Debrecen University, Centre of Agricultural Sciences, Faculty of Agronomy

Interactions of soil and environment

Thesis

Supervisor

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Introduction

In our days due to the improvement of statistical methods and the spreading of high-powered computers the use of such mathematical-statistical methods has become possible which can be applied by scientists in every phase of the evaluation of soil and environment interactions (e.g.: planning-, setting- and evaluation of experiments). Most of the methods have been known and used for a long time in other fields of science. The positive experiences of the previous experiments have given reason for the use of these methods in agricultural experiments and the examination of application conditions in agricultural researches.

Agricultural researches are based on experimental data and cultivation observations. In the previous decades the biometrical computer processing of experimental data was solved to a certain extent by national universities and research institutions. Solutions were mainly restricted to the application of simple statistical methods used in the evaluation of stock- and agrotechnical field experiments.

Carrying out an experiment is getting more and more expensive and the superfluous treatment-combinations result in further unnecessary expenses. The up-to-date experiment-planning methods can help to harmonise the accuracy of effect-prediction with economic efficiency.

The processing of measured experimental data with the help of recent biometrical methods can bring useful results and be carried out only after having taken into consideration the conditions of applicability.

Leaving out of consideration the characteristics of agricultural researches and the conditions of applicability can result in false conclusions. Consequently, research findings are often inaccurate and can be misleading, so the pieces of information behind the gained data can be distorted or in an extreme case can be lost. As a result the high-cost experiments do not give such results which could be usefully applied in practice.

During the writing of the given thesis I concentrated on the following objectives:

1. To introduce a recent method which can be used in experiment-planning.
2. To define the minimum observation number in maize and autumn wheat cultures necessary for a prediction, which is accurate to a certain extent.
3. To take into consideration the characteristic features of field experiments with the help of fault-inheritance conformity during the planning process.
4. To introduce experimental and mathematical methods in order to separate soil-heterogeneity and the individual variability of the plant in the circumstances of field cultivation.

5. To examine the conditions of adaptability of variance-analyses and mean value comparative tests in long-term infield-experiments.
6. The introduction of alternative methods if the applicability conditions of parameter tests cannot be fulfilled.
7. The application of variance-analysis in multifactorial long-term experiments and the evaluation of the conclusions drawn by experts.
8. To give directions in the application of the most important multiple comparatives tests (simultaneous decisions).
9. To demonstrate the quantitative factors and interactions in accordance with the features of agricultural experiments.

2. Definition of the number of observations used in the experiment

The number of observations used in the experiment depends on the characteristic features of the examined phenomenon. Two important things must be known which are: the distribution and the theoretical deviation of the phenomenon. These two factors can be estimated on the basis of the characteristics of the sample, which was taken in order to get to know the phenomenon. In agricultural and tilling researches a certain type of distribution –most often normal distribution- is chosen often without examinations, because most of the statistical tests are made for this type of distribution. These tests are called parameter-tests.

The question is the following: how many individual plants should be set on a parcel in what repetition in order to get the accuracy we intend to.

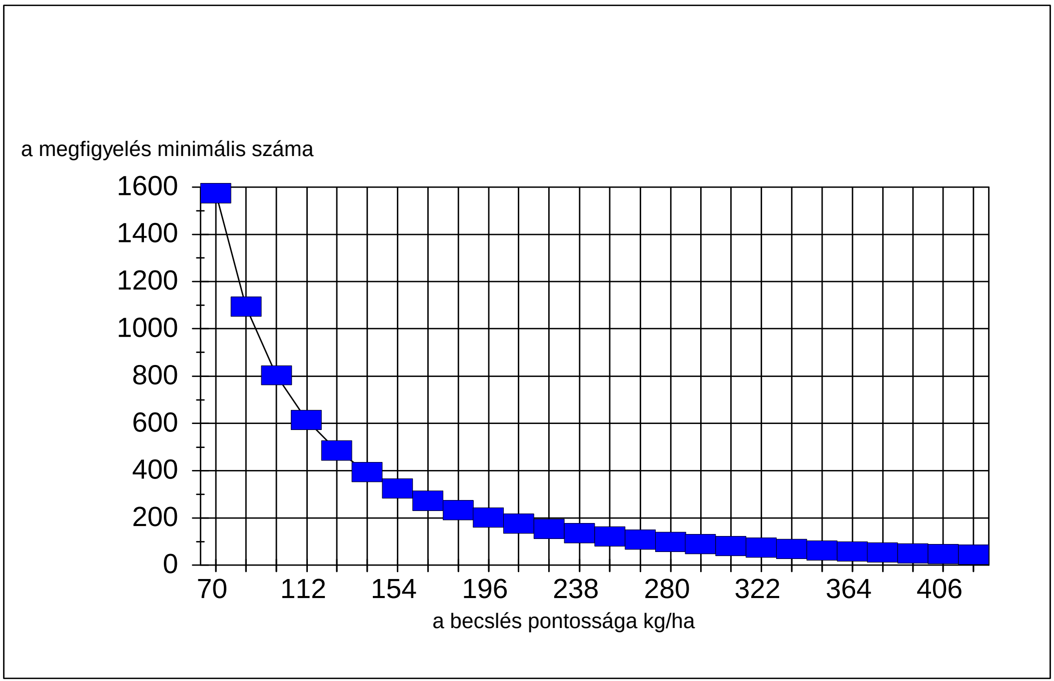
$$n \cong \frac{t_{p_{\%}}^2 \times s^2}{h^2}$$

h = estimation fault (e.g.:±kg)
s = deviation
tp% = the critical value of the t-test on the given probability level besides a certain
degree of freedom.

