

# Package ‘augmentedRCBD’

December 5, 2018

**Title** Analysis of Augmented Randomised Complete Block Designs

**Version** 0.1.0.9000

**Description** Functions for analysis of data generated from experiments in augmented randomised complete block design according to Federer, W.T. (1961) <doi:10.2307/2527837>. Computes analysis of variance, adjusted means, descriptive statistics, genetic variability statistics etc. Further includes data visualization and report generation functions.

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**Encoding** UTF-8

**LazyData** true

**Depends** R (>= 3.0.1)

**VignetteBuilder** knitr

**RoxygenNote** 6.1.1

**URL** <https://github.com/aravind-j/augmentedRCBD>  
<https://CRAN.R-project.org/package=augmentedRCBD>  
<https://aravind-j.github.io/augmentedRCBD>  
<https://doi.org/10.5281/zenodo.1310011>

**BugReports** <https://github.com/aravind-j/augmentedRCBD/issues>

**Imports** emmeans,  
dplyr,  
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ggplot2,  
grDevices,  
methods,  
moments,  
multcomp,  
multcompView,  
Rdpack,  
stats,  
stringi,  
officer,  
reshape2,  
utils

**Suggests** knitr,  
rmarkdown,  
pander  
**RdMacros** Rdpack

**R topics documented:**

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augmentedRCBD	<i>Analysis of Augmented Randomised Complete Block Design</i>
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**Description**

augmentedRCBD is a function for analysis of variance of an augmented randomised block design (Federer, 1956; Federer, 1961) and the generation as well as comparison of the adjusted means of the treatments/genotypes.

**Usage**

```
augmentedRCBD(block, treatment, y, checks = NULL,  
  method.comp = c("lsd", "tukey", "none"), alpha = 0.05,  
  group = TRUE, console = TRUE, simplify = FALSE)
```

**Arguments**

block	Vector of blocks (as a factor).
treatment	Vector of treatments/genotypes (as a factor).
y	Numeric vector of response variable (Trait).
checks	Character vector of the checks present in treatment levels. If not specified, checks are inferred from the data on the basis of number of replications of treatments/genotypes.
method.comp	Method for comparison of treatments ("lsd" for least significant difference or "tukey" for Tukey's honest significant difference). If "none", no comparisons will be made, the ANOVA output will be given as a data frame and the adjusted means will be computed directly from treatment and block effects instead of using <a href="#">emmeans</a> .
alpha	Type I error probability (Significance level) to be used for multiple comparisons.
group	If TRUE, genotypes will be grouped according to "method.comp".

console	If TRUE, output will be printed to console. Default is TRUE.
simplify	If TRUE, ANOVA output will be given as a data frame instead of a summary.aov object

## Details

This function borrows code from DAU.test function of agricolae package (de Mendiburu et al., 2016) as well as from Appendix VIII of Mathur et al., (2008).

## Value

A list of class augmentedRCBD containing the following components:

Details	Details of the augmented design used.
Means	A data frame with the "Means", "Block", "SE", "Mix", "Max" and "Adjusted Means" for each "Treatment".
ANOVA, Treatment Adjusted	An object of class summary.aov for ANOVA table with treatments adjusted.
ANOVA, Block Adjusted	An object of class summary.aov for ANOVA table with block adjusted.
Block effects	A vector of block effects.
Treatment effects	A vector of treatment effects.
Std. Errors	A data frame of standard error of difference between various combinations along with critical difference and tukey's honest significant difference (when method.comp = "tukey") at alpha.
Overall adjusted mean	Overall adjusted mean.
CV	Coefficient of variation.
Comparisons	A data frame of pairwise comparisons of treatments. This is computed only if argument group is TRUE
Groups	A data frame with compact letter display of pairwise comparisons of treatments. Means with at least one letter common are not significantly different statistically. This is computed only if argument group is TRUE

## Note

- Data should preferably be balanced i.e. all the check genotypes should be present in all the blocks. If not, a warning is issued.
- There should not be any missing values.
- The number of test genotypes can vary within a block.

