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Table 1. Data about shoot numbers and root production from sods (ca. 1 dm^2) of Kentucky bluegrass and colonial bentgrass.

Days to harvest	Roots emerged			Shoots Sod thickness, mm			Roots per 100 shoots		
	12	25	50	12	25	50	12	25	50
				Kentucky bluegrass					
8	251	107	45	211	208	198	119	51	23
15	220	109	55	213	206	205	103	53	27
22	329	192	133	187	166	151	176	115	88
means	267	136	78	204	193	185	133	73	46
	$LSD_{0.05} = 26$						$LSD_{0.05} = 17$		
	$LSD_{0.01} = 43$						$LSD_{0.01} = 28$		
				Colonial bentgrass					
8	66	36	2	331	440	240	20	8	1
18	117	118	86	283	306	343	41	39	25
29	263	152	108	184	184	371	143	83	29
means	149	102	65	266	310	318	68	43	18
							$LSD_{0.05} = 17$		
							$LSD_{0.01} = 28$		

roots. After 8 days, 12-mm bluegrass had more emergent roots than thicker sods had at any time in the 3-week period. Samples taken later had more roots emerged, and bluegrass rooted more vigorously than bentgrass. Thinly cut bentgrass rooted best but bentgrass rooting was more affected by the passage of time.

When data were analyzed as roots per sod, most bluegrass variance was due to sod thickness. Bentgrass variance was due to sampling date while sod thickness failed to show statistical significance. Data were biased in favor of the thicker sod, as over half the roots from the 50-mm sod emerged within 10 mm of the top and grew down the outside of the sod.

Qualitative observations follow.

Bluegrass: When sods were taken from the field, each bluegrass shoot had two expanded, short, cold weather leaves and an emerging leaf, some shoots still had an older, longer, summer leaf as well.[5] During the first week, each bluegrass shoot produced one or two new roots at the base of the phytomer having the older short leaf. This was followed later by added roots at that node and by roots at subsequent nodes. Occasionally a rhizome bud began to grow, and roots were produced. The first root generally came from the rhizome node, and the second from the basal node of the new shoot. By the end of the third week, older roots were up to 30 cm long and well branched.

Regrowth of cut bluegrass roots was not common. When sods were cut, the youngest roots (from the base of the most recent long-leaved summer phytomer) sometimes branched and made limited new growth, but there was no evidence of regrowth from older roots. The little regrowth that was observed occurred more often in 12-mm sods than in thicker ones. Cutting bluegrass sod thinner resulted in a greater stimulus for root production by shoots. With thicker sods roots were shorter, slower to develop, and fewer emerged though as many were initiated.

Bentgrass: Roots were slower to develop and the pattern of development was less well ordered than in bluegrass. Every root produced was associated with an active shoot, but not every active shoot produced a root, even after 4 weeks. Some cut bentgrass rhizomes were stimulated to produce clusters of shoots without any immediate associated root growth. On a vigorous shoot the basal leafy phytomer might produce roots, with roots also produced at one or two previous nodes without concurrent bud development at those nodes. Most shoots from 12-mm sods produced roots, epigeous shoots providing exceptions. When sods were cut at 50 mm, many fine, small shoots developed, most of which had not produced roots by 4 weeks. The 50-mm sod seemed well filled with functioning older roots and the many new shoots may have resulted from the better nutrition available from the many roots in the thicker soil layer. Little or no new regrowth from older cut roots was observed.

In conclusion, rooting of bluegrass and bentgrass sods was from new adventitious roots. The thinner sod was cut, the greater the number of new roots which emerged from the sod. Branching and regrowth of old cut roots was negligible. While all bluegrass shoots *initiated* new roots, root *development* appeared stimulated by cutting sod thinly. Bentgrass rooted from only some shoots but these increased in number with time.

[5] A. G. Etter. 1951. How Kentucky bluegrass grows. Mo. Bot. Gard. Annals 38:293-375.

RELATIVE EFFICIENCY OF 4×4 BALANCED LATTICE SQUARES COMPARED TO RANDOMIZED COMPLETE BLOCKS FOR MEASURING COTTON VARIETY LINT YIELDS[1]

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ABSTRACT

The balanced lattice square experimental design was on the average 36% more efficient than a randomized complete block design based on total lint cotton (*Gossypium hirsutum* L.) data obtained from four locations in Missouri over 4 years. Efficiency varied with environment but was inconsistent over locations and years.

Additional index words: **Variety tests, *Gossypium hirsutum* L.**

GENOTYPE-environment interactions among entries in breeding experiments are usually studied by growing entries in replicated tests at several locations for several years. The experimental design which provides the most powerful test should be used for such tests, provided it can be used conveniently and economically.

The balanced lattice square design (BLSD) is known to be one of the most efficient designs compared with the randomized complete block design (RCBD), whenever the same shape plot is used in both. This increase in efficiency is realized when within-replication variation can be identified with rows or columns or both of the BLSD.

Cochran[3] discussed the calculation of relative accuracy (here termed relative efficiency) and gave a comparison of different size BLSD's used in corn yield trials. His results, based on data from these experi-

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[3] Cochrane, W. G. 1941. An examination of the accuracy of lattice and lattice square experiments in corn. Iowa Agr. Exp. Sta. Bull. 289. pp. 400-415.

ments, show an increase in average relative efficiency of BLSD's over randomized blocks of 20, 25, 50, and 50% for 5×5, 7×7, 9×9, and 11×11 designs, respectively.

