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Reviewers:

Prof. nadzw., dr hab. ***Stanisław Kunikowski,*** *Rektor of Cuiavian University in Wloclawek (Republic of Poland);*

Prof. dr hab. ***Joanna Marszałek-Kawa,*** *Uniwersytet Mikołaja Kopernika w Toruniu / Nicolaus Copernicus University (Republic of Poland).*

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AGROTECHNICAL CONDITIONS FOR GROWING BUCKWHEAT AND PANICUM IN RESOWING

Averchev O. V.

INTRODUCTION

As long as the area of distribution of cultivated plants to other ecological zones is limited by natural factors, primarily due to the intensity of light and temperature, the intensification of crop husbandry based on the crops growing in intermediate sowing requires careful justification of local bioclimatic resources, especially in the specific region of Black Sea Steppe[1]. Analyzing the bioclimatic potential of the regions of the Southern Steppe of Ukraine, it should be noted that the perennial indicators show the maximum temperatures in a period of the second half of July – the first decade of August, and the early autumn frosts – in the middle – end of September. The sum of active air temperatures of the warm period of the year ranges from 3200 to 3600 ºC for agro-soil areas, including 1600–1900 ºC and more in the second half of summer, where the daylight hours are 16–20 hours. The annual average sum of rainfalls in the first half of the summer is usually 113 mm, in the second – 107 mm.

In general, the pickling ripeness of spring crops in the southern subzone usually comes in late May, for winter cereals it comes in the second decade of June, and the end of harvest is in the end of June – early July, with the duration of the warm period to the transition of air temperature to 10ºC in the fall (post-harvested period), taking into account that the time for soil preparation for intercrops sowing is 120–145 days. Under these conditions, it is possible to grow not only early – but also mid-ripening varieties of buckwheat and Panicum in post-harvested sowings. It is easy to calculate that crops with a short growing season can produce two yields in the warm season. For

[1] Аверчев О.В. Агротехніка вирощування гречки в проміжних посівах на зрошуваних землях України / О.В. Аверчев, Ю.В. Аверчев // Таврійський науковий вісник: збірник наукових праць. – Вип. 17. – Херсон, 2001. – С. 7–11.

example, two and three crops a year in the southern regions are ensured by the efficient use of solar radiation fluxes by plants that increase from north to south[2].

The influence of agro-technical and climatic conditions on the productivity of cultivated plants has been studied by many scientists. Thus, it has been set that the crop yield varies 2–3 times in the zones of stable moisture, and 5–6 times or more in the zones of unstable moistening, depending on the weather conditions. Even with a high level of crop husbandry intensification, adverse weather conditions cause yield fluctuations of 70–80%.

In recent years, in the scientific world, a great deal of attention has been paid to the study of the peculiarities of the production process of crops in different agro-climatic zones. For example, on the basis of correlation-regression and dynamic-statistical modeling, the production process of buckwheat and Panicum was studied depending on agro-technical and meteorological factors. Thus, the influence of the studied factors on the growth, development and yield of cereal crops has been studied by many scientists who, based on experimental data, have developed a dynamic model of the formation of Panicum productivity depending on agrotechnical and agrometeorological conditions, as well as the scheme of forecasting the average crop, the method of calculating of phases Panicum development, a method of calculating the rate of buckwheat development in the generative period, established the economic optima of air temperature and the amount of precipitation by the stages of plant vegetation, as well as the method of calculating the terms of buckwheat watering. However, most developments concern buckwheat and Panicum in the main sowings for local terrain, taking into account weather factors. In addition, different methods and approaches, indicators and coefficients (often modified) have been applied in different years of research that give different assessment of the connections between factors. Therefore, research in this area is relevant.

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[2] Аверчев О.В. Агротехніка вирощування гречки в проміжних посівах на зрошуваних землях України / О.В. Аверчев, Н.М. Рудік, Ю.В. Аверчев // Вісник ДААУ. – Спец. вип. "Проблеми виробництва екологічно-чистої сільсько-господарської продукції". – Житомир, 2000. – С. 3–4.

It is known that buckwheat and Panicum produce high grain yields, in a condition that the complexes of agrotechnical measures that meet the agrobiological characteristics of these crops are clearly followed.

1. Buckwheat in a crop rotation

The results of scientific research and practical experience show that buckwheat is not very demanding for its forecrops as biological objects. However, after the forecrops that leave the soil foul, buckwheat significantly reduces the yield. This is especially concern the weeds that inhibit its growth (white swan, yellow thistle, prickly grass, yellow foxtail) using water and nutrient reserves from the soil, which coincides with the buckwheat fruiting period[3, 4]. In addition, the effectiveness of the forecrops affects the quality of buckwheat grain: content of protein, starch and fat, fluidity, mass of 1000 seeds and other indicators[5].

Thus, enhancing factors in the field can be reduced to its degree of weediness, nutrient content and moisture content that forecrops leave. These factors are quite regulated and especially important for southern Ukraine, where the natural supply of moisture is insufficient and unstable over the years, and favorable conditions for the development of weed vegetation are created in the sowings of irrigated crops. The results of long-term studies[6, 7] indicate that only following the

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[3] Болдырев А.П. Промежуточные посевы – важный фактор интенсификации / А.П. Болдырев, А.П. Погребняк, А.І. Лунчу // Земледелие. – № 7. – 1984. – С. 42–44.

[4] Медведев Г.А. Влияние приемов агротехники на урожайность сортов проса на светло-каштановых почвах Волгоградской области / Г.А. Медведев, М.В. Иванов // Научные сообщения КДН. – Волгоград, 1998. – Бюл. № 7. – С. 13–16.

[5] Когут В.В. До питання впливу метеорологічних факторів на урожайність гречки сорту Вікторія / В.В. Когут // Збірник наукових праць. – Вип. 8. – Кам’янець-Подільський, 2000. – С. 59–61.

[6] Жученко А.А. Адаптивный потенциал культурных растений (Эколого-генетические основы) / А.А. Жученко. – Кишинев: Штиинца, 1988. – 767 с.

[7] Пучков Л.Н. Совершенствование приемов обработки почвы под пожнивные культуры в условиях орошения / Л.Н. Пучков // Сб.науч.трудов. – Волгоград, 1985. – С. 31–35.

recommended crop rotation makes it possible to reduce the number of weeds in crops by 1.5–2.0 times.

Thus, in the experiments of Brovarenko S. the highest field weediness was observed on the horse-hoeing forecrops, the lowest – on fallow during the whole buckwheat vegetation period. According to Mityanin M.T., the weediness of post-harvested buckwheat sowings (during flowering period) was 26.8 after rye for green fodder, and 31.9 weeds per 1 m^2 for fall-plowingor or 84% and 100% respectively.

In conditions of unstable or insufficient moisture, it is necessary to sow buckwheat on a layer of perennial grasses, but at the same time it is necessary to sow on pure of wheatgrass areas. It is also necessary to pay attention to the excessive compaction of the arable layer of the clover (1.5–1.6 g/cm^3), compared to potatoes (0.88–1.28 g/cm^3)[8].

Due to the fact that different crops leave uneven soil conditions in the degree of weeding, compaction and exhaustion, the buckwheat crop is different. If to take the buckwheat crop after buckwheat as 100%, after winter wheat its yield will be 126, after grazing – 120, winter rye – 114, barley and oats – 110, Panicum – 103%. According to the results of researches, in the steppe zone of Ukraine, the buckwheat yield after Sudanese grass and spring barley was 1360–1380 kg/ha, after winter wheat, peas, corn for grain and silage, the Panicum yild was 1500–1590, after melons and potatoes – 1610–1640 kg/ha[9].

Good forecrops for buckwheat are the legumes of late sowings (vetch, lupine, soybeans) and grass seeds, and in severely dry years it is complete fallow. Also it is recommend sowing post-harvest buckwheat after winter cereals for grain, spring barley and peas for grain, green peas, early vegetables and potatoes[10, 11]. Three-year data indicate the economic feasibility of direct sowing of buckwheat after

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[8] Коровин А.И. Растения и экстремальные температуры / А.И. Коровин. – Л.: Гидрометеоиздат, 1984. – 164 с.

[9] Пустовая З.В. Усовершенствование элементов агротехники выращивания проса в летних посевах / З.В. Пустовая // Сб. науч. тр. межд. конф., посв. 30-лет. науч.-иссл. инс-та круп. культур. – Каменец-Подольский, 2002. – С. 223–228.

[10] Анохин А.Н. Послеукосные посевы гречихи / А.Н. Анохин // Научные труды Белорусского НИИ земледелия. – 1977. – Вып. 21. – С. 155.

[11] Рекомендации по выращиванию гречихи и проса на орошаемых землях. – М.: Колос, 1982. – 16 с.

peas on grain with aggregate SZS-2.1 with introduction of a moderate rate of fertilizers $N_{45}P_{45}$. The energy factor was 1.3.

For steppe conditions, it is recommended to grow buckwheat in the link "fallow – winter wheat – buckwheat".

Thus, according to the data of Kherson State Agrarian University, the largest amount of buckwheat grain per hectare of crop rotation area in the conditions of Northern Kazakhstan was obtained in 4–5-grain-fallow field crop rotations at sowing on complete fallow and wheat after fallow.

However, it should be kept in mind that the sowing on cereal crops threatens the appearance of drops in the buckwheat sowings, which is difficult to remove from the sowings and separate as a black dockage from the mass of commercial grain. It also concerns such forecrops as sunflower, rapeseed, mustard, flax, which sowings have expanded in recent years in the southern steppe regions. The drops of these crops is rapidly gaining ground and successfully competing with buckwheat, which grew slowly in the initial period. Thus, according to Babûrkovà M., considerable damage to the sowings of buckwheat sown before June 15 in the states of Wisconsin and Minnesota causes weediness with drops of the sunflower, rapeseed, corn and mustard. Similar results were obtained when, after corn sown after sunflower, sunflower drops had a negative effect on the development of buckwheat plants[12].

The contentious question arises as to the fertilizer of the forecrop under buckwheat. Thus, Zainchkovsky V.F.[13] proposes to sow buckwheat after fertilized winter corn for silage, grain and potatoes, and in years with sufficient rainfall – after sugar beet. Chlorine-containing fertilizers and ammonia should not be introduced in the soil with sugar beet, and buckwheat should preferably be sown after sugar beet harvested in the first half of September 8. Thus, in the conditions of Sumy region after sugar beet, fertilized sowings of winter wheat and potatoes, 78–84% of buckwheat crops are sown[14]. In Donbass region,

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[12] Подвезько В.В. Просо / В.В. Подвезько // В кн.: Сортовая агротехника зерновых культур / [Под общ. ред. Н.А. Федоровой]. – К.: Урожай, 1989. – 328 с.

[13] Анохин А.Н. Послеукосные посевы гречихи / А.Н. Анохин // Научные труды Белорусского НИИ земледелия. – 1977. – Вып. 21. – С. 155.

[14] Пустовая З.В. Усовершенствование элементов агротехники выращивания проса в летних посевах / З.В. Пустовая // Сб. науч. тр. межд. конф., посв. 30-лет. науч.-иссл. инс-та круп. культур. – Каменец-Подольский, 2002. – С. 223–228.

grain, maize for grain and silage, legumes and sugar beet provide the best crop, that are those forecrops for which high doses of fertilizers are applied. The high yield of buckwheat is formed in the conditions of the Luhansk region after winter crops, fertilized with manure, and in the Kirovohrad region buckwheat is sown after a well-fertilized sugar beet or corn for silage, where in production conditions for an average of 2000 kg/ha of grain was harvested during five years.

However, Efimenko D.Ya. considers that it is not important for buckwheat whether forecrop fertilized or not fertilized: if the difference in yields in favor of the fertilized forecrop is over 50% for winter wheat, then it is only 6–18% for buckwheat. In addition, it is not advisable to apply buckwheat fertilizer for its sowing after winter crops for green feed, as well as after rice, since buckwheat makes good use of the effects of mineral fertilizers introduced in rice.

The list of forecrops that negatively affect the buckwheat yield is usually reduced to a set of crops such as sunflower and oats. According to the recommendations of Shashkin Yu.A., buckwheat should not be sown after oats, as well as after potatoes affected by nematodes. During the sowing of buckwheat after buckwheat there is a shortening of the growing season and a decrease in yield. However, according to Averchev O.V.[15], buckwheat of spring sowing is a good forecrop for its summer sowings.

Regarding Panicum as a forecrop, researcher's opinions are different. Obviously, the question of the buckwheat sowing after this forecrop is solved depending on the degree of weediness of its sowings, as indicated by research Kochetkova V.S., who indicates the high weediness of the field after Panicum. In turn, the field after buckwheat must meet the specific needs of the next crop that is sown after it.

Research results of scientific institutions (Poltava, Sumy and Orel research stations) and practical experience of farms show that buckwheat is a good forecrop for other crops, since the field after it is clean, the content of mobile forms of phosphorus and potassium increases. Due to the dense network of roots, buckwheat scarify the

[15] Аверчев О.В. Агротехніка вирощування гречки в проміжних посівах на зрошуваних землях України / О.В. Аверчев, Ю.В. Аверчев // Таврійський науковий вісник: збірник наукових праць. – Вип. 17. – Херсон, 2001. – С. 7–11.

soil well, increases its aeration, which stimulates the activity of soil macro- and microorganisms.

The post-harvest and root residues left by the buckwheat in the soil enrich it with minerals that are accessible to the following crops. According to Narcisova V.P., in the soil layer of 0–20 cm, the buckwheat root reserve is 1690 kg/ha, which contains total nitrogen of 21 kg, P_2O_5 – 9,9, K_2O – 22, CaO – 53 kg, and according to Zamnius V.K., buckwheat leaves 2360 kg/ha of post-harvest and root residues in the arable layer of soil[16].

Another feature of buckwheat root system is the presence in its rhizosphere of nitrogen-fixing bacteria Azospirillum brasilence, which contribute to the productivity of both buckwheat and subsequent crops in crop rotation[17, 18]. According to the experiments conducted in the Kherson region[19], inoculation of buckwheat seeds by A. brasilence crop contributed to the increase of buckwheat yield in summer crops by 300 and 620 kg/ha in the varieties of Halley and Cosmey, respectively, without the introduction of nitrogen fertilizers.

It is a well-known fact that buckwheat leaves fields weedless. Thus, according to Populida K. H., buckwheat significantly reduces the weediness of rice crops in the rice crop rotation, and under normal moisture supply buckwheat is able to completely clear the field from the couch grass.

In the northeastern United States, continuous buckwheat sowings control the number of couch grass by twice cutting their rhizomes with disk implements in the fall and spring before sowing buckwheat 6.

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[16] Жученко А.А. Адаптивный потенциал культурных растений (Эколого-генетические основы) / А.А. Жученко. – Кишинев: Штиинца, 1988. – 767 с.

[17] Медведев Г.А. Влияние приемов агротехники на урожайность сортов проса на светло-каштановых почвах Волгоградской области / Г.А. Медведев, М.В. Иванов // Научные сообщения КДН. – Волгоград, 1998. – Бюл. № 7. – С. 13–16.

[18] Коровин А.И. Растения и экстремальные температуры / А.И. Коровин. – Л.: Гидрометеоиздат, 1984. – 164 с.

[19] Аверчев О.В. Агротехніка вирощування гречки в проміжних посівах на зрошуваних землях України / О.В. Аверчев, Н.М. Рудік, Ю.В. Аверчев // Вісник ДААУ. – Спец. вип. “Проблеми виробництва екологічно-чистої сільсько-господарської продукції”. – Житомир, 2000. – С. 3–4.

Sowing of honey buckwheat in crop rotation contributes to the intensive reproduction of entomophages, which regulate the number of harmful insects and this makes it possible to reduce the use of pesticides in other field crops. Thus, according to scientist's researches[20, 21, 22] concerning the forecrop of "early potato" repeated crops helped to reduce the number of wireworms by 30–40% compared to areas where no post-harvest crops were used. According to the observations of Panov A.I., cereals are less affected by root rot after their sowing after the buckwheat.

Buckwheat is successfully used as a forecrop for the main winter and spring crops, as well as for peas, potatoes, sugar beets and corn. However, as regards the buckwheat drops that appears in the sowings of the following crops, they do not see any threat, as most crop rotations are treated with herbicides, to which buckwheat seedlings are sensitive and easily destroyed[23]. For example, in rice-growing countries, in particular in Nepal, buckwheat is used in the intensive crop rotation of "rice – buckwheat – corn", collecting three crops of grain per year[24, 25].

Thus, buckwheat can be considered a desirable forecrop in crop rotation for most crops: perennial grasses, legumes, winter fertilized and cultivated crops (potatoes, sugar beet, corn for silage, melon, rice). Instead, it is not desirable to sow it after spring wheat, oats, barley, and

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[20] Анохин А.Н. Послеукосные посевы гречихи / А.Н. Анохин // Научные труды Белорусского НИИ земледелия. – 1977. – Вып. 21. – С. 155.

[21] Медведев Г.А. Влияние приемов агротехники на урожайность сортов проса на светло-каштановых почвах Волгоградской области / Г.А. Медведев, М.В. Иванов // Научные сообщения КДН. – Волгоград, 1998. – Бюл. № 7. – С. 13–16.

[22] Подвезько В.В. Просо / В.В. Подвезько // В кн.: Сортовая агротехника зерновых культур / [Под общ. ред. Н.А. Федоровой]. – К.: Урожай, 1989. – 328 с.

[23] Жученко А.А. Адаптивный потенциал культурных растений (Эколого-генетические основы) / А.А. Жученко. – Кишинев: Штиинца, 1988. – 767 с.

[24] Зубец Г.Г. Влияние предшественников на урожай и количество зерна проса / Г.Г. Зубец // Пути повышения урожайности крупяных культур. – К., 1969. – С. 177–179.

[25] Медведев Г.А. Влияние приемов агротехники на урожайность сортов проса на светло-каштановых почвах Волгоградской области / Г.А. Медведев, М.В. Иванов // Научные сообщения КДН. – Волгоград, 1998. – Бюл. № 7. – С. 13–16.

sunflower. When using buckwheat in crop rotation, it is important to take into account the amount of fertilizer applied to its forecrops.

2. Panicum in a crop rotation

Panicum has been sown almost exclusively on virgin and fallow lands since ancient times. In the case of imperfect agricultural technology, the choice of the layer for Panicum was explained by the fact that the Panicum grown on the layer was much less weediness than on the old arable lands, since virgin and fallow lands were clear of weeds in the first years of use, had a fine-grained structure and were well provided with leftovers. Such conditions ensured good growth and development of plants and high yields[26]. In this regard, Panicum has long been considered a ley crop.

In recent years, Panicum gives high yields and high-quality grain not only on virgin and fallow lands, but with proper agrotechnics it is the same on the old arable lands, under a number of crop rotations.

Due to the fact that in the initial period of growth Panicum plants are very vulnerable to any stress factors (weediness, lack of moisture, nutrients, the harmful organisms, etc.), it requires the soil that is clean of weeds, that exclude the accumulation of pathogens common to a number of crops, that is not depleted and sprayed, as irrigation posed a risk of flooding and crust formation, and has reserves of productive moisture for rapid emergence of seedlings.

Good weed cleaners include perennial legumes. However, there is evidence that not every layer of perennial grasses can provide a good Panicum crop, but only a layer with normal plant formation of legume or legume-grasses herbage mixture. Thus, a layer after some cereals or with a sharp predominance of cereals, and especially weeded by couch grass, canada thistle, etc., may not be a good forecrops. Studies show the feasibility of sowing Panicum after vetch and oat mix and pea- oat mixes as they make it possible to fight with chicken millet and bristle grass more effectively. For this purpose, it is recommended to sow Panicum on low humus black earths after horse-hoeing crops, especially sugar beet and peas.

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[26] Аверчев О.В. Напрями удосконалення вирощування гречки в повторних посівах на зрошуваних землях півдня України / О.В. Аверчев // Збірник наукових праць Уманської державної академії. – Вип. 56. – Умань, 2003. – С. 55–60.

At the same time, the most weediness of Panicum crops was observed after such forecrop as Pancicum, peas and vetch and oat mix (from 37 to 34 pcs/m^2 of weeds). In case of Panicum sowing after legumes the weediness decreased to 27, after potatoes – to 23, barley – 19, sugar beet – 17 pcs/m^2 of weeds. Among the cereal forecrops, weeding by the number of weeds in the Panicum sowings was: after winter wheat – 35, after spring cereals – 63, after corn – 47 pcs/m^2 (according to the Erastov Research Station).

Kochetkov V.S. points to the benefits of corn, which leaves considerable root biomass (60% of the total weight). A number of farms in the Odessa region annually harvest Panicum at 2500–3000 kg/ha in large areas, placing it after corn, which was sown after sugar beet[27].

However, in the southern regions of Ukraine, it should be taken into account that corn and Panicum have a common pest – the corn worm, which causes special damage in wet years, and in dry years it can be found in thickened narrow-row sowings. It poses a significant risk in adjacent to sowings of cereals (for example, corn), or if sowings of both crops are in the same field when the Panicum is sown in the corners of the field irrigated with a "Frigate" type sprinkler or in crops of susceptible Panicum that produce significant losses of the yield[28]. Thus, the pediculate corn worm affect up to 14% of Panicum sowings, and in 1963–1964, up to 50–60% of damaged caulis were observed in the Kursk region. The yield is not formed on such plants.

Different forecrops have different effects on soil moisture. Thus, it is found that the productive moisture in the soil after corn is 1646, after soybeans it is 1558, after barley – 1321 m^3/ha, even less remains after perennial grasses. In alfalfa crop rotations on chestnut soils in the Kherson region, Panicum forms maximum yields, despite the dryness of the soil after alfalfa. Other scientists also testify to the benefits of perennial grasses as a forecrop of Panicum.

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[27] Жученко А.А. Адаптивный потенциал культурных растений (Эколого-генетические основы) / А.А. Жученко. – Кишинев: Штиинца, 1988. – 767 с.

[28] Когут В.В. До питання впливу метеорологічних факторів на урожайність гречки сорту Вікторія / В.В. Когут // Збірник наукових праць. – Вип. 8. – Кам'янець-Подільський, 2000. – С. 59–61.

In the southern regions, Panicum sowings can also be placed on the fallow fields, using it as a fallow crop and producing high yields of Panicum and winter cereals and, in addition, to use it as a cover crop for alfalfa. Thus, in irrigated areas of Kherson region Panicum is effectively sown after winter wheat and after buckwheat[29].

According to the data 8, in the arid regions of the Great Plains (USA), Panicum is widely grown in the "winter wheat – Panicum – naked fallow" link. At the same time, a yield increase of 1 tons/ha ensures a profit increase of more than $ 120/ha in Nebraska, USA. In Colorado, Panicum is placed as follows: wheat – corn – Panicum – fallow, wheat – Panicum – sunflower – fallow.

Many scientists point to the expediency of sowing Panicum after winter wheat grown after fallow in the steppe zone. Thus, according to the Higher Educational State Institute of corn, the yield of Panicum sown after winter wheat varied from 3120 to 4350 kg/ha. Due to five years studies of Panicum forecrops, 50% increase of Panicum yield after wheat and 116% after fallow were obtained in comparison with a link "Panicum – Panicum".

Some researchers cite data about low Panicum yields when it is sown after wheat. Thus, Safonova A.V.[30] notes that the grain yield of Panicum sown after wheat was beaten by hail and twice low in comparison with the fallow field. The authors believe that the decrease in Panicum yield was influenced by, firstly, the low moisture content of the soil profile, secondly, the toxins formed as a result of the decomposition of wheat residues and, third, the residual amounts of herbicides introduced into wheat. In the experiments of Pronko V.V.[31] the yield of Panicum after the sowing of wheat that was frozen was also lower than for the fall plowing – 1780 versus 1930 kg/ha.

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[29] Пучков Л.Н. Совершенствование приемов обработки почвы под пожнивные культуры в условиях орошения / Л.Н. Пучков // Сб.науч.трудов. – Волгоград, 1985. – С. 31–35.

[30] Медведев Г.А. Влияние приемов агротехники на урожайность сортов проса на светло-каштановых почвах Волгоградской области / Г.А. Медведев, М.В. Иванов // Научные сообщения КДН. – Волгоград, 1998. – Бюл. № 7. – С. 13–16.

[31] Зубец Г.Г. Влияние предшественников на урожай и количество зерна проса / Г.Г. Зубец // Пути повышения урожайности крупяных культур. – К., 1969. – С. 177–179.

If the opinions of experts of the Panicum production in the assessment of the positive impact of any forecrop on the Panicum yield differ, then in the definition of worse forecrops, they practically the same. Thus, barley and oats are among the worst forecrops among cereals for Panicum. Panicum grain yields are also significantly reduced after such forecrops as Sudan grass, sorghum and sunflower.

In turn, Panicum sowing after good forecrops allows it to be used as a valuable forecrop for other crop rotations. This, high-yielding Panicum is considered as a good forecrop for spring wheat[32].

Studies have shown that the fields after the Panicum are cleaned from weeds due to the fact that herbicides are used on close-growing sowings, in addition to a perfect system of basic and pre-sowing tillage, and multiply intertillage is made on wide-row sowing, during which weeds are destroyed, and the soil is kept loose[33]. Because of this, after the Panicum harvest, winter crops can be sown without plowing, only with surface tillage. Under the same conditions, US and Australian farmers engage in Panicum crop rotation to clear the field of wintering weeds. Under the same conditions, US and Australian farmers engage Panicum in crop rotation to clear the field of wintering weeds[34]. Panicum, in the cultivation of which herbicides were used, is a good forecrop to corn[35]. Thus, in the production conditions of the Berezovsky district of Odessa region, the average yield of winter wheat for the 7 years was: after Panicum – 2470 kg/ha, after corn for grain – 2120, after corn for silo – 2420, after winter wheat – 1870 kg/ha.

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[32] Болдырев А.П. Промежуточные посевы – важный фактор интенсификации / А.П. Болдырев, А.П. Погребняк, А.І. Лунчу // Земледелие. – № 7. – 1984. – С. 42–44.

[33] Пустовая З.В. Усовершенствование элементов агротехники выращивания проса в летних посевах / З.В. Пустовая // Сб. науч. тр. межд. конф., посв. 30-лет. науч.-иссл. инс-та круп. культур. – Каменец-Подольский, 2002. – С. 223–228.

[34] Рекомендации по выращиванию гречихи и проса на орошаемых землях. – М.: Колос, 1982. – 16 с.

[35] Ушкаренко В.А. Агротехнічні умови одержання високих урожаїв гречки у післяжнивних посівах / В.А. Ушкаренко, А.В. Аверчев, М.С. Черниш // Агрохімія і ґрунтознавство: Міжвідомчий тематичний науковий збірник. – Спец. вип. до 5 з’їзду УТГА (6–10 липня 1998 р., м. Рівне). – Ч. 3. – Харків, 1998. – С. 177.

Economical water consumption creates not only good drought resistance, but also low drainage of fields occupied by Panicum. Thus, in dry areas and after dry years, Panicum becomes a good forecrop for the most wistful crops. According to three-year observations at the Erastov Research Station of Corn Sientific Research Institute, the average reserves of productive moisture in the 0–150 cm soil layer in the spring was (mm): after corn – 164, Panicum – 159, melons – 149, sunflower – 132.5, barley – 132, winter wheat – 122, meaning the highest reserves of productive moisture were formed after corn and Panicum.

Thus, in dry conditions of the steppe zone of Ukraine, the best forecrops for Panicum are winter crops on fallow, corn, melons, and the worst are sunflower, oats and barley. At sowing Panicum in crop rotation, it should be taken into account that herbicides introduced into the previous crop can harm Panicum crops, especially sulphonylurea herbicides (e.g. treflane).

It should be noted that the review of the results of the above studies is significantly related to unirrigated conditions. Data on Panicum forecrops in irrigated lands of southern Ukraine, including in intermediate sowings, are poorly understood.

3. Tillage for buckwheat and Panicum

As one of the main measures to increase soil fertility is to create a favorable root layer of soil, the depth of its tilling has long been of interest to researchers, and this question remains controversial.

Timiryazev K.A. pointed to the primary task of deep, especially autumn, plowing to retain as much water as possible in the soil. Thus, it was found that in the southern regions the use of early autumn plowing gives additional moisture in the steppe zone of 25–30, in dry steppe – 15–30 mm[36].

According to the recommendations for cereals crops, the main tillage of the stubble forecrops is mainly autumn plowing, 15–20 days after the last peeling; after sugar beet and potatoes that are harvested

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[36] Аверчев О.В. Агротехніка вирощування гречки в проміжних посівах на зрошуваних землях України / О.В. Аверчев, Ю.В. Аверчев // Таврійський науковий вісник: збірник наукових праць. – Вип. 17. – Херсон, 2001. – С. 7–11.

rather late, plowing or flat-cutting is carried out as soon as the fields are cleared. The tillage depth is 20–22, after corn – 25–27 cm[37].

Buckwheat. According to the recommendations of intensive buckwheat cultivation technology, autumn tillage consists of stubble peeling (5–7 cm) and underwinter plowing, and after arable crops plowing is carried out immediately after harvesting of the forecrop. Thus, timely peeling of the forecrop stubble provides a yield of buckwheat grain of 310 kg/ha, and timely plowing provides 220 kg/ha. Moreover, in fields with a shallow fertile layer, plowing is carried out to the depth of the humus horizon. In the experiments of the Ukrainian Research and Development Center of Irrigated Agriculture, it was found that in case of autumn plowing (27–30 cm), the moisture reserves during the buckwheat fruiting period were higher than during the ordinary plowing[38].

Other authors point to the advantage of regular plowing. Thus, Krut V.M. believes that underwinter plowing should be done to a depth of 22–25 cm for steppe zone of Ukraine. According to Efimenko D.Ya.[39], plowing to a depth of 20–22 cm after winter wheat and 25–27 cm after corn of the silo provides high yield of buckwheat. The replacement of plowing for surface tillage under intermediate buckwheat causes crop failure, although the difference in yield is reduced by the use of the KPE-3.8 ripper.

Many scientists[40] point to the advantage of plowing to 20–22 cm for afterharvested sowings. Thus, plowing to a depth of 20–22 cm for the summer sowing of buckwheat in irrigation conditions promoted better loosening of the soil rather than disking by 10–12 cm: the density of the horizon 0–10 cm of dark chestnut meddle loamy soil was 1.24 against 1.28 g/cm^3, which accordingly affected its water

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[37] Анохин А.Н. Послеукосные посевы гречихи / А.Н. Анохин // Научные труды Белорусского НИИ земледелия. – 1977. – Вып. 21. – С. 155.

[38] Аверчев О.В. Агротехніка вирощування гречки в проміжних посівах на зрошуваних землях України / О.В. Аверчев, Ю.В. Аверчев // Таврійський науковий вісник: збірник наукових праць. – Вип. 17. – Херсон, 2001. – С. 7–11.

[39] Коровин А.И. Растения и экстремальные температуры / А.И. Коровин. – Л.: Гидрометеоиздат, 1984. – 164 с.

[40] Коровин А.И. Растения и экстремальные температуры / А.И. Коровин. – Л.: Гидрометеоиздат, 1984. – 164 с.

permeability[41]. In addition, buckwheat sown on plowed areas had better rates of photosynthetic activity of plants[42, 43] and higher yields. At the same time, the coefficients of energy use (the ratio of energy input to costs) were at the same level[44].

Plowing is recommended in unirrigated conditions for afterharvested buckwheat sowings[45]. In dry years, the dynamiting by shallow plows (15–17 cm) or heavy disc tillers to a depth of 13–15 cm is recommended.

However, the method of cultivation of the soil depends not only on the presence of irrigation, but also on the natural moisture. Thus, with sufficient moisture in the soil, plowing is carried out to a depth of 18–20 cm with simultaneous harrowing; with insufficient moisture, surface tillage to a depth of 10–12 cm is used.

In the arid regions of Tataria and northern Kazakhstan, subsurface beardless plowing for buckwheat contributes to greater moisture accumulation and reducing its evaporation, while soil with stubble freezes to a lesser depth and is better moistened in the spring. Replacement of tillage by subsurface plowing under these conditions made it possible to reduce production costs for cultivation and increase profitability by up to 108%[46]. The results of industrial experiments in the Poltava region, according to which the yield of buckwheat of different sowing periods was lower in the variant with regular plowing

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[41] Анохин А.Н. Послеукосные посевы гречихи / А.Н. Анохин // Научные труды Белорусского НИИ земледелия. – 1977. – Вып. 21. – С. 155.

[42] Когут В.В. До питання впливу метеорологічних факторів на урожайність гречки сорту Вікторія / В.В. Когут // Збірник наукових праць. – Вип. 8. – Кам'янець-Подільський, 2000. – С. 59–61.

[43] Коровин А.И. Растения и экстремальные температуры / А.И. Коровин. – Л.: Гидрометеоиздат, 1984. – 164 с.

[44] Медведев Г.А. Влияние приемов агротехники на урожайность сортов проса на светло-каштановых почвах Волгоградской области / Г.А. Медведев, М.В. Иванов // Научные сообщения КДН. – Волгоград, 1998. – Бюл. № 7. – С. 13–16.

[45] Коровин А.И. Растения и экстремальные температуры / А.И. Коровин. – Л.: Гидрометеоиздат, 1984. – 164 с.

[46] Болдырев А.П. Промежуточные посевы – важный фактор интенсификации / А.П. Болдырев, А.П. Погребняк, А.І. Лунчу // Земледелие. – № 7. – 1984. – С. 42–44.

compared to the subsurface plowing, although it was almost independent of the depth of its cultivation[47].

Many researchers pay attention to conservation tillage, which promotes the preservation and restoration of soil fertility and is used to reduce water and wind erosion, and decrease the number of operations and mechanical load on the soil[48].

Thus, the subsurface tiller leaves a large number of crop residues and stubble on the surface of the field, at the same time mulching them and cutting the roots of the weeds without turning the soil. According to the data of St. Peterburgskiy A.V.[49], with such a tillage 840–1960 kg/ha of wheat mulch stubble remains in this soil, which is distributed on the surface of the field, protecting the soil and seedlings of plants from crust formation after rain, excessive evaporation of moisture and others. The protected stubble helps to reduce the wind speed near the soil surface by 3–5 times compared to the plowed field, to reduce the soil temperature by 4–7ºC during the daytime hours and additionally keep 10–30 mm of water reserves, for example, snow. It is believed that kept 10 mm of moisture in the soil is equivalent to getting 100 kg of grain[50].

The results of the experiments[51] are in favor of minimal soil cultivation for buckwheat and stubble mulching in areas vulnerable to wind erosion. Thus, the experimental 5-year data show the efficiency of minimal tillage and mulching of stubble at the Voznesenski State Variety Test Plot for buckwheat: as a result, reserves of productive moisture and

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[47] Ушкаренко В.А. Агротехнічні умови одержання високих урожаїв гречки у післяжнивних посівах / В.А. Ушкаренко, А.В. Аверчев, М.С. Черниш // Агрохімія і ґрунтознавство: Міжвідомчий тематичний науковий збірник. – Спец. вип. до 5 з'їзду УТГА (6–10 липня 1998 р., м. Рівне). – Ч. 3. – Харків, 1998. – С. 177.

[48] Медведев Г.А. Влияние приемов агротехники на урожайность сортов проса на светло-каштановых почвах Волгоградской области / Г.А. Медведев, М.В. Иванов // Научные сообщения КДН. – Волгоград, 1998. – Бюл. № 7. – С. 13–16.

[49] Болдырев А.П. Промежуточные посевы – важный фактор интенсификации / А.П. Болдырев, А.П. Погребняк, А.І. Лунчу // Земледелие. – № 7. – 1984. – С. 42–44.

[50] Ушкаренко В.А. Агротехнічні умови одержання високих урожаїв гречки у післяжнивних посівах / В.А. Ушкаренко, А.В. Аверчев, М.С. Черниш // Агрохімія і ґрунтознавство: Міжвідомчий тематичний науковий збірник. – Спец. вип. до 5 з'їзду УТГА (6–10 липня 1998 р., м. Рівне). – Ч. 3. – Харків, 1998. – С. 177.

[51] Анохин А.Н. Послеукосные посевы гречихи / А.Н. Анохин // Научные труды Белорусского НИИ земледелия. – 1977. – Вып. 21. – С. 155.

biological activity in the soil increased, which contributed to a positive balance of humus and increase of NPK content[52].

In the Dnepropetrovsk region, for postharvested buckwheat on irrigation after harvesting the forecrop, it is recommended to immediately make husking and subsequently subsurface plowing to a depth of 16–18 cm with simultaneous rolling, then irrigation and cultivation[53], noting that the economic efficiency of subsurface plowing and harrowing is higher than of the regular plowing[54].

Panicum is known for its demand for tillage quality, due to its low competitiveness and vulnerability to weed infestation. In the southern regions of Ukraine, plows, chisel cultivators, needle-cutters, shallow plow and heavy disc harrows are used for Panicum.

Thus, in the system of cultivation of the soil after cereals, legumes and corn before plowing, scuffing with disk plough-harrow to a depth of 6–8 cm is carried out, and in the fields with rhizome weeds shallow plows are also used, which also helps to reduce the number of harmful organisms[55]. It is set that the clearness of Panicum sowings is ensured by annual plowing in alternation with subsurface tillage to a depth of 12–14 cm: in arid years, the stubble remaining on the soil surface after planed tillage allows to reduce the yield.

The study of the methods of soil cultivation in irrigated conditions of the USA showed that with increasing depth of cultivation the loss of soil moisture due to its evaporation increases[56]. Thus, after treatment with a disk plough-harrow, the evaporation of moisture from 0–12 cm of soil layer in the first day was 73–83 mm, and after 4 days it was120–128 mm / ha. At the same time, 50% of post-harvest residues

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[52] Когут В.В. До питання впливу метеорологічних факторів на урожайність гречки сорту Вікторія / В.В. Когут // Збірник наукових праць. – Вип. 8. – Кам'янець-Подільський, 2000. – С. 59–61.

[53] Коровин А.И. Растения и экстремальные температуры / А.И. Коровин. – Л.: Гидрометеоиздат, 1984. – 164 с.

[54] Болдырев А.П. Промежуточные посевы – важный фактор интенсификации / А.П. Болдырев, А.П. Погребняк, А.І. Лунчу // Земледелие. – № 7. – 1984. – С. 42–44.

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[56] Анохин А.Н. Послеукосные посевы гречихи / А.Н. Анохин // Научные труды Белорусского НИИ земледелия. – 1977. – Вып. 21. – С. 155.

were remained into the soil, which is not enough to protect the surface of the field from winds and direct sunlight. Obviously, as a result of double peeling, the stubble loss of soil moisture was more than 250 mm. Instead, 90% of residues remained on the soil after subsurface tiller with moisture losses of 25 mm in the first day and only 35 mm in 4 days. In addition, such cultivation helped to protect the soil from erosion, increase the moisture content and organic matter in it, and increase the Panicum crop in drought conditions and provide fuel savings and wear of machinery from 25 to 50%[57].

The study of the methods of cultivation of soil for Panicum in Ukraine showed that for sowing after winter rye on green forage subsurface tillage provide a yield increase of 1500 kg/ha compared to plowing[58]. According to the results of studies[59], cultivation of the soil after harvesting winter wheat in the Holopristansky district of Kherson region should be carried out with a BDT-7 disc harrow to a depth of 10–12 cm under post-harvested sowing.

Instead it is believed that in comparison with a plowing to a depth of 10–12 cm, plowing to a depth of 20–22 cm, provides more favorable conditions for the growth and development of Panicum and a significant increase in yield[60]. The efficiency of plowing is significantly increased in irrigated areas. Thus, in the conditions of rice crop rotation in the Kherson region, the disking caused a decrease in the yield of post-harvest Panicum in dry years, but in wet years crop was within a typical year. This is explained by the fact that in dry years, the dryness of soil and air affects the appearance of even sprouts. That is, to obtain even sprouts, surface tillage, in comparison

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[57] Аверчев О.В. Агротехніка вирощування гречки в проміжних посівах на зрошуваних землях України / О.В. Аверчев, Н.М. Рудік, Ю.В. Аверчев // Вісник ДААУ. – Спец. вип. "Проблеми виробництва екологічно-чистої сільсько-господарської продукції". – Житомир, 2000. – С. 3–4.

[58] Ушкаренко В.А. Агротехнічні умови одержання високих урожаїв гречки у післяжнивних посівах / В.А. Ушкаренко, А.В. Аверчев, М.С. Черниш // Агрохімія і ґрунтознавство: Міжвідомчий тематичний науковий збірник. – Спец. вип. до 5 з'їзду УТГА (6–10 липня 1998 р., м. Рівне). – Ч. 3. – Харків, 1998. – С. 177.

[59] Коровин А.И. Растения и экстремальные температуры / А.И. Коровин. – Л.: Гидрометеоиздат, 1984. – 164 с.

[60] Анохин А.Н. Послеукосные посевы гречихи / А.Н. Анохин // Научные труды Белорусского НИИ земледелия. – 1977. – Вып. 21. – С. 155.

to deeper ones, requires rainy weather or additional irrigation. According to data 7, in irrigated areas for Panicum reswoing, the efficiency of plowing increases 1.7 times, with the total conditionally net income reaching 393.7 UAH / ha, including at the expense of Panicum – 259.6 UAH / ha.

According to zero-cultivation technologies, Panicum is grown in boharic areas of Colorado (USA), where sowing is done by direct seeding in stubble or plant residues from previous crops. The prospect of such technology is also proven at the University of Nebraska[61]. It is also widely used by Australian farmers in semi-subsistence rice sowing areas. However, scientists point out that the zero tillage of Panicum is accompanied by a considerable weediness of crops, which requires several herbicides application and leads to additional production costs[62].

For example, at sowing on weeds stubble there are 1.8 more sprouts than at the average plowing, and 2.8 times more than sowing at deep plowing[63]. In contrast, observations[64] showed that in the irrigated fields of Kherson region the tillage of Panicum sowings with cultivator SZS-2,1 reduce weediness by three times by the end of the growing season.

The soil tillage system also requires appropriate fertilizer. Thus, minimal tillage requires increased doses of fertilizers, and at the application of nitrogen fertilizers, the efficiency of stubble sowings is higher than the sowings on plowing, especially with a small wrap of fertilizers.

CONCLUSIONS

Research results and practical experience show that cereal crops growing in resowing is not only possible but also economically viable.

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[61] Зубец Г.Г. Влияние предшественников на урожай и количество зерна проса / Г.Г. Зубец // Пути повышения урожайности крупяных культур. – К., 1969. – С. 177–179.

[62] Пустовая З.В. Усовершенствование элементов агротехники выращивания проса в летних посевах / З.В. Пустовая // Сб. науч. тр. межд. конф., посв. 30-лет. науч.-иссл. инс-та круп. культур. – Каменец-Подольский, 2002. – С. 223–228.

[63] Жученко А.А. Адаптивный потенциал культурных растений (Эколого-генетические основы) / А.А. Жученко. – Кишинев: Штиинца, 1988. – 767 с.

[64] Аверчев О.В. Агротехніка вирощування гречки в проміжних посівах на зрошуваних землях України / О.В. Аверчев, Н.М. Рудік, Ю.В. Аверчев // Вісник ДААУ. – Спец. вип. “Проблеми виробництва екологічно-чистої сільсько-господарської продукції”. – Житомир, 2000. – С. 3–4.