The given formula can only be applied in the case of a multitude in normal distribution for the estimation of accuracy of the mean value. In the following parts by using the maize-experiment of Dr. János Nagy and the above mentioned formula I am going to demonstrate how many individual plants are necessary to accurately estimate the average yield. In the experiment Pioneer 3732 was used as a test-plant. The weight of the raw maize-cobs was measured in the case of 658 plants cultivated on 100 square meters. Out of these measurements I am going to use the deviation and the variance of cob-weight.

In the measurements the deviation of individual production was ±2.024 dkg/maize-cob, consequently the variance is 4.097.Besides a 95% interval confidence and the intended accuracy Figure 1. shows the minimum number of samples. Following the tradition the results are given in kg/ha units in Figure 1.

Figure 1.*The minimum number of observations necessary for the estimation of mean-value with 95% accuracy in the case of maize.*



According to the figure the minimum of 110 individual plants are necessary for the estimation of the average yield of the Pioneer 3732 hybrid besides a ±250 kg/ha or 95% accuracy. This value is in accordance with the minimum number of samples (100) in the cultivation of hoed plants suggested by scientific literature.

The situation in the case of autumn wheat is a bit particular as the authors define its deviation in proportion to the average. This means that the increase of wheat-grain results in the increase of deviation. As in my previous work I came to a different conclusion, I paid special attention to the above-mentioned result. If we suppose an autumn wheat yield of 6.5 t/ha then ±4% estimation accuracy is the equivalent of ± 260kg/ha accuracy. Besides 95% estimation accuracy the minimum number of samples is 500.

In my 1994 dissertation I examined the ten-year-long data list of a 46m2 gross parcel, where 200 plants were harvested, and irrespective of the type of treatment the deviation was 720 kg/ha. This wide deviation cannot be explained on the basis of the deviation of individual production. If the deviation of individual production is 20g, in the case of 200 plants the mean value of deviation per hectare should be 92kg. If the deviation of individual production were 40g then the mean value of deviation would be 184kg/ha. This huge difference cannot be explained by the heterogeneity of the soil. So what could be the cause of the 720kg/ha deviation?

3. The conformity of fault-inheritance in field experiments

Let's create the theoretical model of grain-yield. Let's go in chronological order from sowing to the formation of grain, where "x" means the amount of sown seeds and "y" stands for the yield on a unit of land. The model is:

Y=f(x)

f(x)=xPsprouting(1+Pcob)G

where x = the amount of seeds sown on a unit
Psprouting = expected sprouting (value in use %)
Pcob = expected inclination for double-cob (%)
G = expected weight of cob

Let's suppose that we manage to pass out completely the "x" to each parcel. But the others are stochastic variants, so we have to know the deviation. With full knowledge of the deviation we have to calculate the fault-inheritance of the above simple mathematical model. If the seed-grain is clean, the value in use is synonymous with the percentage of germination. It's a double option even: the seeds either spring or not. For discrete variants the double option event follows a binomial distribution. The probability of "n" from a successful "k" event:

$$\binom{n}{k} p^k (1-p)^{n-k}$$

Expected value:

$$\mu = np$$

Deviation:

$$\sigma = \sqrt{p(1-p)}$$

if pn>*5 és* n*(1*-p*)>5*

If the probability of having double-cobs is *p* then in the case of *n* germinated plants the number of expected cobs is:

2*np*+*n*(1-*p*)

The first side represents the expected number of double-cob-plants while the second side is the number of single-cob-plants. Having completed the operations we get to the given s
solution: *np+n.*

The deviation of the equivalence depends only on the *np* side, which is the deviation of the expected value. To make the operations simpler I have taken the probability of the unfertile and triple-cob-plants zero, consequently the binomial distribution can be applied for the modelling of "double-cobbedness".

I estimate the distribution of cob-weight to be normal distribution so the expected value can be calculated on the basis of arithmetical average. When the weight and deviation of cobs is measured, it also includes the heterogeneity of the soil.

If we further analyse the (1.) formula we get to the following (2.) equivalence:

$F(z) = GxP_{sprouting} + GxP_{sprouting}P_{cob}$

The total differential calculus of the given function should be done to calculate the existing deviation of the parcels in grain-yield.

$$S_z = \sqrt{(\partial f / \partial P_{kel})^2 S^2_{\overline{Pkel}} + (\partial f / \partial P_{cső})^2 S^2_{\overline{Pcső}} + (\partial f / \partial G)^2 S^2_{\overline{G}}}$$

The above written equivalence, which has the following sub-steps, should be solved.

$$(\partial f / \partial P_{kel})^2 S^2_{\overline{Pkel}} = (Gx + GxP_{cső})^2 S^2_{\overline{Pkel}} \qquad \textit{(3.)}$$

$$(\partial f / \partial P_{cső})^2 S^2_{\overline{Pcső}} = (GxP_{kel})^2 S^2_{\overline{Pcső}} \qquad \textit{(4.)}$$

$$(\partial f / \partial G)^2 S_G^2 = \left(xP_{kel} + xP_{cső} P_{kel}\right)^2 S_G^2 \qquad (5.)$$

Having unified (3.), (4.) and (5.) formulas and extracted the roots the deviation is given. Let's calculate the above mentioned example. The number of sawn seeds (*n*) is 100, the value of use is 95%, the inclination for double-cobs is 15%, furthermore the expected cob-weight is 130g while the deviation is 40g. Having solved equivalence (3.) we get 106 164, the result of (4.) is 194 466 while (5.) gives a 190 969 value. After the addition and the extraction of roots the deviation is 701g. Let's choose the original plant density of 70.000 and calculate the expected yield and the deviation per hectare. The expected yield is 9 100 kg/ha, while the deviation is 491 kg/ha. This value approximates the existing measured value, but it is still a lot lower than that. According to this the number of yielding plants is more different in the repetitions than it could be expected on the basis of the deviation originating from the value of use. I solved the above mentioned formula on the basis of such a hypothetical parcel where the average plant density is 200 and in the repetitions the difference in the number of fertile plants is, on the average, 15 plants. I did not modify the other parameters. The deviation was 712 kg/ha, which is surprisingly similar to the 720 kg/ha deviation of my previous paper.

