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THE USE OF DUPLICATED AUGMENTED DESIGNS FOR CHICKPEA (*CICER ARIETINUM* L.) LINES TRIALS

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ABSTRACT

A duplicated augmented design (DAD), which consisted of two sets of an Augmented Design (AD) with randomization of treatments and one fixed and two random checks was compared with a Randomized Complete Block Design (RCBD) and an Incomplete Block Design (IBD) both in simulation models and chickpea field experiments The results suggest that the IBD has advantages over the DAD because it is less input demanding and more efficient Consequently also the usefulness of the frequently used unreplicated AD with regular control is questioned

The use of AD's was proposed by Federer (1961) for testing a large number of varieties and breeding lines In its simplest form, as we often used it, the AD consists of blocks of plots, flanked by what are called regular controls Sometimes, one or more random controls are added to the test plots in a block The design enables adjustment for block effects, using the controls as weights Adjustment by means of control plots was proposed earlier by Yates (1936) through weighting the relative distances from the test plots The presence of regular control plots in a series of test plots is most pleasing to the breeder s eye, but they add to cost and their use has been questioned by various authors Baker and Mckenzie (1967) concluded from their experiments that there had been no advantage from control plots as they increased the experimental error Adjustment for fertility gradients within blocks was initially suggested by Papadkis (1937) and later its use reviewed by Bartlett (1978) and Wilkinson *et al* (1987) who advocated an adjustment based on nearest neighbour plot values Townley-Smith and Hardy (1973) also favoured the use of moving means instead of control plots for adjustments as it is simple and effective in reducing the error variance Subsequently, Binns (1987) showed evidence of effective adjustment by using neighbouring plots especially when fertility gradients were present

The AD, although frequently used by us for unreplicated trials, can also be adopted in replicated experiments We have been using it in duplicate form for international chickpea variety testing, as the design is attractive for its simplicity, but information on its efficiency is lacking (Lin *et al*, 1983) The objective of the present study was to compare the effectiveness of the DAD we use with that of other statistical designs, both in simulation models and field experiments

MATERIALS AND METHODS

We used simulation models to compare DADs with the commonly used RCBDs and IBDs, and we tested these designs also in two field experiments conducted at ICRISAT Center during the postrainy season of 1986-87.

Simulation models

The simulation models used the matrix shown in Figure 1 and data were generated in accordance with the formulas given below. We made use of a program developed in GENSTAT 4.04, a copy of which can be obtained from the Statistics Unit of ICRISAT. The following parameters were introduced.

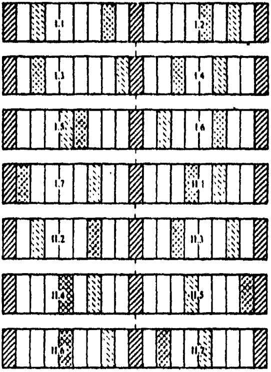

Fig. 1. Matrix for simulation models and layout of field experiment A

I.1 - I.7: Rep. I, blocks 1-7, Incomplete Block Design
II.1 - II.7: Rep. II, blocks 1-7, Incomplete Block Design
Fixed check, Random checks

- m (M) : $\mu = 1$
- Treatment effect (T) : $\tau_i = (\tau_i = 0)$
- Replication effect (p_i) : $P_1 = -5$, $P_2 = +5$
- Block effect within n (β_j) : $\beta_1 = -3$, $\beta_2 = -2$, $\beta_3 = -1$, $\beta_4 = 0$, $\beta_5 = +1$, $\beta_6 = +2$, $\beta_7 = +1$
- Gradient effect (γ_g) : G. Zero : gradient effect zero
  G. one : $\gamma_L = -0.4$, $\gamma_1 = -0.3$, $\gamma_2 = -0.2$, $\gamma_3 = -0.1$, $\gamma_4 = 0.0$, $\gamma_5 = +0.1$, $\gamma_6 = +0.2$, $\gamma_7 = +0.3$, $\gamma_R = +0.4$
  γ_L = gradient effect on left fixed control plot,
  γ_R = gradient effect on right fixed control plot;
  γ_g = gradient effect on gth test plot from left
- Control correction (K) : 1. *Fixed control adjustment, ignoring distance to fixed control plots*

$$Y'_{ijg} = Y_{ijg} - k_1$$

Y'_{ijg} = adjusted yield of plot l at place g in block j of replication i (Y_{ijg}) .