The main condition for obtaining high and stable yields of buckwheat and Panicum is possible when the agrotechnical conditions of cultivation are observed, depending on the agro-climatic conditions of farming. Thus our experiments and Ukrainian and foreign scientists have established that buckwheat is not very demanding to its forecrops as biological objects. However, after the forecrop that leave the soil foul, buckwheat significantly reduces the yield. Concerning the place of Panicum in a crop rotation, the opinions of specialists in the assessment of the positive impact of a forecrop on the crop yield are somewhat different, but in the definition of the worst forecrop they practically agree. Thus, barley and oats are among the worst Panicum forecrops among cereals. Panicum grain yields are also significantly reduced after such forecrops as Sudan grass, sorghum and sunflower. In summer sowings of cereal crops, the main tillage of the forecrops stubble is mainly fall-plowing, 15–20 days after the last husking; after sugar beet and potatoes harvested late, plowing or flat-cutting is carried out as soon as the fields are cleared. The cultivation depth is 20–22, after corn – 25–27 cm.

A study of the methods of cultivation of soil under irrigation conditions in the United States showed that with increasing depth of cultivation, the loss of soil moisture due to its evaporation increases. Thus, after cultivation with disk plow-harrow, the evaporation of moisture from 0–12 cm of soil layer in the first day was 73–83 mm, and after 4 days it was 120–128 mm/ha. According to zero-tillage technologies, Panicum is grown in boharic areas of Colorado (USA), where sowing is done by direct seeding in stubble or plant residues from previous crops. The prospect of such technology is also proven at the University of Nebraska. It is also widely used by Australian farmers in semi-subsistence rice sowing areas. The observations showed that in the irrigated fields of Kherson region the tillage of Panicum sowings with cultivator SZS-2,1 reduce weediness by three times by the end of the growing season.

The soil tillage system also requires appropriate fertilizer. Thus, minimal tillage requires increased doses of fertilizers, and at the application of nitrogen fertilizers the efficiency of stubble sowings is higher than the sowing on plowing, especially with a small wrapping of fertilizers.

SUMMURY

An analysis of the literature sources is made and the results of our own research on the agro-technical and climatic conditions of cereal crops growing in resowing is carried out. The results of studies of the place of Panicum and buckwheat in crop rotations are considered. The evaluated of cereal crops as forecrops to themselves and other cultures is given. The review of scientific researches, concerning influence of soil tillage for buckwheat and Panicum in resowings on the level of productivity is given. Analyzing the bioclimatic potential of the regions of the Southern Steppe of Ukraine and the biological potential of the studied crops, it was found that under these conditions it is possible to grow not only early- but also middle-ripe varieties of buckwheat and Panicum in post-harvested sowings.

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Information about the author:
Averchev O. V.,
Doctor of Agricultural Science, Professor,
Prorector for Scientific Work and International Activity,
State Higher Educational Institution
"Kherson State Agricultural University"
23, Stritenskaya str., Kherson, Ukraine

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INFLUENCE OF DIFFERENT MELIORATION LOADS ON THE PHYSICO-CHEMICAL PROPERTIES OF DARK-CHESTNUT IRRIGATED SOIL

Bidnyna I. O.

INTRODUCTION

Modern agriculture needs measures directed to the increase of the level of crops productivity, obtaining high-quality yield with reduced expenditures for their cultivation. The reduction of expenditures for production of agricultural products can be achieved at the minimization of basic tillage at the expense of decrease in its depth, multiplicity of aggregates' passages or switching from moldboard tillage to less expensive plowless one. Besides, an important role in obtaining high and sustainable yields of crops plays the application of mineral fertilizers. By optimizing the doses of fertilizers' application, the efficiency of their use increases, expenditures and chemical load on the soil decrease. The introduction of the above-mentioned measures significantly reduces the energy, labor and material expenditures on the production at the irrigated lands.

Irrigation is one of the most powerful factors of the intensification of agricultural production. It has got wide distribution throughout the world. Nowadays, more than 270 million ha on the planet are irrigated, which is 18% of the total area of arable land, which produce 40% of the volume of agricultural products, that is the productivity of one irrigated hectare is more than twice higher than the productivity of unirrigated one. Irrigated lands in Ukraine are mainly located in the Steppe and Forest-Steppe natural and climatic zones, the total area of which is about 2 million ha, the actually irrigated every year area is 0.5–0.7 million ha[1].

However, irrigation, along with a positive effect, can firstly result in the transformation of water and gas regimes, and then lead to

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significant changes in the content of absorbed cations of the soil absorption complex and in a number of physical parameters. The intensity of soil transformation is especially increased with the use of water, which is limited suitable and unsuitable by the agronomical and ecological criteria[2].

Therefore, this problem requires a detailed and deep experimental study of the impact of such technologies not only on the productivity of crops, but also on the soil-forming processes and ecological stability of the functioning of agroecosystems in the zone of irrigation.

The system of basic tillage, together with fertilization system, significantly determines the level of energy-saving of a technology, its ecological and economic orientation[3].

The development and application of this or that soil tillage is closely connected with general changes in the industry, the nature of land use, the appropriate structure of cultivated areas, the trends in climate change and melìorative measures. Today, soil-protective resource-saving technologies of soil tillage are getting wider distribution and introduction, which allow to reduce resources and reduce the negative effect on the environment, including the fertility of soils[4].

The increase in the cost of fuels, lubricants and mineral fertilizers has led to a significant increase of their share in the cost of production, so, an important value is assigned to the introduction of energy and resource-saving technologies, which would provide the increase in yields and economical use of material resources, would be environmentally friendly and adapted to the conditions of the soil and climatic zone.

The results of perennial researches testify that the use of conventional soil tillage system with moldboard plowing is not always justified. It does not provide reliable soil protection against deflation and irrigational erosion, may lead to the over-compaction of the soil[5].

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In the conditions of irrigation with the waters of the increased mineralization at the existing agricultural technologies of crops cultivation, the issue of the prolongation of the factors through the integrated interaction between crop rotation, tillage and doses of mineral fertilizers is relevant. An important value has more detailed description of these components, comparison of their impact on soil fertility rates and crop yields[6].

Long-lasted studies found out that the improvement of soil fertility in the conditions of irrigation is observed at the differentiated by the depth plowless tillage, which reduces the expenditures and prevents the development of degradation soil processes. It is also established that deep plowing provides less optimal nutrition regime of soil at the beginning of crops vegetation in comparison to plowless tillage, herewith the microbiological activity of the upper layer is disturbed, the decomposition of post-harvest residues slows down and it delays the growth and development of plants[7].

To determine the changes in the physical and chemical properties of the irrigated soil at different melioration loads in the zone of Ingulets irrigation system, the studies were carried out on the experimental fields of the Institute of Irrigated Agriculture of NAAS in the Department of Irrigated Agriculture during 2016–2018. Th soil of the experimental fields – dark-chestnut middle-loamy slightly alkaline, typical for Southern Steppe. The experiment was performed to study the systems of basic soil tillage and doses of fertilizers in the irrigated fruit-changing crop rotation (Table 1).

The area under the research was 2 ha, the area of the sowing was 218 m^2, the estimated area was 36 m^2.

The field experiences were set and conducted in accordance with the general field research methodologies[8], as well as State standards.

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Table 1

The scheme of the stationary experiment on the studying of basic soil tillage systems in the irrigated crop rotation

No. var.	Basic soil tillage system	Tillage under the culture crop rotation			
		Grain corn	Sorghum	Winter wheat	Soybean
1	Plowing	20–22 (p)	23–25 (p)	14–16 (p)	25–27 (p)
2	Plowless	20–22 (ch)	23–25 (ch)	14–16 (ch)	25–27 (ch)
3	Plowless	12–14 (d)	12–14 (d)	12–14 (d)	12–14 (d)
4	Differentiated-1	8–10 (d)	12–14 (ch) + + 38–40 (s)	8–10 (d)	14–16 (d)
5	Differentiated-2	18–20 (p)	16–18 (ch)	10–12 (d)	14–16 (d)

Note: p – plowing; ch – chisel loosening; d – disc tillage; s – slotting.

The analysis of ion-salt composition of water extraction of the soil was determined according to the Hedroits method (GOST 26424–85); exchangeable sodium – in the extract of 1% acetic acid ammonium, flame-photometric by the GOST 2685086; exchangeable calcium and magnesium – by the DSTU 26487–85.

1. Ion-salt composition of the irrigation water and its irrigation evaluation

Evaluation of irrigation water quality is one of the most relevant issues of meliorative soil science and irrigated agriculture both in Ukraine and abroad. According to the Hydrogeological and Meliorative Service (HGMS) of the State Agency of Ukraine, 70–75% of the irrigated lands' areas use water with the mineralization of less than 1 g/dm^3, the rest – more than 1 g/dm^3. At the same time the irrigation water with the mineralization of 1–2 g/dm^3 is used for watering of 18 – 20% of the area of irrigated land, and only 7–9% of their area are irrigated with the waters with mineralization of more than 2 g/dm^3.

In the fresh waters, the salt composition is mainly represented by hydro carbonates of calcium and magnesium – 50–60%, the rest are. In the mineralized waters, the sulphates and chlorides of sodium and magnesium prevail. Total mineralization and chemical composition of irrigation waters are characterized by clearly identified seasonal variability. The changes in the alkaline properties of water are noticeable, when the hydrogen power (pH) fluctuates between 7.4–7.9 to 8.0–9.0, and sometimes higher, and the content of CO_3^{2-} (soda) – from the slight marks to 0.3–0.8 meq/dm^3.

Agronomic criteria for water suitability for irrigation are defined by the DSTU 2730:2015[9] , according to which the ranking of irrigation water is carried out considering the composition and properties of soils. During the evaluation of the quality of irrigation water, three classes of its suitability are distinguished: class I – Suitable, class II – Limited suitable, class III – Unsuitable.

At the time of the researches conduction at the Institute of Irrigated Agriculture of NAAS, the monitoring of the chemical composition of irrigation water during the plants vegetation was carried out. In 2016, the mineralization of irrigation water fluctuated within 1.444–1.813 g/dm^3, in 2017 – 1.130–1.584 g/dm^3, in 2018 – 1.418–1.891g/dm^3 (Table 2).

The ion-salt composition of the irrigation water during the irrigation period was stable. Mineralization of the irrigation water for 2016 year averaged to 1.596 g/dm^3, for 2017 year – 1.432 g/dm^3, for 2018 year – 1.6932 g/dm^3. According to the chemical composition, the water belonged by the anionic composition to chloride-sulphate, and by the cation composition to magnesium-sodium.

The content of toxic salts in chloric equivalent, which characterizes the quality of water by the threat of secondary soil alkalination, is, on average, for 2016 year – 15.46 meq/dm^3, for 2017 year – 11.48 meq/dm^3, for 2018 year – 13.36 meq/dm^3 and belongs to the II class (limited suitable for irrigation) (Table 3).

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Table 2

Mineralization and ion-salt composition of irrigation water in 2016–2018

Date of sampling	pH	Content of ions, meq/dm^3 %							Mineralization, g/dm^3
		CO_3^{2-}	NCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	
2016									
19.05.	8.3		3.36 / 0.205	8.16 / 0.290	11.80 / 0.566	4.80 / 0.096	6.60 / 0.079	11.92 / 0.274	1.510
14.06.	8.7	0.80 / 0.024	2.64 / 0.161	10.96 / 0.389	9.08 / 0.436	2.40 / 0.048	9.00 / 0.108	12.08 / 0.278	1.444
12.07.	8.6	0.64 / 0.019	2.56 / 0.156	11.04 / 0.392	14.60 / 0.701	4.80 / 0.096	9.40 / 0.113	14.64 / 0.337	1.813
09.08.	7.5	-	3.20 / 0.195	10.00 / 0.355	11.20 / 0.538	4.20 / 0.084	7.80 / 0.094	12.40 / 0.285	1.551
23.09.	7.8	-	3.20 / 0.195	11.20 / 0.398	11.80 / 0.566	5.00 / 0.100	7.60 / 0.091	13.60 / 0.313	1.663
2017									
31.05.	8.0		3.04 / 0.185	10.64 / 0.378	11.40 / 0.547	4.40 / 0.088	8.20 / 0.098	12.48 / 0.287	1.584
29.06.	8.5	0.24 / 0.007	3.04 / 0.185	11.04 / 0.392	13.00 / 0.624	5.00 / 0.100	9.00 / 0.108	13.32 / 0.306	1.723
25.07.	7.8		3.04 / 0.185	10.80 / 0.383	10.80 / 0.518	4.00 / 0.080	8.20 / 0.098	12.44 / 0.286	1.552
29.08.	7.7	-	2.56 / 0.156	8.24 / 0.293	8.00 / 0.384	3.40 / 0.068	6.20 / 0.074	9.20 / 0.212	1.187
25.09.	7.2	-	3.04 / 0.185	6.64 / 0.236	7.80 / 0.374	3.40 / 0.068	5.20 / 0.062	8.88 / 0.204	1.130

Table 3

Evaluation of the irrigation water in 2016–2018

Years of the research	Mineralization g/dm³	pH	The concentration of toxic ions in the equivalents of Cl, meq/dm³	$\frac{100\ Na^{+}}{Ca^{2+} + Mg^{2+} + Na^{+}}$	$\frac{Mg^{2+}}{Ca^{2+}}$	$\frac{Ca^{2+}}{Na^{+}}$	Content of ions meq/dm³			Water class by hazard of (DSTU 2730:2015)			
							CO_3^-	HCO_3^-	Cl^-	Salinization	Alkalination	Alkalinity	Plants toxic effects
2016													
19.05.	1.510	8.3	10.50	51.1	1.4	0.40	0.00	3.36	8.16	II	II	II	II
14.06.	1.444	8.7	20.95	49.7	3.8	0.20	0.80	2.64	10.96	II	II	III	III
12.07.	1.813	8.6	20.02	49.6	2.0	0.33	0.64	2.56	11.04	II	II	III	III
09.08.	1.551	7.5	12.28	50.8	1.9	0.34	0.00	3.20	10.00	II	II	I	II
23.09.	1.663	7.8	13.44	51.9	1.5	0.37	0.00	3.20	11.20	II	II	II	II
Mean	1.596	8.2	15.46	51.2	1.9	0.33	0.29	2.99	10.27	II	II	II	II
2017													
31.05.	1.584	8.0	12.86	49.8	1.9	0.35	0.00	3.04	10.64	II	II	II	II
29.06.	1.723	8.5	15.86	48.3	1.8	0.38	0.24	3.04	11.04	II	II	III	III
25.07.	1.552	7.8	12.98	50.5	2.1	0.32	0.00	3.04	10.80	II	II	II	II
29.08.	1.187	7.7	9.78	48.9	1.8	0.37	0.00	2.56	8.24	II	II	II	II
25.09.	1.130	7.2	8.34	50.8	1.5	0.38	0.00	3.04	6.64	II	II	II	II
Mean	1.432	7.8	11.48	49.6	1.8	0.36	0.003	2.94	9.47	II	II	II	II
2018													
28.05	1.769	7.6	13.50	50.6	1.3	0.43	0.00	4.16	10.96	II	II	II	II
21.06	1.724	8.1	14.23	50.0	2.2	0.31	0.00	4.08	11.52	II	II	II	II
19.07	1.664	8.0	13.62	51.9	1.5	0.37	0.00	3.44	11.36	II	II	II	II
16.08	1.891	8.4	15.64	47.4	1.8	0.39	0.32	3.76	13.10	II	II	III	III
20.09	1.418	7.2	11.73	51.4	1.9	0.32	0.00	2.88	9.76	II	II	II	II
Mean	1.661	7.9	13.36	49.6	1.7	0.38	0.00	3.59	10.98	II	II	II	II

By the hazard of soil alkalinity increase, salinization and toxic effects on plants, the irrigation water also belongs to the same class of quality. The value of water pH changed within 7.2 to 8.7. In certain summer periods of water sampling, the water in the pool by the presence of CO_3^- and high pH of 8.5 belonged to the III class by the alkalinity hazard and its toxic influence on plants.

The ratio of calcium to sodium content is an important criterion of irrigation water assessment. In the irrigation water, used in our experiments, this ratio was 0.36, indicating the activity of sodium cations.

Thus, according to the acting standard, the irrigation water belongs to the class II and it is limited suitable for irrigation by the threat of secondary salinization, alkalination, alkalinity increase and toxic effects on plants.

2. Dynamics of exchangeable cations and ion-salt composition of water extraction of the soil

Analyzing materials on the content of exchangeable cations in the 0–40 cm layer of the soil at the end of the vegetation, it is possible to conclude that the least process of alkalination occurs under plowing in the system of long-term application of the different-depth soil tillage and in the system of differentiated tillage in the crop rotation (variants 1 and 4) (Table 4).

The share of exchangeable sodium in the soil layer 0–40 cm increased in the soil absorption complex at the expense of the absorbed calcium, the content of which relatively decreased (variant 1) at the plowless ways of tillage by 2.67–3.48%, and at the plowing at the depth of 18–20 cm in the system of differentiated soil tillage in the crop rotation (variant 5) – by 2.97%. Under the disk tillage at the depth of 8–10 cm in the system of differentiated tillage of the crop rotation (variant 4), the content of Ca^{2+} was at the level of the plowing (variant 1) and fluctuated within 66.2–68.3% from the sum of the cations. Application of fertilizers with the doses N_{120} and N_{180} increased the Ca^{2+} content by 1.7–2.1% of the sum of the cations. The conduction of plowing in the system of prolonged application of different-depth moldboard soil tillage (variant 1) and the system of differentiated tillage in the crop rotation (variant 4) positively affected the amount of exchangeable cations in the soil, which was the largest and fluctuated in the layer 0–40 cm within 20.9–21.0 meq/100 g, in the variants with application of fertilizers there is also a tendency to the increase by 0.3–0.4 meq/100 g of soil.

Table 4

Dynamics of exchangeable cations in the dark-chestnut soil at different methods of basic tillage and doses of fertilizers at the end of vegetation (the average for 2016–2018)

Variant	Content of exchangeable cations, meq/100 g of soil			Number of exchangeable cations, meq/100 g of soil	Share of the cation,%		
	Ca^{2+}	Mg^{2+}	Na^{+}		Ca^{2+}	Mg^{2+}	Na^{+}
Without fertilizers							
Plowing	13.8	6.4	0.78	21.0	65.8	30.5	3.7
Plowless-1	13.2	6.6	0.80	20.6	64.1	32.0	3.9
Plowless-2	13.0	6.8	0.82	20.6	63.0	33.0	4.0
Differentiated-1	13.8	6.3	0.75	20.9	66.2	30.2	3.6
Differentiated-2	13.4	6.6	0.80	20.8	64.4	31.7	3.8
N_{120}							
Plowing	14.4	6.2	0.71	21.3	67.6	29.1	3.3
Plowless-1	13.7	6.4	0.76	20.9	65.7	30.7	3.6
Plowless-2	13.3	6.7	0.79	20.8	64.0	32.2	3.8
Differentiated-1	14.4	6.1	0.72	21.2	67.9	28.7	3.4
Differentiated-2	13.8	6.4	0.75	21.0	65.9	30.5	3.6
N_{180}							
Plowing	14.6	6.1	0.66	21.4	68.4	28.6	3.1
Plowless-1	14.3	6.3	0.74	21.3	67.0	29.5	3.5
Plowless-2	13.4	6.4	0.77	20.6	65.1	31.1	3.7
Differentiated-1	14.5	6.1	0.64	21.2	68.3	28.7	3.0
Differentiated-2	14.1	6.2	0.73	21.0	67.0	29.5	3.5

LSD_{05}, meq/100 g soil:
A = 0.02, A =0.18 A =0.005
B = 0.03, B =0.02 B =0.006

On the variants with the system of prolonged use of different-depth plowing soil tillage in the crop rotation (variant 1) and in the system of differentiated tillage in the crop rotation (variant 4) and fertilizers application there was a tendency to the decrease of salinization by slightly mineralized irrigation water, where the highest content of absorbed calcium was fixed in the share of the cations of 67.6–68.4%. Whereas the content of magnesium and sodium was the largest under shallow plowless tillage (variant 3) – 33.0 and 4.0% without fertilizer, and 31.1–32.2 and 3.7–3.8% of the cation sum under fertilizers application that testifies about a slight increase in the secondary salinity in the variants with plowless way of tillage without fertilizers application.

Thus, irrigation with the water of high mineralization having adverse ratios of single-and divalent cations leads to changes in the qualitative composition of SAC at the end of crops vegetation that is accompanied by the increase of the share of exchangeable sodium and contributes to the development of the process of irrigative soil salinization.

The studies showed that irrigation with the Ingulets water with adverse ratio of mono- and bivalent cations leads to the changes in ion-salt composition of the soil water extraction. Thus, at the end of the vegetation, the content of water-soluble salts in the layer 0–40 cm increased in all the variants to 0.101–0.152%. The increase in the salts content mainly occurred at the expense of the increase of SO_4^{2-} and Cl^- ions among the anions and Na^+ among the cations. The content of toxic salts also increased in all the variants of the experiment in 0–10 cm layer by 0.45–0.9 times and in the 0–40 cm layer by 0.38–0.87 times.

However, the least their content is noted in the system of differentiated tillage in the crop rotation (variant 4) on the background of N_{180} – 0.064 in the layer 0–10 cm and 0.065% in the layer 0–40 cm. The ratio of calcium to sodium cations in the soil solution varies in the layer 0–10 cm in the range of 0.38 to 0.61 units, and in the 0–40 cm from 0.39 to 0.61 units points to the development of the active process of secondary alkalination (Table 5).

The transformation of the ionic composition of the water extraction led to the change in the chemistry of salinization, it became chloride-sulphate calcium-sodium in all the variants, regardless of the studied factors. Exchangeable processes in the soil-absorption complex have caused the increase of quantity of sodium cations in the soil solution.

Table 5

Ion-salt composition of water cooker hood in dark chestnut soil at various methods of basic processing and doses of fertilizers at the end of vegetation (the average for 2016–2018 years)

	Soil layer, cm	Content of ions, meq/100 g of soil							Sum of salts,%		Ca^{2+} / Na^{+}	pH
		CO_3^-	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	General	Toxic		
Without fertilizers												
1	0–10	0.00	0.22	0.64	1.00	0.50	0.40	0.96	0.121	0.091	0.52	7.0
	0–40	0.00	0.32	0.74	1.03	0.58	0.43	1.08	0.136	0.100	0.53	7.0
2	0–10	0.00	0.22	0.42	0.70	0.30	0.30	0.74	0.089	0.069	0.41	7.0
	0–40	0.00	0.23	0.48	0.83	0.38	0.28	0.88	0.101	0.077	0.43	7.1
3	0–10	0.00	0.28	0.72	1.30	0.50	0.50	1.30	0.151	0.120	0.38	7.2
	0–40	0.00	0.27	0.68	1.35	0.53	0.43	1.35	0.152	0.118	0.39	7.3
4	0–10	0.00	0.22	0.65	1.00	0.50	0.40	0.97	0.122	0.091	0.52	7.1
	0–40	0.00	0.24	0.56	0.93	0,50	0.33	0.89	0.113	0.081	0.56	7.1
5	0–10	0.00	0.28	0.48	0.80	0.40	0.30	0.86	0.104	0.077	0.47	7.2
	0–40	0.00	0.24	0.58	0.98	0.43	0.40	0.97	0.117	0.091	0.44	7.1
N_{120}												
1	0–10	0.00	0.24	0.68	1.20	0.60	0.40	1.12	0.139	0.101	0.54	7.2
	0–40	0.00	0.25	0.67	1.10	0.58	0.40	1.05	0.132	0.096	0.55	7.3
2	0–10	0.00	0.22	0.72	1.20	0.50	0.40	1.24	0.140	0.109	0.40	7.2
	0–40	0.00	0.23	0.56	1.05	0.45	0.33	1.06	0.121	0.092	0.42	7.2

The largest their content in the layer 0–40 cm of 1.26–1.35 meq/100 g of soil was observed on the variants of disk tillage at the depth of 12–14 cm in the system of shallow single-depth plowless soil tillage in the crop rotation (variant 3). Also, under this tillage option, the largest amount of sodium is fixed with no fertilizers applied in the experiment 1.30 in the layer 0–10 cm and 1.35 meq/100 g in the layer 0–40 cm.

The analysis of yield data in the crop rotation on average for 2016–2018 showed that in comparison to the plowing at the depth of 20–22 cm in the system of prolonged use of different-depth plowing soil tillage in the crop rotation (variant 1) the increase of corn yield was only under the carrying out tillage at the depth of 8–10 cm in the differentiated tillage system (variant 4) and constituted on average by the factor A (soil tillage method) 2.8%, with the level of yield depending on the dose of fertilizers 11.09–14.59 t/ha (Table 6).

Carrying out the disk tillage at the depth of 12–14 cm in the system of shallow single-depth plowless tillage in the crop rotation (variant 3) resulted in the decrease in the yield by 26.2%, and without fertilizer application it was up to the least yiled in the experiment of 3.06 t/ha. Fertilizer application of N_{120} and N_{180} increased the yield on average by the factor B (fertilizer dose) by 185.1 and 270.5%, respectively. Application of N_{90} under sorghum resulted in the yield increase by 173.7%, increasing the dosage of mineral fertilizers contributed to a lesser increase in the yield in comparison to other crops in the experiment, which on the background of N_{120} averaged to 179.2%. At the impact of soil tillage on sorghum yield the same tendency as on other crops is observed.

Chisel tillage at the depth of 12–14 cm with slotting at the depth of 38–40 cm in the system of differentiated soil tillage (variant 4) in comparison to plowing at the depth of 23–25 cm in the system of prolonged use of the differentiated plowing soil tillage in the crop rotation (variant 1) resulted in the yield increase on average by factor A (“soil tillage method”) by 14.2%.

Table 6

Yields of crops under the influence of different elements of their cultivation technology, t/ha (average for 2016–2018)

No.variant	Culture of crop rotation															
	Grain corn					Sorghum				Winter wheat			Soybean			
	Doses of fertilizers	N_{120}	N_{180}	Average by factor A	Doses of fertilizers	N_{120}	N_{180}	Average by factor A	Doses of fertilizers	N_{120}	N_{180}	Average by factor A	Doses of fertilizers	N_{120}	N_{180}	Average by factor A
1	3.89	10.82	14.32	9.68	2.76	7.51	7.65	5.97	3.27	6.25	7.03	5.52	2.57	3.71	4.30	3.53
2	3.57	10.39	13.75	9.24	2.35	7.11	7.32	5.59	3.15	5.69	6.38	5.07	2.32	3.25	3.96	3.14
3	3.06	8.25	10.11	7.14	2.08	4.92	5.08	4.03	2.83	5.37	6.15	4.78	1.37	2.11	2.48	1.99
4	4,17	11.09	14.59	9.95	3.26	5.54	8.67	6.82	3.45	6.38	7.29	5.71	2.68	3.79	4.47	3.65
5	3.46	10.81	14.09	9,45	2.28	6.81	6.89	5.33	2.99	5.39	6.24	4.88	2.21	3.38	3.96	3.18
Average by factor B	3.63	10.35	13.45		2.55	6.98	7.12		3.14	5.82	6.62		2.23	3.25	3.81	
LSD_{05}	B-1.59			A-0.41	0.25			0.16	0.31			0.18	0.26			0.17

Replacement of deep tillage with disk tillage at the depth of 12–14 cm in the system of prolonged use of single-depth shallow plowless soil tillage in the crop rotation (variant 3) resulted in a decrease in yield by 32.5%, at the other variants by 6.4–10.7%. The highest yield in the experiment was obtained under the conduction (variant 4) and application of mineral fertilizers in the dose of N_{120}, which averaged to 8.67 t/ha. In the experiment with winter wheat, fertilization increased the yield of the crops on average by factor B ("fertilizer dose") by 85.4 and 110.8%, respectively. The impact of the methods of soil tillage on the yield of winter wheat was less. The disk tillage at the depth of 8–10 cm in the system of differentiated soil tillage with one slotting per the crop rotation (variant 4) resulted in the increase of winter wheat yield on average by factor A ("soil tillage method") by 3.4%, whereas at the other variants (2, 3, 5) the yield losses compared with the plowing at the depth of 14–16 cm in the system of prolonged use of different-depth plowing soil tillage in the crop rotation (variant 1) was from 8.2 to 13.4%.

The level of soybean yield at plowing at the depth of 25–27 cm (variant 1) and disk tillage at the depth of 14–16 cm (variant 4) on the fertilized backgrounds was the best and constituted, depending on the doses of fertilizers, 3.53–4.30 t/ha and 3.65–4.47 t/ha, respectively. Under the reduction of tillage depth (variant 3) the yield decreased on average by factor A ("soil tillage method") by 43.6%, compared to the control, and under the application of $N_{30}P_{60}$ and $N_{60}P_{60}$ – increased on average by factor B ("fertilizer dose") by 45.7 and 70.9%, respectively.

By the results of statistical evaluation, there is a strong positive correlation relationship (r = 0.8227) between the soybean productivity and the ratio of Ca^{2+}/Na^{+} in the water extraction of the soil. A correlation-regression analysis of the experimental data allowed finding out the dependence of soybean yield on the ratio of Ca^{2+}/Na^{+}. The calculations proved that under the increase of the ratio of Ca^{2+}/Na^{+} in the water extraction of the soil higher level of soybean yield was formed. The discovered dependencies allowed us to suggest that changes in the formation of soybean productivity by 80% could be caused by the changes in the ratio of Ca^{2+}/Na^{+} in the water extraction of the soil, i.e. from agrophysical and chemical properties of the soil.

Thus, the best conditions for the formation of yields in the experiment were created by the differentiated soil tillage system with one slotting per the crop rotation (variant 4), and the application of the increased doses of fertilizers.

Evaluating the economic efficiency of agricultural methods of the crops cultivation, the expenditures were calculated according to the norms and prices, which were actual in the production boundaries of the Steppe zone of Ukraine in 2018.

The highest profit from 1 ha of the crop rotation area (35,223 UAH/ha) was obtained at the nutrition background $N_{120}P_{60}$ with the differentiated soil tillage (variant 4) (Table 7).

The highest level of profitability – 197% was determined in the same variant. By the other systems of soil tillage and doses of fertilizers, it decreased to the boundary values of 12 – 179%. The lowest level of profitability was observed at carrying out disk tillage in the shallow single-depth plowless soil tillage (option 3) on the unfertilized background – 12%. Based on the data analysis, it is possible to say that for 1 ha of the crop rotation area, a chisel tillage at the depth of 12–14 cm with one slotting at 38–40 cm per the crop rotation in the system of differentiated soil tillage (variant 4) is the most economically advantageous. Also, the energy evaluation of such elements as the system of basic soil tillage, the system of fertilizers application in the crop rotation was carried out. The outlet of gross energy for 1 ha of the crop rotation area depending on the methods of basic soil tillage and doses of fertilizers was the highest in the unfertilized variant and at the nutrition background of $N_{82.5}P_{60}$ at the chisel tillage at the depth of 12–14 cm and one slotting at the depth of 38–40 cm in the system of differentiated tillage (variant 4) and averaged to 65.6 and 143.4 GJ/ha, and at the $N_{120}P_{60}$ it was the highest under the prolonged use of different-depth plowing tillage (variant 1) – 160.4 GJ/ha, where the indexes of gross energy in the system of differentiated soil tillage (variant 4) were a little bit lower – 156.0 GJ/ha.

In the variants with the use of the different-depth plowless tillage (variant 2) and the differentiated-2 (variant 5) basic tillage it fluctuated within 127.1–127.2 and 150.3–150.7 GJ per hectare according to nutrition backgrounds. In the variant with the plowless shallow tillage, the gross energy outlet in the variants of fertilization (without fertilizers, $N_{82.5}P_{60}$ and $N_{120}P_{60}$) – decreased to 45.0 GJ, 99.2 and 114.0 GJ, respectively.

Table 7

Evaluation of energy and economic efficiency of the crops cultivation technology under the influence of different elements, t/ha (average for 2016–2018)

No. Variant	For 1 ha of the crop rotation area											
	Profit, thousand UAH/ha			Level of profitability,%			Outlet of gross energy, GJ			Energy efficiency coefficient		
	Without fertilizers	$N_{82.5}P_{60}$	$N_{120}P_{60}$	Without fertilizers	$N_{82.5}P_{60}$	$N_{120}P_{60}$	Without fertilizers	$N_{82.5}P_{60}$	$N_{120}P_{60}$	Without fertilizers	$N_{82.5}P_{60}$	$N_{120}P_{60}$
1	7109	26209	32438	55	156	179	60.4	136.2	160.4	1.6	3.5	4.0
2	5445	23343	29419	42	141	165	55.1	127.2	150.7	1.5	3.4	4.0
3	1586	14104	175176	12	86	98	45.0	99.2	114.4	1.3	2.7	3.1
4	8931	28866	35223	70	178	197	65.6	143.4	156.0	1.8	3.9	4.1
5	4798	23621	29470	38	144	166	52.4	127.1	150.3	1.4	3.4	4.0

Comparing the energy coefficient (the correlation between energy in the obtained yield and the energy expenditures in the technological cycle of the crop cultivation), it is possible to conclude that the least payback of the costs for the cultivation technology by the fertilizer doses were created at the shallow single-depth basic soil tillage (variant 3), the energy coefficient was 1.3, 2.7 and 3.1 by the nutrition backgrounds of without fertilizers, $N_{82.5}P_{60}$ and $N_{120}P_{60}$, respectively. While under the chisel tillage at the depth of 12–14 cm with one slotting at 38–40 cm per the crop rotation in the system of differentiated soil tillage (variant 4) it gained the maximum value and reached 1.8, 2.9 and 4.1 by the nutrition backgrounds, respectively.

CONCLUSIONS

By the results of the study we have determined that according to the actual standard the irrigation water of the Ingulets irrigation system belongs to the Class II and is limited suitable for irrigation by the threat of secondary salinization, alkalination, alkalinity increase and toxic effects on plants. Irrigation with the waters of high mineralization with adverse ratios of single-and divalent cations leads to the changes in the qualitative composition of the SAC at the end of the vegetation of crops, where leaching calcium out of the soil is observed, which is accompanied by the growth of the share of exchangeable sodium and contributes to the development of the process of irrigative alkalination of the soil.

Conduction of different methods of basic soil tillage and application of different doses of fertilizers cannot eliminate the process of irrigative alkalination, and at the plowing and differentiated tillage, where plowing during the crop rotation alternates with shallow plowless loosening under the crops of the rotation, with the use of nitrogen fertilizers, where the largest content of absorbed calcium from the sum of cations of 67.6–68.4% was noted, its slight decline was fixed, which allowed obtaining on average for three years for the hectare of the crop rotation area the highest yield.

SUMMARY

The goal is to determine the changes in physical and chemical properties of irrigated soil at different melioration loads. By the results of the research, it was established that with accordance to the actual

standard the irrigation water of the Ingulets irrigation system belongs to the Class II and is limited suitable for irrigation by the threat of secondary salinization, alkalination, alkalinity increase and toxic effects on plants. Irrigation with the waters of high mineralization with adverse ratios of single-and divalent cations leads to the changes in the qualitative composition of the SAC at the end of the crops vegetation, where there is leaching of calcium out of the soil that was accompanied by the growth of the share of exchangeable sodium and contributes to the development of the process of irrigative alkalination of the soil. Conduction of different methods of basic soil tillage and application of different doses of fertilizers cannot eliminate the process of irrigative alkalination, and at the plowing and differentiated tillage, where plowing during the crop rotation alternates with shallow plowless loosening under the crops of the rotation, with the use of nitrogen fertilizers, where the largest content of absorbed calcium from the sum of cations of 67.6–68.4% was noted, its slight decline was fixed, which allowed obtaining for the hectare of the crop rotation area 14.51 t/ha of corn, 8.58 of sorghum, 7.11 of winter wheat, and 4.49 t/ha of soybean.

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Information about the author:
Bidnyna I. O.,
Candidate (Ph.D.) of Agricultural Sciences,
Senior Research, Academic Secretary,
Institute of Irrigated Agriculture
of the National Academy of Agrarian Sciences
Kherson, Naddniprianske, 73483, Ukraine

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BASIS OF ENVIRONMENTAL MONITORING OF POLLUTANTS

Bondar O. I.

INTRODUCTION

The ecological nature of chemical contamination manifests itself in destruction of the principles and rules of existence and functioning of biological systems in various levels, ranging from organism to biosphere. According to *Teilhard de Chardin*, the matter cannot be considered as the "*matter-in-itself*", that is to study the separated fragment from the whole outside the rest[1, 2]. After all, the part of ecosystem cannot develop independently. According to the one of the important ecological principle (namely "Principle of internal dynamic equilibrium"), the substance, energy, information and dynamic qualities of ecosystems and their hierarchies are interrelated so that any change in one of these indicators causes the functional and other changes in whole ecosystem[3]. This principle is one of the key provisions in environmental management.

While environmental changes are weak and arose on a relatively small area, they either are limited to a specific place, or "*fading*" in the chain of hierarchies of ecosystems. According to the second consequence of the above mentioned "Principle of internal dynamic equilibrium", as changes reach significant values for large ecosystems, they result in major displacements in broad natural units, up to the entire biosphere in the Earth. Being relatively irreversible, changes in nature finally become such that it is difficult to neutralize. After all, this changes correction requires considerable material costs and physical effort. Shifting the dynamic equilibrium of natural systems with considerable energy applications (eg. by plowing, the use of pesticides and other farming practices etc.) human disturbs normal

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functioning of environmental components, achieving an increase in useful bioproduction or comfortable conditions for life and human activities.

If the shears "*fad*e" in the hierarchy of natural systems and do not cause a thermodynamic disorder in this natural system – ecosystem's conditions are satisfactory. However, excessive anthropogenic energy applying to ecosystem, which leads to a substance-energy disorder, leads to a decrease in natural resource potential, worsening of the hygienic conditions of human life, and the desolation of territories.

The future of mankind is determined by many circumstances. But among them there are two decisive ones. First: people must know the principles of the biosphere development, the possible causes of its degradation, be informed that they are allowed and where and the fatal limit that a human should not transgress under any circumstances. In other words, science, which is called ecology, must be able to formulate a Strategy in the relationships between nature and man. The second, equally important circumstance, without which it is unreasonable to talk about the future of mankind, is the need to approve such a social order that would be able to implement a system of limitations.

For 2 million years, humanity was in the homeostasis with the biosphere. Homeostasis was supported by the animist outlook[4]. This strategy of life ended when humankind learned to exploit natural resources. The result of this human occupation strategy for Nature is the boundary of the total ecological catastrophe after which biosphere can be transforms into a technosphere in one jump.

Today, the loss of productive land compared with the average annual rate of 10 thousand years of civilization has increased by 30 times. Dehumidification of soils has increased by 24 times, while the average yield increase over the past 50 years was only 30%. There is the risk of disappearance for more than 26,000 species of plants and animals in the World, and for near 1000 species in Ukraine[5]. The

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increasing of general biosphere ecological crises caused, of course, by an anthropogenic factor[6].

The main role in the balanced development in biosphere plays, as is known, the regularity of the individuals' number in the trophic chain. This is a self-regulating system of "producers-consuments-reductants", and the number of individuals varies annually within a certain average. Thus, a balanced circulation of matter and, consequently, a component and territorial ecological balance are provided.

Plants are the source of the formation of phytomass and play a leading role in the presence of the complete conditions for healthy human functioning. Plants are not only oxygen source in biosphere, but also are producent in the trophic chains (in which human is a final link). Moreover, plants play an important role in the soil-forming process and in the soil buffer capacity. Additionally, plants are filtered biosphere as a buffer, which accumulates most of pollutants.

Plants play a main role in ensuring a balanced circulation of matter and, creating the thin membrane of life. The general trend and function of this membrane of life is biodiversity development, balancing of substances and energy in the environment in accordance with its energy-accumulating, geochemical, stabilizing and informational planetary roles. Plants, accumulating the energy of the Sun and producing biomass, ensures the functioning of the biosphere and its permanent composition as well as the territorial and component dynamic equilibrium in ecosystem. From the main function of ecosystems (the ability to accumulate energy in organic matter, in other words, productivity), from its size and dynamics completely depends the life of all existing on Earth.

In the context of any type of contamination by pollutants, the study of their migration is particularly important, since bioaccumulation of toxicants causes quantitative (decrease in productivity) and qualitative changes (increase in the content of pollutants in the plant and reduction of the required substances for the plant itself and consumpts). In this connection, the phytotoxicological scientific direction, which studies toxic effects on plants caused by any

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origin pollutants, in particular, for the population level, is extremely relevant. To the indicator processes of the global ecological crisis, scientists include geochemical pollution of air, water and soil, geochemical poisoning of biota as a result of metallization, chemotoxication, radiootoxication, as well as activation of processes of technogenesis and violation of biogeochemical cycles in the biosphere.

1. Pollutants in environment

Areas of biological stability for ecological systems in general and individual organisms, under the influence of an anthropic factor, are characterized by narrow limits of changes. Chemical components through the atmosphere, soil or water enter the trophic chains, which leads to significant changes in the functioning of ecosystems and, in the end, negatively affect the livelihoods of the human. Excessive thresholds of reliability of ecological systems under the influence of extreme factors of anthropic origin may be the cause of environmental disasters.

In this regard, the study of harmful factors acting on man and biota becomes important. Of the existing dangerous agents, the most negative effects on living organisms are pollutants. As a result of many human activities, the contamination of the biosphere and the receipt of toxic chemicals of pollutants (pollutants) into the trophic chains occur in quantities that go beyond the normal content of natural limited fluctuations or the average natural background in the considered period. Alien to a living organism or their community, xenobiotics found a separate group of very dangerous pollutants.

Today, special attention to environment assessment is also given to such pollutants as persistent organic pollutants (POPs) which, according to the Stockholm Convention, are substances that have toxic properties, exhibit resistance to decomposition, are characterized by bioaccumulation and are the object of trans boundary transport by air, water and migratory species, and also sediment at a great distance from the source of their release, accumulate in the ecosystems of land and aquatic ecosystems[7] (Figure 1).

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[7] Stockholm Convention on Persistent Organic Pollutants (ukr / rus), the Law of Ukraine on Ratification of the Stockholm Convention on Persistent Organic Pollutants, URL: https://zakon.rada.gov.ua/laws/show/995_a07

Typically, POPs are of anthropogenic origin, and their list of Annexes A and B of the Stockholm Convention includes pesticides: Aldrin, Chlorodan, Diederine, Endrin, Heptachlor, Mirex, Toxaphene, Dichlorodiphenyl trichloromethylmethane (DDT), which are now or are not used, or are restricted to application in agriculture, but often make up the hazardous waste[8].

