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Research Article

Research on the morphology, biology, productivity and yields quality of the *Amaranthus cruentus* L. in the southern part of Romania

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Abstract

Currently, according to the specialists in the field, *Amaranthus* species are part of alternative agricultural crops recommended for organic farming. In this context, our scientific approach is to analyse the adaptability of these species in the specific conditions of the southern part of Romania (Reviga village, Ialomita County). Thus, for two consecutive years, two varieties of *Amaranthus cruentus*, namely 'Bolivia 153' and 'Golden Giant', were studied regarding: morphology, biology, cultivation technology, plant productivity and quality of yields in the organic farming conditions. After the study period, the 'Golden Giant' variety was characterized by the following: 8 days - sowing-emergence period; flowering start on 21 July; 124 days - vegetation period; 839.3 Growing Degree Days (GDD) (Σ t °C > 15 °C); 23.24 g - grains mass per plant; 1.375 g - Thousand Weight Grains (TWG); 2,647 kg ha^{-1} - grains yields. By comparison, 'Bolivia 153' variety plants were presented as follows: 11 days - sowing-emergence period; flowering start on 21 July; 127 days - vegetation period; 842.4 GDD; 22.09 g - grains mass per plant; 1.46 g TWG; 23.78 kg ha^{-1} - grains yields. In average, the chemical composition of *Amaranthus cruentus* grains was: 15.20% proteins; 51.70% starch; 5.96% lipids; 13.36% cellulose and 3.35% ash. In conclusion, the experimentation area proved to be favourable to *Amaranthus cruentus* cultivation, so that the tested varieties behaved well, had a fairly uniform emergences, and the good level of grains yields and quality.

Keywords: alternative crops; *Amaranthus cruentus*; grains yield; organic agriculture; yields quality

Introduction

The economic, social and political evolution of human society in the last decades has brought to the fore the question of natural resources, scientists increasingly asking the extent to which these resources will be able to support economic development in the future and will provide food for a growing population, and will contribute to the eradication of underdevelopment (FAO, 2017). The accentuation of major socio-economic phenomena (demographic explosion, tendency of natural resources depletion, deterioration of the quality of the environment, pollution), have led to search and to find the alternative solutions for a sustainable perspective

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of the environment and biodiversity (Haros and Schoenlechner, 2017). In this context, the organic farming system is also included, as an alternative system of agricultural production, which respects the environment, biodiversity and natural resources. Also, alternative crops promoted by organic farming system are based on these principles and represent an alternative of the plant species commonly cultivated by farmers. An alternative crop could be defined as an agronomic crop not usually grown in a geographic reason, selected for use due to potential high sale value or specialized benefit to the farming system (Isleib, 2012). A crop can be very common in one geographic area and considered an alternative in another (Isleib, 2012). Crop diversity is a key tenet of organic agriculture. Having multiple crops that fill distinct niches in an agroecosystem improves the ability to manage weeds, diseases and insect pests as well as potentially improving the environmental performance of the cropping system (Duwayri, 2001). Research can help overcome production and market obstacles that enable the successful introduction of alternative crops (FAO, 2017). Risk reduction through diversification (related to climatic and biotic vagaries, particularly in fragile ecosystems and commodity fluctuations) by expanding locally adapted or introducing novel varieties and related production systems, will contribute to improved food security and income generation for resource poor farmers and protect the environment (Duwayri, 2001). In this sense, *Amaranthus* species with *Chenopodium quinoa*, represented the most popular alternative crop species. These species have the centres of origin in South America and were brought in Europe by the Spanish conquistadors, as an ornamental plant (16th century). Until the sec. XIX the *Amaranthus* species were used as an ornamental plant, but also for the consumption of green leaves, in most areas with tropical climate, and in Africa it became an important vegetable (Cole, 1979). Amaranth is a crop with high potential for economic exploitation similar to maize, wheat, sorghum, barley, rice, and soybean (Innovation NRCACT, 1984; Rastogi and Shukla, 2013; Akin-Idowu, 2017). Amaranth has an excellent nutritional value and high genetic and phenotypic diversity. Their valuable nutritional content, their adaptability to harsh environments, their diversity of uses, and the food culture and traditions associated with these grains, are at the basis of their extensive use in the Andes over centuries (Giuliani *et al.*, 2012). *Amaranthus* species have different uses: mixtures of cereals for bread or for breakfast, crêpes, pastries, cakes, as raw material in the industry (syrups, diet products, starch, and oil), salads. They can be used as an excellent feed for animals, but also as medicinal plants, in digestive disorders or as a disinfectant (Toader and Roman, 2011).

