Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 2, 2020
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

ESTIMATION OF THE SOWING RATE AND ROW SPACING INFLUENCE ON GREEN BIOMASS QUALITY FOR ALFALFA BY MEANS OF MATHEMATICAL AND STATISTICAL ANALYSIS

Velika KUNEVA, Atanas SEVOV

Agricultural University, 12 Mendeleev Blvd, Plovdiv, Bulgaria

Corresponding author email: kuneva.1977@abv.bg

Abstract

The objective of the present study is by means of a mathematical approach (variance, regression and variation analysis) to estimate the yield itself and to determine the row spacing influence on yield. Data analysis and mathematical processing, obtained during the study period (2016-2018), showed that the tested alfalfa varieties produced the best results at standard row spacing of 12.5 cm, regardless the used seed rate. The dispersion analysis of green mass and hay yields registered that the influence in the first year was the strongest (η = 96). In the second and third years, the variety had stronger influence on the yield (η = 95 and η = 99). The strongest factor correlation was the one between variety and row spacing (η = 89; η = 91; η = 94), which confirmed the fact that varieties react differently and have different compensatory capacity with the row spacing increase. The linear regression model between hay yield and total green mass yield for both varieties (Multifolium 1 and Legend) showed a high degree of correlation.

***Key words**: alfalfa, yield, analysis of variance evolution.*

INTRODUCTION

Alfalfa quality and durability depend on both, external environmental conditions and internal genetic factors. Alfalfa related research shows that yields have increased by 20% over the last hundred years (Kertikova, 2000), with only 10% of the increase being due to genetic improvements (Riday and Brummer, 2002).
Along with environmental factors, production potential is also influenced by the alfalfa crop age and the intensity of use (Brink et al., 2010).
Successful alfalfa crop production is a basic factor for obtaining maximum production. The optimum sowing rate continues to be the subject of numerous studies because of the fact that significant differences have been found depending on the region environmental conditions. The recommended sowing rate for alfalfa varies from 4 to 40 kg/ha depending on the area, its soil and climatic conditions, and the sowing method, which directly affects seed germination and sprouting.
The present experiment aims at: 1) analyzing the influence of *variety*, *row spacing* and *sowing rate* factors on plant biometric indices by means of factor dispersion analysis, establishing both, their self-action and their interaction; 2) finding a proper mathematical function that describes empirical data distribution on yield.

MATERIALS AND METHODS

The experiment was conducted during the period 2016-2018 in the experimental field of the Crop Production Department at the Agricultural University – Plovdiv. A basic task was to determine the influence of *variety*, *row spacing* and *sowing rate* factors on plant biometric parameters. The experiment was based on the block method in four repetitions (Barov, 1982).
The obtained experimental data were included in a factor variance analysis. The factors *variety* (factor A), *row spacing* (factor B), *sowing rate* and their interaction were examined. The following options and combinations were tested: b1 - row spacing 12.5 cm; b2 - row spacing 25 cm; b3 - row spacing 50 cm; c1 - seed rate 2.5 kg/da; c2 - seed rate 1.5 kg/da (Table 1).
The total yield of alfalfa green mass and hay was formed by the yield obtained from swaths developed under different climatic conditions, both, during the growing season and the experimental years.

Table 1. Green mass and hey total yields for the period 2017-2019

	Multifolium 1		Legend	
	Average for the period 2017-2019		Average for the period 2017-2019	
Options	Total green mass yield	Total hey yield	Total green mass yield	Total hey yield
b1c1	6.75	1.49	7.59	1.79
b1c2	6.48	1.45	7.41	1.73
b2c1	6.13	1.38	7.36	1.72
b2c2	6.14	1.37	7.28	1.70
b3c1	5.96	1.33	6.29	1.47
b3c2	5.95	1.34	6.27	1.46

The regression analysis included: 1) constructing the mathematical model of dependence, i.e. calculating the function parameters and compiling the regression equation; 2) verifying the model statistical significance and the function parameters; 3) determining the actual deviations size from the theoretically expected results and on this basis, estimating the dependent variable state (Y) according to the individual state of the independent variable (X). Experimental data were estimated by the average values $\bar{x}$ of each variety multiplied with the total yield, the error of the average $S\bar{x}$, the standard deviation s and the variation coefficient CV, %. An interesting approach has been used to manage and compare data on some major food products in Bulgaria (Dimova, 2018). This approach has been used for establishing the relation between important agronomic indicators in maize hybrids (Stoyanova and Delchev, 2014), common wheat (Delchev et al., 2015, Stoyanova et al, 2016, Stoyanova et al., 2018) and celery (Kuneva et al., 2016).
The mathematical and statistical empirical data processing was performed using MS Excel.

