

Package ‘toolStability’

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Type Package

Title Tool for Stability Indices Calculation

Version 0.1.3

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Description Tools to calculate stability indices with parametric, non-parametric and probabilistic approaches. The basic data format requirement for 'toolStability' is a data frame with 3 columns including numeric trait values, genotype, and environmental labels. Output format of each function is the dataframe with chosen stability index for each genotype.

Function ``table_stability`` offers the summary table of all stability indices in this package.

This R package toolStability is part of the main publication:

Wang, Casadebaig and Chen (2023) <[doi:10.1007/s00122-023-04264-7](https://doi.org/10.1007/s00122-023-04264-7)>.

Analysis pipeline for main publication can be found on github: <https://github.com/Illustratien/Wang_2023_TAAG>.

Sample dataset in this package is derived from another publication:

Casadebaig P, Zheng B, Chapman S et al. (2016) <[doi:10.1371/journal.pone.0146385](https://doi.org/10.1371/journal.pone.0146385)>.

For detailed documentation of dataset, please see on Zenodo <[doi:10.5281/zenodo.4729636](https://doi.org/10.5281/zenodo.4729636)>.

Indices used in this package are from:

Döring TF, Reckling M (2018) <[doi:10.1016/j.eja.2018.06.007](https://doi.org/10.1016/j.eja.2018.06.007)>.

Eberhart SA, Russell WA (1966) <[doi:10.2135/cropsci1966.0011183X000600010011x](https://doi.org/10.2135/cropsci1966.0011183X000600010011x)>.

Eskridge KM (1990) <[doi:10.2135/cropsci1990.0011183X003000020025x](https://doi.org/10.2135/cropsci1990.0011183X003000020025x)>.

Finlay KW, Wilkinson GN (1963) <[doi:10.1071/AR9630742](https://doi.org/10.1071/AR9630742)>.

Hanson WD (1970) Genotypic stability. <[doi:10.1007/BF00285245](https://doi.org/10.1007/BF00285245)>.

Lin CS, Binns MR (1988).

Nassar R, Hühn M (1987).

Pinthus MJ (1973) <[doi:10.1007/BF00021563](https://doi.org/10.1007/BF00021563)>.

Römer T (1917).

Shukla GK (1972).

Wricke G (1962).

Depends R (>= 3.5.0)

VignetteBuilder knitr

RoxygenNote 7.2.3

Imports dplyr, data.table, Rdpack, nortest, stats

Suggests testthat (>= 3.0.0), ggplot2, knitr, rmarkdown, pkgdown,
pander, XML, httr, RCurl, covr

RdMacros Rdpack

URL <https://illustratien.github.io/toolStability/>,
<https://link.springer.com/article/10.1007/s00122-023-04264-7>,
<https://github.com/Illustratien/toolStability>,
https://github.com/Illustratien/Wang_2023_TAAG,
<https://doi.org/10.5281/zenodo.4729636>

BugReports <https://github.com/Illustratien/toolStability/issues>

License GPL (>= 3)

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adjusted_coefficient_of_variation
Adjusted coefficient of variation

Description

adjusted_coefficient_of_variation calculate variance of a genotype across environments.

Usage

```
adjusted_coefficient_of_variation(data, trait, genotype, environment)
```

Arguments

| | |
|-------------|--|
| data | a dataframe containing trait, genotype and environment. |
| trait | colname of a column containing a numeric vector of interested trait to be analyzed. |
| genotype | colname of a column containing a character or factor vector labeling different genotypic varieties |
| environment | colname of a column containing a character or factor vector labeling different environments |

Details

Adjusted coefficient of variation (Doering and Reckling, 2018) is calculated based on regression function. Variety with low adjusted coefficient of variation is considered as stable. Equation of adjusted coefficient of variation can be found in vignette file.

Value

a data table with adjusted coefficient of variation

Author(s)

Tien-Cheng Wang

References

Döring TF, Reckling M (2018). “Detecting global trends of cereal yield stability by adjusting the coefficient of variation.” *European Journal of Agronomy*, **99**, 30–36. ISSN 1161-0301, doi: [10.1016/j.eja.2018.06.007](https://doi.org/10.1016/j.eja.2018.06.007).