The next task is to define the number of repetitions.

n= 2 (z

Let's take into consideration an experiment in which the size of the parcels was 46 m2. Using maize as a test plant the deviation was 719 kg/ha. Let's examine the number of necessary observations in the case of a 5% double-sided test, if we want to point out a 500 kg/ha existing difference with the probability of 90%.

z0.05=1.96 (double-sided test)   z0.01=1.282 (single-sided test)

Having the operations carried out the minimal rounded number of necessary observations is 14. Consequently, the observations of 14-14 parcels are needed if we want to define the500 kg/ha real effect of two doses of fertiliser with 5%-test, beside the probability of 90%, if the deviation is 719 kg/ha. In the case of autumn wheat the deviation was 473 kg/ha. Among the same circumstances the minimal rounded number of necessary observations was 6.

In the case of maize the minimal number of necessary observations seems to be significantly higher, but here we not only have to consider the real repetitions but the inner repetitions as well, and then with a 1-, 2- or 3-factor experiment 14 as the minimal observation number can easily be explained. We could have counted the other way around, for example what the probability level of 500 kg/ha real difference is with 4 or 6 observations.

4. The differentiation of soil heterogeneity and the changeability of individual production in maize experiments

The differentiation of soil heterogeneity and the changeability of individual production is a very demanding task. A perfectly homogeneous soil would be necessary to demonstrate the fluctuation of individual production without taking into consideration other interactions.

On the other hand a homogeneous plant-stock is necessary to detect the heterogeneity of the soil, or exactly the same plant should be planted on each parcel. Non of these two conditions could be granted in practice, so a certain kind of approximative method is necessary, which can be carried out in practice with a sensible compromise. What would happen if several cultivating sites were unified and the highest possible number of plants were planted in the area? If the average of several plants were taken it would decrease the deviation, so we could get a more homogeneous plant-stock, as a result the interaction between soil heterogeneity and the diversity of plant production could also be reduced, consequently we could deal with a seemingly homogeneous plant-stock. How could a homogeneous soil be ensured?

For plants sown in the same “soil spot” this cultivating area is completely homogenous. Within one “soil spot”, deviation only depends on the diversity of the particular plant. By choosing maize as a test-plant it seemed like a reasonable compromise to combine the cultivating sites of three plants and to sow three seeds in bunch. The experiment was set up in Pallag, the hybrids used were Furio and Stira. To find the answer to the problem, I have chosen the method of variance component division. Table 1. shows the statistical description of maize sown in bunch. The deviation here is 46g/plant. This deviation comes from the total variance; this is what has to be separated into plant and location effects. To clarify the effects, mathematical statistics has to be applied. The result of separating variance components can be seen in Table 1.

Table 1. *Descriptive statistics of the Furio hybrid’s cob weight (g), sown in bunch*

Expected value	*238.717947*
Standard error	*3.66497968*
Median	*246.5*
Modus	*260*
Distribution	*45.7755808*

Table 2. *The division of variance components*

Source	*SQ*	*FG*	*MQ*	*Variance components*
Total	*324787.5897*	*155*	*2095.403805*	*45.77*
Places	*120680.2564*	*51*	*2366.279537*	*Error(MQ)+ism*S^2_{Places}*
Error(plant)	*204107.3333*	*104*	*1962.570513*	*44.30 (S^2_{Errora})*

The heterogeneity of the soil by using the correlation from the table above:

$$\sqrt{\frac{2366-1963}{3}} = \pm 11{,}59\, g$$

According to this the individual diversity of the plant is 44,3g/plant, the soil heterogeneity is 11,6g/soilspot.

5. The conditions and possibilities of applying variance analysis and mean value comparing tests.

5.1 Examining the condition of independence

When examining the starting-point of conditions this is the most important one. The condition of independence can be ensured by randomising in an experiment, where the experimental area is randomly divided into the number of treatments, thus giving equal opportunity to all treatments. We can only then estimate the real error of the experiment. If this is neglected, systematic errors could occur which cannot be avoided and these deform the result of the experiment. In a repeated measures model from the condition of total independence we have to make allowances. The model of repeated measures is significant in agriculture because the split-plot models belong here. In this model we apply the repeated measures on the same examined unit, which can correlate with each other. Thus, we have make allowances during the F-test, which has several forms. In this case we substitute the condition of total independence with the condition of compound symmetry if the trial factor's grade of independence is more than one when calculating the error. So when we use the F-test, the breaking-down can be done with orthogonal polynomes or if only two levels of experimental factors exists then we do not have to expect the condition of compound symmetry. In all other cases the condition has to be tested. To test this we can use a sphericity-test. During the application of this test we have to take into account that in case of a few observations the test is not as effective. Such a case can occur, when the test is significant but its effect on the variance analysis can be neglected. The test can be very sensitive to outstanding data. When can doubt the existence of compound symmetry?