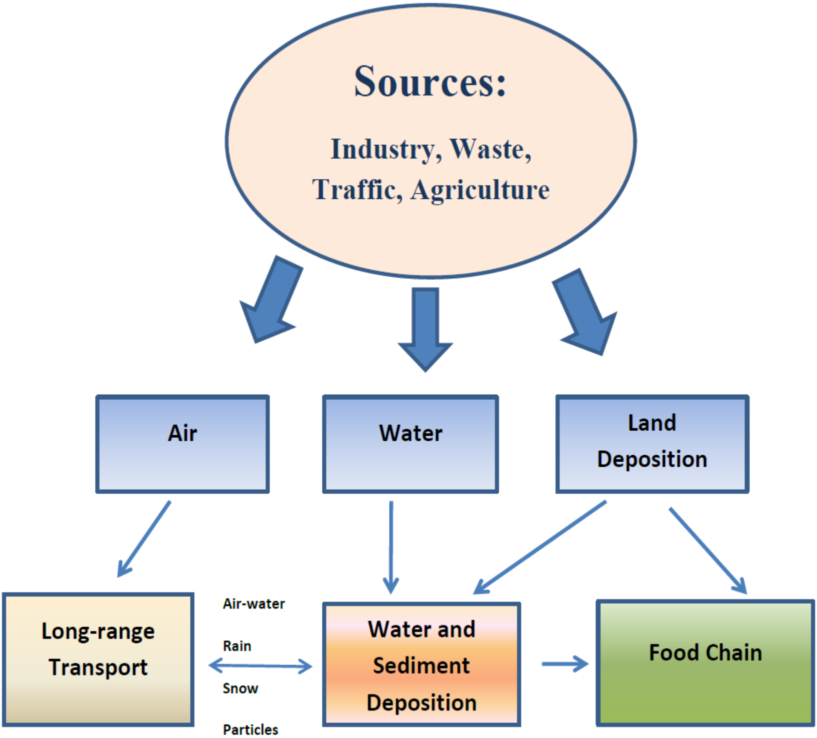

Fig. 1. POPs in the environment[9]

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[8] Stockholm Convention on Persistent Organic Pollutants (ukr / rus), the Law of Ukraine on Ratification of the Stockholm Convention on Persistent Organic Pollutants, URL: https://zakon.rada.gov.ua/laws/show/995_a07

[9] Persistent organic pollutants (POPs). Children's Health and the Environment. WHO Training Package for the Health Sector. World Health Organization. www.who.int/ceh, July 2008 version

POPs are released into air, water and land – from where they deposit into water, sediment, and enter the food-chain, are globally distributed through the air and ocean currents – they travel long distances and enter into atmospheric processes, air–water exchange and cycles involving rain, snow and dry particles. These processes lead to the exposure of even remote populations of humans and animals that depend on aquatic foods. Humans and animals are exposed mainly via ingestion of contaminated aquatic foodstuffs. POPs travel long distances and are found in places far away from industrial sites or from agricultural areas, such as the Arctic Circle[10]. Some POPs will almost always be found if tested for in tissues or environmental samples from different parts of the world. As is the case with many environmental pollutants, it is most difficult to establish that illness or diseases are directly attributable to exposure to a specific persistent organic pollutant or to a group of POPs. This difficulty is further underscored by (a) the fact that POPs rarely occur as a single compound, and (b) that individual field studies are insufficient to provide compelling evidence of cause and effect in their own right.

Polychlorinated dibenzo-para-dioxins (dioxins) and polychlorinated dibenzofurans (furans) are two groups of planar tricyclic compounds that have very similar chemical structures and properties. Their properties vary with the number of chlorine atoms present. Neither dioxins nor furans are produced commercially, and they have no known use. They are byproducts resulting from the production of other chemicals. Dioxins may be released into the environment through the production of pesticides and other chlorinated substances. Furans are a major contaminant of PCBs. Both dioxins and furans are related to a variety of incineration reactions, and the synthesis and use of a variety of chemical products. Dioxins and furans have been detected in emissions from the incineration of hospital waste, municipal waste, hazardous waste, cars, and the incineration of coal, peat and wood. Of the 210 dioxins and furans, 17 contribute most significantly to the toxicity of mixtures. At present, the only persistent effect associated with dioxin exposure in humans is chloracne.

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[10] Persistent organic pollutants (POPs). Children's Health and the Environment. WHO Training Package for the Health Sector. World Health Organization. www.who.int/ceh, July 2008 version

One of the most dangerous for environment and human health POPs are Polychlorinated biphenyls (PCBs)[11]. PCBs are very stable chemicals, with low volatility at normal temperature (non-volatile below 40°C), relatively fire-resistant and do not conduct electricity. PCB mixtures (of about 209 different compounds) are usually light coloured liquids that look like molasses. PCBs are soluble in most organic solvents but are almost insoluble in water. They were used in a wide range of industrial and consumer products, especially in the oil of electric capacitors (closed systems) and converters; as well as in coal-mining. Overheating of electrical equipment containing PCBs can produce emissions of irritating vapours. PCBs are completely destroyed only under extremely high temperatures (over 1100 °C) or in the presence of certain combinations of chemical agents and heat. They are environmentally hazardous due to their extreme resistance to chemical and biological breakdown by natural processes in the environment. In the late 1960s the discovery of PCBs in birds in Sweden (by scientists researching DDT) and the outbreak of poisoning affecting 1200 people who had consumed rice oil contaminated with PCBs in Japan both focused public attention on the problem. PCBs have been released into the environment over the years, without any precautions, through open burning or incomplete incineration; by vaporization (from paints, coatings and plastics); by leakage into sewers and streams; by dumping in landfill sites, and by ocean dumping. Despite strict norms and regulations, PCBs may have been illegally dumped through ignorance, negligence or willfully[12]. The full health effects of PCBs on humans are unknown. It is unlikely that serious injury would result from short-term low-level exposure to PCBs. However, many are concerned about possible adverse health effects of long-term exposure to even low concentrations of these substances. Some PCB mixtures are suspected human carcinogens.

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[11] Polychlorinated biphenyls (pcb) toxicity. U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry Division of Toxicology and Environmental Medicine URL: https://www.atsdr.cdc.gov/HEC/CSEM/pcb/docs/pcb.pdf

[12] PERSISTENT ORGANIC POLLUTANTS (POPs). Children’s Health and the Environment. WHO Training Package for the Health Sector. World Health Organization. www.who.int/ceh, July 2008 version

By the opinion of many scientists, the typical composition of the geochemical man-made anomalies today is Pb, Cu, Zn, Mo, Ba, Co, Mn, Fe, Ni, As, as their accumulation in the environment continues at high rates. In the initial period of the formation of the industrial development of society, large man-made anomalies were formed by a significant number (more than 10) number of chemical elements. The elements with the highest contrast (with higher relative content) are called priority pollutants[13]. At the next stage of development of scientific and technological progress, the association of the composition of the geochemical anomaly will expand considerably.

According to of the ecological postulate (formulated by Alekseyenko), associations of chemical elements, forming large man-made geochemical anomalies, are determined mainly by the level of development of science and technology during the period of pollution[14, 15]. Gradually, the list of man-made sources of toxic metals in the ecosystem is expanding (Figure 2).

Environmental assessment of the pollutants danger includes one of the key indices – the intensity of migration in the ecosystem. It is known, that migration occurs in different vectors with different characteristics in environments. Today migration of substances is increasingly becoming anthropogenic rice. In this connection, the list of elements in the geochemical anomalies, which are formed as a result of the violation in the biogeochemical cycles, at a certain stage of society development, is comparatively constant[16]. According to the frequency, contamination can be systemic (with different frequency and duration), or impacted (one-time alarms with different quantitative effect). The main biogeochemical principles such as Main Biogeochemical Principle (formulated by Goldschmitt), and the Principle of Biogenic Migration of Atoms (formulated by Vernadsky) gave the possibility to distinguish a few essential paths of toxicants migration. There are physical migration and plant up-taking (Figure 3).

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[13] Reimers N. Nature Use: Dictionary. Mosc.: Thought, 1990. 637 P.

[14] Reymers N.F. Ecology (theories, laws, rules, principles and hypotheses). – Mosc.: Russia young, 1994, 367 P.

[15] Dedyu I.I. Ecological Encyclopedic Dictionary. Chisinau: Heads. Ed. ITU, 1990, 408 P.

[16] Prokhorova N.V., Matveev N.M. Heavy metals in soils and plants in the conditions of technogenesis // Vestnik SamGU, 1996, Special issue, pp. 125–147.

Fig. 2. The main sources of man-made toxic metals in ecosystems (by Honcharuk *et al.*, 2017)[17]

Physical migration of pollutants depends on the structural and physical properties of the "soil-plant" system, which characterizes the ability of the ecosystems to be resistant (during possibly maximum period without pollutants adding into biogeochemical processes)[18]. The mechanism of activation of the bioaccumulative capacity of the ecosystem depends on the phytocomponent, because the phytocomponent, as a rule, plays a key role in the whole bioproductivity in the ecosystem and has environment generating function[19]. In this regard, the degree of biogeochemical active accumulation of contaminants determines the stability and balanced development of the ecosystem, and also characterizes the level of toxicity of toxicants to the ecosystem[20].

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[17] Honcharuk E.A, Zagoskina N.V. Heavy metals: Entrance, toxicity and protective mechanisms of plants (by the example of cadmium ions) // Bulletin of Kharkiv National Agrarian University. Series Biology, 2017, Vol. 1 (40), pp. 35–49.

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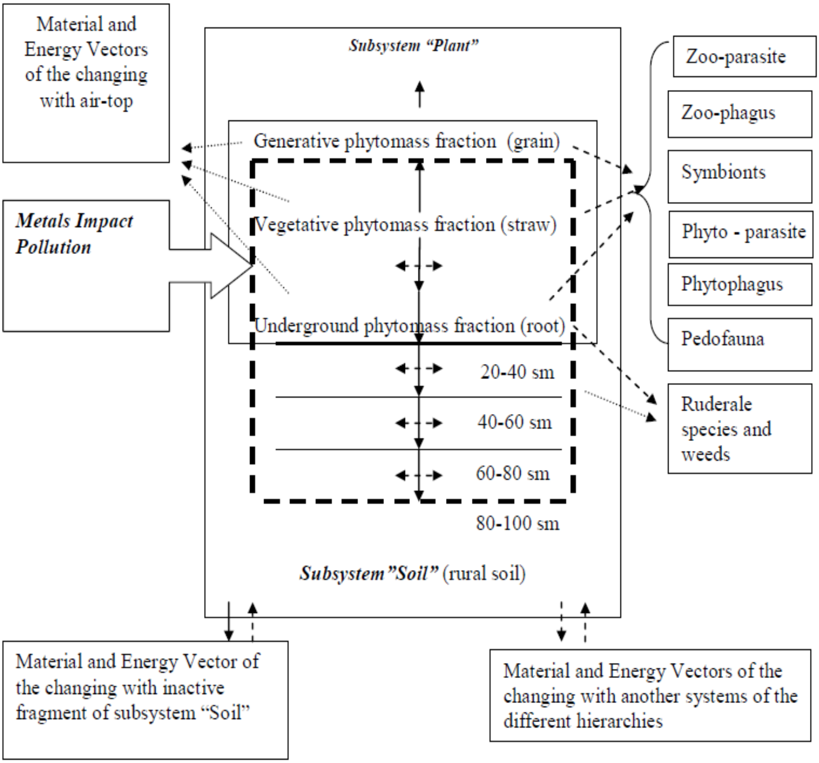

** the designation of the soil profile depth*

→ The main migration ways

- - - → The minor migration ways (carrying-out < 0,01 % of maintenance coming in from the impact pollution)

·········→ The unessential migration ways (carrying-out < 0,001 % of maintenance coming in from the impact pollution)

Remarks:

1. Scheme has been realized during conditional period of observation "from sowing to sowing"
2. The I, II, III consorts take place at HM carrying-out in the consortia level: animals – Phytophagus (trophic bond), parasite plant, animals, symbionts (tropic and topical bonds), saprotrophes,
3. Inactive fragment of subsystem "Soil" represented by soils layers lower 100 sm.

Fig. 3. The Scheme of the ways of heavy metals (HM) migration in the "soil-plant" system[21]

[21] Ryzhenko N., Kavetsky S., Kavetsky V. Heavy Metals (Cd, Pb, Zn, And Cu) Uptake By Spring Barley In Polluted Soils // Polish Journal Of Soil Science, Vol. Xlviii/1, 2015, pp. 111–129.

One of the most dangerous inorganic pollutants is Mercury. Mercury is a highly toxic element that is found both naturally and as an introduced contaminant in the environment. Although its potential for toxicity in highly contaminated areas such as Minamata Bay, Japan, in the 1950's and 1960's, is well documented, research has shown that mercury can be a threat to the health of people and wildlife in many environments that are not obviously polluted. The risk is determined by the likelihood of exposure, the form of mercury present (some forms are more toxic than others), and the geochemical and ecological factors that influence how mercury moves and changes form in the environment.

The toxic effects of mercury depend on its chemical form and the route of exposure. Methyl mercury [CH_3Hg] is the most toxic form. It affects the immune system, alters genetic and enzyme systems, and damages the nervous system, including coordination and the senses of touch, taste, and sight. Methyl mercury is particularly damaging to developing embryos, which are five to ten times more sensitive than adults. Exposure to methyl mercury is usually by ingestion, and it is absorbed more readily and excreted more slowly than other forms of mercury. Elemental mercury, Hg(0), the form released from broken thermometers, causes tremors, gingivitis, and excitability when vapors are inhaled over a long period of time. Although it is less toxic than methyl mercury, elemental mercury may be found in higher concentrations in environments such as gold mine sites, where it has been used to extract gold. If elemental mercury is ingested, it is absorbed relatively slowly and may pass through the digestive system without causing damage. Ingestion of other common forms of mercury, such as the salt $HgCl_2$, which damages the gastrointestinal tract and causes kidney failure, is unlikely from environmental sources. People are exposed to methylmercury almost entirely by eating contaminated fish and wildlife that are at the top of aquatic foodchains. Alkali and metal processing, incineration of coal, and medical and other waste, and mining of gold and mercury contribute greatly to mercury concentrations in some areas, but atmospheric deposition is the dominant source of mercury over most of the landscape. Once in the atmosphere, mercury is widely disseminated and can circulate for years, accounting for its wide-spread distribution[22]. However, the prediction of the behavior in the environment of any toxicants requires a thorough study and the establishment of the limits and specifics of their migration. Toxicants' migration prediction will allow controlling the quality of the environment more efficiently.

The stability of ecosystems to the extreme effects of pollutants is determined not only by the intensity of the influence of the chemical factor (its dose and duration of action), but the ability of the toxicants to translocate and transform in the environment and living organisms. The study of these processes deals with ecotoxicology – a science that has recently been separated from the environment and has been widely developed. Migration of pollutants in the ecosystem is an obligatory indicator that allows assessing the toxicity of substances. The half-life of pollutants (T_{50}) as important index of pollutant toxicity characterizes the persistent as well as predicts contamination levels in the components of the ecosystem. The rate of reduction of toxicants contamination depends on the physical and chemical properties of the substances and the characteristics of the soil (pH, granulometric composition, organic matter, plants canopy, etc.).

The main significant way of migration of pollutants in the ecosystem is bioaccumulation, which is influenced by a number of factors, such as physiological features of plants, type and level of contamination, geochemical capacity of the soil, etc. Bioaccumulation is an important index in the study of toxicity of pollutants, since this indicator not only allows for comparison of toxicity, but also predicts their hazard for biota. In this regard, the results of pollutants monitoring should include not only sanitary and hygiene indicators, but also ecotoxicological.

2. Monitoring of pollutants in environment

The value of developing an environmental monitoring system cannot be overestimated to assess the quality of human conditions. To determine and predict the risk of chemical pollution of the environment, a general methodological approach is used – continuous

[22] Environmental Mercury Mapping, Modeling, and Analysis (EMMMA). URL: https://www.usgs.gov/science-support/emmma

monitoring of the conditions of pollution in the environment by chemicals and their impact on the health of the population, flora and fauna, and prediction of this impact in the future, which can be defined as environmental monitoring. The importance of and need for integrated environmental monitoring systems is well established.

Environmental monitoring is both: 1. Systematic observation of key environmental conditions; 2. Systematic verification of mitigation measure implementation. Systematic observation of key environmental conditions means that environmental indicators are chosen and assessed systematically. Indicators are signals of or proxies for environmental health and ecosystem function. Simple indicators can be more useful and appropriate than more complicated ones[23].

Monitoring often requires systematic measurement of indicators to distinguish the impacts of the activity from other factors. A conceptual basis for the design of integrated monitoring systems and associated networks has received growing attention in the last two decades as part of scientific research to address environmental pollution from a local to global perspective[24]. The design of an integrated environmental monitoring strategy starts with identifying resources as risk in order to initiate development of a conceptual mode. This process of strategic planning is an iterative process whereby the model may be refined, elaborated, or enhanced based on practical and technical considerations, available resources, and defined monitoring objectives. This broad strategic approach usually will culminate in the development of testable questions that feed into the specifics of a detailed sampling and measurement design with a focus on parameter selection, quantifying data variability, and setting up a sampling scheme. This is also an iterative process with feedback to reframe questions and refine technical components of monitoring design. Data quality and statistical models for analyses also are identified as key

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[23] Principles of Environmental Monitoring GEMS Environmental Compliance-ESDM Training Series. URL: Senegal, February, 2014 http://www.usaidgems.org/Workshops/SenegalRegional2014/Session%206%20-%20Env.%20Monitoring/Senegal%20MEO%20Wkshp%20Session6_Env%20Monitoring_11Feb2014pres.pdf

[24] D.A. Bruns and G.B. Wiersma Conceptual Basis of Environmental Monitoring Systems: A Geospatial Perspective, 2004, CRC Press LL, 334 P.

components of this strategy. In monitoring toxic effects of point sources of pollutants, a conceptual model would identify critical sources of contamination inputs to the ecosystem and define which ecological receptors or endpoints (e.g., a particular species, a physical ecosystem compartment, or a target organ system) are likely to be impacted, modified, or changed. As a monitoring system is better defined, a more quantitative model or a suite of models based on different approaches (e.g., kinetic vs. numerical vs. statistical) may be used effectively to address complementary aspects of monitoring objectives. In monitoring pollutant impacts to streams and rivers, watershed boundaries may need to be established since upstream sources of contamination may be transported downstream during storm events, which may add uncertainty in the timing and movement of materials within the natural seasonal or annual patterns in the hydrologic cycle. For these reasons, a monitoring program should be flexible and maintain a continuous process of evaluating and refining the sampling scheme on an iterative basis. Conceptual components of environmental monitoring design and application includes application of a conceptual framework as a heuristic tool, evaluation of source-receptor relationships, multimedia sampling of air, water, soil, and biota as key component pathways through environmental systems, and use of key ecosystem indicators to detect anthropogenic impacts and influences. This conceptual approach allows identifying critical environmental compartments (e.g., air, water, soil) of primary concern, to delineate potential pollutant pathways, and to focus on key ecosystem receptors sensitive to general or specific contaminant or anthropogenic affects[25].

Monitoring combines theoretical conclusions with practical recommendations and aims to justify the use of chemicals, the work of industrial objects, etc. environmental friendly. It should become part of a system of measures that ensure the internal dynamic balance of ecosystems.

The idea of implementing the ecological principles of the development of the national economy at the present stage of human

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[25] D.A. Bruns and G.B. Wiersma Conceptual Basis of Environmental Monitoring Systems: A Geospatial Perspective, 2004, CRC Press LL, 334 P.

existence should become dominant and non-alternative. The application of a systematic approach in monitoring is an important condition for effective solution of complex multi-task environmental problems. Due to the necessity to carry out an assessment of the quality of ecosystems, today the issue of environmental research is put on the agenda, which, first of all, contains a substantiated system of integral and indicative indicators. One of the directions of environmental monitoring is the identification of the real and potential hazards of chemicals, which is the main task of ecotoxicology.

The assessment of the level of hazard of substances makes it possible to predict the conditions of ecosystems. Under the threat of chemicals, the probability of occurrence of a human in contact with them is understood not only by acute and chronic poisoning, but also as a result of the general and selective action of chemicals of pathology, including the probable occurrence of specific long-term effects. This applies not only to the human body, but also to the negative effects of chemicals on ecosystem. In addition, the introduction of pollutants into the biogeochemical cycle leads to a shift in the energy balance of ecosystem and qualitative changes in its structure.

The normal functioning of the geochemical cycle is a guarantee of the internal dynamic equilibrium of ecosystems as the main condition for the existence of the biosphere. The Scheme of ecological monitoring system of pollutants in ecosystems is presented in Figure 4.

Environment monitoring systems can have two main types: permanent and periodically active. The periodically active system is used to solve specific problems during research or as an addition to permanent systems in the event of emergencies. Permanent operating systems are formed in the case of solving long-term tasks for monitoring harmful chemical pollutants of the environment and their effects on the human body, animals, plants, ecosystems, for prediction of this action, development of measures to eliminate their negative effects, etc.

The environmental monitoring is based on two main principles: unification and systematic. The first of them reveals mainly the functional side of the work of a particular system, the other – structural.

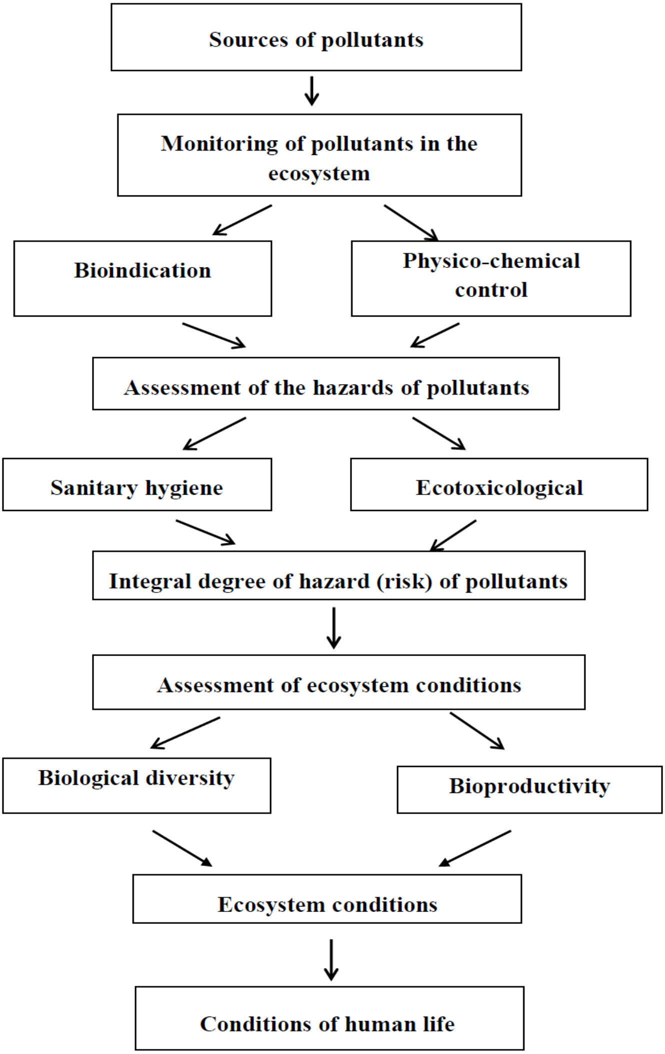

Fig. 4. Scheme of ecological monitoring system of pollutants in ecosystems[26]

[26] Bublik L.I., Kavetskyi V.M. Monitoring and ecotoxicological substantiation of application of chemical plant protection products // Plant protection and quarantine. 1996, Vol. 44. pp. 57–72.

The principle of systems unification is realized through the uniform rules for sampling in researching, the equal methods for the detection of harmful chemicals in environmental objects and biota, the only criterion for obtaining the results, generalized software and information support and documentation forms. The principle of systematic is implemented by combining into the monitoring the main components of different levels such as district, city and others (depending on monitoring level).

The development and formation of environmental monitoring systems includes chemical and analytical, ecotoxicological, information, program and organizational support. The analytical support is one of the major elements in environment monitoring.

Analytical support provides the productivity and quality of monitoring implementation. Objectivity of analytical information regarding the content of toxic substances in environmental objects is ensured, first of all, by the presence of skilled specialists, qualitative sampling and adequate sample preparation of the material.

To ensure the accuracy of the determination of pollutants in the environment is possible only to choice the optimal standard methods (in accordance with the task of monitoring). The unification of methods of determination substance is very important also because it gives the possibility to obtain the correct data. Attestation of laboratories includes the presence of metrological characteristics of the methods in one laboratory, and a comprehensive evaluation of methods through interlaboratory testing with the participation of the most competent laboratories. Environmental Indicators may require laboratory analysis or specialized equipment and techniques[27]. The methods of laboratory analysis should be rapid (they determine the capacity of monitoring), and, if possible, simple. But at the same time methods must provide objective information about the content of certain toxic substances in the environment, and be accurate.

It is effective to assess the environment directly by of living organisms and their communities. It is obvious that the changes in

[27]Principles of Environmental Monitoring GEMS Environmental Compliance-ESDM Training Series. URL: Senegal, February, 2014 http://www.usaidgems.org/Workshops/SenegalRegional2014/Session%206%20-%20Env.%20Monitoring/Senegal%20MEO%20Wkshp%20Session6_Env%20Monitoring_11Feb2014pres.pdf

environment indicated by biota are very expressive for assessment and monitoring. “Living devices” in this sense are no worse than physical, and analysis of their “indicators” is no less important than the chemical analysis of soil, water, air. In some cases, this method of assessment is even better. Evaluating the environment by “living device” is important, because conditions of biota determine ecosystem conditions. However, the speed of reaction appearance in living organism in the result of pollution is not always suitable for environmental assessment. It is also an important task of monitoring to prevent pollution to manifestations of its effects in living organisms.

In addition, for the environment assessment, it is important to have a system of standards that could be linked to our understanding of the “ideal environment”. Such samples are required for each natural-climatic zone and should be provided by biosphere reserves as well as research stations with model crop rotation of cultivated plants.

To establish a comprehensive assessment of the pollutant’s toxicity, it is advisable to use both sanitary-hygienic and ecotoxicological criteria. Ecotoxicological criteria are: stability of the pollutant in soil, water, biological objects, impact on the soil, phytotoxicity, toxicity on the entomophagus, fish, migration rate in the soil profile, plant up-taking, the formation of stable products of transformation, etc.

Integration of sanitary-hygienic and ecotoxicological criteria for assessing the toxicity pollutants enables the formation of information software, in which the accumulation and processing of information will allow to make appropriate decisions. The organizational support of the environment monitoring determines the general principles of their work, the structure, the list of documentation, the order and frequency of pollutants control in the environment.

The problem of environment monitoring of agroecosystem becomes also very important. New pesticides, growing of new species, applying of machinery in the fields, irrigation etc. in the agroecosystems are needs to monitoring and assessing.

Due to the fact that people directly use the field products, the evaluation of chemical agents is a priority task of environment monitoring. And in this case it is not enough to determine the quality indices of agricultural products. Only a comprehensive assessment of agroecosystem provides a complete the overview of the agroecosystem’s state. The main potential pollutants of agroecosystem are pesticides and products of their metabolism, and also impurity substances in fertilizers. The volumes of chemical plant protection products are constantly increasing. The algorithm for assessing the risk of pesticide is based on the use of sanitary-hygienic and ecotoxicological criteria for obtaining the integral degree of pesticides hazard. The main sanitary-hygienic criterion is the dose of LD_{50}, which causes the death of 50% of experimental animals ($mg \cdot kg^{-1}$). Potential danger of pollution of the environment and food depends on the stability (persistence) of a pesticide, which is characterized by a period of its half-life (T_{50}). T_{50} is the time during which amount of pesticide is reduced by 50%. The half-life of T_{50} is a key ecotoxicological criterion for hazardous substances. This indicator is a constant and independent of the initial concentration. Pesticides are considered practically safe if their dose LD_{50} exceeds 1000 mg / kg, and T_{50} is less than 3 days[28]. The integral degree of danger (C) of each pesticide is estimated according to the equation: $C = (Ka + Kb) - 1$, where Ka is toxicological and hygienic class of danger, Kb is ecotoxicological class of danger. The integral degree of danger (C) has 7 classes. Pesticides of 1 and 2 classes are very dangerous, 3 class are dangerous, 4 and 5 classes are moderately dangerous, 6 and 7 classes are not dangerous[29]. The dangers of pesticides is also determined by the maximum permissible concentrations (MAC) in soil, plant, water, air ($mg \cdot kg^{-1}$, $mg \cdot l^{-1}$). Using pesticides and other agrochemicals humane effect primarily on the biosphere and living population. In accordance with Vernadsky's principles, this effect creates the preconditions for deeper chemical changes in the historical perspective. Consequently, the process can become self-evolving, not dependent on the desire of human and practically, in global volumes, unmanageable. The principle of biogenic migration of atoms determines the need for accounting, first of all, for the actions of biota and humans for local and regional changes in the negative chemical action, provides the keys for conscious and active prevention of and control of unwanted biochemical processes.

[28] Kavetsky V.M., Ryzhenko N.O. Physical and Chemical Criteria for Pesticides Determination and Risk Assessment in Ecosystem / V.M. Kavetsky, N.O. Ryzhenko // Polish J. Chem. Vol. 82, 2008, pp. 361–369.

[29] Bublik L.I., Kavetsky V.M. Monitoring and ecotoxicological substantiation of application of chemical plant protection products // Plant protection and quarantine. 1996, Vol. 44. P. 57–72.

CONCLUSIONS

Pollutants (such as toxic metals, persistent organic pollutants etc.) through the atmosphere, soil or water enter the trophic chains, which leads to significant changes in the functioning of ecosystems and, in the end, negatively affect the livelihoods of the human. This affect creates the preconditions for deeper chemical changes in the historical perspective. Consequently, the process can become self-evolving, not dependent on the desire of human and practically, in global volumes, unmanageable. Therefore, monitoring of pollutants becomes important tool tracking changes in the environment.

Both activities on quality improvement of the polluted environment and-a willingness to understand these processes are conditional on possessing reliable information that can be obtained from environmental monitoring. The application of a systematic approach in environmental monitoring of pollutants is an important for effective solution of complex multi-task environmental problems. The principles and concepts of environmental monitoring design are dynamic and iterative in nature. The objective assessment of the pollutants in environment involves some stages: (1) quantitative evaluation of pollutants in the environment (soil, plants, water, air, etc.); (2) assessment of biota intoxication; (3) forecasting the consequences of pollution. Objective observations obtained as a result of environmental monitoring produce the valuable information. Information-derived knowledge usually leads to an enhanced understanding of the environment pollution and situation, which improves the chances of making informed decisions.

SUMMARY

The article is devoted to the basis of pollutants monitoring in environment. The design of an integrated environmental monitoring strategy starts with identifying resources as risk in order to initiate development of a conceptual model. It is presented, that the environmental monitoring is based on two main principles: unification and systematic. The objective assessment of the pollutants in environment involves: quantitative evaluation of pollutants in the environment (soil, plants, water, air, etc.); assessment of biota intoxication; forecasting the consequences of pollution. Information-derived knowledge usually leads to an enhanced understanding of the environment pollution and situation, which improves the chances of making informed decisions.

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Information about the author:
Bondar O. I.,
Doctor of Biology, Professor,
Corresponding Member of the Academy
of Agrarian Sciences of Ukraine,
Rector of State Ecological Academy
of Post-Graduate Education and Management
35 build. 2, Vasylya Lypkivskogo str., Kyiv, 03035, Ukraine

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PRODUCTIVITY OF SEED POTATO AT SPRING AND SUMMER PLANTING WITH FRESHLY-COLLECTED TUBERS IN THE CONDITIONS OF THE SOUTH OF UKRAINE

Boyarkina L. V.

INTRODUCTION

Potatoes have a prolonged vegetation period, during which it assimilates significantly more nutrients from the soil than other crops. On the formation of 10 tons of potatoes it is required 40–60 kg of nitrogen, 15–20 of phosphorus, 70–90 of potassium, 20–40 of sulfur, 10–25 of magnesium, 25–50 kg of calcium and a number of microelements. With a crop of 20 t/ha with the corresponding number of leafy tops it uptakes from the soil about 100 kg of nitrogen, 30 of phosphorus and 140 kg of potassium. It should be mentioned that the root system of potato can absorb from the soil higher amounts of potassium than other crops[1].

The use of mineral fertilizers can create the optimum ratio between nitrogen, phosphorus, potassium and other necessary nutrients on all types of soils. At the present stage, combined complex mixtures of fertilizers are mainly used: nitrophoska, ammonium phosphate, amophos, etc. An important task in the field of potato growing is the development of methods for improving the effectiveness of mineral fertilizers with reduced norms of their application.

In the improvement of the effectiveness of mineral fertilizers, an important role is also played by the way of their application to the soil[2]. This can be achieved by applying mineral fertilizers locally. With the local method of fertilizing, the transfer of nutrients of fertilizers in

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[1] Базалій В.В., Зінченко О.І., Лавриненко Ю.О., Салатенко В.Н., Коковіхін С.В., Домарацький Є.О. Рослинництво : Підручник; за ред. В.В. Базалія, О.І. Зінченка, Ю.О. Лавриненка. Херсон : Грінь Д.С., 2014. 461 с.: іл.

[2] Бондарчук А.А. Наукові основи насінництва картоплі в Україні : монографія. Біла Церква, 2010. 400 с.

the soil into inaccessible forms for plants is also significantly reduced[3, 4].

Researches conducted by scientists in different soil and climatic conditions prove that fertilizers contribute to the increase of yield, simultaneously improving or decreasing the quality of tubers. It depends on a number of factors: doses, ratios, forms, terms and methods of fertilization, weather conditions, etc. Large share of mineral fertilizers expenditures in the structure of production cost of potatoes (19–21%) requires constant seeking for new ways making production cheaper. It is known that the local application of mineral fertilizers with a dose, reduced by a half, provides obtaining almost the same yield of potatoes, as at the full dose of scattered fertilizers applied[5].

The Institute of Potato growing of NAAS developed resource-saving technology of potato cultivation. An important link of this technology is the use of optimum resource-saving system of potato fertilization. It is known that the rational system of fertilization provides not only the increase in yield and improvement of its quality, but also promotes fertility preservation of soil. Science and practice of fertilizers application showed that the return from them depends not only on the norm and singing ratio between the main elements, but also on the methods of their application. Technological regulations of the resource-saving technology of potato growing are provided by the local application of mineral fertilizers at planting of tubers[6, 7].

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[3] Вильдфлуш И. Р. Локальное внесение удобрений – одно из главных средств рационального и экономного использования минеральных удобрений. *Агрохимия*. 1996. Вып. 10. С. 132–141.

[4] Власенко М. Ю., Руденко Г. С. Вплив різних норм мінеральних добрив на вміст на врожайність і якість нових сортів картоплі. *Картоплярство*. К. : "Урожай", 1987. Вип. 18. С. 40–42.

[5] Патика В. П., Макаренко Н. А., Моклячук Л. І. та ін. Агроекологічна оцінка мінеральних добрив і пестицидів: монографія; за ред. В. П. Патики. К.: Основа, 2005. 300 с.

[6] Технологічний регламент вирощування картоплі: рек. : Мінагрополітики України, Ін-т картоплярства УААН. Немішаєве, 2007. 15 с.

[7] Кубарева Л. С. Локальное внесение удобрений. *Бюл. ВИУА.* 1980. № 53. С. 13–15.

One of the conditions for obtaining high yields of seed potato is the use of appropriate plant density per unit area. The average planting density of seed potato depends on the mass of planting material, ripeness of variety, destination of plantings and humidification of soil. In the Steppe zone on irrigation it is recommended to plant the tubers with weight of 50–80 g with a density of 50–55 thousand/ha[8].

By the results of previous studies, it was determined that the optimum density of the plant standing, which provides the maximum yield, is individual for the each separately taken from variety[9].

The basis of any crop cultivation technology is the fertilization system, adapted to local soil and climatic conditions. Therefore, the question of determination of optimal norms of mineral fertilizers and planting density of tubers for the conditions of the South of Ukraine remains of current importance.

1. Productivity of seed potato at early harvesting depending on the norms of fertilizers and planting density

The researches of the Institute of Irrigated Agriculture of NAAS proved high efficiency of application of mineral fertilizers under the potato locally with the ridge planting on the depth of 15–18 cm. This method provided the best productivity of the plants in the biological maturity and at the early harvesting at the application of a low norm of mineral fertilizers – $N_{60}P_{60}K_{60}$. The question of determining the optimal norms of mineral fertilizers application at their local use at planting remains unexplored. Special interest was to the determination of the optimum conditions of the potato plants nutrition in the conjunction with the tubers planting density. In this regard, in 2006–2008, the double-factored field experiment was carried out according to the scheme, specified in the tables.

The analysis of three-year plant growth data showed a tendency to the decrease of the number of stems with a higher density of planting. Thus, at the density of planting of 42.8 thousand of tubers/ha, on the average by the factor, the number of stems per one bush during the

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[8] Картопля: сортозаміна і сортооновлення. *Пропозиція*. 2017. № 1. С. 126–128.

[9] Куценко В.С. Формування оптимальної густоти насаджень картоплі різного господарського призначення : *Картоплярство*. К., 1997. Вип. 27. С. 34. С. 39.

flowering period was 2.5 pcs., at the density of 57.1 thousand – 2.4 pcs., at the density of 71.4 thousand – 2.3 stems per one bush (Table.1). This dependence is confirmed by the inversely proportional pair correlation coefficient (r = -0.887±0.128). The degree of the closeness of the relationship between the investigated factors and the indicator of the number of stems per one bush is strong (R = 0.890). Multiple determination coefficient (R^2 = 0.791) indicates that the variation of the number of stems by 79.1% depends on the influence of factors that were explored.

Table 1

The number of stems of potato depending on the nutrition level and the density of planting

The density of planting, thsd. pcs/ha	Nutrition background	The number of stems	
		thousand pcs/ha	pc/bush
42.8	Without fertilizers	102.5	2.5
	$N_{30}P_{30}K_{30}$	103.2	2.5
	$N_{60}P_{60}K_{60}$	105.3	2.6
	$N_{90}P_{90}K_{90}$	105.2	2.6
	$N_{120}P_{120}K_{120}$	99.0	2.4
57.1	Without fertilizers	130.7	2.4
	$N_{30}P_{30}K_{30}$	128.0	2.4
	$N_{60}P_{60}K_{60}$	132.6	2.4
	$N_{90}P_{90}K_{90}$	129.5	2.4
	$N_{120}P_{120}K_{120}$	137.0	2.5
71.4	Without fertilizers	148.5	2.2
	$N_{30}P_{30}K_{30}$	156.2	2.3
	$N_{60}P_{60}K_{60}$	148.7	2.2
	$N_{90}P_{90}K_{90}$	142.3	2.2
	$N_{120}P_{120}K_{120}$	157.2	2.3

The total number of stems per 1 hectare increased with the increased density of planting. Thus, the density of planting of 42.8 thousand pcs./ha on the average resulted in the value of this indicator of 103 thousand pcs/ha; 57.1–131.6 thousand pcs/ha and 71.4–150.6 thousand pcs/ha. With the increase of planting density by 25 and 20%, the number of the stems per 1 ha increased by 22 and

13%, respectively. There is a proportional dependence of these indicators on each other, indicating by the paired correlation coefficient ($r = 0.974 \pm 0.063$). There is a strong correlation between the investigated factors and the indicator of the number of stems ($r = 0.975$), a multiple determination coefficient ($r^2 = 0.950$) also indicates the dependence of a change in the density of stems on the effects of the studied factors.

The number of stems per 1 hectare at the same density of planting, but on different nutrition backgrounds, was almost identical. The differences were not significant, and consequently, the doses of fertilizers did not refer to the density of the stems. The pair correlation coefficient also indicates the lack of influence of the nutrition background on the density of stems ($r = 0.073 \pm 0.277$).

Height of the plants was determined at the flowering stage. The variant without fertilizer and at the maximum planting density (71.4 thousand pcs/ha) provided the lowest plants – 42cm. The highest this indicator was at the combination of the maximum thickening and nutrition background of $N_{120}P_{120}K_{120}$ – 56 cm. The results of the observations are marked in the Figure 1.

On the average for three years it is traced a clear dependence of the plants height on the fertilizers. So, on the average by the factor, in the variants without fertilizers the height of the plants was the lowest and reached 44cm, application of $N_{30}P_{30}K_{30}$ helped to increase the height by 4.2 cm, with the dose of fertilizer $N_{60}P_{60}K_{60}$ the height was 50.5cm, and on the background of $N_{90}P_{90}K_{90}$ and $N_{120}P_{120}K_{120}$ the height of the plants was 54.7 and 55 cm, respectively. The multiple correlation coefficient ($R = 0.951$) indicates strong relation between the studied factors and the indicator of the plants height. The high degree of dependencies of the variations of the height of the plants on the investigated factors (90.5%) is testified by the determination coefficient ($R^2 = 0.905$). The results of the correlation-based regression analysis of the research data point to the pretty high correlation relationship between the height of the plants and nutrition background, as it is evidenced by the calculated pair correlation coefficient ($r = 0.950 \pm 0.087$). The plants height did not significantly depend on the increase in the density of planting ($r = -0.033 \pm 0.277$), by the scale of Cheddok – the correlation relationship is absent.

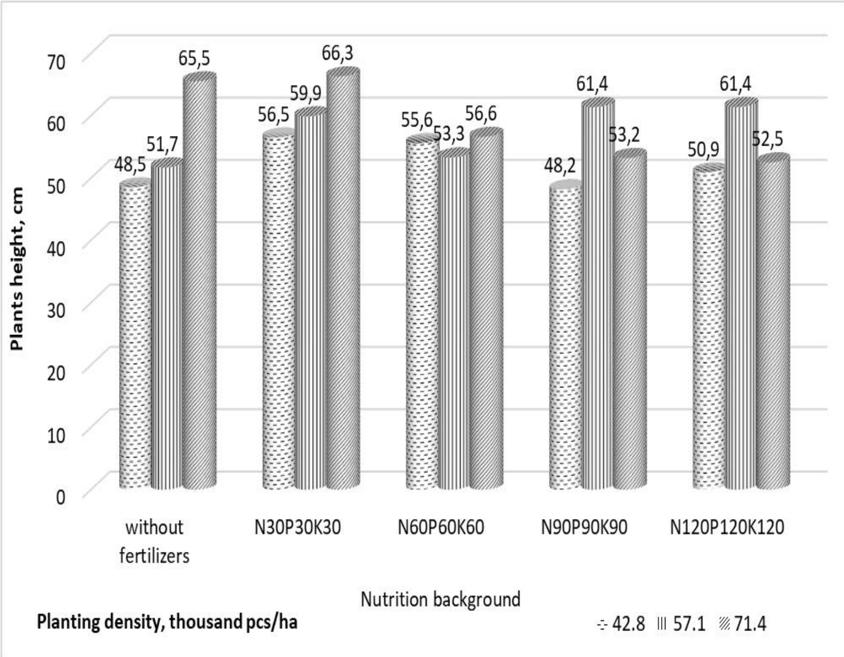

Fig. 1. The height of the potato plants of the spring planting at the flowering stage depending on the density of planting and nutrition background

Analysis of the crop evaluation showed that on the average for three years of the research, the smallest harvest was recorded on the variant with the lowest planting density (42.8 thousand pcs/ha) without fertilizers – 12.39 t/ha. The largest economically justified harvest of tubers at the early harvesting was obtained by the applying of the planting density of 71.4 thousand pcs/ha and application of 60 kg/ha of NPK – 21.42 t/ha. Further enhancement of the dosage of fertilizer does not significantly increase the yield of tubers.

With the increasing density of planting tubers we observed the increased yield. If the density of planting increased by 25 and 40%, the average difference in the yield of tubers between the variants with the lowest (42.8 thousand pcs/ha), and the highest (71.4 thousand pcs/ha) density of planting was 15.8% (Table 2).

