Karadeniz Fen Bilimleri Dergisi, 12(1), 229-245, 2022. DOI: 10.31466/kfbd.1016490

KFBD

Karadeniz Fen Bilimleri Dergisi
The Black Sea Journal of Sciences
ISSN (Online): 2564-7377

Araştırma Makalesi / Research Article

Contrast Coding in Two-Factor Analysis of Variance Studies: An Application to Cotton Data

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Abstract

In this study, how the contrast analysis is performed in a two-way factorial design consisting of contrast estimates containing specific questions determined to investigate the specific differences between averages was examined in detail. For this purpose, after determining the hypotheses to determine the main effects, contrast coefficients suitable for each hypothesis were created and contrast analysis was performed. In the study, some of the data obtained from the cotton trials conducted in the Field Crops Department of the KSU Faculty of Agriculture were used with permission. Cotton varieties, years and interaction effects were evaluated using the R and SPSS 21.0 package programs. With the use of contrast, while performing two-factor analysis, first the main effects were investigated and then the interaction effects were investigated. Among the estimates made with 1 degree of freedom within the main effect A, the contrast estimation showed the greatest effect ($r_{contrast}$=0.7901). Later, among the estimates made with 1 degree of freedom within the main effect B, the contrast estimation showed the greatest effect ($r_{contrast}$=0.6370). Likewise, when looking at the interaction effects, it is seen that the effect of the contrast estimation ($r_{contrast}$=0.4388) shown by the quadratic effect of is more important, that is, the quadratic effect is more important. As a result, this study showed the researchers where the main effects were found when the average differences in factorial designs were analyzed and gave detailed information about their effect sizes.

Keywords: Contrast coding, Factorial ANOVA, Cotton, Comparisons, Means.

İki Faktörlü Varyans Analizinde Kontrast Kodlama: Pamuk Verilerine Bir Uygulama

Öz

Bu çalışmada, ortalamalar arasındaki belirli farklılıkları araştırmak için belirlenen belirli soruları içeren kontrast tahminlerinden oluşan iki yönlü faktöriyel bir tasarımda kontrast analizinin nasıl yapıldığı ayrıntılı olarak incelenmiştir. Bu amaçla temel etkileri belirlemek için hipotezler belirlendikten sonra her bir hipoteze uygun kontrast katsayıları oluşturulmuş ve kontrast analizi yapılmıştır. Araştırmada KSÜ Ziraat Fakültesi Tarla Bitkileri Bölümü'nde yapılan pamuk denemelerinden elde edilen verilerin bir kısmı izin alınarak kullanılmıştır. Pamuk çeşitleri, yılları ve etkileşim etkileri R ve SPSS 21.0 paket programları kullanılarak değerlendirilmiştir. Kontrast kullanımı ile iki faktörlü analiz yapılırken önce ana etkiler, ardından etkileşim etkileri araştırılmıştır. Ana etki A içinde 1 serbestlik derecesi ile yapılan tahminler arasında en büyük etkiyi ($r_{kontrast}$ = 0.7901) kontrast tahmini göstermiştir. Daha sonra; B ana etkisi içerisinde 1 serbestlik derecesi ile yapılan tahminler arasında en büyük etkiyi ($r_{kontrast}$ = 0.6370) kontrast tahmini göstermiştir. Aynı şekilde interaksiyon etkilerine bakıldığında kontrast tahmininin etkisinin ($r_{kontrast}$ = 0.4388) daha önemli yani ikinci dereceden etkinin daha önemli olduğu görülmektedir. Sonuç olarak bu çalışma, faktöriyel tasarımlardaki ortalama farklar analiz edildiğinde ana etkilerin nerelerde bulunduğunu araştırmacılara göstermiş ve etki büyüklükleri hakkında detaylı bilgi vermiştir.

Anahtar Kelimeler: Kontrast kodlama, Faktöriyel ANOVA, Pamuk, Karşılaştırmalar, Ortalamalar.

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1. Introduction

Analysis of variance (VA), which is a method generally used in scientific studies involving more than two groups, is used to examine the effect of the dependent variable on the independent variable. With classical analysis of variance, paired comparisons of all means are made and all binary combinations are tested, then the situation of being different or same is determined in all possible comparisons (Bek et al., 1988; Shavelson, 2016). In this case, a detailed analysis of the differences between binary means is performed with tests such as LSD, Tukey, Duncan, which are also called unplanned (post-hoc or posteriori) comparisons (Özdamar, 1999; Efe et al., 2000; Üçkardeş, 2006; Darlington and Hayes 2016). In addition, in priori comparisons, the researcher has a preliminary idea about the groups and has a curiosity or question about the relevant subject. In this case, the researcher hypothesizes that some averages and other averages may be different from each other, or hypothesizes that one of the averages may be different from the others.

