ИЗБОР НА СТАТИСТИЧЕСКИ КРИТЕРИЙ ЗА ОЦЕНКА НА ЕКСПЕРИМЕНТАЛНИ ДАННИ ОТ АГРОТЕХНИЧЕСКИ ОПИТ С ПШЕНИЦА ОТ СОРТА "ЕНОЛА"
A CHOICE OF STATISTICAL EVALUATION CRITERION FOR DATA FROM AN AGRICULTURAL EXPERIMENT WITH CV *ENOLA* WHEAT

Красимира Узунова[1]*, Аньо Митков[2], Тоньо Тонев[2]
Krasimira Uzunova[1]*, Anyo Mitkov[2], Tonyo Tonev[2]

[1]Аграрен университет – Пловдив, ул. „Менделеев" 12, катедра „Генетика и селекция"
[2]Аграрен университет – Пловдив, ул. „Менделеев" 12, катедра „Земеделие и хербология"
[1]Agricultural University, 4000 Plovdiv, 12 Mendeleev blvd., Department Genetics and Plant Breeding
[2]Agricultural University, 4000 Plovdiv, 12 Mendeleev blvd., Department Agriculture and Weed Science

***E-mail: uzunova@au-plovdiv.bg**

Abstract

In the experimental work with agricultural trials, the last but not insignificant steps are the evaluation of data and determination of the level of confidence compared with the control (untreated) variant. The cv *Enola* wheat was used in the study, treated with chlor cholin chloride (CCC) in different doses in two phenophases: BBCH 21-23 – beginning of tillering to noticeable three brothers and BBCH 29-31 – end of tillering, with a visible maximum number of brothers and the first node – at least 1 cm above the tillering node.

Seven variants were formed. The assay was performed in the *Training and Experimental Base* of the *Department of Agriculture and Herbology*, following a scheme of using a nonstandard design method with an orderly arrangement of the variants in four replications. The samples were taken from all variants by *metrovka* in the latter half of June in 2012 and 2013. Eleven quantitative traits were reported, associated with the growth and development of the plants. The obtained data were statistically analyzed by applying two parametric assessment criteria (*Student* and *Fisher*) t-test and F-test. Varying degrees of confidence were established in the compared variations after applying the above criteria in the assessment. When using the *Student* criterion, lack of evidence was established in 60.6% of all the comparisons, while the application of the *Fisher* criterion established only 46.9%. Therefore we can conclude that in agricultural experiments with a high degree of variability it is more suitable to use the *Fisher* criterion for data evaluation since the degree of variability has a direct impact on the accuracy of the study.

Key words: Statistical evaluation, criteria parametric Student/Fisher, wheat, chlor cholin chloride (CCC).

INTRODUCTION

The major aim of the experimental work in field trials is to significantly reduce the impact of a number of reasons that are beyond the control of the researcher. The actual values of the studied variants in the carried out field trial are always burdened with some inaccuracy and that is taken into account when discussing and interpreting the results. The impact of accidental reasons of variation in the trial, i.e. the error, is defined by statistical processing of the data (Shanin, 1977). The choice of the statistical evaluation criterion is an important stage of the research in agricultural trials.

The aim of the present study was to evaluate the efficiency of two statistical criteria used for data analysis in agrotechnical trails with wheat treated with the growth regulator CCC, applied at different stages of the phenological development of the crop. Based on that, the proper choice of the criterion for result evaluation in future research activities is recommended.

MATERIALS AND METHODS

The trials were carried out on the Training and Experimental Field of the Department of Agriculture and Weed Science of the Agricultural University – Plovdiv in 2012 and 2013. Wheat cv. Enola was used in the present study, treated with the growth regulator CCC, applied at the following rates: 100, 200, 100 + 100 and 100 + 200 ml/da. Treatment was performed at two phenological stages of crop development: beginning of tillering and end of tillering. The experimental design consisted of seven variants, including the untreated variant as control.