- if the sphericity-test is significant
- on the basis of previous information, if we are aware that one experimental level covers the other

In case the symmetry is missing, we have to reduce the experimental factors'grade of independence and the F-probe of the traditional variance analysis has to be completed with the result of Greenhouse-Geisser and Huynh-Feldt probe and we have to make decisions accordingly. In Table 3.the symmetry test of a plant density, hybrid, and fertilisation as well the correlation of these can be seen.

Table 3. *The result of testing compound symmetry*

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SUMS OF SQUARES AND CORRELATION MATRIX OF THE
ORTHOGONAL COMPONENTS POOLED FOR ERROR  2, D.F.=18 (plant density)
          5.37573        1.000
         10.29895       -0.302   1.000
          3.84187       -0.007  -0.059   1.000
SPHERICITY  TEST  APPLIED  TO  ORTHOGONAL  COMPONENTS  -  TAIL  PROBABILITY
0.8924

SUMS OF SQUARES AND CORRELATION MATRIX OF THE
ORTHOGONAL COMPONENTS POOLED FOR ERROR  3, D.F.=12 (hybrid)
          4.38585        1.000
         13.78806       -0.105   1.000

SPHERICITY  TEST  APPLIED  TO  ORTHOGONAL  COMPONENTS  -  TAIL  PROBABILITY
0.4463

SUMS OF SQUARES AND CORRELATION MATRIX OF THE
ORTHOGONAL COMPONENTS POOLED FOR ERROR  4, D.F.=36 (plant density x hybrid)
          3.50025        1.000
          7.26255        0.320   1.000
          1.89831        0.719  -0.058   1.000
          3.17213       -0.426  -0.644   0.091   1.000
          5.17994       -0.735  -0.464  -0.534   0.198   1.000
          4.61616       -0.284  -0.041  -0.022   0.525   0.181   1.000
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SPHERICITY TEST APPLIED TO ORTHOGONAL COMPONENTS - TAIL PROBABILITY 0.7852

SUMS OF SQUARES AND CORRELATION MATRIX OF THE
ORTHOGONAL COMPONENTS POOLED FOR ERROR 5, D.F.=12 (fertilizer)

23.42711	1.000	
7.68182	0.164	1.000

SPHERICITY TEST APPLIED TO ORTHOGONAL COMPONENTS - TAIL PROBABILITY 0.4457

SUMS OF SQUARES AND CORRELATION MATRIX OF THE
ORTHOGONAL COMPONENTS POOLED FOR ERROR 6, D.F.=36 (plant density x fertilizer)

2.45170	1.000					
5.18406	0.529	1.000				
4.59642	0.425	0.857	1.000			
2.38898	-0.352	0.226	-0.029	1.000		
8.90836	-0.126	0.539	0.548	0.003	1.000	
4.75764	-0.397	-0.492	-0.289	-0.662	0.308	1.000

SPHERICITY TEST APPLIED TO ORTHOGONAL COMPONENTS - TAIL PROBABILITY 0.0000

SUMS OF SQUARES AND CORRELATION MATRIX OF THE
ORTHOGONAL COMPONENTS POOLED FOR ERROR 7, D.F.=24 (hybrid x fertilizer)

1.01520	1.000			
1.17612	0.189	1.000		
3.09007	-0.469	0.733	1.000	
3.71478	0.023	-0.135	-0.370	1.000

SPHERICITY TEST APPLIED TO ORTHOGONAL COMPONENTS - TAIL PROBABILITY 0.0241

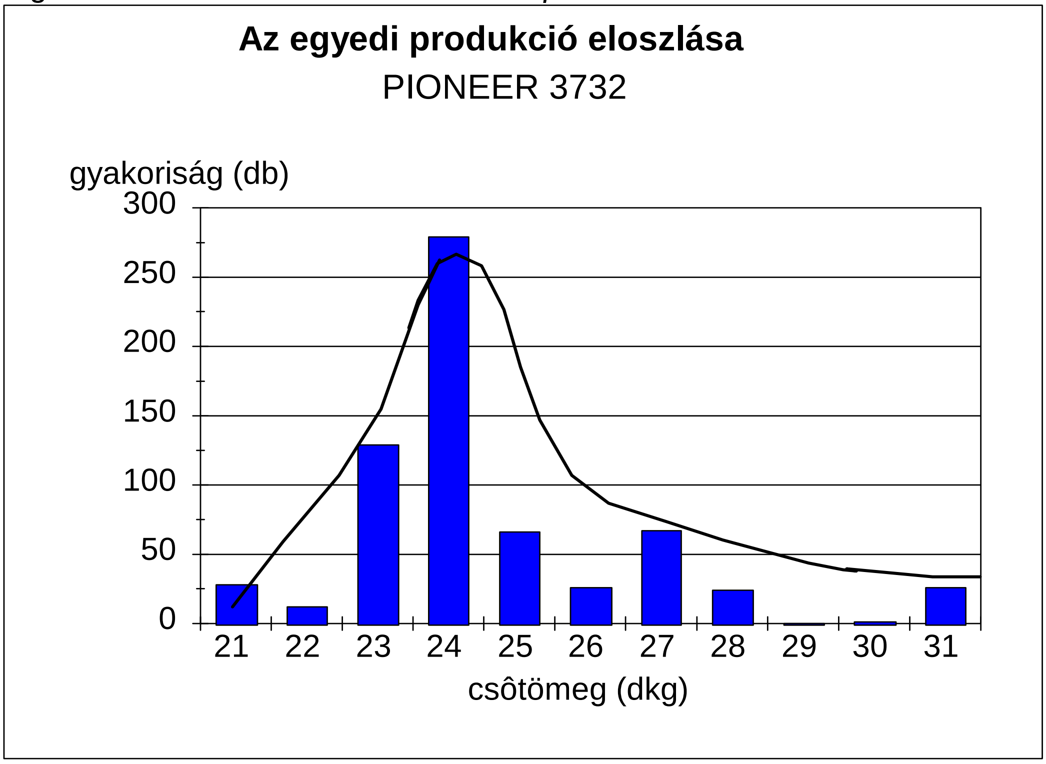
5.2 Examining the condition of normal distribution