There are several advantages compared to unplanned comparison of planned comparisons. First of all, the Unplanned (post-hoc or posteriori) comparisons are used to test whether the means are the same, and all possible pairwise mean differences are tested with multiple comparison tests. These comparisons are called explotory data analysis because they are based on the interpretation of combinations with which of the mean groups are different (Karpinski 2006a; Keppel 1973; Haans, 2018). In other words, in unplanned comparisons, significant results are shown, but there are also a lot of unnecessary comparisons. On the other hand, planned comparisons, if the researcher has an idea about groups or group averages or has questions that he is curious about, transforms them from question to hypothesis and expresses these hypotheses using contrast coefficients. This is also called confirmatory data analysis because the researcher only tests the hypotheses with which is interested by performing contrast analysis (Karpinski, 2006a; Zieffler, 2011; Haans, 2018). Since the researcher only tests the hypotheses, he is interested in in planned comparisons, the power of the test is higher than planned comparisons. This is the most important advantage of planned comparisons over unplanned comparisons. In addition, planned comparisons allow you to compare more than one group with the averages of more than one other group, or to compare one group with the averages of more than one group, not just paired comparisons. At the same time, these comparisons also give the opportunity to test the weight of a group compared to another group such as 1-fold, 1.5 times, 2 times. This is another important advantage of planned comparisons over unplanned ones (Thompson, 1990; Abdi et al., 2009; Haans, 2018).

In contrast coding, which is a planned comparison that is mainly mentioned in this study, there are specific or focused comparisons to examine the effect of the independent variable in detail. In this case, contrast analysis will be used, coded such that the investigated effect is positive while the other is negative. Thus, contrast analysis enables researchers to ask their focused questions about the data and compare the results with hypotheses (Rosenthal and Rosnow, 1985; Efe and Çanga 2017; Haans, 2018; Çanga et al., 2019). The researcher can compare not only paired comparisons, but also the weight of one or several averages, and the average groups desired by the researcher thanks to the weighting done by giving appropriate coefficients. In this study, the detailed use of contrast estimation in two-factor ANOVA, which allows detailed examination of interaction effects, will be examined. For this purpose, firstly the method was introduced, and the variation of cotton groups grown in Kahramanmaraş conditions over the years was compared with contrast analysis.

The study is expected to support the dissemination of the use of contrast analysis, especially in the comparison of averages in the field of agriculture, by eliminating this gap that has arisen due to the lack of any resources studied on this subject before in Turkey.

2. Materials and Methods

2.1 Material

With factorial designed contrast analysis, it is determined whether the data will be explained by two main effects and whether an interaction of the data is required in some findings. Here, the cotton varieties of Maraş 92(M92), Sayar 314(S314), Ağdaş3(AG3), Ağdaş17(AG17), which are determined as 4-level factors, and the other 3-level factor fiber fineness (micronaire index) values between 2002, 2003, 2004 will be examined (Efe et al., 2004). The fiber fineness values of cotton varieties based on years were carried out in 3 repetitions and the mean values (*Means of the variety* x *year combinations*) were given (Table 1a, Table 1b).

Table 1a. Fiber fineness values of cotton varieties depending on years (mic)

		Variety			
		M92 *(local)* *(hirsutum)*	S314 *(Local)* *(hirsutum)*	AG3 *(Azerbaijani)* *(hirsutum)*	AG17 *(Azerbaijani)* *(hirsutum)*
Years	**2002**	4.1	4.98	5.4	3.3
		3.7	3.33	5	3
		4.4	4.1	5.1	3
	2003	4.6	4.01	5.3	5
		4.8	4.29	5.4	5.3
		4.9	4.4	4.5	3.9
		4.6	4.8	4.68	3.01
	2004	4.1	4.3	4.35	2.93
		4.1	4.6	4.26	3.53

Table 1b. Means of values of variety and year values (mic)

		Variety				
		M92 *(local)* *(hirsutum)*	S314 *(Local)* *(hirsutum)*	AG3 *(Azerbaijani)* *(hirsutum)*	AG17 *(Azerbaijani)* *(hirsutum)*	$\overline{X}_{..b}$
Years	2002	4.07	4.14	5.17	3.1	4.12
	2003	4.77	4.23	5.07	4.73	4.7
	2004	4.27	4.57	4.43	3.16	4.11
	$\overline{X}_{.a.}$	4.37	4.31	4.89	3.66	$\overline{X}_{...} = 4.31$