Var. 1 – Control

Var. 2 – CCC 100 ml/dka, BBCH 21-23 – (phenological stage beginning of tillering)

Var. 3 – CCC 200ml/da, BBCH 21-23 – (phenological stage beginning of tillering)

Var. 4 – CCC 100 + 100 ml/da, BBCH 21-23/ BBCH 29-31 – (phenological stage beginning of tillering/tillering with three tillers emerged)

Var. 5 – CCC 100 + 200 ml/da, BBCH 21-23/ BBCH 29-31– (phenological stage beginning of tillering/tillering with three tillers emerged)

Var. 6 – CCC 100 ml/da, BBCH 29-31 – (phenological stage end of tillering)

Var. 7 – CCC 200 ml/da, BBCH 29-31 – (phenological stage end of tillering).

Optimal crop density was 400 plants/m^2. Sowing was performed at optimal time, at the first decade of October. Rapeseed was used as a predecessor in the crop rotation scheme. Standard growing practices were applied during vegetation: combined fertilization with NPK=15:15:15, nutritional fertilization with NH_4NO_3 – 30 + 30 kg/da, control of cereal leaf beetle with Nurelle D – 50 ml/ da, control of brown rust and powdery mildew by timely application of Capalo – 100 ml/da. The trial was set following the non-standard design method with systematic arrangement of the variants. The experimental plot of each variant was 20 m^2. In the last decade of June samples were taken from all the variants with an area sample. Each plant was separately tied, the soil from the roots was removed and each plant was analyzed by 11 quantitative traits:

- total number of tillers
- number of productive tillers
- stem height
- length of the main ear
- number of spiklets in the main ear
- number of grains per plant
- grain weight per main stem ear
- grain weight per plant
- weight of 1000 grains, following the formula:

grain weight per plant/number of grains per plant x 1000

- density of the central ear, following the formula:

number of spiklets in the ear/ear length x 10

The results were processed by SPSS 19 and the criteria of Student – t (Zapryanov and Dimova, 1995) and Fisher – F (Lidanski, 1988) were used for the statistical analysis.

RESULTS AND DISCUSSION

Based on the carried out experiment, the obtained mean values of the studied traits of cv. Enola and the variation coefficients are presented in Table 1. For six of the traits, the values of the variation coefficients are within 29,4 to 66,9%, determining those traits as traits with a high degree of variability: total number of tillers, number of productive tillers, number of grains per main stem ear, number of grains per plant, grain weight per main stem ear and grain weight per plant. Referring to the trait weight of 1000 grains, only the variation coefficient in Variant 7 is 62,3%.

The high degree of variability of a certain quantitative trait is indirectly related to the dependence of the trait on environmental factors, i.e. to its ecological plasticity. The higher degree of variability of a given trait shows the higher level of adaptability of that trait to the growing conditions. In result of the obtained values of the variation coefficients, two types of traits were identified with a high and average variation rate. That is why we used two statistical criteria for data evaluation and the results are presented in Table 2.

Two parametric criteria (Student and Fisher) with powerful evaluation capacity (Lidanski, 1988) were used in the methodological study. The total number of comparisons in the trial was 66. Using the criterion of Student, null hypothesis was confirmed in 40 of them (60,6%), i.e. the differences between the compared variants were insignificant. It means that the application of the growth regulator at a certain rate does not have a significant effect on the reported trait of cv. Enola. Using the criterion of Fisher, insignificant differences to the control variant were reported for 31 of the comparisons. Expressed in percentage, that value is 46,9%. The lower percentage of insignificant differences to the control when using Fisher criterion shows the possibility of reporting existing significant differences in a larger number of treatments and observations, which determines its higher efficiency. Lidanski (1988) mentioned that in trials related to various treatments such as mutagenesis, different growing conditions, etc., the main tendency in the samples is preserved, but the variability is significantly changed. In such cases he recommended to compare the samples and to evaluate the differences using the important characteristics, i.e. variability. The existing significance and its level in the studied variants, using those two criteria, are presented in Table 2. Significant effects of the growth regulator CCC were reported on the following traits:

Total number of tillers – for variants 3, 4 and 5, i.e. treatment with 200 ml at the stage beginning of tillering, 100+100 ml, 100+200 ml at the stage beginning of tillering/tillering with 3 tillers emerged;

Number of productive tillers – for the same number of variants;

Stem height – for variants 2 and 6, i.e. treatment with 100 ml at the stage beginning of tillering and application of the same rate at the stage end of tillering;

Number of grains per plant – for variants 3, 4 and 5;

Grain weight per plant – for variants 3, 4 and 5.

