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ANALYSIS AND MODELING OF MORPHOLOGICAL AND PRODUCTIVE CHARACTERISTICS OF SPECIES OF THE GENUS *AMARANTHUS L*

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Key words: mathematical modeling, morphological and productive characteristics.

Summary. This paper includes research of ten genotypes of introduced species of the genus *Amaranthus L*. Raw materials from the genus *Amaranthus L.* contain high quality starch, pectin, lipids, vitamins and other physiologically active substances, and can be used as important nutritional supplements.
The experiment was monitored in a three-year work, at the same location, under different climatic and meteorological conditions. Morphological and productive characteristics, number of leaves per plant, medium leaf length, medium leaf width and leaf mass per amaranth plant, were studied. Coefficients of variation and standard deviation were calculated for the above characteristics. A mathematical model was developed, by whose application, in simple way, it was possible to predict the leaf mass of all ten genotypes of introduced species of the genus *Amaranthus L*.

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Key words and Phrases: Mathematical Modeling, Morphological and Productive characteristics.

1 INTRODUCTION

Contemporary flora includes over 350 thousand plant species and represents inexhaustible source intensively used by the whole world. Out of that number, 3 thousand plant species are used for nutritional purposes. The first studies of plant species of the genus *Amaranthus L.* appeared in the US National Academy of Sciences in the 80s in the XX century. The studies had rediscovered this ancient plant of Aztec and Inca tribes, and confirmed the high nutritional value and productivity of this species.

The plants of the genus *Amaranthus L.* give a rich yield and are cost-effective in processing, and it provides them a successful introduction in many regions, where they have previously not been cultivated. High ability of adaptation of many species of amaranth (*A. cruentus L., A. lividus L.*, etc.) and an intense flow of productive processes during the short vegetation period are the specificities of this plant species. Plant species of the genus *Amaranthus L.* belongs to the group of C_{-4} plants that are characterized by high productivity of photosynthesis, and researches of amaranth are focused on their use for nutritional purposes. Evidence of this is that the majority of papers presented at international conferences are devoted to the problem of their cultivation, increase of yield and utilization of their high nutritional value.

Raw materials from the genus Amaranthus contain high quality starch, pectin, lipids, vitamins and other physiologically active substances, and can be used as important nutritional supplements. A. caudatus L., A. cruentus L. and A. hypochondriacus 53 L are nowadays cultivated all over the world because of their exceptional nutritional value of seeds and leaves[1]. In the results of researches for the selection of new varieties, species *A. caudatus, A. cruentus* and *A. mantegazzianus* are singled out as nutritionally best varieties[2]. Amaranthus species are widely present as decorative plants and as a source of red food colors and in the last few decades some have been described[3] and 65 studies on yield of the genus Amaranthus have been done [4].

There are different data in Europe for the exact number of species of the genus *Amaranthus L.* So, 9 species are listed in Prodromus Florae Peninsulae Balkanicae[5], 12 in Flora Europaea[6], and 21 species according to Med-Checklist, including non-European and Mediterranean countries[7].Species of the genus *Amaranthus L.* belong to the *Amaranthoidae* subfamily of the *Amaranthaceae* family (order of *Caryophyllales),* which includes about 60 (-90) widespread herbaceous plants, with rarely low bushes, while woody forms are located only in the tropical belt. In the flora of the Balkans, there are only annual herbaceous plants with erect, raised or flattened stem. The leaves are opposite or alternate, simple, entire and without valves. The first data on the genus *Amaranthus* in the Balkans, where 3 species are described *(A. retroflexus, A. blitum = syn. A. lividus* and *A. paniculatus),* are related to the major work "Flora of the Principality of Serbia"[8]. The most complete data on the distribution of the genus *Amaranthus* in the Balkans[9] indicate the presence of the following 13 species: *Amaranthus retroflexus L., A. hybridus L., A. cruentus L., A. paniculatus L., A. caudatus L., A. graecizans L., A. tricolor L., A. albus L., A. blitoides S. Watson, A. crispus (Lesp. et Thev.) N. Terracc., A. deflexus L., A. lividus L. and A. viridis L.* The above study has shown, among other things, that the species of this genus prefer drier habitats, with neutral to moderately acidic reactions, with enough nitrogen; most of the species are heliophytes or semisciophytes, mesothermophilic to thermophilic. The genus *Amaranthus L.* includes annual, biennial and rarely perennial (*Amaranthus greggii S. Wats*, that grows at the mouth of the river of Vera Cruz, Mexico) herbaceous species. In Europe, the genus *Amaranthus L.* is presented with 15 adventive species, which have not so long ago been brought mostly from Central and South America or Africa. Thanks to the remarkable diversity in terms of adaptive capacity of anthropogenic and zoochoric dispersal of seed and fruit, the species of the genus *Amaranthus* very expansively increase the areals of its distribution, so today they become subcosmopolitan and cosmopolitan species. Leaves of the species of the genus *Amaranthus L.* are mainly alternately arranged, simple, entire and narrowed at the base in leaf petiole. A large number of species reaches a height of 30 to 200 cm and blooms during summer or early fall, having a short vegetation period. Compared to other plant species, the genus *Amaranthus L.* contains larger amount of proteins (22 %), which allows its wide consumption for nutritional purposes[10] .