Amaranthus species is considered to potentially offer an alternative crop in temperate and tropical climate (Das, 2016). In recent decades, amaranth grain has been extensively studied for its remarkable nutritional profile and agricultural characteristics, e.g., having a short cultivation period and being drought resistance (Najdi Hejazi *et al.*, 2016). Introduction of amaranth as a human food has been slow, but today it is produced and used as a grain or leafy vegetable in India, China, Southeast Asia, Mexico, the Andean highlands in South America and the United States (Robert, 1996). The Nebraska panhandle has become the most concentrated area of production of grain amaranth in the US (Rani, 2017). This statement is supported because the crop is easy to cultivate and is not pretentious with the cultivation conditions, it can also be used as a flour for obtaining pasta, but also for extracting lysine and tryptophan, starch, oil squalane, substances needed for the drug or cosmetics industry (Alvarez-Jubete *et al.*, 2010). The leaves can be consumed as a soup, but also for the extraction of proteins, dyes or inflorescences can be used for various decorations (Toader and Roman, 2011). *Amaranthus* grains have a high nutritional value due to the presence, in a large quantity, of important biochemical compounds for human nutrition and health (Nadathur, 2016). Most of the biochemical components (proteins, lipids, minerals, vitamins), are present in greater quantity, compared to other species (Nadathur, 2016). Orona-Tomayo and Paredes-Lopez, in 2017, reported that, for the different *Amaranthus* species, proteins can reach up to 19.3%, even 20%; the richness of the essential amino acids was also highlighted: 5-7% lysine (g 100^{-1} g protein), 3-4% tryptophan, 3-4% leucine, which gives it a high nutritional value compared to the conventional cereals (Orona-Tamayo and Paredes-Lopez, 2017).

Information about the phenological growth stages of crops is fundamental and useful to agriculture. These researches can provide valuable data for the planning, organization and timely execution of certain agricultural activities such as those of prevention and protection that require detailed information on the specific vegetation phases of a crop (the appearance of the inflorescences, the flowering, the stages of maturity, etc.). These data can be used in mathematical modelling, which can predict the timing of phenological events according to certain conditions: temperature, precipitation, duration of sun shine, etc (Tonnang *et al.*, 2018, Erten *et al.*, 2014).

However, details about the growth and development of amaranth is fundamental to its cultivation, but reports on the phenological growth stages, development, and the life cycle of amaranth are limited (Martínez-Núñeza *et al.*, 2019; Artemyeva *et al.*, 2019). The importance of this research derives from the improve knowledge about ecology, biology and productivity of *Amaranthus cruentus* in South part of Romania, also about possibility to introduce of this plant in crops rotation system of organic farming.

Materials and Methods

Experimental design

The research was organized with the purpose of studying the morphology, biology, productivity and yields quality of *Amaranthus cruentus* species, respectively, two varieties, 'Bolivia 153' and 'Golden Giant', in terms of adaptability to the organic farming conditions of Romanian, in 2017-2018 period.

The experimental field belongs to a farm in Reviga village (44°41'34"N 27°06'26"E) (Ialomita County), in South part of Romania. The sites were managed according to organic agriculture guidelines (EC 834/2007 and EC 889/2008). The farm soil was analysed by Ialomita County Office of Pedological and Agrochemistry Studies. The pH of soil was weakly acidic oscillating between 6.1-6.5, in average 6.3. Total soluble salts for the analysed samples indicate soil without salinization problems (non-saline soils, with values <0.100%). Mineral nitrogen represents the amount of soil content in changeable and accessible form nitric and ammoniacal nitrogen. The results indicate normal soil supply in mineral N (8.4 g 100 g^{-1} of soil). The supply in Kalium (K) (potentially assimilable) extractable in Aluminium of the soil is very good for the analysed samples (> 200 K ppm). Content in humus was medium supplied for the analysed soil (2.1-4.0% humus).

The biological material for sowing came from Germany, certified by the inspection and certification body for organic agriculture system. The previous crops were peas (*Pisum sativum*, pulses crops category) to benefit from the nitrogen fixed by this plant. No other fertilizer was applied.

The soil tillage consisted in a disking after the harvesting of the previous crop and the release of vegetal debris, followed by the plowing at 25-30 cm depth. In the spring, the field was disked, followed by the preparation of the germinal bed with the combiner, at a depth of 6-8 cm.

The sowing was done by hand, in 20 of April for both years, at a depth of 1-2 cm. The area of the plot was 5 m-2 (2.5 m long, 2 m wide). The experiment was organised by Randomized Block Design Method, in four replications. The density was 100,000 grains ha^{-1}, with 50 cm between plants rows. During on the vegetation period the weed control was executed manually. Other pest or diseases not observed. The harvesting was made manually.

