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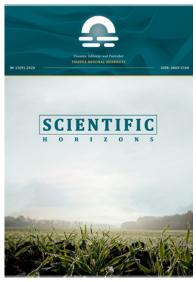

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Yield of Amaranth (*Amaranthus*) Depending on the Cultivar in the Conditions of Ukrainian Western Forest-Steppe

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Abstract. Amaranth is called the culture of the future due to its unique food, feeding and medicinal properties. The acreage of Amaranth in Ukraine is very small, which can be explained by the lack of adaptive cultivation technologies, especially for growing this crop for grain. The purpose of the research was to establish the most productive cultivars for growing in the conditions of excessive and sufficient moisture in the western forest-steppe on dark grey soil. For this purpose, field research was conducted in the experimental field of Lviv National Agrarian University. The total area of the site was 30 m^2, recording – 20 m^2. The studies were conducted in three repetitions. The authors studied seven of the most common cultivars of Amaranth in Ukraine: Kharkivskyi 1, Lera, Sam, Studentskyi, Polishchuk, Aztec, Ultra. It was established that the yield of amaranth considerably depended on the hydrothermal conditions of the year. It was lower in years with excessive rainfall in the first half of vegetation (2019 and 2020). The highest grain yield (2.46-4.35 t/ha) was formed in 2021 when the amount of precipitation in May, June and July was within the normal range. A strong inverse correlation was established (r=-0.82–r=-0.95) between the yield of amaranth cultivars and the amount of precipitation. The highest grain yield (4.03 t/ha) among the studied amaranth cultivars was obtained in Kharkivskyi 1. The lowest yield was formed in the Ultra cultivar (1.97 t/ha), which is less than in the Kharkivskyi 1 cultivar by 2.06 t/ha. The study of elements of the yield structure showed that the height of the plant had a positive effect (r=0.63) on the level of amaranth grain yield, while average relationship was observed between panicle length and yield (r=-0.36). The weight of 1000 seeds in the cultivars ranged from 0.74-0.88 g. The low mass of seeds per plant had the greatest impact on yield (r=0.99). The highest yield of amaranth of the Kharkivskyi 1 cultivar was formed with the following ratio of the main elements of the crop structure: the number of plants – 21 p/m^2 and the mass of seeds from the plant – 19.2 g. To obtain a high stable yield of amaranth grain, additional research is required to clarify the main elements of cultivation technology for these soil and climatic conditions

Keywords: amaranth, cultivars, yield gain, weight of 1000 seeds, hydrothermal conditions, structural elements

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INTRODUCTION

Amaranth is grown as a grain, feeding, vegetable, medicinal, and ornamental crop. It has considerable prospects for growing in Ukraine. V.V. Saratovsky [1] notes that even the climatic conditions of the Carpathian region are suitable for growing amaranth. Its yield can reach 30 dt/ha, amaranth seeds contain 12-18% of protein and 5-17% of oil [2]. Its main value is the ability to accumulate a lot of protein in the grain and leaves. Amaranth protein has a high nutritional value and is estimated at 75-80 points, while cow's milk protein – 72, wheat – 57, corn – 44, soy – 68 points [3]. The value of amaranth oil lies in the fact that it contains squalene (8%), which in combination with tocopherol regulates lipid metabolism. Amaranth is considered a "natural biopharmaceutical" plant [4].

Amaranth products prevent various diseases. It can increase immunity, which is very important now, in the era of coronavirus. Amaranth oil is not inferior in quality to sea buckthorn oil and is widely used for the treatment of radiation sickness, burns, etc. [2]. Production areas in Europe are quite low, only about 1000 hectares. Amaranth is grown in Slovakia, Hungary, and Italy [5]. Accurate statistics on amaranth acreage in Ukraine are not available. Various figures are given – from 1000 thousand ha to 5000 thousand ha.

To expand amaranth crops in Ukraine, it is necessary to study and develop intensive cultivation technologies focused on particular soil and climatic zones [6]. For this relatively new culture, it is necessary to study and refine most of the elements of technology [4]. In particular, the impact of climate change and irrigation [7]. The study of sowing methods has shown the advantage of row spacing of 18 cm over row spacing of 60 cm [8]. There are recommendations to place amaranth according to the scheme of 15x15 cm [9]. In the conditions of the southern steppe, when growing amaranth for grain, it is proposed to sow with a seeding rate of 2.25 million/ha with a row spacing of 60 cm [10]. S.G. Kohut [11] studied the issue of seeding depth. There are recommendations to sow amaranth to a depth of 1 cm to 3 cm in the absence of moisture.

