Bulgarian Journal of Agricultural Science, 24 (Supplement 1) 2018, 3-8

MATHEMATICAL AND STATISTICAL ANALYZES OF THE INFLUENCE OF FOLIAR FERTILIZERS ON THE BIOMETRICS OF COMMON WHEAT

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Abstract

STOYANOVA, A. and V. KUNEVA, 2018. Mathematical and statistical analyzes of the influence of foliar fertilizers on the biometrics of common wheat. *Bulg. J. Agric. Sci.*, 24 (Suppl. 1): 3–8

The purpose of the study is to analyze the impact of foliar fertilizer treatment on the productivity of common wheat. The field experiment was conducted in 2014-2016, in the conditions of meadow-cinnamon soil. One-factor dispersion analysis was performed; variants were evaluated by the Duncan test for multi-directional comparison. From the one-factor dispersion analysis carried out on the main biometric parameters and subsequent comparative analysis on Duncan, it is proved that the height of the plant is statistically very well documented. An additional Duncan test allows grouping of variants. The "length of the spike" of both varieties is distinguished as moderately high. The variation follows a trend for both varieties. In the first year, the coefficient of variation in Apolon and Bologna was 14.29% and 15.59% respectively, for the second one was 4.45% and 5.64% and for the last 5.53% and 5.17% respectively. Correlations between the quantitative indicators for the two varieties of common wheat have been established. There is a high, statistically proven correlation between the indicators: "length of the spike" (x_2), "number of spikelets per spike" (x_3) and "weight of grains per spike" (x_4). The results of the correlation analysis are in line with the conclusions drawn from the analysis of applied irrigation regimes and their impact on plants from a biological point of view.

Key words: common wheat; foliar fertilizers; biometric indicators; correlation analysis

Introduction

Under the current market conditions, increasing yield and improving the quality of wheat grain are becoming increasingly important. This requires the introduction of varieties with high productivity and adaptability to environmental conditions. Wheat varieties are characterized by relatively low ecological plasticity, so it is necessary to study the productive capacities of each variety in different agro-ecological areas (Ivanova et al., 2006; Delibaltova and Ivanova, 2006; Tanchev, 2008). Besides the right selection of varieties and the ecological plasticity, the level of agro-technology is also of great importance. One of the most important agro-technical elements is fertilization. Davidkov and Tocheva (2005) found that nitrogen fertilization leads to the formation of more biomass and the fertilization regime is expressed in the increase of nitrogen in the wheat plants. Feeding with macro and micro nutrients that are easily accessible to plants improves growth, flowering, increases the resistance of culture to stress conditions and improves grain quality characteristics (Arif et al., 2006; Nankov and Nankova, 2007; Suwara et al., 2007; Samodova A., 2008; Toncheva et al., 2008; Sevov et al., 2010; Delibaltova et al., 2010; Vasileva and Uhr, 2012).

According to Tsenov et al. (2009) the crop productivity is closely related to the variety, the level of applied agro-technology and the soil and climatic conditions of the area. Therefore, in order to fully exploit the productive potential of the variety, the right choice of suitable varieties for each individual agro-ecological region is important as a factor in obtaining high yield. This raises the need for systematic researches of the new varieties offered by the selection in the different regions of the country.

The purpose of this study is to assess the degree of influence of foliar fertilization during vegetation on the already

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established Bulgarian common wheat variety Apolon and on the new introduced Bologna variety.

Material and methods

The field experiment was taken into the field of study of the Trakia University, Agricultural Faculty, Stara Zagora, during the period 2014-2016. The object of the study is assessing and comparing two varieties of common wheat: the Bulgarian variety Apolon and the introduced variety Bologna. The soils in the field of the study-experimental farm are typically meadow-cinnamon. They are deep, developed on sediments under the mixed influence of meadow and forest vegetation. The profile power is 103-105 cm, with well-formed horizons. The humus horizon is clearly expressed and has a range of 0-50 cm. There is less power in the horizon. The horizon reaches a depth of 103-105 cm. By mechanical composition the soil is sandy-clayey. The soil in the area is characterized by a slight acidic reaction. It is averagely stocked with humus - 3.93%. The soil is moderately stocked with mineral nitrogen - 40.8 mg/1000 g of soil. Ammoniac nitrogen is 0.45 mg/1000 g soil and nitrate - 40.33 mg/1000 g soil. With mobile phosphorus the soil is also poorly stocked - 3.27 mg/1000 g. The content of mobile potassium is 34.2 mg/1000 g of soil, which characterizes the soil as very well-stocked with potassium.