Collecting data, measurements and methods

During the vegetation period until harvesting, phenological observations and biometric measurements of *Amaranthus* plants were made on the dynamics (at each 8-10 days). Determinations concerned: emergence date, plants height, nodes of stem, leaves formation and their number, Leaf Area Index, appearance data of inflorescence, flowering, maturity and crop density.

Growing Degree Days (GDD) has been used to calculate the durations and thermal requirements for each phenophase. "To calculate the daily thermal units, the equation of Gilmore and Rogers (1958) was used ($GGD = [(Tmax + Tmin)\ 2^{-1}] - Tb$), where Tmax-Tmin are daily maximum and minimum air temperatures, respectively, Tb is the base temperature, evaluated at 15 °C (Gilmore and Rogers, 1958)". The maximum and minimum daily temperatures were obtained from Ialomita weather station. The average multiannual temperature was 10.5 °C, with 1.0 °C higher than Romania's average multiannual temperature of 9.5 °C. The hottest month of the years was July, with a monthly average of 22.1 °C, followed by August with 21.1 °C, and the coldest was January with -3.0 °C. Separately by years it is found that in the years of experimentation, the temperatures have registered great differences in comparison with the multiannual monthly averages. Thus, for the year 2017-2018, the values of the average monthly temperature were recorded with 2.0-6.5 °C higher than the multiannual average. The warmest month was June, with the average temperature higher by 6.5 °C than the multiannual average; at a slight difference were the temperatures in July, with 5.7 °C and August, with 4.5 °C (Figure 1).

