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# RELATIVE EFFICIENCY OF SOME EXPERIMENTAL DESIGNS IN MAIZE YIELD. (*ZEA MAYS* L.)

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***Abstract***

Two maize (Zea mays, L.) uniformity trials were conducted in the 1995 and 1996 seasons by planting maize variety Three way cross 310 (T.W.C. 310) at the Agricultural Research Station of Sids. Experimental plots were arranged to give a wide variety of experimental designs including complete and incomplete blocks with single and double control. Efficiency estimates compared with both completely randomized design and randomized complete block design were as follows :-

As compared with randomized complete blocks design, the relative efficiency of split split plot design was 120.91%, split plot was 131.54%, latin square was 140.63%, strip plot was 190.18%. On the other hand, the relative efficiency of randomized complete blocks and latin square designs were 158.69% and 226.84%, respectively as compared with completely randomized design.

Concerning the incomplete blocks designs as compared with randomized complete block design, the relative efficiency of simple rectangular Lattice with 4 replication was 124.63%, triple rectongular lattice with three replications was 155.18%, simple square lattice with 4 replications was 169.18%, single square lattice with 2 replications was 194.68%, balanced lattice with single control was 204.17% and balanced with double control was 263.19%.

Generally, it was found that the randomized cómplete block design was more efficient than completely randomized, lattice designs were more efficient than randomized complete blocks, balanced incomplete block design was more efficient than partially balanced double control was more efficient than single control, and higher interaction was more efficient than lower and single factors.

## INTRODUCTIONU

Uniformity trials are usually planted with single variety replicated in several basic units in order to find out the optimum plot shape and size as well as soil heterogeneity indices affecting the efficiency of experimental designs. In addition to investigate the efficiency of experimental designs.

Several researchers ound that the randomized complete block design was more efficient than the completely randomized design (Yates, 1935). This was confirmed by other investigators, (Fisher, 1944, Steel and Torrie, 1960). In Egypt, similar conclusions were obtained by Moursi et al (1983) and Abd El-Halim et al (1989).

Latin square was more efficient than the randomized complete blocks (Yates, 1935 and Ma and Harrington, 1948). Also reports by Moursi et al (1983) and Abd-El Halim et al (1989) confirmed that this design was more efficient than the completely randomized and randomized complete block designs.

The incomplete block designs were suggested by Yates (1936). He utilized these designs intensively in soybean yield trials. Results of these trials indicated that these experimental layouts are expected to be efficient if the number of tested varieties are relatively large.

From extensive studies by Cochran (1941) with lattice designs in North Dakota with large number of varieties ranging from 49 to 199 cultivars, it was demonstrated that these designs were highly efficient than the randomized complete blocks. This was also confirmed by Bliss and Dearborn (1942) who evaluted ninety three simple and lattice square designs in maize yield trials to assess their efficiency. Generally, they have concluded that lattice designs are warranted when the experimental field is heterogenous. And in particular, the triple lattice designs excelled the randomized complete block design with 5 replications.

Further evidence for the efficiency of lattice designs came from maize uniformity trials conducted by Johnson and Murphy (1943) who indicated that the lattice designs were generally more efficient than the randomized complete block design. Zuber (1942) found that the square lattice was more efficient than the triple simple lattice. The latter, however, was more efficient than the simple lattice with two replications. Partially balanced design was slightly less efficient than the triple simple lattice. (Robinson et al, 1948). Generally, incomplete block designs were more efficient than the complete block designs (Keller, 1951; Torrie et al, 1963; Moursi et al, 1983 and Abd El-Halim et al, 1989). El-Rassas (1982), suggested that the incomplete block designs were more efficient than the randomized complete block design because of their ability to reduce the experimental error. Because the lattice square design manifested the highest relative precision, consquently, this design was recommendable in maize and wheat yield trials.

With regard to the split-plot design, it was found that this design evaluates the sub-plot treatments i.e. (B) treatments and the first order interaction (A*B) more efficiently than the randomized complete block (Moursi et al, 1983, Mohamed, 1992; 1989). Ottested and Winer (1970) and Essa (1974) recommended this design where the number of treatments is relatively large. However, Bliss and Dearborn (1942) recommended the utilization of this design when the experimental fields are heterogeneous, irrespective of the number of treatments involved.