The variants of the field survey are the following:

1. Control - zero fertilization;
2. Fertilizing with N_{14};
3. Fertilization with N_{14} + Lacticfrost;
4. Fertilization with N_{14} + Lacticfrost + Lactofol base;
5. Fertilization with N_{14} + Lactofol base.

Both varieties of common wheat are treated during the vegetation with liquid leaf fertilizers - Lactifrost and Lactofol base. During the study, it was fertilized with ammonium nitrate to apply the N_{14} fertilization rate. The liquid fertilizer contains the macro elements: nitrogen total (N) - 13.8 g/l, nitrate - 7.4 g/l, ammonium - 6.4 g/l; diphosphate pentaoxide (P_2O_5) - 42.4 g/l; potassium oxide (K_2O) - 37.9 g/l and sulfur trioxide (SO_3) - 2.12 g/l and trace elements boron (B) - 477 mg/l, Cu (106 mg / (Mn) - 106 mg/l, molybdenum (Mo) - 2120 mg/l, zinc (Zn) - 64.0 mg/l as well as physiologically active organic substances and natural adherents. Lactofol base is a formulation containing the macro elements: nitrogen total (N) - 101 g/l, nitrate - 22.6 g/l, ammonium - 11.3 g l, amide - 67.80 g/l; diphosphate pentaoxide (P_2O_5) - 29.4 g/l; Potassium oxide (K_2O) - 50.9 g/l and sulfur trioxide (SO_3) - 1.36 g/l and trace elements boron (B) - 305 mg/l, copper (203 mg/ (Mn) - 226 mg/l, molybdenum (Mo) - 23 mg/l, zinc (Zn) - 452 mg/l as well as physiologically active organic substances and natural adhesives.

In order to assess the influence of leaf fertilizers, the parameters of "plant height", "length of the spike", "number of spikelets per spike", "number of grains per spike", "weight of grains per spike", "weight per 1000 grains ", and "test weight" were analyzed. The field experiment was based on the technology adopted for the area by the fractional plot method with the size of the plot of 10 m^2.

Experimental data are estimated by the average values for each variety and indicator, the mean error, the standard deviation SD and the variance coefficient CV, %. One-factor dispersion analysis (ANOVA) was performed. The differences between the mean variants were evaluated by the lowest tolerance test (LSD) at levels of significance

A correlation analysis has been carried out to establish and evaluate the correlation between the studied indicators, expressed by the correlation coefficient r. The correlation dependencies were a product of the mathematical and statistical processing of Genchev et al.'s output data (Genchev et al., 1975). Correlation coefficients (r) have been calculated with the statistical program SPSS 13.

Results and discussion

The years of the field survey in meteorological terms are characterized by significant differences in terms of the measured daily average temperatures by months compared to the multiannual period (1930-2014). Temperatures were high during the three years of the study. The aggregate temperatures for the three experiment years are 2742.0°C, 2738.0°C, and 3094.0°C at 2545.2°C on average over the long period. Noteworthy is the last year of the field study, where the average total temperature was higher by 21.6%. In contrast, in the first two years, the differences in measured average total temperatures were 7.6 and 7.7%. The first experimental year is characterized by average daily temperatures higher than the norm for January-April.

Regarding the quantity and distribution of precipitation, the three years are characterized by extremely uneven distribution of precipitated rainfall (Table 1). The rate for the past 10 years is 436.76 mm for the period of wheat growing. For the agricultural years of the field survey, precipitation was found to be higher by 26.52%, 61.96% and 6.26% respectively by years.