There is little data on determining the effect of fertilisers on amaranth yields, which is often contradictory. Notably, it is advisable to apply the calculated amount of fertilisers [12], or that the most important fertilisers are nitrogenous ones [13]. It was established that the application of complete mineral fertiliser ($N_{90}P_{90}K_{30}$) in the conditions of the northern steppe of Ukraine caused an increase in the yield of amaranth grain (*Amaranthus paniculatus*) by 0.42 t/ha, compared to the control without fertilisers [14]. According to the authors, this is a low gain in yield. There is practically no data on the use of macroelements such as magnesium, sulfur, and calcium in amaranth cultivation technology. There are no recommendations for the introduction of microelements. Namely, a scientifically based fertiliser system allows increasing the yield to 4.0-5.0 t/ha.

In the technology of growing amaranth, the possibility of using plant protection products has almost not been studied. Amaranth, with the existing small areas of sowing, is almost not affected by diseases but there are many problematic issues with weed and pest control. Amaranth grows very slowly at the early stages and can become infested with weeds. Areas intended for medicinal purposes use agrotechnical methods of weed control: several surface treatments before sowing, harrowing, inter-row aeration, manual weeding. In large industrial areas, these methods will not be effective and it will be impossible to obtain high yields without the use of plant protection. Therefore, it is necessary to study the possibility of using herbicides, their effectiveness, and the cultivar reaction of amaranth to them. There are data on the study of Betanal Max Pro, Dual Gold, Caribou, Lontrel Grand, Piramin Turbo, Frontier Optima, Fusilad Forte, Aramo 45 herbicides on amaranth [15]. The most dangerous and mass pests on amaranth are the following two types: been aphid (*Aphisfabae Scop*.) and amaranth stem borer (*Lixussubtilis Boh*.). To control them on crops that are not intended for medicinal purposes, it is recommended to use insecticides Aktara, Ampligo, Engio, Karate Zeon, Nurel D, Fastak, Mospilan [16].

The purpose of this research was to study the influence of soil and climatic conditions of the Western Forest-Steppe on the adaptive potential and productivity of plants of grain amaranth cultivars.

LITERATURE REVIEW

The use of amaranth cultivars adapted to the growing conditions is important in terms of ensuring high yields of this promising crop. Breeding work with amaranth began relatively recently [17]. Breeding can considerably improve the quality of amaranth grain and increase its yield. New cultivars are of great value, which in certain soil and climatic conditions exceed the yield of the cultivars grown here, given that the cost of producing amaranth seeds is minimal.

The research of I.T. Hoptsii et al. [18] determined a particular morphotype of plants of this culture, which corresponds to a certain area of use. Grain-type cultivars have the following characteristics: low-growing plants (up to 1 m), unbranched, with a large dense or semi-dense panicle, with a high percentage of female flowers, even maturing; white, golden or pink seeds with a mass of 1000 seeds up to 1 g, crude protein content up to 18.0 – 19.0%, starch – 58.0-59%, grain yield up to 30 dt/ha; suitable for mechanised harvesting. The grain group of amaranths is also characterised by such features as panicle length, panicle productivity, seed moisture during harvesting, and seed nutritional qualities.

To determine the economically valuable cultivars for the conditions of the left-bank forest-steppe of Ukraine, 19 types of amaranth were analysed according to a complex of economically valuable features and distributed according to their economic purpose and practical significance. The species *Amaranthus hypochondriacus* had the highest seed yield (1.70 t/ha) [18].

The creation of highly productive cultivars for various soil and climatic conditions will also contribute to the expansion of amaranth acreage. A considerable amount of research in this area was carried out in the M.M. Hryshko National Botanical Garden of the National Academy of Sciences of Ukraine (Sterkh, Early Cream, Carmine), Podillia Institute of Feeding and Agriculture of the National Academy of Sciences of Ukraine (Legin, Aztec, Orchid, Kotyhoroshok), V.V. Dokuchaev Kharkiv National Research University (Ultra, Kharkivskyi 1, Nadiia, Studentskyi, Sam, Roganskyi) [19].

Amaranth belongs to plants of tropical origin with C_4-type of photosynthesis and is characterised by more efficient use of water and high productivity [5; 20]. Therefore, the potential capabilities of modern cultivars of this crop range from 8-15 t/ha, but the average grain yield in Ukraine is 2.8-3.5 t/ha [6]. The yield of amaranth grain is often even lower. Thus, in the conditions of the northern steppe of Ukraine against the background of $N_{90}P_{90}K_{30}$ for sowing with row spacing of 45 cm and a seeding rate of 1 kg/ha, a yield of 1.77 t/ha was obtained [14; 21]. In the southern steppe, the yield was only 5.5-8.7 st/ha [13]. The Dnipro 1 cultivar, depending on the fertiliser standards, formed a yield of 9.4-14.7 dt/ha [22].

In Romania, amaranth cultivars of the Amaranthus cruentus species formed the following yields: the Golden Giant cultivar – 2.65 t/ha and the Bolivia cultivar – 2.38 t/ha [23]. However, there are also high yield indicators. Thus, it was established that in favourable conditions of the year, amaranth provided the highest yield for sowing in the first decade of May and the wide-row method (45 cm), the Ultra cultivar – 4.9 t/ha and the Studentskyi cultivar – 5.1 t/ha [6]. In other studies, the Ultra cultivar is also recommended for growing for grain [11]. As of 2021, 19 cultivars of amaranth were registered in Ukraine [19].