2 MATERIALS AND METHODS

Ten genotypes were chosen, out of which, genotypes 2 and 4 belong to the *A. caudatus* species, genotype 1 belongs to the *A. mantegazzianus* species, genotype 3 belongs to the *A. molleros* species, and genotypes 5, 6, 7, 8, 9 and 10 belong to the *A. cruentus* species.

The experiment was done in a complete random block design, and repeated four times at the experimental field, and observed for 3 years. Surface of the main plot was 10.5 m^2 (2.1 m x 5 m). Size of treatment (70 cm x 30 cm) and the arrangement of plant density were made by standard method. Sowing was done in small houses (5-6 seeds). After germination, thinning to one plant in the small house followed (the distance between plants was 25 cm). Regular care and protection of the experiment was performed during the course of experiment.

Morphological and productive characteristics analyzed during all three years of experiment were the following:

- Number of leaves per plant (n)
- Medium leaf length (cm)
- Medium leaf width (cm)
- Leaf mass per plant (g)

2.1 Biometric methods

Mean value ($\bar{x}$), standard deviation (S) and variation coefficient (Cv %) were calculated as indicators of variability of the studied characteristics. Based on the collected data, the regression analysis was performed, where the characteristics, the number of leaves per plant, medium leaf length and medium leaf width, were chosen as independent variables (variables), and dependent variable was leaf mass per plant. Regression analysis was done using the software package DataFit9-version 2008. In accordance with the number of independent variables, it can be concluded that it is a multifactorial regression analysis. Based on experimentally obtained results, population of 30 members, each with three characteristics, will be defined, which is a relevant sample population. Regression analysis is done according to the following model:

$$Y=\exp(a\cdot X_1 + b\cdot X_2 + c\cdot X_3+d) \quad (1)$$

Where:
X_1 - Number of leaves per plant
X_2 - Medium leaf length
X_3 - Medium leaf width
Y - Leaf mass per plant
a, b, c, d - Regression coefficients

3 RESULTS AND DISCUSSION

3.1 Number of leaves per plant

Genotype 1 showed the highest value for the number of leaves per plant during the three years of research (28 in I year; 23.25 in II year and 19.14 in III year), namely *A. mantegazzianus.* The lower limit for the number of leaves per plant was as follows: 16.1 (genotype 1 - *A. mantegazzianus*) in the first year of research; 10.78 (genotype 8 - *A. cruentus*) in the second year of research and 9.87 (genotypes 5 and 10 - *A. cruentus*) in the third year of research (Table 1). Values of standard variation as a measure of variability are harmonized with the values of variation coefficients. Data from the analysis of mean number of leaves per plant (Table 1) indicate the variability between analyzed genotypes, as demonstrated by the obtained values of LSD (for the level of 5% and 1%).

From cultivated species in the world, the leaf of *A. cruentus, A. dibius, A. tricolor* and *A. blituma* is used as food[11]. In researches[12] on *A. cruentus* and *A. tricolor L.* have come to the conclusion that the young leaves of amaranth are similar to mint, a medicinal species. Fragile amaranth leaves, with a low ash content and reduced cellulose content, are relatively rich in protein, pectin, and flavonoid, and it puts the amaranth in the same row with known medicinal plants.