2.2. Methods

2.2.1. Finding the sum of squares for a contrast

In this case, the contrast coefficients being C_a; the contrast divides the data into two groups with a plus sign for C_a values in one group and a minus sign for C_a values in another group. Since this analysis is done with two groups, the sum of squares of a contrast has only one degree of freedom. Specifically, it is represented as the sum of squares for contrast and calculated as follows:

$$SS_{(\hat{\psi}_i)} = \frac{n(\hat{L})^2}{\sum c_{a,i}^{\ 2}} = \frac{n(\hat{\psi})^2}{\sum C_a^{\ 2}} \quad (1)$$

$$\hat{\psi} = \hat{L} = \sum_{a=1}^{A} \overline{X}_{a.} C_a = \sum_{a=1}^{A} \overline{X}_{a.} c_{a,i} = \overline{X}_{1.} c_{1,i} + \overline{X}_{2.} c_{2,i} + \ldots + \overline{X}_{k.} c_{k,i} \quad (1.a)$$

Here

a : Group index

n : Number of observations in each group

i : Kontrast indisi

$c_{a,i}$: a. for the group i. contrast coefficient

$\hat{L}$: Estimation of the weighted (contrasted) sum of all average conditions (Rosenthal and Rosnow 1985; Rosnow et al., 2000; Abdi et al., 2009; Efe and Çanga 2017; Çanga and Efe 2017; Çanga, 2018; Çanga et al., 2019).

2.2.2. *Contrast tests in two-factor ANOVA*

Generally, contrast is a group of weight values that describe a particular comparison on cell averages. An example of 3x3 for contrast design in two-way ANOVA is shown in Table 2 (Karpinski, 2006c).

Table 2. A 3x3 sample representation for ANOVA design

		A factor			
		A1	A2	A3	$\sum$
B factor	B1	$\bar{X}_{.11}$	$\bar{X}_{.21}$	$\bar{X}_{.31}$	$\bar{X}_{..1}$
	B2	$\bar{X}_{.12}$	$\bar{X}_{.22}$	$\bar{X}_{.32}$	$\bar{X}_{..2}$
	B3	$\bar{X}_{.13}$	$\bar{X}_{.23}$	$\bar{X}_{.33}$	$\bar{X}_{..3}$
	$\sum$	$\bar{X}_{.1.}$	$\bar{X}_{.2.}$	$\bar{X}_{.3.}$	$\bar{X}_{...}$

First, the contrast estimate is calculated for testing the main effects. Contrast calculation A, B is given by the following respectively Equation (2) and Equation (3):

$$\hat{\psi}_{A_{factor}} = \sum_{a=1}^{A} \bar{X}_{.a.} C_a = \bar{X}_{.1.} C_1 + \bar{X}_{.2.} C_2 + \bar{X}_{.3.} C_3 \qquad (2)$$

where, three levels for main factor A and each mean is shown that $\bar{X}_{.1.}, \bar{X}_{.2.}, \bar{X}_{.3.}$

$$\hat{\psi}_{B_{factor}} = \sum_{b=1}^{B} \bar{X}_{..b} C_b = \bar{X}_{..1} C_1 + \bar{X}_{..2} C_2 + \bar{X}_{..3} C_3 \qquad (3)$$

where, three levels for main factor B and each mean is shown that $\bar{X}_{.1.}, \bar{X}_{.2.}, \bar{X}_{.3.}$
And then, the sum of squares of factors A and B definition is calculated respectively as Equation(4) and Equation(5).

$$SS(\hat{\psi}_{Afactor}) = \frac{(\hat{\psi}_{Afactor})^2}{\sum \frac{C_a^2}{n_a}} \qquad (4)$$

$$SS(\hat{\psi}_{Bfactor}) = \frac{(\hat{\psi}_{Bfactor})^2}{\sum \frac{C_b^2}{n_b}} \qquad (5)$$

Depending on these values, when the relevant sum of squares for the A and B factors is written instead, the F value is calculated as Equation 6 (Karpinski, 2006c).

$$F_{1,\mathrm{Error\ df}} = \frac{\mathrm{SS}/\mathrm{contrast\ df}}{\mathrm{ESS}/\mathrm{Error\ df}} \qquad (6)$$

The contrast estimation for testing the interaction effect is as follows. Contrast estimation based on interaction is given by the following Equation (7):

$$\hat{\psi}_{AxB} = \sum_{b=1}^{B}\sum_{a=1}^{A}\overline{X}_{.ab}C_{ab} \quad (7)$$

where, C_{ab} is interaction coefficients and $\overline{X}_{.ab}$ is obtained as a result of interaction means and calculations. Depending on these values, the sum of squares is is calculated as Equation (8).

$$SS(\hat{\psi}_{A\times B}) = \frac{(\hat{\psi}_{A\times B})^2}{\sum \frac{C_{ab}^{2}}{n_{ab}}} \quad (8)$$

Finally, the F value used in the variance analysis table is found when it is written instead of the sum of squares due to interaction. F value is calculated by the formula Equation (9) (Karpinski, 2006c).

$$F_{(1,HSD)} = \frac{SS(\hat{\psi}_{A\times B}) / contrast\ df}{Error\ sum\ of\ squares(SSE) / Error\ df} = \frac{SS(\hat{\psi}_{A\times B})}{SSE / Error\ df} \quad (9)$$

2.2.3. Calculation of effect size in terms of correlation

The measure of effect size in terms of correlation (r measure of effect size); r is called contrast.

$$r_{contrast} = \sqrt{\frac{F_{contrast}}{F_{contrast} + Error\ df}} \quad (10)$$

(Rosenthal and Rosnow, 1985; Rosnow et al., 1996; Karpinski, 2006b). In the analysis of data; The SPSS 21 package program and the R program version 3.4.4, which has been developing with the open architecture technique in recent years and which has become increasingly common in statistical methods, have been (R Core Team, 2021).

