Statistix 8 User Guide

Plant Materials Program

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March 2007

Introduction

The Plant Materials Program generates a tremendous amount of data each and every year. Statistics is a great TOOL to help you make sense of your data. This User's Guide is built in the spirit of helping you use statistics effectively.

Statistics is daunting to some because it has a jargon all of its own. This User's Guide restates much of the "statistics jargon" in terms that Plant Materials scientists can better understand. Call out boxes, colored lettering, and circles are used to point out critical jargon and explain what these numbers, codes, and values really mean.

The User's Guide is not meant to be a substitute for the manual. The User's Guide focuses on information that is most useful to you, a plant scientist.

Statistix 8 is a commercial software package. It was chosen by a team of Plant Materials scientists based upon a number of factors. Ease of use and ability to import data from spreadsheets are two of the factors that weighed in heavily during the selection process.

Statistix 8 provides you with almost all of the statistical analysis techniques that the Plant Materials Program will ever use. If you require more robust, very highly specialized data analysis, there are other software programs available. However, as statistical complexity increases—so does the opportunity to misinterpret your data. Always consult with a qualified statistician before you embark on a study that generates complex data sets and equally complex statistical results.

Members of the Plant Materials Statistics Committee included: Paul Salon, Plant Materials Specialist, Syracuse, New York; Joel Douglas, Plant Materials Specialist, Central National Technology Support Center, Fort Worth, Texas; Ramona Garner, Manager, Tucson Plant Materials Center, Tucson, Arizona; Jim Stevens, Manager, East Texas Plant Materials Center, Nacogdoches, Texas; Mike Owsley, Manager, Jimmy Carter Plant Materials Center, Americus, Georgia; John Englert, Manager, National Plant Materials Center, Beltsville, Maryland; Mark Stannard, Team Leader, Pullman Plant Materials Center, Pullman, Washington.

Conventions

Menu items and button names are referred to in **boldface**: Data, Insert, Variables OK

Names of dialog boxes are *boldface and italicized: Insert Variables*

Item names within a dialog box are *italicized* and include: list and drop down list, text box and text area, radio button, and check box: Variables list

Text to be typed are within "quotes", but the quotes should not be typed: "rep"

A <u>Note</u>: is not a step but a further explanation of a step or a caution of what to avoid.

An Example uses sample information to show what you can type in or what your result could look like.

Text indented in line with the steps describes the results you will see.

Figures are (usually) screen shots of what you will see on the screen; they are numbered according to their chapter.

Tables are marked discussions of output; they are numbered according to their chapter.

STATISTIX 8 USER'S MANUAL

Chapter 1: Data Entry and File Management	1
I. Entering Data into Statistix 8	
A. Keyboard Data Entry	
B. Entering Alphanumeric Data in Variable Name Columns	
C. Renaming Variables	
D. Inserting Additional Cases into Statistix 8 Spreadsheet	5
II. Moving Data from Microsoft Excel Spreadsheet into Statistix 8 Sp	preadsheet 6
III. File Management	7
Chapter 2: Descriptive Statistics	10
I. Tables	
II Granhs	14
A Scatter Plot	
R. Histogram	
C. Normal Probability Plot and Normality Test	
Chapter 3: Analysis of Variance	21
I. Randomized Complete Block Design	
A. Analyzing the 1995 Switchgrass Cultivar Data	
B. Results and Interpretation of the Analyses	
C. Saving the Analysis of Variance Table	
D. Performing Mean Separation Test on Switchgrass Cultivars	
E. Saving the Mean Separation Test Results	
F. General Interpretations and Presentation of Results	
H. Presentation of Results with letters and LSD value	
I. Analyzing all of the Dataset	
J. Including Year as a Variable	
K. Interpretation of the Analysis	
M. Interpreting the Interaction Effect	
N. Graphing the Interaction Effect	
II. Completely Randomized Design	
A. Analyzing Basin Wildrye Seed Germination Trial	
B. Results and Interpretation of the Analyses	
C. Performing Mean Separation Test on Basin Wildrye Populations	
D. General Interpretations	40
III. Split Plot Design (Without Interaction Effect)	41
A. Analyzing Clipping Frquency of Eastern Gamagrass Cultivars	
B. Results and Interpretation of the Analyses	
C. Performing Mean Separation Test on Clipping and Cultivars	

IV. Split Plot Design (With Interaction Effect)	. 46
A. Analyzing Clipping Frequency in Eastern Gamagrass Cultivars	46
B. Results and Interpretation of the Analyses	48
C. Comparing Means of Clipping *Cultivar Interaction	49

Chapter 4: Regression Analysis......52

I. Linear Regression	
A. Eastern Gamagrass Nitrogen Rate Trial	
B. Interpreting the Regression Analyses	
C. Model Defined	
D. Application and Presentation of Regression Equation	55
II. Quadratic Regression	56

56
56
59
61
62
62

Chapter 5: Missing Data.....64

I. Missing Data	64
A. Description	64
B. Results and Interpretation of the Analyses	65

Chapter 6: Data Transformations......67

I. Introduction	67
II. Tukey's One Degree of Freedom Test of Non-additivity	67
A. Description	
B. Results and Interpretation of the Analyses	68
III. Transforming the Data Using Logarithmic	69
A. Transformation	
B. Results and Interpretation of the Analyses	
C. Presenting the Results	

	mouci	Otatements					
Chap	ter 8:	Converting	MSTAT-C	Files to	Statistix	Files	75

I. Converting	MSTAT-C Files to	o Statistix 8 Files	 75

<u>Chapter 1:</u> Data Entry and File Management

I. Entering Data into Statistix 8

A. Keyboard Data Entry

When you first run *Statistix* 8, an empty, untitled spreadsheet is displayed with the main menu bar appearing above it (Fig. 1-1). The main menu, or spreadsheet menu, is visible whenever the spreadsheet dialog box is the active dialog box. When you place your cursor on an item in the main menu, a drop down list of items appears, each of which is a submenu. These submenus offer a variety of data management and statistical procedure options.

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Figure 1-1

Figure 1-2

To create variables in the columns of the spreadsheet:

- 1. From the main menu, select Data, Insert, Variables (Fig. 1-2)
- 2. In the *Insert Variables* dialog box, in the *New Variable Names* list, enter the names of the variables, using a comma to separate the variable names (Fig. 1-3).

Example: "rep, cultivar, location, cover1, cover2, cover3, biomass"

response variables: biomass, cover1, cover2, cover3 treatment variables: cultivar, location

<u>Note</u>: A variable name is one to nine characters in length, must begin with a letter, and can only consist of letters, digits and the underscore character. You should assign meaningful variable names to describe the variables of interest. You cannot use such words as CASE, M, PI and RANDOM because these words have been reserved for other tasks.

3. Click OK.

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Figure 1-3	Figure 1-4

The variable names appear in separate columns followed by the letter "M" below the variable name (Fig. 1-4).

<u>Note</u>: The letter "M" represents missing data. Since no data has been entered in the spreadsheet then there will be "missing data" until data is added. *Statistix 8* requires that cases be added to the spreadsheet so you can enter data.

"Cases" are the total number of observations in the experiment. For example, if you have 2 cultivars of hairy vetch replicated 4 times at 3 test locations then you would enter 24 cases into the spreadsheet ($2 \times 4 \times 3 = 24$). They are represented by the rows.

To add cases (rows) to the spreadsheet:

- 1. From the main menu, select **Data**, **Insert**, **Cases** (Fig. 1-5).
- 2. In the *Insert Cases* dialog box, enter the number "1" in the *First New Case Number* text box to represent the first case (Fig. 1-6).
- 3. Enter the additional number of cases to achieve your total number of cases in the *Number of Cases to Insert* text box. (total first new = number-of-cases-to-insert).

<u>Note</u>: The number of cases to insert is determined by: (Total number of cases – First new case number = Number of cases to insert). So for a total of 25 cases, (25 - 1 = 24):

enter "1" in the *First New Case Number* text box enter "24" in the *Number of Cases to Inser*" text box

4. Click OK.

Once variable names have been entered and the proper number of cases identified, begin populating the *Statistix 8* spreadsheet with numerical values representing treatment variables.

Examples: cultivar =1, 2, etc; location = 1, 2, 3, 4, etc. (Fig. 1-7 and 1-8)

<u>Note</u>: If you prefer to use accession numbers, use only the last four digits rather than the NRCS 9 million number when entering data into the *Statistix* 8 spreadsheet.





Figure 1-6

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B. Entering Alphanumeric Data in Variable Name Columns

There are situations where alphanumeric data such as a cultivar name (e.g. 'Haskell', 'Shelter', 'Plateau') or location of study (e.g. PMC, Tribune, Altus) is preferred rather than designating a numerical value for the variable names (e.g. 1 = Haskell, 2 = Shelter).

The string (s) data type is used to enter alphanumeric data in the variable column(s) in a *Statistix* 8 spreadsheet.

To enter alphanumeric data:

- 1. From the main menu, select Data, Insert, Variables (Fig. 1-2).
- 2. In the *Insert Variables* dialog box, in the *New Variable Names* list (Fig. 1-3), type the variable name, followed by parentheses containing: the letter "s" (without quotes) followed by a number representing the maximum character length for the column, and end-parentheses.

Examples: cultivar (s7), Haskell (s7) (Fig. 1-9 and 1-10)

<u>Note</u>: Review the list of variable names to ensure that you are assigning the appropriate character length to the column. Remember the maximum length for a column variable name is 9 characters.



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C. Renaming Variables

There are situations after data entry where you may want to rename variables to better reflect what data is being collected. For example, rather than "cover1", "cover2", and "cover3" you may want to change them to "canopy1", "canopy2" and "canopy3". To make this change:

- 1. From the main menu, select Data, Rename Variables.
- 2. In the *Rename Variables* dialog box, where you see the old variable name in the *Old Name* column, type the new variable name in the *New Name* column (Fig.1-11).

Example:

Old Name	New Name
cover1	canopy1
cover2	canopy2
cover3	canopy3

3. Click OK.

The new names will have replaced the old names and will appear in the spreadsheet (Fig. 1-12).

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D. Inserting Additional Cases into Statistix 8 Spreadsheet

Statistix 8 allows the user to insert more cases into an existing *Statistix 8* spreadsheet. For example, you wish to insert 5 additional cases into an existing *Statistix 8* spreadsheet which currently has 25 cases.

To add new cases:

- 1. From main menu, select Data, Insert Cases.
- 2. In the *Insert Cases* dialog box, *First New Case Number* text box, enter "26" to specify that the new case will be the 26th case, given that 25 cases already exist. In the *Number of New Cases to Insert* text box, type in the number "5" to add the additional 5 cases to the data set to total 30 cases (Fig. 1-13).

If you view the spreadsheet, you will see that there are now a total of 30 rows available for data input.

3. Click OK.

Once the new cases have been added, you can begin populating the data set (Fig. 1-14).

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II. Moving Data from Microsoft Excel Spreadsheet into Statistix 8 Spreadsheet

If you prefer to copy data from an Excel spreadsheet into a *Statistix 8* spreadsheet for analysis, use the following steps.

- 1. Open the Excel spreadsheet containing the data.
- 2. In Excel, click in the upper-left hand corner where the beige row meets the beige column of the spreadsheet. The entire spreadsheet dataset will be highlighted.

This will highlight the entire spreadsheet (Fig.1-15).

- 3. From the Excel main menu, select Edit, Copy.
- 4. Open a *Statistix* 8 spreadsheet, and click inside the upper left hand corner cell of the spreadsheet to select it.
- 5. From the *Statistix* 8 main menu, select Edit, Paste.

The data set will be pasted in the *Statistix* 8 spreadsheet (Fig.1-16).

<u>Note</u>: The maximum number of letters in the variable names is 9; thus only "replicati" appear in the column.

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8	3	americus	PMC	85	100	100	5162		
9	4	americus	PMC	55	98	100	3534		
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12	3	comm	delta	43	100	100	5120		
13	4	comm	delta	20	95	100	3640		
14	1	americus	delta	63	85	90	4440		
15	2	americus	delta	75	100	100	6135		
16	3	americus	delta	48	90	100	3639		
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	5	1	americus	PMC	48	98	100	4556
	6	2	americus	PMC	78	98	100	3244
	7	3	americus	PMC	85	100	100	5162
	8	4	americus	PMC	55	98	100	3534
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	12	4	comm	delta	20	95	100	3640
	13	1	americus	delta	63	85	90	4440
	14	2	americus	delta	75	100	100	6135
	15	3	americus	delta	48	90	100	3639
	16	4	americus	delta	65	100	100	4819
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	18	2	comm	prairie	33	38	95	3851
	19	3	comm	prairie	20	65	75	1773
	20	4	comm	prairie	20	53	90	2207
	21	1	americus	prairie	38	68	100	4400
	22	2	americus	prairie	33	63	95	2058
	23	3	americus	prairie	25	60	100	3854
	24	4	americus	prairie	20	73	90	1945

Figure 1-15



III. File Management

In this example, we will name the file "hairy vetch" which will be saved in a default folder named "Statistix".

To save a Statistix 8 file:

- 1. From the main menu, select File, Save As.
- 2. Within the *Save As* dialog box, navigate to the folder you want to save the file into using the arrow to the right of the Save in drop down list box. Select the drive and folder your subfolder is located within. Double-click to enter subfolders until the desired folder is reached. Double-click the desired folder to open it.
- 3. In the Save As dialog box, enter the name of the file in the File name text box. In this case, the we entered filename "hairy vetch.sx"
- 4. Click the **Save** button.

Note: The filename will be given the ".sx" extension, which designates it as a *Statistix* 8 file. Inn this case the filename appears as hairy vetch.sx (Fig.17).

You may want to save your data sets and analyses in specific folders other than the Statistix folder. For example, you may want to maintain all of your data sets on cover crops in a folder named "cover crop evaluations" or in folders titled after your study plan.

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To create a new folder, one way is to:

- 1. After selecting File, Save As from the main menu, place the cursor inside the Save As dialog box and right click on the mouse.
- 2. From the shortcut menu, select New, Folder (Fig. 1-18).

A folder icon will appear in the directory you are viewing, with the words "New Folder" highlighted.

- 3. Type the name of the folder and it will replace the words "New Folder." For this example, we named the new folder "cover crop evaluations" (Fig.1-19).
- 4. You can now save the file "hairy vetch.sx" into the "cover crop evaluation" folder (Fig. 1-20).

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	19		3	1	:	3	20	65	75	177
	20		4	1	;	3	20	53	90	220
	21		1	2	;	3	38	68	100	440
	22		2	2	:	3	33	63	95	205
	23		3	2		3	25	60	100	385
	24		4	2	:	3	20	73	90	194

You can move a saved file from the "Statistix" folder into a subfolder by dragging:

- 1. After having saved the file, select **File**, **Save** As from the main menu.
- 2. Within the *Save As* dialog box, navigate to the folder that contains your file, using the arrow to the right of the *Save in* drop down list box. Select the drive and folder your subfolder is located within. Double-click to enter subfolders until the desired folder is reached.
- 3. Double-click the desired folder to open it.
- 4. Highlight the file.
- 5. At the same time, keep the left mouse button held down and drag the file into the chosen subfolder.

The file will have been moved to the new subfolder.

You can also move a saved file into another folder by cutting/copying and pasting:

- 1. After having saved the file, select File, Save As from the main menu.
- 2. Within the *Save As* dialog box, navigate to the folder that contains your file, using the arrow to the right of the *Save in* drop down list box. Select the drive and folder your subfolder is located within. Double-click to enter subfolders until the desired folder is reached.
- 3. Double-click the desired folder to open it.
- 4. Highlight the file.
- 5. Right-click the mouse so that a shortcut menu appears, and select **Cut** or **Copy** from the shortcut menu.
- 6. Navigate to the folder you want to place the file in using the arrow to the right of the "Save in" list box as in step #2.
- 7. Click on the right mouse button so that a shortcut menu appears, and select **Paste** from the shortcut menu to paste the file into the new folder.