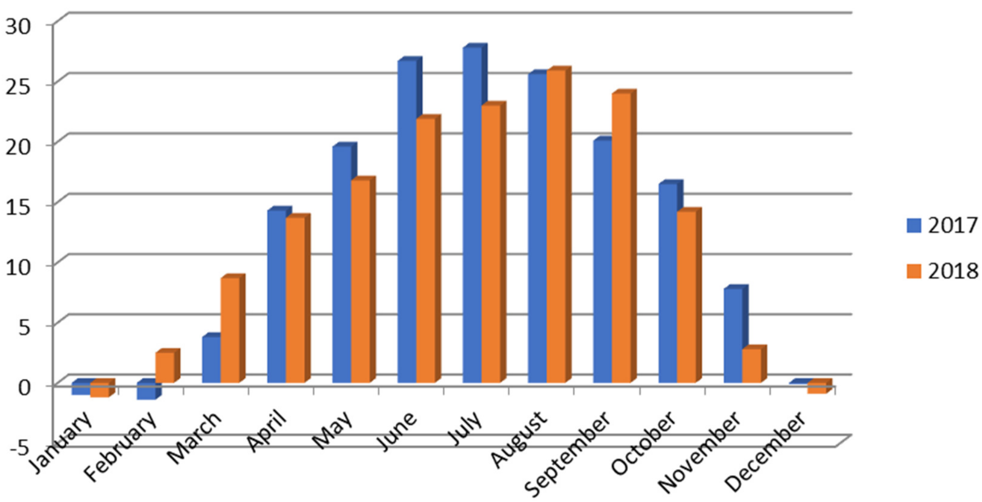

Figure 1. Average air temperature registered in experimental area

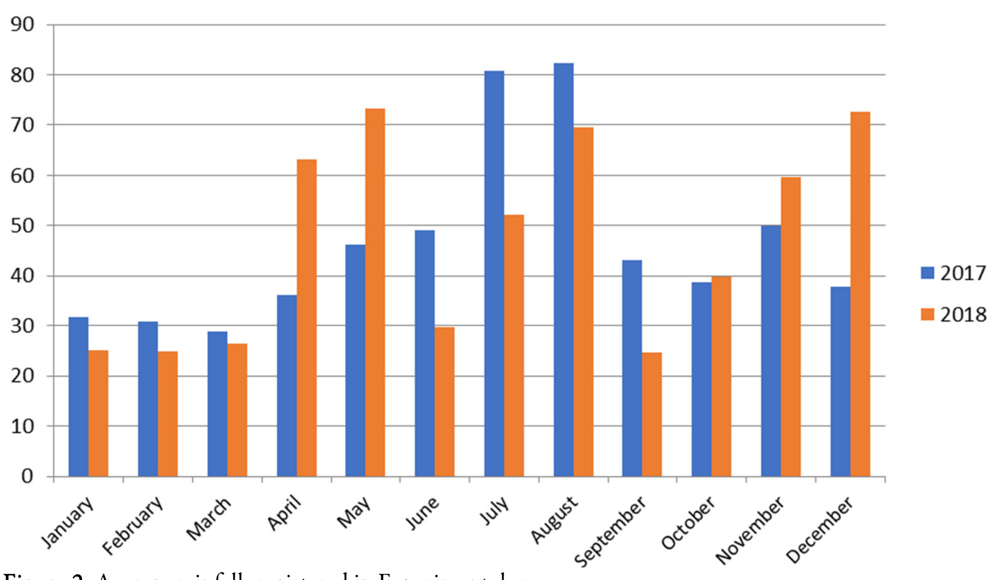

Figure 2. Average rainfalls registered in Experimental area

For the second year of the research (2018) the annual amount of rainfall was 561.3 mm, slightly higher than the multiannual average of 556.1 mm. In this agricultural year the richest precipitations were recorded in May (73.4 mm), more with 5.7 mm, followed by December (72.6 mm), with 35.9 mm more than the average, multiannual monthly. The amount of precipitation in October, November and December was 172 mm, compared to 113.1 mm, which was the multiannual average. The smallest quantities were registered in February (24.8 mm) with a deficit of 7.3 mm compared to the multiannual average and September (24.7 mm), with a minus of 8.9 mm (Figure 2).

10 plants from each plot were used for determinations of productivity elements in laboratory. Have been eliminated the marginal plants to avoid the possible errors. After manually harvesting, in laboratory was made the number and quantity of grains per plants and TWG. For the TWG determination was used the standard method with 2 repetitions of 500 pure seeds.

Chemical analyses of grains were performed in Yields Quality Laboratory of Crop Science Department, Faculty of Agriculture, University of Agronomic Sciences and Veterinary Medicine of Bucharest. The equipment was a spectrophotometer (Instalab 600) calibrated by a company from Novisad (Serbia) to determine the content of dry matter, crude protein, starch, lipids, cellulose and ash. The Instalab 600 uses Near Infrared (NIR) technology and a statistical math treatment to predict the percent of constituent concentration within a sample.

Statistical procedures

Data presentation was done by processing the media for replications and for years. Significant statistical differences were determined by the Fisher's least significant differences (LSD) test and also the Student Neuman Keuls (SNK) test with the ARM 8.5 program.

Results and Discussion

Dynamics of plants height

From the analysis of the data contained in Table 1, it turns out that, in 2017-2018 periods, no significant differences were found between the varieties experienced, in terms of vegetation dynamics.

Under normal conditions, amaranth plants are as high as 2.2 m, making their handling difficult (Martínez-Núñeza *et al.*, 2019). On average, the emergence was observed after 12 days of sowing, for the 'Bolivia 153' variety and after 15 days for the 'Golden Giant' variety. The duration of the vegetation period was 124 days for the 'Golden Giant' variety and 3 days longer for the 'Bolivia 153' variety, and the thermal consumption had values close to both varieties, namely 839.3 GDD for the 'Golden Giant' variety and 842.4 GDD for the 'Bolivia 153' variety.

The inflorescence appeared after 56 days of vegetation or after accumulation of 248.3 GDD in the case of the 'Bolivia 153' variety, and 2 days later, after the accumulation of 291.2 GDD, in the case of the 'Golden Giant' variety.

In terms of the dynamics of plant growth in height, some differences between varieties were found. Further, until maturity, the growth was 22.9 cm, with an average rate of 0.54 cm day^{-1} in the case of the 'Bolivia 153' variety, and 18 cm, with an average rate of 0.43 cm day^{-1}, in the case of the 'Golden Giant' variety.

Dynamics of nodes formation

The formation of nodes at 'Bolivia 153' variety took place during 71 days of vegetation, in which 12 nodes of stem were formed, with an average rhythm of 5.91 days $node^{-1}$. The first node was observed after 11 days from emergence, when 7.9 GDD were accumulated, and the intervals between the formation of nodes 2 and 5 were on average 7 days $node^{-1}$, with an average consumption of 28.37 GDD $node^{-1}$. In parallel with the intense increase in height of the stem, the rate of node formation also became more alert, so that the following 5 nodes at intervals of 3.6 days $node^{-1}$, with an average thermal consumption of 27.46 GDD $node^{-1}$. Node formation continued for another 14 days, resulting 2 nodes, at an interval of 7 days $node^{-1}$ and with an average heat consumption of 69.9 GDD $node^{-1}$ (Table 2).