3. Findings and Discussion

The traditional analysis of variance of the data in Table 2 is given (Table 3). When performing two-factor analysis with the use of contrast, firstly the main effects are investigated, then the interaction effects are investigated.

Table 3. ANOVA results of the values in Table 2

VK	df	SS	MS	F	Sig.
Varieties	3	6.796	2.266	13.389***	2.44e-05
Years	2	2.774	1.387	8.197**	0.001935
Interaction	6	4.426	0.737	4.359**	0.004099
Error	24	4.061	0.169		
Total	35	18.057			

****:P<0.001, **: P<0.01*

The traditional analysis of variance of the data in Table 2 is given (Table 3). When performing two-factor analysis with the use of contrast, firstly the main effects are investigated, then the interaction effects are investigated.

According to the analysis of variance results, the main effects were found to be statistically significant (P<0.001) and the interaction effects were also significant (P<0.01). In order to evaluate this effect, the F test will be examined in detail. By contrast analysis with questions based on hypotheses, first the main effects and then the results of the interaction effects will be investigated.

Step 1: Investigating the A main effect

The questions previously determined by the researcher to investigate the main effect A are as follows. Here, (a-1)= 4-1=3 questions to be addressed through contrasts can be created.

Hypothesis 1: "Is the fiber fineness of the standard local variety and the mutant Azerbaijan variety of cotton varieties the same?"

This first contrast is shown as ψ_1:

$$\psi_1 = \left(\frac{\mu_{M92} + \mu_{S314}}{2}\right) - \left(\frac{\mu_{AG3} + \mu_{AG17}}{2}\right)$$

With a better display;

$$\psi_1 = 1\mu_{M92} + 1\mu_{S314} - \mu_{AG3} - \mu_{AG17}$$

is expressed with.

In the first hypothesis, the comparison of mutant azerbaijani cultivars against standard local cotton cultivars can be converted into a contrast line $\{1, 1, -1, -1\}$.

In the same way, other hypotheses and determined coefficients were created and are shown in Table 4. The calculations by taking the contrast coefficients and group averages related to these hypotheses are shown in Table 4 (Abdi et al., 2009; Howell, 2016; Dubcowsky, 2015; Karpinski, 2006b; Haans, 2018; Çanga, 2018).

Table 4. Hypotheses based on varieties, contrast coefficients

Hypotheses	Contrast statement of the hypothesis (ψ_i)	Contrast coefficients
Hypothesis 1:"Is the fiber fineness of the standard local variety and the mutant Azerbaijan variety of cotton varieties the same?"	$\psi_1 = 1\mu_{M92} + 1\mu_{S314} - 1\mu_{AG3} - 1\mu_{AG17}$	{1, 1, -1, -1}
Hypothesis 2: "Are the local varieties of standard cottons the same as Maraş 92 and Sayar 314 in terms of fiber fineness?"	$\psi_2 = 1\mu_{M92} - 1\mu_{S314} + 0\,\mu_{AG3} + 0\,\mu_{AG17}$	$\{1, -1, 0, 0\}$
Hypothesis3: "Is the fiber fineness of Ağdaş 3 and Ağdaş 17, the two hirsutum species of mutant azerbaijan cotton, the same?"	$\psi_3 = 0\mu_{M92} + 0\mu_{S314} + 1\mu_{AG3} - 1\mu_{AG17}$	$\{0, 0, 1, -1\}$

The calculations by taking the contrast coefficients and group averages written for the hypotheses in Table 4 are shown in Table 5.