Genotype *)	I year	II year	III year	$\bar{X}$ (cm)	Cv (%)
	$\bar{x}$ (cm)	$\bar{x}$ (cm)	$\bar{x}$ (cm)		
genotype 1	28.00	23.25	19.14	23.46	3.62
genotype 2	24.21	19.99	17.43	20.54	2.77
genotype 4	22.78	18.56	16.57	19.31	2.58
genotype 3	16.10	15.42	11.76	14.42	1.90
genotype 5	20.35	11.66	9.87	13.96	4.58
genotype 6	19.25	12.38	10.97	14.20	3.61
genotype 7	19.70	11.07	10.00	13.59	4.34
genotype 8	18.20	10.78	10.07	13.01	3.52
genotype 9	17.77	11.30	10.25	13.10	2.37
genotype 10	17.40	11.42	9.87	12.89	3.24
I.V.	11.90	12.47	9.27	-	-
S	3.44	4.26	3.44	-	-
Cv (%)	16.88	29.25	27.37	-	-
LSD	0.05	0.749			
	0.01	0.992			

Table 1: Mean values ($\bar{x}$) in cm, standard deviations (S) and variation coefficients (Cv) % for the number of leaves per plant in 10 Amaranthus genotypes during three years

*) Species *A. mantegazzianus* includes genotype 1
Species *A. caudatus* includes genotypes 2 and 4
Species *A. molleros* includes genotype 3
Species *A. cruentus* includes genotypes 5, 6, 7, 8, 9 and 10

3.2 Medium leaf length

The mean value for the leaf length in analyzed genotypes ranged from 16.92 cm (genotype 8 - *A. cruentus*) to 30.65 cm (genotype 1 - *A. mantegazzianus*) in the first year of research, namely from 15.85 cm (genotype 9 - *A. cruentus*) to 27.25 cm (genotype 1 - *A. mantegazzianus*) in the second year of research. In the third year of research, the mean value ranged from od 11.5 cm (genotype 10 - *A. cruentus*) to 22.27 cm (genotype 1 - *A. mantegazzianus*) (Table 2). Variability between analyzed genotypes in I year amounted to 19.85 %, in II year 17.36 %, i.e. slightly lower, while in III year amounted to 23.50 % (Table 2). The lowest value of the variation interval for the studied genotypes was 10.77 cm (in the third year), while the maximum value for the above variability indicator was 13.8 cm (in the first year of research). The standard deviation for the leaf length ranged within the limits of 3.09 % (III year) to 3.89 % (I year), and was in accordance with the values of variation coefficients (Table 2).

Obtained that the mean leaf length value of *A. caudatus* was 24 cm, *A. candatus* was 21 cm, *A. paviculatus* was 28 cm and *A. cruentus* was 26 cm[13]. It must be emphasized that these are parameters of the best leaves, and amaranth is classified into two categories: tall *(A. poninculatus* - 180 cm; *A. cruentus* - 193 cm) and short *(A. caudatus* - 153 cm and *A. candatus* - 140 cm).

Genotype *)	I year	II year	III year	$\bar{X}$ (cm)	Cv (%)
	$\bar{x}$ (cm)	$\bar{x}$ (cm)	$\bar{x}$ (cm)		
genotype 1	30.65	27.25	22.27	26.72	3.67
genotype 2	20.97	17.22	13.05	17.08	3.23
genotype 4	19.47	17.10	12.97	16.51	2.68
genotype 3	19.45	17.15	11.75	16.11	3.22
genotype 5	19.00	17.32	12.32	16.21	2.83
genotype 6	17.85	17.45	11.62	15.64	2.84
genotype 7	18.01	17.25	11.62	15.62	2.84
genotype 8	16.92	16.87	12.92	15.57	1.87
genotype 9	16.87	15.87	11.62	14.27	2.26
genotype 10	16.97	16.40	11.50	14.95	2.45
I.V.	13.80	11.40	10.77	-	-
S	3.89	3.12	3.09	-	-
Cv (%)	19.85	17.36	23.50		
LSD	0.05	0.978			
	0.01	1.295			

