UDC 631.62:631.432:633.2

Justification of regimes of water regulation at growing highly productive forage crops on sewed lands

Yatsyk M.[1], Voropai H.[2], Kika S.[3]

Institute of water problems and amelioration of NAAS, Vasylkivska Str., 37, Kyiv, 03022, Ukraine; e-mail: [1]nikomage@ukr.net, [2]voropaig@ukr.net, [3]s.kika@gmail.com

The purpose. To justify technological parameters of water regulation on the basis of probe of features of water requirement of Echin chloa frument cea, amaranth and field beans at their cultivation on sewed lands, formation of demands of these crops to water regime in rooted layer of soil. **Methods.** Experimental determination of meteorological indexes, water-physical characteristics of soil, water requirement of forage crops and their productivity. **Results.** Indexes of total water requirement of Echin chloa frument cea from 0 – 50 cm soil layer on peat-moor area «Chemerne» (Sarne exploratory station) made 374,2 mm, amaranth — 266,4 and field beans — 270,6 mm, on drainage-humidifying system «Romen» — 221,0; 231,4 and 232,2 mm
accordingly. The greatest intensity of water requirement of Echin chloa frument cea and amaranth was determined during healthy growth and development, at field beans — at the period of formation of seeds. Bioclimatic quotients of Echin chloa frument cea, amaranth and field beans were specified at their cultivation in conditions of Western Polissia and Forest-steppe of Ukraine. Averages for vegetative period of their value for Echin chloa frument cea, amaranth and field beans made accordingly 0,63; 0,61 and 0,58 on peat-moor area «Chemerne», and 0,36; 0,42 and 0,39 on drainage-humidifying system «Romen». Importation of phosphoric-potash fertilizers into dose $P_{60}K_{120}$ increased productivity of forage crops on 13,4%, and at full fertilizer — on 20,5%. Optimum times of sowing on sewed lands of Western Polissia of Ukraine: for field beans — II ten-day period of April, Echin chloa frument cea and amaranth — I ten-day period of May. **Conclusions.** Results of probes are the basis for determination of optimum reclamative regimes for Echin chloa frument cea, amaranth and field beans according to phases of their vegetation and in view of features of water requirement. Premises for development of technique of cultivation of these forage crops on the reclaimed lands of humid zone of Ukraine are created.

Key words: *sewed lands, peat lands, vegetative period, groundwater table, water requirement of forage crops, highly productive forage crops.*

DOI: https://doi.org/10.31073/agrovisnyk201906-09

Introduction. For the sustainable development of the forage base for today, it is vital the introduction into agricultural production on drained land of high-yielding and cost-effective forage crops, which could harmoniously supplement traditional crops (corn, alfalfa, etc.) and increase the efficiency of drained land use [1].

In addressing this problem, an important role belongs to the multi-purpose crops with significant adaptive and productive potential when cultivated in difficult agroclimatic conditions of the humid zone. At the same time, climate change that contributes to the agroclimatic conditions of cultivation, as well as microclimatic, water-physical and agrochemical features of the drained lands of the humid zone play an important role in selecting the types of forage crops for cultivation.

For today barnyard grass, amaranth and fodder beans take an important place among the high-yielding but not very commonly used fodder crops, the interest in which arose in the late 80's of the last century.

Analysis of recent research and publications. The scientific results prove the prospect of cultivation of barnyard grass, amaranth, fodder beans for green fodder and silage on contaminated with radionuclides drained peat soils of Western Polissya [2-5].

In view of increasing the climate aridity, the most promising crop is barnyard grass, as it is one of the most drought-resistant grass herbs. This culture is only starting gaining the popularity and it refers to non-

traditional fodder crops. Literary review on barnyard grass cultivation in various ecological and geographical zones of Ukraine proved the prospect of this crops for cultivation, including the conditions of Western Polissya in Ukraine [6 - 8].

Amaranth is considered to be a valuable forage, food and medicinal crop, the green mass of which can be used in animal farming both in fresh and for the preparation of silage and protein-vitamin concentrate. In the United States, Germany, and some African countries, they are considering the feasibility of cultivating amaranth for grain on an industrial scale for food and feed productions. However, nowadays in Ukraine amaranth is cultivated only in some advanced farms and, basically, as a feed crop. The area under this crop is rather small (Kyiv, Kirovograd, Mykolaiv, Dnipropetrovsk and Odessa oblasts) and does not exceed 5 thousand hectares [9, 10].