The second condition of applying variance analysis or linear mathematical models is that the examined multitude should have normal distribution. During the measuring phase many hybrids were examined but I am only going to introduce one. The actual plant density varied between 65 and 75 thousand/ha. I will illustrate the distribution of individual production on Pioneer 3732 hybrids, which can be seen in figure 2.

With the knowledge of the facts, shown above, we can state that among normal cultivating conditions our agricultural plants, in this case maize, the individual production does not follow a normal distribution.

If our data do not have normal distribution, in many cases they can be transformed to make them normal. The most frequently used such transformation is the logarithm-, trigonometric function- and root transformation. This way can make our data suitable for evaluation.

Figure 2. *The distribution of individual production of maize*



5.3 Examining the condition identical distribution

The next task is to examine whether the distribution of treatment groups is identical or they differ for some reasons. To find out if the groups are identical I have used the Levene test. In the experiment the smallest examined unit was a $30m^2$ parcel, so the average distribution of $30m^2$ parcels has to be calculated. It is simple in the case of fertilisation, because here the levels of treatments change. In the case plant density and tillage these parcels were grouped and I have calculated the average distribution. I wanted to find out whether in one of the treatments there is a group of a smaller or bigger distribution. Is there a certain tillage treatment that always cause smaller or greater distribution in the formation of yield averages? The increased fertiliser dosage increases or decreases the distribution of yield averages? Does greater yield mean smaller or greater distribution? To answer this question, regression analysis is a suitable tool. On the basis of the performed regression analysis the following statements can be made:

There is no connection in the case of tillage, there is not such tillage which would consistently cause a smaller or greater distribution in the formation yield averages. The proven distribution differences are accidental or due to the characteristics of the experiment.

The increased fertiliser doses do not increase and do not decrease the deviation of yield averages. No correlation can be found.

Between the degree of yield averages and deviation no correlation can be found. A greater yield means the same degree of deviation. We have to emphasise that this does not measured in percentages, e.g. 20% deviation but rather measured in kg/ha. In other words, with the increase in yield the percentage of deviation (compared to the yield average) decreased. **Presumably, the increase in yield averages is an**

additive phenomenon and not multiplicative. If it was multiplicative, then with the increase in individual production the deviation of the yield would also have to increase.

In my previous doctoral thesis, I have done the above mentioned experiments with winter wheat as well and on the basis of regression analysis the same statements can be made as in the case of maize.

6. The results of the multiple comparing tests of mean values

To introduce the problems of simultaneous decisions I have chosen a binomial example. As a result of many years of experimenting, I have found that it is not just advisable but maybe even essential to graphically describe the data before starting regression analysis and before testing the difference of treatment averages. Much useful information can be obtained this way. The deviation of treatments and outstanding data or any inaccuracy can be visually determined.

The best alternative to determine the equality of variances (deviation squares) in a binomial experiment is to use a Levene test. The null hypothesis of the probe is that the deviations are the same. This test can be carried out before all experiments where the equality of variances is a must. The statistics of the probe is shown in table 4.

Table 4. *Testing the equality of variances within a group*

LEVENE'S TEST FOR EQUALITY OF VARIANCES

SOURCE	*DF*	*F VALUE*	*PROBABILITY*
hybrid	*2, 27*	*0.55*	*0.5837*
fertilizer	*2, 27*	*0.12*	*0.8838*
INTERACTION	*4, 27*	*2.41*	*0.0735*

What would have happened if the null hypothesis had not been fulfilled? The so-called Welch or Brown-Forsythe probe would have to be applied. So far I have not met the agricultural use of Welch and Brown-Forsythe probe so on the basis of many years of research I would like to use this opportunity to give some advise on how to apply them. If the deviation squares (variance) within the group are not similar, then we can safely use either test. The best solution is if we use both to compare the results.

Fortunately, these two tests gave the same results, but if there were differences the evaluation would have had to be continued. In an extreme case the Welch-probe can show significant differences between the treatment averages, while the Brown-Forsythe probe would not. What is the reason for this? This happens if the variance of the groups significantly differ. Then the separate variance tests react with a decrease in the grade of independence thus degrading the result of the test. The great degree of difference in the variances is usually caused by outstanding values within the groups. The disturbing effect of outstanding values can be avoided several ways. One effective tool is the trimmed test when 15% of the greatest and smallest value is trimmed from all groups. The degree of trimming can be changed at will. In the Brown-Forsythe-probe, applied after trimming, the degree of independence will increase and the result of the test will improve.