Table 5. Group means, contrast coefficients and preliminary calculations depending on the variety

	M92 (local) (hirsutum)	*S314* (local) (hirsutum)	*AG3* (Azerbaijani) (hirsutum)	*AG17* (Azerbaijani) (hirsutum)	$\sum$
$\overline{X}_{.a.}$	4.37^{n}	4.31	4.89	3.66	17.23
C_1	+1	+1	-1	-1	0
C_2	+1	-1	0	0	0
C_3	0	0	1	-1	0
$\overline{X}_{.a.} \times C_1$	4.37	4.31	-4.89	-3.66	0.13
$\overline{X}_{.a.} \times C_2$	4.37	-4.31	0	0	0.05
$\overline{X}_{.a.} \times C_3$	0	0	4.89	-3.66	1.22

n=9 (Mean number of observations in each cell)

The first value (17.23) on the right side of Table 5 is the grand total of the cotton varieties in the study. Looking at the next three values, it should be remembered that the contrast weights must be equal to zero. The last three values are, $(\sum \bar{x}_a \times C_a)$ = L when placed in Equation 4, which is used for the sum of squares of contrast of the main effect A in two-way anova;

Here, the contrast sum due to the first contrast estimate of the main effect A is found in the form of

$$SS_{(\hat{\psi}_1)} = \frac{n(\sum \bar{X}_{.a.} C_a)^2}{\sum C_a^2} = \frac{9(0.128)^2}{4} = 0.036$$

The contrast sum generated based on the second and third contrast estimation is $KT_{\hat{\psi}_2} = 0.013$, $KT_{\hat{\psi}_3} =$ 6.746, respectively.

The sum of the squares of these three contrasts is equal to the sum of the squares between varieties (6,796) with 3 degrees of freedom in Table 3.

Step 2: Investigating the B main effect

When the year factor is examined in the data, since there are 3 years (3-1)=2 orthogonal contrasts are created and the hypotheses can be determined as follow:

Hypothesis 4: "Is the fiber fineness values of cotton varieties in 2002 the same as those in 2004?"

Hypothesis 5: "Are the fiber fineness values of cotton varieties in 2003 the same as those in 2002 and 2004?"

These coefficients and related hypotheses are polynomial coefficients that can be used to investigate whether the 3-level year factor shows a linear and quadratic trend and are given in Table 6 (Abdi et al., 2009; Howell 2016; Dubcowsky 2015, Çanga and Efe 2017; Çanga, 2018; Haans 2018). Since the year is an ordinal variable and the number of groups is 3, the polynomial coefficients are taken for the weights of the linear, quadratic forms. Three-level linear and quadratic coefficients {-1, 0, +1}and {+1, -2; +1} (Rosenthal and Rosnow 1985; Logan, 2010; Dubcowsky, 2015; Çelik and Yılmaz 2015; Çanga and Efe 2017; Haans 2018; Çanga, 2018). As mentioned here before; when the coefficients are taken into account; while it is investigated whether the yield of 2004 provides more efficiency than 2003 with the linear trend, it is discussed whether 2003 provides more efficiency than 2002 and 2004 with the quadratic trend. Table 6 shows the rows of orthogonal polynomial contrast coefficients determined as 3-1=2 since there are 3 years, and the product of these coefficients with the averages$(\bar{X}_{..b} \times C_b)$ (Rosenthal and Rosnow 1985; Logan, 2010).

Table 6. Means and contrast weights of sums of year effects

YEARS	$\overline{X}_{..b}$	LINEAR(C_4)	QUADRATIC(C_5)	$\overline{X}_{..b} \times C_4$	$\overline{X}_{..b} \times C_5$
2002	4.12[n]	-1	+1	-4.12	4.12
2003	4.7	0	-2	0	-9.4
2004	4.11	+1	+1	4.11	4.11
Σ		0	0		

n=9 (Mean number of observations in each cell)

With the value of the last two columns, ($\sum \overline{X}_{..b} C_{b.}$) = L) and placed in Equation 5, which is used for the sum of the contrast squares of the main effect B in two-way ANOVA, the sum of squares (SS) for the linear trend is found as

$$SS_{(\hat{\psi}_4)} = \frac{n(\sum \overline{X}_{..b} C_b)^2}{\sum C_b^2} = \frac{12[4.12\times(-1)+4.7\times 0+4.11\times(+1)]^2}{((-1)^2+0^2+(1)^2)} = 0.0009$$

Likewise, when calculations are made, the sum of squares (SS) for quadratic trend is found as

$$SS_{(\hat{\psi}_5)} = \frac{n(\sum \overline{X}_{..b} C_b)^2}{\sum C_b^2} = 2.7730$$

Step 3: Calculation of interaction contrasts

In two-factor studies, using the interaction effect, the researcher investigates the variation of the contrast of one main effect with the contrast of another main effect. In this case, many contrasts can be created by making many kinds of contrast estimation to break up the interaction.

In this case, since there will be a contrast estimate for varieties (4-1) and for years (3-1); For interaction, a maximum of 3x2=6 orthogonal contrast estimates can be generated as follows. The researcher can ask fewer questions if he/she wishes. So the contrast prediction line may be less than 6. Estimates for the interaction contrast, of which there are 6 in this example, are generated as follows:

1) Hypothesis 6: "Is the linear variation of the local versus the Azeri variety the same over the years?"

2) Hypothesis 7: "Is the linear variation of the varieties Maraş 92 vs. Sayar 314 the same over the years?"