In case the large number of treatments or genotypes, it is advisable to avoid comparisons with the group = FALSE argument as it will be memory and processor intensive. Further it is advised to simplify output with simplify = TRUE in order to reduce output object size.

## References

- Federer WT (1956). "Augmented (or hoonuiaku) designs." *The Hawaiian Planters' Record*, **LV**(2), 191–208.
- Federer WT (1961). "Augmented designs with one-way elimination of heterogeneity." *Biometrics*, **17**(3), 447–473.
- Mathur PN, Muralidharan K, Parthasarathy VA, Batugal P, Bonnot F (2008). *Data Analysis Manual for Coconut Researchers-Bioversity Technical Bulletin No. 14*. Bioversity International.
- de Mendiburu F (2015). *agricolae: Statistical Procedures for Agricultural Research*. R package version 1.2-8. <https://CRAN.R-project.org/package=agricolae>.

## See Also

`DAU.test`, `ea1`, `emmeans`, `cld.emmGrid`, `aug.rcb`

## Examples

```
# Example data
blk <- c(rep(1,7),rep(2,6),rep(3,7))
trt <- c(1, 2, 3, 4, 7, 11, 12, 1, 2, 3, 4, 5, 9, 1, 2, 3, 4, 8, 6, 10)
y1 <- c(92, 79, 87, 81, 96, 89, 82, 79, 81, 81, 91, 79, 78, 83, 77, 78, 78,
       70, 75, 74)
y2 <- c(258, 224, 238, 278, 347, 300, 289, 260, 220, 237, 227, 281, 311, 250,
       240, 268, 287, 226, 395, 450)
data <- data.frame(blk, trt, y1, y2)
# Convert block and treatment to factors
data$blk <- as.factor(data$blk)
data$trt <- as.factor(data$trt)
# Results for variable y1 (checks inferred)
out1 <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE)
# Results for variable y2 (checks inferred)
out2 <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE)

# Results for variable y1 (checks specified)
out1 <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE,
                      checks = c("1", "2", "3", "4"))
# Results for variable y2 (checks specified)
out2 <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE,
                      checks = c("1", "2", "3", "4"))

## Not run:
# Error in case checks not replicated across all blocks
# Check 1 and 4 not replicated in all 3 blocks
trt <- c(1, 2, 3, 14, 7, 11, 12, 1, 2, 3, 4, 5, 9, 13, 2, 3, 4, 8, 6, 10)
data$trt <- as.factor(trt)
table(data$trt, data$blk)
# Results for variable y1 (checks specified)
out1 <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE,
                      checks = c("1", "2", "3", "4"))

## End(Not run)
```

```
# Warning in case test treatments are replicated
out1 <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE)
out1 <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE,
                      checks = c("2", "3"))
```

---

augmentedRCBD.bulk	<i>Analysis of Augmented Randomised Complete Block Design for Multiple Traits/Characters</i>
--------------------	--

---

## Description

augmentedRCBD.bulk is a wrapper around the functions augmentedRCBD, describe.augmentedRCBD, freqdist.augmentedRCBD and gva.augmentedRCBD. It will carry out these analyses for multiple traits/characters from the input data as a data frame object.

## Usage

```
augmentedRCBD.bulk(data, block, treatment, traits, checks = NULL,
                  alpha = 0.05, describe = TRUE, freqdist = TRUE, gva = TRUE,
                  check.col = "red", console = TRUE)
```

## Arguments

data	The data as a data frame object. The data frame should possess columns specifying the block, treatment and multiple traits/characters.
block	Name of column specifying the blocks in the design as a character string.
treatment	Name of column specifying the treatments as a character string.
traits	Name of columns specifying the multiple traits/characters as a character vector.
checks	Character vector of the checks present in treatment levels. If not specified, checks are inferred from the data on the basis of number of replications of treatments/genotypes.
alpha	Type I error probability (Significance level) to be used for multiple comparisons.
describe	If TRUE, descriptive statistics will be computed. Default is TRUE.
freqdist	If TRUE, frequency distributions be plotted. Default is TRUE.
gva	If TRUE, genetic variability analysis will be done. Default is TRUE.
check.col	The colour(s) to be used to highlight check values in the plot as a character vector. Must be valid colour values in R (named colours, hexadecimal representation, index of colours [1:8] in default R 'palette()' etc.).
console	If TRUE, output will be printed to console. Default is TRUE.