Table 5. *The results of the Welch and Brown-Forsythe probe*

ANALYSIS OF VARIANCE; VARIANCES ARE NOT ASSUMED TO BE EQUAL

SOURCE	DF	F VALUE	PROBABILITY
WELCH	8, 11	4.48	0.0124
BROWN-FORSYTHE			
hibryd	2, 17	8.98	0.0022
fertlizer	2, 17	14.33	0.0002
INTERACTION	4, 17	1.01	0.4315

From the multiple comparing tests, I will first show the most widely used one, which was introduced by Sceffé in 1953. This method is equivalent with the deviation analysis and suitable for examining all contrasts of the parameters. In this case the variance analysis has one variable, presuming a fixed effect model (Model 1). All differences are contrasts as well and in the case of null hypothesis, all contrasts are zero. The simultaneous evaluations of contrasts are shown in table 6. Since the number of contrasts is infinite, the expansion done by Scheffé means an important generalisation. The levels of significance can be seen in the “Significancia at” table, where the values are shown with different symbols. In tillage experiments a 5% or even lower level of significance can be considered, if we do not chose a greater one. The level of significance can be chosen in all software.

By examining all three hybrids at the sane time, it can be stated that in this year the effect of fertilisation on the yield could not be proved. Except in the case of Volga Sc, but the fertilised treatments only show a significant difference if compared to the unfertilised Dekalb or Pannónia hybrids.

Table 6.*The result of Scheffe-method*

SIGNIFICANCE AT

1% LEVEL	**
5% LEVEL	*
10% LEVEL	-
>10% LEVEL	
FOR 36 TESTS	

GROUP NO.	LABEL	MEAN	SAMPLE SIZE	Dekalb control	N_120	N_240	Pannonia control	N_120	N_240	Volga control	N_120	N_240
	Dekalb											
1	control	9.75	4								*	*
2	N_120	10.81	4									
3	N_240	11.12	4									
	Pannonia											
4	control	9.92	4								*	*

5	*N_120*	*11.02*	*4*				
6	N_240	11.32	4				
Volga							
7	*control*	*10.30*	*4*				-
8	*N_120*	*12.86*	*4*	*	*	-	
9	*N_240*	*12.70*	*4*	*	*		

The following test evaluates the often-occurring problem when the comparison treatment combinations are suited to a pre-selected control group.

GROUP NO.	*LABEL*	*MEAN*	*SAMPLE SIZE*	
1	*Dekalb control*	*9.75*	*4*	*CONTROL GROUP*
2	*Dekalb N_120*	*10.81*	*4*	
3	*Dekalb N_240*	*11.12*	*4*	
4	*Pannonia control*	*9.92*	*4*	
5	*Pannonia N_120*	*11.02*	*4*	
6	*Pannonia N_240*	*11.32*	*4*	
7	*Volga control*	*10.30*	*4*	
8	*Volga N_120*	*12.86*	*4*	**
9	*Volga N_240*	*12.70*	*4*	**

NOMENCLATURE
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*1% SIGNIFICANCE ***
*5% SIGNIFICANCE **
>5% SIGNIFICANCE

Here the number of comparisons is significantly less, in this case 8. In the case of 9 independent (k) groups (k-1) comparisons can be made. For this problem Dunnett has made statistics in 1955. If we compare the other groups with only the control, then this method has the greatest power. In the example the first group, the unfertilised Dekalb hybrid, was chosen as control.

The result of the test, table 7, is very much similar to the result of the Scheffé method. The yield of the fertilised Volga Sc, differed from the control group at 1% level of significance. According to this at a fixed 5% level, even the lower average values can be shown with this method.

As a third method, I would like to introduce a somewhat different evaluation, Tukey-test 8., which is graphically similar to the Scheffé-test, but the level of acceptance differs from it. If the number of number of elements in a group is similar, than the power of the test is greater than in the case of the Scheffé test. But contrary to the Scheffé test, where all the contrasts of the parameters are evaluated at the same time, here the difference of the expected values is possible.

Table 8. *The result of the Tukey-test*

SIGNIFICANCE AT

*1% LEVEL ***
*5% LEVEL **
10% LEVEL -
>10% LEVEL
FOR 36 TESTS

GROUP NO.	LABEL	MEAN	SAMPLE SIZE	Dekalb control	N_120	N_240	Pannonia control	N_120	N_240	Volga control	N_120	N_240
	Dekalb											
1	control	9.75	4								**	**
2	N_120	10.81	4								-	-
3	N_240	11.12	4									
	Pannonia											
4	control	9.92	4								**	**
5	N_120	11.02	4									
6	N_240	11.32	4									
	Volga											
7	control	10.30	4								**	*
8	N_120	12.86	4	**	-		**			**		
9	N_240	12.70	4	**	-		**			*		

Is there a difference between the results of two tests? In essence there is any, because only the level of acceptance is modified. Since the power of the probe is greater, the effect of treatments can be shown at lower levels of significance. In the case of Volga Sc the effects of fertilisation can be shown in a more refined way. The effects shown with the previous two tests can be complimented with the fact that there is a statistically proved difference between the fertilised and unfertilised yield averages of Volga Sc.

Finally, I would like to show a multiple comparing test based on research experiences (Student-Newman-Keuls, table 9). This is similar to the Tukey-test, but here the primary aim is to form homogenous groups. The straight lines show, that the level of treatments do not differ. Thus, the tests have to be carried out again and in the case of significance some of the extreme values have to be left out. Line A. shows that the Volga 120 and 240 kg N does not belong to the group and significantly differs from it. Whether the two fertiliser dosages are similar or they differ cannot be pointed out because the test only shows if these belong to the same group. To answer this question, a new test has to be carried out which is shown by line C. According to this the two fertiliser dosages do not differ. The A. and C. line thus does not show the same thing although graphically this is implied. As I change the aspect of the method, I ask different questions and the applied method and answer are formed accordingly.

