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Short communication

Augmented BIB Design – An alternative statistical design in germplasm evaluation trials

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ABSTRACT

Randomized Block Design (RBD) is commonly employed to evaluate a set of germplasm accessions (test treatments) along with local checks. In such a trial, if the test treatments under evaluation are more in number and the availability of the seeds is limited, then an alternate experimental design has to be employed. As a remedy, Balanced Incomplete Block Design (BIBD), which estimates treatments contrasts with more precision and the treatments are not repeated in all the blocks, unlike RBD, may be used. Such a constructed layout, not only saves the precious seed material of the test treatments, but also directly reduces the cost of all the related inputs such as labour, water, fertilizers, pesticides etc. Foregoing thoughts were elucidated in the evaluation of 100 accessions of okra along with four check varieties (Arka Anamika, Arka Abhay, Parbhani Kranti and PB-7) evaluated using Augmented BIB Design with six blocks in the Division of Vegetable crops at I.I.H.R., Bangalore during Kharif 2005. Results showed that by adopting BIB experimental design, instead of regular complete block design 60.2% of the land area required for conducting germplasm evaluation in Okra had been reduced.

Key word: Accessions, Augmented Balanced Incomplete Block Design, control, germplasm, Okra, test treatments

In any experiment, formulation of certain hypotheses (called as null hypothesis) about the population under study form a basis for making all possible pairwise comparisons among treatments. If the seeds of the test treatments are scarce or limited in quantity, as in the case of breeding trails, the experiment cannot afford to sufficiently replicate the treatments in the design. In any crop improvement programme, an essential activity is to evaluate the germplasm accessions (test treatments) with a set of standard/commercial varieties (check). While evaluating larger number of test treatments in a field, use of traditional complete block designs (such as RBD) will directly increase within block homogeneity leading to erroneous conclusions. Moreover, as the number of test treatments increases the experimental area and all other related inputs, such as, labour, water, fertilizers, pesticides, etc will also increases. In such a situation, there is a need to adopt a design to test the new material with the local checks without loosing the precision of the experimental results. This could be possible by adopting a new experimental set up, wherein the scarce material are singly replicated in the design, and the local checks or the control treatment(s) is (are) added in each block at least once. Such a design is called an augmented design. A general theory of augmented design is well explained in the literature (Federer, 1963; Federer and Raghavarao, 1975; Federer, 1998; May *et al*, 1989; Puri *et al*, 1984; Schaalje *et al*, 1987; Tania and Street, 2002).

One hundred accessions of okra were evaluated along with four check varieties (Arka Anamika, Arka Abhay,

Table 1. Layout plan of okra 100 accessions:(4 Checks : A, B, C and D)

Block 1	1	10	12	A	2	9	11	B	3	5	14	18	C	4	13	17	15	D	6	19	7
Block 2	21	33	22	27	D	26	34	C	23	25	32	A	24	35	28	31	B	29	30	36	
Block 3	A	38	39	45	50	B	37	44	49	C	40	46	48	D	41	51	43	42	47	52	
Block 4	53	60	D	54	61	59	A	58	65	66	C	56	57	69	64	67	B	55	70	62	63
Block 5	71	72	A	78	B	73	85	C	75	77	84	90	80	89	86	88	D	74	81	82	76
Block 6	92	96	C	D	91	95	A	94	99	B	93	98	97	100	8	16	20	83	87	68	

Note: Sl. No. 1-100 are the test treatments (Okra accessions) ; A, B, C and D are check varieties