Examples

```
data(Data)
res <- adjusted_coefficient_of_variation(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  environment = "Environment")
```

coefficient_of_determination
Coefficient of determination

Description

coefficient_of_determination calculate variance of a genotype across environments.

Usage

```
coefficient_of_determination(data, trait, genotype, environment)
```

Arguments

| | |
|-------------|--|
| data | a dataframe containing trait, genotype and environment. |
| trait | colname of a column containing a numeric vector of interested trait to be analyzed. |
| genotype | colname of a column containing a character or factor vector labeling different genotypic varieties |
| environment | colname of a column containing a character or factor vector labeling different environments |

Details

Coefficient of determination (Pinthus, 1976) is calculated based on regression function. Variety with low coefficient of determination is considered as stable. Equation of coefficient of determination can be found in vignette file.

Value

a data table with coefficient of determination

Author(s)

Tien-Cheng Wang

References

Pinthus MJ (1973). "Estimate of genotypic value: A proposed method." *Euphytica*, **22**(1), 121–123. ISSN 1573-5060, doi: [10.1007/BF00021563](https://doi.org/10.1007/BF00021563).

Examples

```

data(Data)
coef.of.determination <- coefficient_of_determination(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  environment = "Environment")

```

coefficient_of_regression
Coefficient of regression

Description

coefficient_of_regression calculate variance of a genotype across environments.

Usage

```
coefficient_of_regression(data, trait, genotype, environment)
```

Arguments

| | |
|-------------|--|
| data | a dataframe containing trait, genotype and environment. |
| trait | colname of a column containing a numeric vector of interested trait to be analyzed. |
| genotype | colname of a column containing a character or factor vector labeling different genotypic varieties |
| environment | colname of a column containing a character or factor vector labeling different environments |

Details

Coefficient of regression (Finlay and Wilkinson, 1963) is calculated based on regression function. Variety with low coefficient of regression is considered as stable. Under the linear model

$$Y = \mu + b_i e_j + g_i + d_{ij}$$

where Y is the predicted phenotypic values, g_i , e_j and μ denoting genotypic, environmental and overall population mean, respectively.

The effect of GE-interaction may be expressed as:

$$(ge)_{ij} = b_i e_j + d_{ij}$$

where b_i is the coefficient of regression and d_{ij} a deviation.

Coefficient of regression may be expressed as:

$$b_i = 1 + \frac{\sum_j (X_{ij} - \bar{X}_i - \bar{X}_{.j} + \bar{X}_{..}) \cdot (\bar{X}_{.j} - \bar{X}_{..})}{\sum_j (\bar{X}_{.j} - \bar{X}_{..})^2}$$

where X_{ij} is the observed phenotypic mean value of genotype i ($i=1, \dots, G$) in environment j ($j=1, \dots, E$), with \bar{X}_i and \bar{X}_j denoting marginal means of genotype i and environment j , respectively. $\bar{X}_{..}$ denote the overall mean of X .

Value

a data table with coefficient of regression

Author(s)

Tien Cheng Wang

References

Finlay KW, Wilkinson GN (1963). "The analysis of adaptation in a plant-breeding programme." *Australian Journal of Agricultural Research*, **14**(6), 742–754. doi: [10.1071/AR9630742](https://doi.org/10.1071/AR9630742).

Examples

```
data(Data)
coefficient.of.regression <- coefficient_of_regression(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  environment = "Environment")
```

Data

Wheat APSIM model simulated database

Description

Multi-environment trial evaluating 5 genotypes in 4 locations for 4 years, with 2 nitrogen application rates, 2 sowing dates, and 2 CO₂ levels of treatments (Casadebaig et al., 2016).

Usage

```
data(Data)
```

Format

A dataframe with 640 observations on the following 8 variables.

- Yield: kg*ha⁻¹.
- Genotype: genotypes, 5 varieties.
- Environment: 128 unique combination of environments for each genotype.
- Year: 4 years.
- Sites: 4 locations.

- Nitrogen: 2 nitrogen application levels.
- CO2: 2 CO2 concentration levels.
- Sowing: 2 sowing dates.

