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MATHEMATICAL APPROACH FOR ASSESSMENT OF THE IMPACT OF GROWTH REGULATORS ON BASIC MORPHOLOGICAL INDICATORS IN MULTIFOLIUM 1 AND LEGEND ALFALFA VARIETIES

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Abstract

The current study aims at using a mathematical approach (correlation and regression analysis) in order to establish a correlation between the examined biometric indicators, to make a more objective assessment, and to express the influence between indicators and trends for yield improvement by means of the regression analysis. Data of a three-year field study are used. It was conducted in Plovdiv in the period 2017-2019. As a result of the correlation analysis, correlations between the examined indicators were established. The strongest positive correlation was found between the indices showing the number of internodes per stalk and the weight of a single stalk r = 0.993 for Legend variety, followed by Multifolium 1 variety with a correlation between the indices of weight of multifolium leaves and green mass yield r = 0.959.

***Key words**: alfalfa, correlation, regression analysis, ANOVA.*

INTRODUCTION

Increasing in green fodder production in Bulgaria and many countries around the world is mainly related to alfalfa production.

It is one of the most widespread and highly productive crops, which occupies a prime place among herbaceous plants.

According to FAO, around 436 million tones of total alfalfa production are produced annually, with the largest producers being the United States, Canada, Australia and more.

The wide application of this crop is due to a number of its biological and economic features such as high productivity, excellent quality of green mass and hay, long durability, low cost of production and more.

Its biological potential is to provide more than 100 tons of green biomass weight per hectare and more than 20 tons of hay under favorable conditions.

Main directions of the selection for gettting high yields of green mass and hay is to create new varieties with improved characteristics. An achievement in this direction is the creation of alfalfa with 4, 5 or more leaflets per leaf.

The production, quality and long life of alfalfa depend on both external (environmental conditions) and internal (genetically determined) factors. These factors are in complex relationships and if eliminating any of them, it would reduce the effect of the others and would have a negative effect on the yield and the long life of the alfalfa crop.

Research on alfalfa show that yields have increased by 20% over the last hundred years (Kertikova, 2000), only 10% of this rise was due to genetic improvements (Riday and Brummer, 2002).

Therefore, most studies are related to the search of opportunities for increasing the green mass yield and hay in alfalfa through the application of various agro-technical means - balanced fertilization, treatment with leaf fertilizers and growth regulators, optimal density, intensity of use (Berg et al.,2005).

The use of Reni preparations alone and in combination with trace elements in other crops (Kertikov, 2005; Jimotudis, 2008; Minev et al., 2009; Minev et al., 2011) leads to positive changes in yield and quality. It is assumed that these preparations can also have a good effect on the multifoliate alfalfa.

Using the mathematical approach in this study, we set out the following goals: to establish a correlational dependence between the biometric indicators in order to make a more objective assessment; using the regression analysis capabilities to express the impact between indicators and trends for yield improvement.

MATERIALS AND METHODS

During the period 2017-2019 a study was carried out at the experimental field of. Its task was to determine the impact of preparations with regulatory effect - RENI. They were applied independently and in combination with additional trace elements. The results were studied as follows: their effect on the enzyme activity, the emergence of multifolium leaves, the productivity and the quality of the multifoilum alfalfa varieties.

RENI preparations were created at the Agricultural University of Plovdiv as a means of the nitrogen exchange regulation. They are used for combinations of the trace elements molybdenum, manganese, magnesium in different concentrations and ratios (Popov 1995). Each RENI combinations consist of additional ingredients, namely: cobalt (Popov et al., 2010) and boron. The activities of enzymes like nitrogenase, nitrate reductase, glutamine synthetase and asparagine synthetase serve as a diagnostic feature for determining the exact concentration and ratio of the individual components in the various combinations.

RENI is applied by foliar treatment of alfalfa with a solution containing the composition. The experimental methods and the examined indicators are mentioned in some other works (Jimotudis et al., 2008; Popov et al., 2007; Popov et al, 2010).

The experiment was set on the method of fractional plots, in 4 repetitions and size of the experimental plot of 10 m^2.

Two alfalfa varieties: *Multifolium 1* and *Legend* were tested for this particular research.

RENI preparations were created at the Department of Crop Production at the Agricultural University of Plovdiv.

The tested options were evaluated by the following indicators: height, number of internodes per stem, total number of leaves per stem, number of multifolium leaves per stem, weight of leaves per stem, weight of multifoliate leaves and weight of one stem, yield of green mass. A correlation analysis was conducted (Lakin, 1990), aiming to establish the existence of statistically significant correlational dependencies between the examined indicators.

The correlation coefficient risen by the square - R^2 (R Square) is called a *coefficient of determination*. It shows the variance percentage of the resultative variable that is explained by the factor variable effect. The linear regression models, expressing the influence of an indicator on the total green mass yield, allow us to determine theoretically how and in what direction the change of these indicators contributes to yield improvement. This approach has been used for establishing the relation between important agronomic indicators in maize hybrids (Stoyanova, A. and Gr. Delchev. 2014) and common wheat (Delchev Gr. and A Stoyanova. 2015).