MATERIALS AND METHODS

The research was conducted in the experimental field of Lviv National Agrarian University. The soil of the experimental site is dark grey podzolic light loam, which was characterised by the following indicators: humus content (according to the Tyurin method) – 2.10%, pH – 6.08, easily hydralised nitrogen – 110 mg/kg of soil, mobile forms of phosphorus (according to the Chirikov method) – 128 mg/kg of soil, mobile forms of potassium (according to Chirikov) – 114 mg/kg of soil, copper content – 1.25 mg/kg and zinc – 1.06 mg/kg, manganese (according to the Peive and Rinkis method) – 16.0 mg/kg, boron (according to the Rinkis method) – 0.94 mg/kg, iron – 128.0 mg/kg.

Hydrothermal conditions differed from the long-term average data. It was warmer and more precipitation fell. In 2019, the average temperature for the vegetation was 16.1°C, which is 1.3°C higher than long-term data. In 2020, these figures were 15.3°C and 0.5°C, respectively, and in 2021, 14.8°C, which corresponded to the long-term average data. In 2019, during the vegetation, the precipitation was 53 mm above normal, in 2020 – by 129 mm, in 2021 – by 73 mm. The total area of the site was 30 m^2, recording – 20 m^2. The studies were conducted in three repetitions. The cultivation technology in the experiment was as follows. The predecessor of amaranth is winter wheat. After harvesting the predecessor, the field was disked and winter plowing was carried out. In spring, soil treatment consisted of closing the moisture, 2 cultivations, and pre-sowing treatment using a combined Compactor tool. Mineral fertilisers were applied according to the norm $N_{120}P_{80}K_{120}$. Phosphorous and potassium fertilisers were applied for plowing. Nitrogenous fertilisers in spring for pre-sowing treatment. Sowing was conducted in a wide-row way with row spacing of 45 cm to a depth of 1 cm. A Horsh Pronto 4 DS seed drill was used. The sowing period is April 25, the seeding rate is 0.8 kg/ha. Row-to-row treatments and Fusilad Forte herbicide (1.0 l/ha) were used to control weeds. Mowing of amaranth was carried out in the phase of full ripeness of seeds in the lower and middle parts of the panicle, amaranth was threshed after drying. Statistical data processing was performed using Microsoft Excel and Statistica 6.0 programmes.

Cultivars. Seven cultivars of amaranth were studied.

Sam. The cultivar was created by individual selection from a sample *A. hypochondriacus* (Panishmen). Entered in the Register of Plant Varieties of Ukraine in 2002. The plant is up to 128 cm tall, the stem and leaves are red, the seeds are white. Panicle red spreading, up to 47 cm long. Drought resistance – 7 points, resistance to shedding and lodging – 9 points. Mid-season – 110 days. The protein content in seeds is 19.5%. The oil content is 6.7%. Seed yield is up to 25 td/ha. The anti-inflammatory activity and protective effect of the cultivar's oil on the development of experimental insulin resistance were established.

Lera. The cultivar was created by individual selection from a sample *A. hypochondriacus* (K-14). Entered in the Register of Plant Varieties of Ukraine in 2002. Plants up to 170-220 cm tall. The stem is green, the leaves are green with red veins. Panicle up to 54 cm long, red, compact. White seeds, weight of 1000 seeds – 0.7 g. Resistance to lodging – 9 points, resistance to shedding – 8 points. The cultivar is mid-season – 105 days. The protein content in seeds is 20.6%, oil – 7.0%. The seed yield is up to 22 td/ha. The grain is suitable for making flour and oil.

Kharkivskyi 1. The cultivar was created by individual selection from the population *A. hypochondriacus* (K-7). Entered in the Register of Plant Varieties of Ukraine in 2001 as a medicinal plant. Plants up to 160 cm tall. The stem and leaves are green, the panicle is white, compact, up to 60 cm long. White seeds, weight of 1000 seeds – 0.65 g, oil content – up to 8% with a high squalene content – up to 10%. The vegetation is 110 days. Grain is used for the production of butter, flour, and oil cake. Based on the results of medicinal properties testing at the V.Ya. Danilevsky Institute of Endocrine Pathology Problems, amaranth seed oil of the Kharkivskyi 1 cultivar is recommended for further study in medical institutions for possible clinical use to prevent and treat Type 2 diabetes mellitus and stomach ulcers. Seed yield is up to 50 dt/ha.