For the rest of the variants and traits, different levels of significance were reported according to one of the two statistical criteria used. Significant differences were reported for 19 of them when using the criterion of Fisher, while when using the criterion of Student their number was only 9.

Table 1. Average values and variation coefficients calculated for the seven variants of two-year observation

Traits	Variants													
	Var. 1 cont		Var. 2		Var. 3		Var. 4		Var. 5		Var. 6		Var. 7	
	$\overline{x}$	S %	$\overline{x}$	S %	$\overline{x}$	S %	$\overline{x}$	S %	$\overline{x}$	S %	$\overline{x}$	S %	$\overline{x}$	S %
1. Total number of tillers	2,85	**42,8**	3,06	**45,7**	3,53	**45,3**	3,66	**40,9**	4.85	**33,6**	2.7	**36,3**	2.7	**35,2**
2. Number of productive tillers	2,09	**44,5**	2,01	**53,7**	2.84	**47,9**	2.44	**41,4**	3.46	**41,6**	2.17	**41,5**	2.13	**43,2**
3. Stem height	105	6,7	103.7	7,9	106.3	9,6	105.2	8,6	106.2	7,7	102.3	8,8	104.7	9,2
4. Ear length	10.56	12,0	10.18	16,6	10.85	11,4	10.39	18,2	10.8	13,8	10.43	13,8	10.3	18,8
5. Number of spiklets in the main ear	22,07	11,8	22,17	15,3	22.6	12,6	22.02	19,5	22.3	13,0	22.02	14,1	22.1	19,0
6. Number of grains in the main ear	39,41	**33,5**	33,81	**36,9**	41.1	**29,4**	4.02	**31,6**	39.5	**33,1**	37.7	**36,8**	37.6	**40,1**
7. Number of grains per plant	68,3	**52,2**	57,9	**61,6**	92.9	**54,9**	80.3	**46,3**	97.7	**46,16**	69.3	**50,5**	65.3	**52,1**
8. Grain weight per main stem ear	1,87	**40**	1,57	**46,5**	1.91	**35**	1.85	**36,2**	1.82	**40,6**	1.78	**41**	1.68	**45,8**
9. Grain weight per plant	3,25	**55**	2,6	**66,9**	4.25	**56,9**	3.4	**50,3**	4.34	**48,4**	3.19	**52,9**	2.9	**56,2**
10. Weight of 1000 grains	46,35	14,7	44,07	21,5	45.04	16,2	42.2	22,5	43.6	20,4	44.5	20	43.6	**62,3**
11. Density of the main ear	20,88	11,5	21,7	11,9	20.85	6,9	20.9	17,22	20.6	11,6	21.3	12,6	21.09	18

Table 2. Comparative assessment and determining the level of significance of differences between the variants by Student (t) and Fisher (F)