References

Casadebaig P, Zheng B, Chapman S, Huth N, Faivre R, Chenu K (2016). “Assessment of the Potential Impacts of Wheat Plant Traits across Environments by Combining Crop Modeling and Global Sensitivity Analysis.” *PLOS ONE*, **11**(1), e0146385. doi: [10.1371/journal.pone.0146385](https://doi.org/10.1371/journal.pone.0146385).

Examples

```
data(Data)

ggplot2::ggplot(Data,ggplot2::aes(x=Sites,y=Yield,col=Genotype))+
  ggplot2::geom_boxplot()+
  ggplot2::facet_grid(Sowing~Nitrogen,labeller =ggplot2::label_both)+
  ggplot2::ylab(bquote('Wheat yield (ton' %.'ha'^-1*'')))
```

deviation_mean_squares

Deviation mean squares

Description

deviation_mean_squares calculate variance of a genotype across environments.

Usage

```
deviation_mean_squares(
  data,
  trait,
  genotype,
  environment,
  unit.correct = FALSE
)
```

Arguments

| | |
|-------------|--|
| data | a dataframe containing trait, genotype and environment. |
| trait | colname of a column containing a numeric vector of interested trait to be analyzed. |
| genotype | colname of a column containing a character or factor vector labeling different genotypic varieties |
| environment | colname of a column containing a character or factor vector labeling different environments |

`unit.correct` logical, default is FALSE, returning the stability index with unit equals to squared unit of trait; when TRUE, returning stability index with the unit as same as unit of trait.

Details

Deviation mean squares (Eberhart and Russell, 1966) is calculated based on regression function. Variety with low stability variance is considered as stable. Equation of deviation mean squares can be found in vignette file.

Value

a data table with deviation mean squares

Author(s)

Tien Cheng Wang

References

Eberhart SA, Russell WA (1966). "Stability parameters for comparing varieties." *Crop Science*, 6(1), 36–40. ISSN 0011-183X, doi: [10.2135/cropsci1966.0011183X000600010011x](https://doi.org/10.2135/cropsci1966.0011183X000600010011x).

Examples

```
data(Data)
deviation.mean.squares <- deviation_mean_squares(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  environment = "Environment",
  unit.correct = FALSE)
```

ecovalence

Ecovalence

Description

ecovalence calculate genetic and environmental interaction.

Usage

```
ecovalence(
  data,
  trait,
  genotype,
  environment,
  unit.correct = FALSE,
  modify = FALSE
)
```

Arguments

| | |
|--------------|--|
| data | a dataframe containing trait, genotype and environment. |
| trait | colname of a column containing a numeric vector of interested trait to be analyzed. |
| genotype | colname of a column containing a character or factor vector labeling different genotypic varieties |
| environment | colname of a column containing a character or factor vector labeling different environments |
| unit.correct | logical, default is FALSE, returning the stability index with unit equals to squared unit of trait; when TRUE, returning stability index with the unit as same as unit of trait. |
| modify | logical, default is FALSE, returning the original ecovalence; when TRUE, returning modified ecovalence in consideration of number of environment. |

Details

Ecovalence (Wricke, 1962) is calculated based on square and sum up the genotype–environment interaction all over the environment. Variety with low ecovalence is considered as stable. Equation of ecovalence can be found in vignette file.

Value

a data table with ecovalence

Author(s)

Tien-Cheng Wang

References

Wricke G (1962). “Über eine Methode zur Erfassung der ökologischen Streubreite in Feldversuchen.” *Zeitschrift für Pflanzenzüchtung*, **47**, 92–96.

Examples

```
data(Data)
eco.valence <- ecovalence(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  environment = "Environment",
  unit.correct = FALSE,
  modify=FALSE)
```

`environmental_variance`*Environmental variance*

Description

`environmental_variance` is used to calculate variance of a genotype across environments.