Chapter 2: Descriptive Statistics

Descriptive statistics such as mean, maximum/minimum, standard deviation, and standard error are popular analyses used to reduce the set of measurements to a few summary measures that provide a rough picture of the original measurements. One of the simplest yet most powerful ways of summarizing data is by means of tables and graphs.

Statistix 8 provides the user with many different descriptive statistics options. In this example we will focus on a few of the descriptive statistics commonly used in exploratory data analyses.

I. Tables

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11	4430	1	88	6	5			11	44	30	1	88		6	5
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20	4432	2	2 89	8	4			20	44	32	2	89		8	4
21	4361	2	2 100	4	6			21	43	61	2	100		4	6
22	4365	2	2 85	5	8			22	43	65	2	85		5	8
23	4456	2	2 95	5	5	:		23	44	56	2	95		5	5
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26	1261	2	2 100	7	3			26	12	61	2	100		7	3
27	4405		65	6	5			27	44	05	3	65		6	5
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For this example, we will use subjective ratings for percent stand ("Stand"), plant vigor ("Vigor"), disease resistance ("Disresist") and seed production ("Seed") collected on 13 accessions of plains bristlegrass planted in a randomized complete block design with 3 replications (Fig. 2-1).

<u>Note</u>: Use only the last four digits of an accession number rather than the NRCS 9 million number when entering data into *Statistix* 8 spreadsheet.

To analyze the data:

- 1. From the main menu, select **Statistics**, **Summary Statistics**, **Descriptive Statistics** (Fig. 2-2).
- 2. In the *Descriptive Statistics* dialog box (Fig. 2-3), move the variables "Stand", "Vigor", "Disresist", and "Seed" from the *Variables* list in the left column to the *Descriptive Variables* list one at a time by highlighting the variables and clicking on the right-arrow button to the left of the *Descriptive Variables* list.

<u>Note</u>: Each variable is moved one at a time from the *Variables* list to the *Descriptive Variables* list.

3. Move the variable "Acc" from the *Variables* list in the left column to the *Grouping Variable* list by highlighting the variable and clicking on the right-arrow button to the left of the *Grouping Variable* list. (Fig. 2-4).



Notice in the "Statistics to Report" grouping in the *Descriptive Statistics* dialog box that options "N", "Mean", "SD", and "Min/max" have been selected by default (Fig. 4-4). These defaults represent:

N = number of observations

Mean = mean of the sum of measurements divided by the total number of measurements SD = standard deviation. SD is a measure of variability and is defined as the positive square root of the variances.

Min/max = minimum and maximum measurement

To add or remove a descriptive statistic:

- 1. Move appropriate variables from the *Variables* list into the *Descriptive Variables* or *Grouping Variable* lists by highlighting the variable clicking on the right-arrow button to the left of the new variable list.
- 2. Enter the appropriate confidence interval in the *C.I. Percent Coverage* text box, which is set to 95 by default.
- 3. Select only the tests you desire in the *Statistics to Report* group.
- 4. Click OK.

The results of the analysis on the 13 accessions are presented below (Table 2-1).

Table 2-1

Descriptive Statistics for Acc = 1261

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	5.0000	2.0000	3.0000	7.0000
Seed	3	7.3333	1.5275	6.0000	9.0000
Stand	3	99.333	1.1547	98.000	100.00
Vigor	3	6.3333	0.5774	6.0000	7.0000

Descriptive Statistics for Acc = 2275

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	5.3333	2.3094	4.0000	8.0000
Seed	3	4.6667	0.5774	4.0000	5.0000
Stand	3	76.667	18.009	56.000	89.000
Vigor	3	6.0000	1.7321	4.0000	7.0000

Descriptive Statistics for Acc = 4356

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	6.3333	2.0817	4.0000	8.0000
Seed	3	6.0000	1.0000	5.0000	7.0000
Stand	3	96.667	5.7735	90.000	100.00
Vigor	3	5.0000	1.0000	4.0000	6.0000

Descriptive Statistics for Acc = 4361

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	5.3333	1.1547	4.0000	6.0000
Seed	3	5.0000	1.0000	4.0000	6.0000
Stand	3	100.00	0.0000	100.00	100.00
Vigor	3	4.3333	0.5774	4.0000	5.0000

Descriptive Statistics for Acc = 4365

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	6.3333	1.5275	5.0000	8.0000
Seed	3	6.3333	1.1547	5.0000	7.0000
Stand	3	82.667	6.8069	75.000	88.000
Vigor	3	6.6667	1.5275	5.0000	8.0000

Descriptive Statistics for Acc = 4366

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	7.0000	1.0000	6.0000	8.0000
Seed	3	5.3333	0.5774	5.0000	6.0000
Stand	3	96.000	5.2915	90.000	100.00
Vigor	3	6.3333	1.1547	5.0000	7.0000

Descriptive Statistics for Acc = 4376

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	6.0000	0.0000	6.0000	6.0000
Seed	3	6.0000	2.0000	4.0000	8.0000
Stand	3	100.00	0.0000	100.00	100.00
Vigor	3	6.3333	2.3094	5.0000	9.0000

Descriptive Statistics for Acc = 4386

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	5.3333	1.5275	4.0000	7.0000
Seed	3	5.0000	1.7321	3.0000	6.0000
Stand	3	97.000	3.6056	93.000	100.00
Vigor	3	6.6667	0.5774	6.0000	7.0000

Descriptive Statistics for Acc = 4405

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	5.0000	1.0000	4.0000	6.0000
Seed	3	5.3333	1.1547	4.0000	6.0000
Stand	3	53.333	13.204	39.000	65.000
Vigor	3	5.6667	0.5774	5.0000	6.0000

Descriptive Statistics for Acc = 4414

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	6.6667	1.5275	5.0000	8.0000
Seed	3	5.0000	1.0000	4.0000	6.0000
Stand	3	100.00	0.0000	100.00	100.00
Vigor	3	6.3333	1.5275	5.0000	8.0000

Descriptive Statistics for Acc = 4430

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	5.6667	1.1547	5.0000	7.0000
Seed	3	6.0000	1.0000	5.0000	7.0000
Stand	3	90.333	2.5166	88.000	93.000
Vigor	3	5.6667	0.5774	5.0000	6.0000

Descriptive Statistics for Acc = 4432

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	4.6667	2.0817	3.0000	7.0000
Seed	3	6.3333	1.5275	5.0000	8.0000
Stand	3	91.667	5.5076	88.000	98.000
Vigor	3	5.6667	2.0817	4.0000	8.0000

Descriptive Statistics for Acc = 4456

Variable	N	Mean	SD	Minimum	Maximum
Disresist	3	7.0000	1.7321	5.0000	8.0000
Seed	3	4.0000	1.0000	3.0000	5.0000
Stand	3	98.333	2.8868	95.000	100.00
Vigor	3	5.6667	2.0817	4.0000	8.0000

II. Graphs

A scatter plots, normality plots and histogram are among the most popular and useful graphics for presentation of data. They allow the user to see the features of the data in a glance.

Statistix 8 can display data in a scatter plot, histogram or normal probability plot and test for normality using Shapiro-Wilk normality test.

For our examples, we will use the plain bristlegrass dataset. For graphing ease and interpretation of the scatter plot the accession numbers were assigned with a different numbering system (e.g. 4405 = 1; 4366 = 2, 4356 = 3); thus, a new variable was created and inserted into the original dataset using the insert new variable procedure.

To enter a new variable:

- 1. From the main menu, select **Data**, **Insert**, **Variables**.
- 2. Enter "acc2" into the *Insert Variables* dialog box, in the *New Variable Names* text box.

3. Click OK.

The new variable "acc2" is added to the list of variables in the dataset (Fig. 2-5).

A. Scatter Plot

To construct a scatter plot of the variable "acc2" against the variable "Seed":

- 1. From the main menu, select Statistics, Summary Statistics, Scatter Plot (Fig. 2-6).
- 2. In the *Scatter Plot* dialog box (Fig. 2-7), move the variable "acc2" from the *Variables* list in the left column to the *X-Axis Variables* list by highlighting the variable and clicking the right-arrow button to the left of the *X-Axis Variables* list (Fig. 2-8).
- 3. Move the variable "Seed" from the *Variables* list in the left column to the *Y*-Axis *Variables* list in the middle column by highlighting the variable and clicking the right-arrow button to the left of the *Y*-Axis Variables list.
- 4. Click OK.

Statistix 8 produces a scatter plot of the data (Fig. 2-9).

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Figure 2-9

In reviewing the scatter plot, it appears that most of the accessions produced seed production rating of 5 and 6. Some accessions had above and below average seed ratings on some plots which may warrant further investigation, if deem necessary, to determine the possible cause(s).

B. Histogram

To construct a histogram of the variable "Seed":

- 1. From the main menu, select, Statistics, Summary Statistics, Histogram (Fig. 2-10).
- 2. In the *Histogram* dialog box (Fig. 2-11), move the variable "Seed" from the *Variables* list to the *Histogram Variables* list by highlighting the variable and clicking the right-arrow button to the left of the *Histogram Variables* list (Fig. 2-12).
- 3. Check the *Display Normal Curve* check box to superimpose a normal curve over the bars of the histogram.
- 4. Click OK.

Statistix 8 produces a histogram of the "Seed" data (Fig. 2-13).

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23	4456	10	2	95	5	5	3
24	4430	11	2	90	6	7	5
25	4376	12	2	100	9	6	4
26	1261	13	2	100	7	3	6
27	4405	1	3	85	5	5	4
28	4366	2	3	90	5	6	5
29	4356	3	3	100	4	7	6
30	4414	4	3	100	8	8	4
31	2275	5	3	85	7	4	5
32	4386	6	3	93	6	5	3
33	4432	7	3	88	4	3	5
34	4361	8	3	100	4	6	6
35	4365	9	3	88	8	5	7
36	4456	10	3	100	8	8	4
37	4430	11	3	93	5	5	7
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31		2275		5	3	85	7	4	5
32		4306		6	3	93	6	5	3
33		4432		7	3	98	4	3	5
34		4361		8	3	100	4	6	6
35		4365		9	3	80	0	5	7
36		4456		10	3	100	0	0	4
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Figu	ire 2-12							Figu	ire 2	2-13

The histogram of the seed variable did not show abnormal distribution of the data. Extreme deviations beyond the normal curve would be of concern but small deviations would not be problematic.

C. Normal Probability Plot and Normality Test

A normality plot is an excellent tool to test the assumption that the data you are working with is normality distributed. The normality probability plot, plots the data against the corresponding rankits. When the plotted data are drawn from a normal population, the points appear to fall on a straight line. The Shapiro-Wilk Test, which examines whether the data conforms to a normal distribution, appears at the bottom of the graph.

For this example, we will apply the normal probability plot to data collected from a seeding rate trial of Florida paspalum (Fig. 2-14).

Chapter 2: Descriptive Statistics

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Figure 2-14

Figure 2-15

To construct a normal probability plot:

- 1. From the main menu, select **Statistics**, **Randomness/Probability Plot**, **Normal Probability Plot** (Fig.2-15).
- 2. In the *Normal Probability Plot* dialog box (Fig. 2-16), move the variable "Pltsft2" from the *Variables* list to the *Plot Variable* list by highlighting the variable and clicking the right-arrow button to the left of the *Plot Variable* list (Fig. 2-17).
- 3. Click OK.

Statistix 8 produces a normal probability plot, which includes a Shapiro-Wilks Test (Fig. 2-18).

The results of the normal probability plot suggest that the data conforms to a normal distribution based on the apparent straightness of the line. Furthermore, since the Shapiro-Wilk test for the W statistic (underlined in red) is approaching 1 (0.9330) for normally distributed data and the P value of 0.3026 is greater than p=0.05, then we conclude that the data meets the assumption of normality.

There are cases when data may not be normally distributed. When this occurs, one may need to increase sample size, transform data or analyze the data using non-parametric statistical analyses.

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Figure 2-17



Figure 2-18

Chapter 3: Analysis of Variance

I. Randomized Complete Block Design

You have been collecting yield data on 5 switchgrass cultivars that were planted in a randomized complete block design with four replications. Two harvests were made in 1995 ("Yield1" and "Yield2") and 1996, respectively. The two harvests were summed ("Yield1"+"Yield2") for the season total yield in 1995 and 1996 ("Total"). Data was entered into the *Statistix 8* spreadsheet (Fig. 3-1). You wish to analyze the yield data to determine if there are any statistically significant differences between cultivars at the 5% level of probability, or p = 0.05.

A. Analyzing the 1995 Switchgrass Cultivar Data

In your first data analyses you want to analyze the 1995 cultivar yields ("Yield1", "Yield2" and "Total"). Since the 1996 data is included in the dataset you will need to disregard or omit the data in cases 21-40 so they will not be included in the analyses.

To omit data:

1. Click on the empty beige cell to the left of the cell marked with the fist case number that you want to delete. In this example, we selected the beige cell to the left of case "21".

A triangle will appear in the beige cell to the left of the case number, and the entire row for the case will be highlighted.

2. Click on the left mouse button and hold, and drag the blue highlighted area to the row with the last case that you want to omit. In this example, drag to the row for case "40."

The rows for cases 21 through 40 will be highlighted.

3. From the main menu, select Edit, Omit Highlighted Cases (Fig. 3-2).

Cases 21-40 will fade to a gray tint indicating that they have been omitted from the dataset and will not be included in the analyses.

🖉 Statistix Eile Edit Data Statistics Preferences Window Help 🖻 🖬 🎒 👗 🖻 🛍 🛱 C:\Statistix\example\swgtest95-96.sx Year Cultivar 1995 Alamo Yield2 Rep Yield1 Total 1995 Blackwell 1995 Shelter 1995 Kanlow 1995 Dacotah 1995 Alamo 1995 Dacotah 1995 Kanlow 1995 Blackwell 1995 Shelter 1995 Alamo 1995 Dacotah 1995 Blackwell 1995 Shelter 1995 Kanlow 1995 Shelter 17 1995 Alamo 1995 Dacotah 1995 Kanlow 1995 Blackwell 1996 Alamo 1996 Blackwell 1996 Shelter 1996 Kanlow 1996 Dacotah 1996 Alamo 1996 Dacotah 1996 Kanlow 1996 Blackwell 1996 Shelter 1996 Alamo 1996 Dacotah 33 1996 Blackwell 1996 Shelter 1996 Kanlow 1996 Shelter 1996 Alamo

Figure 3-1

1996 Dacotah

1996 Kanlow

1996 Blackwell

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	20		1996	1	Alamo		359	3 3573	7020		General AOV/AOCV

Figure 3-3

Statistix 8 User Guide Version 2.0

Chapter 3: Analysis of Variance

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	5	1	1995 Daco	otah	3956	3183	7139
	6	2	1995 Alam	0	4123	5116	9239
	7	2	1995 Daco	otah	2795	2917	5712
	8	2	1995 Kanlo	W	4482	2228	6710
	9	2	1995 Black	well	3122	4092	7214
	10	2	1995 Shelt	er	4805	4618	9423
	11	3	1995 Alam	0	6172	5306	11478
	12	3	1995 Daco	otah	4237	2635	6872
	13	3	1995 Black	well	2723	3879	6602
	14	3	1995 Shelt	er	4906	5836	10742
	15	3	1995 Kanlo	W	4980	3605	8585
	16	4	1995 Shelt	er	5367	5256	10623
	17	4	1995 Alam	0	4908	6102	11010
	18	4	1995 Daco	otah	3365	2176	5541
	19	4	1995 Kanlo	W	5010	2710	7720
	20	4	1995 Black	well	3655	3973	7628
	21	1	1996 Alam	0	3590	3507	7097
	22	1	1996 Black	well	3697	2721	6418
	23	1	1996 Shelt	er	3714	4369	8083
	24	1	1996 Kanlo	W	2648	5391	8035
	25	1	1996 Diaco	otah	3873	4213	8086
	26	2	1996 Alam	0	3076	4304	7380
	27	2	1996 Diaco	otah	3521	3058	6579
	28	2	1996 Kanlo	W	3313	4760	8073
	29	2	1996 Black	well	5585	3337	8922
	30	2	1996 Shelt	er	4685	5012	9697
	31	3	1996 Alam	0	3631	6365	9996
	32	3	1996 Diaco	otah	2772	4468	7240
	33	3	1996 Black	well	4971	2955	7926
	34	3	1996 Shelt	er	3582	5116	8698
	35	3	1996 Kanlo	w	2861	6263	9124
	36	4	1996 Shelt	er	4006	5584	9590