Table 1. Dynamics of *Amaranthus cruentus* plants height (Reviga experimental field)

Data	'Bolivia 153' variety			'Golden Giant' variety		
	Height plants (cm)	Days from emergence	GDD (Σ t > 15 °C)	Height plants (cm)	Days from emergence	GDD (Σ t > 15 °C)
12 May	4.8	11	5.6	3.2	8	2.7
21 May	8.1	20	32.8	6.9	17	29.7
28 May	15.5	28	63.8	13.6	25	70.7
3 June	29.5	35	104.2	26.9	33	101.1
10 June	51.7	42	136.7	37.9	39	133.6
18 June	63.4	50	189.2	54.7	47	186.1
24 June	81.8	56	248.3	76.5	53	245.2
1 July	106.6	63	323.2	100.3	60	320.1
9 July	118.9	71	399	116.6	68	395.9
16 July	137.8	78	455.7	125.9	75	452.6
23 July	143.8	85	518.2	131.8	83	515.1
30 July	149.8	92	568.3	135.3	89	565.2
7 August	152.2	100	643.8	138.6	97	640.7
14 August	157.5	107	707.5	141.9	104	704.4
21 August	161.5	114	769.3	143.8	111	766.2
28 August	165.5	121	815.2	147.5	118	812.1
3 September	166.7	127	842.4	149.8	124	839.3

Table 2. Dynamics of stem nodes (Reviga experimental field)

Nodes per plant							
'Bolivia 153' variety				'Golden Giant' variety			
Number of stem nodes (Average)	Period		GDD (Σ t > 15 °C)	Number of stem nodes (Average)	Period		GDD (Σ t > 15 °C)
	Days from emergence	Days of previous node formation			Days from emergence	Days of previous node formation	
1	11	-	7.9	1	13	-	14.1
2	20	9	34.9	2	21	8	51.3
3	27	7	62.8	3	27	6	78.9
4	33	6	96.4	4	33	6	101.1
5	39	6	121.9	5	38	5	128.6
6	43	4	144.1	6	42	4	161.4
7	47	4	169.4	7	45	3	175
8	50	3	189.2	8	47	2	186.1
9	53	3	212.5	9	50	3	211.8
10	57	4	259.2	10	55	5	281.7
11	63	6	323.2	11	60	5	321.1
12	71	7	399	12	67	7	388.6
-	-	-	-	13	75	8	452.6

Dynamics of leaves formation

The dynamics of leaves formation is presented in Table 3.

The plants of the 'Golden Giant' variety formed during 75 days of vegetation and after a thermal consumption of 452.6 GDD, 13 nodes, with an average rhythm of 5.76 days node^{-1}.

The formation of the first node, for 'Golden Giant' variety, was noted 13 days after emergence, after a thermal consumption of 14.1 GDD, and the following 4 nodes were formed within a period of 25 days, with an average rhythm of 6.25 days node^{-1} and an average consumption of 28.62 GDD node^{-1}. The formation of nodes 6-9 was staggered over 12 days, the average rhythm being 3 days node^{-1} and the thermal consumption of 12.6 GDD node^{-1}. The process of node formation continued for another 20 days, resulting 4 nodes, with an average rhythm of 5 days node^{-1}.

Table 3. Dynamics of *Amaranthus cruentus* leaves formation (Reviga experimental field)

Data	'Bolivia 153' variety				'Golden Giant' variety			
	Number of leaves		Days (from emergence)	GDD (Σ t >15 °C)	Number of leaves		Days (from emergence)	GDD (Σ t >15 °C)
	From sowing	Days of the previous leaf's formation			From sowing	Days of the previous leaf's formation		
12 May	2	0	11	5.6	2	-	8	2.7
21 May	4	2	20	32.8	3	1	17	29.7
28 May	6	2	28	63.8	5	2	25	70.7
3 June	8	2	35	104.2	7	3	33	101.1
10 June	11	3	42	136.7	10	3	39	133.6
18 June	15	4	50	189.2	14	4	47	186.1
24 June	21	6	56	248.3	20	6	53	245.2
1 July	26	5	63	323.2	26	6	60	320.1
9 July	30	4	71	399	30	4	68	395.9
16 July	33	3	78	455.7	33	3	75	452.6
23 July	35	2	85	518.2	35	2	83	515.1
30 July	36	1	92	568.3	37	2	89	565.2
7 August	29	-	100	643.8	38	1	97	640.7
14 August	23	-	107	707.5	28	-	104	704.4
21 August	18	-	114	769.3	24	-	111	766.2
28 August	13	-	121	815.2	18	-	118	812.1
3 September	8	-	127	842.4	11	-	124	839.3