Concerning the efficiency of the strip-plot design, it was found that this design was more efficient in the assessment of the interaction (A*B) than the randomized complete block design (Moursi et al 1983, Abd El-Halim et al, 1989 and Mohamed, 1992).

The aim of this study is to estimate the relative efficiency of experimental designs in addition to its important factors.

## MATERIALS AND METHODS

Maize (*Zea mays*, L.) variety, Three Way Cross 310, (T.W.C. 310) was planted in two uniformity trials in the 1995 and 1996 seasons at the Agricultural Research Station of Sids.

The actual area of the experimental field was divided into 16 strips, each strip was partioned into 50 rows each of 3.0 m long and 70 cm apart and each row was considered as a basic unit. Seeds were sown in hills 25 cm apart.

Grain yield was obtained by harvesting plants of each basic unit. Each unit was threshed separately, then weighed to the nearest kg. The moisture content of grains was adjuested to 15.5%.

The experimental plots were arranged to give a wide variety of experimental plans including complete and incomplete block designs with single and double control. The factorial combination to the different designs was assumed. It can be partioned into two main sections.

1- The efficiency of complete block designs :

a- Randomized complete blocks (R.C.B) as compared with completely randomized design (C.R.D.).

b- Latin square (L.S) versus both R.C.B and C.R.D.

c- Split plot versus R.C.B.

d- Split - Split plot versus R.C.B.

e- Strip plot versus R.C.B.

2- The efficiency of incomplete block designs :

a- Balanced incomplete blocks (B.I.B) versus R.C.B.

b- Partially balanced incomplete (P.B.I.B) versus R.C.B.

c- Balanced incomplete blocks (B.I.B) versus partially balanced incomplete block design (P.B.I.B).

d- Single control versus double control.

The efficiency of randomized complete block design as compared to completely randomized design was estimated according to Cochran and cox (1957) using the formula :

$$RE = \frac{Ee\,(n1+1)\ (n2+3)}{En(n2 + 1)\ (n1 + 3)} \times 100$$

Where Ee = Error mean square of CRD design.

Ee= Error mean square of RCB design.

n1 = Error df of RCB design.

n2 = Error df of CRD design.

Relative efficiency of Latin square design as compared to completely randomized design was specified as reported by Snedecor (1956) using the formula :

$$RE = \frac{Mb + Mg + (a-1)\ Me}{(a+1)\ Me}$$

Where Mb = Mean square error of rows.

mg = Mean square error of columns.

a = Treatment df.

Me = Error mean square of Latin square design.

Efficiency of Latin square design as compared to randomized complete block design was calculted according to Federer (1963) as follows :

$$RE = \frac{(K-1)(K-2)+1}{(K-1)(K-2)+3} \times \frac{(K-1)2+3}{(K-1)2+1} \times \frac{C+(K-1)E}{KE}$$

Where (k-1) (k-2) = Error df of Latin square design.

(K-1)2 = Error df of RCD.

C & R = Mean square of columns and rows, respectively.

E = Error mean square of Latin square design.

K = Number of treatments.

Concerning split-plot and split-split-plot designs as compared to randomized complete block design, the efficiencies were estimated as outlined by Federer (1963) using the following formula :

$$RE\ (Main - plots) = \frac{(P-1\ Ea + P\ (q-1)\ Eb}{(pq - 1)\ Ea}$$

$$RE\ (Sub - plots) = \frac{(P-1\ Ea + P\ (q-1)\ Eb}{(pq - 1)\ Ea}$$

$$RE\ (Sub - sub - plots) = \frac{(P-1\ Ea + P\ (q-1)\ Eb}{(pq - 1)\ Ea}$$

Where p = Number of main plot-treatments.

q = Number of sub-plot treatments.

Ea = Mean square of error (a).

Eb = Mean square of error (b).

Ec = Mean square of error (c).

As compared to randomized complete block design, the relative efficiency of strip plot design was calculated using the following formula :

$$RE = \frac{Ee}{Ee}$$

$$\text{here } Ee = \frac{S.S.\ (Ea + Eb + Ec)}{df\ (Ea + Eb + Ec)}$$

Ee = Error mean square of RCB design.

The relative efficiency of incomplete block designs as compared to randomized complete block design was estimated according to Leclerge et al (1962) as follows :

$$RE = \frac{Ee}{Ee} \times 100$$

Where Ee = Error mean square of randomized complete block design.