A large role in addressing the problem of providing the cattle feed with protein belongs to leguminous crops, namely to fodder beans, which are not only a source of protein, but are also a good preceding crop in crop rotation. Its rich nutritional properties make it possible to use this crop for feeding all types of animals in the form of oil cake, herbal flour, silage, green forage. The area under this crop in Ukraine is rather small (about 10 thousand hectares) [2, 11, 12].

However, insufficient water supply for forage crops during the growing season negatively affects their potential capacity and feed productivity [5, 11]. Therefore, the basis of scientific research is the working hypothesis of possible obtaining high and sustainable yields of perspective forage crops (barnyard grass, amaranth, fodder beans) by providing the crops with optimal water supply during the growing season. To provide favorable water regime during the growing season and to substantiate the technological parameters of water regulation, it is necessary to specify the features of water regime and water supply for these crops by the vegetation phases. That will enable to determine and optimize reclamation regimes, promptly regulate water regime of soil root layer and efficiently use of water resources, contributing to the increased productivity of cultivated crops.

Goal of research. The goal of the research is to substantiate the technological parameters of water regulation based on the study of water consumption of barnyard grass, amaranth and fodder beans when cultivating them on drained lands and their requirements to water regime in soil root laye**r.**

Materials and methods of research. Meteorological parameters, water-physical soil properties, water consumption of fodder crops and their yields were reached with experiments.

The basis of methodological approaches to the experimental research is the use of generally accepted and proven methods of meteorological observations (temperature, relative air humidity, precipitation), determination of RHV, soil moisture, biometric characteristics (time of basic phenological phases, leaf-area index, root system capacity, yield).

The thermostat-weighted and tensiometric methods (measuring the capillary capacity of soil moisture in aeration zone with the use of tensiometers [13]) were used to determine soil moisture. Groundwater levels were measured every ten days using a measuring tape, leaf-area index was determined by the calculation method, total water consumption was determined by water and balance calculations.

Research results. Field research was carried out at pilot site of the peat-marshy array "Chemerne" of Sarny experimental field (SEF) of NAAS and at the site of IDS "Romen".

2017 year by the atmospheric precipitation was extremely dry. The weather conditions of the vegetation period at the pilot site of the peat-swamp array "Chemerne" of Sarny experimental field were quite favorable for the cultivation of fodder crops, since the vegetation period was characterized by a fairly even distribution of precipitation, although the average monthly air temperature was slightly higher (by 0,9°C) compared to its long-term values (Fig.1). At the pilot site of IDS "Romen", the weather conditions were characterized by a rather uneven distribution of precipitation within months and decades, long rainless periods with extreme values of air temperature, prolonged spring frosts, which determined the sowing dates of the studied crops and had a significant impact on their growth and development (Fig.2).

Based on the researches of the dynamics of GWL at the pilot site "Chemerne" it was found that during the growing season GWL was within the range of 51-83 cm, which contributed to the formation of optimal soil moisture regime and provided the necessary deposits of moisture in the root layer of soil when growing the

studied crops (Fig.1). However, at the pilot site of IDS "Romen", due to the insufficient water regime regulation, the moisture content of the soil was none-optimal, which caused insufficient deposits of moisture in the soil root layer (Fig.2).

In the experiments, barnyard grass of Lebedin 2 cultivar, amaranth of Polischuk cultivar, and forage beans of Chabansky cultivar were studied. The sowing was carried out in a wide-ranging manner with a width of rows of 45 cm having a seeding rate for: amaranth - 0,5 kg/ha, barnyard grass - 6 kg/ha, fodder beans - 160 kg/ha.