In the case of the 'Bolivia 153' variety, the leaves formation (36 leaves in total) was carried out over a period of 92 days of vegetation, in which the thermal accumulation was 568.3 GDD; the average rate was 2.55 days leaf^{-1} and the average heat consumption was 15.68 GDD leaf^{-1}. On May 12, after 11 days from emergence, *Amaranthus* plants belong to the 'Bolivia 153' variety had 2 leaves, with a leaves area of 1.1 cm-2 plant^{-1}; after 29 days, the number of leaves reached 11 leaves, with an area of 529.3 cm-2 plant^{-1}, resulting in an average rate of 2.63 days leaf^{-1} and an average consumption of 12.42 GDD leaf^{-1}. There were 29 days when the rate of leaf development was more alert. In this interval, 19 leaves were formed, with an average rate of 1.52 days leaf^{-1} and a thermal consumption of 13.8 GDD leaf^{-1}; at the end of this interval, the Leaf Area Index was 2543.7 cm-2 plant^{-1}. The maximum value of the leaves surface, of 3,401.6 cm-2 plant^{-1}, was reached 21 days later, when the plants had a total of 36 leaves (Table 3).

Table 4 contain data regarding Leaf Area Index of *Amaranthus cruentus* varieties, in 2017-2018 periods.

Table 4. Dynamics of *Amaranthus cruentus* Leaf Area Index (Reviga experimental field)

Data	'Bolivia 153' variety			'Golden Giant' variety		
	Leaf Area Index (cm-2 plant^{-1})		Days from emergence	Leaf Area index (cm-2 plant^{-1})		Days from emergence
	Value	Days of previous nodes formation		Value	Days of previous nodes formation	
12 May	1.1	-	11	0.9	-	8
21 May	28.6	27.5	20	21.4	20.4	17
28 May	57.9	29.3	28	46.2	24.7	25
3 June	123.1	65.2	35	115.9	69.7	33
10 June	529.3	406.2	42	489.5	373.6	39
18 June	1,208.7	679.4	50	1,023.7	534.2	47
24 June	1,723.9	515.2	56	1,598.4	574.7	53
1 July	2,183.6	359.7	63	2,034.6	436.2	60
9 July	2,543.7	260.1	71	2,353.9	319.3	68
16 July	2,897.5	254	78	2,772.8	418.9	65
23 July	3,264.9	67.4	85	3,148.9	376.1	83
30 July	3,401.6	36.7	92	3,318.9	170	89
7 August	3,001.5	-	100	3,357.7	38.8	97
14 August	2,009.5	-	107	3,189.3	-	104
21 August	1,201.9	-	114	1,959.3	-	111
28 August	678.5	-	121	984.5	-	118
3 September	245.6	-	127	395.7	-	124

Regarding the dynamics of leaves formation for the 'Golden Giant' variety, it can be emphasized that the more alert rate was noticed during the period June 10-July 16, in which 23 leaves were formed. In this interval the sum of the useful temperatures was 319 GDD, resulting an average of 1.60 days leaf^{-1} formation rate and a consumption of 13.86 GDD leaf^{-1}. On May 12 (after 8 days after emergence) the Leaf Area Index was 0.9 cm-2 plant^{-1}, then, as the vegetation advanced, the leaf area evolved upwards, so that on June 3 or after the accumulation of 101.1 GDD the leaf surface reached 115.9 cm-2 plant^{-1}; a month later, on July 1, a leaf area of 2,034.6 cm-2 plant^{-1} was determined, and a maximum leaf area of 3,357.7 cm-2 plant^{-1} was reached on August 7, after accumulating 640.7 GDD.

Dynamics of inflorescence formation, flowering and grains formation

Under the conditions of 2017 year, the inflorescence appeared on the 'Bolivia 153' variety plants after 56 days after emergence or 248.3 GDD accumulations, while on the 'Golden Giant' variety plants, the beginning of the inflorescence formation was noted after 58 days after the emergence, and a thermal accumulation of 291.2 GDD. The beginning of flower opening was started after 22 of days for 'Bolivia 153' variety and 23 days for 'Golden Giant' variety. The maturity stages developed during 35 of days for "Bolivia 153' variety and 9 days faster for the 'Golden Giant' maturity. The full maturity means 842.4 GDD of 'Bolivia 153' variety and 839.3 GDD of 'Golden Giant' variety (Table 5).

Productivity elements and grains yields

Following the analysis of the productivity elements, the 'Bolivia 153' variety has a number of 13,660 grains per plant, with a mass of 18.23 g plant^{-1}; 15,876 grains plant^{-1} were determined at the 'Golden Giant' variety, their grains mass being 21.75 g plant^{-1}, in 2017. In 2018, the values were superior at all indexes. TWG was 1.41 g of the 'Bolivia 153' variety, being characterized by slightly larger grains, with TWG of 1.45 g, while the 'Golden Giant' variety formed smaller grains, with a TWG of 1.37 g (Table 6).