Figure 3-2

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	2	1995	1	Blackwell		2494	3372	5866
	3	1995	1	Shelter		4148	5606	9754
	4	1995	1	Kanlow		5154	3564	8718
	5	1995	1	Dacotah		3956	3183	7139
	6	1995	2	Alamo		4123	5116	9239
	7	1995	2	Dacotah		2795	2917	5712
	8	1995	2	Kanlow		4482	2228	6710
	9	1995	2	Blackwell		3122	4092	7214
	10	1995	2	Shelter		4805	4618	9423
	11	1995	3	Alamo		6172	5306	11478
	12	1995	3	Dacotah		4237	2635	6872
	13	1995	3	Blackwell		2723	3879	6602
	14	1995	3	Shelter		4906	5836	10742
	15	1995	3	Kanlow		6020	3605	9625
	16	1995	4	Shelter		5367	6518	11885
	17	1995	4	Alamo		7102	7092	14194
	18	1995	4	Dacotah		3365	2176	5541
	19	1995	4	Kanlow		5010	2710	7720
	20	1995	4	Blackwell		3655	3973	7628
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To analyze the 1995 data, which consists of cases 1-20:

- 1. From the main menu, select Statistics, Linear Models, Analysis of Variance, Randomized Complete Block AOV (Fig. 3-3).
- 2. In the *Randomized Complete Block AOV* dialog box, move the variables you want to designate as dependent variables from the *Variables* list in the left column to the *Dependent Variables* list in the right column by highlighting the variables (in this example, "Yield1", "Yield2", and "Total") and clicking on the right-arrow button to the left of the *Dependent Variables* list (Fig. 3-4).
- 3. Move the variables you want to designate as block variables (in this example, "rep") from the "Variables" list in the left column to the *Block Variable* list in the right column by highlighting the variable and clicking on the right-arrow button to the left of the *Block Variable* list.
- 4. Move the variables you want to designate as treatment variables (in this example, "cultivar") from the *Variables* list in the left column to the *Treatment Variable* list in the right column by highlighting the variable and clicking on the right-arrow button to the left of the *Treatment Variable* list (Fig. 3-5).
- 5. Click OK.
- 6. To return to the data set, from the main menu, select File, Close.



Figure 3-5

B. Results and Interpretation of the Analyses

The following statistical analysis (Table 3-1) was performed by *Statistix 8* on the 1995 data. Rather than discuss all of the numbers generated in the analysis of variance table, we will focus on numbers of greatest interest to the user for Yield 1. Numbers have been highlighted in red followed by an interpretation of the number and its significance to the user.

Table 3-1		

Yield1

Randomized	Comp	olete Block	AOV Table f	Eor YIELI		Since P value of 0.0005 is
Source REP CULTIVAR Error Total	DF 3 4 12 19	ss 1645071 1.343E+07 3532694 1.861E+07	MS 548357 3358870 294391	F 11.41	P 0.0005	less than p= 0.05 then it has been determined that there is statistical differences between switchgrass cultivars for Yield1.
Grand Mean	4266	5.9	CI	/ 12.72		

The grand mean was determined by adding the means of Yield1 for cultivars and dividing the total by 5 (5 cultivars).

The coefficient of variation (CV) indicates the degree of precision with which the treatments are compared and is a good indicator of reliability of the experiment. It expresses the experimental error as a percentage. The lower the CV value the greater the reliability of the experiment. CV values vary depending on crop grown, type of experiment and measurements.

Tukey's 1 De	gree of	Freedom T	est for	Nonadditi	vity
Source	DF	SS	MS	F	P
Nonadditivit	y 1	174979	174979	0.57	0.4649
Remainder	11	3357715	305247		

Statistix 8 conducts a **Tukey's One Degree of Freedom Test for Nonadditivity** for a Randomized Complete Block (RCB) analysis of variance. This test is useful when the experimental design only permits an additive model to be fitted to the data and you suspect that interaction is present. In this example, there is no suggestion of nonadditivity (p=0.4649). If the P value is less than 0.05 then nonadditivity may be present and you should consider transforming the data in an effort to remove it.

Relative Efficiency, RCB 1.11

The purpose of using a RCB design is to reduce the error mean square. The relative efficiency indicates the magnitude to which blocking succeeded in reducing experimental error. In this example, the relative efficiency of using the RCB design over the completely randomized design is1.11 which is ~ 11 % increase in precision.

Means of YIELD1 for CULTIVAR

CULTIVAR	Mean		
Alamo Blackwell Dacotah Kanlow Shelter	2998.5 3588.2 4906.5 4806.5	}	Mean Yield1 for each cultivar was determined by adding the yields of each cultivar by replication and dividing the total by 4 (replications).
Observatio Standard E Std Error	ns per Mea rror of a (Diff of 2	an Mean 2 Means	4 271.29 5) 383.66

<u>Yield2</u> (only the interpretation of the P value is provided for Yield 2)

Randomized Complete Block AOV Table for YIELD2

Source	DF	SS	MS	F	Р	Ν.
REP	3	1087597	362532			
CULTIVAR	4	2.897E+07	7242894	28.33	0.0000	
Error	12	3067458	255622			
Total	19	3.313E+07				

Grand Mean 4126.7 CV 12.25

Tukey's 1 Degr	ee of	Freedom To	est for	Nonaddit	ivity
Source	DF	SS	MS	F	P
Nonadditivity	1	56135	56135	0.21	0.6595
Remainder	11	3011324	273757		

Relative Efficiency, RCB 1.04

Means of YIELD2 for CULTIVAR

CULTIVAR	Mean	
Alamo	5721.0	
Blackwell	3829.0	
Dacotah	2727.8	
Kanlow	3026.8	
Shelter	5329.0	
Observatior Standard Er Std Error (ns per Mean cror of a Mean (Diff of 2 Means)	4 252.80 357.51

Since P value of 0.0000 is less than p= 0.05 then it has been determined that there is statistical difference between switchgrass cultivars for Yield2.

Total Yield (only the interpretation of the P value for total yield is provided)

Randomized Complete Block AOV Table for TOTAL

Source	DF		SS	MS	F	Р
REP	3	39525	591	1317530		
CULTIVAR	4	6.238E+	-07 1	L.559E+07	27.59	0.0000
Error	12	67835	63	565297		
Total	19	7.311E+	-07			\checkmark
Grand Mean	8393.	6 CV	8.96			
Tukey's 1 I	Degree	of Fre	edom 1	lest for No	nadditiv	ity
Source		DF	SS	MS	F	P
Nonadditivi	ity	1 10	72457	1072457	2.07	0.1785
Remainder		11 57	11106	519191		
Relative Ef	ficie	ency, RC	св 1.18	3		
Means of TO	OTAL f	or CULI	IVAR			
CULTIVAR	Mean	ı				
Alamo	10756	-)				
Blackwell	6828	}				
Dacotah	6316	5				
Kanlow	7933	3				
Shelter	10136	5				
Observation	is per	Mean		4		

Since P value of 0.0000 is less than p=0.05 then it has been determined that there are statistical differences between switchgrass cultivars for total vield.

bservations per Mean Standard Error of a Mean 375.93 Std Error (Diff of 2 Means) 531.65

C. Saving the Analysis of Variance Table

To save the analysis of variance table for future reference, follow the procedure outlined in "File Management" in Chapter 1, Section III, except Statistix 8 will save as Rich Text Files. Thus, the filename will be given an ".rtf "extension.

To retrieve the analysis:

- 1. From the main menu, select to click on File, View Text File.
- 2. In the *Open* dialog box, navigate to the folder where the file was saved, and highlight the filename. Click Open.

To copy the file contents and paste them into an MS-Word document:

- 1. Highlight the text in the file you want to copy. Click on the *right* mouse button and select **Copy** from the shortcut menu.
- 2. Open an MS-Word document, click inside the document, and click on the right mouse button and select **Paste** from the shortcut menu.

D. Performing Mean Separation Test on Switchgrass Cultivars

In our example, we determined that there were significant differences between cultivars for "Yield1", "Yield 2", and season "Total" yield based on the analysis of variance, which was performed at the 5% level of probability. Now, we want to know which cultivars are significantly different. For our example, we will perform a mean separation test on the cultivars for "Yield1" only (Fig. 3-6).

- 1. From the main menu, select **Results, Multiple Comparison**, **All-Pairwise Comparison** (Fig. 3-7).
- 2. In the *All-pairwise Comparison* dialog box, select the comparison method of your choice from the *Comparison Method* group (Fig. 3-8). In this example, we select the *LSD* radio button to conduct the least significance difference (LSD) test.
- 3. Keep the default alpha level, which is 0.05 in the *Alpha* text box, or enter 0.01 or 0.10.
- 4. In the *Report Format* group, keep the default selection *Homogenous groups*.

<u>Note</u>: The homogenous groups format will give the means followed by letters (A, B, C, etc) which makes it easier to interpret whether the means are similar or different.

5. Click OK.

Statistix 8 performs a means separation test using the LSD test at the 5% level of probability (Fig. 3-9).

6. To return to the data set, from the main menu, select File, Close.

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Randomized Complete Block AOV Table for YIELD1 Cut 1 yield	Randomized Polynomial Contrasts Comparisons with the Best Plots •
Source DF SS MS F P REP 3 1.645071 548357 CULTIVAR 4 1.3438+07 3358670 11.41 0.0005 Error 12 3532694 2.94391 1 54818+07 Total 19 1.8618+07 1 4 1 1	Source Sawe Residuals P P REP Options 11.41 0.0005 Error 12 332694 294391 Total 19 1.861E+07
Grand Mean 4266.9 CV 12.72 Tukey's 1 Degree of Freedom Test for Nonadditivity Source DF SS B F P	Grand Mean 4266.9 CV 12.72 Tukey's 1 Degree of Freedom Test for Monadditivity Source DF SS MS F P Nonadditivity 1 174979 174979 0.57 0.4649
AUMAAULULUUY 1 174979 174979 0.3, 0.4049 Remainder 11 3357715 305247 Relative Efficiency, RCB 1.11 Means of VIELDI for CULTIVAR	Remainder 11 3357715 305247 Relative Efficiency, RCB 1.11 Means of YIELD1 for CULTIVAR
CULTIVAR Mean Alamo 5034.5 Blacknell 2998.5 Dacotah 3588.2 Kanlow 4906.5 Shelter 4806.5 Observations per Mean 6 Standard Error of a Mean 271.29 Stafard Error of a Mean 383.66	CULTIVAR Mean Alamo 5034.5 Blackwell 2998.5 Dacotah 3588.2 Kanlou 4906.5 Shelter 4806.5 Observations per Mean 4 Standard Error of a Mean 271.29 Std Error (Diff of 2 Means) 383.66
Figure 3-6	Figure 3-7

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Randomized Complete Block AOV - AOV Table	Statistix 8.0 swgtest95-96, 1/18/2006, 2:38:40 PM
Statistix 8.0 swgtest95-96, 1/18/2006, 12:40:11 PM	LSD All-Pairwise Comparisons Test of Yield1 for CULTIVAR
Randomized Complete Block AOV Table for YIELD1 Cut 1 yield	CULTIVAR Mean Homogeneous Groups Alamo 5034.5 A Kanlow 4906.5 A
Source DF SS MS F P REP 3 1645071 548357	Shelter 4806.5 Å Dacotah 3500.3 D Blackwell 2990.5 B
CULITVAR Error 1 All-pairwise Comparisons X	Alpha 0.05 Standard Error for Comparison 383.66 Critical T Value 2.179 Critical Value for Comparison 835.93 Percentery used PEPGriff TVIA 1.3
Grand Mean 4: C Tukey HSD OK	There are 2 groups (A and B) in which the means are not significantly different from one another.
Tukey's 1 Det C Scheffe Lancel ity Source Multiplicative Sidak Help P	LSD ALL-Pairwise Comparisons Test of Yield2 for CULTIVAR CULTIVAR Hean Hemogeneous Groups
Remainder Alpha 0.05	Alamo 5721.0 A Shelter 5329.0 A Blackwell 3029.0 B Kanlow 3026.8 C
Relative Eff:	Dacotah 2727.8 C
Means of YIEI Homogeneous groups Timenday matrix	Alpha 0.05 Standard Error for Comparison 357.51 Critical T Value 2.179 Critical Value for Comparison 778.94
CULTIVAR	Error term used: REP*CULTIVAR, 12 DF There are 3 groups (λ , B , etc.) in which the means
Alamo 5034.5 Blackwell 2998.5	LSD All-Pairwise Comparisons Test of Total for CULTIVAR
Dacotah 3588.3	
Kanlow 4906.5 Shelter 4806.5	CULTIVAR Mean Homogeneous Groups Alamo 10756 A
Observations per Mean 4	Shelter 10136 A Kanlow 7933 B
Standard Error of a Mean 271.29	Blackwell 6828 BC
Std Error (Diff of 2 Means) 383.66	Dacotah 6316 C
	Alpha 0.05 Standard Error for Comparison 531.65
E'	Figure 3-9

Figure 3-8

E. Saving the Mean Separation Test Results

To save the mean separation test for future reference follow the procedure outlined in Chapter 1-III File Management.

To retrieve the analysis or to copy the file contents and paste them into an MS-Word document, follow the procedure outlined in "Saving the Analysis of Variance Table" in Chapter 3-I-C Saving the Analysis of Variance Table.

F. General Interpretations and Presentation of Results

Table 3-2

Yield1

```
LSD All-Pairwise Comparisons Test of Yield1 for CULTIVAR
CULTIVAR
              Mean Homogeneous Groups
Alamo 5034.5 A
Kanlow 4906.5 A

        Shelter
        4806.5
        A

        Dacotah
        3588.3
        E

                      В
Blackwell 2998.5
                        В
                      0.05
Alpha
                                  Standard Error for Comparison 383.66
                                 Critical Value for Comparison 835.93
Critical T Value 2.179
Error term used: REP*CULTIVAR, 12 DF
There are 2 groups (A and B) in which the means are not significantly different
from one another.
```

<u>Interpretation</u>: In the first cutting, we found that Alamo, Kanlow, and Shelter switchgrass cultivars produced significantly higher (P<0.05) yields than Dacotah or Blackwell.

Yield2

LSD All-Pairwise Comparisons Test of Yield2 for CULTIVAR

Mean	Homogeneo	us Groups	3			
5721.0	A					
5329.0	A					
3829.0	В					
3026.8	C					
2727.8	С					
Value used: R	0.05 2.179 EP*CULTIVA	Standard Critical R, 12 DF	Error Value	for for	Comparison Comparison	357.51 778.94
	Mean 5721.0 5329.0 3829.0 3026.8 2727.8 Value used: R	Mean Homogeneor 5721.0 A 5329.0 A 3829.0 B 3026.8 C 2727.8 C 0.05 Value 2.179 used:	Mean Homogeneous Groups 5721.0 A 5329.0 A 3829.0 B 3026.8 C 2727.8 C 0.05 Standard Value 2.179 Critical used: REP*CULTIVAR, 12 DF	Mean Homogeneous Groups 5721.0 A 5329.0 A 3829.0 B 3026.8 C 2727.8 C 0.05 Standard Error Value 2.179 Critical Value used: REP*CULTIVAR, 12 DF	Mean Homogeneous Groups 5721.0 A 5329.0 A 3829.0 B 3026.8 C 2727.8 C 0.05 Standard Error for Value 2.179 Critical Value for used: REP*CULTIVAR, 12 DF	Mean Homogeneous Groups 5721.0 A 5329.0 A 3829.0 B 3026.8 C 2727.8 C 0.05 Standard Error for Comparison Value 2.179 Critical Value for Comparison used: REP*CULTIVAR, 12 DF

<u>Interpretation</u>: In the second cutting, Alamo and Shelter were the highest yielding cultivars. Their yields were significantly higher (P<0.05) than the other cultivars in the trial.

