign and significance of *gca* and *sca* effects of traits studied on environmental designs viz., RCBD, RCD and VBD (Gupta and Kapoor, 2020).

Results and Discussions

The results (Table 1) indicated significant or highly significant differences among the F₂ progeny for all studied traits across the three environmental designs. Furthermore, the analysis revealed substantial genotypic variation in the traits among the crosses. Notably, the *gca* effects exhibited high significance across all three experimental designs for YPP, NFP, AWF and FL. Fruit girth yielded highly significant variation in RCD, significant variation in VBD and non-significant in RCBD. The *sca* effects demonstrated highly significant or significant differences among crosses for YPP, AFW, FL, and FG across all experimental designs. In the case of NFP, significant differences were observed among *sca* effects in the RCBD. However, the *sca* effect did not exert significant differences in NFP in the RCBD and RCD designs.

The results indicate a consistent trend of error variance, $\sigma_{\text{RCBD}}^2 > \sigma_{\text{RCD}}^2 > \sigma_{\text{VBD}}^2$ for all studied traits. This trend indicated that the incomplete block designs RCD and VBD were helpful in lowering variation caused by uncontrolled sources like soil fertility, entering in the data (results), as compared to RCBD. In this respect VBD was better than RCD. Replication effect in RCBD and row and column effect in RCD were found non-significant while in case of VBD block effects were found highly significant for all the character studied. The resultant information (Table 1) revealed that the area used to accommodate RCBD and RCD (in general) was uniform in fertility variation. On other side blocking within replication (VBD) had helped in lowering experimental error. The results obtained from Bartlett's test showed heterogeneity in error variances for YPP, NFP and AFW.

Lower error mean square provides higher precision for estimates. It could be generalized that error estimates calculated through ANOVA can be used to judge the precision (efficiency) of the field experimental designs.

Considering error mean square (EMS), the average relative efficiency (Table 2) of Variance Balanced Design (VBD) in comparison to RCBD and RCD was 152.70, 147.83 percent whereas the relative efficiency of RCD over RCBD was 220.80 percent. Relative efficiency of VBD was 142.80 and 214.00 percent over RCBD and 102.99 and 186.11 percent over RCD considering SEM and CV percent, respectively. Considering SEM and CV (%), relative efficiency of RCD over RCBD was 139.73 and 115.18 percent, respectively. Overall, the gain in efficiency was 92.53 and 45.71 percent for VBD over RCBD and RCD, whereas it was 35.87 for RCD over RCBD.

Results revealed that Incomplete Block Designs viz., RCD and VBD were efficient as compared to RCBD. VBD was the best from gain in efficiency view point followed by RCD in comparison to RCBD for field experiments on F₂s of brinjal crops.

Present findings are in line to those reported by Yates (1936) [11] who used pseudo factorial arrangement; Goulden (1937) [2] who used uniformity trials data; Yau (1997) [12] who used lattice design; Masood *et al.* (2008) [7]; Khan *et al.*

(2015) [5]; Kumar *et al.* (2020) [6] who used alpha lattice design and Popat (2021) [8] who used Variance Balanced Design (VBD). All these researchers had worked out efficiency in relation to RCBD. They found IBD as efficient design.

The χ^2 test for the frequency distributions (Table 3) for sign and significance of *gca/sca* estimates showed that the sign (positive/negative) of *gca/sca* estimates were independent of experimental designs used in the comparisons, whereas significance of the estimates were not independent of experimental designs.

Results revealed a significant χ^2 estimate while comparing *gca* estimates between RCBD and VBD, indicating statistical significance. Furthermore, the χ^2 test also found significant while comparing the *sca* effect of RCBD with RCD and VBD. The number of significant *gca* and *sca* estimates (Table 3) were high in both the incomplete block designs compared to RCBD. Here also VBD proved better than RCD. The number of non-significant *gca* and *sca* estimates were high in RCBD. Results indicated that the in-built parameters of the field experimental designs influence(s) the precision of the estimate(s). This holds true for VBD and RCD which proved better than RCBD.

Table 1: Analysis of Variance (mean sum of square) for designs and Bartlett's test for homogeneity of error variances

Design	Source	df	YPP	NFP	AFW	FL	FG
RCBD	Rep	3	0.04	3.77	257.76	0.36	0.87
	Crosses	14	0.49**	74.16**	2535.58**	6.73**	24.15**
	<i>gca</i>	5	0.83**	154.84**	3944.95**	7.80**	18.22
	<i>sca</i>	9	0.30*	29.33	1752.60**	6.13**	27.44**
	Error	12	0.11	24.98	517.78	1.1	7.48
RCD	Column	5	0.31*	11.73	193.61	0.7	1.48
	Row	14	0.14	20.01	515.09	1.54	2.99
	Crosses	14	0.69**	60.31*	2878.32**	10.30**	33.22**
	<i>gca</i>	5	1.23**	123.26**	5045.51**	13.32**	28.33**
	<i>sca</i>	9	0.38**	25.33	1674.32**	8.63**	35.93**
	Error	56	0.11	19.29	362.22	0.84	4.96
VBD	Block	5	0.12**	32.45**	729.51**	5.84**	18.3**
	Crosses	14	0.21**	20.7**	736.8**	6.73**	13.96**
	<i>gca</i>	5	0.22**	28.42**	853.17**	6.98**	8.65*
	<i>sca</i>	9	0.20**	16.43*	672.16**	6.59**	16.91**
	Error	10	0.02	3.98	54.63	0.7	2.55
Bartlett's test			6.86**	9.05**	12.46**	0.73 ^{NS}	3.66 ^{NS}