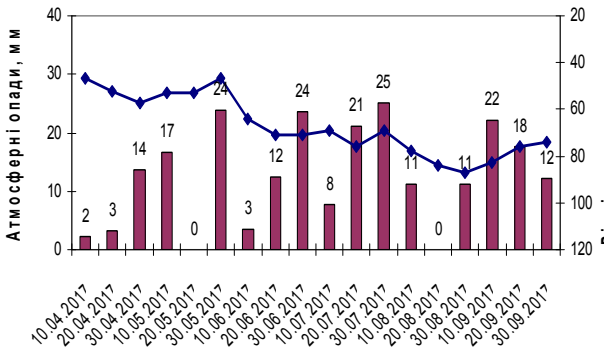


Fig. 1 – Dynamics of precipitation and GWL at pilot site of the peat-swamp array "Chemerne", 2017

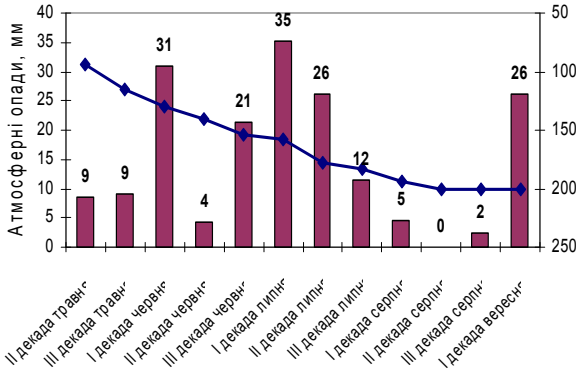


Fig. 2 - Dynamics of precipitation and GWL at pilot site of IDS "Romen, 2017

The analysis of the fertilizer effect on the yield of fodder crops at the pilot site "Chemerne" indicates that when applying the phosphoric-potassium fertilizers in the rate of $P_{60}K_{90}$, the average yield of vegetative mass of fodder beans increases by 16 %, amaranth - by 10% and barnyard grass - by 13 %. Application of complex mineral fertilizers increases the yield of fodder beans, amaranth and barnyard grass respectively by 20, 14 and 21% (Table 1).

1. Yield of barnyard grass, amaranth and fodder beans

Crop	Pilot site "Chemerne"		Pilot site "Romen"	
	Fertilization	Productivity of vegetative mass, c/ha	Fertilization	Productivity of vegetative mass, c/ha
Fodder beans	$P_{60}K_{90}$	383,6	no fertilizer	140,8
	$P_{60}K_{120}$	426,9	$N_{30}P_{30}K_{30}$	176,0
	$N_{45}P_{60}K_{120}$	433,9		
Amaranth	$P_{60}K_{90}$	422,3	no fertilizer	305,4
	$P_{60}K_{120}$	464,5	no fertilizer	350,0
	$N_{45}P_{60}K_{120}$	484,9		
Barnyard grass	$P_{60}K_{90}$	511,7	no fertilizer	421,7
	$P_{60}K_{120}$	586,6	$N_{30}P_{30}K_{30}$	486,7
	$N_{45}P_{60}K_{120}$	618,5		

The results of the study on the yield of vegetative masses of barnyard grass, amaranth and fodder beans, in the background of fertilizer application at the pilot site "Romen" in 2017, showed that when applying the mineral fertilizers with a rate of $N_{30}R_{30}K_{30}$ it increases by 14 - 25%. Fodder beans were the most susceptible to fertilization, and somewhat lower yields were recorded for barnyard grass and amaranths.

The unfavorable weather conditions of IDS "Romen" in the year of study influenced on the growth and development of the studied crops in the initial stages of development, which adversely affected the formation

of vegetative mass and their yields. The low yield of fodder beans was due to the late timing of their sowing due to weather conditions and damage caused by pests and diseases.

Field study of water consumption of barnyard grass, amaranth and fodder beans during the growing season was carried out at the pilot site of the peat-bearing array "Chemerne" in 2016 - 2017. The accounting area of the experimental plots is 4 m^2, with threefold repetition. The soils of the experimental plots are powerful low-lying hypnotic-sedge eutrophic drained peat. The arable layer is characterized by the following indicators: density - 0,29-0,33 g/cm^3, porosity - 80-85%, full moisture-holding capacity - 280-295%. The acidity of soil is 5,0-5,2. Provision of mobile forms: NH_4 and NO_3 - 67,2; P_2O_5-21; K_2O - 14 mg/100g of soil.

It was determined that barnyard grass, amaranth and fodder beans use the largest amount of moisture in the period of June-July, i.e. during the period of an intensive accumulation of vegetative mass and maximum moisture consumption.