Total Yield

LSD All-Pairwise Comparisons Test of Total for CULTIVAR

CULTIVAR	Mean	Homogeneous	Groups				
Alamo	10756	A					
Shelter	10136	A					
Kanlow	7933	В					
Blackwell	6828	BC					
Dacotah	6316	С					
Alpha		0.05 5	standard	Error	for	Comparison	531.65
Critical T	Value	2.179 C	ritical	Value	for	Comparison	1158.4
Error term	used:	REP*CULTIVAF	R, 12 DF				

<u>Interpretation</u>: Season total yield of Alamo was higher than Shelter but the yield difference was not significant (P<0.05). However, Alamo and Shelter produced significantly (P<0.05) higher season total yield than Kanlow, Blackwell and Dacotah.

G. Using an LSD Value for Comparing Significant Means

Some users may prefer to use an LSD value for comparison of significant means rather than letters when presenting results in data tables (Fig. 3-10 and 3-11). See Gomez and Gomez (1984) for calculating LSD values.

H. Presentation of Results with letters and LSD value

	Harvest					
Cultivar	Yield 1	Harvest Yield 2 Season Total lb/acre 5721 a 5721 a 10 756 a 5329 a 10 136 a 3027 b 7933 b 3829 c 6828 bc 2728 c 6316 c 4127 8394				
		lb/acre				
Alamo	5035 a*	5721 a	10 756 a			
Shelter	4907 a	5329 a	10 136 a			
Kanlow	4807 a	3027 b	7933 b			
Blackwell	2999 b	3829 c	6828 bc			
Dacotah	3588 b	2728 с	6316 c			
Mean	4267	4127	8394			

Comparison of switchgrass cultivars **<u>using letters</u>** to denote differences in cultivars for yield.

Figure 3-10

* Means within column followed by the same letters are not significantly different as determined by least significant difference test at P<0.05.

Comparison of switchgrass cultivars **<u>using LSD</u>** value to determine yield differences between cultivars.

	Harvest						
Cultivar	Yield 1 Yield 2		Season Total				
	lb/acre						
Alamo	5035	5721	10 756				
Shelter	4907	5329	10 136				
Kanlow	4807	3027	7933				
Blackwell	2999	3829	6828				
Dacotah	3588	2728	6316				
Mean	4267	4127	8394				
LSD (0.05)*	836	779	1158				

Figure 3-11

Least significant difference at P<0.05.

<u>Note</u>: Two treatment means are determined to be significantly different at a prescribed level of significance if their difference is greater than the LSD value; other wise they are not significant. For example, the difference between season total yield of Alamo (10 756 lb/acre) compared to Kanlow (7933 lb/acre) is 2823 lb/acre, which is greater than the computed LSD value of 1158 (lb/acre); thus, there is differences in yields between Alamo and Kanlow.

To analyze the 1996 switchgrass cultivar data, follow the procedure as the 1995 analysis.

I. Analyzing all of the Dataset

At the beginning of this example, you may remember that we were only interested in analyzing cultivar yields ("Yield1", "Yield2" and "Total") for 1995. Because the 1996 data was included in the original dataset we "omitted" the data in cases 21-40 so they would not be included in the

analyses (Fig. 3-2 in Chapter 3-I-A Analyzing the 1995 Switchgrass Cultivar Data). Notice that the omitted cases have a gray tint (Fig. 3-12). Now, we want to include the entire dataset in the final analysis.

To restore the 1996 data, or cases 21 to 40:

1. Click on the beige cell to the left of the cell marked with the case number. In this example, we selected the beige cell to the left of "21".

A triangle will appear in the beige cell to the left of the case number. The entire row for the case will be highlighted.

2. Click on the left mouse button and hold, and drag the blue highlighted area to the row with the last case that you want to omit. In this example, drag to the row for case "40."

The rows for cases 21 through 40 will be highlighted.

3. From the main menu, select Edit, Restore Highlighted Cases (Fig. 3-13).

Cases 21-40 will return to normal number tint indicating that they have been restored and can be included in the analyses (Fig. 3-14).

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Т		B	ер	Year	Cultivar		Yiel	d1	Yield2	Total
	1		. 1	1995	Alamo			4935	6360	11295
T	2		1	1995	Blackwell			2494	3372	5866
T	3		1	1995	Shelter			4148	5606	9754
	4		1	1995	Kanlow			5154	3564	8718
	5		1	1995	Dacotah			3956	3183	7139
	6		2	1995	Alamo			4123	5116	9239
	7		2	1995	Dacotah			2795	2917	5712
	8		2	1995	Kanlow			4482	2228	6710
Γ	9		2	1995	Blackwell			3122	4092	7214
	10		2	1995	Shelter			4805	4618	9423
Γ	11		3	1995	Alamo			6172	5306	11478
	12		3	1995	Dacotah			4237	2635	6872
	13		3	1995	Blackwell			2723	3879	6602
	14		3	1995	Shelter			4906	5836	10742
	15		3	1995	Kanlow			4980	3605	8585
	16		4	1995	Shelter			5367	5256	10623
	17	•	- 4	1995	Alamo			4908	6102	11010
	18		- 4	1995	Dacotah			3365	2176	5541
	19		- 4	1995	Kanlow			5010	2710	7720
	20		- 4	1995	Blackwell			3655	3973	7628
			1	1996	Alamo			3590	3507	7097
			1	1996	Blackwell			3697	2721	6418
			1	1996	Shelter			3714	4369	8083
	- 24		1	1996	Kanlow			2648	5391	8039
	25		1	1996	Dacotah			3873	4213	8086
	26		2	1996	Alamo			3076	4304	7380
	27		2	1996	Dacotah			3521	3058	6579
			2	1996	Kanlow			3313	4760	8073
			2	1996	Blackwell			5585	3337	8922
	30		2	1996	Shelter			4685	5012	9697
			3	1996	Alamo			3631	6365	9996
			3	1996	Dacotah			2772	4468	7240
			3	1996	Blackwell			4971	2955	7926
	34		3	1996	Shelter			3582	5116	8698
	35		3	1996	Kanlow			2861	6263	9124
	36		4	1996	Shelter			4006	5584	9590
			4	1996	Alamo			3566	7306	10872
			4	1996	Dacotah			2407	3614	6021
			4	1996	Kanlow			2224	5235	7459
	40		4	1996	Blackwell			4508	3867	8375

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	6		2 1995	Alamo			4123	5116	9239
	7		2 1995	Dacotah			2795	2917	5712
	8		2 1995	Kanlow			4482	2228	6710
	9		2 1995	Blackwell			3122	4092	7214
	10		2 1995	Shelter			4805	4618	9423
	11		3 1995	Alamo			6172	5306	11478
	12		3 1995	Dacotah			4237	2635	6872
	13		3 1995	Blackwell			2723	3879	6602
	14		3 1995	Shelter			4906	5836	10742
	15		3 1995	Kanlow			4980	3605	8585
	16		4 1995	Shelter			5367	5256	10623
	17		4 1995	Alamo			4908	6102	11010
	18		4 1995	Dacotah			3365	2176	5541
	19		4 1995	Kanlow			5010	2710	7720
	20		4 1995	Blackwell			3655	3973	7628
	21			Alamo			3590	3507	7097
	22		1 1996	Blackwell			3697	2721	6418
	23		1 1996	Shelter			3714	4369	8083
	24		1 1996	Kanlow			2648	5391	8039
	25		1 1996	Dacotah			3873	4213	8086
	26		2 1996	Alamo			3076	4304	7380
	27		2 1996	Dacotah			3521	3058	6579
Е.	28		2 1996	Kanlow			3313	4760	8073
	- 29		2 1996	Blackwell			5585	3337	8922
	30		2 1996	Sheller			4685	5012	9697
	31		3 1996	Alamo			3631	6365	3336
	32		3 1996	Dacotah			2772	4458	7240
	33		3 1996	BlackWell			4971	2955	7926
	34		3 1996	Kanlau			3082	5116	9124
	35		3 1996	Challer			2861	6263	9124
H	35		4 1996	Alama			4006	5584	10070
H	3/		4 1996	Alamo Decembra			3366	7306	10872
H	30		4 1996	Kaplow			2407	5005	7450
	40		4 1990	Blackwell			4509	3233	9375

Figure 3-12

Figure 3-13
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	3	3		1	1995	Shelter		4148	5606	9754
Т	4	l.		1	1995	Kanlow		5154	3564	8718
Т	5	5		1	1995	Dacotah		3956	3183	7139
Т	e	5		2	1995	Alamo		4123	5116	9239
	7	,		2	1995	Dacotah		2795	2917	5712
Т	e	3		2	1995	Kanlow		4482	2228	6710
Т	9)		2	1995	Blackwell		3122	4092	7214
	10)		2	1995	Shelter		4805	4618	9423
T	11			3	1995	Alamo		6172	5306	11478
Τ	12	2		3	1995	Dacotah		4237	2635	6872
T	13	3		3	1995	Blackwell		2723	3879	6602
T	14	l.		3	1995	Shelter		4906	5836	10742
	15	5		3	1995	Kanlow		4980	3605	8585
t	16	5		4	1995	Shelter		5367	5256	10623
t	17			4	1995	Alamo		4908	6102	11010
t	18	3		4	1995	Dacotah		3365	2176	5541
T	19	9		4	1995	Kanlow		5010	2710	7720
t	20			4	1995	Blackwell		3655	3973	7628
t	21			1	1996	Alamo		3590	3507	7097
t	22	2		1	1996	Blackwell		3697	2721	6418
t	23	3		1	1996	Shelter		3714	4369	8083
t	24			1	1996	1996 Kanlow		2648	5391	8039
t	25	5		1	1996	Dacotah		3873	4213	8086
t	2E			2	1996	Alamo	307		4304	7380
t	27			2	1996	Dacotah		3521	3058	6579
t	28	2		2	1996	Kanlow		3313	4760	8073
t	29			2	1996	Blackwell		5585	3337	8922
t	30	1		2	1996	Shelter		4685	5012	9697
t	31			3	1996	Alamo		3631	6365	9996
t	32			3	1996	Dacotah		2772	4468	7240
t	33	3		3	1996	Blackwell		4971	2955	7926
t	34	l		3	1996	Shelter		3582	5116	8698
t	35			3	1996	Kanlow	-	2861	6263	9124
t	36			4	1996	Shelter	-	4006	5584	9590
t	37			4	1996	Alamo	-	3566	7306	10872
Ŧ	37 4 13: 29 4 19		1996	Dacotah	-	3066 /306		6021		
+	39 4 1996 Kaplow		-	2224	5235	7459				
+	30	1		4	1990	Rischwall		4502	3967	7403 9076

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	16		4	1995	Shelter		5367	5256	10623		Factorial Design	
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	18		4	1995	Dacotah		3365	2176	5541		Strip-Plot Design	
	19		4	1995	Kanlow		5010	2710	7720		Solit-Solit-Plot Design	
	20		4	1995	Blackwell		3655	3973	7628		Strin-Solit-Plot Design	
	21		1	1996	Alamo		3590	3507	7097		Reneated Measures Design	
	22		1	1996	Blackwell		3697	2721	6418		Coporal AOM/AOCM	
	23		1	1996	Shelter		3714	4369	8083		General wov/woov	
	24		1	1996	Kanlow		2648	5391	8039			
	25		1	1996	Dacotah		3873	4213	8086			
	26		2	1996	Alamo		3076	4304	7380			
	27		2	1996	Dacotah		3521	3058	6579			
	28		2	1996	Kanlow		3313	4760	8073			
	29		2	1996	Blackwell		5585	3337	8922			
	30		2	1996	Shelter		4685	5012	9697			
	31		3	1996	Alamo		3631	6365	9996			
	32		3	1996	Dacotah		2772	4468	7240			
	33		3	1996	Blackwell		4971	2955	7926			
	34		3	1996	Shelter		3582	5116	8698			
	35		3	1996	Kanlow		2861	6263	9124			
Γ	36		4	1996	Shelter		4006	5584	9590			
	37		4	1996	Alamo		3566	7306	10872			
	38		4	1996	Dacotah		2407	3614	6021			
T	39		4	1996	Kanlow		2224	5235	7459			

J. Including Year as a Variable

The variable "Year" can be included in the overall analyses if year (1995 or 1996) may have an effect on switchgrass cultivar yield; 1995 was considered a wet year and 1996 a dry year. *Statistix 8* allows the user to write math statements or models to analyze datasets containing multiple variables. In this case, we are interested in knowing if there is a significant "Year*Cultivar" interaction effect in "Total" yield, which may give insight on which cultivar(s) performed the best under wet or dry conditions.

To perform the analyses to determine the "Year*Cultivar" interaction effect in "Total" yield:

- 1. From the main menu, select Statistics, Linear Models, Analysis of Variance, General AOV/AOCV (Fig. 3-15).
- 2. In the *General AOV/AOCV* dialog box (Fig. 3-16), move the variables you want to designate as dependent variables from the *Variables* list in the left column to the *Dependent Variables* list in the right column by highlighting the variable and clicking on the right-arrow button to the left of the *Dependent Variables* list. In this example, we selected the variable "Total".
- 3. In the AOV/Model Statemen" text area, enter the statistical statement.

Example: "Rep Year Cultivar Year*Cultivar" without quotes (Fig. 3-17).

<u>Note</u>: The statement "Rep Year Cultivar Year*Cultivar" tells *Statistix 8* to perform an analysis of variance using the variables "Rep", "Year", "Cultivar", with the "Year* Cultivar" interaction effect as the sources of variation.

4. Click OK.

Statistix 8 will compute the error term for the model. The results of the analysis of variance (Table 3-3) is discussed below.

Note: Other model statements for general analysis of variance can be found in Chapter 7.



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	22	1	1996	Shelter	3037	4369	9093
\square	23	1	1996	Kanlow	2648	5391	8039
	25	1	1996	Dacotab	3873	4213	8086
	26	2	1996	Alamo	3076	4304	7380
	27	2	1996	Dacotah	3521	3058	6579
	28	2	1996	Kanlow	3313	4760	8073
	29	2	1996	Blackwell	5585	3337	8922
	30	2	1996	Shelter	4685	5012	9697
	31	3	1996	Alamo	3631	6365	9996
	32	3	1996	Dacotah	2772	4468	7240
	33	3	1996	Blackwell	4971	2955	7926
	34	3	1996	Shelter	3582	5116	8698
	35	3	1996	Kanlow	2861	6263	9124
	36	4	1996	Shelter	4006	5584	9590
	37	4	1996	Alamo	3566	7306	10872
	38	4	1996	Dacotah	2407	3614	6021
	39	4	1996	Kanlow	2224	5235	7459
H	40	4	1996	Blackwell	4508	3867	8375
1.54/							

Figure 3-16

K. Interpretation of the Analysis

Table 3-3

Source	DF	SS	MS	F	Р
REP	3	4418919	1472973	1.53	0.2294
YEAR	1	440160	440160	0.46	0.5047
CULTIVAR	4	6.016E+07	1.504E+07	15.62	0.0000
YEAR*CULTIVAR	4	1.277E+07	3193780	3.32	0.0247
Error	27	2.600E+07	962859		
Total	39	1.037E+08			
Grand Mean 828	8.7	CV 11.84			

Analysis of Variance Table for TOTAL

Figure 3-17

<u>Interpretation</u>: The analysis of variance determined that there were no significant differences in years (p=0.5047) but there were differences in cultivars (p=0.0000). Because there was a significant "Year*Cultivar" interaction effect (p=0.0247) we will ignore the cultivar differences and focus only on the interaction (Table 3-3).