"Plant height" in Apolon variety varies considerably. For the three-year fertilization period with N_{14}, the average height was 94.63 cm. In 3rd and 4th variants, 102.27-102.47 cm was measured (Table 2). In the latter version, the height varies from 71.43 to 112.97 cm during the different years. In Bologna the variant with the introduction of the two specialized foliar fertilizers stands out with the highest measured stem (Table 3).

In terms of "length of the spike", the variation is lower. During the field survey, the average lengths were measured for both varieties, and it was found that in Bologna this indicator was 8.5% and Apolon is characterized by a greater "length of the spike". The variation is in the range of 9.28 to 10.35 cm. Bologna is distinguished by a smaller length of the spike, which varied from 8.05 to 10.25 cm. In variant 4, the largest length of the stem was measured - 10.25 cm.

Table 1
Meteorological characteristics, by months, for the growing period of common wheat, 2013-2016 for the region of Stara Zagora

Years	Rainfalls, mm								
	October	November	December	January	February	March	April	May	June
2013/2014	75.3	49.3	8.6	58.6	1.1	133.7	64.5	110.2	51.3
2014/2015	109.2	38	168.8	21.8	63.3	95.2	31.8	57.8	121.8
2015/2016	69	70.2	1.3	68	19.6	43.2	68	95.7	58.8
1930/2014	**109.2**	**38**	**168.8**	**21.8**	**63.3**	**95.2**	**31.8**	**57.8**	**121.8**
	Temperature, C°								
2013/2014	11.6	9.4	1.3	3.2	5.7	9.5	12.7	17	21.2
2014/2015	12.8	7.4	4.5	2.7	4.2	7.2	11.9	19.1	21.1
2015/2016	12.9	10.3	3.7	-0.1	7.8	8.8	14.6	16.2	23
1930/2014	**13.3**	**7.5**	**3**	**1.9**	**3.1**	**6.4**	**12**	**17.1**	**21**

Table 2
Structural elements of the harvest of Apolon variety, average for the survey period 2014-2016

Variants	Plant height	Length of the spike	Number of spikelets per spike	Number of grains per spike	Weight of grains per spike	Weitght per 1000 grains	Test weight
	cm	cm	-	-	g	g	kg/hl
1	81.02	9.49	17.29	37.15	1.14	37.3	-
2	94.63	10.35	18.91	40.03	1.18	39.31	73.95
3	102.46	9.28	17.16	31.61	1.27	40.15	73.6
4	102.27	9.74	16.92	32.55	1.36	40.95	74.75
5	90.53	9.43	18.02	42.09	1.34	42.1	74.7

Table 3
Structural elements of the harvest of Bologna variety, average for the survey period 2014-2016

Variants	Plant height	Length of the spike	Number of spikelets per spike	Number of grains per spike	Weight of grains per spike	Weitght per 1000 grains	Test weight
№	cm	cm	-	-	g	g	kg/hl
1	65.6	8.6	15.79	35.17	0.92	34.2	-
2	71.01	9.64	17.59	40.93	1.02	35.56	75.8
3	77.36	9.69	16.55	36.57	1.02	37.03	75.4
4	82.34	10.25	16.25	35.17	1.39	36.95	75.05
5	74.14	8.05	14.32	32.77	1.22	36.35	75.1

There is also a large variation in the "number of spikelets per spike". On average, during the study period, Apolon has 7.6% higher number of spikelets per spike for all the variants. The "number of grains per spike" varies widely across different varieties and variants of treatment. In the second year higher number of grains in Apolon for all variants was observed. In Bologna, an increase in the number of grains has also been recorded, but it is noticeable that even in the first year some of the grains in the spike are lifted in some variants.

The "weight of grains per spike" is a structurally determinant indicator that is influenced by the conditions of the year and the levels of mineral feed. The "weight of grains per spike" in the Apolon varies within the range of 1.14-1.36 g, with the highest values recorded in variant 4, where we have applied both types of liquid fertilizer enriched with macro and trace elements. The variation in Bologna is within a broader range of 0.92-1.39 g. The highest "weight of grains per spike" was recorded in the variant with the two fertilizers examined. Expressed as a percentage, the weight per spike of the Lactiftrost treated variant was 11.4 and 107.6% compared to the first and second variants of the Apolon variety, whereas in the variant treated with Lactifrost and Lactofol the baseline was 19.3 and 15.3%.