Usage

```
environmental_variance(data, trait, genotype, unit.correct = FALSE)
```

Arguments

| | |
|---------------------------|---|
| <code>data</code> | a dataframe containing trait, genotype and environment. |
| <code>trait</code> | colname of a column containing a numeric vector of interested trait to be analyzed. |
| <code>genotype</code> | colname of a column containing a character or factor vector labeling different genotypic varieties |
| <code>unit.correct</code> | logical, default is FALSE, returning the stability index with unit equals to squared unit of trait; when TRUE, returning stability index with the unit as same as unit of trait.' |

Details

Environmental variance (Roemer, 1917) is calculated by squared and suming up all deviation from genotypic mean for each genotype. The larger the environmental variance of one genotype is, the lower the stability. Equation of environmental variance can be found in vignette file.

Value

a data table with environmental variance

Author(s)

Tien-Cheng Wang

References

Roemer T (1917). "Sind die ertragreichen Sorten ertragssicherer?" *Mitteilungen der Deutschen Landwirtschaftlichen Gesellschaft*, **32**(1), 87–89.

Examples

```
data(Data)
environmental.variance <- environmental_variance(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  unit.correct = FALSE)
```

genotypic_stability *Genotypic stability*

Description

genotypic_stability calculate variance of a genotype across environments.

Usage

```
genotypic_stability(data, trait, genotype, environment, unit.correct = FALSE)
```

Arguments

| | |
|--------------|---|
| data | a dataframe containing trait, genotype and environment. |
| trait | colname of a column containing a numeric vector of interested trait to be analyzed. |
| genotype | colname of a column containing a character or factor vector labeling different genotypic varieties |
| environment | colname of a column containing a character or factor vector labeling different environments |
| unit.correct | logical, default is FALSE, returning the stability index with unit equals to squared unit of trait; when TRUE, returning stability index with the unit as same as unit of trait.' |

Details

Genotypic stability (Hanson, 1970) is calculated based on regression function. Variety with low stability variance is considered as stable. Equation of genotypic stability can be found in vignette file.

Value

a data table with genotypic stability

Author(s)

Tien-Cheng Wang

References

Hanson WD (1970). "Genotypic stability." *Theoretical and Applied Genetics*, **40**(5), 226–231. ISSN 1432-2242, doi: [10.1007/BF00285245](https://doi.org/10.1007/BF00285245).

Examples

```
data(Data)
genotypic.stability <- genotypic_stability(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  environment = "Environment",
  unit.correct = FALSE)
```

```
genotypic_superiority_measure
      Genotypic superiority measure
```

Description

genotypic_superiority_measure calculate variance of a genotype across environments.

Usage

```
genotypic_superiority_measure(
  data,
  trait,
  genotype,
  environment,
  unit.correct = FALSE
)
```

Arguments

| | |
|--------------|--|
| data | a dataframe containing trait, genotype and environment. |
| trait | colname of a column containing a numeric vector of interested trait to be analyzed. |
| genotype | colname of a column containing a character or factor vector labeling different genotypic varieties |
| environment | colname of a column containing a character or factor vector labeling different environments |
| unit.correct | logical, default is FALSE, returning the stability index with unit equals to squared unit of trait; when TRUE, returning stability index with the unit as same as unit of trait. |

Details

Genotypic superiority measure (Lin and Binns, 1988) is calculated based on means square distance between maximum value of environment j and genotype i . Variety with low genotypic superiority measure is considered as stable. Equation of genotypic superiority measure can be found in vignette file.

Value

a data table with genotypic superiority measure

Author(s)

Tien-Cheng Wang

References

Lin CS, Binns MR (1988). "A superiority measure of cultivar performance for cultivar \times location data." *Canadian Journal of Plant Science*, **68**(1), 193–198. ISSN 0008-4220.

Examples

```
data(Data)
res <- genotypic_superiority_measure(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  environment = "Environment",
  unit.correct = FALSE)
```

safety_first_index *Safety-first Index*

Description

safety_first_index calculate variance of a genotype across environments.

Usage

```
safety_first_index(data, trait, genotype, environment, lambda)
```

Arguments

| | |
|----------|---|
| data | a dataframe containing trait, genotype and environment. |
| trait | colname of a column containing a numeric vector of interested trait to be analyzed. |
| genotype | colname of a column containing a character or factor vector labeling different genotypic varieties. |

| | |
|-------------|--|
| environment | colname of a column containing a character or factor vector labeling different environments. |
| lambda | the minimal acceptable value of trait that the user expected from crop across environments. Lambda should be between the ranges of trait values. |

Details

Safety-first index (Eskridge, 1990) is calculated based on the assumption of that the trait from each genotype follows normal distribution over environments. Among different environments, trait below a given critical level λ is defined as failure of trait. The probability of trait failure can be obtained by entering mean and variance of trait and λ into the cumulative density function of normal distribution. Variety with low safety first index is considered as stable. Equation of adjusted coefficient of variation can be found in vignette file.