$$\frac{Y_{ijL} + Y_{ijR}}{2} - \frac{\Sigma(Y_{i,L} + Y_{i,R})}{14}$$

Y_{ijL} : Yield control plot at left (L) in block j of replication i

Y_{ijR} : Yield control plot at right (R) in book j of replication i

2. *Fixed control adjustment, weighting distance to fixed control plots*

$$Y'_{ijg} = Y_{ijg} - k_2$$

$$k_2 = d_{ijR} Y_{ijL} + d_{ijL} Y_{ijR} - \frac{\Sigma(Y_{i,L} + Y_{i,R})}{14}$$

d_{ijL} = relative distance of Y_{ijg} to Y_{ijL}
d_{ijR} = relative distance of Y_{ijg} to Y_{ijR}

3. *Random control adjustment*

$$Y'_{ijg} = Y_{ijg} - k_3$$

Y_{ijr1} = Yield of random check 1 in block j of replication i

Y_{ijr2} = Yield of random check 2 in block j of replication i

4. All control adjustment, ignoring distance to control plots

$Y'_{ijg} = Y_{ijg} - k_4$

$$k_4 = \frac{Y_{...} + Y_{...} + Y_{...} + Y_{...}}{4} - \frac{\Sigma\,(Y_{i,L} + Y_{i,R} + Y_{i,R1} + Y_{i,R2})}{28}$$

5. All control adjustment, weighting distance to fixed control plots

$Y'_{ijg} = Y_{ijg} - k_5$

$$k_5 = \frac{d_{ijL}\,Y_{ijL} + d_{ijR}\,Y_{ijR} + 0.5\,(Y_{ijR1} + Y_{ijR2})}{2} - \frac{\Sigma\,(Y_{i,L} + Y_{i,R} + Y_{i,R1} + Y_{i,R2})}{28}$$

- Error effect (E_i) : $\varepsilon_{ijl} \sim N(0,1)$; C.V. = 5%

The plot yields are represented by the formula : $Y_{ijg} = \mu + \rho_i + \beta_j + \tau_{ig} + \gamma_g + \varepsilon_{ijl}$, and the different statistical analyses followed and plot yield data analysed were as shown below :

Model I : RCBD : Y_{ijg}

Model II : DAD with fixed control adjustment, ignoring distance to fixed control plots (DAD – k_1) : $Y_{ijg} - k_1$

Model III : DAD with fixed control adjustment, weighting distance to fixed control plots (DAD – k_2) : $Y_{ijg} - k_2$

Model IV : DAD with random control adjustment (DAD – k_3) : $Y_{ijg} - k_3$

Model V : DAD with all control adjustment, ignoring distance to fixed control plots (DAD - k_4) : $Y_{ijg} - k_4$

Model VI : DAD with all control adjustment, weighting distance to fixed control plots (DAD – k_5) : $Y_{ijg} - k_5$

Model VII : IBD : Y_{ija}

For each model 25 computer runs were completed and the General Mean (GM) the Standard Error of the Difference (SED) and the Coefficient of Variation (CV) were recorded. We did the modeling exercise separately for the two situations : without fertility gradient (G. zero) and with gradient (G. one).

Field experiments

Two kinds of experiments were conducted.

Experiment A

A layout following the simulation models is shown in Fig. 1. The experiment was sown on 21.10.1986 in an irrigated deep vertisol (Al) and on 26-10-1986 in an unirrigated deep vertisol (A2). Each plot had 4 rows of 4 m length of which the outer 0.25 m, and the outer 2 rows were discarded at harvest. The plant spacing was 30 cm × 10 cm. There were 7 incomplete blocks, each block had 6 test entries, 2 random checks, and a fixed check on both sides of the blocks. The trial had 2 replications. Harvesting was done on 10-2-1987 for Al and on 17-2-1987 for A2.