Studentskyi. Created by individual selection from a sample *A. hypochondriacus* (K-1267). Entered in the Register of Plant Varieties of Ukraine in 2009. Mid-season. Plants up to 125 cm tall. The stem is red, the leaves are green with red veins. Panicle up to 40 cm long, red, compact. White seeds, weight of 1000 seeds – 0.8 g. Resistance to lodging – 9 points, resistance to shedding – 9 points. The cultivar is mid-season – 100-125 days. The oil content is 6-10%, and the squalene content in the oil is 6-8%. The protein content in seeds is 18.6%. Seed yield is up to 30 dt/ha.

Aztec. Entered in the Register of Plant Varieties of Ukraine in 1998. Feeding Institute of the National Academy of Agrarian Sciences of Ukraine. The cultivar is grain, feeding, mid-season. The vegetation to full ripeness of seeds is 120 days. The plant reaches 150 centimetres. The length of the panicle with light brown seeds is 45-50 cm. The panicle is red, and the stem is the same colour. The leaves of the plant of this species have a red-green colour. It is characterised by a high level of grain yield and green mass. The seed yield is 30-40 dt/ha. The content of crude protein in dry matter is 17.8%. Grain is used for making oil and for producing flour, which, in turn, is used for baking products. Suitable for combine harvesting.

Ultra. Entered in the Register of Plant Varieties of Ukraine in 1998. *A. hybridus*. Early season – 90-95 days. Plants up to 180 cm tall. The leaves are green, downiness is absent. Inflorescence – semi-dense compact panicle, light green, yellow when ripe. The seeds are light yellow. The cultivar is resistant to shedding. The seed yield is 14 dt/ha. The oil content in seeds is up to 5%. The oil contains 11.25% of squalene, tocopherols – 0.28%.

Polishchuk. Entered in the Register of Plant Varieties of Ukraine in 1999, mid-season. Originator Polissia Institute of Agriculture. The plant reaches 150 centimetres. The length of the panicle with dark brown seeds is 45-50 cm. The panicle is red, and the stem is the same colour. The leaves of this species are green with red veins. Grain yield up to 3 t/ha. It is characterised by low resistance to shedding and high resistance to drought.

The Ultra cultivar, selected by KNAU, was used as a standard.

RESULTS AND DISCUSSION

Due to global climate change, it is important to establish the response of amaranth to new growing conditions. The dependence of the level of genetic potential fulfilment of amaranth cultivars on weather conditions is quite high. Therewith, the conditions of moisture and temperature regime that develop during the vegetation and especially in the first half of vegetation have the greatest influence on crop productivity in all soil and climatic zones.

In the studies conducted by the authors, the yield of amaranth grain varied depending on the hydrothermal conditions of the year. In 2019, the yield was lower compared to 2021 and varied depending on the cultivar in the range of 2.08-4.11 t/ha (Table 1). The difference between the lowest yield in the Ultra cultivar and the highest in the Kharkivskyi 1 cultivar was 2.03 t/ha.

***Table 1**. Yield of amaranth seeds depending on the cultivar*

Cultivars	Years			Average for three years	Crop gain	
	2019	2020	2021		Yield, t/ha	%
Studentskyi	2.51	2.22	2.62	2.45	0.48	24.4
Kharkivskyi 1	4.11	3.67	4.35	4.03	2.06	104.6
Lera	3.32	3.08	3.44	3.28	1.31	66.5
Ultra (standard)	2.08	1.37	2.46	1.97	–	–
Aztec	2.33	1.68	2.56	2.19	0.22	11.2
Sam	2.93	2.31	2.98	2.74	0.77	39.1
Polishchuk	2.39	1.71	2.53	2.21	0.24	12.2

***Notes**: HIP_{05} 2019 – 0.15 t/ha; 2020 – 0.16 t/ha; 2021 – 0.19 t/ha*

The decrease in amaranth yield in 2019 is explained by specific hydrothermal conditions. In general, vegetation was characterised by higher temperatures and precipitation compared to the average long-term data. However, in May, at an average annual rate of 69 mm, 161 mm of precipitation fell, which is 92 mm higher than normal (Fig. 1). Due to the constant rains, it was difficult to effectively control the level of contamination of amaranth crops. In addition, due to overwatering, air was displaced from the soil and there was not enough oxygen in the soil for the normal development of the root system. This limited the assimilation of nutrients, slowed down the growth processes in amaranth, inhibited the development of the root system, the increase in biomass, which ultimately led to a decrease in yield.

The works of T.I. Hoptsii note that when establishing the interaction and effect on the sowing-germination period of climatic conditions of the year, sowing methods and plant density on the yield of green mass, the conditions of the research year had a more pronounced effect for species *A. hypochondriacus* and *A. hybridus* – 4.7 and 4.9% than for the species *A. cruentus* – 2.4% [18].