[1] Division of Vegetable Crops

Table 2. Mean performance of Okra accessions and check varieties

B-1	TCR. No	IC. No	Plant height (Cm)	Stem diameter at base (Cm)	Internodal Length (Cm)	No. Of Branches / plant	First flowering Node on main stem	No. of Fruits / Plant	Fruit length (Cm)	Fruit diameter (Cm)	No.of Ridges / Fruit	Avg. Fruit weight (g)	Yield / Plant (Kg)
1	28	33315	137.9	1.2	7.4	2.5	4.1	11.9	13.8	2.4	4.9	18.2	0.1990
10	76	43748	158.9	1.2	7.4	4.5	4.1	17.4	16.6	1.9	4.9	18.0	0.3030
12	80	43752	132.9	0.9	7.9	2.5	4.1	19.2	14.5	2.0	4.9	18.3	0.3430
2	35	33344	138.9	2.9	11.9	2.5	4.1	21.3	15.1	2.1	4.9	18.6	0.3910
9	74 B	43716	140.9	2.1	9.9	2.5	3.1	18.1	13.5	2.0	4.9	17.5	0.3080
11	78	43750	110.9	2.4	10.9	2.5	4.1	18.3	15.8	1.8	4.9	18.9	0.3370
3	48 sel 87	43720	142.9	2.4	12.4	3.5	4.1	25.7	13.5	2.1	4.9	15.5	0.4000
5	61	43733	141.9	2.4	10.9	2.5	4.1	20.3	11.1	2.1	6.9	18.3	0.3770
14	136	45800	135.9	2.7	11.9	3.5	3.1	20.9	11.3	2.4	4.9	20.2	.4160
18	150	45814	163.9	2.8	10.9	1.5	4.1	14.6	15.4	1.8	4.9	17.4	0.2400
4	60	43732	150.9	2.2	11.9	2.5	3.1	14.9	16.5	2.0	5.9	17.8	0.2520
13	124	45792	145.9	2.2	11.9	1.5	4.1	13.5	16.8	2.0	4.9	19.7	0.2500
17	142	45806	143.9	3.0	9.9	2.5	3.1	13.4	10.8	2.1	7.9	16.4	0.2040
15	138	45802	161.9	2.2	12.1	2.5	4.1	15.9	18.1	1.8	4.9	18.2	0.2774
6	63	43735	176.9	2.4	11.4	2.5	3.1	20.4	21.5	2.1	4.9	18.8	0.3770
19	151	45815	127.9	3.0	12.4	3.5	4.1	17.9	13.8	2.0	7.9	17.9	0.3110
7	70	43742	147.9	2.4	11.9	2.5	4.1	14.1	17.8	2.0	4.9	15.4	0.2030
B-2													
21	356 Sel86	69237Sel.86	134.4	2.7	9.3	3.5	4.1	13.6	16.3	1.7	5.1	17.4	0.3617
33	760	282231	126.4	2.7	9.4	3.5	4.1	15.9	19.0	1.9	5.1	16.3	0.3827
22	360	69242	144.4	2.1	9.3	1.5	4.1	10.2	15.0	1.9	5.1	21.7	0.3477
27	795	218878											
26	409 Sel 87-1	69290	143.4	3.0	7.8	2.5	4.1	13.1	16.0	2.1	6.1	20.0	0.3877
34	780-A	282232	152.4	2.7	9.5	2.5	3.1	12.8	18.7	2.5	8.1	20.7	0.3907
23	367-1	69248-1	125.4	3.0	9.8	3.5	3.1	8.9	13.0	2.4	9.1	22.4	0.3257
25	378 III	69259	155.4	3.1	9.5	3.5	4.1	11.5	15.0	1.9	5.1	20.2	0.3577
32	785	218872	103.4	1.9	9.5	1.5	4.1	14.0	15.5	1.8	5.1	16.2	0.3517
24	376	69257	127.4	2.7	9.5	1.5	4.1	14.6	16.7	2.9	11.1	21.2	0.4337
35	772	282230	125.4	2.7	9.3	3.5	4.1	17.2	13.0	1.9	5.1	15.4	0.3877
28	783	218877	133.4	2.4	9.5	2.5	4.1	20.4	17.0	1.9	5.1	18.5	0.4997
31	787-A	218873	89.4	3.0	8.3	4.5	3.1	12.7	16.0	2.1	10.1	20.0	0.3797
29	789	282233	151.4	2.1	9.3	1.5	4.1	19.1	20.0	2.1	5.1	20.0	0.5027
30	788	218874	134.4	2.2	8.8	1.5	3.1	15.3	16.3	2.0	5.1	17.5	0.3927
36	773	282231	124.4	2.4	6.8	3.5	3.1	12.0	17.0	2.1	7.1	20.2	0.3677
38	497	EC 133336	176.6	3.0	9.1	1.7	2.6	18.7	17.8	2.4	4.9	17.2	0.2735
39	421 Sel 86 III	69302	164.6	2.7	8.1	1.7	3.6	12.6	13.8	2.1	9.9	19.4	0.1895
B-3													
45	878	218894	173.6	2.5	9.6	0.7	3.6	15.4	17.6	2.0	4.9	19.1	0.2405
50	937	282278	174.6	2.1	9.6	0.7	3.6	20.6	14.8	2.1	4.9	15.9	0.2845
37	771	282229	162.6	2.1	8.6	1.7	3.6	13.8	17.8	2.4	4.9	17.2	0.1885
44	823	282241	145.6	3.4	8.6	0.7	3.6	18.5	19.3	2.1	4.9	17.1	0.2695
49	933	282277	190.6	4.7	7.6	1.7	3.6	20.6	17.3	2.1	4.9	20.3	0.3625
40	423 Sel 86	69304	166.6	4.0	8.2	0.7	2.6	15.8	17.1	1.8	4.9	17.8	0.2315