Ee = Effective error.

The effective error is calculated, for balanced lattice design, using the formula :

$$Ee = Ee\ (1 + Ku)$$

## RESULTS AND DISCUSSION

Raising agricultural production depends mainly on agricultural research. Experimentation is its distinctive tool, this gave field plot techniques such as efficiency of design and their parameters, special importance.

The efficiency of experimental designs can be estimated via either uniformity trails or previous experimental data. Uniformity trails are more efficient in that regard, it provides the researcher with all information that he needs.

Data of relative efficiency of the experimental designs, RCB, LS, SP, SSP and STP are presnted in Table (1). The results in that table indicate the following :

Table . The minimum, maximum and mean relative efficiency of randomized complete block, RCB, latin square, LS, split plot, split-split plot and strip plot relative to completely randomized and randomied complete block design for maize yield in the 1995 and 1996 seasons.

| DesigDesigns | Relative efficiency | | Overall mean |
|---|---|---|---|
| | Minimum level | Minimum level | |
| RCB relative CRD | 95.22 | 313.13 | 158.69 |
| LS relative RCB | | | |
| Row | 82.12 | 213.40 | 153.83 |
| Columns | 75.13 | 196.16 | 127.42 |
| Mean | | | 140.63 |
| LS relative CRD | 120.18 | 421.19 | 226.84 |
| Split plot relative RCB | | | |
| Treatment A | 52.18 | 80.16 | 68.84 |
| Treatment B | 98.60 | 178.20 | 131.54 |
| Split-split relative RCB | | | |
| Treatment A | 45.98 | 121.16 | 72.88 |
| Treatment B | 69.18 | 155.18 | 98.94 |
| Treatment C | 77.18 | 210.11 | 120.91 |
| Split plot relative RCB | | | |
| Treatment A | 27.18 | 62.19 | 38.64 |
| Treatment B | 75.20 | 190.22 | 123.19 |
| Interaction A*B | 120.15 | 295.14 | 190.18 |

CRD = Complete randonized design .
RCB = Randonized complete block
LS = Latin square

1. The randomized complete block design was more efficient than completely randomized (158.69 %) (Fig.1). Similar results were reported by Yates (1935), Fisher (1949) and Steel and Torrie (1960). In Egypt, Moursi et al (1983) and Abd

El-Halim et al (1989) came to similar conclusion.

2. Latin square design expressed high relative efficiency over randomized complete blocks (140.63 %). It was found that the relative efficiency of rows was higher than that of columns (153.83 %, 127.42%) (Table 1 and Fig. 2A). This indicates that the heterogeneity of the experimental field is not of the same degree in the two directions. (Yates, 1935; Ma and Harrington, 1948).

Table . Relative efficiency of the balanced lattice and partial balanced compared with randomized complete block design for maize yield in the 1995 and 1996 seasons.

| Designs | No. of T | No. of R | K | Relative efficiency 1995 | Relative efficiency 1996 | Mean |
|---|---|---|---|---|---|---|
| 1- Balanced incomplete blocks | | | | | | |
| A- Single Control | 9 | 4 | 3 | 210.18 | 198.16 | 204.17 |
| B-Double Control | 25 | 3 | 5 | 310.16 | 216.22 | 263.19 |
| Mean | | | | | | 233.68 |
| 2- Partial balanced designs | | | | | | |
| A-Square lattice | | | | | | |
| 1- Simple square lattice | 25 | 4 | 5 | 140.20 | 198.16 | 169.18 |
| With 4 replications. | | | | 190.13 | 199.22 | 194.68 |
| 2- Simple square lattice | 25 | 25 | | | | |
| with 2 replications | | | | | | |
| Mean | | | | | | 181.93 |
| B- Rectangular lattice | | | | | | |
| 1- Simple rectangular (4 Reps) | 12 | 43 | | 117.13 | 132.12 | 124.63 |
| 2- Triple rectangular (3 Reps) | 16 | 34 | | 120.23 | 190.13 | 155.18 |
| Mean | | | | | | 139.91 |
| Mean | | | | | | 160.92 |
| Over all mean | | | | | | 185.17 |

3. The split plot design was found to evaluate the sub plot treatments i.e. (B) treatment and the first order interaction (A*B) more efficiently than the randomized complete block designs (131.54%) (Table 1 and Fig.2 B). Similar results were obtained by Moursi et al (1983) and Abd El-Halim et al (1989).