Table 2

Yield of potato tubers depending on the norms of fertilizers and planting density, t/ha

Nutrition background (factor B)	The density of planting, thousand pcs/ha (factor A)			The average by the factor B, LSD_{05}= 1.33 t/ha
	42.8	57.1	71.4	
	Yield, t/ha			
Without fertilizers	12.39	12.69	13.66	12.91
$N_{30}P_{30}K_{30}$	15.51	16.91	18.33	16.87
$N_{60}P_{60}K_{60}$	17.65	18.74	21.42	19.29
$N_{90}P_{90}K_{90}$	18.05	19.24	21.47	19.56
$N_{120}P_{120}K_{120}$	16.71	17.08	20.50	18.07
Average Factor A	16.04	16.88	19.09	

LSD_{05} for individual differences, t/ha: A 2.73
B 1.68

The dependence of the yields of tubers on the nutrition background is traced. According to the results of the studies, it is determined that the smallest crop regardless of the density of planting was on the control variant (without fertilizers) and was 12.91 t/ha. Application of fertilizers at the dose of 60 kg/ha of NPK, on the average by the factor, provided the maximum economically justified yield – 19.29 t/ha. Further increased dosage of fertilizer does not significantly affect the productivity of early potato. Average difference with control (no fertilizer) and background fertilization of $N_{90}P_{90}K_{90}$ averaged to 34%. Further increased dosage of fertilizer from 90 to 120 kg/ha of NPK decreased the yield of tubers on average by 1.49 t/ha (7.7%).

The results of the ANOVA indicate a strong relation between the yield index of potato variety Kobza and the investigated factors (r = 0.802). Determination coefficient (R^2 = 0.644) indicates that the yield of potato depends on the impact of the studied factors by 64.4%. Paired correlation coefficients confirm the previous assumption regarding the significant impact on the crop formation of the nutrition background (r = 0.667±0.207). The density of planting has moderate effect (r = 0.445±0.248) on the specified indicator.

The number of tubers under the bush was the largest at the least density of planting (42.8 thousand pcs/ha) and on the background of $N_{90}P_{90}K_{90}$ and averaged to 9.0 pcs/bush, and the smallest number of them – 4.5 pcs./bush was recorded on the variant without fertilizers and the most thickened background – 71.4 thousand pcs./ha. The increasing density of planting resulted in fewer tubers under the bush. The number of tubers formed from thickening of the crops up to 57.1 thousand pcs/ha and 71.4 thousand pcs/ha decreased by 13 and 23.4%, respectively (Table 3).

Fertilization allowed increasing the productivity of one plant. Thus, compared with the unfertilized variants for the density of planting of 42.8 thousand pcs/ha, the number of tubers under the bush increased by 15.6% at the application of $N_{30}P_{30}K_{30}$ up to 22.6% on the background of $N_{90}P_{90}K_{90}$, and for the density of planting of 57.1 thousand pcs/ha the number of tubers under the bush increased by 22.5% at the application of $N_{30}P_{30}K_{30}$ up to 26.6% on the background of $N_{120}P_{120}K_{120}$, and at the density of planting of 71.4 thousand pcs/ha, the difference between the variants without fertilizers and $N_{30}P_{30}K_{30}$ averaged to 22.4%, and on the background of $N_{120}P_{120}K_{120}$ increased to 38.4%.

Table 3

Indexes of the crop structure depending on the density of planting and fertilizer norms

The density of planting, thousand pcs/ha	Nutrition background	Number of tubers under the bush, pcs/bush	Weight of average tubers, g
42.8	Without fertilizers	6.5	48.8
	$N_{30}P_{30}K_{30}$	7.7	54.4
	$N_{60}P_{60}K_{60}$	8.5	55.3
	$N_{90}P_{90}K_{90}$	9.0	53.3
	$N_{120}P_{120}K_{120}$	8.4	47.8
57.1	Without fertilizers	5.5	45.4
	$N_{30}P_{30}K_{30}$	7.1	45.7
	$N_{60}P_{60}K_{60}$	7.3	47.4
	$N_{90}P_{90}K_{90}$	7.4	46.8
	$N_{120}P_{120}K_{120}$	7.6	42.9
71.4	Without fertilizers	4.5	43.1
	$N_{30}P_{30}K_{30}$	5.8	47.0
	$N_{60}P_{60}K_{60}$	6.3	47.6
	$N_{90}P_{90}K_{90}$	6.8	46.5
	$N_{120}P_{120}K_{120}$	7.3	42.6

A multiple correlation coefficient indicates rather strong connection between the investigated factors and the formation of the total number of tubers under the bush: R = 0.935. High dependence of the parameters of total quantity of tubers under the bush on the planting density was marked by the determination coefficient $R^2 = 0.875$. Inverse-proportional pair correlation coefficient of the dependence of the total number of tubers under the bush on the planting density of potato (r =-0.663±0.208) is an additional confirmation of the trend to the reduction of the number of tubers under the increasing density of their planting. Pair correlation coefficient (r = 0,660±0.208) displays high directly proportional dependence of the studied indicator on the nutrition background of potato.

The difference in the indicator of the mass of tubers depended on the density of planting stronger. Average total mass of tubers was the highest at the smallest thickening of the planting (42.8 thousand pcs/ha) and averaged to 51.9 g. By increasing the density of planting to 57.1 and 71.4 thousand pcs/ha, the mass of average tubers decreased by 14.3 and 13.9%, respectively. The difference between the planting density of 57.1 and 71.4 thousand pcs/ha is considered insignificant.

On the background of nutrition $N_{60}P_{60}K_{60}$, the largest mass of average tubers was recorded on all the variants of planting density (42.8 thousand pcs/ha – 55.3 g; 57.1–47.4 and 71.4 thousand pcs/ha – 47.6 g).

According to the results of correlation-regression analysis, the connection between the mass indexes of tubers and the investigated factors is significant (R = 0.568). Dependence of the variability of the mass of tubers, expressed by the determination coefficient, can be considered moderate ($R^2 = 0.323$). Inversely-proportional pair coefficient of correlation of the mass formation of the tubers from the density of the potato planting (r =-0,703±0,097) is an additional proof of the tendency to the reduction of the mass of tubers depending on the increase in their density of planting. The pair correlation coefficient (r =-0,105±0.2,76) reflects the weak inversely-proportional dependence of the investigated indicator on the background of the potato nutrition.

The economic efficiency of local application of different doses of mineral fertilizers at different density of planting at an early harvest time was expected, based on the mass of the seed tubers of 50 g, the price of planting material (Super-super-elite) – 4.78 UAH/kg. The price of the sale was 8.5 UAH/kg, respectively. The price of fertilizers was adopted as 10,100 UAH for 1 ton (Table 4).

Table 4

Economic efficiency of the densities of planting potato for different backgrounds of mineral nutrition at the spring planting and early harvesting

The density of planting	Nutrition background	Yield, t/ha	Average cost, thousand UAH/t	Conditionally net profit, thousand UAH/ha	Profitability,%
42.8	Without fertilizers	12.39	4.19	47.16	91
	$N_{30}P_{30}K_{30}$	15.51	3.61	68.08	122
	$N_{60}P_{60}K_{60}$	17.65	3.37	81.69	137
	$N_{90}P_{90}K_{90}$	18.05	3.44	82.29	132
	$N_{120}P_{120}K_{120}$	16.71	3.82	69.90	110
57.1	Without fertilizers	12.69	4.58	43.37	75
	$N_{30}P_{30}K_{30}$	16.91	3.71	72.52	116
	$N_{60}P_{60}K_{60}$	18.74	3.53	83.80	127
	$N_{90}P_{90}K_{90}$	19.24	3.57	85.16	124
	$N_{120}P_{120}K_{120}$	17.08	4.10	66.63	95
71.4	Without fertilizers	13.66	4.74	44.59	69
	$N_{30}P_{30}K_{30}$	18.33	3.54	70.67	93
	$N_{60}P_{60}K_{60}$	21.42	3.43	97.80	133
	$N_{90}P_{90}K_{90}$	21.47	3.54	95.79	126
	$N_{120}P_{120}K_{120}$	20.50	3.80	86.16	111

Analysis of the economic efficiency indexes for different density of planting and local application of different doses of fertilizers under the potato early harvesting showed that the seed material production on all the variants was profitable. However, the additional cost of seed material reduced profitability on the variants without fertilizer. So, with an increase in the density of planting to

57.1 thousand tubers/ha without the use of fertilizers we received the least conditional net profit of 43,370UAH/ha, and the increase in the density to 71.4 thousand/ha (20%) did not provide significant increase in the profits, which amounted to 44,590 UAH/ha, or increased by 2.7%. The use of fertilizers in the dose of 30 kg/ha NPK increases the cost of production by 6,640 UAH/ha, at the same time, the price of additional products was 24,960 UAH, and the net profit of 20,920 UAH/ha.

The level of the net profit in the production of seed material of higher reproductions is the best result obtained in the application of the density of planting 71.4 thousand tubers/ha and fertilizer application rates of 60 kg/ha NPK – 97,800 UAH/ha.

That is, according to the results of the three years of the research, to receive seed material of higher reproductions of the variety Kobza at the spring planting and early harvesting and local application of nitroammofoska, the dosage of fertilizers should be appointed at the rate of 60 kg/ha of NPK, and the density of planting – 71.4 thousand tubers/ha.

2. Influence of the nutrition level and density of planting on the productivity of seed potatoes at the summer planting with fresh-harvested tubers

In the South of Ukraine, the best way to obtain a potato seed material, which is to a lesser extent exposed to the degeneration under the influence of high air temperatures, is summer planting of freshly harvested tubers in the double-crop. This method is used in the scientific and research institutions for the reproduction of the elite in the Steppe zone. After all, at the time of tubers formation in the second crop, during the vegetation period the temperature regime of environment decreases that is favorable for the conservation of the productive qualities of seed material[10].

In 2007–2008 at the Institute of irrigated Agriculture of NAAS the experiment was carried out, which envisaged the determination of the

[10] Potato: Variety change and renewal / O. Vyshnevska // Propozytsiya. 2017. No. 1. P. 126–128.

impact on the performance of the summer planting potato by using different norms of complex mineral fertilizers and the density of planting of fresh tubers of the variety of potato Kobza. Planting material was treated by 4-component solution of stimulants to interrupt the period of rest and planted in the field according to the scheme of the experiment in late June.

Field germination in the experiment was quite high – from 73.1 to 100%. Average indicators of field germination on the background of different density of planting had differences. Thus, on the background of the planting density of 42.8 thousand pcs/ha, the average value of this indicator was the lowest and reached 86.7%. The maximum average indicator was fixed with an increase of thickening to 57.1 thousand pcs/ha – 97.4%. At the highest level of planting density (71.4 thousand pcs/ha) field germination averaged to 92.2% (Table 5).

Field germination was the minimum at the application of the highest dose of fertilizers ($N_{120}P_{120}K_{120}$), on the average, 82.1%. On the other backgrounds, this index did not have significant differences and reached 95%. On the variant without fertilizers there were 92.7% of the germinated plants.

According to the results of correlation-regression analysis, this index almost did not depend on the studied factors ($R = 0.474$; $R^2 = 0.225$). Pair correlation coefficients also indicate a faint effect of factors on the field germination of the plants: the density of planting ($r = 0.287 \pm 0.266$) and moderate – nutrition background ($r = -0.378 \pm 0.277$).

The minimum index of the plant height in the experiment (48.2 cm) was recorded on the variant with the nutrition background $N_{90}P_{90}K_{90}$ at the density of planting 42.8 thousand pcs/ha, the maximum (66.3 cm) – at the application of $N_{30}P_{30}K_{30}$ and the density of planting 71.4 thousand pcs/ha. The height of the plant at the planting density of 42.8 thousand pcs/ha was the smallest and averaged to 51.9 cm. At the density of planting of 57.1 thousand tubers/ha, the average value of this indicator was at the level of 57.5 cm. At thickening of the planting up to 71.4 thousand pcs/ha, the average index of the height of the plants was 58.8 cm (Fig. 2).

Table 5

Development of the plants of potato of early-ripening variety Kobza at the summer planting at different planting density and norms of fertilization

The density of planting	Nutrition background	Field germination,%	Number of stems per bush, pcs.
42.8	Without fertilizers	87.0	2.9
	$N_{30}P_{30}K_{30}$	91.7	3.4
	$N_{60}P_{60}K_{60}$	91.7	3.1
	$N_{90}P_{90}K_{90}$	89.8	2.8
	$N_{120}P_{120}K_{120}$	73.1	2.6
57.1	Without fertilizers	91.0	3.5
	$N_{30}P_{30}K_{30}$	99.3	3.1
	$N_{60}P_{60}K_{60}$	100	3.2
	$N_{90}P_{90}K_{90}$	100	3.5
	$N_{120}P_{120}K_{120}$	96.5	4.4
71.4	Without fertilizers	100	2.4
	$N_{30}P_{30}K_{30}$	94.0	4.1
	$N_{60}P_{60}K_{60}$	94.0	2.3
	$N_{90}P_{90}K_{90}$	96.2	2.7
	$N_{120}P_{120}K_{120}$	76.6	1.6

By the nutrition background there were no sharp fluctuations in the height of the plants. The highest were plants at the application of $N_{30}P_{30}K_{30}$ – the average by the variant value was 60.9 cm. In the variant with application of fertilizers $N_{90}P_{90}K_{90}$, the minimum indicators of the plant height – 54.3 cm were noted. On the remaining variants (without fertilizers, $N_{60}P_{60}K_{60}$, $N_{120}P_{120}K_{120}$), there were no significant differences in this index, the height of the plant was within the range of 55 cm.

According to the results of correlation-regression analysis, the average closeness of connection (R = 0.540) is revealed between the studied factors and the indicator of plant height. Dependence of the plants height on the influence of the planting density of tubers and the nutrition background can be considered weak, but close to moderate

(R^2 = 0.292). Pair correlation coefficients indicate a noticeable effect of the density (r =0.507 ± 0.239) by the Cheddok scale, and the weak (r =-0.189 ± 0.273) – for the nutrition background.

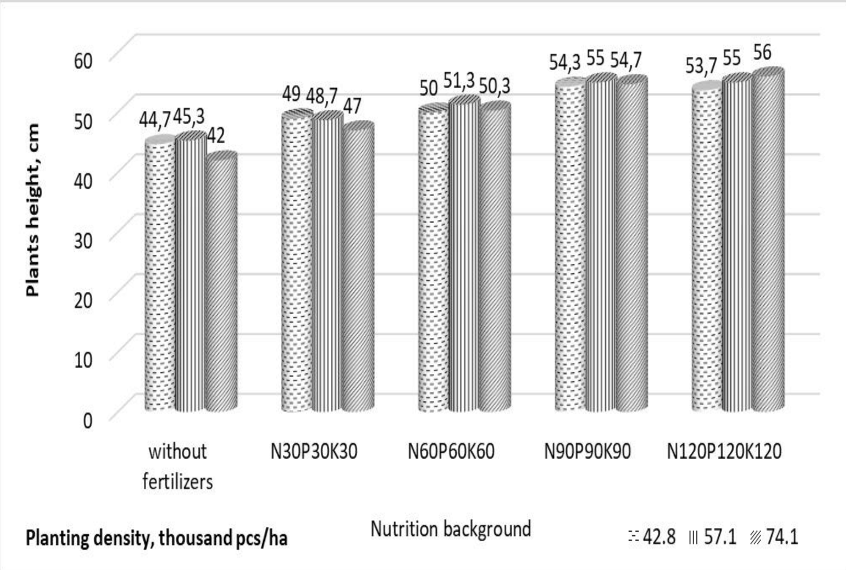

Fig. 2. Summer planting potato plants height at the flowering stage depending on the density of planting and nutrition background

An evident tendency of the influence of the studied factors on the formation of the number of stems per bush was not found. The maximum number of them on the experiment (4.4 pcs/bush) was determined by the version with the density of planting of 57.1 thousand pcs/ha, the minimum – at the thickening of 71.4 thousand pcs/ha and at the same power background – $N_{120}P_{120}K_{120}$.

The case in the development of the plants in the experiment was not found – the stage of budding and flowering took place in all the variants of the experiment.

The evaluation of crop showed that the conditions of years of the research were quite different. Rough weather conditions for the formation of the crop of tubers differed in 2007, where the density of planting of 42.8 thousand pcs/ha provided the average yield index of 10.41 t/ha, at thickening to 57.1 thousand – 10.92 and at the 71.4

thousand pcs/ha – 12.3 t/ha, which is less than 40.9; 41.3 and 47.5%, respectively, in comparison to 2008, the more drastic fluctuations in the yield indexes were observed as a result of the application of different nutrition backgrounds. Thus, the average yield on the control variant (without fertilizers) was 8.61 t/ha, at the application of 30 kg/ha NPK – 10.8 t/ha, at 60 kg/ha NPK – 11.5 and on the background of 90 and 120 kg/ha NPK – 12.57 t/ha, which was less than in 2008 to 39.1; 40.6; 42.0 and 45.2 and 48.9%, respectively (Table 6).

Table 6

The yield of potato tubers of the variety Kobza depending on the norms of fertilizers and planting density in the summer planting, t/ha

The density of planting, thousand pcs/ha	Nutrition background	2007	2008	Average
42.8	Without fertilizers	8.53	21.31	14.92
	$N_{30}P_{30}K_{30}$	9.81	26.61	18.21
	$N_{60}P_{60}K_{60}$	10.40	27.83	19.12
	$N_{90}P_{90}K_{90}$	11.50	28.47	19.99
	$N_{120}P_{120}K_{120}$	11.80	22.93	17.37
57.1	Without fertilizers	8.70	21.96	15.33
	$N_{30}P_{30}K_{30}$	10.20	26.53	18.37
	$N_{60}P_{60}K_{60}$	10.60	27.77	19.19
	$N_{90}P_{90}K_{90}$	12.40	28.17	20.29
	$N_{120}P_{120}K_{120}$	12.70	27.69	20.20
71.4	Without fertilizers	8.60	22.85	15.73
	$N_{30}P_{30}K_{30}$	12.40	26.74	19.57
	$N_{60}P_{60}K_{60}$	13.50	26.53	20.02
	$N_{90}P_{90}K_{90}$	13.80	26.85	20.33
	$N_{120}P_{120}K_{120}$	13.20	26.50	19.85
	LSD_{05} I	1.51	1.62	
	LSD_{05} II	1.16	1.25	
	LSD_{05} A	0.68	0.901	
	LSD_{05} B	0.67	1.02	

The investigated factors had influence on the formation of the crop in 2007, this is indicated by the results of the correlation-regression analysis of the data. A multiple correlation coefficient ($R = 0.900$) confirms strong connection between the investigated factors and the formation of the yield of tubers. Determination coefficient ($R^2 = 0.811$) characterizes the high dependence of the yield indicators on the planting density and nutrition background. Pair correlation coefficient revealed the moderate impact of the density of planting ($r = 0.443 \pm 0.249$) and strong effect of nutrition background ($r = 0.784 \pm 0.172$) on the studied indicators.

In 2008 the weather conditions contributed to the accumulation of great levels of the tubers yields. By the factor of the density of planting there were no steep fluctuations observed. The most comfortable conditions for the formation of the yield were formed on the background of plants thickening to 57.1thousand pcs/ha, with the average value of 26.42 t/ha. The increase in the dose of fertilizers up to 30, 60 and 90kg/ha of NPK contributed to an increase in yield by an average of 4.59t/ha, 5.34 and 5.79 t/ha or 17.2%, 19.5 and 20.8%, respectively, compared with the unfertilized variant. Further increase in the dosage of fertilizer from 90 up to 120 kg/ha of NPK led to a decrease in the yield of tubers by 2.12 t/ha, or 7.6%.

According to the results of correlation-regression analysis of the data, the factors had a noticeable impact by the scale of the Cheddok on the formation of the yield in 2008, this is specified by the multiple correlation coefficient ($R = 0.529$). Weak variability of the yield indicators from the influence of the planting density and nutrition background is characterized by the determination coefficient ($r^2 = 0.279$). The pair correlation coefficient ($r = 0.082 \pm 0.276$) indicates the lack of the effects of planting density and the noticeable impact of nutrition background ($r = 0.522 \pm 0.237$) on the formation of a potato variety Kobza yield at the summer planting of 2008.

An important structural characteristic of the crop is the number of tubers formed under one bush. By the research results the dependence of this index on the investigated factors was found out. So, with the increasing density of planting the number of tubers decreased: from 5.3 pcs/bush – on the background with the smallest thickness (42.8 thousand pcs/ha) to 4.8pcs/bush – at the largest density of planting (71.4 thousand pcs/ha), or by 9.4%. The pair correlation coefficient is inverse (r =-0.448±0.248) and points to a moderate, but stronger, influence of the planting density factor on the formation of the number of tubers per bush. By the increasing dosage of fertilizers to 90 kg/ha of NPK the tendency to the formation of more tubers per bush from 4.8 PCs. to 5.2 pcs/bush, or 7.7%, was observed. Further increase in the nutrition background from 90 to 120 kg/ha of NPK resulted in no changes in the number of tubers. The correlation coefficient between the nutrition background and the indicated value is moderate (r = 0.300±0.265), but slightly less than of the density of planting. The multiple correlation coefficient (r = 0.539) indicates significant closeness in the relationship between the investigated factors and the formation of the tubers per one bush. The determination coefficient (R^2 = 0.290) is an indicator of the fact that the impact of the investigated factors on the amount of tubers was 29% (Table 7).

Table 7

Structure of the crop of potato variety Kobza in the summer planting depending on the norms of fertilizers and density of planting

The density of planting, thousand pcs/ha	Nutrition background	Number of tubers under the bush, pcs	Weight of average tubers, g
42.8	Without fertilizers	5.1	94.5
	$N_{30}P_{30}K_{30}$	4.4	114.2
	$N_{60}P_{60}K_{60}$	5.2	107.2
	$N_{90}P_{90}K_{90}$	6.1	93.5
	$N_{120}P_{120}K_{120}$	5.7	98.1
57.1	Without fertilizers	4.7	93.0
	$N_{30}P_{30}K_{30}$	5.3	81.3
	$N_{60}P_{60}K_{60}$	4.7	93.4
	$N_{90}P_{90}K_{90}$	4.8	90.0
	$N_{120}P_{120}K_{120}$	5.0	95.6
71.4	Without fertilizers	4.5	81.0
	$N_{30}P_{30}K_{30}$	5.4	87.9
	$N_{60}P_{60}K_{60}$	4.6	86.2
	$N_{90}P_{90}K_{90}$	4.7	99.7
	$N_{120}P_{120}K_{120}$	4.8	103.3

The mass of average tubers changed under the influence of the studied factors. With the increase of planting density, weight of tubers was reduced by the average of 9.8% – from 101.5 g at the least thickened variant (42.8 thousand pcs./ha) to 91.6 g – at the most thick crops (71.4 thousand pcs./ha). The pair correlation coefficient (r =-0.458±0.247) indicates the correctness of our assumption. The increase of the doses of fertilizers positively influenced the formation of the tubers weight. On the unfertilized background, the minimum value of this indicator was fixed – 89.5 g, and the maximum mass of the average tubers was observed on the background of 120 kg/ha of NPK and was 99.0 g – the difference between the indexes was 9.6%. Weight dependence degree of the tubers weight on the nutrition background is moderate, according to the pair correlation coefficient (r = 0.304±0.264). The multiple correlation coefficient (R = 0.550) indicates significant closeness of the relationship between the investigated factors and the mass of the avergae tubers. The simultaneous influence of the factors of the planting of tubers and the nutrition background on the mass indicator of the average tuber is characterized as insignificant (R^2 = 0.303).

The indexes of the economic efficiency of the use of local fertilizer for potato of the summer planting show that at growing seed material all the studied options were profitable.

The economic efficiency of cultivation of the summer planted potato at different nutrition backgrounds and the density of planting was evaluated on the basis of the mass of the planting tubers, the price of planting material of 50 g (super-super-elite) – 8500UAH/t. The sale price is 10 UAH/kg. The price of the fertilizer was 10,100 UAH/ton (Table 8).

The least production cost was obtained at the density of planting of 42.8 thousand pcs/ha and nutrition background of $N_{90}P_{90}K_{90}$ – 3.62 thousand UAH/t, as a consequence, the specified variant was the most profitable (127.49 thousand/ha) and the most cost-effective – 176%. The opposite values of the indexes were fixed on the variant without fertilizers and with the density of planting of 71.4 thousand pcs/ha – 4.41 thousand UAH/t, 88.01 thousand UAH/ha and 127%, respectively.

Table 8

Economic efficiency of the application of the density of planting potato at different backgrounds of mineral nutrition of potato at the summer with freshly harvested tubers

The density of the planting	Nutrition background	Yield, t/ha	Average cost, thousand UAH/t	Conditionally net profit, thousand UAH/ha	Profitability, %
42.8	Without fertilizers	14.92	4.03	89.12	148
	$N_{30}P_{30}K_{30}$	18.21	3.69	113.98	167
	$N_{60}P_{60}K_{60}$	19.12	3.70	120.40	170
	$N_{90}P_{90}K_{90}$	19.99	3.62	127.49	176
	$N_{120}P_{120}K_{120}$	17.37	4.21	100.61	138
57.1	Without fertilizers	15.33	4.22	88.61	137
	$N_{30}P_{30}K_{30}$	18.37	3.89	111.12	153
	$N_{60}P_{60}K_{60}$	19.19	3.90	115.98	153
	$N_{90}P_{90}K_{90}$	20.29	3.89	124.03	157
	$N_{120}P_{120}K_{120}$	20.20	4.02	120.88	149
71.4	Without fertilizers	15.73	4.41	88.01	127
	$N_{30}P_{30}K_{30}$	19.57	4.04	116.59	147
	$N_{60}P_{60}K_{60}$	20.02	4.03	119.47	148
	$N_{90}P_{90}K_{90}$	20.33	4.00	121.95	150
	$N_{120}P_{120}K_{120}$	19.85	4.27	113.85	134

The highest yield of tubers was obtained by applying the density of planting potato variety Kobza in the summer terms at 57.1 and 71.4 thousand pcs/ha and applying 90 kg/ha of NPK – respectively, 20.29 and 20.33 t/ha. In the same group by the performance with these variants there were the density of 42.8 thousand pcs./ha + 90 kg/ha of NPK, 71.4 thousand pcs/ha + 60 kg/ha of NPK. That is, if we have to choose the least expensive variant, it is the best variant to plant with the density of 42.8 thousand pcs/ha + 90 kg/ha of NPK.

CONCLUSIONS

1. The maximum performance and out pay of the investment at the determination of the optimum elements of cultivation technology of potato seed material of higher categories at the spring planting and early harvesting is obtained under the application of the density of planting of 71.4 thousand pcs/ha and local mineral fertilizer application in the dose of $N_{60}P_{60}K_{60}$. The yield in this case is 21.42 t/ha, conditionally net profit – 97,800 UAH/ha, production cost of the unit – 3.43 thousand UAH/t, profitability – 133%.

2. At the obtaining seed potatoes at the summer planting with freshly collected tubers, the largest yield of tubers was at the application of the density of planting potato variety Kobza in the summer terms of 57.1 and 71.4 thousand pcs/ha and application of $N_{90}P_{90}K_{90}$ – respectively, 20.29 and 20.33 t/ha. But the most economically feasible is the combination of the main elements of cultivation: planting density of 42.8 thousand pcs/ha and local application of fertilizer in the dose of $N_{90}P_{90}K_{90}$. The yield in this case was 19.99 t/ha, conditionally net profit – 115,980 UAH/ha, the production cost of the unit – 3.62 thousand UAH/t, profitability – 176%.

3. The studied factors had different impact on the formation of the crop over the years. Multiple correlation coefficients under the conditions of the spring ($R = 0.802$) and summer planting ($r = 0.900$) and coefficient of determination ($r^2 = 0.811$) and ($R^2 = 0.644$) confirm strong connection between the investigated factors and the formation of the yield of tubers in the unfavorable weather-climatic conditions of 2007. In 2008, the dependence indicators in the conditions of the spring ($R = 0.529$) and summer planting ($R^2 = 0.279$) indicate a reduction in the impact of the studied factors and positive impact of the environmental conditions on the improvement of the seed productivity. Nutritive supply, both in the conditions of spring ($r = 0.667 \pm 0.207$) and summer planting ($r = 0.784 \pm 0.172$) had more significant impact on the yield value than the density of planting ($r = 0.443 \pm 0.249$) and ($r = 0.445 \pm 0.248$), respectively.

SUMMARY

The paper considers the question of the determination of the optimal norms of mineral fertilizers application by the local method at

the different density of planting for the conditions of spring and summer planting. As a result of the research on the cultivation of higher categories of potato seed material at the spring planting and early harvesting it is recommended to apply the density of planting of 71.4 thousand tubers at the local application of mineral fertilizers in the dose of $N_{60}P_{60}K_{60}$. The yield in this case is 21.42 t/ha, conditionally net profit – 97,800 UAH/ha, the production cost of the unit is 3.43 thousand UAH/t, profitability – 133%. Regarding the determination of the cultivation productivity of seed potato at the summer planting with freshly collected tubers it should be noted that the most cost-effective combination of the main elements of cultivation was: planting density of 42.8 thousand pcs/ha at the local application of mineral fertilizers in the dose of $N_{90}P_{90}K_{90}$. The yield in this case is 19.99 t/ha, the conditionally net profit – 115,980 UAH/ha, the production cost of the unit – 3.62 thousand UAH/t, profitability – 176%. The effect of nutrition background on most productivity indicators, according to the results of the correlation-regression analysis, proved to be more significant than of the density of planting.

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Information about the author:
Boyarkina L. V.,
Candidate (Ph.D.) of Agricultural Sciences,
Senior Researcher of the Laboratory of Economics,
Institute of Irrigated Agriculture
of the National Academy of Agrarian Sciences of Ukraine
Kherson, Naddnipryanske, 73483, Ukraine

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GENETIC FEATURES OF THE "WINGED FORELAND" COASTAL SYSTEM

Davydov O. V.

INTRODUCTION

The coastal zone is a complex natural formation that develops on the border between land and ocean. It is the most important link in the global lithodynamic system. The conceptual idea of the coastal zone as a system is reflected in the scientists' works of various scientific schools. This is what determines the generally accepted use of a systematic approach to its study[1, 2, 3, 4, 5, 6]. The main system-forming factor in the coastal zone is the flows of matter and energy of a special kind, which are called sedimentary[7, 8].

Along the shores of the World Ocean is shown a wide variety of natural conditions and factors of development. Numerous combinations of natural conditions and development factors contribute to the formation of the corresponding lower-rank systems within the coastal zone, the allocation of which is due to the nature of the transported substance, its genesis and orientation[9, 10, 11].

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All the diversity of coastal systems of various ranks is characterized by alongshore geographical differentiation of the World Ocean, which manifests itself with a certain regularity.

In the coastal zone, sedimentary flows are subdivided into muddy, sandy and boulder-gravel by the nature of the substance. According to the genesis of coastal marine sediments, these flows differ in terrigenous, biogenic, chemogenic, and volcanogenic. Depending on the dominant direction of the transported substance, transverse and alongshore flows are distinguished in the coastal zone[12, 13, 14].

The coastal zone of the World Ocean should be considered as a powerful sedimentation filter, capable of not only to pass a diverse material in genesis, mechanical composition and orientation, but also to accumulate "wave field" sediment within its limits.

Mud sediment flows, which are often manifested in the rivers estuarine areas, usually do not end in the coastal zone, but continue their movement the underwater slope down, heading to the deepest zones of the reservoir. Sand flows are characterized for deposits wave processing areas of glacial, alluvial or aeolian genesis. Boulder-gravel flows appear in areas of glacial and mountain-alluvial deposits. Moreover, these flows, in most cases, are delayed in the coastal zone and form a variety of accumulative forms.

It should be noted that the diversity of marine accumulative forms is caused not only by the mechanical composition of the sediments which they are composed from, but also by other factors mainly related to the characteristics of the wind-wave effect.

Lithodynamic systems and their diversity. The coastal zone of the oceans consists of individual sections set within which an independent

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regime and sediment budget are manifested. These areas represent unified complex developing systems, which are called lithodynamic systems in specialized Russian-language literature[15, 16, 17, 18], and littoral cells in English-language literature[19, 20, 21, 22, 23].

By the nature of the substance within the lithodynamic systems, they are divided into three groups: abrasion, abrasion-accumulative and accumulative[24].

Abrasion systems are characterized by active destruction processes of the surface and underwater parts of the coastal zone, with the simultaneous formation of clastic material and its downward movement in the underwater slope. Accumulative systems develop under active formative conditions of clastic material on the underwater slope, from where it is transferred to the coastal zone due to the transverse or alongshore sediment flow, where it accumulates. Abrasion-accumulating lithodynamic systems are complex natural formations that are most widespread in the coastal zone of the World Ocean.

Structurally, within the framework of this system, three components are distinguished: the abrasion section (feeding zone), the abrasion-accumulating section (transit zone) and the accumulation

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section (unloading zone). The system-forming process and, at the same time, an important genetic feature of abrasion-accumulating systems is the alongshore sediment flow [25, 26, 27, 28].

Abrasion-accumulating systems are characterized by a significant variety of morphogenetic and lithodynamic features, which contributes to the manifestation of their morphological diversity. The most specific coastal systems of this type are the so-called "winged foreland", which were first described in English-language literature as "winged beheadland (headland)"[29, 30]. In morphological terms, this system is an abrasion section of the root coast, to which accumulative coastal forms adjoin from opposite sides.

The lack of clear criteria for distinguishing this system and understanding its place in the evolution of the coast, contributed to the fact that they were not deservedly deprived of attention and did not have an appropriate level of study. That is why we decided to analyze the history of this system isolation and determine its main genetic features.

A brief history of allocation and description of the "winged foreland" coastal system. The definition of the term "winged foreland", in the original English interpretation of "Winged beheadland", was first proposed by the American scientist F. Gulliver[31] in 1898. The basis for highlighting this formation, among other objects of the coastal zone, was the author's own research on the United States Atlantic coast, in the Sandy Hook Spit area (near the Long Branch,

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New Jersey), as well as materials analysis of the Cape Peninsula-Code, Massachusetts study, which were described by W. Davis[32] (Fig. 1).

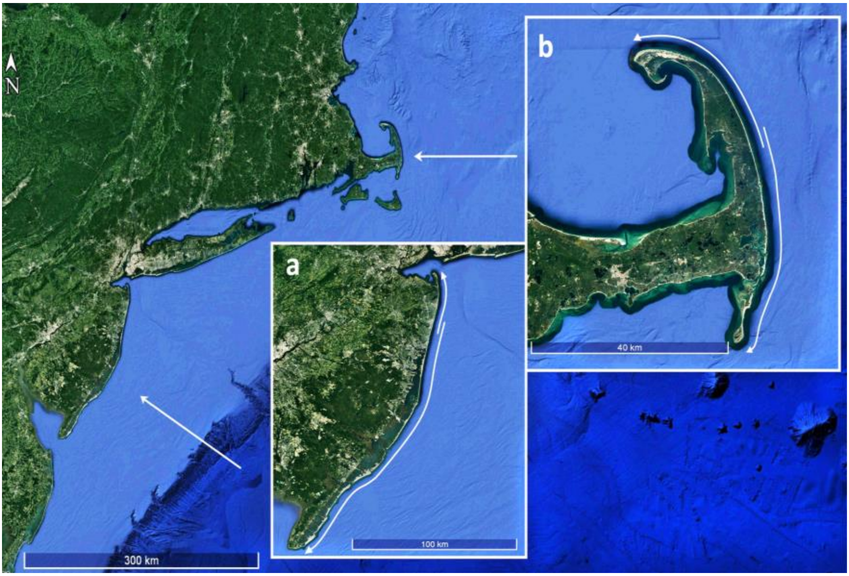

Fig. 1. The geographical location of the "winged foreland" coastal systems within the United States Atlantic coast: a) Sandy Hook Coast Bar and Spit in the area of Long Branch; b) Cape Cod Peninsula. White lines with arrows indicate the direction of alongshore sediment flows (developed on the basis of Google Earth resource).

F. Gulliver[33] as a part of the formation "winged foreland" identifies three components: a promontory of the root coast and two accumulative forms symmetrically located from this protrusion.

It should be noted that in determining the genetic characteristics of accumulative formations, the author focuses on the coastal sediment movement from the abrasion to accumulative.

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Thus, we can state that F. Gulliver considers the "winged foreland" as a complex coastal lithodynamic system in which the features of the accumulative forms formation and evolution are inseparable from the abrasion section and the nature of the alongshore sediment flow.

The complexity of this abrasion-accumulative system is caused not only by the presence of two accumulative forms instead of one, but also by certain morphogenetic characteristics. So, genetically, the formation of accumulative forms within the "winged foreland" system is due to the interaction of both transverse and alongshore sediment flow[34, 35].

F. Gulliver describing this system, uses an evolutionary approach and justifies the formation of the coastal system "winged foreland" in the context of the general transformation of the bay coast, stating that these formations arise at the stage of "youth".

In his work[36], this American scientist also considers the geographical extension of the same coastal systems on the Earth surface. According to him, the abrasive-accumulative systems of the "winged foreland" are not very widespread along the World Ocean shores of the, but at the same time they develop under very diverse environmental conditions. As an example, he shows coastal formations in the region of separate islands and peninsulas in the southwestern and southeastern parts of the Baltic Sea, namely, in the area of the Jutland and Sambian peninsulas, as well as the Pomeranian protrusion[37].

It should be emphasized that special attention he pays to the coast area in the north-west of the Crimean peninsula, where the "striking", according to him, the area of the "winged foreland" is located. He describes the coast with a very rugged primary coastline, which is separated from the open sea by protruding accumulative forms. F. Gulliver writes: "Despite the lack of good quality and large scale

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[34] Gulliver F.P. Shoreline topography. Proceeding of the American Academy of Arts and Sciences, 1898. Volume 34. P. 151–258.

[35] Davis W.M. The outline of Cape Code. Proceedings of the American Academy of Arts and Sciences, Vol. 31 (May, 1895 – May, 1896). P. 303–332.

[36] Gulliver F.P. Shoreline topography. Proceeding of the American Academy of Arts and Sciences, 1898. Volume 34. P. 151–258.

[37] Gulliver F.P. Shoreline topography. Proceeding of the American Academy of Arts and Sciences, 1898. Volume 34. P. 213–214.

maps, as well as geological studies materials, this coastal system should be interpreted as a "winged foreland", due to the typical contour of the coast"[38]. In our opinion, this description fits the Tendra – Dzharylgach natural coastal system.

No less interesting is the information that to the north of this system he describes a similar formation, which the genesis is not very clear, but it looks like very much a "winged foreland", noting that a large number of lakes are located within it and the Dnieper delta is nearby[39]. Based on the description, we defined this system as the Kinburn Peninsula distal part.

In summarizing the work of Douglas Johnson[13] "Development of the coastline", these natural coastal systems had already identified as "winged headland". The author, referencing F. Gulliver, describes them as very specific coastal forms, having the appearance of a cape, bounded on both sides by bays and braids.

At the same time, he confirms F. Gulliver's idea[40] that such formations appear within the limits of the originally bay coast, at the stage of its youth, when active abrasion of capes occurs and young accumulative forms begin to form[41].

In the mid-twentieth century, the American scientist R. Nikols, examined the "winged foreland" natural systems in the context of the evolution of drumlins coast[42]. This genetic type of coast is developed in the areas of glacier retreat[43], where it is represented by rather easily collapsing coastal sections, on both sides of which specific accumulative formations, called "flying bars", are located.

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[38] Gulliver F.P. Shoreline topography. Proceeding of the American Academy of Arts and Sciences, 1898. Volume 34. P. 214.

[39] Gulliver F.P. Shoreline topography. Proceeding of the American Academy of Arts and Sciences, 1898. Volume 34. P. 214.

[40] Gulliver F.P. Shoreline topography. Proceeding of the American Academy of Arts and Sciences, 1898. Volume 34. P. 151–258.

[41] Johnson D.W. Shore process and development. New York: John Wiley&Sons, INC / London: Chapman&Hall, Limited, 1919. P. 329–330.

[42] Nichols R.L. Flying bars. American Journal Science, 1948. CCXLVI. P. 96–100.

[43] Морская геоморфология: Терминологический справочник. Береговая зона: процессы, понятия, определения [науч.ред. В.П. Зенкович, Б.А. Попов]. Москва: Мысль, 1980. 280 с.

V. Zenkovich often paid attention to "winged foreland" coastal systems[44, 45, 46]. Initially he describes the "winged foreland" as the abrasion-accumulative pair (system) kind of variety, paying attention to the specific appearance of the formation, but stating that the formation of these coastal systems in most cases is due to different processes.

The identification of this system common features was made by V. Zenkovich after a detailed analysis of specialized literature in English[47, 48, 49, 50] and his own detailed studies of various seas shores[51, 52, 53]. The final definition of the coastal system "winged foreland" was presented by V. Zenkovich in the terminological reference[54]:

"The Winged foreland – a combination of eroded root cape and two braids, growing due to the transfer of destruction products on both sides of it. Examples are frequent on the Drumlin shores. In native literature, the term has not been disseminated".

It should be noted that in this reference manual[55] according to natural system also includes wellhead area of single-arm deltas that are

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[44] Зенкович В.П. Основы учения о развитии морских берегов. Москва: АН СССР, 1962. 710 с.

[45] Зенкович В.П. Берега Черного и Азовского морей. Москва: Географгиз, 1958. 371 с.

[46] Зенкович В.П. Морфология и динамика советских берегов Черного моря. Т. II (Северо-западная часть). Москва: АН СССР, 1960. 216 с.

[47] Gulliver F.P. Shoreline topography. Proceeding of the American Academy of Arts and Sciences, 1898. Volume 34. P. 151–258.

[48] Johnson D.W. Shore process and development. New York: John Wiley&Sons,INC / London: Chapman&Hall, Limited, 1919. 584 p.

[49] Davis W.M. The outline of Cape Code. Proceedings of the American Academy of Arts and Sciences, Vol. 31 (May, 1895 – May, 1896). P. 303–332.

[50] Nichols R.L. Flying bars. American Journal Science, 1948. CCXLVI. P. 96–100.

[51] Зенкович В.П. Берега Черного и Азовского морей. Москва: Географгиз, 1958. 371 с.

[52] Зенкович В.П. Морфология и динамика советских берегов Черного моря. Т. II (Северо-западная часть). Москва: АН СССР, 1960. 216 с.

[53] Зенкович В. П. Динамика и морфология морских берегов. Ч. 1. Волновые процессы. Москва - Ленинград: Морской транспорт, 1946. 496 с.

[54] Морская геоморфология: Терминологический справочник. Береговая зона: процессы, понятия, определения [науч.ред. В.П. Зенкович, Б.А. Попов]. Москва: Мысль, 1980. 280 с.

[55] Морская геоморфология: Терминологический справочник. Береговая зона: процессы, понятия, определения [науч.ред. В.П. Зенкович, Б.А. Попов]. Москва: Мысль, 1980. С. 134.

released as “flanking bars”[19]. The isolation of the “winged foreland” natural system in the area of the river estuarine region does not correspond to the initial definition of such systems, at the same time, indicates the lithological and morphological emphasis of these formations.