RESULTS AND DISCUSSIONS

The dispersion analysis of green mass and hay yields (Table 2) showed that in the first year the influence of row spacing on yield was the strongest (η = 96). In the second and third years, the variety had stronger influence on yield (η = 95 and η = 99). The strongest factor correlation was the one between variety and row spacing (η = 89; η = 91; η = 94), which confirmed the fact that varieties react differently and have different compensatory capacity as the row spacing increases.

Interaction between sowing rate and row spacing factors (η = 91) was also proven, leading to changes in plant height, leaf weight and number, emergence of multifoliage, with changes in sowing density.
2018 differed slightly from the previous year due to the fact that variety influence was the strongest (η = 98). Row spacing influence came on the second place (η = 95). The correlation between variety and row spacing factors (η = 89) was the strongest, as it was also the case for green mass production.
In 2019, the trends observed over the years were confirmed. Variety had the most significant influence on hay production (η = 99). Row spacing influenced yield (η = 97), and the interaction between sowing and row spacing (η = 94) was also proven. Data analysis and mathematical processing obtained during the study period (2017-2019) showed that the tested alfalfa varieties produced the best results at a standard row spacing of 12.5 cm, regardless the used seed rate. In rarer crops, both varieties formed more leaves, the degree of multiplicity was higher and biomass with a higher protein content was obtained. For successful practice, alfalfa leaf can also be used in a lower seed rate of 1.5 kg/da, as recommended by other authors (Contreras-G et al., 2009), without affecting green mass and hay yield and quality.
Table 3 presents the analysis data of variance for hay yield. The results showed that in 2016 the row spacing (η = 98), followed by the variety effect on yield (η = 97), had the strongest influence on hay production, as in the case of green mass. The interaction between sowing and row spacing (η = 84) was also proven (Table 2).
For both tested cultivars, considering the three mowings and the growing season in general, the best results were obtained with the standard alfalfa cultivation - 12.5 cm, for the case of Multifolium 1 - 6.90 t/da, and 6.79 t/da, and for the Legend variety - 7.67 and 7.76 t/da, respectively, for both sowing rates. Again, the Legend variety exceeded the Multifolium 1 variety in both, green mass and hay production, regardless the swath sequence (Table 1), 2 kg - 0.235 kg of hay were obtained from 1 kg green mass for the Multifolium 1 variety through different swaths, while the Legend yield ranged from 0.220-0.240 kg.

Table 2. Dispersion analysis of green mass yield by years

Sourse of variation	SS	Df	MS	P-value	ETA, Sqd
2016					
Variety (A)	2630343.6	1	2630343.4	0.000	87
Line spacing (B)	9594649.0	2	4797324.1	0.000	96
Sowing rate (C)	9441.36	1	9441.6	0.465	2
Interaction (A×B)	414676.2	2	207228.6	0.000	50
Interaction (A×C)	104868.3	1	104868.03	0.021	20
Interaction (B×C)	996371.2	2	498185.86	0.000	71
Interaction (A×B×C)	1496264.6	2	74632.03	0.024	27
Errors	411250.7	24	17135.44		
2017					
Variety (A)	5666780.3	1	5666780.3	0.000	95
Line spacing (B)	6742886.0	2	3371443.0	0.000	96
Sowing rate (C)	2256.3	1	2256.3	0.672	0,8
Interaction (A×B)	2293728.0	2	1146864.0	0.000	89
Interaction (A×C)	39800.3	1	39800.3	0.085	12
Interaction (B×C)	7214.0	2	3607.0	0.749	24
Interaction (A×B×C)	134304.0	2	67152.0	0.011	31
Errors	295516.0	24	12313.2		
2018					
Variety (A)	9770834.03	1	9770834.0	0.000	99
Line spacing (B)	2690550	2	1345275.0	0.000	98
Sowing rate (C)	573806.25	1	9770834.0	0.000	89
Interaction (A×B)	1094505.6	2	547252.8	0.000	94
Interaction (A×C)	2417.4	1	2417.4	0.362	4
Interaction (B×C)	654450.0	2	327225.0	0.000	91
Interaction (A×B×C)	86822.2	2	43411.1	0.000	56
Errors	67235.3	24	2801.5		