Table 2 **:** Mean values ($\bar{x}$) in cm, standard deviations (S) % and variation coefficients (Cv) for medium leaf length (cm) in 10 Amaranthus genotypes during three years

*) Species *A. mantegazzianus* includes genotype 1
Species *A. caudatus* includes genotypes 2 and 4
Species *A. molleros* includes genotype 3
Species *A. cruentus* includes genotypes 5, 6, 7, 8, 9 and 10

3.3 Medium leaf width

The lowest mean values for leaf width were observed in genotype 8 (6.95 cm) in I year, in genotype 6 (6.85 cm) in II year, i.e. in genotype 9 (4.9 cm) in III year. The highest mean values for the above characteristic, per years of research, were observed in genotype 1 (Table 3). Observed by types, the lowest mean values for the concerned characteristic were observed in species *A. cruentus*, and the highest mean values were observed in species *A. mantegazzianus.* Maximum value of the variation interval (9.47) and standard deviation (2.88 %) were in the first year, while the minimum value of variation interval (7.13) and standard deviation (2 %) were in the third year of research.

Studying biometric indicators of five amaranth genotypes in conditions of the Northern Ural[13] is determined the mean values of leaf width for *A. gangeticus* - 16 cm, *A. paniculatus* - 15 cm, for *A. caudatus* - 13 cm, for *A. candatus* - 11 cm and for *A. cruentus* - 16 cm.

Genotype *)	I year	II year	III year	$\bar{X}$ (cm)	Cv (%)
	$\bar{x}$ (cm)	$\bar{x}$ (cm)	$\bar{x}$ (cm)		
genotype 1	16.42	15.23	11.73	14.46	1.99
genotype 2	12.07	9.88	6.07	9.34	2.47
genotype 4	11.82	9.32	5.72	8.59	2.52
genotype 3	9.70	8.10	5.87	7.89	1.56
genotype 5	8.05	7.00	4.97	6.67	1.27
genotype 6	7.65	6.85	4.70	6.40	1.24
genotype 7	7.40	7.52	5.20	6.70	1.06
genotype 8	6.95	7.05	5.00	6.33	0.94
genotype 9	7.45	6.95	4.60	6.30	1.24
genotype 10	7.77	7.02	4.90	6.56	1.21
I.V.	9.47	8.38	7.13	-	-
S	2.88	2.46	2.00	-	-
Cv (%)	30.35	29.00	34.19		
LSD	0.05	0.050			
	0.01	0.670			

Table 3 **:** Mean values ($\bar{x}$) in cm, standard deviations (S) and variation coefficients (Cv) in % for medium leaf width in 10 Amaranthus genotypes during three years

*) Species *A. mantegazzianus* includes genotype 1
Species *A. caudatus* includes genotypes 2 and 4
Species *A. molleros* includes genotype 3
Species *A. cruentus* includes genotypes 5, 6, 7, 8, 9 and 10

3.4 Leaf mass per plant

The results in Table 4 show that the mean leaf mass among the analyzed genotypes ranged from 94.05 g (genotype 3 - species *A. molleros*) to 246.81 g (genotype 1 - species *A. mantegazzianus*). At high temperatures and dry growing conditions (I year), amaranth forms a large biomass. Variation interval in the analyzed genotypes ranged from 91.42 g (in the first year) to 204.83 g (in the third year of research). The maximum value of standard deviation (60.40 %) was observed in I year, and considerably lower value (24.01 %) was characteristic for III year, Table 4.

At high temperatures and dry growing conditions, amaranth forms a large biomass. The mean value of leaf mass per plant, under the conditions of the Moscow area ranges: from 92 g to 366 g in genotype *A. caudatus,* from 222 g to 654 g in genotype *A. tricolor* and in genotype *A. cruentus* approximately 220 g[14]. Tchernov points out in his researches that the increase in the yield of phytomass is the result of functioning of specific mechanism of CO_2 photosynthetic assimilation, and high productivity is based on a specific metabolization of carbon and nitrogen (C_{-4} photosynthesis), which provides morphological, physiological and biochemical specificity of amaranth[15].