3) Hypothesis 8: "Is the linear variation of Ağdaş 3 versus Ağdaş 17 cultivars the same over the years?"

4) Hypothesis 9: "Is the quadratic variation of the Azeri variety the same versus the native variety?"

5) Hypothesis 10: "Is the quadratic variation of the Maraş 92 vs. Sayar 314 cultivars the same over the years?"

6) Hypothesis 11: "Is the quadratic variation of Agdas 3 versus Agdas 17 cultivars the same over the years?"

The interaction contrast weights of these comparisons are obtained by multiplying the column effect contrasts with the Ca's in the row effect contrasts, as shown in Table 7 (Rosenthal and Rosnow 1985; Çanga, 2018).

Table 7. Creating interaction contrasts by multiplying row and column weights

		VARIETIES				
	C_{linear} / C_{cotton}	M92 (local) (hirsutum)	S314 (local) (hirsutum)	AG3 (Azerbaijani) (hirsutum)	AG17 (Azerbaijani) (hirsutum)	
YEARS		+1	+1	-1	-1	∑
2002	-1	-1	-1	+1	+1	0
2003	0	+0	0	0	0	0
2004	+1	+1	+1	-1	-1	0
∑		0	0	0	0	0

Multiply the Ca heading of Column 1 by the Ca of each row to get the entries for the first column. In this case, multiplying 1 by -1,0.1 in order gives -1,0,1. If the results of the second column are multiplied by 1 by -1,0.1, the result will be -1, 0, 1, respectively, and continue in the same way to find the values for the third and fourth columns. Six different interaction contrasts created one by one by doing this way are shown in Table 8.

Table 8. Forming interaction contrast weights by multiplying by row and column contrasts

				VARIETIES			
				M92 (local) (hirsutum)	*S314 (local) (hirsutum)*	*AG3 (Azerbaijani) (hirsutum)*	*AG 17 (Azerbaijani) (hirsutum)*
	YIL	*C_{linear}/ C_{cottom}*		+1	+1	-1	-1
LINEAR TREND	2002	1. interaction coefficients	-1	-1	-1	+1	+1
	2003	*C_6*	0	0	0	0	0
	2004		+1	+1	+1	-1	-1
		C_{linear}/ C_{pamuk}		+1	-1	0	0
	2002	2. interaction coefficients	-1	-1	+1	0	0
	2003	*C_7*	0	0	0	0	0
	2004		+1	+1	-1	0	0
		C_{linear}/ C_{cotton}		0	0	+1	-1
	2002	3. interaction coefficients	-1	0	0	-1	+1
	2003	*C_8*	0	0	0	0	0
	2004		+1	0	0	+1	-1
		$C_{quadratik}$/ C_{cotton}		+1	+1	-1	-1
	2002	4. interaction coefficients	+1	+1	+1	-1	-1
	2003	*C_9*	-2	-2	-2	+2	+2

	2004		+1	+1	+1	-1	-1
		$C_{quadratik}$/ C_{cotton}		+1	-1	0	0
QUADRATIC TREND	2002	5. interaction coefficients	+1	+1	-1	0	0
	2003	C_{10}	-2	-2	+2	0	0
	2004		+1	+1	-1	0	0
		$C_{quadratik}$/ C_{cotton}		0	0	+1	-1
	2002	6. interaction coefficients	+1	0	0	1	-1
	2003	C_{11}	-2	0	0	-2	+2
	2004		+1	0	0	1	-1

According to Hypothesis 6, {+1,+1,-1,-1} in the row and column; {+1, 0,-1} coefficients are given in accordance with the linear trend, and the reciprocal elements of the row and column cell values are multiplied and the rows of contrast coefficients resulting from the calculations in Table 8 are named C_6. Continuing in this way, other hypotheses were formed. The total value (-1.31), which is obtained by multiplying the mean values with each cell value and the C_6 values, which are the coefficients of the interaction prediction contrast in Table 8, as a scalar, is written in Equation 8 and the sum of the squares of the Ψ_6 interaction contrast is found (Rosenthal and Rosnow 1985; Çanga 2018; Haans 2018).

$$SS_{(\hat{\psi}_6)} = \frac{n(\sum_{b=1}^{B}\sum_{a=1}^{A}\overline{X}_{.ab}C_{ab})^2}{\sum C_{ab}{}^2}$$

$$= \frac{3*(4.07*(-1)+4.14*(-1)+...+4.43*(-1)+3.16*(-1))^2}{8} = \frac{3*(1.31)^2}{8} = 0.644$$

Continuing in the same way, calculating the sum of the other squares, respectively; all these values are placed in the variance analysis table. The last column in Table 9 gives the magnitude of each effect in terms of $r_{contrast}$, which is a measure of correlation. Using Equation 10, each effect is calculated in turn and the results are interpreted. Consideration is given to the research given to learn the direction of each effect. In the research, the main effects of the means in the definition and the interaction effects are investigated (Buckless and Ravenscroft 1990; Çanga 2018).