Our purpose is to present relative efficiencies of the BLSD obtained in recent yield trials in our cotton (*Gossypium hirsutum* L.) breeding program compared to the RCBD. The data were taken from four locations in Missouri representing large differences in plant environment enabling us to make evaluations of the BLSD under several different conlitions.

Materials and Methods

Yield trials involving 16 cotton varieties were performed each year from 1964 through 1967 using the BLSD. The same varieties were used in the 1964-65 trials. Four entries were substituted in 1966, and seven were changed in 1967.

Each set of entries was grown each year in a BLSD at the locations described below:

Location	*Environmental conditions*
1	Sandy loam soil, wilt-free, nonirrigated;
2	Sandy loam soil, infested with verticillium wilt (*Verticillium albo-atrum* Rinke and Berth), irrigated;
3	Clay soil, wilt-free, nonirrigated;
4	Sandy soil, infested with fusarium wilt (*Fusarium oxysporum* Schlecht. f. sp. *vasinfectum* (Atk) Synder and Hanson) and root-knot nematode (*Meloidogyne incognita* var. *acrita* Chitwood), irrigated.

Locations 1, 2, and 3 are near Portageville in Pemiscot County and location 4 is near Clarkton in New Madrid County, both in southeast Missouri. Conditions influencing plant growth at locations 2, 3, and 4 were characteristically more variable than at location 1.

Data were recorded on total lint cotton from the interior two rows of four-row plots at all places except location 1 the last 3 years, when only two rows were planted. Row lengths were 15.2 m at locations 1 and 2 all years, 17.4 m at location 3 the first 3 years and 13.7 m the fourth year, and 10.1 m at location 4 all years.

Statistical analyses were conducted for each by year-location combination in this study using the analysis given by Cochran and Cox[4] on pages 489-93. The relative efficiencies were computed as the ratio of the error mean square of the RCBD to the effective error variance of the BLSD, the same statistic as used by Cochran[3].

Results and Discussion

The average efficiency of the BLSD over the RCBD was 1.36 which is slightly greater than one would anticipate based on the work of Cochran[3] with corn. Estimates by location averaged over years were 1.20, 1.50, 1.42, and 1.30 for locations 1, 2, 3, and 4, respectively. Relative efficiencies for each year-location combination are given in Table 1.

Considerable variation was found among the individual estimates of relative efficiency, ranging from 1.00 to 2.51. The range in efficiencies over locations was greatest in 1966, least in 1967.

Although yields were lowest in 1966, the year of highest average efficiency and greatest within-season variability, no rank correlation was found between yield and relative efficiency. Within-year estimates of efficiency are independent of entries present, but yields are not; and since the 1967 trial included several different entries, that year's effect and average yield are confounded.

[4] Cochran, W. G., and G. M. Cox. 1957. Experimental Designs, 2nd ed. John Wiley and Sons, Inc., New York 611p.

Table 1. Estimated relative efficiencies of the BLSD compared to the RCBD by year and location.

Location	Year 1964	1965	1966	1967
1	1.37	1.16	1.27	1.02
2	1.02	1.47	2.51	1.00
3	1.69	1.10	1.71	1.20
4	1.00	1.45	1.76	1.00

No gain or loss in relative efficiency of biological importance was found between wilt-infected and wilt-free locations (1.40 and 1.31). Average efficiencies exhibit little relation to plot size of the BLSD, although a slight trend was noted: 1.42 for large plots, 1.35 for intermediate size plots, and 1.30 for small plots. This trend would be meaningful only if one discounts the gross location differences. Climatic variables differed greatly each year; but their effects, as indicated by yield, had a negligible influence on efficiency.

These results indicate that an average gain in efficiency of 36% can be gained by using the BLSD in place of the RCBD in the determination of relative lint yields in cotton variety trials. Deviations from the average efficiency were often large, indicating that in many cases one may find the BLSD substantially more or less beneficial than the 36%. The diversity of environmental conditions among the four locations showed a minimum gain of 20%, suggesting that one could effect near the same increase in efficiency in other areas of the cotton belt.

DEVELOPMENT OF B-LINES FOR TWO CYTOPLASMICALLY CONTROLLED MALE STERILITIES OF COTTON[1]

Vesta G. Meyer[2]

ABSTRACT

One form of male sterility in cotton, *Gossypium hirsutum* L., depends upon the interaction of nuclear and cytoplasmic factors. Maintenance of such lines is difficult, but is facilitated by using B-lines as male parents. B-lines have the same nuclear factors as cytoplasmically male-sterile lines, but lack the "male-sterile" cytoplasm. Test crosses of such B-lines with homozygous male sterile stocks with "pollen-sterile" cytoplasm gave progenies with pollen sterility equal to, or greater than, those obtained from self pollination of the cytoplasmically male sterile cottons in question.

***Additional index word:* Gossypium.**

STRAINS of cotton which breed true for a high degree of male sterility have been produced by backcrossing Upland cotton (*Gossypium hirsutum* L.), a tetraploid, to interspecific hybrids with cytoplasm from wild diploid species. One such strain was developed from the hybrid (*G. arboreum* L. × *G. thurberi* Todaro) × *G. hirsutum* L., and another from (*G.*

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[2] Associate Geneticist, Delta Branch Experiment Station. The author wishes to thank Dr. James R. Meyer for the original species hybrids used to develop the male sterile cottons discussed in this paper, and for his advice and encouragement.