Table 5. Dynamics of *Amaranthus cruentus* inflorescence formation, flowering and grains formation (Reviga experimental field)

Amaranthus cruentus varieties	Data	Length of inflorescence (cm)	Phenophase	Days from emergence	GDD (Σ t > 15 °C)
'Bolivia 153'	24 June	1.8	The appearance of the inflorescence	56	248.3
	9 July	15.6	-	71	399
	16 July	25.4	The beginning of the flower opening	78	455.7
	30 July	32.6	The beginning of grains formation	92	568.3
	21 August	35.4	-	114	769.3
	3 September	37.1	Full maturity	127	842.4
'Golden Giant'	29June	1.1	The appearance of the inflorescence	58	291.2
	16 July	13.6	-	65	452.6
	21 July	27.4	The beginning of the flower opening	81	493.6
	5 August	34.7	The beginning of grains formation	95	621.7
	21 August	36.9	-	111	766.2
	3 September	39.8	Full maturity	124	839.3

Table 6. Productivity elements of *Amaranthus cruentus* (Reviga experimental field)

Year	Productivity elements	'Bolivia 153' variety	'Golden Giant' variety	Average
2017	Height of plant (cm)	166.7	149.8	158.3
	No of plants ha^{-1}, at harvesting	92,000	98,000	95,000
	No of grains plant^{-1}	13,660	15,876	14,768
	Mass of grains plant^{-1} (g)	18.23	21.75	19.99
	TWG (g)	1.45	1.37	1.41
2018	Height of plant (cm)	178.3	169.1	173.7
	No of plants ha^{-1}, at harvesting	98,000	99,000	98,500
	No of grains plant^{-1}	18,911	22,921	11,469.96
	Mass of grains plant^{-1} (g)	30.06	31.63	30.85
	TWG (g)	1.59	1.38	1.49

Rusu *et al.* (2009) and Marin *et al.* (2011), obtained 2,530.36 kg ha^{-1} of the grains production of *Amaranthus* sp. on the Somesan Plateau, out of the 12 *Amaranthus* varieties studied, 7 recorded grains productions over 4,000 kg ha^{-1} (4 varieties belonging to *A. cruentus* L. and 3 varieties of *A. hypochondriacus* L.) (Rusu *et al.*, 2009; Marin *et al.*, 2011).

In our experiments, the grains yields were, in average, 2,002 kg ha^{-1} in 2017 and 3,023 kg ha^{-1} in 2018. Regarding grains yields, the 'Golden Giant' variety surpassed the 'Bolivia 153' variety distinctly significant in both 2017 and 2018 years with 91 kg ha^{-1}, respectively 179 kg ha^{-1} (Table 7). Also, the same variety has a good production in 2018. Also, in 2018, this variety behaved well, significantly exceeding the average.

Table 7. Grains yields of *Amaranthus cruentus* varieties (Reviga experimental field)

Year	2017			2018		
Variety	Grains yield (kg ha^{-1})	Difference of average (kg ha^{-1})	Significance	Grains yield (kg ha^{-1})	Difference of average (kg ha^{-1})	Significance
'Bolivia 153'	1,822	- 180	ooo	2,933	- 90	oo
'Golden Giant'	2,181	179	***	3,114	91	**
Average	2,002	Control	-	3,023	Control	-

LSD 5% = 141 kg ha^{-1}; LSD 5% = 57.2 kg ha^{-1}; LSD 1% = 214 kg ha^{-1}; LSD 1% = 86.6 kg ha^{-1}; LSD 0.1% = 344 kg ha^{-1}; LSD 0.1% = 139.1 kg ha^{-1}

Chemical composition and quality yields

The values for protein content were on average 16.11%. Higher protein content was determined for the 'Golden Giant' variety (17.03%) and lower in the 'Bolivia 153' variety (15.38%) (Table 8).

Table 8. Chemical composition of *Amaranthus cruentus* grains (Reviga experimental field) (% d.m.)