Genotype *)	I year	II year	III year	$\bar{X}$ (g)	Cv (%)
	$\bar{x}$ (g)	$\bar{x}$ (g)	$\bar{x}$ (g)		
genotype 1	340.50	237.60	162.34	246.81	72.02
genotype 2	249.37	166.47	107.45	174.43	58.21
genotype 4	219.44	170.52	104.62	164.86	47.04
genotype 3	115.61	95.63	70.92	94.05	18.27
genotype 5	180.43	160.31	82.94	141.22	42.02
genotype 6	183.94	131.94	94.74	136.87	36.58
genotype 7	184.78	123.46	91.70	133.31	38.63
genotype 8	159.88	119.54	90.36	123.26	28.07
genotype 9	156.36	121.54	85.72	121.20	28.83
genotype 10	146.87	99.15	81.14	109.05	27.73
I.V.	224.89	141.97	91.42	-	-
S	60.40	40.29	24.01	-	-
Cv (%)	31.18	28.26	24.71	-	-
LSD	0.05	22.375			
	0.01	29.672			

Table 4 : Mean values ($\bar{x}$) in g, standard deviations (S) and variation coefficients (Cv) in % for leaf mass per plant in 10 Amaranthus genotypes during three years

*) Species *A. mantegazzianus* includes genotype 1
Species *A. caudatus* includes genotypes 2 and 4
Species *A. molleros* includes genotype 3
Species *A. cruentus* includes genotypes 5, 6, 7, 8, 9 and 10

3.5 Analysis according to model $Y=\exp(a\cdot X_1 + b\cdot X_2 + c\cdot X_3+d)$

Results of regression analysis according to model (1) are shown in the table (Table 5).

DataFit version 9.0.59
Results from project "Untitled1"
Equation ID: exp(a*x1+b*x2+c*x3+d)
Model Definition:
Y = exp(a*x1+b*x2+c*x3+d)
Number of observations = 30
Number of missing observations = 0
Solver type: Nonlinear
Nonlinear iteration limit = 250
Diverging nonlinear iteration limit =10
Number of nonlinear iterations performed = 7
Residual tolerance = 0.0000000001
Sum of Residuals = -2.49851048649646
Average Residual = -8.32836828832152E-02
Residual Sum of Squares (Absolute) = 9866.24188286265
Residual Sum of Squares (Relative) = 9866.24188286265
Standard Error of the Estimate = 19.4800113359455
Coefficient of Multiple Determination (R^2) = 0.9061596259
Proportion of Variance Explained = 90.61596259%
Adjusted coefficient of multiple determination (Ra^2) = 0.8953318904

Table 5: Software results of regression analysis according to model $Y=\exp(a*X_1 + b*X_2 + c*X_3+d)$

From the obtained results we will assess the parameters of independent variables, determine the value of coefficient of linear regression and assess the treated model.

The parameters with independent variables a, b, c and d are shown in the table (Table 6):

Regression Variable Results				
Paramet.	Value	Standard Error	t-ratio	Prob(t)
A	5.47777046820307E-02	9.18308825296083E-03	5.965063514	0.0
B	3.52389869011109E-02	1.51840198985584E-02	2.320794305	0.02841
C	-2.46247718122256E-02	2.54485929462844E-02	-0.967628028	0.34215
D	3.64327641709977	0.119679186463363	30.44202192	0.0

Table 6: Parameter values with independent variables

t-ratio - is the ratio of the estimated parameter and standard deviation of the same. The higher the value of "t-ratio" is, the influence of independent variable on the dependent is more significant. It can be seen in Table 6 that the value of "t-ratio" for the parameter (a) is the highest 5.965063514 and it indicates that the influence of the coefficient X1, i.e. the number of leaves per plant, is the highest.