The rates of water consumption of barnyard grass, amaranth and fodder beans by the decades and phases of development at the pilot sites are shown in the Table.2

2. Rates of water consumption of barnyard grass, amaranth and fodder beans by decades and phases of development, mm

Crop	Water consumption, mm												Total
	by decades												
	V		VI			VII			VIII			IX	
	II	III	I	II	III	I	II	III	I	II	III	I	
	by phases of development												
	I – seeds, sprouting, shooting				II – phase of intensive accumulation of organic matter				III – seed ripeness, decay of leaves				
Peat-bearing array "Chemerne" of Sarny experimental field (2016-2017)													
Barnyard grass	-	7,8	22,9	20,0	36,9	51,8	61,0	45,2	34,6	35,8	25,5	24,2	**365,6**
	50,6 (13,8%)				**194,9 (53,3%)**				**120,1 (32,9%)**				
Amaranth	-	17,8	16,1	23,5	31,4	44,3	51,9	45,1	34,9	22,9	19,6	-	**307,3**
	57,4 (18,7%)				**172,6 (56,1%)**				**77,4 (25,2%)**				
Fodder beans	26,8	22,6	27,3	40,7	47,6	45,8	32,1	43,1	17,2	16,2	6,4	-	**325,6**
	117,4 (36,0%)				**168,6 (51,8%)**				**39,7 (12,2%)**				
IDS "Romen" (2017)													
	I – seeds, sprouting, shooting			II – phase of intensive accumulation of organic matter				III – seed ripeness, decay of leaves					
Barnyard grass	-	10,5	29,9	33,4	35,0	24,7	27,9	4,9	27,0	12,5	15,2	-	**221,0**
	40,4 (18,2 %)			**121,0 (54,8%)**				**59,6 (27,0 %)**					
Amaranth	-	14,7	28,4	31,4	26,1	34,8	26,2	5,2	22,7	19,6	22,3	-	**231,4**
	43,1 (18,6 %)			**118,5 (51,2%)**				**69,8 (30,2%)**					
Fodder beans	-	7,5	37,1	26,3	36,1	27,1	18,5	14,7	19,1	21,6	24,3	-	**232,3**
	44,6 (19,2 %)			**108,0 (46,5%)**				**79,7 (34,3%)**					

The index of total water consumption of barnyard grass from the soil layer of 0 - 50 cm was 365,6, amaranth - 307,3 and fodder beans - 325,6 mm on the peat-bearing array "Chemerne" of SEF. The highest water consumption of barnyard grass was observed during the period from the 3rd decade of June to the 3d decade of July (53% of the total for the vegetation period), amaranth - from the 3rd decade of June to the 3 decade of July (68 % of the total for the vegetation period), that is in the period of intensive growth and development. The water consumption of fodder beans was smooth until the 2nd decade of June and the highest intensity of it was recorded in the period from the 2nd decade of June to the 3d decade of July, when bean formation occurred.

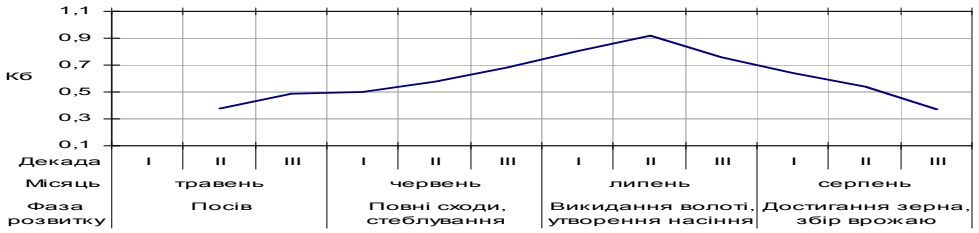
At the site of IDS "Romen" during the growing season in 2017, the water consumption of barnyard grass, amaranth and fodder beans amounted to 221,0; 231,4 and 232,2 mm respectively. The maximum moisture consumption of these crops (54,8, 51,2 and 46,5%, respectively, of the consumptive water use for vegetation period) were recorded from the 2d decade of June to the 2d decade of July, that is, during the period of intensive accumulation of organic matter. Late spring frost, uneven distribution of precipitation and long periods with high air temperatures during the vegetation period significantly effected crop water consumption.

Based on the research results on deficit of air humidity and water consumption of barnyard grass, amaranth and fodder beans, obtained at the pilot sites, bioclimatic coefficients, that reflect the dependence of the phases of development on the water consumption of these crops, have been obtained.