Value

a data table with coefficient of determination

Author(s)

Tien-Cheng Wang

References

Eskridge KM (1990). "Selection of Stable Cultivars Using a Safety-First Rule." *Crop Science*, **30**(2), 369. ISSN 0011-183X, doi: [10.2135/cropsci1990.0011183X003000020025x](https://doi.org/10.2135/cropsci1990.0011183X003000020025x).

Examples

```
data(Data)
safety.first.index <- safety_first_index(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  environment = "Environment",
  lambda = median(Data$Yield))
```

stability_variance *Stability variance*

Description

stability_variance calculate variance of a genotype across environments.

Usage

```
stability_variance(data, trait, genotype, environment, unit.correct = FALSE)
```

Arguments

| | |
|--------------|--|
| data | a dataframe containing trait, genotype and environment. |
| trait | colname of a column containing a numeric vector of interested trait to be analyzed. |
| genotype | colname of a column containing a character or factor vector labeling different genotypic varieties. |
| environment | colname of a column containing a character or factor vector labeling different environments. |
| unit.correct | logical, default is FALSE, returning the stability index with unit equals to squared unit of trait; when TRUE, returning stability index with the unit as same as unit of trait.#' |

Details

Stability variance (Shukla, 1972) is calculated based on linear combination of ecovalence and mean square of genotype-environment interaction. Variety with low stability variance is considered as stable. Negative values of stability variance is replaced with 0. Equation of stability variance can be found in vignette file.

Value

a data table with stability variance

Author(s)

Tien-Cheng Wang

References

Shukla GK (1972). "Some statistical aspects of partitioning genotype environmental components of variability." *Heredity*, **29**(2), 237–245.

Examples

```
data(Data)
stability.variance <- stability_variance(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  environment = "Environment")
```

| | |
|------------------------------|-----------------------------------|
| <code>table_stability</code> | <i>Table of stability indices</i> |
|------------------------------|-----------------------------------|

Description

`table_stability` export all the stability indices in the package.

Usage

```
table_stability(
  data,
  trait,
  genotype,
  environment,
  lambda,
  normalize = FALSE,
  unit.correct = FALSE
)
```

Arguments

| | |
|---------------------------|---|
| <code>data</code> | a data frame containing trait, genotype and environment. |
| <code>trait</code> | colname of a column containing a numeric vector of interested trait to be analyzed. |
| <code>genotype</code> | colname of a column containing a character or factor vector labeling different genotypic varieties. |
| <code>environment</code> | colname(s) of a column containing a character or factor vector labeling different environments, if input is a vector containing multiple column names, then it will be merged into single environment column in the function. |
| <code>lambda</code> | the minimal acceptable value of trait that the user expected from crop across environments. Lambda should between the ranges of trait vlaue. |
| <code>normalize</code> | logical, default is FALSE, indicating whether stability indices should be normalized to the range from 0 to 1, where 1 refer to stable and 0 is unstable. |
| <code>unit.correct</code> | logical, default is FALSE, returning the stability index with unit equals to squared unit of trait; when TRUE, returning stability index with the unit as same as unit of trait. |

Details

Combine all stability indices in this package and export as a table, including mean trait, normality of the trait across environment.