Table 9. The result of the STUDENT-NEWMAN-KEULS multiple comparison test

```
GROUP               SAMPLE
 NO. LABEL       MEAN  SIZE
   1 Dekalb       9.75    4    |
     kontroll                  |
   4 Pannonia     9.92    4    |
     kontroll                  |
   7 Volga       10.30    4    |
     kontroll                  |
   2 Dekalb      10.81    4    |
     N_120                     |
   5 Pannonia    11.02    4    |   |
     N_120                     |   |
   3 Dekalb      11.12    4    |   |
     N_240                     |   |
   6 Pannonia    11.32    4    |   |
     N_240                     |   |
   9 Volga       12.70    4        |   |
     N_240                         |   |
   8 Volga       12.86    4            |
     N_120                             |
                              A.  B.  C.
```

7. Pointing out correlation with the breaking down of variance components

The mathematical method of breaking down variance components always gives the values compared to the main average, so the total effects of treatment levels is always zero. Let's suppose that we are doing a binomial experiment, where we are evaluating the effects of irrigation and fertilisation on the formation of yield averages.

The concrete example comes from the maize mono-culture experiment, in 1990. The level of α-error is taken as 5% and I have only shown the significant effects. The thick numbers are the values given by the program, the rest has to calculated.

Table 10. *The computer results obtained after breaking down the variance components (kg/ha)*

Main effects					
I1=	***-3759***			*M1=*	***-2341***
I2=	***1460***			*M2=*	***-554***
I3=	*2299*			*M3=*	***779***
				M4=	***1313***
				M5=	*803*
Correlation					
I1M1=	***1674***	*I2M1=*	***-929***	*I3M1=*	*-745*
I1M2=	***1080***	*I2M2=*	***n.s***	*I3M2=*	*-1080*
I1M3=	***-495***	*I2M3=*	***n.s.***	*I3M3=*	*495*
I1M4=	***-772***	*I2M4=*	***n.s.***	*I3M4=*	*772*
I1M5=	*-1487*	*I2M5=*	*929*	*I3M5=*	*558*

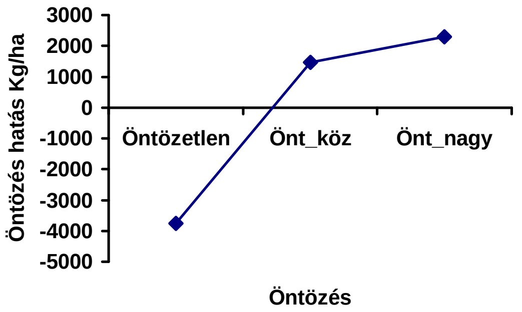
The yield of a specific plot can be calculated with the following model and the help of table 10:

$$Yield_{ijk} = 7973 + I_i + M_j + I_iM_j + \sigma e_i$$

The model gives a numerically correct result. What does non-irrigated treatment mean? According to the table –3759n kg/ha so the main average of the experiment (7973 kg/ha) almost decreases by 4 t/ha. So if we did not apply irrigation in this year, then we decreased the average yield by 4 t/ha. The same applies to fertilisation. What is he correlation in this case? If there is no correlation then irrigation will result in the same degree of yield increase or decrease and it does not matter what fertiliser dosages were applied.
Table 10. is very consistent from this aspect. It is easy to decide from the table, that if the results are the same then the correlation is positive if not then it is negative. If the experiment is more than binomial then evaluating the correlation is almost impossible, so in my opinion it is not worth examining more than two factors. Since the reaction of a biological species is examined, the formation of the model will not be linear. It is naive thinking that one factor will increase yield by x and the other by y thus, applying both we will get x+y yield increase. The evaluation correlation is suited to a linear mathematical model. If we were to examine the correlation from different, let's say biological aspect, then an entirely new model would have to be created. And from the new model, new theoretical categories would have to be made.

Let's go back to the original table and observe the first column in the case of correlation. Is there really irrigation x fertilisation correlation in a non-irrigated treatment? Logically and professionally speaking, yes. The correlation of irrigation and fertilisation has to be generalised and has to be extended to the correlation of water and nutrient-supply. The main effects and correlation is worth depicting.

Figure 3. The main effect of irrigation   *Figure 4. The main effect of fertilisation*



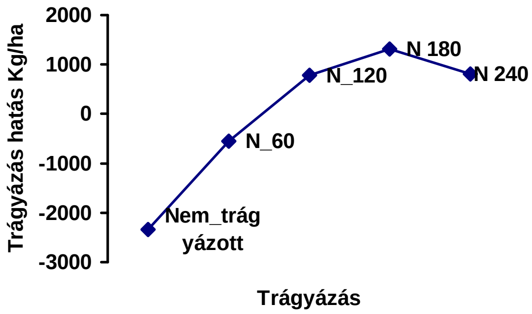
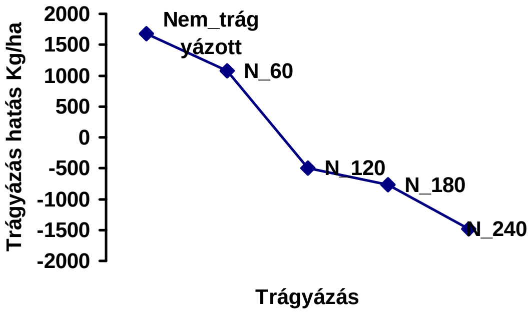
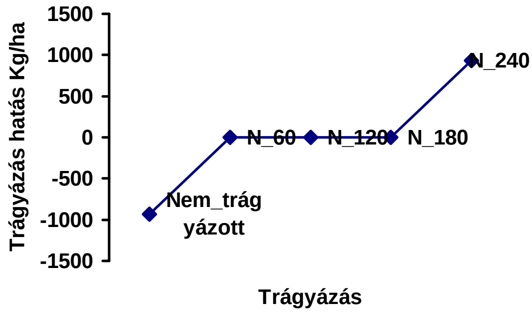