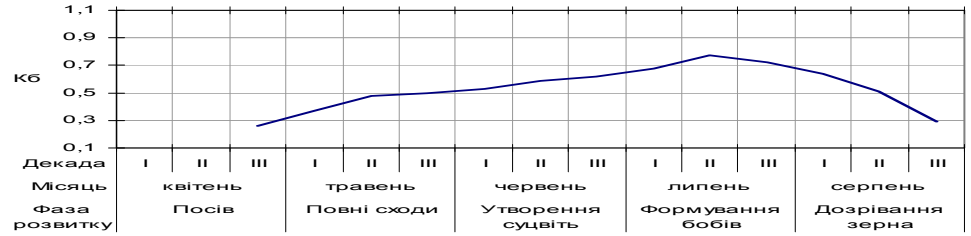
Using the experimentally obtained bioclimatic coefficients, it is possible to calculate the water consumption of barnyard grass, amaranth and fodder beans both for the short periods of vegetation (decades) and for the entire vegetation period.

The dynamics of bioclimatic coefficients during the vegetation season at the pilot site of the peat-bearing array "Chemerne" of the SEF is shown in Fig.3.

a)



b)



c)

Fig. 3. Dynamics of bioclimatic coefficients a) barnyard grass; b) amaranth; c) fodder beans (peat-bearing array "Chemerne" of the SEF, based on the research results 2016 - 2017)

Thus, in the period from the sprouting to the maximum moisture consumption phase, the bioclimatic coefficients of the studied crops were in the range: for barnyard grass – 0,32 – 0,59; for amaranth – 0,38 – 0,58; for fodder beans – 0,26 – 0,59. In the period of maximum water consumption (formation of blossom clusters - full blossom - formation of seeds), their indices increased up to 0,67 – 1,03 for barnyard grass, 0,68 – 0,92 for amaranth and 0,62 – 0,77 for fodder beans. Further, as the crop growth slowed down, the transpiration capacity of the crops was reduced and the effect of the climatic conditions on crop water consumption waned, the bioclimatic coefficient decreased up to 0,29 - for barnyard grass; 0,37 - for amaranth; 0,29 - for fodder beans.

The dynamics of the bioclimatic coefficients of barnyard grass, amaranth and fodder beans during the vegetation season at the pilot site of IDS "Romen" is shown in Fig. 4. In the period from the sprouting to the maximum moisture consumption phase, the bioclimatic coefficients of the studied crops were in the range: 0,25 – 0,35 for barnyard grass; 0,28-0,36 - for amaranth; 0,21-0,36 - for fodder beans.

In the period of maximum water consumption (formation of blossom clusters - full blossom - formation of seeds), their indices increased up to 0,43 – 0,54 for barnyard grass; 0,43 – 0,50 - for amaranth; 0,43 - 0,56 - for fodder beans. Further, as the crop growth slowed down, the transpiration capacity of the crops was reduced and the effect of the climatic conditions on crop water consumption waned, the bioclimatic coefficient decreased up to 0,25 for barnyard grass; 0,37 – for amaranth; 0.27 - for fodder beans (Fig.4).