Value

a data table with multiple stability indices

Author(s)

Tien-Cheng Wang

References

Döring TF, Reckling M (2018). “Detecting global trends of cereal yield stability by adjusting the coefficient of variation.” *European Journal of Agronomy*, **99**, 30–36. ISSN 1161-0301, doi: [10.1016/j.eja.2018.06.007](https://doi.org/10.1016/j.eja.2018.06.007). Pinthus MJ (1973). “Estimate of genotypic value: A proposed method.” *Euphytica*, **22**(1), 121–123. ISSN 1573-5060, doi: [10.1007/BF00021563](https://doi.org/10.1007/BF00021563). Finlay KW, Wilkinson GN (1963). “The analysis of adaptation in a plant-breeding programme.” *Australian Journal of Agricultural Research*, **14**(6), 742–754. doi: [10.1071/AR9630742](https://doi.org/10.1071/AR9630742). Eberhart SA, Russell WA (1966). “Stability parameters for comparing varieties.” *Crop Science*, **6**(1), 36–40. ISSN 0011-183X, doi: [10.2135/cropsci1966.0011183X000600010011x](https://doi.org/10.2135/cropsci1966.0011183X000600010011x). Wricke G (1962). “Über eine Methode zur Erfassung der ökologischen Streubreite in Feldversuchen.” *Zeitschrift für Pflanzenzüchtung*, **47**, 92–96. Rämmer T (1917). “Sind die ertragreichen Sorten ertragssicherer?” *Mitteilungen der Deutschen Landwirtschaftlichen Gesellschaft*, **32**(1), 87–89. Hanson WD (1970). “Genotypic stability.” *Theoretical and Applied Genetics*, **40**(5), 226–231. ISSN 1432-2242, doi: [10.1007/BF00285245](https://doi.org/10.1007/BF00285245). Lin CS, Binns MR (1988). “A superiority measure of cultivar performance for cultivar × location data.” *Canadian Journal of Plant Science*, **68**(1), 193–198. ISSN 0008-4220. Shukla GK (1972). “Some statistical aspects of partitioning genotype environmental components of variability.” *Heredity*, **29**(2), 237–245. Nassar R, Hahn M (1987). “Studies on estimation of phenotypic stability: Tests of significance for nonparametric measures of phenotypic stability.” *Biometrics*, **43**(1), 45–53. ISSN 0006-341X. Eskridge KM (1990). “Selection of Stable Cultivars Using a Safety-First Rule.” *Crop Science*, **30**(2), 369. ISSN 0011-183X, doi: [10.2135/cropsci1990.0011183X003000020025x](https://doi.org/10.2135/cropsci1990.0011183X003000020025x).

See Also

[adjusted_coefficient_of_variation](#)
[coefficient_of_determination](#)
[coefficient_of_regression](#)
[deviation_mean_squares](#)
[ecovalence](#)
[environmental_variance](#)
[genotypic_stability](#)
[genotypic_superiority_measure](#)
[stability_variance](#)
[variance_of_rank](#)
[safety_first_index](#)

Examples

```
data(Data)
tb <- table_stability(
  data = Data,
  trait = "Yield",
```

```

genotype = "Genotype",
environment = "Environment",
lambda = median(Data$Yield),
normalize = TRUE,
unit.correct=TRUE)

```

| | |
|------------------|-------------------------|
| variance_of_rank | <i>variance of rank</i> |
|------------------|-------------------------|

Description

variance_of_rank calculate variance of a genotype across environments.

Usage

```
variance_of_rank(data, trait, genotype, environment, unit.correct = FALSE)
```

Arguments

| | |
|--------------|--|
| data | a dataframe containing trait, genotype and environment. |
| trait | colname of a column containing a numeric vector of interested trait to be analyzed. |
| genotype | colname of a column containing a character or factor vector labeling different genotypic varieties |
| environment | colname of a column containing a character or factor vector labeling different environments |
| unit.correct | logical, default is FALSE, returning the stability index with unit equals to squared unit of trait; when TRUE, returning stability index with the unit as same as unit of trait.#' |

Details

Variance of rank (Nassar and Huehn, 1987) is calculated based on regression function. Variety with low variance of rank is considered as stable. Equation of variance of rank can be found in vignette file.

Value

a data table with variance of rank

Author(s)

Tien-Cheng Wang

References

Nassar R, Hähn M (1987). "Studies on estimation of phenotypic stability: Tests of significance for nonparametric measures of phenotypic stability." *Biometrics*, **43**(1), 45–53. ISSN 0006-341X.

Examples

```
data(Data)
variance.of.rank <- variance_of_rank(
  data = Data,
  trait = "Yield",
  genotype = "Genotype",
  environment = "Environment",
  unit.correct = FALSE)
```

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