4. Split split plot design, was more efficient than the complete block design

for the sub-sub-plots (120.91%) (Table 1 and Fig. 2C). Similar results were reported by Abd El-Halim et al (1989).

5. Concerning the efficiency of the strip plot design, it was found that this design was more efficient for the interaction A*B (190.18%) than the randomized complete blocks, (Table 1 and Fig. 2D). These results are in agreement with those obtained by Moursi et al (1983) and Abd El-Halim et al (1989).

Data of the relative efficiency of the balanced lattice and partially balanced compared with randomized complete block design for maize yield in the 1995 and 1996 seasons are presented in Table (2). Results in the table indicate the following:

1. The balanced designs were more efficient than the partially balanced designs 233.68%, 160.92% (Table 2 and Fig. 3). These results are in line with those obtained by Moursi et al (1983) and Mohamed (1992).

2. Double control, DC, was more efficient than single control, SC, 263.19%, 204.17% (Table 2 and Fig 3). Similar results were reported by Moursi et al (1983) and Mohamed (1992).

3. The square lattice, SL, designs were more efficient than the rectangular lattice, RL, 181.93%, 139.91%, (Table 2 and F.g. 3).

4. Simple square lattice with 2 replications, SSL 2R, was more efficient than with 4 replications, SSL 4R, 194.68%, 169.18, (Table 2 and Fig.3), Similar results were reported by Mohamed (1992).

5. Triple rectangular, TR, with 3 replications was more efficient than simple rectangular, SR, with 4 replications, 155.18%, 124.63%, (Table 2 and Fig. 3). These results are in agreement with those obtained by Moursi et al (1983) and Mohamed (1992).

It could be concluded that incomplete blocks designs were generally more efficient than the randomized complete blocks designs. Its relative efficiency was 185.17% (Table 2). Similar results were obtained by Torrie et al (1963), Moursi et al (1983), Abd El-Halim et al (1984) and Mohamed (1992).

Generally, it was found that complete blocks were more efficient that complete randomization, double control was more efficient than single control, lattice designs were more efficient than randomized complete blocks, higher interaction

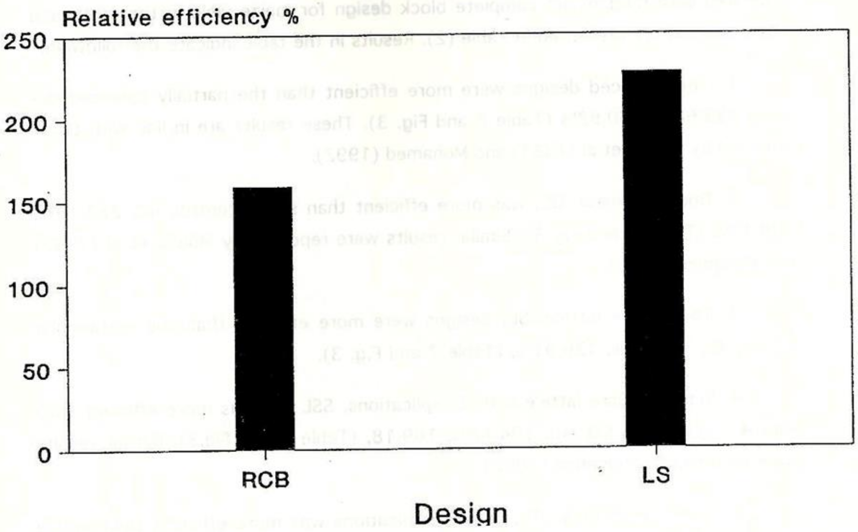


Fig. 1 Relative efficiency of RCB and LS designs compared to CRB design.