Experiment B

The layout is shown in Figure 2. The experiment was sown on 21-10-1986 in field BP 6 B. Field, plot size, spacing and harvesting date were as for experiment Al. The DAD had 10 test entries, and 2 random checks per block and each block was flanked

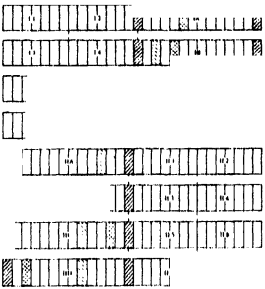

Fig. 2. Layout of field experiment II

I.1 - I.7 : Rep. I, blocks 1-7, Incomplete Block Design
II.1 - II.7 : Rep. II, blocks 1-7, Incomplete Block Design
I.A - I.D : Rep. I, blocks A-D, Augmented Design
II.A - II.D : Rep. II, blocks A-D, Augmented Design
Fixed check, Random checks

by fixed checks. The trial had 2 replications and 4 blocks in each replication. The IBD contained the same 40 test entries, and 3 checks of the DAD and additionally six checks as dummy entries.

The test plot yield data of the DAD were adjusted like the data of the simulation models. We calculated standard errors of differences, coefficients of variation, and variance ratios (F-values) as main statistics of relevance for estimating the efficiency of the adjustments, and compared the results with those of the IBD.

RESULTS AND DISCUSSION

The results of the 25 computer runs for each simulation model are shown in Table 1 and the results of the field experiments in Table 2.

Table 1. Average general mean (GM), average standard error of the difference (SED), and average coefficient of variation (CV)for 25 data sets, generated by computer simulation for each of 7 experimental models under a fertility gradient and no gradient situation[1]

		Average analysis results					
		No fertility gradient (G. zero)			Fertility gradient (G. one)		
Model	Description	GM	SED	CV (%)	GM	SED	CV (%)
I	RCBD	0.999	2.019	202.0	0.999	2.046	204.7
II	DAD-k_1	0.999	0.061	6.1	0.999	0.219	21.9
III	DAD-k_2	0.999	0.063	6.3	0.999	0.079	7.9
IV	DAD-k_3	0.999	0.059	5.9	0.999	0.219	21.9
V	DAD-k_4	0.999	0.055	5.5	0.999	0.218	21.8
VI	DAD-k_5	0.999	0.056	5.6	0.999	0.122	12.2
VII	IBD	0.999	0.055	4.9	0.999	0.258	23.2

(1) The models are described under : Materials and Methods. RCBD = Randomized Complete Block Design; DAD = Duplicated Augmented Design; IBD = Incomplete Block Design; k_1 = Fixed control adjustment, distance not weighted; k_2 = Fixed control adjustment, distance weighted; k_3 = Random control adjustment, k_4 = all control adjustment, distance not weighted; k_5 = all control adjustment,distance weighted.

Table 2. General mean (GM), standard error of the difference (SED) and coefficient of variation (CV) and variance ratio (F) for field experiments A and B[1]

Model	Description	Experiment A1				Experiment A2				Experiment B			
		GM	SED	CV	F	GM	SED	CV	F	GM	SED	CV	F
I	RCBD	1970	367.2	18.6	2.630***	2133	209.2	9.8	3.457***	1770	382.2	21.6	7.952***
II	DAD-k_1	1970	388.7	19.7	2.224*	2133	307.3	14.4	1.863*	1770	394.6	22.4	7.812***
III	DAD-k_2	1970	403.6	20.5	2.066**	2133	304.5	14.3	2.141**	1770	413.8	23.4	7.297***
IV	DAD-k_3	1970	412.0	20.9	2.140**	2133	247.0	11.6	2.459**	1770	387.0	21.9	8.110***
V	DAD-k_4	1970	346.7	17.6	2.660**	2133	226.2	10.6	2.784***	1770	364.4	20.6	9.018***
VI	DAD-k_5	1970	335.9	17.1	2.759***	2133	221.6	10.4	3.050***	1770	348.4	19.7	9.821***
VII	IBD	1970	376.5	16.8	2.715***	2133	261.9	10.8	2.277**	1823	426.6	21.0	9.873***

(1) The models are described under : Materials and Methods. RCBD = Randomized Complete Block Design; DAD = Duplicated Augmented Design; IBD = Incomplete Block Design; k_1 = Fixed control adjustment, distance not weighted; k_2 = Fixed control adjustment, distance weighted; k_3 = Random control adjustment; k_4 = all control adjustment, distance not weighted; k_5 = all control adjustment, distance weighted.