Data processing was conducted through the SPSS statistical program and ANOVA.

RESULTS AND DISCUSSIONS

Correlation coefficients expressing the relationship between the studied indicators are shown in the correlation matrices (Tables 1 and 2). For *Multifolium 1* variety, a strong positive correlation was found between the weight of leaves and the green mass yield r = 0.959. Strongly negative are the following correlations: between the number of nodes per stem and leaf weight; between leaf weight and single stem weight, with correlation coefficients of r = -0.906 and r = -0.851, respectively. All correlational coefficients are statistically proven at a reliability level $\alpha = 0.001$.

The correlations between height, total number of leaves, number of multifolium leaves and other monitored indicators are mathematically unproven.

Legend variety showed stronger correlational dependence; there were both negative and positive correlations between the examined indicators. A negative correlation was observed between height and weight of the multifolium leaves; number of internodes per stem and leaf weight; leaf weight and weight of a single stem, with coefficients r = -0.944, r = -0.952 and r = -0.923, respectively. A strong positive correlation was registered between the number of internodes per stem and the weight of a single stem r = 0.993; between the number of multifolium leaves and their weight r = 0.884. The correlations between the total number of leaves per stem and the rest of the examined indicators remained mathematically unproven.

Table1. A correlational matrix for *Multifolium 1* variety

	Height	Number of internodes per stem	Total number of leaves	Number of multifolium leaves	Weight of leaves	Weight of multifolium leaves	Weight of a single stem	Yield of green mass
Height	1	0.313	0.307	-0.199	-0.509	0.631	0.457	0.623
Number of internodes per stem		1	-0.458	0.581	-0.906*	0.099	0.831	0.173
Total number of leaves			1	-0.386	0.555	0.803	-0.485	0.663
number of multifolium leaves				1	-0.332	-0.298	0.684	-0.427
Weight of leaves					1	-0.018	-0.851*	-0.142
Weight of multifolium leaves						1	-0.090	0.959**
Weight of a single stem							1	-0.112
Yield of green mass								1

The determination coefficient indicates the percentage of the scattering of the resultative variable as it is explained by the action of the factor variable. In our case, $R^2 = 0.9188$, i.e. 91.9% of the yield depends on the weight of the multifolium leaves for *Multifolium 1* variety (Figure 1), and for *Legend* variety it is $R^2 = 0.3068$, i.e. 30.7% (Figure 2).

Table 2. A correlational matrix for *Legend* variety

	Height	Number of internodes per stem	Total number of leaves	Number of multifolium leaves	Weight of leaves	Weight of multifolium leaves	Weight of a single stem	Yield of green mass
Height	1	-0.112	-0.501	-0.803	-0.106	-0.944*	-0.122	-0.449
Number of internodes per stem		1	-0.672	0.155	-0.952*	-0.105	0.993**	0.256
Total number of leaves			1	0.620	0.835	0.725	-0.605	0.474
Number of multifolium leaves				1	0.132	0.884*	0.233	0.866
Weight of leaves					1	0.360	-0.923*	-0.026
Weight of multifolium leaves						1	-0.068	0.554
Weight of a single stem							1	0.361
Yield of green mass								1

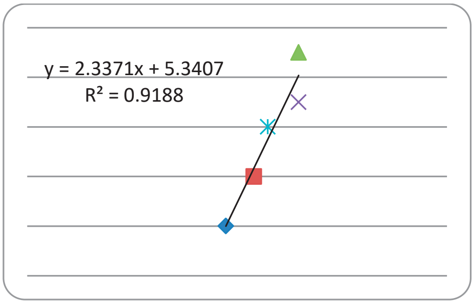

Figure 1. A linear regression model between the weight of multifolium leaves and the green mass yield for *Multifolium 1* variety

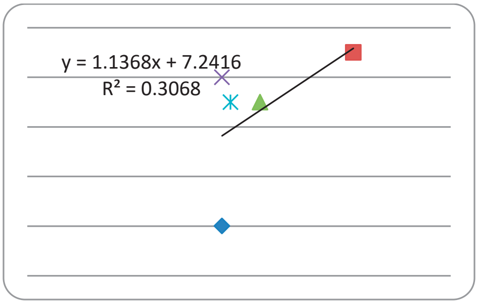

Figure 2. A linear regression model between the weight of multifolium leaves and the green mass yield for *Legend* variety

Table 3 presents the data of the multifolium leaves weight.

In 2017, there is an increase in the multifolium leaves weight at all treated variants, compared to the untreated in both studied varieties wich is statistically proven. However, this is due to the increased number of leaflets, as a result of the treatment rather than their weight. This indicator also does not show that the application of the Reni preparations leads to a change in leaves weight in the direction of increase or decrease. If comparing the results obtained and calculate one leaf weight from the untreated variants (controls) with the treated with the most leaves, the following is obtained: At *Multifoium 1* variety for the first, second and third swaths in the control, the weigh of one leaf is average 0.11 g, 0.07 g and 0.05 g, and the variant with the largest number of leaflets (treated with RENI + B; b4, with RENI + (RENI + B) and RENI + Co across different slopes) – 0.09 g, 0.08 g, and 0.06 g. In 2018, the unidirectionality of the results is maintained, with the difference that at *Multifolium 1* variety is observed a proven higher leaf weight in the treated variants compared to the control, whereas in the Legend variety this is not the case. Here again, it can be seen that there is no varietal difference in the weight of the leaves before and after RENI treatment.