Variety	Proteins	Starch	Lipids	Cellulose	Ash
2017					
'Bolivia 153'	15.38 c	51.56 c	6.41 d	5.23 b	3.34 b
'Golden Giant'	16.82 b	52.92 b	7.11 a	6.67 a	3.41 a
Average	16.10	52.24	6.76	5.95	3.375
2018					
'Bolivia 153'	15.20 d	51.45 d	6.81 c	5.05 c	3.10 b
'Golden Giant'	17.03 a	53.2 a	6.68 c	6.67 a	3.20 c
Average	16.12	52.33	6.75	5.86	3.15
2017-2018 Average	16.11	52.28	6.75	5.91	3.26
Statistical results					
LSD (P=0.05)	0.052	0.069	0.103	0.071	0.015
Standard Deviation	0.032	0.043	0.064	0.044	0.010
CV	0.2	0.08	0.95	0.75	0.29
Bartlett's X2	6.556	8.972	18.194	11.345	0.971
P (Bartlett's X2)	0.087	0.03*	0.001*	0.01*	0.808
Replicate F	1.777	1.120	0.763	1.538	1.000
Replicate Prob (F)	0.2214	0.3911	0.5425	0.2708	0.4363
Treatment F	3,477.124	1,761.780	81.365	1,589.377	936.996
Treatment Prob (F)	0.0001	0.0001	0.0001	0.0001	0.0001

Means followed by same letter do not significantly differ (P=0.05, Student-Newman-Keuls)
Mean comparisons performed only when AOV Treatment P (F) is significant at mean comparison OSL.

The starch content was on average 51.7%, with values ranging from 51.0% in the 'Golden Giant' variety to 52.4% in the 'Bolivia 153' variety. Regarding lipids, 'Bolivia 153' is best presented with a content of 6.11%, compared to the 'Golden Giant' variety, at which 5.81% lipids were determined. The cellulose content was on average 13.36%, a higher value, 15.05%, being registered in the 'Golden Giant' variety, and the ash content was on average 3.3%, the highest value, of 3.4%, being analysed in the 'Bolivia 153' variety.

In average, the protein production per ha was 404.9 kg ha^{-1}. Something more being obtained from the 'Golden Giant' variety, i.e. 530.3 kg ha^{-1}, and less from the 'Bolivia 153' variety, respectively, 280.0 kg ha^{-1} (Table 9).

Table 9. Protein production of *Amaranthus cruentus* (kg ha^{-1}) (Reviga experimental field)

Variety	Average of grains yields (kg ha^{-1})	Production of proteins (kg ha^{-1})	Difference of average	Significance
2017				
'Bolivia 153'	1822	280.0	-42.3	ooo
'Golden Giant'	2181	366.8	44.5	***
Average	2002	322.3	Control	-
LSD 5% = 2.25 kg ha^{-1}; LSD 1% = 3.62 kg ha^{-1}; LSD 0.1% = 5.25 kg ha^{-1}				
2018				
'Bolivia 153'	2933	445.8	-41.7	ooo
'Golden Giant'	3114	530.3	42.8	***
Average	3023	487.5	Control	-
LSD 5% = 2.94 kg ha^{-1}; LSD 1% = 4.18 kg ha^{-1}; LSD 0.1% = 6.05 kg ha^{-1}				

The high protein content of the 'Golden Giant' variety is noticeable, of over 16% in 2017 and over 17% in 2018. This proves the superiority of the grains of this variety which exceeded the average very significantly in both years of experimentation compared to the common wheat which has on average around 12-14%.

Conclusions

On average, for two years of experiments, the two varieties of *Amaranthus* were sowing in the second decade of April (April 17-19), plants emerged after 12-15 days, during the first decade of May and flowering in the last decade of June. From a morphological point of view, amaranth plants were characterized by: 149.8-166.7 cm of height plants; 12-13 steam nodes per plant; 36-38 leaves per plant and 3,301.6-3,357.7 cm-2 plant^{-1} Leaf Area Index. The harvest maturity was reached in the first decade of September, after 124-127 days of vegetation, in which 839.3-842.4 GDD were accumulated. The productivity elements showed: 92,000-98,000 plants per ha - density of plants; 18.23-31.63 g grains plants^{-1}; 1.37-1.59 g TWG. In terms of chemical composition, amaranth grains contain on average: 15.20-17.03% proteins; 51.45-53.2% starch; 6.41-7.11% lipids; 5.05-6.67% cellulose; 3.10-3.41% ash. In both years of research, the most productive variety proved to be the 'Golden Giant' variety, which yield was over 3,000 kg ha^{-1} and around 400 kg ha^{-1} proteins. Regarding organic agriculture technology for growing, it is recommended to sow the *Amaranthus cruentus* varieties in the second half of April, at the distance 50 cm between rows and density of 100,000 grains ha^{-1}. For weed control, repeated weeding will be applied whenever necessary, manual or mechanical. In conclusion, *Amaranthus* species reflect a good ability to adapt to the conditions of south part of Romania, and cultivation in organic agriculture conditions, with good yields and high level of quality grains.

Authors' Contributions

The authors contributed equally to the writing of the paper. All authors read and approved the final manuscript.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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