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Analysis of	Contrasts Polynomial Contrasts	Comparisons with a <u>C</u> ontrol Comparisons with the <u>B</u> est		Source DF REP 3 VEAR 1	SS MS 4418919 1472973 440160 440160	F P 1.53 0.2294 0.46 0.5047	
Source REP YEAR CULTIVAR YEAR*CULTIVA Error Total Grand Mean 8	Plots Plots Save Residuals Options AR 4 1.277E+07 27 2.600E+07 39 1.037E+08 32288.7 CV 11.84	MS F P 1472973 1.53 0.2294 440160 0.46 0.5047 504E+07 15.62 0.0000 3193780 3.32 0.0247 962859 9 0.0247		CULTVAR 4 YEAR+CULTVAR 4 Error 27 Total 39 Grand Mean 8288.7 All-pairwise Co Iems in Model CULTVAR NETWAR	6.0158-07 1.5042-07 1.2778-07 3193780 2.6002+07 3193780 CV 11.84 mparisons Terms Salec YEAP-CUL	15. 62 0.0000 3.32 0.0247	
				Comparison Method C Tukey HSD C LSD C Scheffe C Multiplicative Sidak C Borderroni	Alpha 0.05 Beport Format r Homogeneous groups r Triangular matrix	OK Cancel Help	

Figure 3-18

Figure 3-19

L. Comparing Means of "Year*Cultivar" Interaction

Statistix 8 can perform an All-Pairwise Comparison Test on the simple effects means of the "Year*Cultivar" interaction effect, which may help to explain the interaction.

- 1. Once the result of the analysis of variance table is in the active dialog box, from the main menu, select **Results, Multiple Comparison, All-Pairwise Comparison** (Fig. 3-18).
- 2. In the *All-pairwise Comparison* dialog box, highlight "Year*Cultivar" from the *Terms in Model* list in the left column, then press the right-arrow button to move it to the *Terms Selected for Mean Comparison* list in the right column(Fig. 3-19).
- 3. In the *All-pairwise Comparison* dialog box, select the preferred method in the *Comparison Method* group. In this example, we selected *LSD*.
- 4. Keep the default alpha level, which is 0.05, in the *Alpha* text box or enter 0.01 or 01.0.
- 5. In the *Report Format* group, keep the default section *Homogeneous groups*.
- 6. Once the information is in place, click on OK.

<u>Note</u>: The homogenous groups format will give the means followed by letters (A, B, C, etc) which makes it easier to interpret whether the means are similar or different and may aid in the explanation of the analysis.

Statistix 8 will perform a mean comparison test on the simple effect means (Table 3-4).

Table 3-4

LSD All-Pairwise Comparisons Test of Total for YEAR*CULTIVAR

YEAR	CULTIVAR	Mean	Homogeneous	Groups							
1995	Alamo	10756	A								
1995	Shelter	10136	AB								
1996	Shelter	9017	BC								
1996	Alamo	8836	BC								
1996	Kanlow	8174	CD								
1995	Kanlow	7933	CD								
1996	Blackwell	7910	CD								
1996	Dacotah	6982	DE								
1995	Blackwell	6828	DE								
1995	Dacotah	6316	E								
- 7 1		0.0		1 -		600 0F					
Alpha	a.	0.0	5 Standa	rd Error	for Comparison	693.85					
Criti	ical T Value	e 2.05	2 Critic	al Value	for Comparison	1423.7					
Erroi	Error term used: REP*YEAR*CULTIVAR, 27 DF										
There	e are 5 grou	ups (A,	B, etc.) in	which th	ne means						
are r	not signific	cantly o	different fr	om one ar	nother.						

M. Interpreting the Interaction

Earlier in the example, we stated that 1995 was a wet year and 1996 was a dry year. Because of the differences in moisture conditions we wanted to determine how the switchgrass cultivars would perform. Obviously, with the "Year*Cultivar" interaction there is indication that one or more of the cultivars responded to the different moisture conditions in 1995 and 1996.

Notice that *Statistix 8* ranks the performance of the cultivars based on high to low yields. Shelter, Kanlow, Blackwell and Dacotah performed similarly under both moisture regimes. Alamo experienced the greatest yield loss (1,920 lb/acre) when moisture became limited in 1996, and appears to have caused the significant "Year*Cultivar" interaction effect. Results suggest Alamo may require supplemental water to maximize yields in a dry year.

N. Graphing the Interaction Effect

Some may prefer to graph the simple effect means in order to have a better understanding of what may be causing the interaction. A graph of the "Year*Cultivar" interaction effect is illustrated in Fig. 3-20.



Figure 3-20

II. Completely Randomized Design

A. Analyzing Basin Wildrye Seed Germination Trial

Statistix 8 can analyze data from a completely randomized design using a one-way analysis of variance or by the completely randomized design analysis of variance model built into the program.

For this example, we will use germination data from four populations of basin wildrye replicated 10 times and arranged in a completely randomized design by randomly rotating the Petri dishes inside the germinator on a daily basis.

To determine if there are significant differences in the basin wildrye populations and identify the one(s) with superior germination:

- 1. Enter data into a *Statistix* 8 spreadsheet (Fig. 3-21).
- 2. From the main menu, select Statistics, Linear Models, Analysis of Variance, Completely Randomized Design (Fig. 3-22).
- 3. In the *Completely Randomized Design AOV* dialog box (Fig. 3-23), move the chosen variable from the *Variables* list in the left column to the *Dependent Variables* list in the right column by highlighting the variable name ("Germ" in this example) and clicking on the right-arrow button to the left of the *Dependent Variables* list.

- 4. Move the chosen variable from the Variables list in the left column to the Treatment *Variable* list in the right column by highlighting the variable ("BWPOP" in this example) and clicking the right-arrow button to the left of the *Treatment Variable* list (Fig. 3-24)
- 5. Click OK

Statistix 8 performs the data analyses (Fig. 3-25).

6. To return to the data set, from the main menu, select File, Close.

B. Results and Interpretation of the Analyses

Statistix 8 performed the following Analysis of Variance for a completely randomized design. Rather than discuss all of the numbers generated in the analysis of variance, we will focus on numbers of greatest interest. Numbers have been highlighted in red followed by an interpretation of the number and its significance to the user (Table 3-5).

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	4	4	2 58	8		15	15 5	15 5 2	15 5 2 66	15 5 2 66	15 5 2 66
	6	6	2 50	a		16	16 6	16 6 2	16 6 2 59	16 6 2 59	16 6 2 59
	7	7	2 63	3		18	18 8	18 8 2	18 8 2 63	18 8 2 53	18 8 2 63
	8	8	2 63	3		19	19 9	19 9 2	19 9 2 76	19 9 2 76	19 9 2 76
	9	9	2 76	6		20	20 10	20 10 2	20 10 2 67	20 10 2 67	20 10 2 67
	20	10	2 67	7		21	21 1	21 1 3	21 1 3 90	21 1 3 90	21 1 3 90
_	21	1	3 90	0		22	22 2	22 2 3	22 2 3 96	22 2 3 96	22 2 3 96
_	2	2	3 96	6		23	23 3	23 3 3	23 3 3 98	23 3 3 98	23 3 3 98
	3	3	3 98	8		24	24 4	24 4 5	24 4 5 52	24 4 3 32	24 4 3 32
	:4 IE	5	3 100	<u>2</u>		26	26 6	26 6 3	26 6 3 88	26 6 3 88	26 6 3 88
	:6	6	3 88	8		27	27 7	27 7 3	27 7 3 91	27 7 3 91	27 7 3 91
	27	7	3 91	đ		28	28 8	28 8 3	28 8 3 93	28 8 3 93	28 8 3 93
	8	8	3 93	3		29	29 9	29 9 3	29 9 3 89	29 9 3 89	29 9 3 89
	:9	9	3 89	9		30	30 10	31 1 4	30 10 3 33	30 10 3 33	30 10 3 33
	10	10	3 99	9		32	32 2	32 2 4	32 2 4 24	32 2 4 24	32 2 4 24
	1	1	4 23	3		33	33 3	33 3 4	33 3 4 34	33 3 4 34	33 3 4 34
	12	2	4 24	4		34	34 4	34 4 4	34 4 4 35	34 4 4 35	34 4 4 35
-	4	4	4 34	5		35	35 5	35 5 4	35 5 4 26	35 5 4 26	35 5 4 26
	15	5	4 26	6		36	36 6	36 6 4	36 6 4 33	36 6 4 33	36 6 4 33
	6	6	4 33	3		37	38 8	38 8 4	31 1 4 21	38 8 4 31	3/ / 4 2/
	17	7	4 27	7		39	39 9	39 9 4	39 9 4 35	39 9 4 35	39 9 4 35
	8	8	4 31	1		40	40 10	40 10 4	40 10 4 32	40 10 4 32	40 10 4 32
	19	9	4 35	5		*	*	*	*	*	*

Figure 3-22

Chapter 3: Analysis of Variance

Statistix - [C:\Statistix\example\basin wildrye.sx]	Statistix - [C:\Statistix\example\basin wildrye.sx]
Rep BwPOP Germ 1 1 1 80 2 2 1 82 3 3 1 90 4 4 1 92 5 5 1 84 6 6 1 78 7 7 1 90 Serm Dependent Variables OK BwPOP Ireatment Variable Help	Rep BWPDP Germ 1 1 1 80 2 2 1 82 3 3 1 90 4 4 1 32 5 5 1 84 6 6 1 78 7 7 1 90 Completely Randomized AOV Variables Dependent Variables Rep Ireatment Variables OK Cancel Help
18 8 2 63 19 9 2 76 20 10 2 77 21 1 3 90 22 2 3 96 23 3 3 98 24 4 3 92 25 5 3 100 26 6 3 88 27 7 3 91 28 8 3 93 Figure 3-23	18 8 2 63 19 9 2 76 20 10 2 77 21 1 3 90 22 2 3 96 23 3 3 98 24 4 3 92 26 6 3 88 27 7 3 91 28 8 3 93 Figure 3-24

Statistix - [Completely Randomized AOV - AOV Table] Eile Edit Results Window Help 🗲 🖬 🚭 🕺 🖻 🔂 Statistix 8.0 basin wildrye, 1/26/2006, 1:36:24 PM Completely Randomized AOV for Germ SS Source DF MS F Р
 BWPOP
 3
 24198.7
 8066.23

 Error
 36
 895.2
 24.87

 Total
 39
 25093.9
 25093.9
 324 0.0000 Grand Mean 68.450 CV 7.29 Chi-Sq DF Ρ 0.70 3 0.8730 Bartlett's Test of Equal Variances Cochran's Q 0.3088 Largest Var / Smallest Var 1.6221 Component of variance for between groups 804.137 Effective cell size 10.0 BWPOP Mean 1 85.600 2 64.600 3 93.600 4 30.000 Observations per Mean 10 Standard Error of a Mean 1.5769 Std Error (Diff of 2 Means) 2.2301

Figure 3-25

Table 3-5	
Source DF SS MS F BWPOP 3 24198.7 8066.23 324 0.0000 Error 36 895.2 24.87 10.0000 10.0000 Total 39 25093.9 250.000 0.0000 0.0000	Since P value of 0.0000 is less than $p=0.05$ then it has been determined that there are statistical differences between basin wildrye population for germination.
Bartlett's Test of Equal Variances 0.70 3 Cochran's Q 0.3088 Largest Var/Smallest Var 1.6221	Since P value 0.8730 is greater than p= 0.05 then Bartlett's test for equal variances is not significant meaning that the
Component of variance for between groups 804.137 Effective cell size 10.0	variances are equal and satisfies the assumption of the F test which assumes within group
Mean germination for each population wildrye was determined by adding the each population by replication and div by 4 (replications).	e germination of viding the total

C. Performing Mean Separation Test on Basin Wildrye Populations

In this example, we determined that there were significant differences between basin wildrye populations for germination based on the analysis of variance which was performed at the 5% level of probability.

To determine which basin wildrye germination means are significant:

- 1. From the main menu, select **Results**, **Multiple Comparison**, **All-Pairwise Comparison** (Fig. 3-26).
- 2. In the *All-Pairwise Comparison* dialog box (Fig. 3-27), select the LSD (least significance difference test) option from the *Comparison Method* group.
- 3. Keep the default alpha level, which is 0.05, in the *Alpha* text box, or enter 0.01 or 0.10.
- 4. In the *Report Format* group, keep the default selection *Homogenous groups*.

<u>Note</u>: The homogenous groups format will give the means followed by letters (A, B, C, etc) which makes it easier to interpret whether the means are similar or different and may aid in the explanation of the analysis.

5. Click OK.

Statistix 8 performs a means separation test using the LSD test at the 5% level of probability (Fig. 3-28).

6. To return to the data set, from the main menu, select File, Close.



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Figure 3-26

Figure 3-27

Statistix - [Completely Randomized AOV - All-pairwise Comparisons]	
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Statistix 8.0 basin wildrye, 1/25/2006, 4:06:15 PM	
LSD All-Pairwise Comparisons Test of Germ by BWPOP	
BWPOP Mean Homogeneous Groups	
3 93.600 A	
1 85.600 B	
2 64.600 C	
4 30.000 D	
Alpha 0.05 Standard Error for Comparison 2.2301	
Critical T Value 2.028 Critical Value for Comparison 4.5228	
All 4 means are significantly different from one another.	

Figure 3-28

D. General Interpretations

Table 3-6

```
LSD All-Pairwise Comparisons Test of Germ by BWPOP
```

```
BWPOP
        Mean Homogeneous Groups
    3
      93.600
             Α
   1
      85.600
               в
    2 64.600
                С
    4
      30.000
                 D
Alpha
                           Standard Error for Comparison 2.2301
                  0.05
Critical T Value 2.028
                           Critical Value for Comparison 4.5228
All 4 means are significantly different from one another.
```

<u>Interpretation</u>: The analysis of variance determined that statistical differences exist in basin wildrye populations for germination characteristics. Using the LSD test, we found that population 3 had significantly higher germination (P<0.05) rate than the other populations.

III. Split Plot Design (Without Interaction Effect)

A. Analyzing Clipping Frequency of Eastern Gamagrass Cultivars

The split plot design is often used in agricultural research when two or more treatments are applied in factorial combinations. *Statistix 8* has the capability to perform an analysis of variance from data collected from studies arranged as a split plot design.

For this example, we will evaluate the effects of clipping frequency on yield of eastern gamagrass cultivars. Clipping frequency of 30, 45, and 60 days were assigned to the main plot and cultivars of Highlander, Jackson, Medina, and San Marcos to the subplots. The total yield by clipping frequency and cultivar was entered into *Statistix 8* spreadsheet (Fig. 3-29).

To analyze the data:

- 1. From the main menu, select Statistics, Linear Models, Analysis of Variance, Split-Plot Design (Fig. 3-30).
- 2. In the *Split Plot Design AOV* dialog box (Fig. 3-31), move the variable "Yld" from the *Variables* list in the left column the to the *Dependent Variables* list in the right column by highlighting "Yld" and clicking on the right-arrow button to the left of *Dependent Variables* list.
- 3. Move the variable "Rep" from the *Variables* list in the left column to the *Replication Variable* list in the right column by highlighting "Rep" and clicking on the right-arrow button to the left of the *Replication Variable* list.
- 4. Move the variable "Clipping" from the *Variables* list in the left column to the *Main-Plot Factor* list in the right column by highlighting "Clipping" and clicking on the right-arrow button to the left of the *Main-Plot Factor* list.
- 5. Move the variable "Cultivars" from the *Variables* list in the left column to the *Subplot Factor* list in the right column by highlighting "Cultivars" and clicking on the rightarrow button to the left of the *Subplot Factor* list (Fig. 3-32).