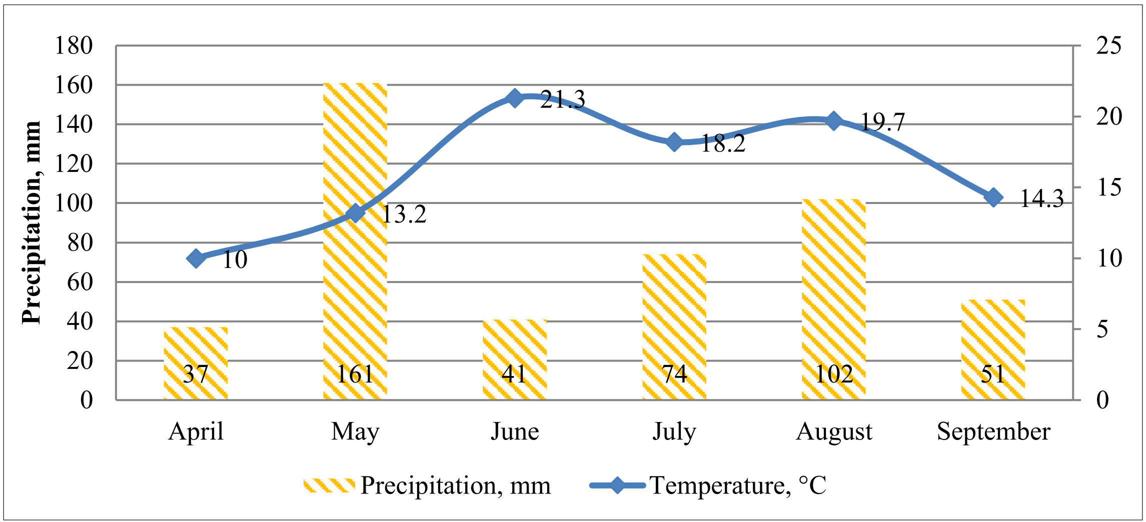

Figure 1. *Hydrothermal conditions in 2019*

The lowest grain yield in all the studied cultivars was in 2020 and ranged from 1.37-3.67 t/ha (Table 1). The difference between the lowest yield in the amaranth Ultra cultivar and the highest in the Kharkivskyi 1 cultivar is 2.30 t/ha. The reason for the decline in yields in 2020, as in 2019, was excessive precipitation. However, unlike in 2019, when soil overwatering was observed in May, in 2020 it was very wet for a longer period of two months – May and June. Thus, in May, 138 mm of precipitation fell, which is twice as much as normal, by 69 mm (Fig. 2). June was also rainy, with 140 mm falling, or 56 mm higher than the long-term average. Notably, in addition to overwatering, May 2020 was cold. The average monthly temperature this month was only 10.9°C, which is 3.1°C less than normal. Excessive rainfall combined with low temperatures in May caused a significant reduction in yields in 2020 compared to 2019 and 2021. Amaranth is of tropical origin and is characterised by heat-loving and drought resistance.

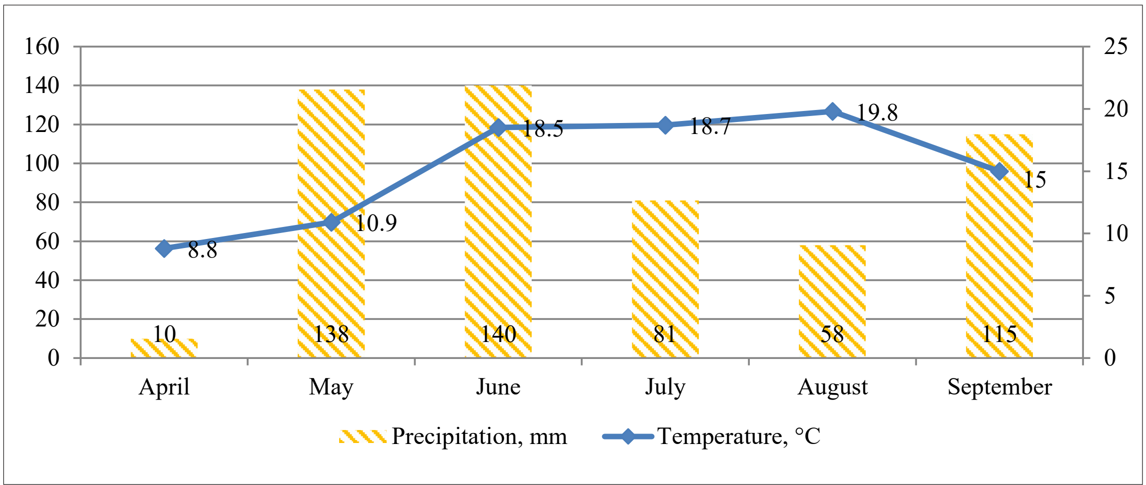

Figure 2. *Hydrothermal conditions in 2020*

Similar results of studies on the negative impact of overwatering in May-June 2014 on amaranth yield in the Polissia zone were also obtained by other researchers [24]. Correlation and regression analysis has shown that the amount of precipitation during the vegetation affects the grain yield of all the studied amaranth cultivars. A strong relationship was identified for: Kharkivskyi 1, Ultra and Lera cultivars, the correlation coefficient was r=-0.82, r=-0.82 and r=-0.83, and for the Studentskyi, Aztec, Polishchuk, and Sam cultivars it was r=-0.86, r=-0.87, r=-0.91, and r=-0.95, respectively.