Table 2: Relative efficiency of VBD over RCBD on basis of different parameters for character studied

Character	Over RCBD						Over RCD		
	RCD			VBD			VBD		
	EMS	SEm	CV (%)	EMS	SEm	CV (%)	EMS	SEm	CV (%)
YPP	116.70	121.43	103.79	235.71	154.55	214.46	202.04	127.27	206.63
NFP	151.12	139.66	113.27	268.99	164.47	240.72	178.04	117.76	212.53
AFW	166.82	146.46	120.56	406.20	201.42	306.64	243.56	137.52	254.34
FL	152.82	140.54	115.42	67.35	81.25	138.15	44.08	57.81	119.69
FG	176.04	150.55	122.88	125.75	112.30	170.02	71.45	74.59	138.37
Avg. RE	152.70	139.73	115.18	220.80	142.80	214.00	147.83	102.99	186.11
Avg. gain	52.70	39.73	15.18	120.80	42.80	114.00	47.83	2.99	86.11
Avg. gain	35.87			92.53			45.71		

RE = Relative Efficiency

Table 3: Frequency distribution of *gca* and *sca* values in different designs

Sign				Significance			
Particulars	RCBD	RCD	VBD	Particulars	RCBD	RCD	VBD
gca effects							
Positive	14	14	14	Significant	12	17	23
Negative	16	16	16	Non-significant	18	13	7
χ^2 test v/s RCBD	-	0.00 (1.00)	0.00 (1.00)	Individual χ^2 test v/s RCBD	-	1.67 (0.19)	8.30** (0.003)
Individual χ^2 test v/s RCD	-	-	0.00 (1.00)	Individual χ^2 test v/s RCD	-	-	2.70 (0.10)
				Combined χ^2 test	8.29*(0.015)		
sca effects							
Positive	39	41	34	Significant	18	32	44
Negative	36	34	41	Non-significant	57	43	31
Individual χ^2 test v/s RCBD	-	0.11 (0.74)	0.67 (0.41)	Individual χ^2 test v/s RCBD	-	5.88* (0.015)	18.59** (0.0001)
Individual χ^2 test v/s RCD	-	-	1.31 (0.25)	Individual χ^2 test v/s RCD	-	-	3.84* (0.05)
				Combined χ^2 test	18.56** (0.0001)		
Figures in parentheses are p values							

Figures in parentheses are p values

Conclusion

Findings revealed that VBD outperformed both RCBD and RCD, with an average relative efficiency of 192.53% over RCBD and 145.71% over RCD. This indicates that VBD provides improved estimation accuracy and efficiency in terms of resource utilization. Furthermore, the significance of general combining ability (*gca*) and specific combining ability (*sca*) estimates varied among the designs, emphasizing the influence of experimental design on the precision of these estimates. It suggests that VBD is the most suitable environmental design for diallel method-IV experiments in brinjal crops. This design offers improved estimation accuracy, requires less experimental area and effectively handles the challenges of soil fertility heterogeneity. The outcomes of this research contribute valuable insights to the field of plant breeding, providing guidance for researchers and breeders in selecting appropriate environmental designs for diallel method-IV experiments. Implementing VBD in plant breeding programs can enhance the design and execution of experiments, leading to improved breeding outcomes.

References

1. Ghosh DK, Ahuja S. On variance balanced designs. *Journal of Modern Applied Statistical Methods*. 2017;16:124-137.
2. Goulden CH. Efficiency in field trials of pseudo-factorial and incomplete randomized block methods. *Canadian Journal of Research*. 1937;15:231-241.
3. Gupta SC, Kapoor VK. *Fundamentals of Mathematical Statistics*. New Delhi: Sultan Chand & Sons; 2020.
4. Gupta S, Choi KC. Optimal row-column designs for complete diallel crosses. *Communications in Statistics - Theory and Methods*. 1998;27:2827-2835.
5. Khan MI, Ali SA, Khan M, Ullah K, Ullah R, Khatak SI. Comparative efficiency of alpha lattice design and complete randomized block design in wheat, maize and potato field trials. *Journal of Resources Development and Management*. 2015;11:115-117.
6. Kumar A, Bharti B, Kumar J, Bhatia D, Singh GP, Jaiswal JP, Prasad R. Improving the efficiency of wheat breeding experiments using alpha lattice design over randomized complete block design. *Cereal Research Communications*. 2020;48:95-101.
7. Masood MA, Farooq K, Mujahid Y, Anwar MZ. Improvement in precision of agricultural field experiments through design and analysis. *Pakistan Journal of Life and Social Sciences*. 2008;6:89-91.
8. Popat R. Comparison of randomized complete block design and variance balanced design for diallel crosses [Published Doctoral Thesis]. Anand Agricultural University; 2021.
9. Sharma MK, Fanta S. Variance balanced designs for complete diallel cross. *Journal of Agricultural Biotechnology and Sustainable Development*. 2010;2:56-60.
10. Varghese C, Varghese E, Jaggi S, Prasad R. Row-column designs for diallel cross experiments with specific combining abilities. *Journal of the Indian Society of Agricultural Statistics*. 2015;69:201-225.
11. Yates F. A new method of arranging variety trials involving a large number of varieties. *The Journal of Agricultural Science*. 1936;26:424-455.
12. Yau SK. Efficiency of alpha-lattice designs in international variety yield trials of barley and wheat. *The Journal of Agricultural Science*. 1997;128:5-9.
13. Griffing BR. Concept of general and specific combining ability in relation to diallel crossing systems. *Australian journal of biological sciences*. 1956;9(4):463-493.