Table 3. Dispersion analysis of hey yield by years

Sourse of variation	SS	df	MS	P-value	ETA, Sqd
2017					
Variety (A)	310620.4	1	310620.4	0.000	97
Line spacing (B)	489887.7	2	244943.9	0.000	98
Sowing rate (C)	1272.1	1	1272.1	0.083	12
Interaction (A×B)	20291.7	2	10145.9	0.000	69
Interaction (A×C)	2952.1	1	2952.1	0.011	24
Interaction (B×C)	49457.1	2	24728.5	0.000	84
Interaction (A×B×C)	6927.1	2	3463.5	0.001	43
Errors	9307.3	24	387.8		
2018					
Variety (A)	551306.3	1	551306.3	0.000	98
Line spacing (B)	333747.2	2	166873.6	0.000	96
Sowing rate (C)	0.03	1	0.03	0.994	0
Interaction (A×B)	136620.2	2	68310.1	0.000	91
Interaction (A×C)	2721.4	1	2952.1	0.035	17
Interaction (B×C)	1147.4	2	573.7	0.363	8
Interaction (A×B×C)	6517.1	2	3258.5	0.008	33
Errors	13039.3	24	543.3		
2019					
Variety (A)	794475.1	1	794475.1	0.000	99
Line spacing (B)	128376.1	2	64188.0	0.000	97
Sowing rate (C)	28448.4	1	28448.4	0.000	88
Interaction (A×B)	58628.7	2	29314.4	0.000	94
Interaction (A×C)	44.4	1	44.4	0.601	12
Interaction (B×C)	30935.4	2	15467.7	0.000	89
Interaction (A×B×C)	4605.4	2	2302.7	0.000	55
Errors	3806.7	24	158.6		

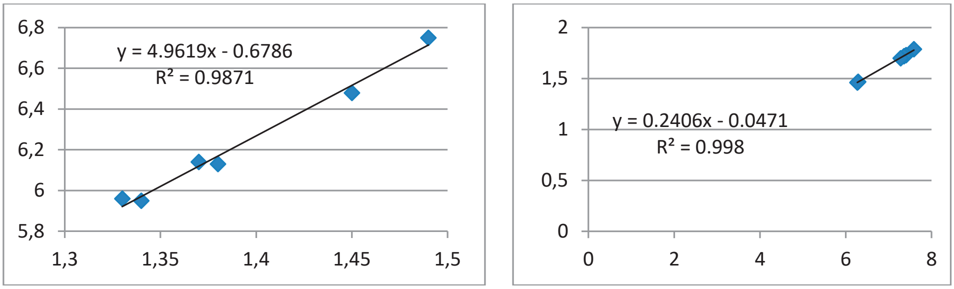

Figure 1. A- Linear regression model between hey yield and green mass total yield for Multifolium1 variety
B- Linear regression model between hey yield and green mass total yield for Legend variety

The visual representation of the correlation between both indicators for the tested varieties is obtained from the graphical presented data (Figures 1 A and B). Based on the empirical values, a point diagram (scatterplot) is drawn. The obtained linear regression models express the influence of hay yield indicator on green mass yield, allowing us to theoretically determine how and in what direction the change in these indicators contributes to yield improvement.

The determination coefficient R^2 indicates the percentage of resultative variable scattering and is explained by the factor variable action.
In our case, $R^2 = 0.9871$, i.e. hay yield depends on 98.7% of green mass yield for Multifolium 1, and for Legend variety it is $R^2 = 0.998$, ie. 99.8%. As green mass yield increases, the total hay yield increases.
We can assume that the linear regression models are reliable.