Prob(t) - is the probability that the value of parameter with the independent variable is zero. This parameter is used to verify the null hypothesis, i.e. that the value of parameter with independent coefficient is zero, i.e. that the independent variable is not relevant to the assessment of the dependent variable. If the value of the parameter is higher, the probability that the null hypothesis is true is higher. It can be seen in the table that we have a relatively small values of "Prob (t)" for the parameters (b) and (c), which indicates that the probability that the parameter X2 will be zero is 2.841% and that X3 will be zero is 34.21%. The obtained results are in favor of the fact that the number of leaves per plant has the greatest influence on the leaf mass, followed by the medium leaf length and medium leaf width. Based on the variance analysis table we verify the assumption that all parameters with independent variables are equal to zero (the null hypothesis) against the assumption that at least one parameter with independent variable is different from zero. The value of "Prob (F)" indicates the percentage of probability that the null hypothesis is true. As a result of this verification, we obtain the information as to whether relation between dependent variable and the regression model is valid or not, i.e. whether the model is adequate or not.

Variance Analysis					
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob(F)
Regression	3	95272.3189871373	31757.4396623791	83.68874806	0
Error	26	9866.24188286265	379.470841648564		
Total	29	105138.56087			

Table 7: Variance analysis

It can be clearly seen in Table 7 that Prob(F) = 0, which completely eliminates the hypothesis that all parameters with independent coefficients are equal to zero and confirms that the independent variable can be determined by the assumed model.

The fact that the deviations of the predicted values from the actually measured values of the control group are relatively small says that the model parameters have been very well selected in this particular case (Figure 1).

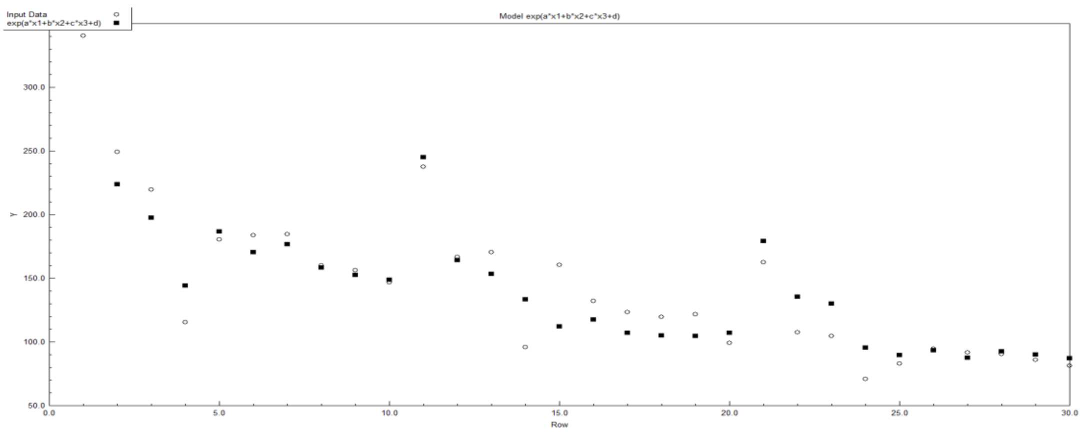

Figure 1 : Deviation diagram of predicted and empirically obtained values

The fact that the coefficient of nonlinear regression analysis R^2=0.9061596259, which is very close to the "best fit" value of R^2=1, says about the applicability and accuracy of the developed model (Table 5).

The final form of the model is given by the following expression:

$$Y = \exp(5.47777046820307E\text{-}02\,X1 + 3.52389869011109E\text{-}02\,X2 - 2.46247718122256E\text{-}02\,X3 + 3.64327641709977) \qquad (2)$$

4 CONCLUSIONS

The results of the research give us the possibility to draw conclusions:

- Significant divergence was determined for the analyzed morphological and productive characteristics, and it varied for the number of leaves per plant, from 12.89 (genotype 10 - *A. cruentus*) to 23.46 (genotype 1 - *A. mantegazzianus*); medium leaf length, from 14.77 cm (genotype 9 - *A. cruentus*) to 26.72 cm (genotype 1 - *A. mantegazzianus*); medium leaf width, from 6.30 cm (genotype 9 - *A. cruentus*) to 14.46 cm (genotype 1 - *A. mantegazzianus*) and leaf mass per plant, from 94.05 g (genotype 3 - *A. molleros*) to 246.81 g (genotype 1 - *A. mantegazzianus*).
- Regression model for assessment of morphological and productive characteristics of introduced species of the genus *Amaranthus L.* has been developed. The validity of the model is confirmed by very small deviations of empirically obtained values in comparison to corresponding values obtained by calculation. The number of leaves per plant is highlighted as a factor that specifically influences the assessed leaf mass per plant. By applying the regression model, is it possible to predict the leaf mass of all ten genotypes of introduced species of the genus *Amaranthus L.* in a very simple way.