The "weight of grains per spike" at Apolon is average for the period and by 11.1% higher than that of Bologna. The best results are the variants with implemented liquid fertilizers. At Apolon the "weight per 1000 grains" was measured highest at variant 5. An increase of 7.0% compared to variant 2 was found. Bologna is a responsive variety and has been found to have an increase in "weight per 1000 grains" of 4.1% in lactate feed. The two-fold treatment with Lactifrost and Lactofol base resulted in seed having a 3.9% higher weight.

The "test weight" influences the determination of the commercial quality of the grain and, in particular, the selling price. The number of "test weight" shows good grain security over the years. In the first experimental year Bologna is distinguished by a higher indicator per "test weight". In the last year, for both varieties, high values of this indicator have been measured, which is an indicator of good grain protection. Meanwhile, "test weight" ranged from 72.10-76.45 kg/hl for Apolon and 74.53-76.18 kg/hl for Bologna, which was 1.5% higher than the Apolon score. The close high values of this indicator define the two varieties as having good quality, security and good commercial judgment.

Experimental data are estimated by the average values for each variety and indicator, the mean error, the standard deviation SD and the coefficient of variation CV, %. One-factor dispersion analysis (ANOVA) was performed. The differences between the mean variants were assessed by the lowest tolerance test (LSD) at significance levels. The values (separately for each year), followed by the same letters, do not differ significantly with $p<0.05$ according to the Duncan Multiple Test. Through the Duncan test for a multidimensional comparison a grouping of variants was made (Table 4, 5 and 6).

The coefficient of variation is a useful statistic to identify varieties with stable indicators. The two wheat varieties in the study are characterized by the lowest variation coefficients at "plant height". Apolon has a coefficient of variation for the first and last year - 1.35% and 3.63%, while for the second year it is calculated to be 9.66%.

In Bologna, a reverse trend was observed in the wet second year, the coefficient of variation was 1.32%, while the first and the last were 4.26% and 5.27% respectively. A higher coefficient of variation is characterized for the "number of grains per spike", for both wheat varieties.

The "number of spikelets per spike", indicator has a more stable coefficient of variation. For Apolon, the values range from 0.82% to 6.65%, while in Bologna the variance coefficient ranges from 3.86% to 16.12%.

The "length of the spike", of both varieties is distinguished as moderately high. The variation follows a trend for both varieties. In the first year, the coefficient of variation in Apolon

Table 4
Results of the variance analysis and Duncan test for the indicators of both varieties for 2014

Biometric identifiers	Apolon				Bologna			
	$\bar{x}$	$S\bar{x}$	$\bar{x}$	$S\bar{x}$	$\bar{x}$	$S\bar{x}$	$\bar{x}$	$S\bar{x}$
1 Plant height	112.96	0.76	1.52	1.35	79.08	1.69	3.37	4.26
2 Length of the spike	9.45	0.68	1.35	14.29	8.08	0.63	1.26	15.59
3 Number of spikelets per spike	17.3	0.57	1.15	6.65	15.82	1.27	2.55	16.12
4 Number of grains per spike	32.52	0.34	0.67	2.06	36.46	4.24	8.47	23.23
5 Weight of grains per spike	1.4	0.03	0.06	4.29	1.07	0.01	0.02	1.87

and Bologna was 14.29% and 15.59% respectively, the second one was 4.45% and 5.64% and the last 5.53% and 5.17% respectively.

The positive correlation between "length of the spike" (x_2) and "number of spikelets per spike" (x_3) is well-known for Apolon variety. This feature can be used as a reliable criterion in the production team. A negative correlation relation is established between the "length of the spike" (x_2) and "weight of grains per spike" (x_5), (r = -0.996), also between the "number of spikelets per spike" (x_3) and "weight of grains per spike" (x_5), (r = -0.992).