Table 3. shows the effect of irrigation, with applied average nutrient supply. It can be seen that irrigation had a great effect in this year, it increased yield by more than 5t. In fact increasing the amount of water we could achieve an extra 800kg/ha increase. The year of 1990 was droughty the amount of precipitation was not sufficient for maize so only a small yield (3.5t/ha) was achieved.
The great heat was sufficient for maize.
In figure 4. the effect of fertilisation can be seen. 60 kg/ha nitrogen increased yield by almost 2t/ha. Increasing up to 180 kg/ha the nitrogen dosage increases yield but at a slowing rate.

Let’s examine what happens if irrigation and fertilisation is simultaneously increased or decreased. From table 10. We can see that the irrigation x fertilisation correlation is positive. If the two treatments are increased at the same time, yield will increase more than expected.

Figure 5. The correlation of the non-irrigated treatments   Figure 6. The correlation of treatments with medium water amount





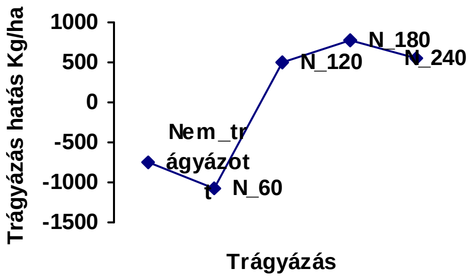


Figure 5 shows the interaction of non-irrigated treatments. With lower water supply, less fertiliser dosage is needed. If solely the amount of applied fertiliser is increased, the interaction becomes negative and yields decreases more drastically than expected. The excess nitrogen dosage hinders the formation of great yield. The great fertiliser dosage makes increased water supply necessary and in droughty years promotes the vegetative growth of plants to such extent that the large vegetative mass consumes the limited amount of water and this hinders the formation of a greater yield.

In figures 6 and 7 the interaction of irrigated treatments is shown. Applying medium water dosage, in unfertilised treatment, yield will be a ton less than expected. Between 60-180kg/ha nitrogen amount, the average effects of irrigation and fertilisation dominates. In this case no significant interaction can be noticed. 240 kg/ha nitrogen dosage increases yield by a ton. In this specific year, the greatest yield was achieved with good water supply and high nutrient supply. A high level of irrigation should be complemented with large nutrient dosage, as seen in figure 7.

In conclusion it can be said that by evaluating the interaction, water and nutrient supply should be examined together. Because of the positive interaction, the two factors should be changed alongside in order to achieve the planned yield. Reverse changes will result in yield limitation. The breaking down of variance components can be well used to clarify the main correlation of agro-technical factors.

7. RESULTS TO BE APPLIED IN PRACTICE

- When planning maize and winter yield experiments the number of minimal observations can be well planned with the help of graphics described in the thesis.
- In tillage experiments it is sufficient to measure yield and plant density in a single plot and by using the regularity of defection inheritance, the deviation can be calculated. In determining the deviation of individual production, all plants should be examined separately which involves a lot of work.
- The so-called "bunch sowing" is suitable in wide plot cultures to separate soil heterogeneity and the deviation of individual production of plants. The measured data in the experiments should be evaluated with breaking down of variance components.
- When examining the interaction of nutrient and water supply a statistically proven positive interaction was found. The positive interaction does not only highlight the importance of water supply, irrigation and fertilisation but calls our attention to the fact that the both agro-technical tasks should be decreased at the same time. If water supply is decreased then nutrient supply should also be decreased.

8. NEW AND LATEST SCIENTIFIC RESULTS

- I have introduced an up-to-date planning method for tillage experiments.
- I have determined the minimal number of samples for maize and winter wheat cultures as well as for other hybrids commonly cultivated.
- By using the regularities of defection inheritance, I have shown that among research conditions the deviation within a plot is greatly effected by the deviation in plant density. More so than by the individual difference of plants.
- By setting up my own experiment, I have separated soil heterogeneity and the individual difference in maize crop stands. On the basis of the method suggested by me, the deviation of individual production was more significant than soil heterogeneity.
- I have suggested the re-evaluation of the condition of independence in the split-plot experiments where variance analysis has been widely applied.
- I have shown that among normal cultivating conditions the distribution of maize production is not normal. The possibility of small individual production occurrence is more likely.
- By evaluating the data collected from long-term experiments, I have found that the similarity of deviation occurs in the case of tillage, fertilisation and plant density treatments. No correlation can be found between yield average and standard deviation. The experiments proved that yield projected on a unit area is an additive phenomenon.
- I have called the attention to the fact that in a split-plot experiment where from the condition of independence allowances have to be made, the F-probe of the variance analysis has to be complemented with the result of

the Greenhouse-Geisser and Huynh-Feldt probe. Decisions have to made by taking these into consideration.

- I have made suggestions that if the condition of standard deviation is not fulfilled an alternative method can be applied. I have given guidance on how to apply the Welch and Brown-Forsythe variance analysis in agriculture.
- I have introduced an easily applicable method to evaluate nutrient and water supply correlation. The breaking down of variance components, on the basis of maximum likelihood, has proved the positive interaction between nutrient- and water supply. In order to achieve a safe production these two factors have to be changed simultaneously.

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