A list of class `augmentedRCBD.bulk` containing the following components:

**Also**

```
augmentedRCBD, describe.augmentedRCBD, freqdist.augmentedRCBD, gva.augmentedRCBD
```

augmentedRCBD, describe.augmentedRCBD, freqdist.augmentedRCBD, gva.augmentedRCBD

[illegible]

```

                                "forestgreen", "purple"),
                                console = TRUE)

# Frequency distribution plots
lapply(bout$`Frequency distribution`, plot)

# GVA plots
bout$`GVA plots`

```

---

describe.augmentedRCBD

*Compute Descriptive Statistics from augmentedRCBD Output*


---

## Description

describe.augmentedRCBD computes descriptive statistics from the adjusted means in an object of class augmentedRCBD.

## Usage

```
describe.augmentedRCBD(aug)
```

## Arguments

aug                      An object of class augmentedRCBD.

## Details

describe.augmentedRCBD computes the following descriptive statistics from the adjusted means in an object of class augmentedRCBD.

- Count
- Mean
- Standard deviation
- Standard error
- Minimum
- Maximum
- Skewness statistic along with p-value from D'Agostino test of skewness (D'Agostino, 1970).
- Kurtosis statistic along with p-value from Anscombe-Glynn test of kurtosis (Anscombe and Glynn, 1983).

## Value

A list with the following descriptive statistics:

Count	The number of treatments/genotypes.
Mean	The mean value.
Std.Error	The standard error.
Std.Deviation	The standard deviation.

Min                    The minimum value

Max                    The maximum value

Skewness(statistic)                    The skewness estimator.

Skewness(p.value)                    The p-value from D'Agostino test of skewness.

Kurtosis(statistic)                    The kurtosis estimator.

Kurtosis(p.value)                    The p-value from Anscombe-Glynn test of kurtosis.

## References

D'Agostino RB (1970). "Transformation to normality of the null distribution of  $g_1$ ." *Biometrika*, **57**(3), 679–681.

Anscombe FJ, Glynn WJ (1983). "Distribution of the kurtosis statistic  $b_2$  for normal samples." *Biometrika*, **70**(1), 227–234.

## See Also

[augmentedRCBD](#)

## Examples

```
# Example data
blk <- c(rep(1,7),rep(2,6),rep(3,7))
trt <- c(1, 2, 3, 4, 7, 11, 12, 1, 2, 3, 4, 5, 9, 1, 2, 3, 4, 8, 6, 10)
y1 <- c(92, 79, 87, 81, 96, 89, 82, 79, 81, 81, 91, 79, 78, 83, 77, 78, 78,
      70, 75, 74)
y2 <- c(258, 224, 238, 278, 347, 300, 289, 260, 220, 237, 227, 281, 311, 250,
      240, 268, 287, 226, 395, 450)
data <- data.frame(blk, trt, y1, y2)
# Convert block and treatment to factors
data$blk <- as.factor(data$blk)
data$trt <- as.factor(data$trt)
# Results for variable y1
out1 <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE)
# Results for variable y2
out2 <- augmentedRCBD(data$blk, data$trt, data$y2, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE)

# Descriptive statistics
describe.augmentedRCBD(out1)
describe.augmentedRCBD(out2)
```



**Description**

freqdist.augmentedRCBD plots frequency distribution from an object of class augmentedRCBD along with the corresponding normal curve and check means with standard errors (if specified by argument highlight.check).

**Usage**

```
freqdist.augmentedRCBD(aug, xlab, highlight.check = TRUE,
  check.col = "red")
```

**Arguments**

aug	An object of class augmentedRCBD.
xlab	The text for x axis label as a character string.
highlight.check	If TRUE, the check means and standard errors are also plotted. Default is TRUE.
check.col	The colour(s) to be used to highlight check values in the plot as a character vector. Must be valid colour values in R (named colours, hexadecimal representation, index of colours [1:8] in default R 'palette()' etc.).