For the first, second and third swath at untreated variants, one leaf weighs an average of 0.1 g, 0.09 g and 0.08 g, and the variant with the most multifoliolate leaves has an average weight of one leaf in the same sequence of swaths, respectively (the one treated with RENI + RENI + B) - 0.15 g, 0.07 g and 0.083 g. In the Legend variety, the untreated control forms leaves with a mean weight of 0.19 g, 0.17 g and 0.1 g, but the most multifoliolate variant (RENI treatments) respectively - 0.12 g, 0.07 g and 0.11 g. Interesting here is the record highs for the average mass of Legend leaves on untreated variants. Given that this is the wettest year and it is normal for the leaves to be heavier with better moisture content of the crop, it would follow that the application of Reni under such conditions acts in the direction of getting smaller leaves at the American variety.

This explanation is logical also due to the fact that during the remaining years of the experiment no such drastic difference in leaf mass was observed in the treated and untreated variants. There is no such difference with *Multifolium 1* variety. This may be due to the lack of evidence and the balanced weight values of the multifaceted leaves in the Legend variety, despite the proven increase in the number of complex leaves resulting from the treatment.

It was conducted an one-way ANOVA. The difference between the average of the options were assessed by test smallest permissible dif ference in levels of significance. By Duncan's test to cross comparison is grouping the variants.

Table 3. Multifolium Leaf Weight/1 Step (g) Mowing for 2016 -2019

Variants	**Multifolium leaves weight/1 stem (g)**								
	2017			**2018**			**2019**		
Mnogolistna 1	I swath	II swath	III swath	I swath	II swath	III swath	I swath	II swath	III swath
b1	1.1^{a}	1.0^{ab}	0.3^{a}	0.5^{a}	0.3^{a}	0.1^{a}	1.4^{a}	0.6^{a}	0.4^{a}
b2	1.2^{a}	0.9^{a}	0.4^{b}	0.8^{b}	0.5^{c}	0.2^{b}	2.1^{c}	0.7^{b}	0.5^{b}
b3	1.3^{b}	1.1^{b}	0.5^{b}	0.9^{b}	0.4^{b}	0.2^{b}	1.9^{b}	0.7^{b}	0.5^{b}
b4	1.3^{b}	1.3^{c}	0.6^{c}	1.2^{c}	1.3^{d}	0.6^{d}	2.0^{b}	1.0^{c}	0.5^{b}
b5	1.3^{b}	1.25^{c}	0.5^{b}	1.1^{b}	0.5^{c}	0.3^{c}	1.9^{b}	0.7^{b}	0.6^{bc}
LSD 5%	0.14	0.14	0.07	0.12	0.07	0.04	0.18	0.11	0.07
Legend									
b1	0.5^{a}	0.6^{a}	0.3^{a}	0.5^{b}	0.1^{a}	0.1^{a}	1.4^{a}	0.2^{a}	0.4^{c}
b2	1.0^{c}	0.9^{c}	0.5^{c}	0.8^{c}	0.2b	0.2^{b}	2.2^{c}	0.7^{c}	0.5^{d}
b3	0.6^{ab}	0.7^{ab}	0.4^{b}	0.4^{a}	0.1^{a}	0.1^{a}	2.0^{c}	0.5$^{b, c}$	0.2^{a}
b4	0.6^{ab}	0.8^{b}	0.4^{b}	0.7^{c}	0.1^{a}	0.1^{a}	1.8^{b}	0.3^{b}	0.3^{b}
b5	0.5^{a}	0.7^{ab}	0.4^{b}	0.6^{b}	0.1^{a}	0.1^{a}	2.1^{c}	0.4^{b}	0.4^{c}
LSD 5%	0.4	0.1	0.03	0.06	0.02	0.02	0.14	0.04	0.04

b1 - Control; b2 - RENI; b3 - RENI + B*; b4 - c ½ RENI +(½RENI +B); b5 - RENI + C*

CONCLUSION

As a result, the correlation analysis led to the registration of correlations between the studied indicators. The strongest positive correlation was found between the number of internodes per stalk and the weight of a single stalk r = 0.993 for *Legend* variety, followed by *Multifolium 1* variety between the weight of multifolium leaves and the green mass yield r = 0.959. The correlations showed the degree of influence of each indicator in the formation of yields for both alfalfa varieties.

The linear regression models, which express the influence of the weight index on the multifolium leaves, allow us to determine theoretically how and in what direction the change of these indicators contributes to the improvement of green mass yield. The received results could be a basis for determining the more promising alfalfa varieties.

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