Analysis of materials submitted by V. Zenkovich in his work “Fundamentals of Seashores Development”[56], has helped us to define the generalized genetic traits that can be used to interpret the studied coastal system among others. These features are lithodynamic, morphodynamic and morphological in nature.

Highlighted “winged foreland” coastal system common features, suggested V. Zenkovich, are the best examples of these formations and can be considered the abrasion-accumulative systems of the Cheleken Peninsula (eastern coast of the Caspian Sea) and Yeisk (eastern coast of the Azov Sea). At the same time, in his opinion, the Tendra-Dzharylgach lithodynamic system is not a “winged foreland” due to the specific location of the feeding zone, but has morphological similarity[57].

In 1980, I. Shchukin in his encyclopedic dictionary[20] presented the following definition: “a winged foreland is a cape from which braids extend from both sides – “wings” washed by the sea”. This definition gives only a general idea of the formation and does not fully describe its specific features.

In 1982, the fundamental work “The Encyclopedia of Beaches and Coastal Environments” was edited by Maurice L. Schwartz. In this work, the “winged foreland” is considered not as a natural system, but as one of the specific types of accumulative coastal forms – braids, which develop under the conditions of manifestation of divergent sediment flows[58].

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[56] Зенкович В.П. Основы учения о развитии морских берегов. Москва: АН СССР, 1962. 710 с.

[57] Зенкович В.П. Основы учения о развитии морских берегов. Москва: АН СССР, 1962. 710 с.

[58] The Encyclopedia of Beaches and Coastal Environments. Volume XV. [Edited by Maurice L. Schwartz]. Stroudsburg, Pennsylvania: Hutchinson Ross Publishing Company, 1982. P. 790.

The scientists Yu. Shuisky and G. Vykhovanets (Odesa) paid attention to this specific type of coastal system. Detailed studies of the Black Sea northwestern coastal zone carried out in the 70–90s allowed them[59, 60, 61] to develop the idea of V. Zenkovich on the existence and diversity of these entities in this region. So, on the coastal section between the Danube and the Dniester, the "winged foreland" coastal system is located, which was called Burnas-Budak.

Within this system, the bars of the Burnass and Budak estuaries are separated by an abrasion step, i.e. morphologically the formations are similar to "winged foreland".

However, unlike the "classical" examples of "winged foreland", the accumulative formations located here do not belong to free, but to closing forms. It should also be noted that within this coastal system only a unidirectional sediment flow appears, which is not a characteristic feature of "winged foreland".

It should also be noted that the Tendra-Dzharylgach coastal system which is located in the Black Sea northwestern region unambiguously distinguishes as a "winged foreland" Yu. Shuisky[62], not supporting the opinion of V. Zenkovich about its "only resemblance" to formations of the type.

Thus, for more than a century of coastal studies development, a complete scientific description of the coastal system has not yet occurred; there is no consensus on its genetic characteristics, its diversity, and its place in the system of the coastal zone of the World Ocean.

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[59] Шуйский Ю.Д., Выхованец Г.В. Экзогенные процессы развития аккумулятивных берегов в Северо-западной части Черного моря. Москва: Недра, 1989, 198 с.

[60] Шуйский Ю.Д., Выхованец Г.В., Борисевич Т.Д. Современная динамика абразионных и аккумулятивных форм береговой системы "Тендра – Джарылгач" на побережье Черного моря. Фальцфейнівські читання: Зб.наук.праць [відп.ред. С.В.Шмалей]. Херсон, 2005. Т. 2. С. 270–278.

[61] Выхованец Г.В., Гыжко Л.В., Вербжицкий П.С., Стоян А.А., Гыжко А.А., Муркалов А.Б. Физико-географическая характеристика лимана Бурнас на северо-западном побережье Черного моря. Вісник Одеського національного університету. Географ. та геол.науки, 2008. Т. 13. Вип. 6. С. 44–56.

[62] Шуйский Ю.Д., Выхованец Г.В., Борисевич Т.Д. Современная динамика абразионных и аккумулятивных форм береговой системы "Тендра – Джарылгач" на побережье Черного моря. Фальцфейнівські читання: Зб.наук.праць [відп.ред. С.В.Шмалей]. Херсон, 2005. Т. 2. С. 271.

Genetic features of the "winged foreland" coastal system. After analyzing the literature devoted to the study and description of these coastal systems[63, 64, 65, 66, 67, 68, 69, 70, 71] we identified its main genetic features: lithodynamic, hydrodynamic, morphological and evolutionary.

Lithodynamic sign. In a generalized understanding, this coastal system is a section of the root coast, on both sides of which coastal accumulative forms are located. The root site is actively destroyed, retreats and supplies the accumulative formations that have joined it with detrital material. The most important connecting link for the entire system is alongshore sediment flows that begin within the divergent zone and diverge in opposite directions, thereby forming the morphological features of the "winged foreland" coastal system.

Hydrodynamic sign. Within the framework of the studied natural formation, two adjacent abrasion-accumulative pairs interact, which develop in a reverse mode, depending on the wave's nature. When a certain direction of disturbance manifests itself, between the abrasion section and one of the braids, the sediment flow is activated, while the other braid does not receive power, it remains blocked. In a situation where the waves appearance of a different direction develops, the braids, as it were, exchange places. It is the factor that determines the existence of two accumulative forms within the "winged foreland".

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[63] Зенкович В.П. Основы учения о развитии морских берегов. Москва: АН СССР, 1962. 710 с.

[64] Шуйский Ю.Д. Проблема исследования баланса наносов в береговой зоне морей. Ленинград: Гидрометиздат, 1986. 240 с.

[65] Морская геоморфология: Терминологический справочник. Береговая зона: процессы, понятия, определения [науч.ред. В.П. Зенкович, Б.А. Попов]. Москва: Мысль, 1980. 280 с.

[66] Gulliver F.P. Shoreline topography. Proceeding of the American Academy of Arts and Sciences, 1898. Volume 34. P. 151–258.

[67] Johnson D.W. Shore process and development. New York: John Wiley&Sons,INC/ London: Chapman&Hall, Limited, 1919. 584 p.

[68] Nichols R.L. Flying bars. American Journal Science, 1948. CCXLVI. P. 96–100.

[69] Зенкович В.П. Берега Черного и Азовского морей. Москва: Географгиз, 1958. 371 с.

[70] Зенкович В.П. Морфология и динамика советских берегов Черного моря. Т. II (Северо-западная часть). Москва: АН СССР, 1960. 216 с.

[71] Зенкович В. П. Динамика и морфология морских берегов. Ч. 1. Волновые процессы. Москва - Ленинград: Морской транспорт, 1946. 496 с.

Morphological sign. Within this system, on both sides of the abrasive portion, arranged coastal accumulative forms that in most cases pushed into the sea, so, they are free. Considering such systems, using the cartographic method, one gets the impression of “wings” formed at Cape, which in fact allowed F. Gulliver to apply the term “winged headland” to this formation.

Evolutionary sign. It should be noted that in most descriptions the “winged foreland” coastal system is considered as an integral part of the evolution of the dissected bay coast to varying levels. According to American researchers, the “winged foreland” coastal system is formed within a dissected coast at the initial stage of its alignment and transformation into an abrasion-aligned[72, 73].

V. Zenkovich[74] developed a theoretical scheme for the development of this coastal system. In his opinion, all “winged foreland” at the initial stage of their development are characterized by braids that are bent towards the land and make up a certain angle with the edges of the foreland. Subsequently, the entire system is aligned in one line due to the abrasion of the foreland and the simultaneous accumulation at the extremities of both braids, as a result of their extension. Accordingly, the coast, within which there are “winged foreland” with braids bent towards the land, is at a youth stage, while such formations with aligned contours are the evidence of the coast maturity.

In this case, the alignment of the “winged foreland” and the subsequent adjoining of the accumulative forms to the root sections of the coast is a natural stage of the coast evolution, which ultimately leads to the formation of an abrasion-accumulative leveled coast.

Geomorphologic analysis of the most typical “winged foreland” coastal systems examples. To determine the most complete genetic signs of this coastal system, we analyzed the lithodynamic, hydrodynamic, morphological and evolutionary features of the most typical formations of this type.

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[72] Gulliver F.P. Shoreline topography. Proceeding of the American Academy of Arts and Sciences, 1898. Volume 34. P. 151–258.

[73] Johnson D.W. Shore process and development. New York: John Wiley&Sons, INC / London: Chapman & Hall, Limited, 1919. 584 p.

[74] Зенкович В.П. Основы учения о развитии морских берегов. Москва: АН СССР, 1962. 710 с.

The "winged foreland" coastal system of the Cheleken Peninsula. The considered peninsula is located on the border between the eastern and southeastern coast of the Caspian Sea, south of the Turkmenbashi Gulf[75] (Fig. 2). The central part of the peninsula is occupied by the Chokrak Upland, which is a strongly denuded surface of the arch part of the brachianticline structure[26]. In lithological terms, this object is composed of clay and sandy rocks with a large number of abrasion terraces in the east and dunes in the west[76, 77, 78].

From the north and south to the peninsula the South Cheleken and North Cheleken spits adjoin. They are free and extended towards the sea. Both accumulative forms have similar morphological features, they expand towards the distal part and taper towards the basal. This similarity indicates the manifestation of accumulation only in the distal braids, while erosion and retreat simultaneously with the cliff occur in the basal areas. It is this feature that allows V. Zenkovich[79, 80] conclude that the evolution of the "winged foreland" coastal system occurs in the direction of its alignment in one line, and this is the most important theoretical justification of the evolutionary sign.

Investigations of the coastal zone of the Caspian Sea in the second half of the 60s, in the mid-70s of the 20th century made it possible to determine the genesis of the accumulative forms adjacent to the Cheleken Peninsula[81, 82, 83, 84]. The lithological analysis of these

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[75] Davydov O.V., Kotovsky I.N. Geographical allocation of "winged foreland" abrasion-accumulative systems. Leidinyje pateikiama 12-osios mokslines-praktines konferencijos "Jurosir krantu tyrimai 2019". Klaipedoje, medziaga, 2019. P. 49–52.

[76] Леонтьев О.К., Маев Е.Г., Рычагов Г.И. Геоморфология берегов и дна Каспийского моря. Москва: МГУ, 1977. 208 с.

[77] Леонтьев О.К., Халилов А.И. Природные условия формирования берегов Каспийского моря. Баку: АН Азербайджанской ССР, 1965. 215 с.

[78] Курбанов Р.Н. Береговые процессы на полуострове Челекен. Проблемы освоения пустынь, 2011. Т. 1. № 2. С. 17–20.

[79] Зенкович В.П. Основы учения о развитии морских берегов. Москва: АН СССР, 1962. 710 с.

[80] Зенкович В. П. Динамика и морфология морских берегов. Ч. 1. Волновые процессы. Москва - Ленинград: Морской транспорт, 1946. 496 с.

[81] Никифоров Л. Г. Структурная геоморфология морских побережий. Москва: МГУ, 1977. 176 с.

[82] Леонтьев О.К., Маев Е.Г., Рычагов Г.И. Геоморфология берегов и дна Каспийского моря. Москва: МГУ, 1977. 208 с.

formations led to the conclusion that their bodies are composed of oolitic and shell sands, with a slight admixture of abrasive material. It is these data that allowed researchers to come to the conclusion that the accumulative forms studied are a coastal bar that has shifted and subsequently joined the root protrusion of the Cheleken Peninsula.

Fig. 2. The geographical location of the Cheleken Peninsula "winged foreland" coastal system within the southeastern part of the Caspian Sea. White lines with arrows indicate the direction of alongshore sediment flows (developed on the basis of Google Earth resource)

[83] Леонтьев О.К., Халилов А.И. Природные условия формирования берегов Каспийского моря. Баку: АН Азербайджанской ССР, 1965. 215 с.

[84] Курбанов Р.Н. Береговые процессы на полуострове Челекен. Проблемы освоения пустынь, 2011. Т. 1. № 2. С. 17–20.

An analysis of the hydrometeorological conditions of the southeastern coast of the Caspian Sea[85, 86] indicates that the wind-wave regime of the Cheleken Peninsula region is characterized by dominance of northwestern and northern winds exposure, and this does not contribute to the formation of symmetrical accumulative forms.

Accordingly, lithodynamically, this coastal system does not develop due to abrasion of the root site, since the underwater slope is the main source of nutrition. Modern hydrodynamic conditions of the region cannot lead to the formation of accumulative forms symmetry. However, the morphological features of the distals of both braids allow us to conclude that within the system there is sediment divergence and two alongshore sediment flows. Evolutionarily, considering the deviation angle of the accumulative forms relative to the root protrusion of the coast, these formations indicate the initial stage of alignment of the complex bay coast.

The Tendra – Dzharylgach "winged foreland" coastal system. This natural system occupies a central place in the northwestern part of the Black Sea[87] (Fig. 3). In geological terms, its axial place is occupied by two gentle anticlinal folds composed of clay and forest-clay rocks[88, 89].

18 km took part in this race, which was called "headland"[90, 91, 92, 93]. On the other hand, two accumulative forms

[85] Леонтьев О.К., Халилов А.И. Природные условия формирования берегов Каспийского моря. Баку: АН Азербайджанской ССР, 1965. 215 с.

[86] Курбанов Р.Н. Береговые процессы на полуострове Челекен. Проблемы освоения пустынь, 2011. Т. 1. № 2. С. 17–20.

[87] Davydov O.V., Kotovsky I.N. Geographical allocation of "winged foreland" abrasion-accumulative systems. Leidinyje pateikiama 12-osios mokslines-praktines konferencijos "Jurosir krantu tyrimai 2019". Klaipedoje, medziaga, 2019. P. 49–52.

[88] Котовский И.Н. Морфология и динамика берегов Черного моря в пределах Херсонской области УССР. Автореф. дисс. …. канд. геогр. наук: 11.00.04. Киев, 1991. 19 с.

[89] Давидов О.В., Котовський І.М., Зінченко М.О., Сімченко С.В. Аналіз тектонічної зумовленості геоморфологічних умов берегової зони Херсонської област. Науковий вісник Херсонського державного університету. Серія Географічні науки. 2017. Вип. 6. С. 134–140.

[90] Зенкович В.П. Берега Черного и Азовского морей. Москва: Географгиз, 1958. 371 с.

[91] Шуйский Ю.Д., Выхованец Г.В., Борисевич Т.Д. Современная динамика абразионных и аккумулятивных форм береговой системы "Тендра – Джарылгач"

adjoin the "headland": in the west – the Tendra Spit, in the east – the Dzharylgach Spit. These are characterized by the formation of accumulative seated participants and expanded distal aspects. This is an indicator of the entire system in the direction and manifestations of accumulation only at their extremities[94].

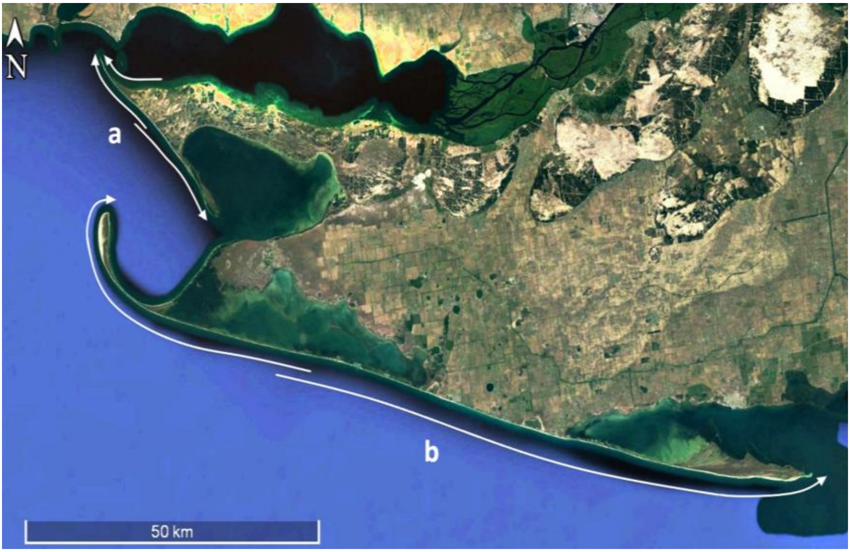

Fig. 3. The geographical location of the "winged foreland" coastal systems within the northwestern part of the Black Sea: a) Kinburnska – Pokrovska – Dovgiy; b) Tendra – Dzharylgach. White lines with arrows indicate the direction of alongshore sediment flows (developed on the basis of Google Earth resource)

на побережье Черного моря. Фальцфейнівські читання: Зб. наук. праць [відп.ред. С.В.Шмалей]. Херсон, 2005. Т. 2. С. 270–278.

[92] Котовский И.Н. Морфология и динамика берегов Черного моря в пределах Херсонской области УССР. Автореф. дисс. …. канд. геогр. наук: 11.00.04. Киев, 1991. 19 с.

[93] Давидов О.В., Котовський І.М., Ціомашко О.В., Герасимчук А.М. Аналіз морфогенетичних особливостей коси-острова Джарилгач. Науковий вісник Херсонського державного університету. Серія Географічні науки. 2018. Вип. 8. С. 169–176.

[94] Зенкович В.П. Основы учения о развитии морских берегов. Москва: АН СССР, 1962. 710 с.

The lithodynamic feature of this coastal system is that the nutrition of both accumulative forms does not occur due to the destruction of the abrasion site, but is the result of erosion of the underwater accumulative terraces and the influx of a large amount of biogenic sediment[95, 96, 97, 98].

Within this system, alongshore sediment transport is represented by two sediment flows[99, 100, 101], which diverge in opposite directions from the divergence zone in the region of the Tendra spit central part. The presence of a divergence zone within a given coastal system is an important genetic sign of “winged foreland”.

Analysis of the hydrodynamic factor[102] indicates the dominance of south-western, southern and eastern waves exposure. Considering the orientation of the coastal system, it should be noted that these wind-wave regime conditions are important morphogenetic sign and they correspond to the formation of the “winged foreland” conditions.

So, lithodynamically, this natural formation is not a classical abrasion-accumulative system, because its nutrition is not carried out

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[95] Зенкович В.П. Берега Черного и Азовского морей. Москва: Географгиз, 1958. 371 с.

[96] Зенкович В.П. Морфология и динамика советских берегов Черного моря. Т. II (Северо-западная часть). Москва: АН СССР, 1960. 216 с.

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due to abrasion of the root coast protrusion. From the point of view of the hydrodynamic feature, the Tendra-Dzharylgach natural system is an indicative "winged foreland", as evidenced by two symmetrical accumulative forms. In evolutionary terms, this coastal system fits very well into the alignment scheme of a complex bay coast, which is at the maturity stage[103].

The Kinburnska – Pokrovska – Dovgiy "winged foreland" coastal system. This coastal system is located in the northwestern part of the Black Sea, to the northeast of the Tendra Spit tip, within the Kinburn Peninsula western tip[104] (Fig. 3).

Unlike all the coastal systems described earlier, a root abrasion site is absent within this formation; the central place of the system is occupied by the Kinburn Peninsula sandy protrusion, which is periodically eroded. The Kinburnska Spit adjoins this protrusion in the northwest, and in the southeast there is a complex formation represented by the Pokrovska Spit, Krugliy and Dovgiy islands. The total length of this system is 35 km[105, 106].

Lithodynamically, the described formation is characterized by bottom feeding and reverse alongshore sediment movement, which creates divergent developmental conditions. In morphological terms, this system is a complex formation, where the north-western part is an arrow, and the south-eastern part is a spit and two accumulative islands, interconnected by an underwater coastal bar[107].

Accordingly, this coastal system can be classified as "winged foreland" according to morphological characteristics and partly

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according to lithodynamic characteristics due to the absence of an abrasion section between the braids, however, in the presence of a zone of sediment flows divergence. In evolutionary terms, the coastal system of Kinburnska – Pokrovska – Dovgiy is not the result of the bay coast abrasion alignment, but is the result of coast alignment due to the outgoing bar from the water and its subsequent adjoining to the Kinburn Peninsula protrusion.

The Burnass – Budak "winged foreland" coastal system. The studied coastal system is located in the northwestern part of the Black Sea, on a coastal segment between the Dniester and Danube rivers estuarine areas[108, 109, 110]. The central place of the system is occupied by the section of the abrasive coast between the settlements of Kurortne and Lebedivka. There is a Burnass estuary bar in the south-west, and Budak estuary bar in the north-east (Fig. 4).

Lithodynamically, this section is characterized by a longshore sediment flow, which is southwest directed toward the Zhebriyanska bay[111, 112]. However, in the warm period of the year, in the area of the Budak bar, a divergence zone appears and a sediment flow forms, directed towards the Odesa Gulf[113, 114]. In morphogenetic terms, the accumulative forms of this region are a coastal bar, which, as a result

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of displacement, joined the protrusion of the root coast. Subsequently, along the coastal zone of this accumulative form, alongshore movements of sediments were actively manifested, which led to its transformation into bar. The narrowed character of the bar indicates the dominance of sediment transport within their limits without a tendency to accumulation[115].

So, this formation, in morphological and lithodynamic terms, can be attributed to the classic "winged foreland" very conditionally. In evolutionary terms, the Burnass – Budak coastal system is a mature stage of the bay abrasive coast alignment and its transformation into an abrasion-accumulating coast.

Fig. 4. The geographical position and structure of the Burnas – Budak "winged foreland" coastal system of the Black Sea. White lines with arrows indicate the direction of alongshore sediment flows (developed on the basis of Google Earth resource)

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The Dolgaya – Kamyshevatskaya "winged foreland" coastal system. This example of the "winged foreland" coastal system is located within the eastern coast of the Azov Sea, in the Yeisk Peninsula region[116] (Fig. 5).

The central part of the system is occupied by an abrasion clay protrusion, which is a slope of the Mill zone of the Yeisk monocline elevation, within the Rostov arch[117]. The Dolgaya Spit adjoins this protrusion, which stands out as a "headland", in the northwest, and the Kamyshevatskaya spit in the southeast.

Fig. 5. The geographical position and morphological structure of the Dolgaya – Kamyshevatskaya "winged foreland" coastal system of the Azov Sea. White lines with arrows indicate the direction of alongshore sediment flows (developed on the basis of Google Earth resource)

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116 Davydov O.V., Kotovsky I.N. Geographical allocation of "winged foreland" abrasion-accumulative systems. Leidinyje pateikiama 12-osios mokslines-praktines konferencijos "Jurosir krantu tyrimai 2019". Klaipedoje, medziaga, 2019. P. 49–52.

117 Геология Азовского моря [Отв. ред. д-р геол.-минерал. наук Е.Ф.Шнюков]; АН УССР. Ин-т геохимии и физики минералов. Киев: Наукова думка, 1974. 247 с.

The nutrition of this system is carried out mainly due to the biogenic material coming from the underwater slope. However, a significant part of these sediments is involved in the longshore movement, which is characterized by a divergent character due to the hydrodynamic factor specific manifestation. It is the divergent nature of the sediment movement that contributes to the formation of accumulative forms on both sides of the Dolgaya and Kamyshevatskaya abrasion protrusions[118]. In morphogenetic terms, the Dolgaya Spit is an arrow, as it develops in the convergence of two sediment flows, and the Kamyshevatskaya is a typical spit[119, 120, 121].

So, in morphological and hydrodynamic terms, this coastal system is a classic "winged foreland". The lithodynamic analysis allows us to state that it is manifested only partially, due to the existing divergence of the sediment flow. In evolutionary terms, the Dolgaya-Kamyshevatskaya coastal system represents the youth stage of the bay coast which is aligned.

The Curonian-Baltic "winged foreland" coastal system. This coastal system is located in the southeastern part of the Baltic Sea, it is a Sambian Peninsula protrusion and two accumulative forms on both sides adjoin it: the Curonian and Baltic (Vistula) spits[122] (Fig. 6).

The Sambian Peninsula is a section of the root coast composed of glacial and fluvioglacial deposits and located in the central part. The Curonian Spit adjoins this cape in the north, and the Baltic (Vistula) Spit in the south. In morphogenetic term, these accumulative forms are coastal bars, within which alongshore sediments movement has manifested at certain stages.

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R. Knaps[123] distinguished alongshore sediment movement within the southeastern part of the Baltic Sea, directed from the Sambian Peninsula to Cape Kolkasrags, located in the Irbensky Strait region. The author also pays attention to the sediment flow directed to south from the Sambian Peninsula, but as not clearly expressed. V. Boynagryan[124], V. Gudelis[125], V. Boldyrev[126] also studied and described the coastal sediment flows in this region.

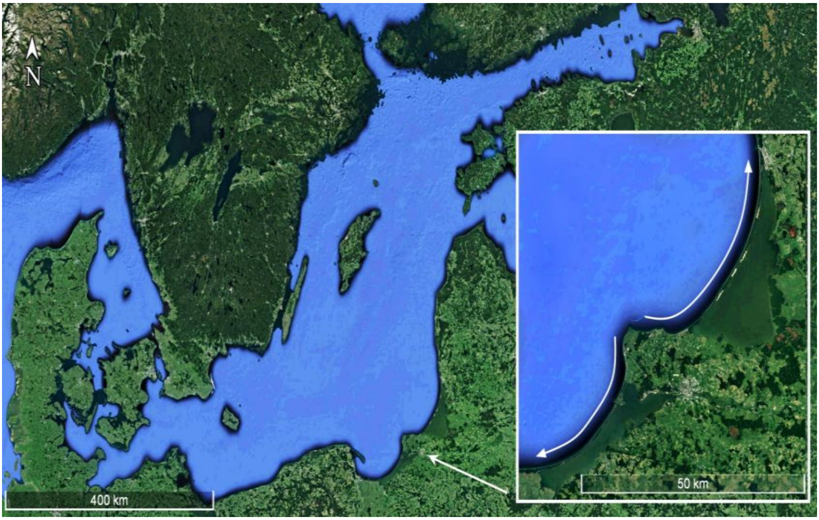

Fig. 6. The geographical position of the Curonian-Baltic "winged foreland" coastal system of the Baltic Sea. White lines with arrows indicate the direction of alongshore sediment flows (developed on the basis of Google Earth resource)

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[123] Кнапс Р.Я. Перемещение наносов у берегов Восточной Балтики. Развитие морских берегов в условиях колебательных движений земной коры. Таллин: Валгус, 1966. С. 21–29.

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During the many years of research and subsequent calculations, A. Babakov[127] concluded that within the southeast coast of the Baltic Sea, from the Gulf of Gdansk to Kolkasrags Cape, there is no single unidirectional sediment flow and there is a system of local countervailing flows, located on both sides of the Sambian Peninsula. Thus, this peninsula is a zone of sediment flows divergence[128, 129], which corresponds to the genetic feature of the "winged foreland" coastal system.

An analysis of the hydrodynamic factor in the development of the southeastern Baltic coasts indicates the dominance of the west, northwest, and southwest winds exposure[130, 131]. The winds of these directions are the most important from the morphogenetic point of view, they determine the direction of wave processes, alongshore and sediment flows. Thus, this factor contributes to the formation of the "winged foreland" coastal system type.

According to morphological characteristics, the Sambian Peninsula coastal system is a typical example of a "winged foreland". In evolutionary terms, this coastal system does not fit into the concept of an aligning bay coast.

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CONCLUSIONS

We came to the conclusion that the most typical natural formations belonging to the “winged foreland” are not characterized by full compliance with all the genetic features of these coastal systems.

Lithodynamic sign. Analysis of coastal systems data from the perspective of lithodynamics allowed us to determine that within the majority of “winged foreland” there is no dominant nutrition due to the abrasion section destruction. We find an explanation of this situation in the abrasion protrusions lithological structure:

a) Cheleken, Tendra-Dzharylgach, Burnas-Budak, Dolgaya-Kamyshevatskaya – are composed of clay and loamy rocks;

b) The Sambian Peninsula, the Cape Cod Peninsula – are represented by moraine deposits, composed of more than a third of the rocks, which produce sediments of a non-wave field upon destruction.

The analysis allowed us also come to the conclusion that the divergence zone is not always located in front of the surface area abrasion, in most cases it is somewhat biased towards one of the accumulative forms.

It should be also noted that there are “winged foreland” where the lithodynamic situation significantly differs the generally accepted one. So, for example, in the area of the flanking bars of the Ebro River single-armed delta the divergence zone is connected with the river branch and not with the root section of the coast. Within the Burnas-Budak coastal system, the divergence zone, at the moment, does not appear at all, although it was described in earlier sources.

Thus, the most important lithodynamic feature of the “winged foreland” coastal system is the divergence zone of alongshore sediment flows. This zone can be confined to the coast abrasion section or underwater slope, and in some cases, even to the river branch. The absence of a divergent zone within these formations may be due to the modern coastal evolution peculiarity. However, it must necessarily appear at earlier stages of the system development, when its morphological appearance was formed.

Morphological sign. The analysis allows to think about a significant variety of accumulative forms that make up the “winged foreland” coastal system. So, within the formations there can be both free, adjoining and closing accumulative forms.

Accordingly, the formation of these coastal relief forms may be due to the action of both transverse and alongshore sediment flows. However, in most cases, these processes occur simultaneously or alternately. It is the morphological accumulative forms diversity that make up the formation of the “winged foreland” that makes us think that their appearance is not a determining system genetic feature. The most important is the presence of two accumulative forms located symmetrically relative to the extended stretch of the shore as a rule.

Hydrodynamic sign. Analysis of the wind-wave regime of “winged foreland” coastal systems areas spread allows us to say that modern conditions do not always contribute to these coastal systems formation. Therefore, for the occurrence of symmetrical to the abrasion protrusion accumulative forms, the requied conditions for hydrodynamic blocking at the initial stage of system formation must necessarily appear.

Evolutionary sign. An analysis of the most typical of the “winged foreland” coastal systems from the position of their place in the general evolution of the bay coast tells us that the occurrence of these systems is naturally associated with the coast alignment. However, it has not sense to talk about the belonging of this system to any development particular stage.

SUMMARY

The article presents the results of literary and geomorphological analyzes of a specific coastal abrasion-accumulative systems variety It is known as the “winged foreland”. The features of their geographical spread, general and specific characteristics are described. Based on the results of the analysis, the main genetic features of this coastal systems type are identified. It must be very important for the identification, understanding the evolutionary orientation and determining the most rational way of their use.

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Information about the author:
Davydov O. V.,
Candidate of Geographical Sciences, Associate Professor,
Ecology and Geography Chair,
Kherson State University
27, Universitetska str., Kherson, 37000, Ukraine

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THE INCREASE OF ECOLOGICAL SAFETY OF IRRIGATED LANDS USE

Dymov O. M.

INTRODUCTION

The importance of irrigated melioration for Southern region of Ukraine is connected not only with natural and climatic conditions, but also with a number of socio-economic factors, namely: the presence of a powerful water-meliorative complex, increasing demand for agricultural products and long-term training of high-qualified specialists in this field.

The State Agency of Water Resources of Ukraine for the prevention of accidents, disasters, emergencies and reaction on them has the approved list of potentially dangerous objects, which counts 231 objects, which are on the balance of water economy organizations. All these objects do not constitute a single set of structures designed to provide reliable protection against weather and technogenic risks. Besides, a large number of them, due to the lack of operating costs, every year loses reliability and creates the risk of emergencies, including those that occur as a result of possible hydrodynamic accidents on the objects of water economy and hydrotechnical constructions.

A significant number of the objects of water economy have been constructed on the territory of the South of Ukraine, which amplify the hydrodynamic and environmental hazards in the region: the Main Kakhovka Canal and Hydroelectric Power Station, the cascade of reservoirs on the Dnipro River. The total bulk of cascade reservoirs is 43.7 billion m^3, the useful project bulk is 18.7 billion m^3, but today the efficient bulk of reservoirs is 7.7 billion m^3. On the territory of Kherson region 426.8 thousand ha of irrigation systems (IS) were built, including: Kakhovka IS 243.1 thousand ha (57%), Krasnoznamensk IS 102.0 thousand ha (24%), Ingulets IS 18.2 thousand ha (4%), native irrigation systems 42.3 thousand ha (10%), local IS 21.2 thousand hectares (5%).

1. Ecological safety of the agrarian sector of the economy in the zone of irrigation: theoretical and practical aspects

Environmental safety in the Law of Ukraine "On Environmental Protection"[1] is interpreted as a state of the environment, which ensures the prevention of environmental degradation and the occurrence of danger to human health. Extrapolated to agriculture, ecological safety can be understood as the state of the objects of the agrosphere when they and their products are not a source of safety threats to the population and do not have a negative impact on the environment.

The aggravation of the ecological situation in the agrarian sector and other sectors of the economy of Ukraine, the growth of anthropogenic loads on the environment, the irrational use of nature require the formation of fundamentally new concepts of economic development.

A number of scientists consider that[2, 3, 4, 5] environmental safety is uncertain, due to the lack of knowledge about the sustainability of ecosystems and the consequences of their disruption. It is impossible to achieve an absolute balance between society and the environment, since unpredictable types of crisis socio-ecological-economic situations always arise. Therefore, the main point of environmental safety in the agrarian sector is in reduction of the anthropogenic impact on the agro-ecosystem, which will ensure normal human life.

At different stages of social development, the concept of safety had little difference in interpretation. The development of safety theory can be divided into several main stages. At the first of them, the concept of safety was limited to the physical protection of man from

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[1] Закон України "Про охорону навколишнього природного середовища" [Електронний ресурс]. Режим доступу: http://zakon.rada.gov.ua

[2] Качинський А. Б. Екологічна безпека України: системний аналіз перспектив покращення : монографія. К.: НІСД, 2001. 311 с.

[3] Карпіщенко О. І., Ксенофонтова М. М. Агроекосистеми: проблеми стійкого розвитку : монографія. Суми: ВАТ "Сумська обласна типографія вид-во "Козацький вал", 2004. 185 с.

[4] Косякова И. В. Организационно-экономические основы экологической деятельности промышленных предприятий : монография. М.: Компания Спутник+, 2006. 316 с.

[5] Шевчук В. Я., Саталкін Ю. М., Білявський Г. О. та ін. Екологічне управління : підручник. К.: Либідь, 2004. 432 с.

the influence of external natural factors and threats of the animal world. At the next stage, the need for social security appeared. Further, the concept of safety obtains technogenic expression. And finally, the modern stage, which, in addition to the pointed out features, includes another, new feature – ecological[6].

Famous ecologist M.F. Reimers defines environmental safety as a set of actions, conditions and processes that do not directly or indirectly cause vital losses to the environment, to man as an individual and to society[7].

E.G. Degodiuk, S.E. Degodiuk emphasize that in modern society, environmental safety prevails over all other types of safety, because most of the disturbances in the environmental sphere are caused by technogenic intervention of mankind in the nature with the gradual and irreversible transformation of the biosphere into the techno sphere[8].

Agrarian production on irrigated lands involves the use of environmentally insecure substances. Thus, the use of increased doses of mineral fertilizers causes an increase in the concentration of nitrogen and phosphorus in aquatic ecosystems, which in its turn, increases the intensity of processes such as algae growth, stream slowing down, degradation of river ecosystems. Environmental pollutants also include pesticides.

Not less important factor of the effect of irrigated agriculture on agro-ecosystems is irrigation machines and mechanisms used in the production process. Thus, the result of their activity is soil over-compaction, and with the use of DDA-100MA irrigation machines – pollution of lands, water resources and atmospheric air with fuel materials. As a result, dangerous substances get into the human's body through food chains, damaging the health. It is possible to solve this problem through a complex approach, which provides for the modernization of fixed assets, taking steps to reduce the pressure of

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[6] Фирсов И. В. Методологические основы практического управления в системе обеспечения экономической безопасности. *Экономика и предпринимательство*. 2014. № 1. Ч. 2 (42–2). С. 123–126.

[7] Реймерс Н. Ф. Экология (теория, законы, правила, принципы и гипотезы). М., 1994. С. 297–316.

[8] Дегодюк Е. Г., Дегодюк С. Е. Еколого-техногенна безпека України : монографія. К.: ЕКМО, 2006. 306 с.

machinery on soils and reduce the number of passages of this machinery over the land[9].

To restore and expand the areas of irrigation, it is necessary to solve environmental and ameliorative problems in the zone of irrigation, to determine the current technological capabilities of irrigation systems and hydraulic constructions, to conduct ecological and ameliorative assessment of agricultural lands, to develop directions and stages of irrigation systems modernization, to provide integrated water resources management, to specialize irrigation systems and crop irrigation regimes to the climate changes, to increase quality and fertility indexes of the irrigated soil, to introduce innovative ways of irrigation, to improve the system of land ownership and land use, and the institutional support system to ensure efficient water economy management. In this way, to create conditions for sustainable socio-economic development of rural areas.

One of the most important aspects in the field of environmental safety is the formation of an institutional environment, which is understood as a set of system components that provide environmental safety[10, 11]. In other words, the institutional approach involves differentiating between the subjects of functioning and powers at the different levels of environmental safety.

The most powerful water-ameliorative complex in Ukraine is located in Kherson region with an area of irrigated land of 426.8 thousand ha, of which 312 thousand ha is actually irrigated recently, and therefore it is the most typical in the country in terms of irrigation development and conduction of agriculture on the irrigated lands. On the territory of the region there are elements of ecological network, which are of national importance, so the formation of nature protection territories of the state, which would represent all the natural resources,

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[9] Фурдичко О. І. Агроекологія : монографія. К.: Аграрна наука, 2014. 400 с.

[10] Муравых А. И. Теоретические основы управления экологической безопасностью : монография. М.: КОМЭК, 2008. 296 с.

[11] Чудовська В. А. Інституційне забезпечення органічного виробництва в сільському господарстві / Матеріали доп. міжнар. наук.-практ. конф. “Економічні проблеми сталого розвитку” (м. Суми, 3–5 квітня 2012 р.). Суми: СумДУ, 2012. Т. 1. С. 190–191.

is an integral part of the state policy in the field of environmental protection and preservation.

92.5 thousand ha (62.4 thousand ha – vertical and 30.1 thousand ha – horizontal drainage) and 106 settlements are protected against flood by the drainage systems built in the region. Areas with groundwater levels less than 2 meters in the zone of the influence of the drainage systems form 15.2 thousand ha. Partially flooded territory in 58 inhabited localities is provided with drainage systems.

Since the mid-1990s, the dramatic reduction in the area of actual irrigation has been accompanied by the following processes and phenomena: a significant deterioration of the technical condition of the irrigation systems (IS); insufficient quantity and unsatisfactory updating of the park of irrigation technique; disturbance of technological integrity of the IS; disturbance of the structure of croplands, technologies of crops cultivation, low level of resource support of cultivation technologies; unsatisfactory ecological reclamation (EC) of irrigated lands; insufficient level of budget financing for the maintenance of state water-ameliorative systems and natural conservation measures; insufficient implementation of innovative technologies of conduction of agriculture at the irrigated lands [12].

The deterioration of the technical condition of the existing IS, especially their inward part, is a consequence of a significant reduction in budget financing and lack of own funds from land users. The results of the research show that in the structure of croplands on the irrigated lands there is a infringement of the optimal ratio of crops, mainly due to a critical decrease in the percentage of forage crops and an increase in the proportion of industrial crops in crop rotation, which does not meet state standards. Industrial crops are relatively highly profitable, so they are often grown on unreasonably large areas, especially in the case of sunflower. Excessive share of sunflower in the structure of the cropland leads to the depletion and decrease of soil fertility, which negatively affects the yield of the next 2–3 crops. In this regard, irrigated crop rotations should be optimized in the crop area of

[12] Ромащенко М. І., Балюк С. А. Зрошення земель в Україні. Стан та шляхи поліпшення. К.: Світ, 2000. 114 с.

sunflower, replacing it with other crops, for example soybean. Saturation with this crop in crop rotations can also be no more than 20–25%. Reduction of industrial crops' areas can be achieved by increasing the share of cereals to optimum crop rotation limits (up to 40–82%) at the expense of winter wheat and corn.

In the conditions of constant use of water resources, with their limited reserves and uneven distribution, a scientifically based system of water management and irrigated agriculture is required, which would ensure optimal distribution of water resources by natural-geographical zones and industries of the economy, reproduction, protection and integrated use of water as well as a rational management system for the water economy complex.

The current level of fertilizer application in agriculture of Kherson region, as well as in other regions of Ukraine, does not meet the requirements of modern agriculture. The extended reproduction of soil fertility are not guaranteed, and even the nutrients supply of those nutritive elements are not restored, which were used by crops for the yield formation. The required amounts of them are used by plants from the nutrient supply of soils, impoverishing the latter (Fig. 1). Because of the lack of fertilizers and their unbalanced use, the need for mineral components of the soil increases each year. Thus, in 2016–2017, it reached 112.6–115.0 kg/ha. At the same time, a significant share of the deficit (35–40% of this amount) belongs to nitrogen.

Organic fertilizers play an extremely important role in preserving, restoring and increasing soil fertility. However, the situation with the use of the latter in Kherson region leaves much to be desired. The number of them per 1 ha during the period of 1990–2015 decreased by 64 times, and the share of the fertilized with them area – by 40 times. This situation is a consequence of the decrease in the number of cattle in enterprises. This significantly increases the cost production of crops that require the uptook nutrients replacement in the soil. Therefore, one of the conditions for improving this situation is the development of animal husbandry and the increase of livestock in all categories of agricultural enterprises.

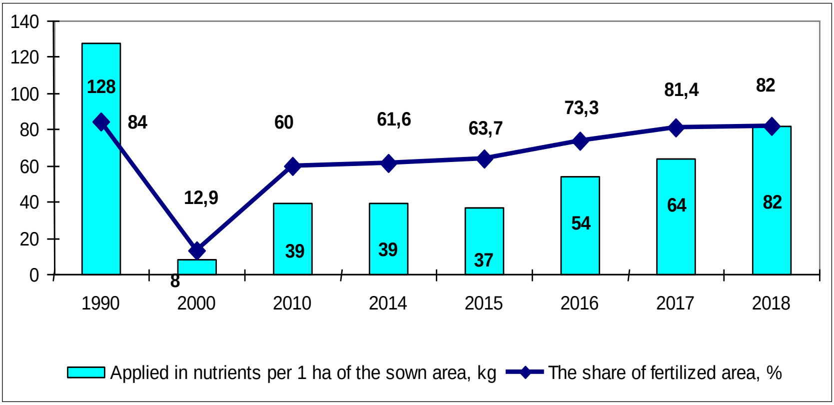

Fig. 1. Application of mineral fertilizers to the soil in agricultural enterprises of Kherson region

Source: formed by the author with accordance to the data of statistical bulletin [13]

Under the influence of irrigation, the ion-salt composition of the water extract of the soil changes. Prolonged irrigation with waters of high mineralization leads to the accumulation of easily soluble salts in the soil solution. Similar to the increase in the total salt content, the amount of toxic salts also increases: in the arable layer by 1.4–1.7, and in the meter layer by 1.3 times. Accordingly, the calcium content in the soil solution of the irrigated soils decreased by 0.07 mEq/100 g in the arable layer and by 0.09–0.13 mEq/100 g – in the meter layer. This leads to a narrowing of the ratio of water-soluble calcium to sodium in the arable layer from 1.7 to 0.6–0.7 units, and in the meter layer – from 1.1 to 0.5–0.6 units, indicating an increase in the intensity of solonetz process. The application of mineral fertilizers does not significantly affect the chemistry of the soil solution salinization of the meter layer of soil, compared to the variant without fertilizers.