**Value**

The frequency distribution plot as a ggplot2 plot grob.

**See Also**

[augmentedRCBD](#)

**Examples**

```
# Example data
blk <- c(rep(1,7),rep(2,6),rep(3,7))
trt <- c(1, 2, 3, 4, 7, 11, 12, 1, 2, 3, 4, 5, 9, 1, 2, 3, 4, 8, 6, 10)
y1 <- c(92, 79, 87, 81, 96, 89, 82, 79, 81, 81, 91, 79, 78, 83, 77, 78, 78,
      70, 75, 74)
y2 <- c(258, 224, 238, 278, 347, 300, 289, 260, 220, 237, 227, 281, 311, 250,
      240, 268, 287, 226, 395, 450)
data <- data.frame(blk, trt, y1, y2)
# Convert block and treatment to factors
data$blk <- as.factor(data$blk)
data$trt <- as.factor(data$trt)
# Results for variable y1
out1 <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
  alpha = 0.05, group = TRUE, console = TRUE)
# Results for variable y2
out2 <- augmentedRCBD(data$blk, data$trt, data$y2, method.comp = "lsd",
  alpha = 0.05, group = TRUE, console = TRUE)

# Frequency distribution plots
freq1 <- freqdist.augmentedRCBD(out1, xlab = "Trait 1")
class(freq1)
plot(freq1)
freq2 <- freqdist.augmentedRCBD(out2, xlab = "Trait 2")
plot(freq2)
```

```
# Change check colours
colset <- c("red3", "green4", "purple3", "darkorange3")
freq1 <- freqdist.augmentedRCBD(out1, xlab = "Trait 1", check.col = colset)
plot(freq1)
freq2 <- freqdist.augmentedRCBD(out2, xlab = "Trait 2", check.col = colset)
plot(freq2)

# Without checks highlighted
freq1 <- freqdist.augmentedRCBD(out1, xlab = "Trait 1",
                                highlight.check = FALSE)
plot(freq1)
freq2 <- freqdist.augmentedRCBD(out2, xlab = "Trait 2",
                                highlight.check = FALSE)
plot(freq2)
```

---

<code>gva.augmentedRCBD</code>	<i>Perform Genetic Variability Analysis on augmentedRCBD Output</i>
--------------------------------	---

---

## Description

`gva.augmentedRCBD` performs genetic variability analysis on an object of class `augmentedRCBD`.

## Usage

```
gva.augmentedRCBD(aug, k = 2.063)
```

## Arguments

<code>aug</code>	An object of class <code>augmentedRCBD</code> .
<code>k</code>	The standardized selection differential or selection intensity. Default is 2.063 for 5% selection proportion (see <b>Details</b> ).

## Details

`gva.augmentedRCBD` performs genetic variability analysis from the ANOVA results in an object of class `augmentedRCBD` and computes several variability estimates.

The phenotypic, genotypic and environmental variance ( $\sigma_p^2$ ,  $\sigma_g^2$  and  $\sigma_e^2$ ) are obtained from the ANOVA tables as follows:

$$\sigma_p^2 = \text{Sum of squares of test treatments(genotypes)}$$

$$\sigma_e^2 = \text{Sum of squares of residuals(error)}$$

$$\sigma_g^2 = \sigma_p^2 - \sigma_e^2$$

Phenotypic and genotypic coefficients of variation (*PCV* and *GCV*) are estimated according to Burton (1951, 1952) as follows:

$$PCV = \frac{\sigma_p^2}{\sqrt{x}} \times 100$$

$$GCV = \frac{\sigma_g^2}{\sqrt{\bar{x}}} \times 100$$

Where  $\bar{x}$  is the mean.