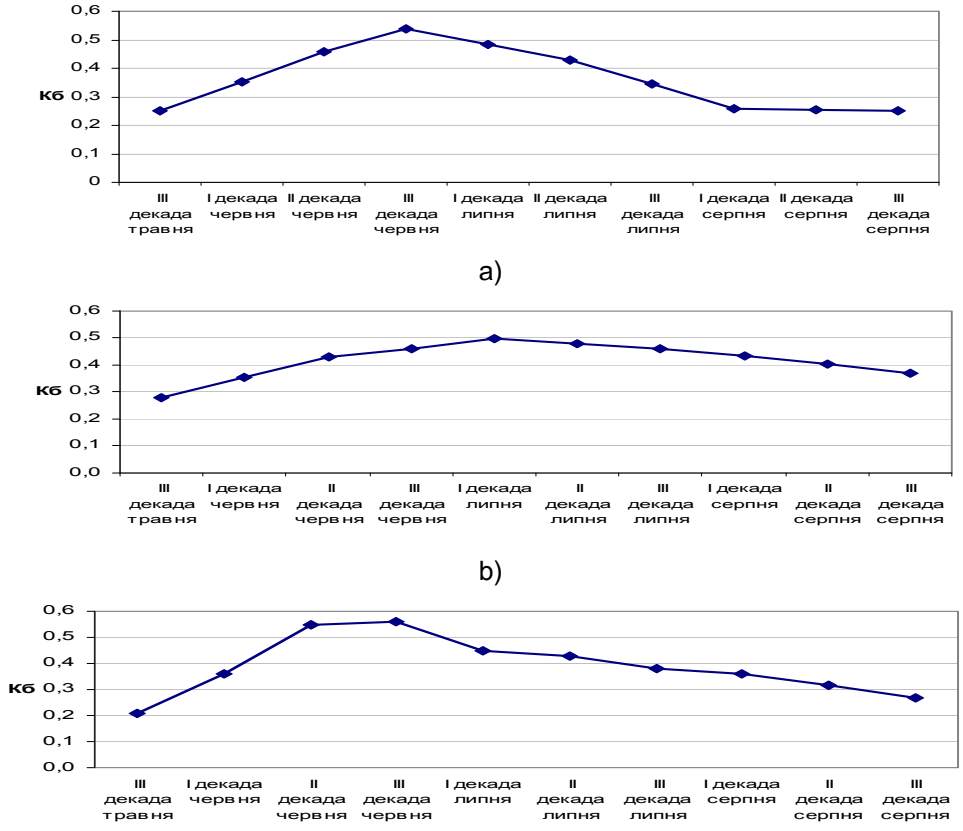


Fig. 4. Dynamics of bioclimatic coefficients a) barnyard grass; b) amaranth; c) fodder beans (IDS "Romen", 2017)

Conclusions. The indices of total water consumption from the soil layer of 0 - 50 cm at the peat-bearing array "Chemerne" of the SEF amounted to 374,2 for barnyard grass; 266,4 - for amaranth and 270,6 mm for fodder beans; at the site of IDS "Romen" - 221,0, 231,4 and 232,2 mm respectively. The highest intensity of water consumption for barnyard grass and amaranth was recorded during the period of intense growth and development, for fodder beans - during the formation of bean seeds.

When cultivating barnyard grass, amaranths and fodder beans on drained peat soils, the application of phosphoric-potash fertilizers at the rate of $P_{60}K_{120}$ increased their yield by 13,4%, and the application of complete mineral fertilizers increased it by 20,5%.

The optimal terms of crop sowing on the drained lands of the Western Polissya of Ukraine were determined: for fodder beans – the 2d decade of April, for barnyard grass and amaranth – the 1st decade of May.

The bioclimatic coefficients of barnyard grass, amaranth and fodder beans when cultivating them in the conditions of Western Polissya and Forest-steppe of Ukraine were determined, which reflect the effect of the phase of crop development on their water consumption.

The presented research results are the basis for determining optimal reclamation regimes for the perspective fodder crops by the phases of their vegetation and water consumption characteristics. The prerequisites for the development of a cultivation technology for highly productive fodder crops (barnyard grass, amaranth and fodder beans) on the reclaimed land of the humid zone of Ukraine have been created.

References

1. Stetsiuk M.H., Zosymchuk M.D. (2017) Ratsionalne silskohospodarske vykorystannia osushuvanykh torfovykh hruntiv Zakhidnoho Polissia [Rational agricultural use of drained peat soils of Western Polesie] Rozdil 37 monohrafii «Melioratsiia ta oblashtuvannia Polissia» [Section 37 of the monograph "Reclamation and arrangement of Polesie"] Kyiv-Rivne: Oldi plius. pp 155 – 194. [in Ukrainian].

2. Zosymchuk O.A., Zosymchuk O.A., Zosymchuk M.D. (2009) Vyroshchuvannia maloposhyrenykh i netradytsiinykh kormovykh kultur na osushuvanykh torfovykh gruntakh Zakhidnoho Polissia [Cultivation of widespread and unconventional fodder crops on the dried peat soils of Western Polesie] Visnyk Lvivskoho natsionalnoho ahrarnoho universytetu [Bulletin of the Lviv National Agrarian University]. Seriia “Ahronomiia”. № 13. pp. 434 – 440. [in Ukrainian].