In the conditions of dry Steppe climate, close groundwater laying, irrigation with highly mineralized waters, the processes of secondary

[13] Про внесення мінеральних, органічних добрив, гіпсування та вапнування ґрунтів під урожай 2010–2017 року в сільськогосподарських підприємствах Херсонської області: Статистичний бюлетень / Відп. за випуск Побрус С. В. Херсон: Головне управління статистики у Херсонській області, 2019. 48 с

salinization and alkalization begin to occur in the soils, and the soils are subjected to wind and water erosion, etc. (Table 1).

Table 1

Areas of degraded and low-productive arable lands in Kherson region, thousand ha

Lands	Years						
	2010	2011	2012	2013	2014	2015	2016
Agricultural lands	1970.7	1969.5	1969.5	1968.4	1969.0	1969.0	1969.0
Including arable land	1777.2	1776.8	1776.8	1776.8	1777.9	1777.9	1777.9
Among them: deflation-dangerous	1689.3	1689.3	1689.3	1689.3	1689.3	1689.3	1689.3
saline	590.6	599.6	599.6	599.6	599.6	599.6	599.6
eroded	441.9	441.9	441.9	441.9	441.9	442.0	442.0

Source: by the data of Kherson Department of Ecology and Natural Resources of the Regional State Administration

The high content of salts in soil solution and soil-absorbing complex causes a number of negative soil properties. They have an unfavorable agronomic structure, often over crust after rains, and in the post-germination period of crops there is crust formed on the surface. Too little volumes of annual soil reclamation cause an increase in the areas of saline, alkaline lands and solonetz.

Chemical amelioration of soils has been carried out in the past at state expenses and, although was cost-consumptive, has had the expected returns. Unfortunately, the measures provided for the implementation by the Law of Ukraine "On Land Reclamation"[14], state target and interstate land reclamation programs are not always implemented in the full size, mainly due to the lack of funds. In case of annual need for the gypsuming of alkaline soils in the area of 75 thousand ha, chemical amelioration is carried out on the territories,

[14] Закон України "Про меліорацію земель" / Відомості Верховної ради України. 2000. № 11. С. 90.

which form just about 2.4% of the required one. This is confirmed by the data on the bulks of chemical ameliorants used in Kherson region (Table 2).

Table 2

Gypsuming of the soils in Kherson region

Measure	Years							
	2010	2011	2012	2013	2014	2015	2016	2017
Soils gypsumed, thousand ha	1.8	3.8	1.3	1.4	2.8	3.0	5.3	5.6
Gypsum and gyspseous rocks, thousand tons	8.6	7.9	3.4	3.9	8.5	9.0	15.95	24.2

Source: formed by the data of Statistical bulletin

During the years of transformation of land relations in Ukraine, no ecologically-balanced land use was formed. Imperfect reform practices have deepened the ecological imbalance of the land fund, led to a decrease in the efficiency of irrigated land use, the ability to natural restoration of fertility of soils.

2. Ranking of agricultural enterprises by the level of ecological safety and directions of the improvement of environmentally safe use of the irrigated soils

The difficulty of selection and substantiation of the criteria for environmental safety assessment in the field of irrigated agriculture is in the considerable variety of indexes that characterize the condition of the natural and anthropogenic environment, as well as their diversity, which virtually eliminates the possibility of a single quantitative measure of comparison and assessment.

An important element of the information and analytical component of the implementation of the environmental safety strategy in the agrarian sector is a system of criteria and indexes that provide an assessment of environmentally-oriented development, quantification of the level of environmental safety and ranking of its species[15].

During the scientific research, we performed diagnostics of the level of ecological safety of 471 agricultural enterprises and farms in Kherson region that conduct agriculture on irrigated lands (Table 3).

Table 3

Environmental safety level of agricultural enterprises in Kherson region that perform agriculture on irrigated lands, 2017

Environmental safety level	The number of agricultural enterprises, pc.	Share,%
Stable	261	56
Unsatisfactory	135	29
Crisis	70	14
Critical	5	1
Total	471	100

The results of the analysis show that 56% of the surveyed enterprises of Kherson region, which conduct irrigated agriculture, have a stable level of environmental safety and do not create any danger to the environment and humans through their activities, 29 – meet the requirements of unsatisfactory level, 14 – at the crisis level, and 1% are in the critical level zone.

Sustainable development of the agrarian sector of the zone of irrigation, stable economic growth of agricultural production, which does not lead to significant degradation of the environment, can be ensured by developing an institutional mechanism for ensuring environmental safety in irrigated agriculture. The tools of this mechanism can be conditionally grouped into the following blocks: environmental standards, environmental control, financial and economic instruments and environmental culture.

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[15] Індикатори стану екологічної безпеки держави: [Електронний ресурс] / Аналітична записка. Національний інститут стратегічних досліджень. Режим доступу: http://www.niss.gov.ua/articles/993/

Taking into account the existing forms of the appearing threats to ecological safety, we have determined the list of indicators by the criteria and constituent elements of ecological safety in the field of irrigated agriculture. Indexes characterize the conditions of irrigated lands, the likelihood of risks, which have a negative effect on the level of environmental safety (Fig. 2).

We have analyzed and determined the level of environmental safety for specific agricultural enterprises. To be more objective, we excluded from the indexes that are on the list of integrative index of ecological safety in the agrarian sector the indexes that characterize the criterion of human health and normal vital functions. In our opinion, the complex of the indexes, which characterize the level of environmental safety of an agricultural enterprise, consists of nine indicators (Table 4).

The intensification of irrigated agriculture, the increase in levels of anthropogenic loads on agricultural landscapes require a systematic approach to the problems of the use of irrigated land, which must be solved on the basis of the data of environmental monitoring, which allows identifying changes, carrying out a comprehensive assessment, prevention and elimination of the negative effects of degradation processes. The orientation, periodicity and speed of soil conversion under the influence of irrigation are determined by: initial soil condition, quality of irrigation water, level of natural drainage of the territory, irrigation technology and intensity of use of irrigated lands. Environmental monitoring of irrigated lands gives a systematic assessment of the ecological situation, shows the degree of vulnerability of the territories to negative phenomena and the possibility of developing proposals to eliminate and prevent degradation processes. Various scenarios of ecologically oriented land use systems have been developed to evaluate the further efficient use of irrigated lands, taking into account the ecological status of these lands (Fig. 3).

The results of the investigations showed that the improvement of the existing system of monitoring management is possible through the formation and implementation of a unified state environmental monitoring system (USEMS), which will be regional by its nature and will define the territorial subsystems of USEMS in the formation of the regional environmental monitoring system.

Table 4

Indexes of ecological safety of an agricultural enterprise and their threshold values

The name of an indicator	Threshold values	The criterium of the optimum of threshold indicator	Value of weighing coefficient
Ecological and agro-chemical evaluation, points	100	max	0.10
Coefficient of ecological stability of the area, units	0.51	max	0.11
Land erosion,%	10	min	0.16
Pesticide load, kg/ha of active substances per year	1.2	min	0.11
Chemical load, kg/ha of active substances per year	90	min	0.11
Dynamics of the humus content,%	100	max	0.15
The level of use of substantiated rates of organic fertilizers,%	100	max	0.08
The area of polluted with ribonuclear agricultural lands,%	1	min	0.07
The share of the components of ecological network in the total structure of agricultural lands,%	40	max	0.10

In order to improve the environmental safety of irrigated agricultural land use on the basis of the USEMS of irrigated land, scenarios of ecologically oriented land use systems in the irrigation zone should be developed and scientifically proved, namely: the use of irrigated land for the cultivation of environmentally safe products; the use of irrigated land in generally accepted regional systems of irrigated agriculture; exclusion of land from irrigation by conservation of separate arrays of irrigated lands that are in degraded condition.

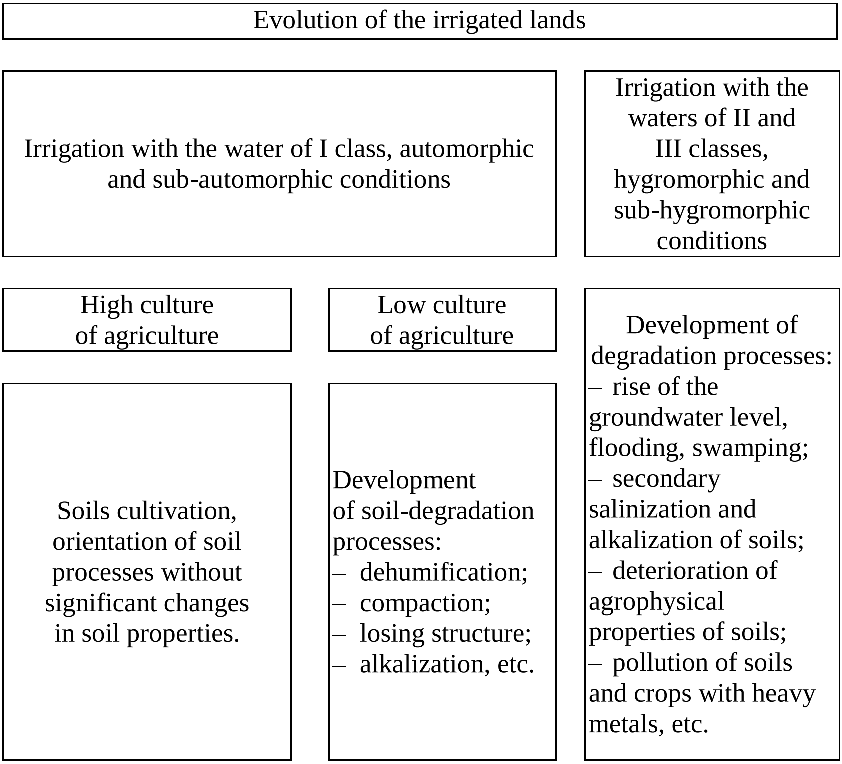

Fig. 3. Scheme of the evolution of irrigated soils

In order to improve the environmental safety of irrigated agricultural land use on the basis of the USEMS of irrigated land, scenarios of ecologically oriented land use systems in the irrigation zone should be developed and scientifically proved, namely: the use of irrigated land for the cultivation of environmentally safe products; the use of irrigated land in generally accepted regional systems of irrigated agriculture; exclusion of land from irrigation by conservation of separate arrays of irrigated lands that are in degraded condition.

The organizational and economic mechanism for the implementation of environmental monitoring of agricultural land in the zone of irrigation is conducted with the help of land policy instruments: norms, standards, orders, recommendations and instructions.

One of the measures that will ensure the introduction of ecologically-oriented land-use systems based on environmental monitoring in the conditions of irrigation, is a separate allocation of conservation-exclusion from agricultural circulation for a certain term to implement measures in restoration of their fertility. Exclusion of irrigated land has to be performed in accordance with the requirements presented in the Figure 4.

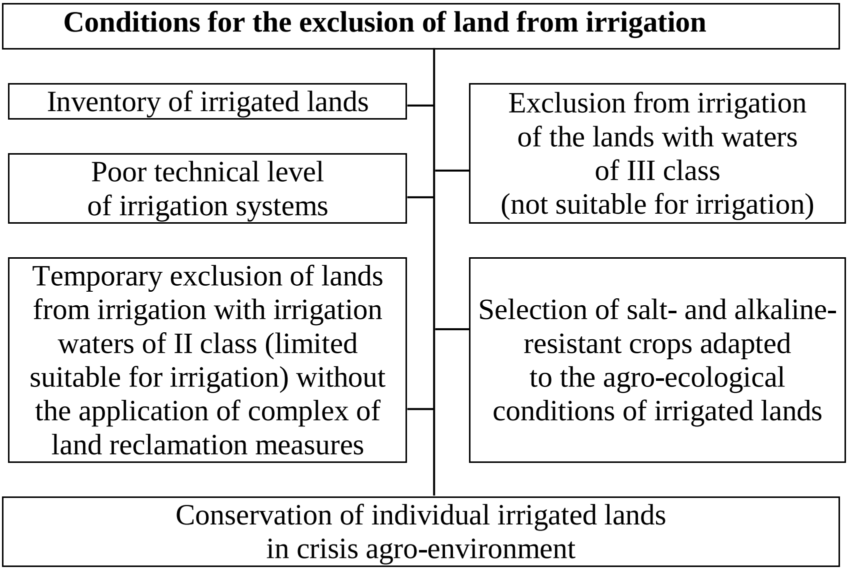

Fig. 4. Conditions for the exclusion of land from irrigation

Low-productive, erosion-hazardous and technogenically polluted soils are to be the first to be excluded from agricultural circulation. Conservation of land is carried out by padding or afforestation. Afforestation is one of the efficient measures to improve the ecological stability of the land, which contributes to the restoration of their natural condition.

Due to the growing demand for food in the international market, the territory of Kherson region requires strong controls on the use of land resources. In recent years, a large number of unsolved problems have been accumulated in this field that require to be responded at once: the highest plowed land area in Ukraine of 90.4%; unproductive lands, which could be used for afforestation, were shared; there is no efficient system of consulting for agricultural producers as for the management of agricultural land; there are no tools to support the infrastructure for maintaining soil fertility: irrigation systems, forest belts, inland roads.

In order to improve the land use system, it is necessary to exclude from the intensive cultivation the most degraded and low-productive lands, to provide through the introduction of resource-saving agrotechnologies non-deficient balance of humus and balanced phosphorus content, to stabilize the increase in the areas of saline and alkaline soils.

Schemes for the conservation of degraded and low-productive lands have been developed for each district of Kherson region (Table 5).

It is expected that the conservation and enhancement of degraded and dangerously contaminated lands will contribute to the improvement of the productivity and environmental stability of agricultural landscapes, sustainable land use, improvement of the ecological economic efficiency of agriculture and living conditions of the population.

As the world and domestic experience of irrigation testify, the task of preservation and extended reproduction of soil fertility, in which processes such as salinization, sedimentation, alkalization, compaction, deconstruction, cohesion, crust formation, decalcification, dehumification, impoverishment, contamination, could be solved only with the help of controlled agricultural influences, among which the system of agromeliorative measures occupies the leading place. The list and content of the means of influence on soils depend, firstly, on the degree of their cultivation and degradation; secondly, on the quality of irrigation water and, thirdly, on the ecological agromeliorative conditions of the irrigated lands.

The zones of primary application of the measures should be soils with unsatisfactory (crisis) ecological agromeliorative condition, on which negative processes have reached a strong stage of development. The complex of existing agromeliorative measures in Ukraine, which is the result of many years of the developments of a number of research and project-technological institutions, can minimize the negative impact of irrigation on soils when the irrigation waters of 2–3rd classes are used, but it cannot completely stop soil degradation processes.

Table 5

Lands of Kherson region subjected to conservation, ha

The names of districts	Lands subjected to conservation							
	total	among them		including				
		through padding	through afforestation	communal ownership	reserved	stored	personal house-holds	farmers
Beryslav	3952.6	3952.6	-	2066.5	492.6	550.7	-	842.8
Bilozerka	201.0	201.0	-	-	-	-	-	-
Velyka Lepetykha	4165.3	4165.3	-	2882.5	523.9	526.0	232.9	-
Velyka Oleksand-rivka	6186.2	5545.3	640.9	3762.7	1006.7	938.6	330.6	147.6
Verkhnii Rohachyk	5085.0	5085.0	-	3185.6	241.5	824.1	11.3	822.5
Vysokopillia	4835.7	4835.7	-	3577.6	821.6	180.5	-	256.0
Henichesk	11001.4	11001.4	-	7759.4	2014.1	657.6	200.1	370.2
Hola Prystan	4492.6	3670.0	822.6	-	-	-	-	-
Hornostaivka	3271.14	2714.1	557.06	-	-	-	-	-
Ivanivka	5500.7	5267.9	232.8	4067.1	849.2	422.9	34.00	127.5
Kalanchak	3948.1	3948.1	-	2828.7	512.4	-	14.4	592.6
Kakhovka	1930.06	1930.06	-	1451.84	478.22	-	-	-
Nyzhni Sirohozy	1934.3	1922.3	12.0	1590.1	81.6	137.7	62.4	62.5
Novo-vorontsovka	3347.5	3347.5	-	1322.3	635.3	778.7	-	611.2
Novotroitsk	5804.2	5804.2	-	3801.5	597.4	551.8	-	853.5
Oleshshia	3063.0	1022.3	2040.7	-	-	-	-	-
Skadovsk	2581.2	2581.2	-	1526.1	234.6	574.3	246.2	-
Chaplynka	3651.2	3651.2	-	676.5	385.1	2504.9	35.8	48.9
Total	74951.2	70645.14	4306.06	38908.34	8874.22	8510.1	1105.3	4672.8

The main components of such a complex are: the transfer of irrigated agriculture to landscape-adaptive environmentally friendly compensatory systems of agriculture; introduction of a differentiated resource-saving fertilization system; renewal of works on chemical melioration of irrigated soils and irrigation waters; planning of crop irrigation regimes and methods based on compensatory and adaptive principles; exclusion of lands from irrigation in accordance with scientifically based principles and regulations; detoxification of contaminated soils; use of modern models of land reclamation management; organization and maintenance of ecological and ameliorative monitoring of irrigated lands.

CONCLUSIONS

1. In the conditions of constant use of water resources under the limited reserves, a scientifically substantiated system of water economy management and irrigated agriculture, which would ensure optimal distribution of water resources by natural geographical zones and industries, reproduction, protection, complex water use, rational system of water economy complex management, is required.

2. One of the most important aspects in the field of environmental safety of the use of irrigated land is the formation of an institutional environment – a set of system components that provide environmental safety.

3. The main components in the system of institutional support of balanced use of land and water resources in agricultural activities on irrigated lands are: development of institutions of state regulation of the economy in the direction of use of the whole set of forms and methods for land optimization and water use in agricultural formations; taking into account the impact of informal institutions in the use of land and water resources in the process of agricultural policy implementation; optimization of agricultural land use, taking into account the environmental constraints established by existing institutions.

4. The task of preservation and renewal of the fertility of soils, in which degradation processes have developed, can be solved by the means of a system of agromeliorative measures, the main components of which are: the transfer of irrigated agriculture to landscape-adaptive ecologically safe compensatory systems of agriculture; introduction of a differentiated resource-saving fertilization system; renewal of works on chemical melioration of irrigated soils and irrigation waters; planning of crop irrigation regimes and methods based on compensatory and adaptive principles; exclusion of lands from irrigation in accordance with scientifically substantiated principles and regulations; use of modern models of land reclamation management; organization and maintenance of ecological and ameliorative monitoring of irrigated lands.

SUMMARY

Agrarian production on irrigated lands anticipates the use of environmentally unsafe substances, irrigation machinery and mechanisms used in the production process and has a certain negative impact on soil, water resources and human health. The article defines the level of ecological safety of agricultural enterprises of Kherson region, which conduct their economic activity on the irrigated lands. The analysis shows that 56% of the surveyed enterprises have a sustainable level of environmental safety and do not pose a threat to the environment and human, 29 – belong to the unsatisfactory level, 14 – to the crisis, and 1% are on the critical level. Taking into account existing forms of manifestation of threats to ecological safety, the list of indicators by the criteria and constituent elements of ecological safety in the field of irrigated agriculture is determined. Different scenarios of ecologically oriented land-use systems are presented to evaluate the further efficient use of the irrigated lands, taking into account the ecological conditions of these lands. It is proved that in order to improve the land-use system, the most degraded and low-productive lands should be excluded from intensive cultivation and through the use of modern resource-saving agrotechnologies a non-deficient humus balance and balanced content of phosphorus have to be provided, the increase of the areas of saline and alkaline soils has to be stabilized.

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Information about the author:
Dymov O. M.,
Candidate (Ph.D.) of Agricultural Sciences,
Senior Researcher, Head of the Laboratory of Economics,
Institute of Irrigated Agriculture
of the National Academy of Agrarian Sciences of Ukraine
Kherson, Naddnipryanske, 73483, Ukraine

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ECOHYDROLOGICAL INVESTIGATION OF PLAIN RIVER SECTION IN THE AREA OF SMALL HYDROELECTRIC POWER STATION INFLUENCE

Korzhov Ye. I.

INTRODUCTION

The mode of operation of a hydroelectric power station is one of the main abiotic factors regulating the status of aquatic ecosystems of the river on which it is installed. The ecologically unjustified regime of the hydropower station can lead to significant ecological consequences and irreversible changes in the processes of formation of water quality, biodiversity and building stable trophic connections in the area of direct influence.

The more electricity is produced, the greater the environmental impact of the station. Equally important is the level of inter-annual regulatory capacity of hydroelectric power stations. The small hydroelectric power stations (with installed capacity not exceeding 5 MW), which have no regulating capacity, have the smallest impact on the aquatic ecosystem. In this paper, we will consider the ecohydrological aspects of the impact of the operation of small hydropower stations without intra-annual regulation on aquatic ecosystems and biotopes that are located in their area of influence.

The object of the study we have selected was the Myhiya hydroelectric power station, which is located on the left bank of the Southern Bug River near the village of Myhiya in the Pervomaisky district of the Mykolaiv region in Ukraine (Fig. 1).

The complex of hydroelectric power station includes a building with hydroelectric turbines, with a total area of 847.9 m^2, a drainage channel of 124 m length, a spillway of overflow type of 208 m in length and a height of 2.25 m. The normal propped level is 5.5 m. The power installed on the HEPS tires is 750 kW.

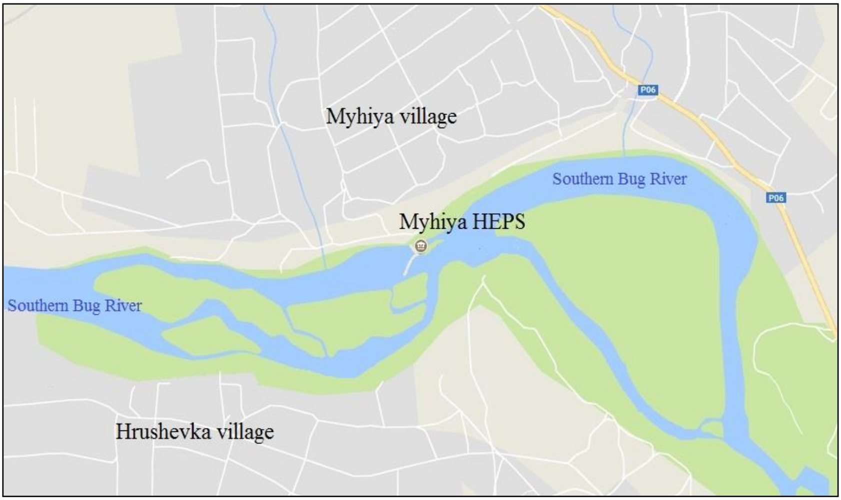

Fig. 1. Scheme of the Myhiya hydroelectric power station location

The largest settlements in the study area are the town of Pervomaysk (5 km upstream) and the Myhiya and Hrushevka villages, located near the hydroelectric power station along the left and right shores of the left sleeve of the Southern Bug River in the Pervomaisk region respectively.

The terrain has a slight slope in the southeast direction, which is 0.00034. The terrain is shaped like a steppe plain, characterized by alternation of valleys with ravines and beams. The vegetation of the basin has the character of forest-steppe. The slopes of the shores in this area are mostly flat, overgrown with reeds and shrubs. In the course of the river, bumps and sills are often found, forming a heterogeneity in the distribution of depths, flow velocities, water transparency, sediments and other environmentally significant characteristics of the aquatic ecosystem.

We conducted research in July 2017 (before the launch of the Migia HEPS) and in July 2018 (after a year of the hydroelectric power station operation). The choice of such time periods made it possible to assess the effect of the operation of the hydroelectric power station on the aquatic environment state in the area of its operation, to identify elements of the redistribution of individual hydrological parameters after the commissioning of the hydroelectric power.

For research, we used the methodological base of ecohydrology. Ecohydrology as an independent scientific field is recognized relatively recently. Since the 1970s-1980s, studies in Ukraine, Poland, and Russia have been widely developed with the aim of assessing hydrological processes for shaping the state of ecosystems of water bodies and watercourses, their bio-productivity, and water quality. As a result, three main blocks of hydrological factors that are most environmentally significant were identified. These are water balance and water exchange processes, intra-water dynamics, and hydrophysical properties of water masses and bottom sediments. Using this approach to the analysis of hydrological factors allows you to maximize their environmental significance and identify the most important aspects of the aquatic environment, by regulating which it is possible to rationally control the state of the water bodies[1, 2].

A few more outdoor visits have been established, with a flood zone territory, a view of the depression of the left sleeve of the Southern Bug River before rowing of the hydraulic branch (350 m above the main power supply) until the main channel is lower than 130 m. Itself in the assigned area is included in the introduction of the Myhiya HEPS.

Behind the hydrological indicators and morphological features, the zone is more likely to be divided into a number of woodlands, which, however, are almost different between themselves (Fig. 2).

The characteristic pattern of the access to the area is that there are a variety of abnormal factors in the middle ground, equally large for the flat aquatorium, there are significantly more floristic and unique complexes.

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1. Hydrographic characteristics and orography of the bottom

Investigations were carried out on the section of the Southern Bug River, 350 m above and 150 m below the structure of the Myhiya hydroelectric power station. Depth distribution in the studied area is rather uneven (Fig. 3).

Data on the distribution of depths along the water area are given for a limited period under conditions of low water levels in the river (Nature survey from 18.07.2017). In other hydrological periods of the year the depths in the studied area are higher. The maximum depths are noted during the period of spring waterhole and are greater than those indicated by 0.5–0.7 m.

The zone of maximum depths is located mainly in the central part of the study area and just before the hydroelectric dam. Depths here in the period of boundaries are 2.0–2.6 m. The rest of the dam above is shallow. Along the left bank, the depths are 0.5–0.8 m, at the bottom a considerable layer of sludge with vegetable detritus. In the area of the dam and between the rocky islands, there is also a shallow zone with a range of values of 0.5–0.9 m. In this part, due to the high flow velocities, the bottom is represented by stones, pebbles on which various rheophilic species of higher aquatic vegetation grow.

In the lower side of the hydroelectric power station, the average depth is about 1.0 m. The greatest depth is noted near the oval tunnel, and, at a distance of 5 m from it, on the day of observations was 2.5 m. Further along the channel, the depth rapidly decreases to 0.6–1.0 m. Due to the lack of water flow, the bottom is muddy, overgrown with water vegetation and clogged with tree fragments. At the point of exit of the water from the outlet channel at a distance of 55 m from the dam, the soil changes to muddy sand with shell detritus, well washed.

2. Water flow, its variability and intra-annual distribution

Myhiya HEPS is located 609 km from the source. The catchment area of the Southern Bug River near Myhiya village is 44230 km^2, the average long-term value of water consumption in terms of this area is 81.9 m^3/s or 2583 million m^3 per year.

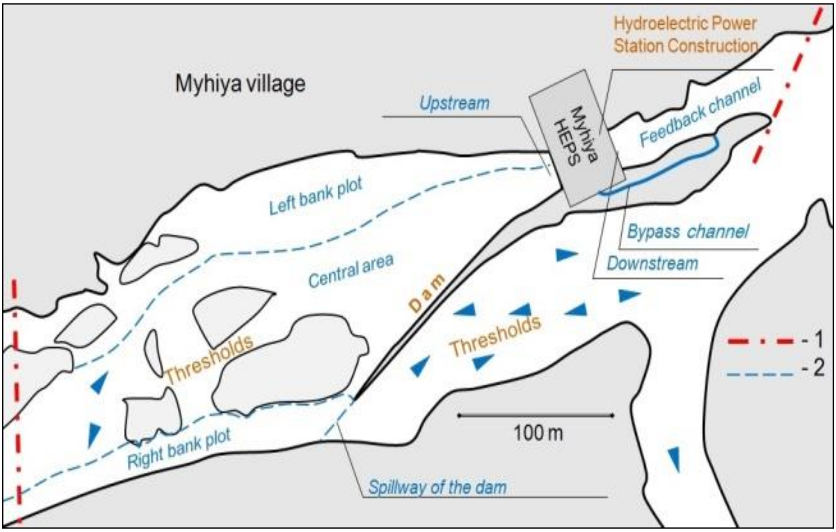

Fig. 2. The boundaries of the Myhiya hydroelectric power station influence zone (1) and the location of the water areas hydrological-morphological features (2)

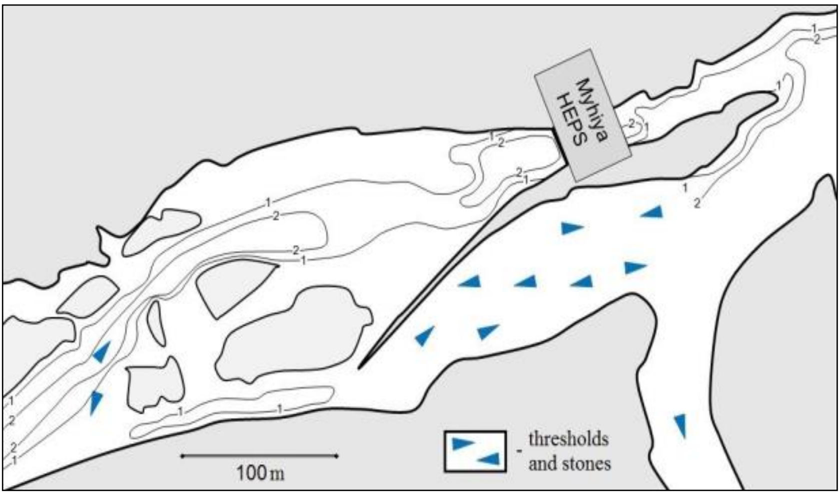

Fig. 3. Scheme of the area of e Myhiya HEPS influence in isobates (m) in the low hydrological season. According to the materials of full-scale shooting 18.07.2017

Data were recovered for the study area by the method of interpolation with neighboring posts, taking into account local factors. The analogue data is selected from the water post of the Alexandrovka village for a long period (1914–2012)[3]. The difference between the catchment areas of the river between these points is almost 2000 km^2, which is 4.5% as a percentage.

According to the average annual water consumption, we have constructed a supply curve for the Southern Bug River in the region of Myhiya village (Fig. 4).

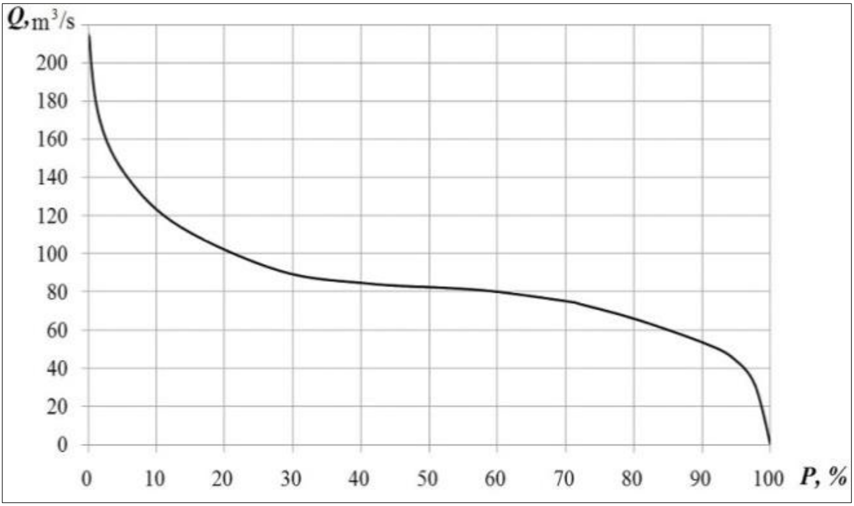

Fig. 4. Current water supply curve in the area of Myhiya village in the modern period. Q_m = 81,9 m^3/s, C_V = 0,39, C_S = 2 C_V

The variation coefficient of water flow in the area of hydroelectric power station (C_V) is 0.39, which indicates a moderate variability of river flow over many years. Based on the calculated values of Q_m and the coefficients of C_V and C_S, we obtained the values of average annual water flow in low-water, average water and high-water years under current conditions (Table 1).

[3] Водне господарство в Україні. За ред. А. В. Яцика, В. М. Хорєва. 2000. 456 с.

Table 1

Estimated water flow of the Southern Bug River in the Myhiya village in the characteristic water years

Characteristic of the year	Probability *P*,%	*K*	*Q*, m^3/s	*W*, million m^3
Low-water	95	0,529	43,3	13655
Moderate low water	75	0.874	71,6	22579
Medium	50	1.000	81,9	25827
Moderate high water	25	1.164	95,3	30053
High-water	5	1,770	145,0	45727

K – Flow coefficient, *Q*, *W* – water consumption and volume, respectively

From the archival materials and passport data of the Myhiya HEPS, it is known that the maximum flow rate recorded in the hydroelectric turbines was 5320 m^3/s (spring 1932), the minimum – 3.3 m^3/s (August 1936). A similar change in water content is also characteristic of the Southern Bug River.

The intra-annual flow distribution is typical of most plain rivers in Ukraine. It stands out for spring flood, summer and autumn fringes with autumn rains and winter. The spring flood, which runs from March to May, accounts for about 59% of the annual water volume. The lowest water levels are from July to September. The share of flow during this period ranges from 2.2 to 5.5%. In November, a short-term increase in river water content (6.7% share) is possible due to the flow of flood waters formed from precipitation. The share of water consumption in the winter months is about 12% of the total for the year.

3. Dynamics of water masses

The dynamic characteristics of the water masses in the study area are quite variable – at short distances the rapid flow can change to a station with almost no water flow. Such heterogeneous distribution of flow velocities in the area of the Myhiya hydroelectric power station influence is caused by morphological features of the channel network and distribution of flow over the water system. The exit of rocky rapids from the water, the presence of separate islands of different size and configuration, large rocks are accordingly reflected in the speed and direction of the flow of water and the formation of rolling and deep-sea sections.

Based on the materials of field observations of water consumption for the investigated area, we constructed a scheme for the distribution of time in the Myhiya village in the low-water period (Fig. 5)

Fig. 5. Distribution of flow over the Southern Bug River water system in the region of Myhiya village in the low water period of the year. Figures on the diagram – the share of flow on a separate site in% of the total river flow (water consumption 43 m^3/s). According to the materials of full-scale shooting 18.07.2017

From the above materials it can be seen that under the current conditions (with the turbines not working), only 16% of flow from the total volume from which only a part is transported to the outlet channel reaches the hydroelectric station. The other 10% is lost as a result of the transfusion of the water through the dam (mainly in its outermost part) and other channels. Such a cost distribution in the upper stream, especially near the left bank, creates favorable conditions for the siltation and sedimentation of small fractions.

The same situation occurs in the lower side of the hydroelectric power station, where good running water becomes only at the exit point of the discharge channel. Under modern conditions, in the downstream 60 m from the dam formed a stagnant shallow zone, which is significantly muddy (maximum silt capacity of 0.8 m) and is almost completely overgrown with higher aquatic vegetation.

Further downstream in the downstream, the silt zone extends along the left shore with a width of 15–25 m from the water cut. Such distribution of silt deposits indicates the presence of stagnant zones in the area of influence of hydroelectric power stations. In order to identify their location, we, based on field data, constructed a scheme of water circulation in the studied area. To do this, we used a two-dimensional, horizontal plane mathematical model of water circulation, a full-flow method adapted for shallow depths[4]. As input parameters for the calculations, we used the morphometric indicators of the water object, the average values of inflow and outflow of water, meteorological data.

Circulation patterns clearly illustrate how water flow is distributed along the water area and the main (summary) direction of displacement of water masses at a particular site of a water body (Fig. 6).

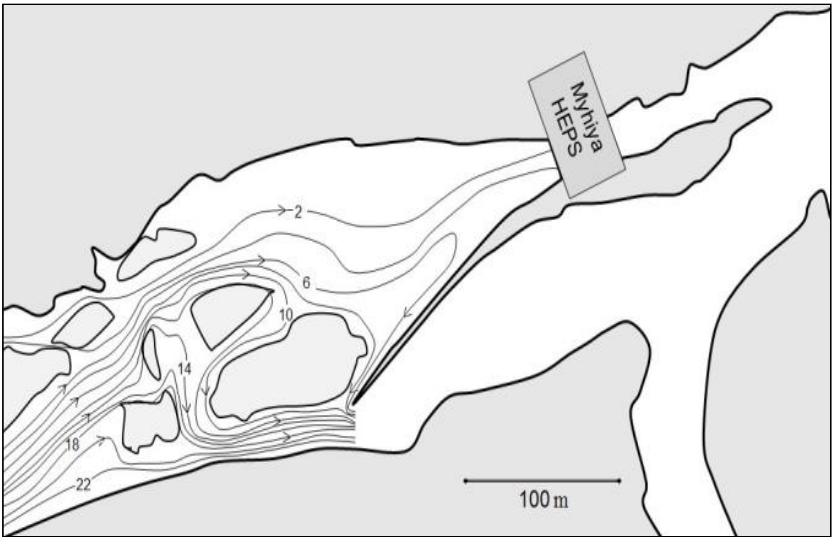

Fig. 6. Water circulation schemes in the area of influence of Myhiya HEPS under calm weather conditions (with turbines off). Current lines are given in m^3/s

[4] Фельзенбаум А.И. Теоретические основы и методы расчета установившихся морских течений. 1960. 126 с.

The results of mathematical modeling show that the most dynamically active section is the right-bank part of the object near the threshold exit and the far section along the dam. Under modern conditions (intermittent period, hydroelectric power turbines are switched off), water flows from the western part of the channel and flows mainly along the channels along the right bank. In the central part of the body of water, a large-sized stagnant zone is formed, which is located along the left bank and partly in the central part and extends to the dam of the hydroelectric power station. The velocity of flow in this zone, on the basis of full-time shooting materials, on 18.07.2017 averaged 0.03–0.08 m/s, in the central area it increased to 0.10–0.20 m/s, while in the area of the outlet of the stream through the dam at the thresholds of the flow increased to 1.20–1.40 m/s. Such heterogeneous distribution of flow velocities over a relatively short distance causes the formation of different types of biotopes coexisting in a small area. Along the left bank, mainly water flows, which are then diverted to the hydroelectric turbines, and the volume of this water depends on the capacity of the hydroelectric power station. Therefore, in order to increase the flow in the congested areas, an effective measure may be to pass more water through sewage and bypass channels, which will cause additional water supply to the left-bank and central sections of the water area and significantly improve their ecological status.

4. Hydrophysical properties of water masses and sediments

A less significant but no less important element of the hydrological regime for the object of study is the hydrophysical properties of the water masses, since they depend almost entirely on the intensity of the flow dynamics. The distribution of flow and the inhomogeneity of the flow velocity field in the area of the hydroelectric power station cause the formation of sites with different types of water masses and sediments. The study area is mostly shallow and porous, so despite the considerable content of substances suspended in water, the transparency of water masses in most cases reaches the bottom, the water temperature does not change with depth (Table 2).

Table 2

Distribution of the main characteristics of water masses properties in different parts of the area of Myhiya HEPS influence

The name of the site according to Fig. 2	Flow velocity, m/s	Water temperature, °C	Water transparency, m
Left bank above the hydroelectric power station	0,050	24,0	0,7 (to the bottom)
The central section above the hydroelectric power station	0,200	23,5	1,6
The shore along the dam above the hydroelectric power station	0,700	23,0	0,7 (to the bottom)
Upper hydroelectric power station	0,150	23,8	1,6 (to the bottom)
Wastewater canal, the lower side of the hydroelectric station	0,030	25,2	0,5
Wastewater canal, 60 m below hydroelectric power station	0,150	24,0	0,5 (to the bottom)
Southern Bug River 250 m below Myhiya hydroelectric station	0,118	24,0	1,8

Only in the most stagnant areas (left bank above the hydroelectric power station, downstream at a distance of up to 50 m from the hydroelectric power station), as the water content of organic compounds increases, the water becomes less transparent, weak thermal stratification occurs, the water temperature in them is higher, than in more flowing sections of the water area.

The distribution of sediments is in good agreement with the position of stagnant and flowing sections of the water circulation scheme (Fig. 7).

Due to the almost complete absence of currents in certain areas of the water area, substances suspended in water are not able to remain in a state of sediment and sediment, which leads to their accumulation in the sediments.

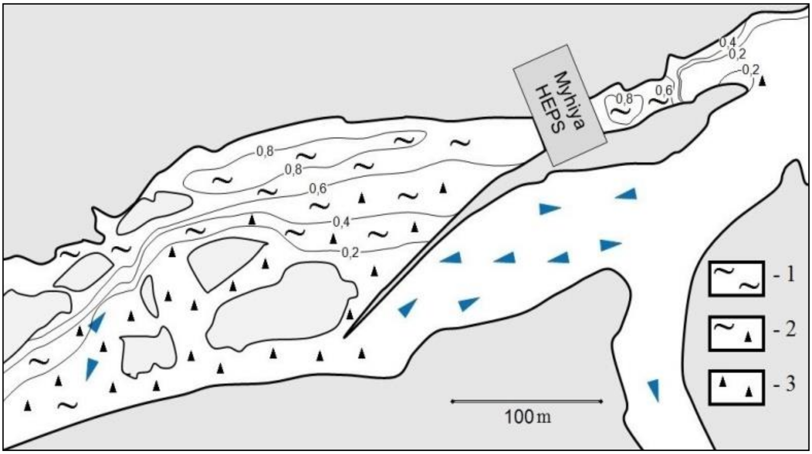

Fig. 7. Scheme of distribution of bottom sediments in the area of Myhiya HEPS. The figures show the sludge capacity in meters. 1 – organically saturated silt, 2 – silt on stones, 3 – pebbles, stones

Above the hydroelectric power station, the highest silt capacity is recorded along the left bank. The maximum capacity of the sludge layer here is 0.8 m. The average particle diameter of the solid sludge fraction in the impact zone is 0.05 mm. Then it gradually decreases in the direction of the right-bank part of the study area, where the bottom sediments consist mainly of pebbles and stones.

In the central part there is a transition zone where the soils are represented by silt on the rocks. The hilly and rocky bottom is the starting point for the river bed in the area. The distribution of sediments indicates that the mulching processes in these zones began here after the dam was closed, which altered the natural uniform distribution of costs along the waters and divided the study area into well-flowing and stagnant zones. In the discharge channel below the hydropower turbines at a distance of 60 m from the dam is also occupied by silt, whose power is unevenly distributed and averages 0.6 m (see Fig. 7). As above the hydroelectric power station, so in the feedback channel, sediments are predominantly (60%) composed of organic matter. The channel bed in some places is clogged with tree branches and station detritus. The canal is approached by the bypass channel, which serves for removal of debris from the water intake of the hydroelectric power station, which in modern conditions transports some of the fresh water to the downstream. In the area around the outlet of the bypass channel, the soils are represented by sandbars and rifts of muddy sand.

The smallest fractions are noted in the lower basin of the Myhiya HEPS, as this site is the least flowing and the soils here are formed mainly from the sedimentation products of organic substances produced by the aquatic ecosystem.

5. Assessment of the impact of the Myhiya hydroelectric power station restoration on the state of the aquatic environment

The restoration of the operation of the Myhiya hydroelectric power station in environmentally hazardous changes in the studied area did not cause.

The commissioning of the hydroelectric power station did not cause changes in the annual flow volume, since it is of the dam type and has no regulatory ability either on a daily or seasonal scale.