B-3	TCR. No	IC. No	Plant height (Cm)	Stem diameter at base (Cm)	Internodal Length (Cm)	No. Of Branches / plant	First flowering Node on main stem	No. of Fruits / Plant	Fruit length (Cm)	Fruit diameter (Cm)	No.of Ridges / Fruit	Avg. Fruit weight (g)	Yield / Plant (Kg)
46	926	282272	176.6	4.3	8.6	1.7	2.6	8.5	15.6	1.8	4.9	16.4	0.2825
48	930	282274	161.6	3.9	9.1	0.7	4.6	13.9	13.8	2.4	9.9	16.7	0.1845
40	423 Sel 86	69304	166.6	4.0	8.2	0.7	2.6	15.8	17.1	1.8	4.9	17.8	0.2315
40	423 Sel 86	69304	166.6	4.0	8.2	0.7	2.6	15.8	17.1	1.8	4.9	17.8	0.2315
46	926	282272	176.6	4.3	8.6	1.7	2.6	8.5	15.6	1.8	4.9	16.4	0.2825
48	930	282274	161.6	3.9	9.1	0.7	4.6	13.9	13.8	2.4	9.9	16.7	0.1845
41	810	282236											
51	939	252279	154.6	3.6	10.1	2.7	4.6	23.9	17.3	2.1	5.9	17.2	0.3655
43	822	282240	171.6	4.2	9.7	0.7	3.6	14.2	16.5	1.9	4.9	18.5	0.3225
42	813	282237	168.6	4.1	9.1	2.7	3.6	23.1	10.3	1.8	4.9	16.6	0.3395
47	929	282273	188.6	4.7	9.6	3.7	2.6	20.9	16.8	2.3	6.9	18.9	0.3315
52	941	282280	178.6	4.4	9.7	1.7	3.6	20.3	13.8	2.2	4.9	17.6	0.3085
B-4													
53	945	282282	159.1	3.1	9.7	2.2	2.9	6.0	13.8	2.4	9.1	20.9	0.1380
60	978	282289	135.1	3.0	10.2	2.2	3.9	7.4	15.8	2.2	8.1	17.5	0.1220
54	960	282283	115.1	2.7	9.2	3.2	3.9	16.9	15.8	2.1	5.1	18.2	0.2980
61	983	282292	162.1	2.4	9.7	3.2	2.9	17.1	16.6	1.8	5.1	19.3	0.3280
59	976	282288	157.1	2.8	8.7	2.2	3.9	12.1	23.3	2.4	5.1	18.4	0.2180
58	974	282287	130.1	3.0	9.7	1.2	2.9	9.1	18.8	2.4	7.1	17.4	0.1500
65	1070	140902	148.1	2.5	7.2	1.2	3.9	6.3	10.8	2.4	6.1	20.6	0.1400
66	1075	140906	175.1	3.0	8.7	2.2	2.9	18.6	20.3	2.4	5.1	17.1	0.3200
57	970	282286	170.1	3.0	8.7	1.2	2.9	17.9	18.3	2.0	5.1	24.7	0.4710
69	1086	140912	167.1	2.7	9.2	1.2	3.9	13.3	21.3	2.0	5.1	21.9	0.3050
64	1002	282266	165.1	2.4	9.7	1.2	2.9	7.8	18.3	2.1	5.1	20.6	0.3720
67	1083	140910	137.1	3.0	9.9	3.2	3.9	12.0	20.3	2.5	9.1	21.5	0.2700
55	964	282284	132.1	3.0	8.7	3.2	3.9	12.9	16.8	2.0	5.1	16.8	0.2020
70	1089	140915	174.1	2.5	10.6	3.2	3.9	7.0	16.8	2.1	5.1	20.6	0.4430
62	985	282293	227.1	3.0	8.7	3.2	3.9	16.2	21.3	1.8	5.1	21.3	0.3550
63	989	282294	205.1	3.0	8.7	2.2	2.9	7.3	13.8	2.2	6.1	19.3	0.1410
B-5													
71	1110	282298	122.4	2.5	5.6	1.5	3.1	22.9	18.2	2.2	7.1	19.4	0.4342
72	1116	140927	163.4	3.0	9.6	1.5	4.1	21.6	18.2	2.1	10.1	19.3	0.4072
78	11170	140880	158.4	3.0	8.6	4.5	2.1	14.4	18.1	2.0	5.1	18.3	0.2552
73	1118	140929	175.4	3.0	9.1	1.5	4.1	18.5	22.2	2.5	8.1	16.6	0.1352
85	1222	140877	155.4	3.0	10.0	1.5	2.1	16.5	18.7	2.2	5.1	17.7	0.2842
75	1130	140872	230.4	3.0	9.9	3.5	5.1	11.5	18.2	1.9	5.1	16.9	0.1872
77	1166	128885	165.4	3.0	9.7	2.5	4.1	21.0	15.7	1.8	7.1	19.0	0.3902
84	1215	128903	162.4	3.0	9.9	1.5	3.1	11.5	20.7	2.0	8.1	19.2	0.2142
90	1273	EC329402	181.4	2.7	9.8	2.5	3.1	20.0	17.2	2.1	5.1	20.1	0.3922
80	1173	128889	140.4	3.0	9.8	2.5	5.1	8.9	19.2	2.1	5.1	19.1	0.1642
89	1265	EC329380	154.4	3.0	9.8	2.5	3.1	19.6	19.2	2.2	5.1	18.4	0.3512
86	1254	EC329357	133.4	2.7	9.8	2.5	4.1	16.0	20.2	2.1	7.1	18.2	0.2832
88	1256	EC329360	186.4	2.8	9.8	2.5	3.1	16.1	17.2	2.4	9.1	19.9	0.3155