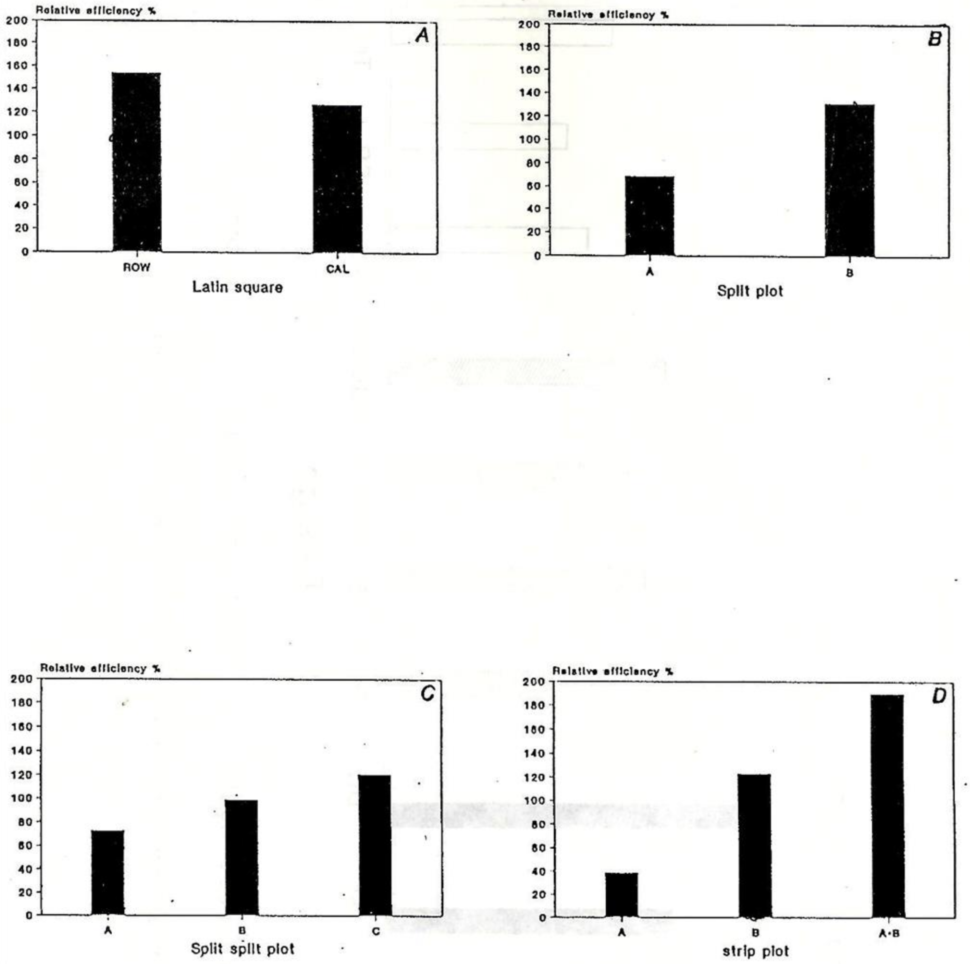


Fig. 2. Relative efficiency of Latin square, Split plot, Split split plot and Strip plot designs relative to Randomized complete block design.