3. Babych A.O., Babych A.O., Petrychenko V.F., Poberezhna A.A. (1994) Svitove vyrobnytstvo odnorichnykh zernovykh bobovykh kultur dlia vyrishennia problemy bilka i biolohichnoho azotu [World production of annual grain legumes to solve the problem of protein and biological nitrogen] Materialy Pershoi Vseukrainskoi (mizhnarodnoi) konferentsii po problemi “Kormy i kormovyi bilok” [Proceedings of the First All-Ukrainian (International) Conference on the Problem of Feed and Feed Protein] 16–17 lystopada 1994 r. Vinnytsia, pp. 164–165. [in Ukrainian].

4. Osadets Ya., Vivcharyk V. (2002) Kormovi boby – tsinna kormova kultura [Feed beans - valuable forage culture] Propozytsiia [Proposal]. № 11. pp. 45 – 47. [in Ukrainian].

5. Iatsyk M.V., Voropai H.V., Kika S.M. (2017) Dosvid ta perspektyvy vyroshchuvannia vysokoproduktyvnykh kormovykh kultur (paizy, amarantu ta kormovykh bobiv) na osushuvanykh zemliakh v umovakh zmin klimatu [Experience and prospects of cultivation of high-yielding forage crops (paisas, amaranth and forage beans) on the drained lands under climate change] Melioratsiia i vodne hospodarstvo [Reclamation and water management]. V. 105 pp. 61 – 66. [in Ukrainian].

6. Zosymchuk O.A. (2012) Kormova ta nasinnieva produktyvnist paizy na osushuvanykh torfovykh gruntakh zakhidnoho polissia [Feed and seed productivity of pauses on the dried peat soils of western Polissya] Intensyfikatsiia tekhnolohii – shliakh do pidvyshchennia efektyvnosti zemlerobstva: materialy Vseukr. nauk.-prakt. Internet-konf [Intensification of technologies - a way to increase the efficiency of agriculture: materials All-Ukrainian. scientific-practical Internet conf.]. 20 hrudnia 2012 r. Rivne, pp. 48 – 51. [in Ukrainian].

7. Stetsiuk M. (2015) Perspektyvna paiza [The Prospective Pause] The Ukrainian Farmer. 13 May. 2015. pp. 90. [in Ukrainian].

8. Sadeghloo, A., Asghari, J., and Ghaderi-far, F. Seed germination and seedling emergence of velvetleaf (abutilon theophrasti) and barnyardgrass (echinochloa crus-galli). Planta Daninha, Vi osa-MG, 2013. V. 31. N. 2. pp. 259 – 266.

9. Onyango C.M., Imungi J.K., Mose L.O., Harbinson J., Olaf Van Koteen (2009). Feasibility of commercial production of amaranth leaf vegetable by small scale farmers in Kenya. African Crop Science Conference Proceedings. Vol. 9. pp. 767 – 772.

10. Zraly Z., B. Pisarikova, H. Hudcova, M. Trckova, I. Herzig (2004) Effect of Feeding Amaranth on Growth Efficiency and Health of Market Pigs. Acta Veterinaria. Brno, pp. 437 – 444.

11. Stetsiuk M.H., Danylytskyi O.A., Zosymchuk M.D. Perspektyvni vydy kormovykh kultur dlia vyroshchuvannia na osushuvanykh torfovykh gruntakh Zakhidnoho Polissia [Perspective Species of Forage Crops for Cultivation on the Dried Peat Soils of Western Polesie] Materialy Mizhnarodnoi naukovo-praktychnoi konferentsii «Upravlinnia vodnymy resursamy v umovakh zminy klimatu», prysviachenomu Vsesvitnomu dniu vody [Proceedings of the International Scientific and Practical Conference "Management of Water Resources in the Conditions of Climate Change", dedicated to the World Water Day], m. Kyiv, IVPiM, 2017. pp. 77 – 79. [in Ukrainian].

12. Mohankumar R., Karthik R., Paramesh V., Sudhakara T.M. and Manjunathachari K. (2012) Studies on farmers perception on growing field bean (var. local) as intercrop with maize in central part of Karnataka. World research journal of agronomy, V. 1. I. 1. pp. 4 – 6.

13. Romashchenko M.I., Koriunenko V.M., Muromtsev M.M. (2012) Rekomendatsii z operatyvnoho kontroliu ta upravlinnia rezhymom zroshennia silskohospodarskykh kultur iz zastosuvanniam tenziometrychnoho metodu [Recommendations for the operational control and management of crop irrigation regime using the tensiometric method]. Kyiv. 72 p. [in Ukrainian].