The estimates of *PCV* and *GCV* are categorised according to Sivasubramanian and Madhavanon (1978) as follows:

<b>CV (%)</b>	<b>Category</b>
$x < 10$	Low
$10 \leq x < 20$	Medium
$\geq 20$	High

The broad-sense heritability ( $H^2$ ) is calculated according to method of Lush (1940) as follows:

$$H^2 = \frac{\sigma_g^2}{\sigma_p^2}$$

The estimates of broad-sense heritability ( $H^2$ ) are categorised according to Robinson (1966) as follows:

<b><math>H^2</math></b>	<b>Category</b>
$x < 30$	Low
$30 \leq x < 60$	Medium
$\geq 60$	High

Genetic advance (*GA*) and genetic advance as per cent of mean (*GAM*) are estimated and categorised according to Johnson et al., (1955) as follows:

$$GA = k \times \sigma_g \times \frac{H^2}{100}$$

Where the constant  $k$  is the standardized selection differential or selection intensity. The value of  $k$  at 5% proportion selected is 2.063. Values of  $k$  at other selected proportions are available in Appendix Table A of Falconer and Mackay (1996).

$$GAM = \frac{GA}{\bar{x}} \times 100$$

<b>GAM</b>	<b>Category</b>
$x < 10$	Low
$10 \leq x < 20$	Medium
$\geq 20$	High

## Value

A list with the following descriptive statistics:

Count	The number of treatments/genotypes.
Mean	The mean value.
Std. Error	The standard error.

Std.Deviation    The standard deviation.  
 Min              The minimum value.  
 Max              The maximum value.  
 Skewness(statistic)              The skewness estimator.  
 Skewness(p.value)              The p-value from D'Agostino test of skewness.  
 Kurtosis(statistic)              The kurtosis estimator.  
 Kurtosis(p.value)              The p-value from Anscombe-Glynn test of kurtosis.

### Note

Genetic variability analysis needs to be performed only if the sum of squares of "Treatment: Test" are significant.

Negative estimates of variance components if computed are not abnormal. For information on how to deal with these, refer Dudley and Moll (1969).

### References

- Lush JL (1940). "Intra-sire correlations or regressions of offspring on dam as a method of estimating heritability of characteristics." *Proceedings of the American Society of Animal Nutrition*, **1940**(1), 293–301.
- Burton GW (1951). "Quantitative Inheritance in pearl millet (*Pennisetum glaucum*)." *Agronomy Journal*, **43**(9), 409–417.
- Burton GW (1952). "Qualitative inheritance in grasses. Vol. 1." In *Proceedings of the 6th International Grassland Congress, Pennsylvania State College*, 17–23.
- Johnson HW, Robinson HF, Comstock RE (1955). "Estimates of genetic and environmental variability in soybeans." *Agronomy journal*, **47**(7), 314–318.
- Robinson HF (1966). "Quantitative genetics in relation to breeding on centennial of Mendelism." *Indian Journal of Genetics and Plant Breeding*, 171.
- Dudley JW, Moll RH (1969). "Interpretation and Use of Estimates of Heritability and Genetic Variances in Plant Breeding." *Crop Science*, **9**(3), 257–262.
- Sivasubramaniam S, Madhavamenon P (1973). "Genotypic and phenotypic variability in rice." *The Madras Agricultural Journal*, **60**(9-13), 1093–1096.
- Falconer DS, Mackay TFC (1996). *Introduction to quantitative genetics*. Pearson/Prentice Hall, New York, NY.

### See Also

[augmentedRCBD](#)

### Examples

```
# Example data
blk <- c(rep(1,7),rep(2,6),rep(3,7))
trt <- c(1, 2, 3, 4, 7, 11, 12, 1, 2, 3, 4, 5, 9, 1, 2, 3, 4, 8, 6, 10)
y1 <- c(92, 79, 87, 81, 96, 89, 82, 79, 81, 81, 91, 79, 78, 83, 77, 78, 78,
       70, 75, 74)
```

```

y2 <- c(258, 224, 238, 278, 347, 300, 289, 260, 220, 237, 227, 281, 311, 250,
        240, 268, 287, 226, 395, 450)
data <- data.frame(blk, trt, y1, y2)
# Convert block and treatment to factors
data$blk <- as.factor(data$blk)
data$trt <- as.factor(data$trt)
# Results for variable y1
out1 <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE)
# Results for variable y2
out2 <- augmentedRCBD(data$blk, data$trt, data$y2, method.comp = "lsd",
                      alpha = 0.05, group = TRUE, console = TRUE)

# Genetic variability analysis
gva.augmentedRCBD(out1)
gva.augmentedRCBD(out2)

```

---

print.augmentedRCBD	<i>Prints summary of augmentedRCBD object</i>
---------------------	---

---

## Description

print.augmentedRCBD prints to console the summary of an object of class augmentedRCBD including the augmented design details, ANOVA (Treatment adjusted), ANOVA (Block adjusted), treatment means, coefficient of variation, overall adjusted mean, critical differences and standard errors. The treatment/genotype groups along with the grouping method are also printed if they were computed.