REFERENCES

[1] D.M. Brenner, D.D. Baltensperger, P.A. Kulakow, J.W. Lehmann, R.L. Myers, M. Slabbert and B.B. Sleugh, *Genetic resources and breeding of Amaranthus*, Plant 242 Breed. Rev. 19, 227–285 (2000).

[2] A.F. Vrachev *K voprosu predvaritel'nogo ispytanija otdel'nyh vidov i obrazcov amarantt*,Vtoroj mezhdunarodnyj simpozium, Novye i netradicionnye rastenija i perspektivy ih prakticheskogo ispol'zovanija., Pushhin, 81-83 (1997).

[3] S. Das, *Systematics and taxonomic delimitation of vegetable, grain and weed 254 amaranths: a morphological and biochemical approach.*, Genet Resour Crop Evol. 255 59, 289–303 (2012).

[4] M. Costea, D.M. Brenner, F.J. Tardif, Y.F. Tan and M. Sun, *Delimitation of 250 Amaranthus cruentus L. and Amaranthus caudatus L. using micromorphology and 251 AFLP analysis: an application in germplasm identification,* Genetic Resources and 252 Crop Evolution 53, 1625–1633 (2006).

[5] A. Hayek, *Amaranthus L.*, Prodromus Florae Peninsulae Balcanicae 1, Berlin-Dehlem, 160-162 (1927).

[6] P. Allen, *Amaranthus L.*, Flora Europea 1, London, 105-111 (1964).

[7] W. Greuter, H.M. Burdet and G. Long, Med-Checklist 1. Berlin Dehlem, Geneve, (1984).

[8] J. Pancic, *Amaranthus L.* Flora of the Principality of Serbia, Belgrade , 586-587 (1874).

[9] S. Jovanovic S. and B. Pal, *Genus Amaranthus L. in Serbia; Taxonomy, Distribution and Ecology,*Willdenowia, 29, 1-2 (1999).

[10] A.E. Solov'eva, O.A. Zvereva, *Biohemicheskie svojstva ovoshhnyh amarantor*, Vtoroj mezhdunarodnyj simpozium, Novye i netradicionnye rastenija i perspektivy ih prakticheskogo ispol'zovanija, 16-20 ijunja 1997, Pushhin, 24-25 (1997).
[11] C. Daloz, *Amaranth as a leaf Vegetable Horticultural Observation in a temperature climate*, Proceedings of the Second Amaranth Conference, Rodale Press, 68-74 (1979).
[12] M.P. Kolesnikov, V.K Gins, *Biohimicheskij sostav i kremij amaranta i nekotoryh lekarstvennyh rastenij,* Vtoroj mezhdunarodnyj simpozium, Novye i netradicionnye rastenija i perspektivy ih prakticheskogo ispol'zovanija, 16-20 ijunja 1997, Pushhin, 20-21 (1997).
[13] I.I. Gerasimova, G.Z. Berson, *Sravnitl'naja ocenka produktivnosti vidov amaranta v uslovijah severnogo zaural'ja,* Novye i netradicionnye rastenija i perspektivy ih prakticheskogo i spol'zovanija, Vtoroj mezhdunarodnyj simpozium, Pushhin, 73-74 (1997).
[14] P.F. Kononkov, I.N. Vasjakin, *Rezul'taty izuchenija kollekcii amaranta v podmoskov'e,*Vtoroj mezhdunarodnyj simpozium, Novye i netradicionnye rastenija i perspektivy ih prakticheskogo ispol'zovanija, 16-20 ijunja 1997, Pushhin, 76-78 (1997).
[15] I.A. Thcernov, *The potential of Amaranthus L. and the problem of leaf protein. Green vegetation fractionation,* Proceedings of the V. Intern. Congress on Leaf Protein Research, Rostov on Don, V. 3., 44-50 (1996).

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