B-5	TCR. No	IC. No	Plant height (Cm)	Stem diameter at base (Cm)	Internodal Length (Cm)	No. Of Branches / plant	First flowering Node on main stem	No. of Fruits / Plant	Fruit length (Cm)	Fruit diameter (Cm)	No.of Ridges / Fruit	Avg. Fruit weight (g)	Yield / Plant (Kg)
74	1123	140934	123.4	3.0	6.1	3.5	5.1	20.1	15.2	1.7	5.1	18.0	0.3522
81	1176	128891	141.4	2.4	7.6	0.5	5.1	10.5	16.2	1.7	5.1	24.2	0.2482
82	1178	128893	142.4	2.4	9.6	2.5	3.1	12.0	16.2	2.1	5.1	14.0	0.3432
76	1145	128883	176.4	2.2	9.8	0.5	4.1	25.3	18.7	1.7	5.1	18.9	0.4682
B-6													
92	1276	EC329407	145.4	3.0	9.6	1.5	3.9	8.6	15.6	2.5	4.6	19.6	0.2357
96	1457	282269	120.4	3.0	7.5	0.5	2.9	10.8	15.1	2.4	4.6	18.6	0.2647
91	1275	EC329406	122.4	3.0	9.9	2.5	3.9	6.3	15.6	2.1	5.6	19.8	0.1927
95	1454	282269	165.4	2.8	9.6	1.5	3.9	15.8	17.6	2.1	4.6	19.6	0.3767
94	1444	EC169359	127.4	2.8	9.6	3.5	2.9	13.0	18.6	2.1	4.6	18.5	0.3017
99	1508	EC169378	126.4	3.0	7.5	2.5	3.9	15.5	19.1	2.3	4.6	18.8	0.3567
93		EC329422	116.4	2.4	9.6	1.5	3.9	9.8	17.6	1.8	4.6	16.2	0.2157
98	1501	EC169362	115.4	3.0	10.0	0.5	2.9	13.8	16.1	1.8	4.6	19.1	0.3287
97	1497	EC169362	139.4	2.8	9.6	1.5	2.9	9.9	18.6	2.1	4.6	20.0	0.2667
100	1512	EC169384	124.4	3.0	9.0	2.5	3.9	18.2	23.6	2.1	4.6	19.7	0.4257
8	71	43743	136.4	3.0	10.0	2.5	3.9	13.6	20.8	2.2	4.6	19.0	0.3237
16	141	45805	136.4	2.7	9.6	1.5	3.9	8.2	17.6	2.8	8.6	23.7	0.2737
20	167	45831	154.4	3.0	8.5	1.5	2.9	9.3	19.1	1.9	4.6	19.3	0.2457
83	1180	128894	114.4	2.4	8.5	1.5	2.9	11.5	17.6	1.8	4.6	19.3	0.2877
87	1255	EC329359	123.4	2.7	9.5	1.5	4.9	11.3	16.8	2.1	4.6	20.4	0.2997
68	1085	282296	142.4	2.7	9.6	2.5	3.9	5.8	18.1	2.2	7.6	21.2	0.1947
79	1172	128889	142.4	3.0	9.5	2.5	4.9	7.1		2.4	5.6	17.4	0.1837
SEM			15.2	1.4	1.4	0.79	0.63	5.80	2.21	0.83	0.63	1.57	0.09
CD@5%			32.5	3.1	3.1	1.69	1.35	12.3	4.71	1.78	1.35	3.36	0.19
CV(%)			7.09	10.9	10.8	25.0	11.9	24.7	9.0	8.21	7.66	5.83	20.2
(A) A .Anamika			138.3	2.4	8.2	1.6	3.8	17.3	18.0	2.0	5.1	18.6	0.3
(B) A. Abhay			131.8	2.4	9.5	2.1	3.6	18.7	18.5	1.8	5.1	18.9	0.3
(C) P.Kranti			148.1	2.9	9.8	2.6	3.5	19.2	18.6	1.9	5.3	17.2	0.3
(D) PB-7			154.3	2.8	9.3	1.5	3.6	18.0	14.6	1.8	5.0	17.9	0.2
SEM			7.2	0.2	0.7	0.3	0.3	2.7	1.0	0.09	0.3	0.7	0.04
CD@ 5%			15.5	0.4	1.5	0.8	0.6	5.9	2.2	0.2	0.6	1.6	0.09
CD@1%			21.5	0.6	2.0	1.1	0.8	8.1	3.1	0.3	0.8	2.2	0.12
CV (%)			7.0	10.9	10.8	25.0	11.9	24.7	9.0	8.2	7.6	5.8	20.2