3.1. Calculation of Effect Size in terms of Correlation

The measure of effect size in terms of correlation is called r contrast. Accordingly, when the r contrast value is placed in Equation 10 for the first contrast estimation; It is in the form of an first rcontrast:

$$r_{contrast(\hat{\Psi}_1)} = \sqrt{\frac{F_{contrast}}{F_{contrast} + \text{Error df}}} = \sqrt{\frac{0.217}{0.217 + 24}} = 0.0957$$

After all these calculations, variance analysis including other contrast estimates and correlations of effect sizes was created as in Table 9 with the help of R Core Team (2021) program.

Table 9. Decomposition of interaction effects of two-factor analysis of variance with degrees of freedom

Analysis of Variance Tables						
Source	df	SS	MS	F	p	$r_{contrast}$
Varieties	3	6.796	2.266	13.390***	2.44e-05	--
$\hat{\psi}_1$: **Local vs Azerbaijan**	1	0.036	0.036	0.217	0.6454	**0.0947**
$\hat{\psi}_2$: **M92 vs S314**	1	0.013	0.013	0.079	0.7812	0.0572
$\hat{\psi}_3$: **AG3 vs AG17**	1	6.746	6.746	39.873***	1.58e-06	0.7901
Years	2	2.774	1.387	8.197**	0.00193	---
$\hat{\psi}_4$: **Lineer effect** (L)	1	0.0009	0.0009	0.0009	0.9412	0.0152
$\hat{\psi}_5$: **Quadratic effect** (**Q**)	1	2.7739	2.7739	16.389***	0.0004	0.6370
Varieties x Years	6	4.426	0.738	4.360**	0.0040	---
$\hat{\psi}_6$: $\hat{\psi}_1$ *vs* **L**	1	0.644	0.644	3.803	0.0629	0.3699
$\hat{\psi}_7$: $\hat{\psi}_2$ *vs* L	1	0.040	0.040	0.234	0.6326	0.0984
$\hat{\psi}_8$: $\hat{\psi}_3$ *vs* L	1	0.472	0.472	2.790	0.1078	0.3227
$\hat{\psi}_9$: $\hat{\psi}_1$ *vs Q*	1	0.968	0.968	0.527*	0.0249	0.4388
$\hat{\psi}_{10}$: $\hat{\psi}_2$ *vs Q*	1	0.516	0.516	3.050	0.0935	0.3358
$\hat{\psi}_{11}$: $\hat{\psi}_3$ *vs Q*	1	1.787	1.787	10.559**	0.0034	0.5528
Within (Error)	24	4.061	0.169			---
GENERAL	35	18.058				

****: P<0.001, **: P<0.01, *: P<0.05*

In the study, first the main effects and then the interaction effects were interpreted. Among the 1-degree of freedom estimates within the main effect A, the contrast estimate $\hat{\psi}_3$ showed the greatest effect ($r_{contrast}$ = *0.7901*). In other words, if Azeri varieties were selected, Ağdaş 3 gave better results than Ağdaş 17 in terms of fiber fineness. Then among the 1-degree-of-freedom estimates within the B main effect, the $\hat{\psi}_5$ contrast estimate showed the greatest effect ($r_{contrast}$ = *0.6370*). According to this result, the quadratic effect was found to be significant. Thicker fiber was obtained in 2003 because it had a larger average in 2003 (Rosenthal and Rosnow 1985; Keppel andWickens 2004; Haans, 2018). Considering the interaction effects; large value $r_{contrast}$ effects should be interpreted. $\hat{\psi}_1$ is shown with the linear effect of $\hat{\psi}_6$. Likewise, the quadratic effect of $\hat{\psi}_1$ is shown with $\hat{\psi}_9$. In this case, if Hypothesis 6 and Hypothesis 9 are remembered, the linear or quadratic change depending on the years of the Azeri variety against the Native variety was interpreted by looking at the $r_{contrast}$ values. That is, the linear and quadratic effect of the same $r_{contrast}$ value ($\hat{\psi}_1$) with $\hat{\psi}_6$ and $\hat{\psi}_9$ has been investigated. Here it is seen that the effect of contrast estimation ($r_{contrast}$ = 0.4388) is more important, ie the quadratic effect is more important. Therefore, in local varieties, since the quadratic effect is significant, the effect value of fiber fineness in 2003 is higher than the effect value in 2004 and 2002. However, since the linear effect was found to be significant in the Azeri variety, the effect values of fiber fineness in 2002 and 2004 were higher. The linear effect of $\hat{\psi}_3$ is denoted by $\hat{\psi}_8$. Likewise, the quadratic effect of $\hat{\psi}_3$ is shown with $\hat{\psi}_{11}$. In this case, if we remember Hypothesis 8 and Hypothesis 11; the linear or quadratic variation of Ağdaş 3 versus Ağdaş 17 cultivars depending on years will be interpreted by looking at their contrast values. Therefore, linear and quadratic comparison of $\hat{\psi}_8$ and $\hat{\psi}_{11}$ with the same $r_{contrast}$ ($\hat{\psi}_3$) value was made. In other words, if the Azeri variety was determined, the quadratic effect was chosen ($r_{contrast}$ = 0.5528), and the fiber fineness values of Ağdaş 3 variety in 2003 were more important in 2004 and 2002. For Ağdaş 17 the fiber fineness values of 2004 and 2002 are more important (Rosenthal and Rosnow 1985; Logan, 2010; Çelik and Yılmaz 2015; Haans, 2018).