After the hydroelectric power station was restored, there was some redistribution of flow over the water system of the investigated section of the Southern Bug River (Fig. 8). In the area above the dam, water consumption increased in the area of the left bank and in the central part of the water area.

Due to the operation of the hydroelectric turbines, the flow to the downstream has more than tripled and now accounts for 20% of the river's flow. The increase in the water content of this section was due to the decrease in the flow rate of water that had previously passed the thresholds. If, according to the data taken on July 18, 2018, 51% of the water from the total flow of the Southern Bug River flowed through the thresholds, then after the start of the hydroelectric power station the water consumption here decreased by 15%.

This redistribution of water consumption had a positive effect on the abiotic and biotic parameters of the area of the Myhiya HEPS influence. Flow rate increase of the left bank and the central section above the dam contributes to a greater dilution of the water collected here in the congestion zones. Due to the practical disappearance of the stagnant zones in these areas, the water masses became more transparent, the capacity of silt deposits decreased by 0.15–0.20 m, the color of water changed from yellow to yellow-green.

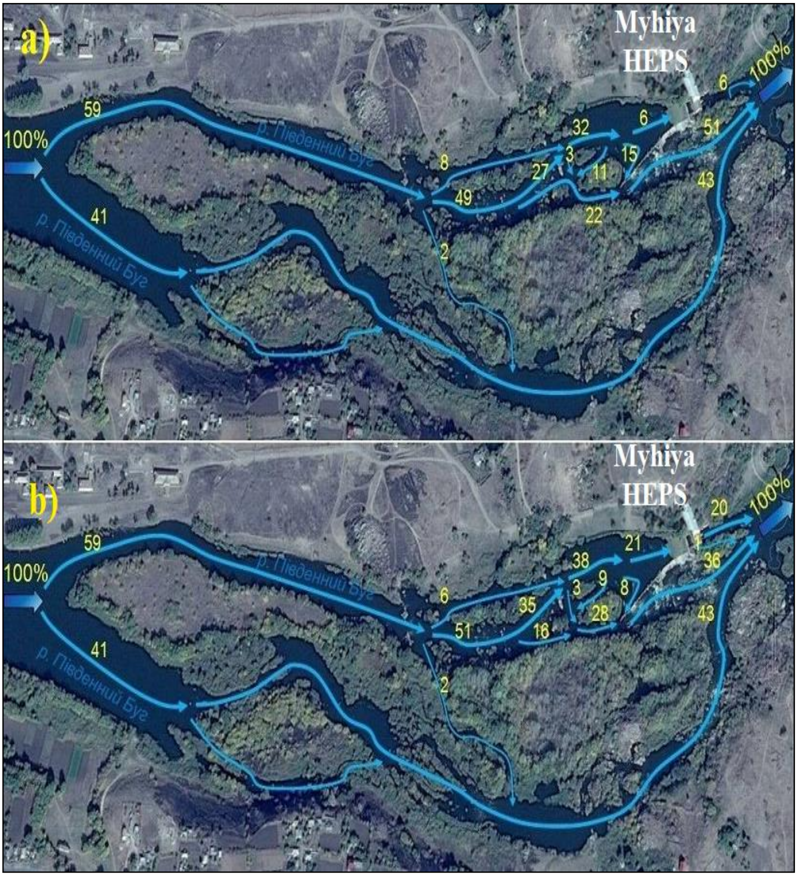

Fig. 8. Changes in the distribution of flow on the water system in the area of the Myhiya hydroelectric power station after its introduction

Flow distribution: *a)* – before start of hydraulic turbines (18.07.2017), *b)* – after start of hydraulic turbines in 2017 (23.07.2018)

Reducing water consumption at rapids also has positive aspects for the aquatic ecosystem of the site. With decreasing water costs, the flow rates of water have decreased, allowing certain flora and fauna species to more effectively stay on rocky thresholds and grow, increasing the biodiversity of the site.

Similar studies were carried out by us and other lowland rivers, particularly in the lower section of the Dnieper[5, 6, 7, 8, 9, 10, 11, 12, 13, 14]. They showed that the mobility of the water mass (water exchange processes) is one of the most environmentally significant factor aqueous medium regardless of the size of the water object.

In the downstream of the hydroelectric station and the discharge channel, due to the flow of large volumes of water, a section with intensive movement of water masses was formed. Due to the

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considerable flow of water and the relatively small capacity of the channel of the flow velocity in the specified area, they reach values of 1.5–1.8 m/s. Fast turbulent flow promotes considerable mixing of water masses, both horizontally and vertically. Compared to the field survey data we conducted in 2017 prior to the launch of the hydro turbines, the environmental status of the site has improved in hydrological terms. The congestion area, which covered the area of the entire wastewater channel, disappeared completely after the start of the hydraulic turbines. The small fractional silt and the aquatic vegetation that had accumulated here for many years, under the influence of the erosion ability of the stream, completely disappeared. Depths in the channel have now increased from 0.8–1.0 m (July 2017) to 1.6–1.8 m. However, it should be noted that the high turbulent activity of the water stream has a significant erosion ability, so at this site it is worth considering the possibility of installing additional coastal fortifications and to conduct regular inspection of the coast here once a year after a steady passage of spring flood (tentatively in June).

The resulting redistribution in the field of velocities and water flow in the area of the hydroelectric power station contributed to the alignment of ecosystem indicators to the average level – the most flowing parts of the water body became less flowing, and in the stagnant zones the flow increased.

A more even distribution of water flow through the water system due to the operation of the Myhiya HEPS reflected in the distribution of sediments and sediments in the area of constant impact. Compared to field surveys in July 2017, the capacity of silt above the hydroelectric power station in the region of the left bank decreased by 0.15–0.20 m, indicating a positive change in the status of the aquatic ecosystem of the site. In the central part of the area above the hydroelectric power station, the silt capacity decreased by 0.05–0.10 m.

In the area of influence below the hydroelectric power station, a complete transformation of the soil complex took place. Due to the stormy stream of water, the bottom is represented by well-washed sand and stones. Only at a distance of 100 m from the downstream along the coast, mainly in reeds thickets, there is a slight seasonal muddy of the bottom.

It should be noted that the process of redistribution of the soil complex in the zone of permanent impact is not complete, so we should expect further changes of this element of the aquatic ecosystem. Soil redistribution takes a certain amount of time (2–4 years), and blurred bottom sediments may, during this period, become water-suspended substances that can cause a temporary decrease in the transparency of downstream water, saturation of their organic and biogenic substances. In the feedback and bypass channel, the change of soils, due to the constant dynamic action of the water flow, is almost complete. According to eyewitnesses, during the start of the hydroelectric power station, as previously predicted, there was a short-term disturbance of the water masses in the downstream Southern Bug River network. During a observations in July 2018, we did not find changes in the transparency of water masses in the canal network under the Myhiya hydroelectric power station.

At the site above the hydroelectric power station as of July 2018, the process of soil reformation has not been completed, so here it is possible to increase the turbidity of water during the passage of spring waterfalls and heavy rain floods. The transportation of suspended substances in the water will also be temporary in nature and, according to our calculations, will occur at a site 1.2 km below the Myhiya hydroelectric station. At an average velocity in the Southern Bug River channel network below the hydroelectric power station 0.10–0.12 m/s, the particles washed away by the water flow from the upper stream can be attributed to a distance of 1.1–1.2 km. Under such conditions, the maximum possible zone of temporary (short-term) impact will be 24780 m^2 with a channel capacity of about 44600 m^3.

In general, the restoration of the Myhiya hydroelectric power station is a factor that has positively influenced the functioning of the aquatic ecosystem of the river within the impact zone, in particular its abiotic components. Water masses in the studied area, compared to the previous inspection (before the introduction of hydroelectric power stations), became more dynamically active, their processes of self-purification were activated.

Thus, the current operation of the Myhiya hydroelectric power station did not adversely affect the distribution of abiotic and functioning of biotic components of the aquatic ecosystem, the processes of water quality formation and the sanitary and biological state of the Southern Bug River.

CONCLUSIONS

The long-term presence of the Southern Bug River aquatic ecosystem in the area of the Myhiya hydroelectric power station influence in a partially without running state caused a number of negative ecological aspects, which for many years had a negative impact on the state of the surrounding aquatic environment.

The resumption of the Myhiya hydroelectric power station in 2017 on the plain of the river significantly improved the abiotic indices of the aquatic ecosystem in the area of Myhiya village. After the hydropower station was launched, a number of elements of the hydrological regime were reformed. An increase in the dynamic activity of the water masses, after the hydropower turbines was restored, had a positive effect on the transformation of bottom sediments in the left-bank and central sections of the water area above the dam and dramatically changed the characteristics of the biotope in the lower stream of the hydroelectric power station. In particular, the capacity of silt bottom sediments in the area of influence of the Myhiya hydroelectric power station decreased by 20–40%, and the congestion zone disappeared completely in the feedback channel.

In general, the restoration of the Myhiya hydroelectric power station is a factor that has positively influenced the functioning of the aquatic ecosystem of the river within the impact zone, in particular its abiotic components. Water masses in the studied area, compared to the previous inspection (before the introduction of hydroelectric power station), became more dynamically active, their processes of self-purification were activated.

Thus, the operation of small hydropower stations has virtually no adverse effect on the aquatic environment of the plain rivers and is one of the most environmentally friendly types of electricity production.

SUMMARY

The article examined the ecohydrological aspects of the impact of small hydropower stations without intra-annual regulation on aquatic ecosystems and biotopes, which are located in the zone of their influence on plain rivers.

We chose the zone of the Myhiya hydroelectric power station influence, which is located on the section of the Southern Bug River near the Myhiya village in Ukraine. The reports showed that it was

possible to fill the tidal base with the water system of the Southern Bug River in the zone of the HEPS influence at the often without flowing station, a number of negative environmental aspects were seen, some of which were negatively visible at the station.

The restoration of the Myhiya hydroelectric power station had a positive effect on the functioning of the river aquatic ecosystem within the impact zone, in particular its abiotic components. Water masses in the studied area, compared with the previous decades, became more dynamically active, their processes of self-purification were activated. From the material considered, it can be concluded that the operation of small hydroelectric power station has virtually no negative impact on the aquatic environment of the plain rivers and is one of the most environmentally friendly types of electricity production.

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Information about the author:
Korzhov Ye. I.,
PhD, Candidate of Geographic Sciences, Senior Researcher,
Kherson Hydrobiological Station
of National Academy of Sciences of Ukraine
87, M. Fortus str., Kherson, 73000, Ukraine

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IMPACT OF THE SYSTEMS OF BASIC TILLAGE AND MINERAL NUTRITION BACKGROUND ON THE PRODUCTIVITY OF GRAIN-ROW CROP ROTATION AT IRRIGATION

Maliarchuk A. S.

INTRODUCTION

Crop rotation is a scientifically substantiated alternation of crops in time and space, which corresponds to the natural and economic conditions of farms, biological and technical peculiarities of cultivated crops. It provides preservation and increase of soil fertility, obtaining high, stable yields at the least expenditures of labor and funds per unit of production considering environmental protection requirements[1].

As the central link of the system of agriculture, a crop rotation is directed on the rational use of arable land and systematic improvement of the level of agriculture. It consists of a complex of interrelated systems: soil tillage, fertilization, irrigation, protection of plants against weeds, diseases and insects, which have to optimize the growing conditions of crops.

Scientifically based crop rotation foresees the placement of crops in space, which provides the most complete compliance with the requirements of plants to growing conditions – rational use of the first and the after effects of mineral and organic fertilizers, systems of tillage, the combination of different in intensity ways of soil cultivation, reduction of the destructive effect of tillage machinery tools and the improvement of phytosanitary condition of crops.

In general, the complex of agrotechnical and organizational measures, which are combined in a crop rotation, has to reduce the energy intensity of crop cultivation technologies, improve economic indexes, increase the efficiency of crop protection against diseases,

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insects and reduce the risk of contamination of the environment due to the rational use of chemicals.

In the conditions of climate change, formation of the main components of highly intensive systems of irrigated agriculture with scientifically-grounded crop rotations, systems and ways and depth of tillage, doses of fertilization and optimal regimes of irrigation is a guarantee of stable crop yields.

Considering the ability of field crops not only to use, but also to effectively restore fertility of irrigated soils, a crop rotation significantly affects their biological activity, water-physical and chemical properties, the supply of plants with water, elements of mineral nutrition, as well as the ability to create a favorable phytosanitary and meliorative condition of crops and soil in agrocenosis.

In one time, the 7–8-field fruit-changing crop rotations for the diversified farms on the irrigated lands were developed, which considered their specialization, acreage area, the area of irrigated lands and their water supply.

Currently, the proposed crop rotations do not always meet the requirements of time, the law of Ukraine on “Land Protection” and the Resolution of the Cabinet of Ministers of Ukraine No. 164 dated 11.02.10 and No. 536 dated 30.06.10.

First of all, it concerns the selection of more profitable crops, their compatibility in the short crop rotation and the conditions of regulation of soil processes and their stabilization. In addition to selection of crops, it is necessary to consider the peculiarities of their individual varieties and hybrids, as well as the methods of agrotechnology. The crops cultivated in the crop rotation should meet market requirements, its demand, as well as provide high and stable profitability.

The combination of crops in the irrigated crop rotation with different effects on soil can provide optimum parameters of its properties. Conducting such researches will scientifically substantiate the peculiarities of construction of field irrigated agrophytocenosis and alternation of crops in them, which will stabilize the area of irrigated lands and increase the efficiency of their use.

The appearance of new forms of ownership and management, the share of land and the development of market relationships increased the number of enterprises with small areas of land use and narrow specialization. In this regard, there is a need to develop the optimum forms of land use and to introduce short crop rotations[2].

It should be noted that the appropriate agricultural technology (soil tillage, application of fertilizers, use of herbicides, etc.) can diminish the negative effect of mono-crops. At the same time, it is impossible to completely replace a scientifically-based alternation of crops with other measures of agricultural technology. At the intensive agricultural production, a crop rotation obtains a main role in the phytosanitary regulation as an important biological factor of protection of plants against diseases, insects, weeds and protection of soil from contamination with harmful substances[3, 4].

The existing non-systematic use of irrigated lands has now led to substantial deterioration of soil fertility, reduction of their resistance to self-regulation. Under such conditions, it is necessary to substantiate scientifically the ways of stabilization of soil processes, one of which could be the optimization of placement and ratio of crops.

For the last years, significant experimental material has been accumulated in the development of scientific principles of the crop rotation construction, the ratio of crops in them, the norms of saturation of the crop rotation with cereal, industrial and forage crops were determined. Therefore, reforming agriculture, a part of which is irrigated agriculture, led to the use of new approaches to the building of crop rotations[5].

The purpose of the article is to provide scientific substantiation of the optimum parameters of the ratio of competitive crops, minimized soil tillage and doses of nitrogen fertilizers, which will ensure the preservation of soil fertility, resource saving and an increase in productivity in the conditions of southern Steppe.

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Materials and methods of the study. The study was carried out within the stationary research of the Institute of Irrigated Agriculture of NAAS in the 4-field link of grain-row crop rotation during 2016–2018. The scheme of the study is presented in the Table 1. The soil of the experimental field is dark-chestnut, middle-loamy, the humus content in the arable layer is 2.06%, total nitrogen content – 0.103, phosphorus – 0.120 and potassium – 2.3%.

According to the scheme, winter wheat, grain sorghum received mineral fertilizers dose of $N_{120}P_{60}$, grain corn received $N_{180}P_{60}$ and soybean received $N_{60}P_{60}$ kg/ha that on average for the crop rotation was: without fertilizers, $N_{82.5}P_{60}$ and $N_{120}P_{60.}$

Agrotechnology in the experiments was generally accepted for the crops of the crop rotation in exception of the studied factors. The experiment was conducted in 4 replications. The area of sowing plot – 742 m^2, of the estimated one – 14 m^2.

Factor A – the system of basic tillage:

1 – plowing on different depth – plowing on the depth from 14–16 to 25–27 cm (control);

2 – plowless on different depth (chisel tillage at the same depth as in the control);

3 – plowless single-depth shallow (disk tillage on the depth of 12–14 cm);

4 – differentiated-1 with one slotting on 38–40 cm per the crop rotation;

5 – differentiated-2 with one plowing on 18 cm per the crop rotation.

Factor B (fertilization system):

1. Organic (post-harvest residues of the crops of the crop rotation);
2. Organo-mineral (post-harvest residues + $N_{82.5}P_{60}$);
3. Organo-Mineral (post-harvest residues + $N_{120}P_{60}$).

The watering was carried out according to the scheme by the DDA-100 MA sprinkler irrigation machine. The layout of the field experiments was performed with accordance to the methodological guidelines for the experiments at irrigation and generally accepted techniques[6, 7].

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[6] Методика польових і лабораторних досліджень на зрошуваних землях: монографія / Р.А. Вожегова та ін. Херсон: Грінь Д.С., 2014. 286 с.

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Table 1

Stationary experiment scheme on the investigation of the efficiency of application of methods, techniques, depths and systems of basic soil tillage in the grain-row rotation at irrigation

No var.	Basic soil tillage system	Method and depth of the basic tillage				Energy capacity, Mj/ha
		Winter wheat	Sorghum grain	Grain corn	Soybean	
1	Plowing	14–16 (p)	23–25 (p)	20–22 (p)	25–27 (p)	1501.6
2	Plowless	14–16 (ch)	23–25 (ch)	20–22 (ch)	25–27 (ch)	871.6
3	Plowless	12–14 (d)	12–14 (d)	12–14 (d)	12–14 (d)	499.4
4	Differentiated-1	8–10 (d)	12–14 (ch) + + 38–40 (sl)	8–10 (d)	14–16 (d)	697.7
5	Differentiated-2	10–12 (d)	16–18 (ch)	18–20 (p)	14–16 (d)	800.0

Note: p – plowing; ch – a chisel loosening; d – disk tillage; sl – slotting.

1. Agrophysical Properties of soil

The use of tools with different construction of working bodies for soil tillage to a certain extent affects the whole complex of agrophysical properties of soil, including the bulk density, porosity and water permeability.

Our study found that the methods, techniques and depth of tillage had a significant effect on the bulk density (Table 2).

Thus, at the beginning of the spring vegetation, the closest to the optimum indexes for the crops of the crop rotation were the different depth tillage and differentiated-1 tillage systems, by the time of harvesting the compaction of the soil in all the studied variants occurs, at the same time, the most significant it was in the variant of a single-depth shallow plowless tillage (var. 3)

Table 2

The bulk density of dark-chestnut soil in different systems of basic soil tillage in the crop rotation, g/cm^3

No.	Basic soil tillage system	Bulk density, g/cm^3				On average by the crop rotation
		Grain corn	Sorghum	Winter wheat	Soybean	
At the beginning of vegetation						
1	Plowing on different depth	1.26	1.28	1.26	1.26	1.27
2	Plowless on different depth	1.28	1.29	1.28	1.28	1.28
3	Plowless single-depth	1.32	1.33	1.32	1.32	1.32
4	Differentiated-1	1.27	1.27	1.30	1.29	1.28
5	Differentiated-2	1.28	1.31	1.31	1.31	1.30
Before harvesting						
1	Plowing on different depth	1.28	1.29	1.28	1.28	1.28
2	Plowless on different depth	1.30	1.30	1.30	1.30	1.30
3	Plowless single-depth	1.34	1.35	1.35	1.35	1.35
4	Differentiated-1	1.27	1.29	1.33	1.32	1.30
5	Differentiated-2	1.31	1.32	1.33	1.33	1.32

Determination of the bulk density in the soil layer 0–40 cm under the influence of different systems of soil tillage gave the possibility to determine the fluctuations in the studied index within the range of 1.27–1.32 g/cm^3 in the period of sprouting. The most loosened was the soil layer of 0–40 cm in the variant of different-depth plowing (var. 1) in the crop rotation, where the bulk density averaged to 1.27 g/cm^3.

Application of a single-depth shallow (12–14 cm) disking of the soil in the crop rotation led to the increase in the bulk density by 0.05 g/cm^{3}or by 3.9%.

The closest to the control by its influence on the soil is the 4-th variant with differentiated-1 system of basic tillage. In all the years of the study the difference between the control and this variant for did not exceed 0.01 g/cm^3 or was insignificant.

The same regularity was observed before harvesting. The tendency to over-compaction of the upper layers saved that led to the formation of the increased indexes of the bulk density of the soil layer 0–40 cm, which fluctuated within 1.28–1.35 g/cm^3.

During the vegetation, a different-depth plowing and differentiated-1 systems of the basic tillage (var. 1, 4) provided a relatively close by the bulk density arable layer of the soil, and the plowless shallow one (var. 3) resulted in the separation of the arable layer into more loose upper (0–15 cm) and more compacted bottom (15–40 cm) parts due to the concentration of the post-harvest residues in the upper part of the arable layer at the tillage with the working bodies of the disk type.

Thus, on average for three years of the use in the experiment, plowing on different depth and differentiated-1 systems of basic soil tillage ensured the formation of the optimum indexes of the bulk density for the crops of the crop rotation at the stage of sprouting and initial stages of organogenesis. By the time of harvesting, the indexes of the bulk density increased, and at the same time the regularity determined at the spring time remained actual.

The porosity of the soil directly depended on its bulk density. The more compacted the soil was, the lower its porosity was, that complicated absorption and infiltration of water in the zone of root system placement.

The results of the experimental researches, obtained in our study, testify that at the stage of sprouts the indexes of total porosity of the soil layer 0–40 cm were almost equal, although the tendency to their increase was observed in the variants of plowing and plowless different-depth and differentiated-1 tillage systems. The difference between the variants was only 1.3% (Table 3).

The same regularity was determined before harvesting yield almost in all the variants. In the variant of different-depth plowing basic tillage of the soil (variant 1) the total porosity was within the optimal parameters and averaged to 50.86%, while in the variant of shallow single-depth tillage it was only 48.40%, i.e. decreased by 4.8% in comparison to the control variant.

Table 3

Porosity of the dark-chestnut soil at different systems of basic soil tillage in the crop rotation,%

No.	Basic soil tillage system	Porosity,%				On average by the crop rotation
		Grain corn	Sorghum	Winter wheat	Soybean	
At the beginning of vegetation						
1	Plowing on different depth	51.85	50.96	51.60	51.72	51.53
2	Plowless on different depth	50.83	50.57	50.96	51.09	50.86
3	Plowless single-depth	49.55	49.17	49.30	49.30	49.33
4	Differentiated-1	51.47	51.21	50.32	50.45	50.86
5	Differentiated-2	50.96	49.81	49.68	49.81	50.06
Before harvesting						
1	Plowing on different depth	50.96	50.57	50.96	50.96	50.86
2	Plowless on different depth	50.32	50.06	50.19	50.32	50.22
3	Plowless single-depth	48.66	48.40	48.28	48.28	48.40
4	Differentiated-1	51.21	50.70	49.17	49.55	50.16
5	Differentiated-2	49.94	49.30	48.91	49.04	49.30

Significant differences by the years of the study were not determined.

It is possible only to mention the reduction of the total porosity to the optimum indexes for the crops of the crop rotation from sowing to the harvesting in all the variants of basic tillage and in the layers of arable horizon.

Thus, the most loosened soil was in the variant of different-depth plowing in the crop rotation and it corresponded to the optimum indexes of the plants growth and development.

The results of our researches testify that the methods of basic tillage have the effect on the soil water permeability. Mostly its index depends on the depth of loosening.

In the case of determination of the water-permeability of the soil after the sprouting stage of the crops, it was within the optimum values through all the studied variants. The highest it was in the variant of plowing on the background of prolonged use of different-depth plowing basic tillage in the crop rotation and averaged by 3 years of the study at the 3-hour exposition to 3.92 mm/min. Switch form plowing to chisel tillage on the same depth led to the decrease of water-permeability by 11.5%, and the substitution with shallow disk tillage – by 26.8% with the indexes 3.47 and 2.87 mm/min, respectively.

At the end of the vegetation of the crops of the crop rotation, the indexes of water-permeability decreased in comparison to the initial ones, that is connected with the compaction of the soil due to the solar radiation effect, atmospheric precipitation, irrigation water, running gears of tractors and working bodies of tillage machines.

The results of the analysis of the experimental researches by the years of the study proved the observed at the beginning of vegetation regularity. The highest water-permeability of the soil before the period of harvesting was at the different-depth plowing with the index of 3.44 mm/min, while at the variant with shallow tillage plowless single-depth tillage (12–14 cm) it was 2.31 mm/min or was less by 32.8%. Differentiated-1 tillage system of basic tillage was close to the different-depth plowing with the index of 3.07 mm/min (Table 4).

So, the studies, conducted during 3 years, provide the possibility to conclude that the depth of basic tillage plays a decisive role in the formation of water-permeability of the soil and water supply of the plants.

The process of the reduction of water-permeability of the soil depending on the basic tillage before sowing and harvesting is under the effect of hydrothermal conditions of autumn-winter and spring-summer period and compaction action of tractors running gears and working bodies of tillage machines, sowing and harvesting machinery.

Table 4

Water permeability of the dark-chestnut soil under the different basic soil tillage systems in the crop rotation, mm/min

No.	Basic soil tillage system	Water permeability, mm/min				On average by the crop rotation
		Grain corn	Sorghum	Winter wheat	Soybean	
At the beginning of vegetation						
1	Plowing on different depth	4.27	4.30	3.33	3.77	3.92
2	Plowless on different depth	3.90	3.70	2.90	3.37	3.47
3	Plowless single-depth	3.30	3.13	2.33	2.70	2.87
4	Differentiated-1	3.90	4.33	2.73	3.23	3.55
5	Differentiated-2	3.97	3.57	2.33	2.97	3.21
Before harvesting						
1	Plowing on different depth	3.83	3.70	3.07	3.17	3.44
2	Plowless on different depth	3.27	3.10	2.60	2.77	2.93
3	Plowless single-depth	2.87	2.43	1.87	2.07	2.31
4	Differentiated-1	3.53	3.77	2.37	2.60	3.07
5	Differentiated-2	3.43	3.03	2.00	2.37	2.71

2. Crop yields in the crop rotation

Under the influence of basic soil tillage systems, there were the changes of agrophysical properties, nutrition regime that caused the creation of different conditions for growth and development of the crops and yield formation. As a result, different yields of the crops in the crop rotation were formed.

The doses of fertilizer also had a valuable influence on the yield formation. Thus, on average for three years of the study, it was found that the highest yields in the crop rotation were provided by the application of fertilizers in the dose of $N_{120}P_{60}$ on the background of different-depth plowing and differentiated-1 systems. Thus, the yield of grain corn was 14.44 and 14.82 t/ha, respectively, soybean – 4.31 and 4.34 t/ha, winter wheat 6.81 and 6.90 t/ha and sorghum grain – 7.09 and 7.70 t/ha (Table 5).

Table 5

Yields of the crops of the short crop rotation at different systems of basic soil tillage and doses of fertilizers, for 2016–2018

Basic soil tillage system (factor A)	Nutrition background (Factor B)	The crop of the crop rotation				Average by factor	
		Winter wheat	Corn for Grain	Soy	Sorghum grain	A	B
Plowing (control)	Without fertilizer (control)	3.15	4.26	2.76	2.89	6.15	2.98
	$N_{82.5}P_{60}$	6.01	11.43	3.68	6.90		6.46
	$N_{120}P_{60}$	6.81	14.44	4.34	7.09		7.51
Plowless	Without fertilizers	3.01	3.81	2.48	2.51	5.73	
	$N_{82.5}P_{60}$	5.53	10.81	3.34	6.58		
	$N_{120}P_{60}$	6.25	13.64	3.98	6.81		
Plowless	Without fertilizers	2.70	3.05	1.77	2.04	4.46	
	$N_{82.5}P_{60}$	5.26	8.16	2.41	4.59		
	$N_{120}P_{60}$	5.91	10.08	2.83	4.76		
Differentiated-1	Without fertilizers	3.24	4.46	2.81	3.03	6.37	
	$N_{82.5}P_{60}$	6.08	11.81	3.79	7.51		
	$N_{120}P_{60}$	6.90	14.82	4.31	7.70		
Differentiated-2	Without fertilizers	2.89	3.73	2.40	2.54	5.53	
	$N_{82.5}P_{60}$	5.34	10.28	3.37	6.28		
	$N_{120}P_{60}$	6.13	13.01	3.94	6.43		

The use of plowless shallow single-depth and differentiated-2 basic soil tillage systems (variant 3, 5) resulted in a significant decrease in the yield of all the crops of the crop rotation.

Shallow (12–14 cm) loosening in the system of prolonged application of a single-depth plowless tillage without application of mineral fertilizers resulted in the formation of the smallest yields in the crop rotation (from 1.77 t/ha of soybean to 3.05 t/ha of corn).

3. Economic and energy efficiency of the crops cultivation in the crop rotation

Evaluating the efficiency of low-cost – shallow and different-depth plowless soil tillage systems in the crop rotation, it is necessary to say that providing significant cost savings on their implementation, they had a little influence on the overall expenditures of the crops cultivation technology on the whole (Table 6).

The calculations of the economic efficiency of the fertilizers use at the cultivation of the crops in the crop rotation testify that their application provided the increase of the monetary expenditures per 1 ha of the crop rotation. Thus, on the control variant, the expenditures per 1 ha of the crop rotation averaged to 10,470.7 UAH, with the dose of $N_{82.5}P_{60}$ under the same system of basic tillage they increased by 3,356.6 UAH or by 32.1%, at the dose of $N_{120}P_{60}$ – by 4,545.6 UAH or by 43.4%.

The highest conditionally pure profit – 27,602.3 UAH, on average by the years of the study, was obtained in the variant with the application of mineral fertilizers in the dose of $N_{120}P_{60}$ under differentiated-1 system of basic tillage (var. 4). The cost of products in this variant was 42,397.7 UAH, total expenditures – 14,794.0 UAH with the profitability level of 185%.

The increase in the dose of fertilizers increased the conditionally pure profit because the yield increases due to the fertilizers were very considerable.

The highest expenditures for the cultivation of the crops in the crop rotation were in the variant with the system of different-depth plowing basic soil tillage and nitrogen fertilizers application dose of $N_{120}P_{60}$, and the lowest ones – 10,155.7 UAH, or by 32.4% less – at the disk basic tillage system of a single-depth loosening without fertilizers application.

Table 6

Economic efficiency of the crops cultivation technologies per hectare of the sown area at different basic soil tillage systems in the crop rotation at irrigation (2016–2018)

No.	Basic soil tillage system	Fertilizers dose	The cost of the gross product	Expenditures, UAH	Profit, UAH/ha	Profitability, %
1	Plowing (control)	Without fertilizer	17743.0	10470.7	7272.3	71.4
		$N_{82.5}P_{60}$	34984.3	13827.3	21157.0	152.7
		$N_{120}P_{60}$	40752.7	15016.3	25736.0	170.5
2	Plowless	Without fertilizers	16119.0	10312.3	5806.7	57.9
		$N_{82.5}P_{60}$	32757.0	13631.7	19125.3	140.3
		$N_{120}P_{60}$	38285.3	14832.7	23452.7	157.5
3	Plowless	Without fertilizers	12654.0	10155.7	2498.3	26.4
		$N_{82.5}P_{60}$	25479.3	13494.3	11985.0	89.4
		$N_{120}P_{60}$	29008.3	14701.3	14307.0	97.1
4	Differentiated-1	Without fertilizers	18606.0	10248.7	8357.3	82.9
		$N_{82.5}P_{60}$	36860.7	13494.3	23366.3	172.6
		$N_{120}P_{60}$	42397.7	14794.0	27602.3	185.0
5	Differentiated-2	Without fertilizers	15697.3	10224.7	5472.7	55.6
		$N_{82.5}P_{60}$	32083.3	13537.0	18546.3	136.2
		$N_{120}P_{60}$	37488.3	14750.0	22738.3	152.7

It should be noted that the cultivation of the crops in the crop rotation was profitable in all the studied variants, while the application of the basic disk tillage did not allow obtaining as high profits as on the other variants. The increase of the doses of fertilizers under this system of tillage increased the level of profitabilityonly by 63–70.7%, while the differentiated-1 system provided the increase of 89.7–102.1%.

Thus, the calculation of the economic efficiency makes possible to claim that cultivation of the crops in the crop rotation at the application of fertilizers in the dose of $N_{120}P_{60}$ under the system of differential-1 basic soil tillage is the the most rational and profitable from the economic point of view.

Despite all the advantages of monetary evaluation, the final conviction in the efficiency of production requires the energy assessment.

To establish the energy efficiency of the cultivation technologies of the crops in the crop rotation we used such indexes: yield, energy expenditures for the crop cultivation, energy income with the product, energy increase, energy coefficient.

Our calculations proved that technological expenditures for the application of mineral fertilizers contributed to the increase of the energy consumption

The highest technological expenditures were determined in the variant of the system of plowing basic tillage with plowing under the crops of the crop rotation on the depth of 14–16 – 25–27 cm and application of mineral fertilizers in the dose of $N_{120}P_{60}$ – 39.7 GJ/ha, while the least energy expenditures (35.2 GJ/ha) were in the variant with disk loosening on 12–14 cm in the system of plowless shallow single-depth tillage without application of nitrogen fertilizers (Table 7).

Table 7

Energy efficiency of the crop cultivation technology at different soil tillage and fertilization systems

No.	Soil tillage system	Indexes of the efficiency		
		Energy expenditur es, GJ	Output of the gross energy, GJ	EC
1	*2*	*3*	*4*	*5*
System of Fertilizing No. 1 (without fertilizera)				
1	Different-depth plowing	37.8	62.9	1.7
2	Different-depth plowless	36.4	57.0	1.6
3	Single-depth shallow plowless	35.2	46.2	1.3
4	Differentiated-1	36.1	66.0	1.8
5	Differentiated-2	35.9	55.3	1.5

End of Table 7

1	*2*	*3*	*4*	*5*
System of Fertilizing No. 2 with the application of $N_{82.5}P_{60}$ kg/ha				
1	Different-depth plowing	38.7	134.4	3.5
2	Different-depth plowless	37.9	126.1	3.3
3	Single-depth shallow plowless	36.1	98.2	2.7
4	Differentiated-1	37.0	141.6	3.8
5	Differentiated-2	36.8	121.3	3.3
System of Fertilizing No. 3 with the application of $N_{120}P_{60}$ kg/ha				
1	Different-depth plowing	39.7	156.8	4.0
2	Different-depth plowless	38.2	147.6	3.9
3	Single-depth shallow plowless	37.0	113.4	3.1
4	Differentiated-1	37.9	159.5	4.2
5	Differentiated-2	37.7	141.7	3.7

Evaluating the energy efficiency of the crop cultivation technologies in the crop rotation at irrigation, it is possible to conclude that they are all sufficiently effective, at the same time, the maximal energy coefficient of 4.0–4.2 was obtained at the cultivation of the crops in the crop rotation at differentiated-1 basic tillage and application of mineral fertilizers in the dose of $N_{120}P_{60}$. The minimal index (1.3) was on the non-fertilized plots and disk tillage on the depth of 12–14 cm.

CONCLUSIONS

Therefore, to obtain the profitability level of production of 185%, energy coefficient of 4.2 conventional units and the optimum agrophysical properties of the soil on the irrigated lands, it is necessary to use differentiated-1 system of basic soil tillage, in which during the crop rotation all the crops receive disk tillage, and sorghum receives chisel loosening followed by slotting to the depth of 38–40 cm and fertilization with the dose of $N_{120}P_{60}$ kg per 1 hectare of the sown area.

SUMMARY

Goal: To substantiate scientifically the optimum parameters of the ratio of the competitive crops, minimized soil tillage and doses of nitrogen fertilizers, which will ensure the preservation of soil fertility,

resources saving and the increase of the productivity in the conditions of Southern Steppe. **Methods:** field, quantitatively-weight, visual, laboratory, calculation-comparative and mathematical-statistical methods with the use of generally accepted in Ukraine methods and methodological recommendations. **Results.** On average for 3 years of the study, the use in the study of a different-depth plowing and differential-1 systems of basic tillage system ensured the formation of the optimum agrophysical indexes for the plants in the crop rotation at the stage of sprouts and the initial stages of organogenesis. By the time of harvesting, the indexes increased, while the regularity, found out at the beginning of spring vegetation, remained. On average for three years of the study, it was found that the highest yield of the crops in the crop rotation were provided by the fertilizers dose of $N_{120}P_{60}$ on the background of different-depth and differentiated-1 systems of tillage. Thus, the yield of grain corn was 14.44 and 14.82 t/ha, respectively, soybean – 4.31 and 4.34 t/ha, winter wheat 6.81 and 6.90 t/ha and grain sorghum – 7.09 and 7.70 t/ha. The highest conditional pure profit – 27,602.3, on average by the years of the study, was received in the variant with the application of mineral fertilizers in the dose of $N_{120}P_{60}$ in the system of differentiated-1 basic tillage. **Conclusions:** Therefore, to obtain the profitability level of production of 185%, energy coefficient of 4.2 conventional units and the optimum agrophysical properties of the soil on the irrigated lands, it is necessary to use differentiated-1 system of basic soil tillage, in which during the crop rotation all the crops receive disk tillage, and sorghum receives chisel loosening followed by slotting to the depth of 38–40 cm and fertilization with the dose of $N_{120}P_{60}$ kg per 1 hectare of the sown area.

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Information about the author:
Maliarchuk A. S.,
Candidate (Ph.D.) of Agricultural Sciences,
Senior Researcher of Department of Irrigated Agricultural,
Institute of Irrigated Agriculture
of the National Academy of Agrarian Sciences of Ukraine
Kherson, Naddniprianske, 73483, Ukraine

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MODELLING PRODUCTIVITY OF CROPS IN SHORT CROP ROTATION AT IRRIGATION TAKING INTO ACCOUNT AGROECOLOGICAL AND TECHNOLOGICAL FACTORS

Markovska O. Ye.

INTRODUCTION

Obtaining of high and qualitative yields under the diminished watering and irrigation norms is an actual problem of innovative irrigation technologies in Ukraine and many other countries of the world. In this direction, numerous decision support tools have been developed over the last decades in the field of irrigated agriculture, which have provided an opportunity to regulate the consumption of irrigation water and other resources per unit of crop production[1].

This scientific and practical direction allows solving the problem of application of the newest irrigation methods all over the world taking into account natural-climatic and economic indexes. As a result, special computer programs have been developed directed to the information support of irrigated agriculture, but unfortunately, they have not yet been widely implemented in the production conditions of Southern Steppe of Ukraine[2].

Therefore, an important scientific and practical task is to adapt the latest computer technologies to the local conditions of the farms and irrigation systems from the point of view of optimization of crop cultivation technologies, primarily tillage systems, fertilization, plant protection, irrigation regimes, etc. Such innovative approaches at the expense of the use of mathematical models will allow estimation of

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different scenarios for irrigated agriculture and choice of the optimal combination of technological operations to save resource expenditures, obtain economically feasible levels of yields and solve environmental problems of agricultural production.

1. Scientific bases and practical tools for modeling water use and crop yields in short crop rotations

At the moment, there are many imitation crop productivity models that can be used to evaluate the effectiveness of irrigation in crop rotations with different degrees of saturation with grain, industrial and other crops under biologically optimal and water-saving irrigation regimes, which will greatly improve the efficiency of irrigation water, fertilizers and pesticides use at the level of each field, crop rotation and farm. The imitative models of plant growth and development that can be created in the DSSAT and CROPWAT software complexes are of practical importance, however, none of these programs allows controlling soil fertility parameters, its ecological and meliorative conditions and optimize crop rotation on the basis of a comprehensive analysis of the initial data. One of the strategic solutions to these problems was the development of the United Nations FAO (Food and Agriculture Organization) Division of Land and Water Resources, a special software complex, AquaCrop, which is designed to simulate water and nutrient expenditures for the formation of programmed yield levels, to establish the optimal response and resource-saving irrigation by different biological parameters of crops, study the impact of meteorological factors on plant production processes, etc.[3].

This simple and reliable model has been successfully tested for many cereals, industrial and forage crops in different regions of the world (for example, barley – in Southern Sahara region of Africa, wheat – in Iran and western provinces of Canada, forage crops – in Ethiopia, corn for grain – in California (USA) et al.)[4, 5, 6, 7].

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[3] Raes D., Steduto P., Hsiao T.C., Fereres E. AquaCrop training handbooks. *Running AquaCrop*. 2017. Book 2. Chapters 3–7. P. 19–61.

[4] Adger N., Wreford A., Hulme M. Strategic Assessment of the Impacts, Damage Costs, and Adaptation Costs of Climate Change in Europe. Adaptation and Mitigation Strategies: Supporting European Climate Policy (ADAM project). *Tyndall Centre for Climate Change Research*. 2003. Technical Report № 7. 20 p.

Many studies have been conducted in arid regions using the AquaCrop model to optimize grain yield and herbage mass using water-saving or biologically optimal irrigation. For example, Farahani and Garcia-Vila used AquaCrop in 2009 for bio-optimal and water-saving irrigation in Syria and Spain, Salem, etc., in 2011 for winter wheat in resource-saving irrigation – in arid regions of Iran, Iraq etc. in 2010 – for barley in different regions of Ethiopia[8, 9, 10].

The AquaCrop software and information system achieves the optimal balance between the simplicity of data entry, accuracy and reliability, which are aimed at studying the dynamics of basic and very complex biophysical processes to guarantee accurate modeling of the plant-soil crop reactions. AquaCrop can be used as a strategic planning tool or for short-term forecast and for the provision of assistance to agronomists in management decisions for both irrigated and non-irrigated agriculture.

Practical use of AquaCrop has great advantages in such cases:

– study of the response of crops to environmental changes (training tools);

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[5] Fritz B. K., Kirk I. W., Hoffmann W. C., Martin D. E. Aerial application methods for increasing spray deposition on wheat heads. *Applied Engineering in Agriculture American Society of Agricultural and Bigical Engineers*. 2006. Vol. 22(3). P. 357–364. URL: http://ddr.nal.usda.gov/bitstream/10113/1926/l/ IND43877934.pdf

[6] McCarthy N. Understanding agricultural households' adaptation to climate change and implications for mitigation: land management and investment options. *Integrated Surveys on Agriculture*. Washington D.C., USA: LEAD Analytics Inc. 2011. P. 42–47.

[7] Milton C., Chamala S. Conservation Tillage and Cropping Innovation: Constructing the New Culture of Agriculture. *Iowa State University Press*. 2008. URL: http://onlinelibrary.wiley.com/book/10.1002/9780470290149 (дата звернення: 27.02.2018).

[8] Araya A., Solomon H., Kiros M.H., Afewerk K., Taddese D. Test of AquaCrop model in simulating biomass and yield of water deficient and irrigated barley (*Hordeum vulgare*). Published on the 1 November 2010. URL: http://www.sciencedirect.com/ science/article/pii/ S037837741000226

[9] FAO IRRIGATION AND DRAINAGE PAPER by Pasquale Steduto (FAO, Land and Water Division, Rome, Italy) T. Hsiao (University of California, Davis, USA) Elias Fereres (University of Cordoba and IAS-CSIC, Cordoba, Spain) D. Raes (KU Leuven University, Leuven, Belgium). FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. Rome, 2012. № 66. P. 70–85.