This dependence for the Kharkivskyi 1 cultivar can be described by the regression equation:

$$Y=0.12X+3.803 \qquad (1)$$

where Y – yield, t/ha;

This equation describes the process of forming the yield of amaranth, which is confirmed by the multiple correlation coefficient (r=-0.82), the relationship between the effective feature and the argument is quite close. The coefficient of determination is R^2=0.121.

The hydrothermal conditions of 2021 were the most favourable for the development of amaranth grain yields. The yield, depending on the cultivar, varied in the range of 2.46-4.35 t/ha. The difference between the lowest yield of the Ultra cultivar and the highest yield of the Kharkivskyi 1 cultivar is 1.89 t/ha. In the third year of research, the amount of precipitation in the first half of the vegetation was within the normal range, as a result of which there was no soil overwatering. Higher than normal precipitation in August (144 mm) and September (108 mm) did not have a negative impact on the development of amaranth yield (Fig. 3). The sum of temperatures also corresponded to the long-term average, and what is important, in July it was the highest in three years of research – 21.7°C, which is 3.1°C higher than normal. Influence of hydrothermal conditions during studies on the productivity of paniculate amaranth (*Amaranthus paniculatus*) of the American cultivar sample R-158 was observed in studies in the conditions of the northern steppe of Ukraine. In particular, the most favourable growing conditions of amaranth with a hydrothermal coefficient of 1.06 were noted [9].

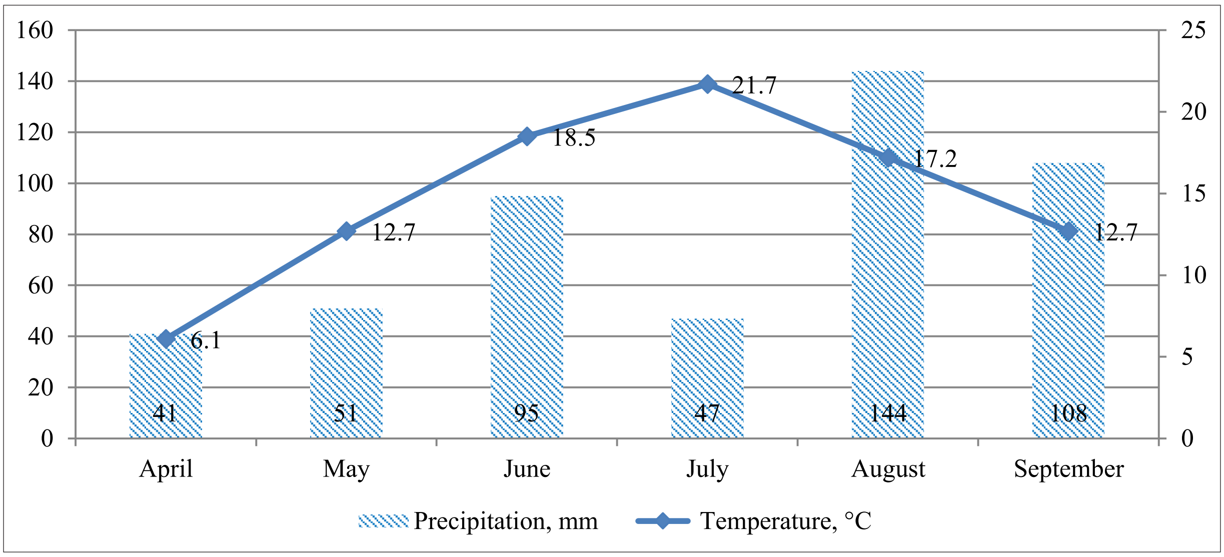

***Figure 3**. Hydrothermal conditions in 2021*

On average, for three years among amaranth cultivars, the lowest grain yield was obtained in the Ultra cultivar – 1.97 t/ha (Table 1). The Aztec cultivar also had a low yield of 2.19 t/ha, which is 0.22 t/ha higher than the Ultra cultivar (11.2%). The grain yield of the Polishchuk cultivar was formed almost at the same level – 2.21 t/ha, or more than the Ultra cultivar by 0.24 t/ha (12.2%). The Studentskyi cultivar had a yield of 2.45 t/ha, which is 0.48 t/ha higher than the Ultra cultivar (24.4%). The Sam cultivar with a yield of 2.74 t/ha exceeded the Ultra cultivar by 0.77 t/ha (39.1%). Fluctuations in the yield of Ultra (1.8-4.9 t/ha) and Studentskyi cultivars (1.6-5.1 t/ha) depending on weather conditions during the study years were noted in studies conducted in the left-bank forest-steppe of Ukraine during 2014-2016 [20]. Seed yield of species *A. hypohondriacus* and *A. hybridus* ranged from 51.8-203.3 g/m^2 and 104.7-142.2 g/m^2 accordingly [17].