For the Bologna variety there is a negative correlation between the "plant height" (x_1) and "number of grains per spike" (x_4) (r = -0.998), as well as between the "number of grains per spike" (x_4) and "weight of grain per spike" (x_5), (r = -0.994). The positive correlation dependence is between the

Table 5
Results of the variance analysis and Duncan test for the indicators of both varieties for 2015

Biometric identifiers		Apolon				Bologna			
		$\bar{x}$	$S\bar{x}$	SD	CV, %	$\bar{x}$	$S\bar{x}$	s	CV, %
1	Plant height	70.4	3.93	6.8	9.66	60.02	0.45	0.79	1.32
2	Length of the spike	10.33	0.26	0.46	4.45	8.51	0.28	0.48	5.64
3	Number of spikelets per spike	20.42	0.43	0.74	3.62	18.66	0.61	1.05	5.63
4	Number of grains per spike	54.97	3.39	5.86	10.66	44.67	2.69	4.65	10.41
5	Weight of grains per spike	1.2	0.1	0.18	15	1.15	0.14	0.24	20.87

Table 6
Results of the variance analysis and Duncan test for the indicators of both varieties for 2016

Biometric identifiers		Apolon				Bologna			
		$\bar{x}$	$S\bar{x}$	SD	CV, %	$\bar{x}$	$S\bar{x}$	s	CV, %
1	Plant height	91.89	1.67	3.34	3.63	79.27	2.09	4.18	5.27
2	Length of the spike	9.58	0.26	0.53	5.53	10.25	0.27	0.53	5.17
3	Number of spikelets per spike	16.99	0.07	0.14	0.82	16.05	0.31	0.62	3.86
4	Number of grains per spike	31.87	1.04	2.09	6.56	34.27	1.36	2.73	7.97
5	Weight of grains per spike	1.18	0.04	0.08	6.78	1.06	0.06	0.13	0.12

Table 7
Correlational dependencies of Apolon variety and Bologna variety

Apolon								**Bologna**							
X_i	x_1	x_2	x_3	x_4	x_5	x_6	x_7	X_i	x_1	x_2	x_3	x_4	x_5	x_6	x_7
x_1	1							x_1	1						
x_2	0.614	1						x_2	-0.836	1					
x_3	0.55	0.997**	1					x_3	-0.834	0.986*	1				
x_4	0.899	0.557	0.49	1				x_4	-0.998**	0.866	0.866	1			
x_5	-0.599	-0.996**	-0.992**	-0.582	1			x_5	0.986*	-0.894	-0.907	-0.994**	1		
x_6	-0.241	-0.909	-0.94	-0.172	0.901	1		x_6	0.388	-0.216	-0.07	-0.357	0.262	1	
x_7	0.944	0.342	0.271	0.787	-0.314	0.047	1	x_7	-0.165	-0.312	-0.385	-0.106	0	-0.72	1

"plant height" (x_1) and "weight of grain per spike" (x_5), (r = 0.986).

The correlations observed show the degree of influence of each indicator in the yields of the studied varieties of common wheat.

The lowest and most mathematically unsupported are the correlations between "plant height" (x_1) and "number of spikelets per spike" (x_3), "weitght per 1000 grains " (x_6), "test weight" (x_7) for both varieties examined.

Conclusion

From the experiment and its analysis, the following conclusions can be drawn:

- Analysis of structural elements shows that on average, Apolon is distinguished by 7.6% "number of spikelets per spike" of records for all variants.
- The fertilizing of Apolon variety with Lactifrost provides an increase in "weight of grains per spike" by 7.6% compared to those with N_{14}.
- The two-fold treatment of common wheat with Lactifrost and Lactofol base results in a higher "weitght per 1000 grains". In Apolon, an increase of 4.1% was found, and in Bologna the increase was 3.9%.
- The indicator "number of spikelets per spike" has a more stable coefficient of variation. For Apolon, the values range from 0.82% to 6.65%, while in Bologna the variance coefficient ranges from 3.86% to 16.12%.
- Correlations between the quantitative indicators for the two varieties of common wheat have been established. There is a high, statistically proven correlation between the indicators: "length of the spike" (x_2) and "number of spikelets per spike" (x_3) and "weight of grains per spike" (x_5). The results of the correlation analysis are in line with the conclusions drawn from the analysis of the applied treatment options and their impact on plants from a biological point of view.

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