Parbhani Kranti and PB-7) using Augmented BIB design with 6 blocks in the Division of vegetable crops at IIHR, Bangalore during Kharif 2005. Check varieties were replicated in each of the six blocks once and the 100 test treatments were randomly allotted to six blocks. The Plot size maintained was 3m x 1.2m; Spacing provided was 60 x 30 cm. Recommended cultural practices were adopted in raising the crop. The layout plan of the experimental plan is given in Table 1.

Observations on yield and yield related characters, namely, plant height (cm), stem diameter at base (cm), inter nodal length (cm), number of branches / plant, first flowering node on the main stem, number of fruits/plant, fruit length (cm), fruit diameter (cm), number of ridges / fruit, average fruit weight (g) and fruit yield / plant (kg) were recorded. Statistical analysis of the data was performed using standard augmented design procedure (Federer, 1963; Federer and Raghavarao, 1975; Federer, 1998; May *et al*, 1989; Schaalje *et al*, 1987; Tania and Street, 2002).

The mean performance of the test entries (Okra accessions) and the check varieties for different characters is presented in Table 2 along with standard error of mean (SEM) and Coefficient of Variation, CV%. Perusal of the results showed that 45 accessions outperformed all the four check varieties in terms of yield/ plant (kg). Remaining test treatments (55, out of which three did not germinate) performed below normal as compared to local checks. Among the four checks, Arka Anamika, Arka Abhay, Parbhani Kranti were on par in terms fruit yield (300 g/ plant) and they differed significantly from PB-7 (200 g/ plant). The highest fruit yield of 503 g/plant was recorded in accession T 29: TCR 789 (IC 282233), followed by 499 g/plant in the accession T 28: TCR 783 (IC 218877), which exceeds the average check varieties performance by 67.6% and 66.3%, respectively. These two accessions could be used as a potential parent in future hybridization programme.

Utility of BIB design vs complete block designs

The advantage of using this Augmented BIB Design is that there is a considerable reduction in experimental area, as the entire layout (total of 124 entries; 100 test treatments each repeated once in the entire set up and four check varieties repeated in all six blocks) was accommodated in an area of 1004 m^2. On the contrary, if RBD was used for evaluating these 104 entries with a minimum of three replications, the area required would have been 2527 m^2. Thus, by adopting this experimental augmented BIB design, about 60.2% of the land area required for the experiment is reduced. This, in turn, reduces the cost of all the related inputs, such as labour, water, fertilizers, pesticides etc. To conclude, the utility of such an incomplete block design in breeding trials, instead of regular complete block design is to optimize the use of inputs like seeds, water, labour, nutrients and pesticides in field experiments and subsequently useful for improving input use efficiency in crop production

Keeping in view the importance of the experimental design, a user-friendly program in C language is also developed to perform statistical analysis of the data. The programme takes care of both equal and unequal number of test treatments across different blocks. The efficacy of the programme in producing consistent results is tested by running and debugging the codes using data for different characters.

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