As a result of research, it was established that the highest yield on average for three years was formed by the cultivars Kharkivskyi 1 and Lera. The Lera cultivar had a yield of 3.28 t/ha, which is 1.31 t/ha (66.5%) more than the Ultra cultivar. The highest yield was obtained in the Kharkivskyi 1 cultivar, which was 4.03 t/ha, or higher than in the Ultra cultivar by 2.06 t/ha (104.6%). Compared to the Lera cultivar, the yield increase in the Kharkivskyi 1 cultivar is 0.75 t/ha or 22.9%.

Analysis of the structural elements shows that sufficient precipitation provided good vegetative growth. The biggest plant height was in the Sam cultivar (207.4 cm). The most productive cultivars were also distinguished by good growth: in Kharkivskyi 1, the plant height was

193.6 cm, in the Lera cultivar – 195.3 cm (Table 2). As a result of the correlation and regression analysis, a direct strong influence of precipitation on the height of the stem of amaranth plants was identified, namely, for the cultivars Kharkivskyi 1, Polishchuk, and Aztec, the correlation coefficient was *r*=0.84, *r*=0.83, *r*=0.79, and for the cultivars Sam, Ultra, Lera, Studentskyi – *r*=0.77, *r*=0.74, *r*=0.72, *r*=0.70, respectively. The relationship between the height of plants and the temperature regime in the years of research was also established: the correlation coefficient for the Studentskyi, Lera, Ultra cultivars was *r*=0.39, *r*=0.37, *r*=0.34, which indicates an average direct and weak direct relationship – for Polishchuk (*r*=0.20), Sam (*r*=0.30), Aztec (*r*=0.27), and Kharkiv 1 (*r*=0.17) cultivars.

***Table 2**. Elements of the crop structure of amaranth cultivars*

Cultivar	Plant height, cm	Panicle length, cm	Seed weight per plant, g	Weight of 1000 seeds	Number of plants per m^2 at the time of harvesting
Studentskyi	192.0	49.2	12.4	0.76	20
Kharkivskyi 1	193.6	54.5	19.2	0.88	21
Lera	195.3	61.0	16.4	0.76	20
Ultra	131.5	69.4	11.0	0.78	18
Aztec	171.2	55.2	11.5	0.74	19
Sam	207.4	60.3	15.2	0.75	18
Polishchuk	170.0	64.7	11.6	0.85	19

The length of the panicle was the highest in Ultra cultivar, but this cultivar was the least productive, while in the Kharkivskyi 1 cultivar, the panicle length was one of the shortest and the yield was the highest, which is conditioned upon botanical and morphological features and the yield potential of the cultivars. An average inverse correlation was identified between the panicle length and the yield of the studied cultivars – *r*=-0.36. It was also established that the amount of precipitation had a direct strong effect on the development of panicle length in Aztec (*r*=0.76), Ultra (*r*=0.75), Polishchuk (*r*=0.77), and Lera (*r*=0.71) cultivars, and correlation coefficient in the Sam, Kharkivskyi 1 and Studentskyi cultivars was *r*=0.63, *r*=0.54 and *r*=0.58, respectively, which indicates a direct relationship of average strength. There is a positive average correlation between the temperature regime and the development of the panicle length – from *r*=0.30 to *r*=0.57.

The weight of 1000 seeds ranged from 0.74-0.88 g. The largest grain was in the Kharkivskyi 1 cultivar, which provided this one with the highest yield. A direct average relationship was established between the weight of 1000 seeds and the yield of amaranth grain – *r*=0.47. According to the results of studies in the conditions of the left-bank forest-steppe of Ukraine, the mass of 1000 seeds fluctuated depending on the conditions of the year, and amounted to 0.51-0.68 g in the Ultra cultivar and 0.57-0.71 g in the Studentskyi cultivar [6].

Number of plants per m^2 at the time of harvesting varied in a narrow range, from 18 to 21 plants. With such a relatively small number of plants, a pattern was observed: the higher the density of plants, the higher the yield. Correlation and regression analysis has shown that an increase in the number of plants at the time of harvesting provides an increase in the yield of amaranth grain. The correlation coefficient was *r*=0.76, which indicates a direct strong connection.