Table 4. Descriptive Statistics for the Multifolium 1 variety

Indicator	Min	Max	Mean		Std.	Variance
			Statistic	Std. error		
Yield of hay	5.95	6.75	6.24	0.13	0.32	0.100
Yield of green mass	1.33	1.49	1.39	0.03	0.06	0.004

Table 5. Descriptive Statistics for the Legend variety

Indicator	Min	Max	Mean		Std.	Variance
			Statistic	Std. error		
Yield of hay	6.27	7.59	7.03	0.24	0.59	0.351
Yield of green mass	1.46	1.79	1.65	0.06	0.14	0.020

It is logical that the hay yield for both varieties decreases with the row spacing increase, regardless of the sowing rate. For Multifolium 1, this is mathematically proven within all options with row spacing of 25 and 50 cm; for the Legend variety it is proven only within options with row spacing of 50 cm.
Variation analysis for Multifolium 1 and Legend varieties take into account the limits of variation in yields for each individual variety (Tables 4 and 5). Results of the variability between the studied indicators show lowest value at the yield of green mass for Multifolium 1 (x = 1.33), and highest at the yield of hay for Legend variety (x = 7.59).

CONCLUSIONS

The dispersion analysis registered that the examined alfalfa varieties showed best results at standard row spacing of 12.5 cm, regardless the used seed rate. The obtained linear regression models express the influence of the hay yield indicator on the green mass yield, allowing us to theoretically determine how and in what direction the change in these indicators contributes to yield improvement.
In our case, $R^2 = 0.9871$, i.e. hay yield depends on 98.7% of green mass yield for Multifolium 1, and for the Legend variety it is $R^2 = 0.998$, i.e. 99.8%. As green mass yield increases, the total hay yield increases.

REFERENCES

Barov, W. (1982). Analysis and outline of Polish experience. NACA, Sofia.

Brink, G., H., Marvin, Sh., Glen, U., Dan, M., Neal, W., Richard (2010). Changes in Alfalfa Yield and Nutritive Value within Individual Harvest Periods. *Agronomy Journal*, *102*(4), 1274–1282.

Contreras-Govea Francisco E., Lauriault, L., Marsalis, M. (2009). Furrow-Irrigated Alfalfa Dry Matter Yield is Not Affected by Different Seeding Rates in the Southern *High Plains, USA, NM University HM*. Research Report 766.

Delchev, Gr., Stoyanova, A. (2015). Stability Valuation of Some Mixtures between Retardants and Antigrass Herbicides for Grain Yield of Durum Wheat. *Bulgarian Journal of Agricultural Science*, *2*, 358–362.

Dimova, D. (2018). An Approach for Managing and Comparing Data Concerning Some Main Food Products, 18th International Multidisciplinary Scientific GeoConference SGEM 2018, *Conference Proceedings, 18*(2.1.), 55–62, Albena, Bulgaria. DOI: 10.5593/sgem2018/2.1/S07.007

Kertikova, D., Yancheva, H. (2000). Variability of some traits in Lucerne within one breeding cycle, *Genetics and Breding*, 30(1-2), 1–2.

Kuneva, V., Harizanova-Petrova, B., Stoyanova, A., Dospatliev, L. (2016). Assessment of the Impact of Different Irrigation Regimes on Several Biometric Indicators for Celery through Mathematical - Statistical Analysis, *International Journal of Scientific and Research Publications*, *6*(4), 80–84.

Riday, H., Brummer, E.C. (2002). Forage yield heterosis in alfalfa. *Crop Science*, *42*, 716–723.

Stoyanova, A. Delchev, Gr. (2014). Testing of Various Regimes of Irrigation Furrows in Grain Maize. *Bulgarian Journal of Agricultural Science, 20*(3), 631–639.

Stoyanova, A., Ganchev, G., Kuneva, V. (2016). Nutrition value of two grain common wheat, *Scientific Papers, Series A. Agronomy, LIX*, 421–425.

Stoyanova, A., Kuneva, V. (2018). Mathematical-statistical analyzes of the influence of leaf fertilizers on the biometrics of common wheat. *Bulg. J. Agric. Sci*., *24*(Supplement 1), 3–8.