## Usage

```
## S3 method for class 'augmentedRCBD'
print(x, ...)
```

## Arguments

x	An object of class augmentedRCBD.
...	Unused

## See Also

[augmentedRCBD](#)

---

```
print.augmentedRCBD.bulk
```

*Prints summary of augmentedRCBD.bulk object*

---

### Description

print.augmentedRCBD.bulk prints to console the summary of an object of class augmentedRCBD.bulk including the augmented design details, trait-wise mean sum of squares from ANOVA (Treatment adjusted) and ANOVA (Block adjusted), adjusted means, coefficient of variation, overall adjusted means critical differences, standard errors, descriptive statistics, frequency distribution plots, genetic variability statistics and plots of genetic variability parameters.

### Usage

```
## S3 method for class 'augmentedRCBD.bulk'
print(x, ...)
```

### Arguments

x	An object of class augmentedRCBD.bulk.
...	Unused

### See Also

[augmentedRCBD.bulk](#)

---

```
report.augmentedRCBD
```

*Generate MS Word Report from augmentedRCBD Output*

---

### Description

report.augmentedRCBD generates a tidy report from an object of class augmentedRCBD as docx MS word file using the [officer](#) package.

### Usage

```
report.augmentedRCBD(aug, target)
```

### Arguments

aug	An object of class augmentedRCBD.
target	The path to the docx file to be created.

### See Also

[officer](#), [flectable](#)

**Examples**

```
# Example data
blk <- c(rep(1,7),rep(2,6),rep(3,7))
trt <- c(1, 2, 3, 4, 7, 11, 12, 1, 2, 3, 4, 5, 9, 1, 2, 3, 4, 8, 6, 10)
y1 <- c(92, 79, 87, 81, 96, 89, 82, 79, 81, 81, 91, 79, 78, 83, 77, 78, 78,
       70, 75, 74)
y2 <- c(258, 224, 238, 278, 347, 300, 289, 260, 220, 237, 227, 281, 311, 250,
       240, 268, 287, 226, 395, 450)
data <- data.frame(blk, trt, y1, y2)
# Convert block and treatment to factors
data$blk <- as.factor(data$blk)
data$trt <- as.factor(data$trt)
# Results for variable y1 (checks inferred)
out <- augmentedRCBD(data$blk, data$trt, data$y1, method.comp = "lsd",
                     alpha = 0.05, group = TRUE, console = FALSE)

report.augmentedRCBD(out, file.path(tempdir(), "augmentedRCBD output.docx"))
```

---

report.augmentedRCBD.bulk

*Generate MS Word Report from augmentedRCBD.bulk Output*


---

**Description**

report.augmentedRCBD.bulk generates a tidy report from an object of class augmentedRCBD.bulk as docx MS word file using the [officer](#) package.

**Usage**

```
report.augmentedRCBD.bulk(aug.bulk, target)
```

**Arguments**

aug.bulk	An object of class augmentedRCBD.bulk.
target	The path to the docx file to be created.

**See Also**

[officer](#), [flectable](#)  
[augmentedRCBD.bulk](#)

**Examples**

```
# Example data
blk <- c(rep(1,7),rep(2,6),rep(3,7))
trt <- c(1, 2, 3, 4, 7, 11, 12, 1, 2, 3, 4, 5, 9, 1, 2, 3, 4, 8, 6, 10)

y1 <- c(92, 79, 87, 81, 96, 89, 82, 79, 81, 81, 91, 79, 78, 83, 77, 78, 78,
       70, 75, 74)
```

[illegible]



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