<u>Note</u>: For a greater degree of precision for Factor B than for Factor A, assign B to the subplot and Factor A to the main-plot. In our example, we are more interested in the cultivars than the clipping frequency so cultivars were assigned to the subplot and clipping frequency to main-plot.

6. Click OK.

Statistix 8 performs the data analyses.

7. To return to the data set, from the main menu, select File, Close.

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	4			1	Medina		30 da		6534		
	5			2	Jackson		30 da		6743		
	6			2	Highlander		30 da		6789		
	7			2	San Marcos		30 da		6700		
	8			2	Medina		30 da		6500		
	9			3	Jackson		30 da		6721		
	10			3	Highlander		30 da		7000		
	11			3	San Marcos		30 da		6345		
	12			3	Medina		30 da		6512		
	13			1	Jackson		45 da		8812		
	14			1	Highlander		45 da		9500		
	15			1	San Marcos		45 da		7816		
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_	22			3	Highlander		45 da		9595		
_	23			3	San Marcos		45 da		9800		
_	24			3	Medina		45 da		7934		
	25			1	Jackson		60 da		11345		
	26			1	Highlander		60 da		11999		
	27			1	San Marcos		60 da		10456		
	28			1	Medina		60 da		10009		
	29			2	Jackson		60 da		11099		
_	30			2	Highlander		60 da		11678		
_	31			2	San Marcos		60 da		10678		
	32			2	Medina		60 da		10999		
	33			3	Jackson		60 da		11567		
	34			3	Highlander		60 da		11890		
	35			3	San Marcos		60 da		10367		
	36			3	Medina		60 da		11345		

36 3 Figure 3-29

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	2	1	Highlander	30 da	6578	
	3	1	San Marcos	30 da	6589	
	4	1	Medina	30 da	6534	
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	23	3	San Marcos	45 da	9800	
	24	3	Medina	45 da	7934	
	25	1	Jackson	60 da	11345	
	26	1	Highlander	60 da	11999	
	27	1	San Marcos	60 da	10456	
	28	1	Medina	60 da	10009	
	29	2	Jackson	60 da	11099	
	30	2	Highlander	60 da	11678	
	31	2	San Marcos	60 da	10678	
	32	2	Medina	60 da	10999	
	33	3	Jackson	60 da	11567	
	34	3	Highlander	60 da	11890	
	35	3	San Marcos	60 da	10367	
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Chapter	3:	Analysis	of	Variance
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4		1	Time Se	eries		1	Linear Regression		
5		2	Quality	Control		1	Best Subset Regressions		
6		2	Sur <u>v</u> iva	Analysis		•	Stepwise Linear Regression		
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8		2	Medina	30 da	6500		Stepwise Logistic Regression		
9		3	Jackson	30 da	6721		Poisson Regression		
10		3	Highlander	30 da	7000		<u>T</u> wo Stage Least Squares		
11		3	San Marcos	30 da	6345		Eigenvalues - Principal Comp	L	
12		3	Medina	30 da	6512		Analysis of Variance	۲.	Completely Randomized De
13		1	Jackson	45 da	8812				Randomized Complete Bloc
14		1	Highlander	45 da	9500				Latin Square Design
15		1	San Marcos	45 da	7816				Balanced Lattice Design
16		1	Medina	45 da	8816				Eactorial Design
17		2	Jackson	45 da	8745				Split-Plot Design
18		2	Highlander	45 da	9654				Strip-Plot Design
19		2	San Marcos	45 da	8721				Split-Split-Plot Design
20		2	Medina	45 da	7934				Strip-Split-Plot Design
21		3	Jackson	45 da	8867				Repeated Measures Design
22		3	Highlander	45 da	9595				General &OV/&OCV
23		3	San Marcos	45 da	9800			5	2010/01/10/01/11
24		3	Medina	45 da	7934				
25		1	Jackson	60 da	11345				
26		1	Highlander	60 da	11999				
27		1	San Marcos	60 da	10456				
28		1	Medina	60 da	10009				
29		2	Jackson	60 da	11099				
30		2	Highlander	60 da	11678				
31		2	San Marcos	60 da	10678				
32		2	Medina	60 da	10999				
33		3	Jackson	60 da	11567				
34		3	Highlander	60 da	11890				
35		3	San Marcos	60 da	10367				
36		3	Medina	60 da	11345				

Figure 3-30

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22	3	Highlander	45 da	9595	
23	3	San Marcos	45 da	9800	
24	3	Medina	45 da	7934	
25	1	Jackson	60 da	11345	
26	1	Highlander	60 da	11999	
27	1	San Marcos	60 da	10456	
28	1	Medina	60 da	10009	
29	2	Jackson	60 da	11099	
30	2	Highlander	60 da	11678	
31	2	San Marcos	60 da	10678	
32	2	Medina	60 da	10999	
33	3	Jackson	60 da	11567	
34	3	Highlander	60 da	11890	
35	3	San Marcos	60 da	10367	
20	2	Medina	60 da	11345	

B. Results and Interpretation of the Analyses

The following statistical analysis was performed by *Statistix 8* (Fig. 3-33). Rather than discuss all of the numbers generated in the analysis of variance, we will focus on numbers of greatest interest to the user. Interested numbers have been highlighted in red followed by an interpretation of the number and its significance to the user (Table 3-7).

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Grand Mean 8872.9 CV (REP*CLIPPING) CV (REP*CLIPPING* Figure 3-33	2.31 CULTIVARS) 4	.87					
Table 3-7							
Analysis of Va Source REP CLIPPING	riance Ta	ble f	or YLD DF 2 2	5 310673 1.198E+08	5 3 15 3 5.993	MS 5336 E+07	F 1422.26
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Grand Mean 887 CV(REP*CLIPE CV(REP*CLIPE	2.9 NG) 2.31 NG*CULTI	VARS)	4.87				

<u>Note</u>: Notice that the analysis of variance for a split plot uses two error terms, one for testing factor A and one for testing factor B.

C. Performing Mean Separation Test on Clipping and Cultivars

In this example, we determined that there were significant differences in clipping frequency and cultivars for yield based on the analysis of variance which was performed at the 5% level of probability.

To determine which clipping frequency and cultivars are significantly different:

- 1. From the main menu, select **Results**, **Multiple Comparison**, **All-Pairwise Comparison** (Fig. 3-34).
- 2. In the *All-pairwise Comparison* dialog box (Fig. 3-35), highlight "Clipping" and "Cultivars" in the *Terms in Model* list in the left column, and click on the rightarrow button to the left of the *Terms Selected for Mean Comparison* list in the right column (Fig. 3-36).
- 3. From the *Comparison Method* group, select *LSD* (least significance difference test).
- 4. Keep the default alpha level, which is 0.05, in the *Alpha* text box, or enter 0.01 or 0.10.
- 5. In the *Report Format* group, keep the default *Homogeneous groups*.

<u>Note</u>: The homogenous groups format will give the means followed by letters (A, B, C, etc) which makes it easier to interpret whether the means are similar or different and may aid in the explanation of the analysis.

6. Click OK.

Statistix 8 performs a means separation test on "Clipping" and "Cultivars" using the LSD test at the 5% level of probability (Fig. 3-37, Table 3-8).

7. To return to the data set, from the main menu, select File, Close.

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Total	LIPPING"COLIIVAR5	35	1.299E+08	100994		
Grand Mean CV(REP*CL	8872.9 IPPING) 2.31					
CV (REP*CL	IPPING*CULTIVARS) 4	.87				

Figure 3-34



Chapter 3: Analysis of Variance

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Figure 3-36

Figure 3-37

D. General Interpretations

Table 3-8

LSD All-Pairwise Comparisons Test of Yld for CLIPPING

CLIPPING	Mean	Homogeneou	is Groups	
60 da	11119	A		
45 da	8850	В		
30 da	6650	C		
Alpha		0 05	Standard Error for Comparison	82 802
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LSD All-Pairwise Comparisons Test of Yld for CULTIVARS

CULTIVARS Mean Homogeneous Groups Highlander 9409.2 A Jackson 8965.3 в San Marcos 8608.0 BC 8509.2 Medina С Alpha 0.05 Standard Error for Comparison 203.85 Critical T Value 2.101 Critical Value for Comparison 428.27 Error term used: REP*CLIPPING*CULTIVARS, 18 DF

IV. Split Plot Design (With Interaction Effect)

A. Analyzing Clipping Frequency in Eastern Gamagrass Cultivars

Anytime two or more factors are included in an experiment interaction between factors may occur. Experiments designed with two factors are conducted in anticipation of finding a significant interaction effect between factors; thus, providing a better understanding of how changing the level of one factor affects the change in another factor in the experiment.

For our example, we will use another clipping frequency and eastern gamagrass cultivar dataset (Fig. 3-38). To analyze the data:

- 1. From the main menu, select Statistics, Linear Models, Analysis of Variance, Split-Plot Design (Fig. 3-39).
- 2. In the *Split Plot Design AOV* dialog box (Fig. 3-40), move the variable "Yld" from the *Variables* list in the left column to the *Dependent Variables* list in the right column by highlighting "Yld" and clicking on the right-arrow button to the left of the *Dependent Variables* list.
- 3. Move the variable "Rep" from the *Variables* list in the left column to the *Replication Variable* list in right column by highlighting "Rep" and clicking on the right-arrow button to the left of the *Replication Variable* list.
- 4. Move the variable "Clipping" from the *Variables* list in the left column to the *Main-Plot Factor* list in the right column by highlighting "Clipping" and clicking on the right-arrow button to the left of the *Main-Plot Factor* list.
- 5. Move the variable "Cultivars" from the *Variables* list in the left column to the *Subplot Factor* list in the right column by highlighting "Cultivars" and clicking on the right-arrow button to the left of the *Subplot Factor* list (Fig. 3-41).
- 6. Click **OK**.

Statistix 8 performs the data analyses.

7. To return to the data set, from the main menu, select File, Close.

Chapter 3: Analysis of Variance

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Figure 3-38

Figure 3-39

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32 2 Medina 60 da 10999	Figure 3 /1
Figure 3-40	1'igui t 5-41

B. Results and Interpretation of the Analyses

The following statistical analysis was performed by *Statistix 8* (Fig. 3-42). Rather than discuss all of the numbers generated in the analysis of variance, we will focus on numbers of greatest interest to the user (Table 3-9). Interested numbers have been highlighted in red followed by an interpretation of the number and its significance to the user.

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Rep	2	875333	437667		
Clipping	2	1.204E+08	6.022E+07	384.08	0.0000
Error Rep*Clipping	4	627157	156789		
Cultivars	3	7223245	2407748	17.61	0.0000
Clipping*Cultivars	6	4541992	756999	5.54	0.0021
Error Rep*Clipping*Cultivars	18	2461661	136759		
Total	35	1.362E+08			
Grand Mean 8794.1 CV(Rep*Clipping) 4.50 CV(Rep*Clipping*Cultivars)	4.21				



Table 3-9

Analysis of Variance Table for Yld

Source Rep Clipping Error Rep*Clipping	DF 2 2 4	ss 875333 1.204E+08 627157	MS 437667 6.022E+07 156789	F 384.08	P 0.0000			
	Since P value of 0.0000 is less than $p=0.05$ then it has been determined that there are significant differences between clipping frequency for yield.							
Cultivars	3	7223245	2407748	17.61	0.000			
	Since P value determined cultivars for	ue of 0.0000 is that there are s r yield.	less than p= 0.0 ignificant differ	5 then it ha	as been veen			
Clipping*Cultivars	6	4541992	756999	5.54	0.0021			
Since P value of 0.0021 is less than $p=0.05$ then it has been determined that there is a significant clipping * cultivar interaction effect for yield.								
Error Rep*Clipping*Culti	vars 18	2461661	136759					
Total Grand Mean 8794.1 CV(Rep*Clipping) 4.50 CV(Rep*Clipping*Cultiva	35 ars) 4.21	1.362E+08						

<u>Note</u>: When a significant interaction effect is detected in the analysis of variance, the user will ignore the main effect means of the treatment variables and analyze the simple effects means of the interaction.

<u>Interpretation</u>: In reviewing the analysis of variance table we find that there are significant differences in "Clipping" and "Cultivars" for total yield. Because there was a significant "Clipping*Cultivar" interaction effect (p=0.0021), we will ignore the significant "Clipping" and "Cultivars" differences and focus on the "Clipping*Cultivar" interaction effect.

C. Comparing Means of Clipping *Cultivar Interaction

Statistix 8 performs an all-pairwise comparison Test on the simple effects means of the "Clipping*Cultivars" interaction, which may help to explain what may be causing the interaction.

To perform a mean comparison test on the simple effect means:

- 1. Make sure the result of the analysis of variance table is in the active window.
- 2. From the main menu, select Results, Multiple Comparison, All-Pairwise Comparison (Fig. 3-43).
- 3. In the All-pairwise Comparison dialog box, move the statement "Clipping*Cultivar" from the Terms in Model list in the left column to the Terms Selected for Mean *Comparison* in the right column by highlighting the statement and clicking on the rightarrow button to the left of the Terms Selected for Mean Comparison (Fig. 3-44).
- 4. In the *Comparison Method* group, select *LSD* or some other preferred method.
- 5. Keep the default alpha level, which is 0.05, in the *Alpha* text box, or enter 0.01 or 0.10.
- 6. In the Report Format group, select the default Homogeneous groups.

Note: The homogenous groups format will give the means followed by letters (A, B, C, etc). The letters assigned to the simple effects means by the All Pairwise Comparison test have little or no impact on explaining the interaction.

7.Click OK.

Statistix 8 performs a mean comparison test on the simple effect means (Table 3-10).

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Figure 3-43

Table 3-10

LSD All-Pairwise Comparisons Test of Yld for Clipping*Cultivars

Cl	ipping	Cultivars	Mean	Homogeneous	Groups
60	da	Highlander	11856	A	
60	da	Jackson	11337	AB	
60	da	Medina	10784	BC	
60	da	San Marcos	10500	C	
45	da	Highlander	9583	D	
45	da	Jackson	8808	Е	
45	da	San Marcos	8779	Е	
45	da	Medina	7282	F	

Highlander	6789	FG	
Jackson	6751	FG	
San Marcos	6545	G	
Medina	6515	G	
_			
sons of means	for the	same level of Clipping	
	0.05	Standard Error for Comparison 301.95	
cal T Value	2.1	Critical Value for Comparison 634.37	
term used: Re	ep*Clippi	ing*Cultivars, 18 DF	
sons of means	for diff	ferent levels of Clipping	
	0.05	Standard Error for Comparison 307.43	
cal T Value	2.3	Critical Value for Comparison 703.30	
terms used: 1	Rep*Clipp	ping and Rep*Clipping*Cultivars	
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Figure 3-45

<u>Chapter 4:</u> Regression Analysis

I. Linear Regression

A. Eastern Gamagrass Nitrogen Rate Trial

Statistix 8 performs simple and multiple linear regression analysis. The menu driven options make it easy to analyze data from gradient experiments such nitrogen (N) fertilizer rates, seeding depths, seeding rates, row spacing, and chemical concentration experiments.

The focus of a gradient treatment design is to investigate the response relationship. To do that, one should plot the response (Y) against the treatment level (X) and look for an equation describing the relationship between X and Y.

For example, you wish to determine if there is a relationship in the response of eastern gamagrass to increased rates of nitrogen fertilizer. Your study design is a randomized complete block with 3 replications. Nitrogen rates ("Nrate") are applied in increments of 120 lbs beginning with 0 lb/acre up to 480 lb/acre (0, 120, 240, 360 and 480 lb/acre). Yield is taken ever 45 days during the growing season and reported in tons/acre. Data is entered into the *Statistix 8* spreadsheet (Fig. 4-1).