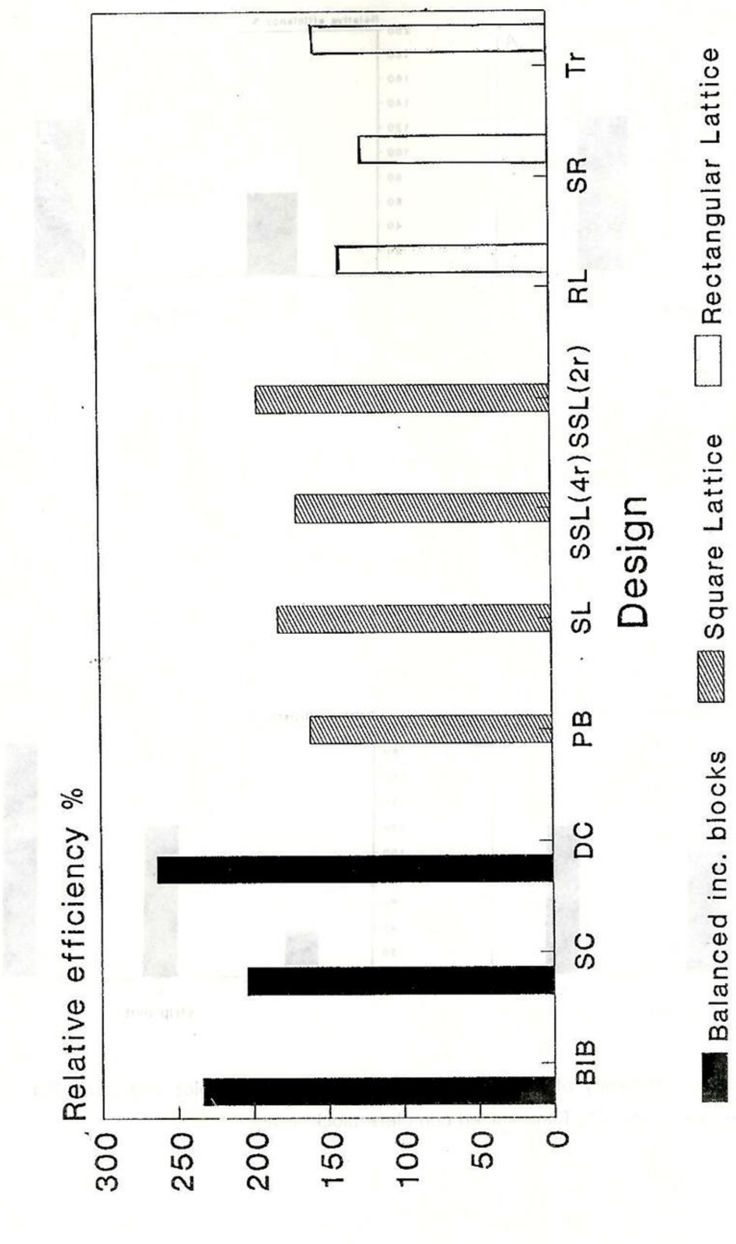


Fig. 3. Relative efficiency of balanced and partial balanced designs compared to RCBD .

was more efficient than lower and sigle factors.

This insures the validity of experimental design theory and put stress on the importance of planning experiments and amount of relative information gained.

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# الكفاءة النسبية للتصميمات التجريبية فى الذرة الشامية

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اجريت تجربة تجانس على الذرة الشامية فى محطة البحوث والتجارب الزراعية بسدس (بنى سويف) فى موسمى ١٩٩٥ / ١٩٩٦ وكان الصنف المستخدم هجين ثلاثى ٣١٠ . وتم ترتيب القطع التجريبية المتحصل عليها لتعطى ترتيبات مختلفة تكون فى مجموعها أغلب التميمات التجريبية المستخدمة فى مجال البحوث الحقلية، وقد إجرى تحليل التباين لها وقدرت الكفاءة النسبية لكل تصميم من التصميمات فى موسمى الدراسة :-

ويمكن ترتيب قيم الكفاءة النسبية تصاعديا كما يلى :-

١ - القطع المنشقة مرتين بالنسبة للقطاعات الكاملة ٩١, ١٢٠ ٪.

٢ - القطع المنشقة مرة واحدة بالنسبة للقطاعات الكاملة ٥٤, ١٣١ ٪.

٣ - المربع اللاتينى بالنسبة للقطاعات الكاملة ٦٣, ١٤٠٪.

٤ - القطاعات الكاملة بالنسبة للتام العشوائية ٦٩, ١٥٨ ٪.

٥ - الشرائح المعامدة بالنسبة للقطاعات الكاملة ١٨, ١٩٠ ٪.

٦ - المربع اللاتينى بالنسبة للتام العشوائية ٨٤, ٢٢٦٪.

القطاعات الناقصة بالنسبة للقطاعات الكاملة :-

١ - اللاتس المستطيل الشبكى البسيط ذو الأربع مكررات ٦٣, ١٢٤ ٪.

٢ - اللاتس المستطيل الشبكى ذو الثلاث مكررات ١٨, ١٥٥ ٪.

٣ - اللاتس المربع ذو الأربع مكررات ١٨, ١٦٩٪.

٤ - اللاتس المربع ذو المكررين ٦٨, ١٩٤ ٪.

٥ - القطاعات الناقطة المتزنة ذات التحكم المفرد ١٧, ٢٠٤ ٪.

٦ - القطاعات الناقصة المتزنة ذات التحكم المزدوج ١٩, ٢٦٣٪.

وكانت تصميمات القطاعات الناقصة ذات كفاءة عالية بالنسبة لتصميمات القطاعات الكاملة (١٧, ١٨٥٪)، وكانت كفاءة القطاعات الناقصة المتزنة ٦٨, ٢٣٣ ٪ ، والمتزنة جزئيا ٩٢،١٦٠٪.