Finally, Rosenthal and Rosnow (1991), Rosenthal et al., (1999) and Bird (2002) mentioned the advantages of analyzing data from factorial designs over typical factorial ANOVA as follows (Wiens and Nilsson 2017; Haans, 2018). First, classical ANOVA with factorial design often has large degrees of freedom (for example, 6 dfs for interaction in a 3x4 design). It is therefore not specific and therefore it can be difficult to catch any difference between the averages. Contrast analyzes are more specific in this case because in their simplest form it is done like a t-test (with 1 degree of freedom). Buckless and Ravenscroft (1990) showed that the most important aspect of contrast analysis with factorial design is the comparison of two or more mean set. Second, ANOVA is mainly used to test for significance on main effects and interactions, and these are generated as F values. However, while F values reveal nothing about the direction of effect, effect sizes can also be examined in terms of correlation with contrast analysis. The researcher who wants to examine the effect sizes should pay attention to this when determining the contrast coefficients in whichever direction he wants to compare the effect. In other words; should give the coefficients with positive signs in the direction of the effect he wants to examine. If it is desired to compare the effect in which direction, the positive value comparison coefficients should be given accordingly (Wiens and Nilsson 2017; Haans, 2018). Third, in ANOVA, the mean model needs to be examined to understand non-standard effect sizes (i.e. mean differences), the direction and magnitude of the effect. Contrast analysis is more informative in this sense because the contrast number captures the true mean difference (ie, the non-standardized effect size) for the contrast of interest (Rosenthal and Rosnow 1996; Abelson and Prentice 1997; Rosenthal et al., 1999; Wiens and Nilsson 2017; Haans, 2018).

In this research, while the detailed solution and codes of contrast analysis and its construction in the R program are given; Haans (2018) explained in his research how it is done using test or contrast matrix L and transformation matrix M. SPSS analysis was used in the research using the LMATRIX and MMATRIX subcommands of the GLM procedure. The focus of the Haans (2018) article is predefined hypotheses regarding the differences between groups or cell tools versus empirical data obtained through psychological experimentation. As in this study, contrast analysis instead of complex interactions obtained with traditional ANOVA (Bek et al., 1988; Efe et al., 2000); with specific questions formed by hypotheses, the researcher can be relieved of these burdens. This article will therefore be able to make a modest contribution to making the technique more accessible to use. As seen in this study, the goal is to test hypotheses that are not captured by a typical ANOVA and to utilize the flexibility of contrast analysis.

4. Conclusions and Recommendations

As a result, contrast analysis carries the weights of one or more means and combines them into one or two sets and compares the groups of means that it weights by giving the appropriate coefficients. In this research, how to compare and interpret different means with contrast analysis is shown in practice. In the study, if Azeri varieties with A main effect were selected, Ağdaş 3 gave better results than Ağdaş 17 in terms of fiber fineness. In the B main effect, the quadratic effect was found to be significant, fiber fineness; Because it had a larger average in 2003, that is, thicker fiber was obtained in 2003. According to the interaction effect, the fiber fineness values in 2003 were higher than the effect in 2004 and 2002, since the quadratic effect was significant in local varieties. However, since the linear effect was found to be significant in the Azeri variety, the effect was greater in 2002 and 2004. In the light of all these results, It is expected that this gap in the literature will be filled with this original study, which contains detailed information on the use of contrast, which is little known in our country but is quite common in foreign literature.

Using planned comparison, it is explained how researchers can test their specific questions for their mean group through contrasts. It is expected that this gap in the literature will be filled with this original study, which contains detailed information on the use of contrast, which is little known in our country but is quite common in foreign literature. At the same time, it is aimed to find more rational results by increasing the field of use of this analysis, thanks to its advantageous use compared to post-hoc comparisons, known as unplanned comparisons. For this reason, it is thought that it will be a very useful resource for researchers who want to analyze the mean differences using contrast with direct guidance, with its use in appropriate data sets in different research areas.

Acknowledgements

This study is summarized from the PhD thesis.

Authors' Contributions

All authors contributed equally to the study.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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