To execute the regression analyses:

- 1. From the main menu, select Statistics, Linear Models, Linear Regression (Fig. 4-2).
- 2. In the *Linear Regression* dialog box (Fig. 4-3), move the variable "TotalYld" from the *Variables* list in the left column to the *Dependent Variable* list in the right column by highlighting the variable and clicking on the right-arrow button to the left of the *Dependent Variable* text area.
- 3. Move the variable "Nrate" from the *Variables* list in the left column to the *Independent Variable* list in the right column by highlighting the variable and clicking on the right-arrow to the left of the *Independent Variable* list (Fig. 4-4).
- 4. Click OK.

Statistix 8 performs the linear regression analyses and provides a table of the coefficients (Fig. 4-5, Table 4-1).

Chapter 4: Regression Analysis

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	5	1	480	5.179			
	6	2	120	3.544			
	7	2	0	2.8665			
	8	2	480	5.3125			
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Figure 4-1

Figure 4-2

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				▲ ▶ [™]	_eight Variable	(Opt)	Eit Consta	nt	

Figure 4-3





🛎 Statistix	- [Lin	ear Reg	ression - (Coefficie	ent Table	9]
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Statistix 8.	.0				egnrate,	1/23/2006,
Unweighted I	Least So	quares Li	near Regres	sion of T	OTALYLD	
Predictor						
Variables	Coeffic	cient S	td Error	Т	Р	
Constant	2.7	76620	0.20076	13.78	0.0000	
NRATE	0.0	00553 6	.830E-04	8.09	0.0000	
R-Squared		0.8344	Resid.	Mean Squ	are (MSE)	0.20153
Adjusted R-S	Squared	0.8217	Stands	rd Deviat	ion	0.44892
Source	DF	SS	MS	F	Р	
Regression	1	13.2043	13.2043	65.52	0.0000	
Residual	13	2.6199	0.2015			
Total	14	15.8242				
Cases Includ	ded 15	Missin	g Cases O			

Figure 4-5

B. Interpreting the Regression Analyses

```
Table 4-1
```

Linear Regro	ession of TOTA	LYLD			
Predictor Variables	Coefficient	Std Error	т	Р	
Constant	2.76620	0.20076	13.78	0.000	
The constant intercepts or (rounded) wh	coefficient (2.766 crosses the Y axis hich would be 2.8	520) is the point s. In this exampl tons/acre.	where the r e, the line i	egression line intercepts Y at 2	2.8
NRATE	0.00553	6.830E-04	8.09	0.000	
The 0.00553 or the amoun every one lb o gamagrass. F 0.00553 tons/ get an 11 lb/a	is the linear regre t of change in Y f of N applied we s For a better interp /acre to lbs/acre so acre increase in yi	ssion coefficient for each unit chan ee a 0.00553 ton retation of the nu o we find that for eld.	which is the nge in X. In s/acre yield umber we we r every 1 lb	ne slope of the l n this example, l increase in vill convert o of N applied w	ine for ⁄e
R-Squared	0.834	4 Resid.	Mean Squa	are (MSE)	0.20153
The R-squar can be accou is N fertiliza regression ec	ed (R ²) value of 0 inted for by linear tion rate. The hig quation is in chara	0.8344 or 83% is function of the factor of the R ² value factorizing Y.	the total va independen the more in	riation in yield at variable X, wi aportant the	that hich

Adjusted R-Squ	uared	0.8217	Standar	rd Deviat	ion	0.	44892
Source Regression Residual Total	DF 1 13 14	ss 13.2043 2.6199 15.8242	MS 13.2043 0.2015	F 65.52	P 0.0000		Since the P value is less than p=0.05 then we can conclude that the analysis of variance for the overall
Cases Included	d 15	Missing	Cases 0			:	model is significant.

<u>Note</u>: If the R^2 value is low, even if the P value is significant for the model, the regression equation may not be meaningful. For example, an R^2 is .30, even if the model is significant, indicates that only 30% of the variation in the dependent variable Y is explained by the linear function of the independent variables considered. In other word, 70% of the variation in Y cannot be accounted for by the regression. With such low level of influence, the estimated regression equation would not be useful in estimating, much less predicting, the value of Y.

C. Model Defined

The model for this example is defined as linear

$$\mathbf{Y} = a + b\mathbf{X}$$

Where: Y is estimated yield; *a* is intercept and b is slope.

In our example, the model would be written with the following coefficients:

$$Yield = 2.7660 + 0.00553 (X)$$

D. Application and Presentation of Regression Equation

Our question at the beginning of this example was whether or not there is a relationship in yield of eastern gamagrass as a function of N fertilizer. The linear model was significant and N fertilizer explained 83% of the variation in yield (Fig. 4-6). We can conclude that there is a positive relationship in yields of eastern gamagrass with increased rates of N fertilization.



Figure 4-6

We can use the regression equation to predict yield at treatment levels not included in the data. For example, you want to predict what the yield of eastern gamagrass would have been if 100 of N was applied. Since 100 lbs is between 0-480 lbs, which was in the range of fertilizer rates applied, we are able to predict the yield using the coefficients calculated by *Statistix 8*.

Using the equation, Y = 2.7660 + 0.00553(N), and inserting 100 for N, the equation is written as:

Yield = 2.7660 + 0.00553(100)

To estimate the yield of eastern gamagrass multiply 0.00553 by 100, then add 2.7660. The calculated result is 3.319. Thus, the predicted yield of eastern gamagrass fertilized with 100 lbs of N would be approximately 3.3 tons/acre.

II. Quadratic Regression

A. Eastern Gamagrass Nitrogen Rate Trial

Statistix 8 can also perform quadratic regression analysis or second-degree polynomials. In order to perform this task we will need to transform the data using the built-in mathematical formulas in the *Statistix 8* software program.

B. Regression Analysis (Quadratic) and Transformations

For our example, we will use the data set from the pervious N fertilization experiment example (Fig. 4-1). In order to describe eastern gamagrass response to N fertilization using a quadratic regression equation we will need to "square" the independent variable X, which in our case is "Nrate", and create a new variable called "N2".

To create a new variable and transform the data:

- 1. From the main menu, select **Data**, **Insert**, **Variable** (Fig. 4-7).
- 2. In the *Insert Variable* dialog box, enter the new variable "N2" without quotes in the *New Variable Names* text area (Fig. 4-8).
- 3. Click OK.

The new variable "N2" is inserted into the data set (Fig. 4-9).

Note: Notice that the column contains the letter "M" which indicates missing data.



Figure 4-7

Figure 4-8

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녎 Eil	e <u>E</u> dit	<u>D</u> ata	<u>S</u> tatistics	Preferences	<u>W</u> indow <u>F</u>)	讀 Eil	Eile Ed	Eile Edit Data Statistics Preferences Wi
2	3 😂	X 🖻					😅 🕻	🚔 🖬 🎒	😂 🖬 🎒 🕴 Insert
		Rep	N2	Nrate	TotaMld				
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_	2	1	M	1 120	3.5875			2	2 <u>T</u> ransformations Ctrl+T
_	3	1	M	1 240	4.862			3	3 R <u>e</u> code
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_	7		. IV	1 120	3.344			6	6 <u>U</u> nstack
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	11	3	. N	1 360	4.6585			10	10 Bename Variables
	12	3	M	1 480	4.5945			11	Reorder Variables
	13	3	M	1 240	4.5475			12	
	14	3	M	1 0	2.3125			13	<u>C</u> olumn Formats
	15	3	M	1 120	3.207			14	Labels
*								CI	10 J M 120

Figure 4-9

Figure 4-10

To calculate the square of the variable "Nrate":

- 1. From the main menu, select Data, Transformations (Fig. 4-10).
- 2. In the *Tranformations* dialog box (Fig. 4-11), move the variable "N2" from the *Variables* list in the left column to the *Transformation Expression* text area by highlighting the variable and clicking on the right-arrow button to the left of the *Transformation Expression* text area.
- 3. Insert an equals sign (=) after the "N2" variable (e.g. N2=).
- 4. Insert the square function into the *Transformation Expression* text area by scrolling down the *Functions* list in the right column, highlighting the function "Sqr()", and clicking on the left-arrow button to the left of the "Functions" list (Fig. 4-12). The equation in the *Transformation Expression* text area should be:

N2=Sqr()

9	Statisti	ix - [(C: \Stati s	tix\exam	ple\egn	rate.sx]			Statistix -	[C:\Statistix\ex	ample\e	egnrate.s>	(]		
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*	Yariables N2 Nrate Rep TotaMd	forma	Trans	formation Expres	sion	Close Help	Eunctions Angle(x) Angle(x) Arctan(x) Arctan(x) Arctan(x) Arctan(x) Capitalize(s) Capitalize(s) Capitalize(s) Casit(x) Cosit(x) Cosit(x) Cosit(x) Cosit(x) Cosit(x) Cosit(x) Cosit(x) Date(s) D	► 	N2 Nrate Flep TotalYld	Transformation <u>E</u> xp N2= Sqr() <u>G</u> o	pression eear	Close	•	Abs(x) Angle(x) Arcsin(x) Arcsin(x) Arcsin(x) Capitalize(s) Case Cat(i,) Cop(x), i,) Cos(x) Cos(x) Cos(x) Cos(x) Cos(x) Cos(x) Cos(x) Date(s) Date(s) Detete(s, i,) Diff(x(i,)) Diff(x(i,))	

Figure 4-11

Figure 4-12

To take the square of the "Nrate":

1. Move the variable "Nrate" from the *Variables* list in the left column to the *Transformation Expression* text area by highlighting the variable and clicking the right-arrow button to the left of the *Transformation Expression* text area.

The expression "N2=Sqr(Nrate)" appears in the *Transformation Expression* text area (Fig. 4-13).

2. Click Go.

The transformation is executed and the new values are added into the N2 column (Fig 4-14).

Statistix - [C:\Statistix\example\egnrate.sx]	-	Stat	istix - [(: <mark>\Stati</mark> s	tix\exan	nple\egn	rate.sx]
Eile Edit Data Statistics Preferences Window Help		Eile	<u>E</u> dit <u>D</u> ata	<u>S</u> tatistics	Preferences	<u>W</u> indow <u>I</u>	Help
		€ 🖬 🤅	5) X B	ß			
Transformations			Rep	N2	Nrate	TotaMld	
		1	1	0	0	2.3045	
Variables Eurotions		2	1	14400	120	3.5875	
N2 Close Abs(x)	<u>^</u>	3	1	57600	240	4.862	
Rep Arcsin(x)		4	1	129600	360	4.899	
TotaMd Help Arctan(x)		5	1	230400	480	5.179	
Transformation Expression Capitalize(s	s)	6	2	14400	120	3.544	
N2= Sqr(Nrate) Case		7	2	0	0	2.8665	
- Copy(s,i,j)		8	2	230400	480	5.3125	
		9	2	129600	360	5.479	
CumSum(x)	[.k])	10	2	57600	240	4.042	
Go Clear Date(s)		11	3	129600	360	4.6585	
DayofWee	k(x)	12	3	230400	480	4.5945	
Delete(s,i,j)		13	3	57600	240	4.5475	
* Function		14	3	0	0	2.3125	
		15	3	14400	120	3.207	
	*						

Figure 4-13

Figure 4-14

C. Quadratic Regression

To execute the regression analyses:

- 1. From the main menu, select **Statistics**, **Linear Models**, **Linear Regression** (Fig. 4-15)
- 2. In the *Linear Regression* dialog box (Fig. 4-16), move the variable "TotalYld" from the "Variables" list in the left column to the *Dependent Variable* list in the right column by highlighting the variable and clicking n the right-arrow button to the left of the *Dependent Variable* list.
- 3. Move the variables "Nrate" and "N2" from the *Variables* list in the left column to the *Independent Variable* list in the right column by highlighting each variable one at a time and clicking on the right-arrow button to the left of the *Independent Variable* list.
- 4. Click **OK.**

Statistix 8 performs the linear regression analyses and provides a table of the coefficients (Fig. 4-17, Table 4-2).



Figure 4-15

Figure 4-16

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📃 Eile Edit	<u>R</u> esults	<u>W</u> indow	Help						
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Statistix 8	.0					egnrate,	1/24/2006,	1:15:03	ΡM
Unweighted	Least S	guares	Linear	Regres	sion of 1	TOTALYLD			
Predictor									
Variables	Coeffi	cient	Std E	rror	Т	Р	VIF		
Constant	2.	42625	0.1	.8602	13.04	0.0000			
NRATE	ο.	01119	0.0	0184	6.10	0.0001	12.4		
N2	-1.18	80E-05	3.668	E-06	-3.22	0.0074	12.4		
R-Squared		0.911	.1	Resid.	Mean Squ	uare (MSE)	0.11720		
Adjusted R-	Squared	1 0.896	3	Standa	rd Deviat	cion	0.34235		
Source	DF	s	s	MS	F	Р			
Regression	2	14.417	87.	20889	61.51	0.0000			
Residual	12	1.406	4 0.	11720					
Total	14	15.824	2						
Cases Inclu	ided 15	Miss	ing Ca	ises O					

Figure 4-17

D. Interpretation of the Regression Analysis

```
Table 4-2
```



E. Model Defined

The model for this example is defined as:

$$\mathbf{Y} = a + B_1 \mathbf{X} + B_2 \mathbf{X}^2$$

Where: Y is estimated yield; a is intercept and B_1 and B_2 are partial regression coefficients.

In our example, the quadratic regression equation would be written with the following coefficients:

Yield = 2.42 + 0.01 N + - 1.18E-05 N²

F. Application and Presentation of Regression Equation

A quadratic equation fit the real data on which this example was based better than the linear equation we used earlier (91% vs. 83%). We can conclude that eastern gamagrass evaluated in this study produced a curvilinear response to N fertilization (Fig. 4-18).



Figure 4-18

We can also use the quadratic equation to predict the yield of eastern gamagrass at a treatment level not included in the data. For example, we wish to estimate the yield of eastern gamagrass fertilized with 200 lbs/acre N. Insert 200 in the partial regression coefficients (N and N²) and calculate the estimated yield.

Yield =
$$2.42 + 0.01 (200) - 1.18E - 05 (200)^2$$

The estimated yield of eastern gamagrass fertilized with 200 lbs of N/acre is 3.9 tons/acre.

The quadratic equation can also be useful in determining at which treatment becomes cost-effective or the treatment level associated with the maximum or minimum response. For example, we wish to determine the N rate at maximum yield. To make this calculation we will take a derivative of the regression equation and set it equal to 0 (zero) and solve for N (nitrogen).

The equation becomes:

$$B_1 + 2(B^2 N) = 0$$

Solving for Nitrogen = $\frac{B_1}{-2B_2}$
Nitrogen = $\frac{0.01}{-2(0.0000118)}$

Nitrogen = 424

The N rate at maximum yield occurred at 424 lb/acre.

<u>Chapter 5:</u> Missing Data

I. Missing Data

A. Description

There is a difference between missing data and the number zero (0). For example, if cultivar A was used as standard of comparison in an adaptation trial in Pullman, WA and was winterkilled, then it would be reported as a 0 because the cultivar was not adapted. Conversely, if you have 10 clover cultivars planted in a randomized complete block with four replications and deer forages on cultivar A in replication 4, and no production data can be collected, then replication 4 would be reported as missing data.

There are times when you may encounter missing data in your experiment. There are techniques to estimate missing data that are based on data for the treatment with the missing value that are available and data for treatments in the surrounding plots (see Gomez and Gomez, 1984). However, the question is can statistical analyses be performed on data collected from unequal observations? In other words, can data collected from "accession A" from 3 observations (replications) be compared to data collected on accessions from 4 replications without estimating a missing value for accession A? The answer to this question is yes. *Statistix 8* handles missing data for a treatment observation without requiring that you estimate a missing value for the treatment.