Traits	Variants, experimental values of t-test and F-test, level of confidence													
	Var. 1 cont		Var. 2		Var. 3		Var. 4		Var. 5		Var. 6		Var. 7	
	t	F	t	F	t	F	t	F	t	F	t	F	t	F
1. Total number of tillers			1,6 ns	**2,04 +++**	**4,16 +++**	**1,67 ++**	**4,16 +++**	**1,67 ++**	**12,9 +++**	**1,78 +++**	1,52 ns	**1,54 ++**	1.84 ns	**1.64 +++**
2. Number of productive tillers			0,82 ns	**1,33 +**	**6,25 +++**	**2,09 +++**	**6,25 +++**	**2,09 +++**	**10,79 +++**	**2,36 +++**	0,85 ns	1,07 ns	0,42 ns	1,02 ns
3. Stem height			2,68 ++	1.35 ++	1,52 ns	**2,08 +++**	1,52 ns	**2,08 +++**	1,55 ns	**1,34 +**	3,29 +++	1,62 +++	0,27 ns	**1,94 +++**
4. Ear length			2,69 ++	**1,75 +++**	2,14 +	1,05 ns	2,14 +	1,05 ns	1,63 ns	**1,36 +**	1,0 ns	1,27 ns	1,62 ns	**2,3 +++**
5. Number of spiklets in the main ear			0,31 ns	**1,69 +++**	1,84 ns	1,16 ns	1,84 ns	1,16 ns	0,84 ns	1,24 ns	0,2 ns	**1,36 +**	0,13 ns	**2,54 +++**
6. Number of grains in the main ear			4,67 +++	1,12 ns	1,28 ns	1,19 ns	1,28 ns	1,19 ns	0,11 ns	1,03 ns	1,22 ns	1,11 ns	1,26 ns	**1,3 +**
7. Number of grains per plant			3,1 +++	1 ns	**5,44 +++**	**2,04 +++**	**5,44 +++**	**2,04 +++**	**6,7 +++**	**1,6 ++**	0,39 ns	1,03 ns	0,9 ns	1,09 ns
8. Grain weight per main stem ear			4,36 +++	0,95 ns	0,47 ns	1,24 ns	0,47 ns	1,24 ns	0,61 ns	1,03 ns	1,32 ns	1,03 ns	2,71 ++	1,05 ns
9. Grain weight per plant			3,8 +++	1,05 ns	**4,5 +++**	**1,83 +++**	**4,5 +++**	**1,83 +++**	**5,17 +++**	**1,38 +**	0,4 ns	1,12 ns	2,11 ns	1,19 ns
10. Weight of 1000 grains			2,74 ++	1,44 ++	1,59 ns	1,2 ns	1,59 ns	1,2 ns	3,05 ++	1,2 ns	2,2 +	2,24 ns	1,42 ns	**11,4 +++**
11. Density of the main ear			3,51 +++	1,21 ns	0,1 ns	**2,68 +++**	0,1 ns	**2,68 +++**	1,09 ns	1,01 ns	1,54 ns	**1,3 +**	0,67 ns	**2,6 +++**

$t_{tabl.} p_{5\%} = 1,960$ $p_{1\%} = 2,576$ $p_{0,1\%} = 3,290$ $F_{tabl.} p_{5\%} = 1,3$ $p_{1\%} = 1,4$ $p_{0,1\%} = 1,7$

$t_{critical}$ $F_{critical}$

In result of the analysis made, in all the variants and traits observed, 53% (35 in number) significant differences to the control were reported when using criterion of Fisher. When applying Student criterion for the statistical processing, the significant differences were reported for only 26 comparisons or 39%.

CONCLUSIONS

Two parametric statistical criteria were used in the present study – those of Student and Fisher, for explaining their methodological unity and specificity in assessing differences and multifactor impacts through analytical and empirical comparisons of the experimental data in agricultural trials. The following conclusions can be drawn on the basis of the results obtained:

1. Average and high values of variability of the studied quantitative traits were reported for wheat of cv. Enola treated with the growth regulator CCC.

2. With the aim of increasing the number of the significant comparisons, it is recommended to evaluate the experimental impacts by the statistical characteristics variability, using the criterion of Fisher.

3. When using the criterion of Student, null hypothesis was confirmed for 40 out of all the comparisons (60,6%), i.e. the differences between the compared variants were insignificant.

4. Using the criterion of Fisher, insignificant differences to the control variant were reported for 31 of all the comparisons, which is 46,9%.

5. Using both criteria (Student and Fisher), significant impacts of the regulator CCC were reported on the following traits:

- number of productive tillers;
- number of grains per plant;
- grain weight per plant.

in the variants treated at the stage:

- beginning of tillering at the rate of 200 ml,
- beginning of tillering / tillering with three tillers emerged at the rate of: 100+100 and 100+200 ml, which confirms the efficiency of the applied growth regulator when growing wheat of cv. Enola.

Based on the results of the carried out study, it could be concluded that in agricultural trials with a high degree of variability, it is more suitable to use Fisher criterion for data evaluation, as the degree of variability has a direct impact on the accuracy of the study.

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