Where no fertility gradient was included in the simulation models, the DAD with fixed control adjustment gave higher CV values than the IBD. The field experiments showed the same trend. Van Rheenen and Das Gupta (1990) made a similar observation in a series of trials conducted at 17 locations during 1988-89 and suggested that the increase in CV was probably due to using a yardstick for adjustment that in itself is subjected to error. The addition of checks in models V and VI brought down the CV as expected, both in the simulation and field experiments. Weighting the distance for adjustment didn't help in the simulation nor in the field trials. The RCBD showed a very high CV for the simulation data as the simulated block effect was made large. The field experiments, also those reported by Van Rheenen and Das Gupta (1990) show only small CV differences between RCBD and IBD, which can be expected, if the soil variation is patchy in pattern, with patches smaller in size than the incomplete blocks (Allard, R.W. 1952). The F values for the RCBD was higher in two out of the three trials than those of the IBD.

Where a fertility gradient was included in the simulation models, the DAD-k_2 with distance weighting, and to a lesser extent the DAD-k_3 with partial distance weighting were able to reduce the gradient effect on the CV as we expected.

Although our DADs with fixed controls at the end of blocks are simple in layout and attractive for easy visual evaluation, the results of simulation models suggest, that IBDs produce lower CVs than DADs, if no fertility gradient occurs, and the results of the field experiments are in agreement with the simulation results. As the addition of random controls failed to reduce the CVs below those of the IBD to an appreciable extent, it is concluded that the added costs of land and labour do not seem to justify the inclusion of controls. The use of the IBD, or RCBD in the absence of block effects, is therefore preferred by the authors over the use of the DAD. Where fertility gradients are known to occur, appropriate directional adjustment of the layout can possibly overcome the problem although control plots and distance weighting can help to reduce it. Our conclusions about DADs also seem to apply to similar unreplicated ADs. They are not likely to give more useful information than sets of observation plots without repeated controls, and leaving out regular controls can save sometimes 20% or more of often scarce resources.

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Allard, R.W. 1952. The precision of lattice designs with a small number of entries in lima bean yield trials. *Agron. J.*, 44 : 200-202.

Baker, R.J. and Mckenzie, R.I.H. 1967. Use of control plots in yield trials. *Crop Sci.*, 7 : 335-337.

Bartlett, M.S. 1978. Nearest-neighbour models in the analysis of field experiments. *J. Royal Stat. Soc.*, Series B, 40 : 147-174.

Binns, M.R. 1987. Practical use of neighbour methods and alternatives in the analysis of field trials. *Can. J. Plant Sci.*, 67 : 477-489.

Cochran, W.G. and Cox, G.M. 1957. Experimental Designs, 2nd edn. New York : John Wiley. p. 387.

Federer, W.T. 1961. On augmented designs with one-way elimination of heterogeneity. *Biometrics*, 17 : 447-473.

Lin, C.S., Poushinsky, G. and Jui, P.Y. 1983. Simulation study of three adjustment methods for the modified augmented design and comparison with the balanced lattice square design. J. agric. Sci., Camb., 100 : 527-534.

Papadkis, J.S. 1937. Methods statistique pour des experiences sur champ. *Bulletin de l'Institute d' Amelioration des plantes a' solonique* no. 23.

Townley-Smith, T.F. and Hardy, E.A. 1973. Use of moving means in wheat trials. *Can. J. Plant Sci.*, 53 : 447-450.

Van Rheenen, H.A. and Dasgupta, T. 1990. Efficiency of duplicated augmented designs in international chickpea screening nurseries. *Indian J. Pulses Res.*, 3 (2) : 103-106.

Wilkinson, G.N., Rai, K.N. and Singh, Murari 1987. Nearest neighbour analysis of grain yield in pearl millet, ICRISAT, p. 18.

Yates, F. 1936. A new method of arranging variety trials involving a large number of varieties. *J. agric. Sci.*,Camb., 26 : 424-455.

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