For example, you collected yield data on 5 accessions of wheatgrasses that were planted in a randomized complete block design replicated 4 times (Fig. 5-1). Unfortunately, you were unable to collect data on accession 4567 in replication 1 and accession 1245 in replication 2 due to loss of the sample. In the dataset, the missing data is represented by the letter "M".

Perform the analysis of variance for a randomized complete block design with the missing data in the dataset (Fig. 5-2).

Statistix - [C:\Statistix\example\wheatgrass example.sx]	Randomized Complete Block AOV Table for YIELD					
Elle Edit Data Statistics Preferences Window Help	Source DF SS MS F P					
Image: Constraint of the	REP 3 1148484 382828 ACCN 4 9.005E+07 2.251E+07 117.25 0.0000 Error 10 1920020 192002 192002 Total 17 Note: SS are marginal (type III) sums of squares Grand Mean 8401.5 CV 5.22 CV 5.22 Tukey's 1 Degree of Freedom Test for Nonadditivity Source DF S MS F P Nonadditivity 1 401596 401596 2.38 0.1573 Remainder 9 1518424 168714 Relative Efficiency, RCB 1.13 Means of YIELD for ACCN ACCN Mean SE 1245 3 10797 252.98 1580 4 5407 219.09 4567 3 10882 252.98					
20 4 7890 6500 *	4689 4 8803 219.09 7890 4 6120 219.09 Figure 5-2					

B. Results and Interpretation of the Analyses

Rather than discuss all of the numbers in the analysis of variance we will discuss those of interest to the user (Table 5-1).

Table 5-1

Randomized Complete Block AOV Table for YIELD								
Source	DF	SS	MS	F	P			
REP ACCN	3 4	1148484 9 005E+07	382828 2 251E+07	117 25	0.0000			
Error Total	10 17	1920020	192002	117.23				

Since the P value is less than 0.05 then we conclude that there are significant differences between wheatgrasses.

Note: SS are marginal (type III) sums of squares

A Type III sums of squares test the same hypothesis that would have been tested if the cell size would have been equal that is. if there was no missing data.

Grand Mean 8401.5 CV 5.22

Tukey's 1	Degree of	Freedom	Test for	Nonadditi	vity		
Source	DF	SS	MS	F	Р		
Nonadditiv	rity 1	401596	401596	2.38	0.1573		
Remainder	9	1518424	168714				
Relative Efficiency, RCB 1.13							

Means	of	YIELD	for	ACCN		
ACCN 1245 1580 4567 4689 7890	N 3 4 3 4 4	Mean 10797 5407 10882 8803 6120	252 219 252 219 219	SE 2.98 9.09 2.98 9.09 9.09	}	The mean for ACCN 1245 and 4567 was determined by 3 replications (N=observations) rather than 4 replications as in the other accessions (ACCN).

Since there were significant differences in wheatgrass accessions as determined by the analysis of variance (p=0.0000), you may perform a mean separation test to determine significant means and report the results.

<u>Chapter 6:</u> Data Transformations

I. Introduction

The analysis of variance is valid when certain assumptions are made such as *additive effects*, (treatment and environmental effects are additive) *independence of errors* (experimental errors are independent), *homogeneity of variance* (experimental errors have common variance) and *normal distribution* (experimental errors are normally distributed). When these assumptions are not valid (e.g. when there is a significant treatment x replication), data transformations may be used. Some of the more popular data transformations are square root, logarithmic, and arc sine. In another chapter, we used the square root transformation of N rate to create a new variable named N2.

II. Tukey's One Degree of Freedom Test of Non-additivity

A. Description

Statistix 8 conducts a Tukey's One Degree of Freedom Test for Non-additivity for a randomized complete block design analysis of variance. In the example given in chapter 2, we found that there was no suggestion of non-additivity in the Yield1 data of the switchgrass cultivar trial (p=0.4649). If the P value had been less than p=0.05, which would have indicated the likely presence of non-additivity, we would have transformed the data in an attempt to reduce the non-additive effect. The question is how do we transform the data to remove the non-additive effect and how is it reported?

For this example, we will use seed weight data of 7 accessions of crested wheatgrass harvested from plots arranged in a randomized complete block design with four replications (Fig. 6-1). You perform the analysis of variance (Fig. 6-2).

Stat	istix - [C:\Statis	tix\exan	nple\transformedcrestedwheat.sx]	Statistix - [Randomized Complete Block AOV - AOV Table]
」 唐ile	Edit Data	Statistics	Preferences	Window Help	Eile Edit Results Window Help
🛩 🖬	a 🖁 🕹	8			
	REP	CWHEAT	SEEDWT		Sta Open x 8.0 transformedcrestedwheat, 2/15/2006, 3:05:09 PM
▶ I 2	1	7432	57.77		Randomized Complete Block AOV Table for SEEDWT
3	1	7320	24.09		
4	1	6293	35.64		Source DF SS MS F P
5	1	4409	18.63		REP 3 333.66 111.221
6	1	7621	14.15		CWHEAT 6 2325.57 387.595 3.28 0.0234
7	1	6622	55.51		Total 27 4788 47
8	2	7621	22.58		
9	2	6293	23.78		Grand Mean 29.954 CV 36.31
10	2	7432	30.03		
11	2	4409	23.37		Tukey's 1 Degree of Freedom Test for Nonadditivity
12	2	6622	38.54		Source DF SS MS F P
13	2	7401	27.27		Nonadditivity 1 473.61 473.613 4.86 0.0415
14	2	7320	22.84		Remainder 17 1655.62 97.389
15	3	4409	29.55		Deletive Efficiency DCB 0 08
16	3	7320	13.58		Actually hildreney, Ap 0.55
17	3	6293	32.14		Means of SEEDWT for CWHEAT
18	3	7432	36.77		
19	3	7621	21.24		CWHEAT Mean
20	3	6622	35.74		4409 25.175
21	3	7401	29.48		6293 28.460
22	4	7401	59.41		
23	4	4409	29.15		7401 37,773
24	4	7621	9.53		7432 39.403
25	4	6622	37.34		7621 16.875
26	4	7320	20.33		Observations per Mean 4
27	4	6293	22.28		Standard Error of a Mean 5.4381
28	4	/432	23.04		Std Error (Diff of 2 Means) 7.6906
禾					




B. Results and Interpretation of the Analyses

Results of the analysis of variance (Table 6-1) indicate that there are significant differences in crested wheatgrass accessions as indicated by the P value of 0.0234. However, we also find that there is evidence of non-additivity effect as determined by Tukey's 1 Degree of Freedom Test for Non-additivity (p=0.0415). The next step is to see if we can reduce the non-additivity by transforming the data.

```
Table 6-1
Randomized Complete Block AOV Table for SEEDWT
                                    F
Source
        DF
                  នន
                            MS
                                             Ρ
REP
         3
              333.66
                       111.221
                                        0.0234
CWHEAT
         б
             2325.57
                       387.595
                                 3.28
        18
             2129.23
                       118.291
Error
Total
        27
             4788.47
Grand Mean 29.954
                   CV 36.31
Tukey's 1 Degree of Freedom Test for Nonadditivity
Source
         DF
                        SS
                                  MS
                                            F
Nonadditivity
                    473.61
                              473.613
                                         4.86
                                               0.0415
               1
               17
                    1655.62
                              97.389
Remainder
Relative Efficiency, RCB 0.98
Means of SEEDWT for CWHEAT
CWHEAT
         Mean
  4409
       25.175
  6293
       28.460
  6622
       41.782
  7320 20.210
  7401
       37.773
  7432 39.403
 7621 16.875
Observations per Mean
                                4
Standard Error of a Mean
                           5.4381
Std Error (Diff of 2 Means) 7.6906
```

III. Transforming the Data Using Logarithmic

A. Transformation

To transform the seed weight data into a logarithmic scale:

- 1. From the main menu, select Data, Transformation (Fig. 6-3).
- 2. In the *Transformation* dialog box (Fig. 6-4), in the *Transformation* Expression text box, enter "NEWT=" without quotes, to represent new weight (Fig. 6-5).
- 3. In the *Functions* list, scroll down and select "Log(x)" and click on the right arrow button to insert the Log (x) function into the Transformation Expression text area (Fig. 6-6).



Figure 6-3





He Edit Data Statistics Preferences Window Help



Statistix - [C:\Statistix\example\transformedcrestedwheat.sx]

Figure 6-5

Figure 6-6

Figure 6-4

Statistix 8 User Guide Version 2.0

The seed weight variable upon which the data transformation will be performed is now added to the mathematical equation.

4. Insert "SEEDWT" within the parenthesis by highlighting the variable in the *Variables* list and clicking on the right-arrow button to the left of the *Transformation Expression* text area, to achieve (Fig. 6-7):

```
(NEWT=Log(SEEDWT)
```

5. Click Go.

A new variable named "NEWT" plus the logarithmic of the seed weight data is inserted into the original data set (Fig.6-8).

To determine if transforming the data removed the nonadditivity effect, we will perform an analysis of variance on the "NEWT" variable.



Figure 6-7



B. Results and Interpretation of the Analyses

Since the P value for the Tukey's 1 Degree Test for Nonadditivity is greater (p=0.3887) than p=0.05 then we can conclude that transforming the seed weight data using the logarithmic transformation was successful in removing the nonadditivity effect (Table 6-2).

Table 6-2

Randomized Complete Block AOV Table for NEWT

Source	DF	SS	MS	F	P
REP	3	0.03514	0.01171		
CWHEAT	б	0.54876	0.09146	4.54	0.0057
Error	18	0.36228	0.02013		\ /
Total	27	0.94617			\smile

Grand Mean 1.4380 CV 9.87

Tukey's 1 Degree of Freedom Test for Nonadditivity

Source N	DF	SS	MS	F	Р
onadditivity Remainder	1 17	0.01594 0.34633	0.01594 0.02037	0.78	0.3887

Relative Efficiency, RCB 0.94

Means of NEWT for CWHEAT

CWHEAT	Mean	
4409	1.3935	
6293	1.4458	
6622	1.6139	
7320	1.2954	
7401	1.5556	
7432	1.5591	
7621	1.2027	
Observa	ations per Mean	4
Standar	d Error of a Mean	0.0709
Std Err	cor (Diff of 2 Means)	0.1003

C. Presenting the Results

Now that we have successfully transformed the data and removed the nonadditivity effect, how is the transformed data used and how do you present the results? Since the analysis of variance determine that there were significant differences in the crested wheatgrass accessions (p=0.0057; Table 6-2) then perform an all Pairwise Comparison Test (e.g. Tukey's HSD) on the transformed means to determine differences between accessions (Fig. 6.9).

Like any other data presentation, report the original seed weight data of the 7 crested wheatgrass accessions (means are found in Table 6-1) in a table **but use mean separation test results from the transformed data** (Fig. 6.9). Results are presented in Table 6-3. If the paper is peer viewed for symposia proceedings or journal article, you will need to report in the materials and methods section that the seed weight data was transformed (e.g. logarithmic, square root, etc.). It would also be advisable to report it in the PMC ATR.

Stati	stix - [Rand	omized Complete Block AOV - All-pair	wise Comparisons]
📃 Eile	<u>E</u> dit <u>R</u> esults	<u>W</u> indow <u>H</u> elp	
🖻 🔒	😂 X 🖣	6	
Tukey	HSD All-H	airwise Comparisons Test of H	WEWT for CWHEAT
CWHEAT	Mean	Homogeneous Groups	
6622	1.6139	A	
7432	1.5591	A	
7401	1.5556	A	
6293	1.4458	AB	
4409	1.3935	AB	
7320	1.2954	AB	
7621	1.2027	В	
Alpha		0.05 Standard Error f	for Comparison 0.1003
Critic	al Q Valu	e 4.674 Critical Value f	for Comparison 0.3315
Error	term used	: REP*CWHEAT, 18 DF	
There	are 2 gro	ups (A and B) in which the me	eans
are no	t signif:	cantly different from one and	other.

Figure 6-9

Table 6-3

Presenting crested wheatgrass seed weight using original means in Table 6-1 and the means separation test using Tukey's HSD in Fig 6-9 that was performed on the transformed data.

	Seed weight	
Accession		
	g/plot	
6622	41.782 a*	
7432	39.403 a	
7401	37.773 a	
6293	28.460 ab	
4409	25.175 ab	
7320	20.210 ab	
7621	16.875 b	
Mean	29.954	

 \ast Means followed by the same letters are not significantly different as determined by Tukey's HSD at P<0.05.

Chapter 7: Other Model Statements

I. Other Model Statements

Listed below are examples of model statements that *Statistix 8* recognizes and will perform the appropriate analyses given the model statement has been correctly entered.

In most situations, neither the order in which terms are specified in the model nor the order in which variables are specified within terms has any influence on the analysis. The only exception occurs in certain models with multiple error terms.

Example 1: Completely randomized design, also called the one-way design. If the treatment factor is A, the model is specified simply as:

Α

Example 2: Randomized complete block design. BLK is the factor for blocks and A if the treatment factor.

BLK A

Example 3: Single-factor Latin square design. The variables ROW and COL are the row- and column blocking factors, and A is the treatment factor.

ROW COL A

Example 4: Three-factor factorial in a completely randomized design with all two factor interactions.

A B C A*B A*C B*C

<u>Note</u>: The example factorial design above could be entered more concisely using the ALL2 keyword.

ALL2(A B C)

Example 5: Split-plot design. The variable REP is the factor for replication, A is the main-plot factor, and B is the subplot factor.

REP A REP*A(E) B A*B

<u>Note</u>: the interaction REP*A is an error term. The three factor interaction term REP*A*B is also an error term, but was omitted above because Statistix 8 always adds the high order interaction term automatically.

Example 6: Strip-plot design. The variable REP is the factor for replication, A is the main-plot factor, and B is the subplot factor.

REP A REP*A(E) B REP*B(E) A*B

Example 7: One-way repeated measures design. SUBJ is the subjects factor and A is the withinsubjects factor.

SUBJ A

Example 8: Two-factor repeated measures design with a between-subjects factor A and a withinsubjects factor B.

A SUBJ*A(E) B A*B

Examples 1 - 8 above are all models that could be more easily specified using the specific AOV procedures discussed earlier in this chapter. But the General AOV/AOCV procedure allows you to specify other models, including variations of the above models.

Example 9: A two-factor nested model with factor B nested within factor A.

A B*A

Compare the nested model with the two-factor cross-classified (factorial) model:

A B A*B

Example 10: A three-factor factorial experiment in a split-plot design. The factors A and B are both main-plot factors, and C is the subplot factor.

REP A B A*B REP*A*B(E) C A*C B*C A*B*C

Chapter 8: Converting MSTAT-C Files to Statistix 8 Files

Many PMCs and PMSs used MSTAT-C to analyze performance data of plant accessions and cultivars. The question is how to convert MSTAT-C data files into Statistix 8 files without reentering the data? The following steps provide a procedure on how to convert MSTAT-C files to Statistix 8 files:

- Step 1 Open the file in MSTAT-C.
- Step 2 Select 41 (SEDIT). Select which variables that you want to convert (i.e., 1 = rep; 4 = seed trt; 5 = cultivar, etc.
- Step 3 Select 36 (Printlist) and chose all cases
- Step 4 Enter the variables of interest (i.e., 1, 4, 5) left justified = No wide paper = No paginagation = No variable description = No
- Step 5 Save output to disk
- Step 6 Exit MSTAT-C
- Step 7 Open OUTPUT file in Microsoft Word (Excel had problems copying alphanumeric variables).
- Step 8 Open Statistix 8
- Step 9 From the main menu bar in *Statistix 8* select **Data, Insert, Variables** Enter the name of the variables you want to move over from the MSTAT-C file. For example, rep, seedtrt, cultivar
- Step 10 Copy data from OUTPUT to Statistix 8 spreadsheet (*shift-alt to prevent copying the "case no." column*)

Step 11 Save file