The greatest direct impact on the level of grain yield in amaranth cultivars is the low mass of seeds per plant, which is confirmed by the correlation coefficient *r*=0.99. In the Kharkivskyi 1 cultivar, the grain weight per plant was 19.2 g, which is 0.14 g higher with the Aztec cultivar. A high inverse relationship was established between the amount of precipitation during the vegetation and the weight of seeds from 1 plant: *r*=-0.84 for the Aztec cultivar, *r*=-0.92 for Ultra and Polishchuk cultivars, *r*=-0.83 for the Lera cultivar, *r*=-0.90 for the Studentskyi, Kharkivskyi 1, and Sam cultivars. A strong direct relationship was also established between the temperature regime and the weight of grain from 1 plant: *r*=0.72 for Polishchuk and Ultra cultivars, *r*=0.75 for Studentskyi, Kharkivskyi 1, Sam cultivars, *r*=0.82 for the Aztec cultivar, and *r*=0.84 for the Lera cultivar. Thus, the highest yield of the Lera cultivar (3.28 t/ha) was obtained with a plant density of 20 pcs/m^2 and the mass of grain in the panicle was 16.4 g, and in the Kharkivskyi 1 cultivar with the highest yield (4.03 t/ha), these structural elements were higher: 21 plants/m^2 and the weight of grain in the panicle was 19.2 g.

CONCLUSIONS

The yield of amaranth, as a drought-resistant crop, decreased (in 2019 and 2020) with excessive precipitation in the first half of vegetation. The highest yield (2.46-4.35 t/ha) was formed in 2021 when the amount of precipitation in May, June and July was within the normal range. A strong inverse correlation was established (*r*=-0.82–*r*=-0.95) between the yield of amaranth cultivars and the amount of precipitation. In the conditions of the western forest-steppe, with sufficient and excessive moisture supply on dark grey podzolised light loamy soil, the highest grain yield (4.03 t/ha) among the seven studied amaranth cultivars was obtained in Kharkivskyi 1. The lowest yield was formed in the Ultra cultivars (1.97 t/ha), which is less than in the Kharkivskyi 1 by 2.06 t/ha.

Plant height and panicle length did not directly affect the level of amaranth grain yield. The study of elements of the crop structure showed that the height of the plant had a positive effect (*r*=0.63) on the level of amaranth grain yield, while average relationship was observed between panicle length and yield (*r*=-0.36). The weight of 1000 seeds in the cultivars ranged from 0.74-0.88 g. The low mass of seeds per plant had the greatest impact on yield (correlation coefficient *r*=0.99). The highest yield of amaranth in the Kharkivskyi 1 cultivar was formed with the following ratio of the main elements of the crop structure: the number of plants is 21 p/m^2 and the mass of seeds from the plant is 19.2 g.

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Урожайність амаранту (*Amaranthus*) залежно від сорту в умовах Лісостепу Західної України

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Анотація. Амарант називають культурою майбутнього завдяки його унікальним харчовим, кормовим і лікарським властивостям. Посівні площі амаранту в Україні є дуже малі, що можна пояснити відсутністю адаптивних технологій вирощування, особливо для вирощування цієї культури на зерно. Метою досліджень було встановити найбільш урожайні сорти для вирощування в умовах надмірного і достатнього зволоження в умовах західного Лісостепу на темно-сірому ґрунті. Для цього проводили польові дослідження на дослідному полі Львівського національного аграрного університету. Загальна площа ділянки становила 30 м^2, облікова – 20 м^2. Дослідження проводились у трьох повтореннях. Автори вивчали сім найбільш поширених в Україні сортів амаранту: Харківський 1, Лєра, Сем, Студентський, Поліщук, Ацтек, Ультра. Встановлено, що врожайність амаранту значно залежала від гідротермічних умов року. Вона була меншою у роки з надмірною кількістю опадів у першій половині вегетації (2019 та 2020 рр.). Найвища врожайність зерна (2,46–4,35 т/га) формувалась у 2021 році, в якому сума опадів у травні, червні і липні була в межах норми. Встановлено сильний зворотній кореляційний зв'язок (*r*=-0,82–*r*=-0,95) між урожайністю сортів амаранту та кількістю опадів. Найвищу врожайність зерна (4,03 т/га) серед досліджуваних сортів амаранту одержано в сорту Харківський 1. Найменша урожайність формувалась у сорту Ультра (1,97 т/га), що менше порівняно з сортом Харківський 1 на 2,06 т/га. Вивчення елементів структури урожаю показало, що висота рослини мала позитивний вплив (*r*=0,63) на рівень урожайності зерна амаранту, тоді як між довжиною волоті та урожайністю спостерігався зворотній зв'язок середньої сили (*r*=-0,36). Маса 1000 насінин у сортів коливалась в межах 0,74–0,88 г. Найбільший вплив на врожайність мала маса насіння з рослини (*r*=0,99). Найвища врожайність амаранту сорту Харківський 1 формувалась за такого співвідношення основних елементів структури урожаю: кількість рослин – 21 р/м^2 та маса насіння з рослини – 19,2 г. Для одержання високого стабільного урожаю зерна амаранту необхідні додаткові дослідження з уточнення основних елементів технології вирощування для даних ґрунтово-кліматичних умов

Ключові слова: амарант, сорти, приріст врожаю, маса 1000 насінин, гідротермічні умови, елементи структури