[10] García-Vila M., Fereres E., Mateos L., Orgaz F., Steduto P. Deficit irrigation optimization of cotton with AquaCrop. Published on the 22 of May 2008. URL: https://dl.sciencesocieties.org/ publications/aj/abstracts/101/3/477

– comparison of modeled and actually harvested crops at each field, crop rotation, farm or region;

– identifying factors that limit agricultural production output and irrigation productivity (benchmarking tools);

– development of a strategy in the conditions of water scarcity in order to maximize the productivity of irrigation water and use of resource-saving irrigation regimes;

– choice of a strategy of artificial humidification: biologically optimal, water-saving, soil-protective;

– adjusting the time of sowing (planting), selection of varieties (hybrids), optimization of the fertilization system, efficiency of mulch use, water accumulation from atmospheric precipitation (methods and practices of management of agro-production systems);

– study of the impact of climate change on crop production, comparing meteorological parameters over the past years and forecasting for the future;

– strategic planning, multivariate analysis, local modeling that can be carried out by agronomists, hydraulic engineers, economists, water management officials, scientists, graduate students and students.

It should be mentioned that there are some limitations to the use of this system: daily biomass accumulation rates and programmed yield levels are modeled only for a limited number of crops that have a single cycle of growth and development. Yield forecasting is intended for the local field level (point modeling) with a clear account of the constituents of irrigation systems on irrigated lands based on the control of such indexes as: precipitation, irrigation regimes (watering and irrigation norms, number of watering, calendar dates for watering, etc.), capillary lift, evaporation from the soil surface and transpiration by plants (evapotranspiration), movement of moisture deep into the soil profile where it becomes inaccessible to the root system of plants, etc.[11].

Although the AquaCrop algorithm is designed on the basis of complex biophysical processes, users need only to enter a relatively small number of parameters to adapt the program to different soil and climatic conditions and crops.

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[11] Karlen D. L., Shannon M. C., Schneider S. M., Amerman C. R. Using Systems Engineering and Reductionist Approaches to Design Integrated Farm Management Research Programs. Jour. of Prod. Agric. 1994. Vol. 119. P. 144–151.

The AquaCrop software and information system provides the possibility of planning and operation management of irrigation, as well as other technological operations, which allows to optimize the system of irrigated agriculture at the farm level.

You have to determine the irrigation method in advance, because it affects the simulation of the water balance in the soil (i.e., evaporation from the percentage of the humidified soil surface)[12].

Using AquaCrop instruments to model individual elements of crop technology in irrigated crop rotation, you must enter:

- the percentage of the increase/decrease in CN_{soil}, which have occurred through the use of different ways and depths of tillage in separate fields of crop rotation;
- agro-measures that prevent surface runoff. When, for example, the irrigation regime consists of the distribution of water with small norms on separate micro-sections by the means of drip irrigation, then the parameter – "surface discharge" should be switched off;
- the creation of furrows or shafts on the surface that block the surface runoff and store increased volumes of irrigation water over certain sections of the field, such as in the case of rice checks;
- mulching – AquaCrop program models the reduction of evaporation when mulch covers the soil surface. Such mulch can consist of organic plant residues, special synthetic films, plastic or any other materials, which reduces the evaporation of the soil, raises its temperature in the early stages of organogenesis, prevents the mass development of weeds, etc .;
- the degree of the soil surface covergae by plants (in percents) at different stages of their growth and development[13].

From the point of view of optimization of the crop fertilization system in crop rotation and increase of soil fertility, modeling of stress caused by the nutritive elements deficit through the nutrient balance and constructing a model of soil nutrition is of great scientific and

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[12] Steduto P., Hsiao T.C., Raes D., Fereres D. AquaCrop – The FAO Crop Model to Simulate Yield Response to Water: I. Concepts and Underlying Principles. Agr. Jour. 2009. Vol. 101(3). P. 26–37.

[13] Raes D., Steduto P., HsiaoT.C., Fereres E. AquaCrop Reference manual. *Running AquaCrop*. 2012. Book 1. Version 4.0. Chapter 1–3. P. 1–39.

practical importance. Because the program does not simulate nutrient cycles and nutrient balance dynamics, but only simulates the impact of stress on plant development and biomass production, the system provides an opportunity to adjust the response of crops to changes in soil fertility parameters[14].

Such negative phenomena can lead to a sharp decrease in yield, deterioration of quality, decrease of economic efficiency, occurrence of environmental problems in the soil.

2. Models of crop production process in the crop rotations at irrigation for the optimization of agricultural technologies at field levels, crop rotation, enterprise

In order to adapt the AquaCrop program to the conditions of Southern Steppe of Ukraine, we modeled the parameters of the agro-production system and compared the scenarios of corn grain productivity, soybean, winter barley by the amount of irrigated water used, fertilizer consumption and programmed yields at the level of the fields of a short crop rotation. The experimental data and local conditions of Research Farm “Askaniiska” of the Institute of Irrigated Agriculture of NAAS for the period of 2011–2016 were used for modeling.

The input indexes concerning temperature data, amount of precipitation, wind speed and duration of sunlight for AquaCrop were Internet resource data[15]. Reference evapotranspiration was calculated by using the CROPWAT software and information complex[16].

The resulting information was subsequently imported as a formatted file and uploaded to the AquaCrop database. The average annual CO2 concentration was obtained from the program database over historical time ranges of atmospheric CO2 concentrations with periodic measurements at the Mauna Loa Observatory in Hawaii. As a result of downloading this input data, the program generates graphical blocks of atmospheric precipitation, reference evapotranspiration, air

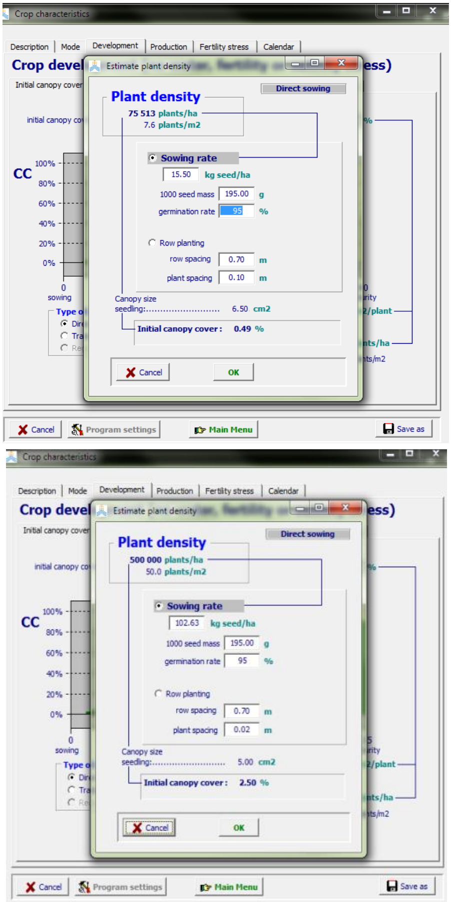
[14] Drought-resistant soils optimization of soil moisture for sustainable plant production. Sales and marketing group FAO UN. Rome, Italy. 2007. 96 p.

[15] The archive of weather in Kherson for the period of January, 1, 2005 to December, 31, 2016. URL: https://rp5.ru/Архив_ погоды_в_Херсон.

[16] CROPWAT 8.0 for WINDOWS. URL: http://www.fao.org/nr/water/ infores_databases_cropwat.html

temperatures and CO_2 concentrations, which provides a possibility to analyze the meteorological conditions that occur in a certain year.

For the modeling of the cultivation technologies constituents, irrigation water consumption rates, fertilizers and other resources, as well as productivity levels of crops in short crop rotation at irrigation, the input databases were formed. For each crop, sowing rate, 1000 seed mass, seed germination, row spacing, plant spacing calibration was performed.



a

b

Fig. 1. A copy of the AquaCrop program screen with the calibration of the plant densities for corn (a) and soybean (b)

Figure 1 shows a copy of the calibration screen for the plant densities of corn and soybean on the experimental plots. After entering these characteristics, the program automatically calculates the plant density of crops and the size of the "cover" of the crop – CC. The sowing date in our study coincided with the starting date of the simulation, that is, the beginning of the growing season of the crops in the crop rotation.

Further, we adjusted the parameters about the number of days from the first day after sowing to the moment of seed germination (emergence), from the first day after sowing to the date of formation of maximum leaf-stem mass – "maximum canopy" (max canopy), from the first day after sowing to the date of crop maturity – senescence, from the first day after sowing to the date of full maturity of the crop, as well as the data on the duration of flowering stage for each crop of the short crop rotation.

Taking into consideration that intensive crop cultivation technologies were used in the studied short crop rotation, the possibility of mulching of the soil surface on the fields was not indicated in the block of the soil fertility management program (Fig. 2a). Soil fertility was determined at the level of optimal parameters.

The stress from the effect of weeds on the crop development was conditionally set at the level of 3% througout the whole vegetation period (Fig. 4, b), which is connected with the use of an integrated plant protection system, which provides highly efficient weed control.

The required water-physical characteristics of the dark-chestnut soils were taken from the field measurements (minimum field moisture content, wilting points) and compared with the soil texture class characteristics of the AquaCrop database according to the properties of the local middle-loamy soils at three soil levels.

The groundwater on the studied irrigated array are at the depth of more than 18 m, so they do not affect the water regime of the active (estimated) soil layer. The content of salts in groundwater according to the reference data[17] is on low level.

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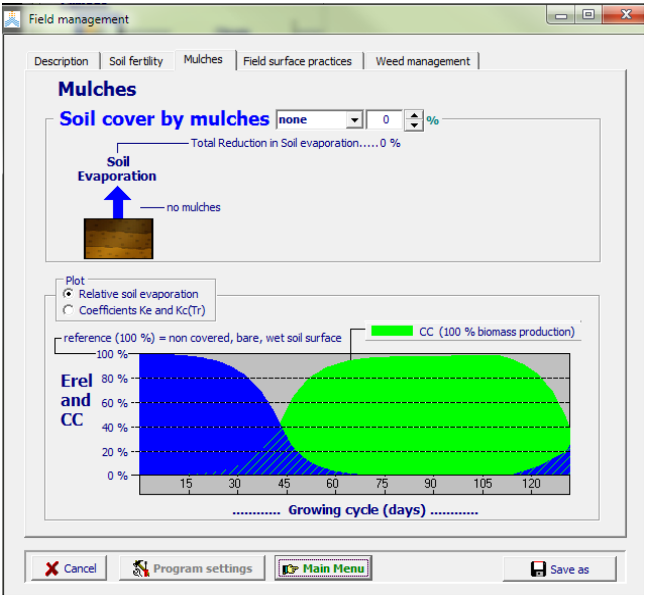
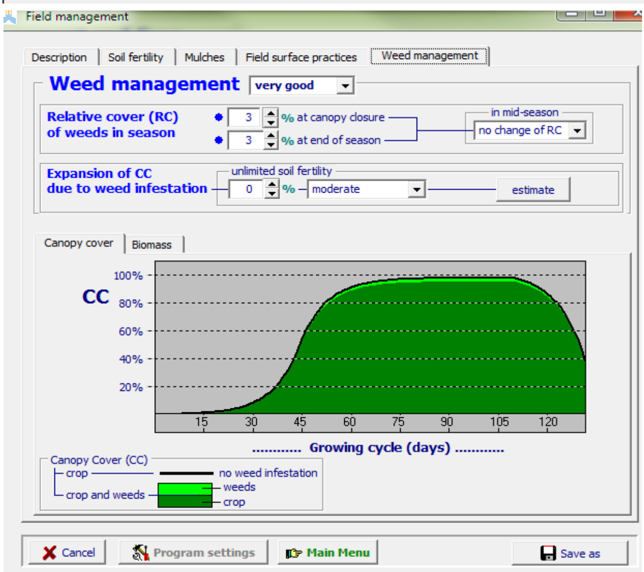
[17] Greene R., Timms W., Rengasamy P., Arshad M., Cresswell R. Soil and Aquifer Stalinization. *Toward an Integrated Approach for Salinity Management of Groundwater*. 2008. URL: http://link.springer.com/chapter/10.1007/978-3-319-23576



a



b

Fig. 2. A copy of the AquaCrop parameter selection screen with soil fertility (a) and weediness (b) crop management options

At the beginning of the modeling, soil and water content were obtained by measuring them in the soil profile. Sampling was carried out on the day of sowing, and the beginning of the modeling period was recorded on the day of sowing.

The field capacity (FC) was determined at the level of 22.3% for dark-chestnut soil, wilting point (9.75%), the TAW index was taken at the level of 80%, since in the spring the soil is saturated with water, and this parameter is close to the FC level (Fig. 3), the electrical conductivity was accepted at the level of FAO statistical values for the middle-loamy soil – 1.5 dS/m[18].

The modeling start date for the crop rotation crops such as corn, winter barley, soybean was adopted as their sowing dates at the experimental plots, it is, for example, May 3, September 20, May 10, 2015. After adapting the above mentioned indexes to the plan of a specific irrigation strategy, we chose the "automatic irrigation schedule" mode, the irrigation method was sprinkling according to time and depth criteria. Subsequently, simulation of the existing schedule of artificial humidification with different characteristics and variants of indexes of permissible reduction of soil moisture from the RAW – readily available water was carried out.

So, this parameter reflects the amount of moisture that the plant can easily uptake from the soil, it is found through the option "return to the level of the field capacity". The advantage of this irrigation mode is the normalization of irrigation schedules, which clearly take into account the dynamics of soil moisture content in the range from the field capacity (FC) to readily available water (RAW). In this case, water losses due to deep soaking are limited, and stresses from the lack of water supply and yield loss – are completely eliminated.

After forming the groups of Climate-Crop-Soil Moisture diagrams with quantitative characteristics of biomass and grain yields, we analyzed the optimal relationships between the input irrigation parameters and the modeling of the highest yield level with irrigation water used for each crop of the rotation.

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[18] Wagner W., Lemoine G., Rott H. A Method for Estimating Soil Moisture from ERS Scatterometer and Soil Data. *Remote Sens. Environ*. 1999. Vol. 70. P. 191–207.

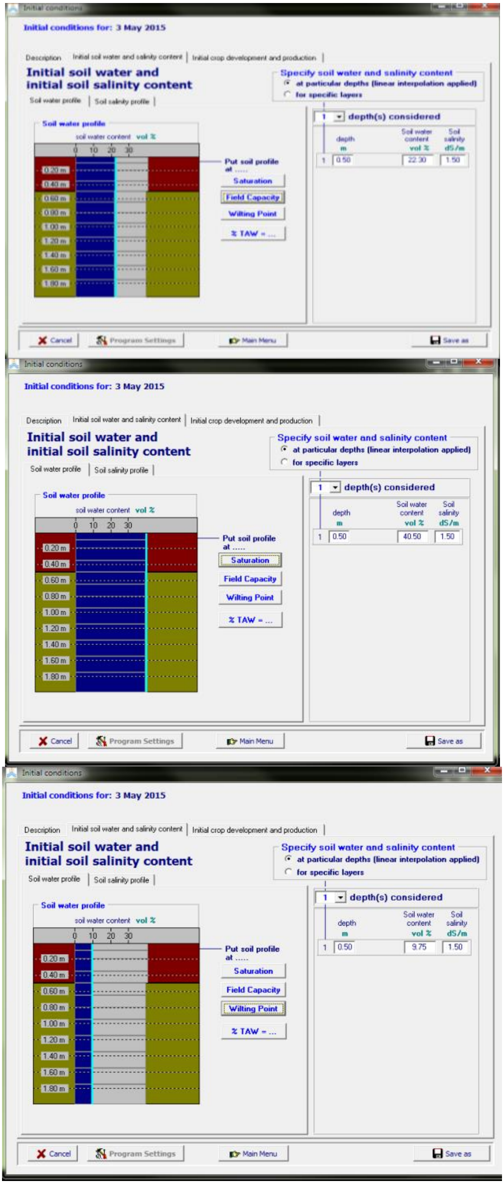

Fig. 3. Input conditions at the beginning of modeling of the productivity of short crop rotation in the AquaCrop program

It is known that at the current level of development of irrigated agriculture, there are three main types of irrigation regimes – biologically optimal, water-saving, soil-protective[19]. The AquaCrop program enables you to formulate irrigation schedules based on specific soil and climate and farming and economic factors, depending on the chosen irrigation strategy. In order to improve the productivity of short crop rotation at irrigation and economical use of irrigation water, we have chosen the strategy of forming both biologically optimal and water-saving irrigation regimes to show the possibilities of the program.

It should be emphasized that for corn with a predicted vegetation period of 132 days, the best scenario was with the programmed grain yield level of 14.16 t/ha (biomass – 29.49 t/ha), for which the biologically optimal irrigation regime requires the use of 290 mm (it is equivalent to 2900 m^3/ha) (Fig. 4).

Modeling in the mode of so-called "scarce" irrigation (i.e. water-saving mode of irrigation) allowed to obtain a water-saving schedule of vegetation watering with the irrigation norm for the vegetative period of corn – 264.6 mm (2646 m^3/ha). At the same time, the planned level of crop yield was 13.67 t/ha with the biomass yield – 28.33 t/ha.

Thus, the conducted modeling made it possible to determine the difference between biologically optimal and water-saving irrigation regime. When applying the first irrigation regime, the maximum yield level was obtained, which was 0.49 t/ha or 3.6% higher than the second artificial humidification model. However, the water-saving scheme provided a reduction of irrigation norm by 254 m^3/ha or 9.6%.

The ratio between the actual soybean biomass obtained on the experimental plots and the stress-simulated ones for the period of the crop development under the biologically optimal irrigation regime was 96% and for the water-saving one – 92%. Using similar technology, simulation models of yields, irrigation schedules and fertilizers for barley during the vegetation period from September 20 to July 1, 2015, were formed, which coincides with the modeling period.

[19] Наукове обґрунтування та практична реалізація режимів зрошення сільськогосподарських культур з врахуванням природних та господарсько-економічних чинників : монографія [Р.А. Вожегова, Ю.О. Лавриненко, П.В. Писаренко та ін.]. Херсон: Грінь Д.С., 2015. 232 с.

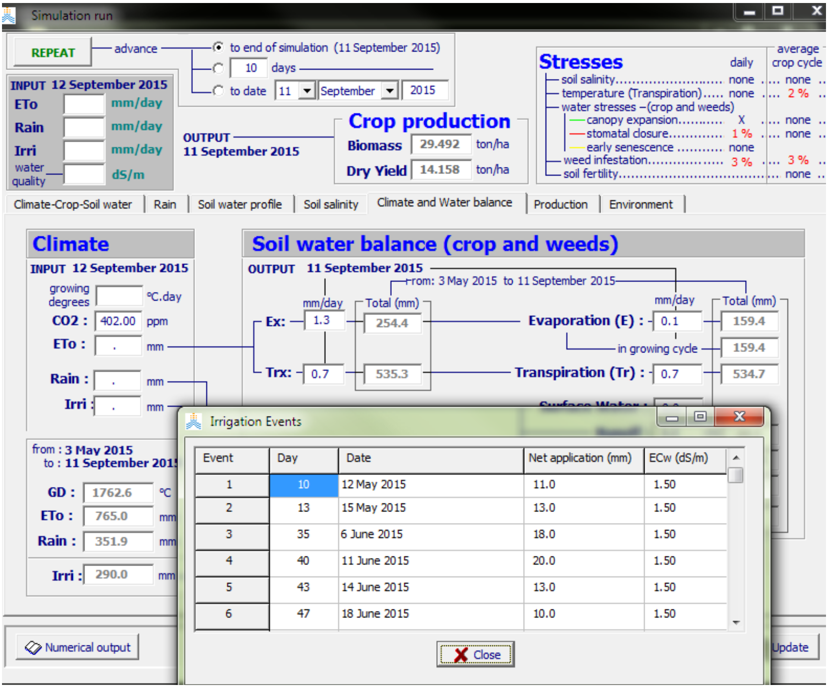

Fig. 4. Modeled indexes of biologically optimal regime of grain corn irrigation with accordance to the approximate dates and norms of vegetative watering

At the modeling of the water-saving regime of winter barley irrigation, it is proved that the estimated irrigation rate of 164 mm (1640 m^3/ha) should be used to compensate the water supply deficit during the vegetation period. Under such natural and technological conditions, the programmed yield was 4.19 t/ha (biomass – 11.19 t/ha). Continuing yield modeling, we have formed a biologically optimal irrigation regime under 80% of the permissible reduction of RAW with the irrigation norm of 2310 m^3/ha and the maximum grain yield of 4.43 t/ha (biomass of 11.85 t/ha). The ratio between the actual obtained and the potential biomass of winter barley, taking into account the stresses during the period of the crop development under water-saving irrigation was 96%, the yield index decreased to 37% (Fig. 5).

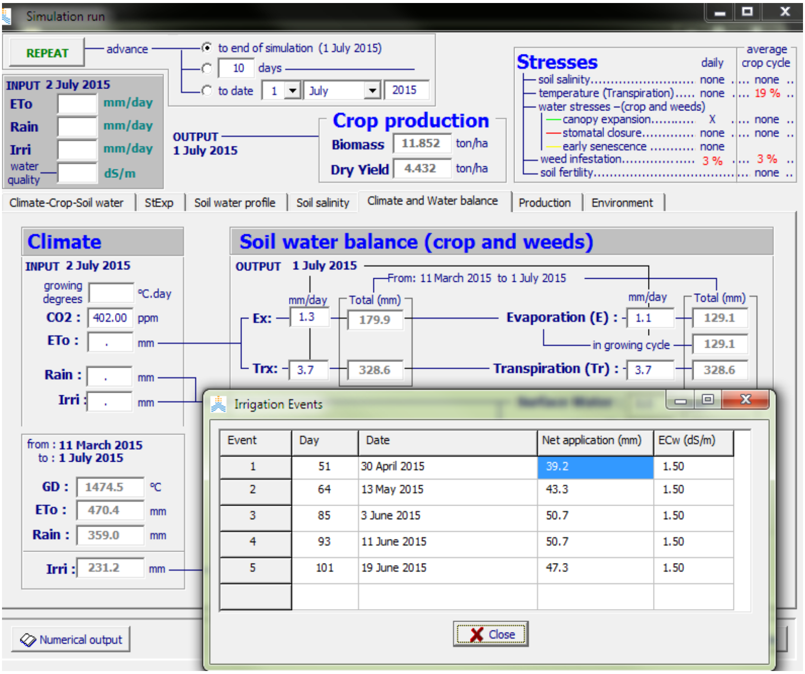

Fig. 5. Biologically optimal schedule of winter barley irrigation for cultivation in short crop rotation at irrigation

A very convinient tool of the AquaCrop program is that at every step of the modeling there is the possibility of controling the water and salt balance, nutrient content, taking into account the impact of all types of stress on a certain period of crop development in concrete stages of its growth and development, in the process of which can be reduced or completely overcomed various stresses by applying irrigation with the calculated norms, changing the sowing time, adjusting the plant density, differentiating doses of mineral fertilizers, etc. (Fig. 6).

At the modeling of the soybean irrigation regime, two technological scenarios of the regimes were developed – water-saving with irrigation norm of 3590 m^3/ha, programmable crop seed yield level of 4.7 t/ha (biomass – 11.7 t/ha), as well as biologically optimal irrigation norm of 3830 m^3/ha, yield of 4.9 t/ha and biomass – 12.2 t/ha.

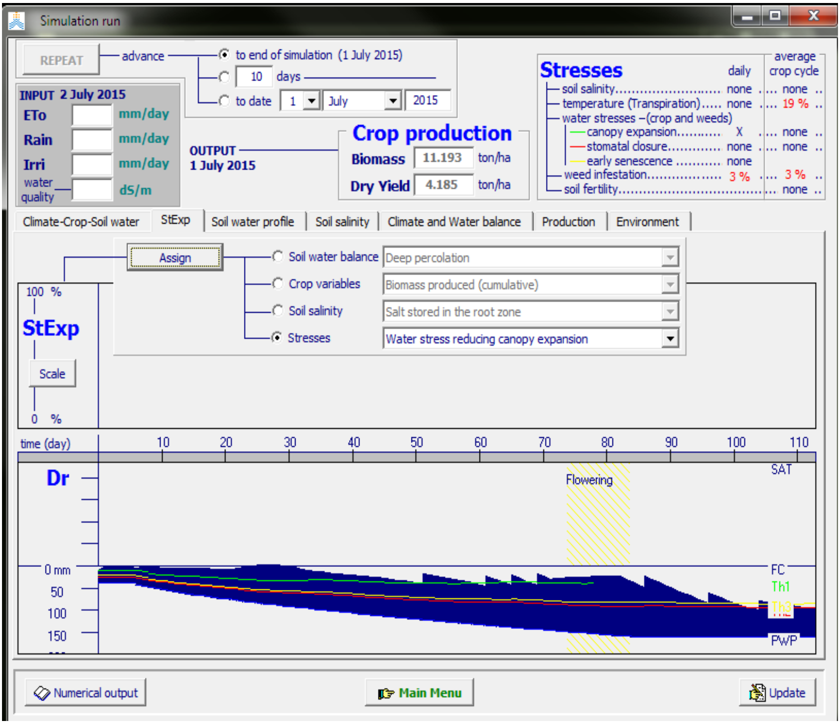

Fig. 6. The regime of control and adjustment of the balances and stresses in the AquaCrop program toolkit

The ratio between the actually obtained and the potential biomass of soybean under taking into account the influence of stresses during the vegetation period of the crop under the biologically optimal irrigation regime was 96% with a yield index of 39.3% (Fig. 7).

After the imitation modeling, it is possible to evaluate the results using the crop cover (CC) calculated data, aboveground biomass (B) and soil water content (SWC). All of this data is stored as databases in separate AquaCrop files.

After the modeling process is started, the AquaCrop software compares the modeled data with the field data and provides graphically the results in the following statistics:

– correlation coefficient of Pirson (r);
– mean square error (RMSE);

– the usual correlation mean square error (CV (RMSE);
– the efficiency of the model (NF);
– Wilmouth range index (d).

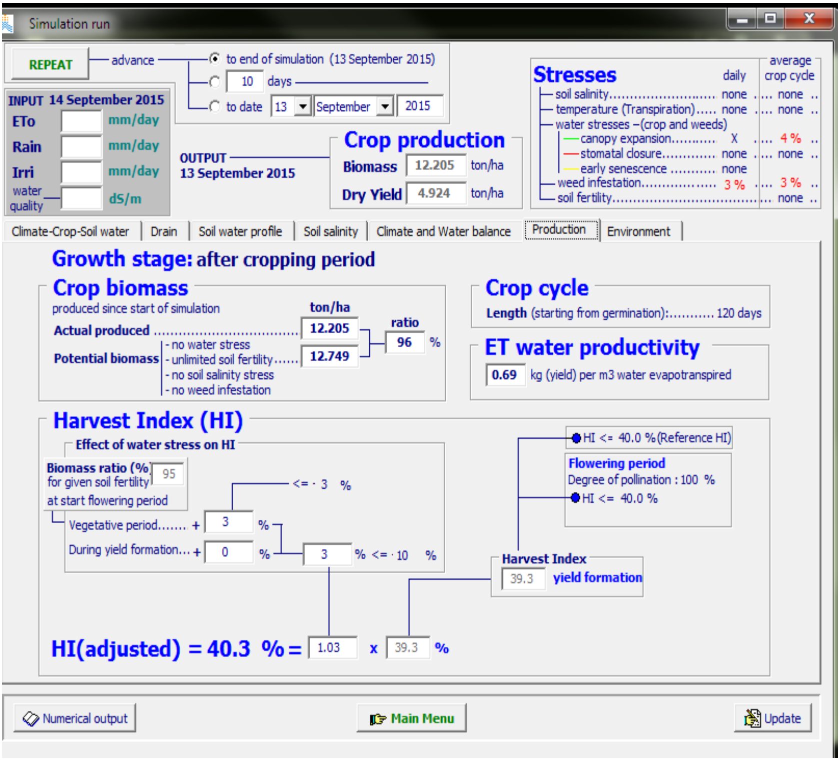

Fig. 7. Characteristics of biomass productivity, soybean yield index in the crop productivity modeling

The mathematical analysis of the program allows obtaining of dynamic reflection of the results of evaluation of the modeled (lines) and observed (points) data, and also to compare them with standard deviations (vertical lines) in the menu "Evaluation of the results of modeling" for crops of corn, winter barley and soybean. If we analyze the diagrams and metrics obtained from the experimental data, we can see that the modeling was performed with high mathematical accuracy.

CONCLUSIONS

1. The application of special computer programs allows planning and optimizing both individual agro-technological operations and the whole integrated system of agriculture in irrigated lands of a particular farm with its unique natural climatic and farming and economic conditions. It is possible to schedule irrigation regimes, taking into account the parameters of irrigation schedules, methods of artificial moistening, time criteria, depth of soil wetting, and so on. Carrying out simulation modeling of irrigation schedules with different characteristics and variants allows optimizing the water, air and nutrient regimes of soil, prevent the loss of irrigation water through deep soaking and prevent the decrease in productivity of crops in short crop rotation due to the lack of water supply.

2. It is determined that in the developed short crop rotation the estimated level of soybean grain yield is about 4.9 t/ha with irrigation water consumption at the level of 3830 m3/ha, and the formation of irrigation schedule according to the water-saving scheme allows reduction of water consumption by 17%. For corn, the potential grain yield is – 14.2 t/ha, with the saving of irrigation water by 13%, and for winter barley these figures are equal to 2.9 t/ha and 10%, respectively.

3. By the results of our study, the functionality of the AquaCrop software and information complex has been adapted to the conditions of Southern Steppe of Ukraine. Using this program allows modeling of natural and agrotechnological factors, including irrigation regime at the level of short crop rotation, quickly and reliably estimate and choose the most economical variants of irrigation schedules for each crop with reduction of irrigation water consumption by 10–17%, program yield on the basis of parameters of soil, a set of agrotechnological operations, characteristics of varieties and hybrids, changes in weather conditions, etc.

SUMMARY

The article presents the results of the study on the adaptation to the conditions of Southern Steppe of Ukraine the functionality of the AquaCrop software and information complex, developed by FAO scientists (2014–2017). Modeling of natural and agrotechnological factors, including irrigation regime at the level of short crop rotation, was carried out. The most economical variants of irrigation schedules

for grain corn, soybean, winter barley and 10–17% reduction of irrigation water consumption were quickly and accurately evaluated. The yield of these crops has been programmed on the basis of soil parameters, a set of agrotechnological operations, characteristics of varieties and hybrids, changes in weather conditions, etc. It was determined that for grain corn with a predicted vegetation period of 132 days, it is most advantageous to apply a scenario with a programmed grain yield level of 14.2 t/ha (biomass – 29.5 t/ha), for the formation of which according to the biologically optimal regime the irrigation norm was 2900 m3/ha. Soybean productivity levels have also been modeled in two cultivation scenarios according to irrigation regimes – water-saving with irrigation norm of 3590 m3/ha, programmed grain yield of 4.7 t/ha and biomass – 11.7 t/ha, biologically optimal with irrigation norm of 3830 m3/ha, yield of 4.9 t/ha and biomass – 12.2 t/ha.

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Information about the author:
Markovska O. Ye.,
Doctor of Agricultural Sciences, Professor, Senior Researcher,
Head of the Department of Botany and Plant Protection,
State Higher Educational Establishment
“Kherson State Agrarian University”
23, Stritenska str., Kherson, 73006, Ukraine

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SCIENTIFIC BASIS OF THE DEVELOPMENT OF THE BASIC ELEMENTS IN THE TECHNOLOGY OF SOYBEAN SOWING IN THE CONDITIONS OF FOREST-STEPPE OF UKRAINE

Shevnikov M. Ya.

INTRODUCTION

For the effective use of bioclimatic potential of natural and climatic conditions of unstable moistening of the Forest-Steppe of Ukraine, it is important to develop and introduce into the production of modern competitive technologies of cultivation of crops that ensure the maximum realization of their productive potential. In this regard, the research of the development of the basic elements of soybean cultivation technology, which would ensure high yields and would completely satisfy the Ukrainian market, is of particular relevance. Soybean production can become not only one of the important resources of protein and oil, but also an article of considerable financial income. This is convincingly evidenced by the much larger volumes of world production of soybeans and their trade and products of their processing than the volumes of production and sale of all other protein-oil crops combined.

Taking into consideration its leading position in the world agriculture, nitrogen-fixing ability, unique biological features, versatility of use, consistently high growth rates of production, value in eliminating vegetable protein and oil deficiency, use in industry, the soybean crops will increase. It is also important to keep in mind that modern varieties of this crop with high yield potential have emerged in production and require the development of effective technologies that would ensure the stabilization of the production of high quality soybean seeds. Soybean crops will increase as the potential of this crop is not fully understood. Other leguminous crops have, of course, an important role in some regions, but they only complement the soybeans in solving the protein problem. Due to the intensification of soybean production, the question arises as to the elements of cultivation technology that must ensure its high productivity. Among them are sowing period, method of sowing and seeding rate of soybeans. For soybeans, sowing time is of great importance, because it depends on the simultaneous germination, plant density, uniformity of ripening, size and quality of the crop. The rational placement of plants on the area to create optimal conditions for photosynthesis and the functioning of the root system is a subject of constant attention of researchers. It is noted that the soybean is characterized by the ability to change its productivity according to the area of nutrition, sowing method and depends, first of all, on the characteristics of the variety, meteorological conditions, as well as on the interaction of these factors. In recent years, there has been a tendency to narrow rows and increase plant density. Therefore, the question of the correct choice of sowing method and seeding rate should be addressed in relation to the variety and locality selected. These considerations were the basis for studying the terms, methods of sowing and sowing rates of soybeans in conditions of unstable moistening of the Forest-Steppe of Ukraine.

1. Recommended parameters of economically valuable characteristics of soybean varieties for conditions of the left-bank Forest-Steppe of Ukraine

Recently, the scientific literature indicates the feasibility of further progress in increasing crop yields by reducing the share of the empirical component in modern breeding practice. Breeders believe that in this regard, the tendencies of changing the complex of economic and valuable features in the process of sorting are important. The breeding work underwent significant changes in the architectonics of soybean plants. The ratio of the elements of the crop structure at different stages of the breeding work had a definite character. The growth and development of soybeans depended on the duration of the interphase periods. High-yielding soybean varieties have physiological features that influence the mechanism of plastic substance redistribution between plant organs. As a result of the analysis of the experimental material, the parameters of the model of soybean varieties with a yield potential of 4.5 t/ha are substantiated.

Soybean varieties, grown in Ukraine, are created for different soil and climatic zones and differ substantially from each other according to the requirements to environmental factors and economic and valuable indicators. Changing the area of cultivation in relation to the place of creation of soybean varieties in most cases negatively affects their productivity[1, 2].

The duration of the growing season is important as this indicator affects soybean productivity. New varieties must guarantee the achievement of optimal sowing time and minimal energy costs for seed drying[3, 4].

According to the breeders' research, the variety should be considered as a balanced system of displaying individual indicators and characteristics that are closely linked. A decrease or increase in one of them leads to a significant change in other indicators. The overall productivity of plants depends on the optimal combination of economically valuable traits in one variety. Studying the correlation between environmental conditions and the economic value of soybeans is of practical importance. There is a close relationship between the height of the attachment of the lower beans and the total yield of soybeans, which in most cases is associated with the loss of seed yield when harvested in a high cut. The data indicate that the later ripe variety, the effect of the attachment height of the lower beans is shown stronger[5, 6].

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The purpose of our research was to evaluate the soybean varieties for agricultural purposes in order to identify the most suitable for growing in the conditions of the left-bank Forest Steppe of Ukraine. The purpose of the research was to study the economically valuable characteristics of soybean varieties under different conditions of the growing season.

The productivity of agricultural crops in the region depends mainly on the conditions of moisture supply, since all other components of the agriculture system (species and varietal crop selection, tillage, fertilizer system, etc.) are evaluated, first of all, from the point of view of their impact on their accumulation, conservation and economical use of moisture. In order to identify the impact of individual environmental factors on soybean yield, it was found that the sum of effective temperatures in the conditions of the left-bank Forest Steppe is quite sufficient for the cultivation of early and middle-ripe soybean varieties. The more significant factor is the unstable and uneven soil moisture during the growing season.

Historical experience indicates that breeding for drought resistance in order to improve soybean productivity is a difficult task, and progress in this area is slow. Given the high variability of moisture conditions over time, in some years, the drought resistance of the variety is crucial, in others its potential productivity, resistance to lodging and disease. Such a list of problems in the practical implementation of soybean cultivation technology requires the study of the effects of drought, both on individual physiological processes and on the growth, development and productivity of soybean plants.

Growth of plants under tightly controlled conditions is required to identify the stress factor. But artificial simulation of stress regimes is significantly different from field conditions. This requires years of field research with a large number of arid and favorable years, which helps to identify the appropriate impact of soil moisture on the main indicators of productivity of soybean crops in comparison with the change in meteorological factors and the dynamics of soil moisture content. A significant increase in the aboveground mass of most crops is observed with the maximum use of solar energy, sufficient nutrition and water supply. Prolonged drought during the growing season of soybeans causes significant irreversible changes – the active leaf surface is intensively reduced, the leaves turn yellow and dry. Reducing the size of the photosynthetic apparatus accordingly reduces the synthesis of organic matter.

The characteristic of the water regime is determined by the flow of water into the soil and its use, i.e. water balance. If the formation of the vegetative mass of early spring crops mainly depends on autumn-winter and spring moisture reserves in the soil, then atmospheric precipitation during the growing season is important for the formation of the soybean crop. The researchers indicate the particular significance of the nature of the distribution of precipitation during the growing season: the closer this distribution to the needs in the critical period for plants, the more productive the water will be used for the formation of the harvest.

The weather conditions of the growing season significantly influenced the duration of the interphase periods. The varieties responded differently to a set of environmental factors. Relatively stable by this indicator varieties were selected. The main elements of seed productivity, as well as the overall seed yield, are more dependent on environmental conditions. Seed yield per plant depended, to a greater extent, on the height of the main stem, the number of fruiting nodes, beans and seeds on the plant. Late-ripening varieties showed a significant negative effect of the height of attachment of the lower beans on seed productivity.

The variety should have the following parameters of economic value:

- be resistant to low temperatures during germination and emergence of seedlings;
- be resistant to lack of moisture in the soil, high temperature and arid summer conditions;
- have a high intensity of growth and accumulation of above-ground mass at the beginning of the growing season with a view to rational use of spring moisture reserves and biological regulation of weed numbers;
- photosynthetic and symbiotic apparatus must be fully formed during the flowering period, and these two interrelated processes must function for a long period, allowing the generative organs to be fully

provided with synthetic substances and readily available nitrogen compounds;

- it is necessary to increase the number of productive nodes of the main and lateral shoots, the proportion of three-seeded beans and the size of the seeds;
- reduce the gap between yields in different weather conditions by making varieties plastic.

Soybean varieties created for different soil and climatic zones differ substantially from one another to the requirements for environmental factors and economically valuable indicators. Changing the growing area in most cases adversely affects their productivity. The selection of soybean varieties for the conditions of the left-bank Forest-Steppe of Ukraine should be carried out on the basis of many years of research, since the environmental conditions of different years have a significant impact on this indicator.

As a result of studying a large selection of soybean varieties, the most productive varieties of Sinara, Mentor, Kent, and Sigalia are selected, which in the conditions of the left-bank forest-steppe combine a short growing season and the main components of productivity (Table 1).

Based on the study of economically valuable features of regional and perspective varieties, we offer some practical indicators for modeling soybean varieties in the conditions of the left-bank Forest Steppe of Ukraine (Table 2). The determined productivity indicators allow the rational use of soil and climatic conditions, ensure high economic efficiency of cultivation.

The value of such economic features as the height of the plants, the height of the attached lower beans, the number of fruiting nodes, beans and seeds per plant, as well as the total mass of seeds from one plant, significantly depended on the environmental conditions. In the group of early-ripening varieties of plant height fluctuations ranged from 64.1 to 73.5 cm, the middle-early varieties ranged from 90.8 to 114.2 cm, the middle-ripened ones ranged from 64.1 to 118 cm. An even greater variability in this trait was observed in the number of fruiting nodes, beans, and seeds per plant. The coefficient of variability of these features ranged from 15.5 to 43.0%.

Table 1

Yield of soybean varieties in the conditions of the left-bank Forest Steppe of Ukraine

Variety	Yield, t/ha
Cordoba	2,55
Cardif	2,75
Lisabon	2,75
Kent	3,33
Merlin	2,35
Madison	2,55
Larisa	2,75
Diona	2,16
Khutorianka	2,55
Aligator	2,35
Mentor	2,94
Sultana	2,75
Sinara	3,14
Sigaliia	3,92
Medeia	1,57
SSD 0,5	0,08

Table 2

Recommended parameters of economically valuable characteristics of soybean variety adapted to the conditions of the left-bank Forest-Steppe

№	Characteristics	Indicator
1	*2*	*3*
1.	Yield of seeds, t/ha	2,5–3,0
2.	Plant height, cm	70–75
3.	The number of branches on the plant, pcs.	1,8–2,2
4.	Number of beans per plant, pcs.	25–30
5.	Number of seeds per plant, pcs.	50–60
6.	Number of seeds in beans, pcs.	2,0–2,2
7.	Weight of 1000 seeds, g	160–180
8.	Duration of vegetation, days	110–120
9.	Height of attachment of the lower beans, cm	15–17
10.	Resistance to lodging	High

End of Table 2

1	*2*	*3*
11.	Collective index,%	40–45
12.	Reaction to photoperiodism	Weak
13.	Drought resistance	High
14.	Nitrogen-fixing ability, mcg / plant / h	20–30
15.	Growth type	Semi-determinant
16.	Protein content,%	40–45
17.	Fat content,%	20–25

Studying the correlation between environmental conditions and the economic value of soybeans is of practical importance. There is a close relationship between the height of the attachment of the lower beans and the total yield of soybeans, which in the most cases is associated with the loss of the seed harvest for harvesting in the high cut. The data indicate that the later ripe variety, the effect of the attachment height of the lower beans is shown stronger.

2. Soybean productivity, depending on the timing, methods of sowing and sowing rates

Due to the spread of new soybean varieties, the question arises as to the elements of cultivation technology that must ensure its high productivity. Of particular importance are the timing, methods of sowing and the rate of seeding of soybean seeds. Soybean, as a light-loving crop, forms a high yield only with the optimal nutrient density and density of plants, provided with moisture and nutrients, but the basic requirement is the best coverage of the leaf surface. As a light-loving crop, it forms a high yield only at the optimal for the specific variety of the area of nutrition and plant density, as well as with the appropriate structure of sowing. With the introduction into production of adapted early-ripe soybean varieties, there was a problem of providing a guaranteed annual formation of quality seed crop before the adverse to collect the conditions of the autumn period. The further spread of soybeans in conditions of unstable moistening of the left-bank part of the forest-steppe is constrained by insufficiently grounded zonal cultivation technology, especially in early sowing, where heat is a limiting factor.

The question of the correct choice of sowing method and sowing standards should be solved in relation to the selected variety and terrain. In this regard, the rational use of heat resources in the early spring due to early sowing is of particular importance. These considerations are the basis for studying the methods of sowing and sowing rates of soybeans in conditions of unstable moistening of the left-bank part of the Forest-Steppe of Ukraine.

For soybeans, sowing time is crucial, because it depends on the quantity of the seedlings, plant density, uniformity of ripening, size and quality of the crop. The main criterion for the selection of the sowing period is the steady warming of the sowing soil. The minimum temperature for soybean seedlings is about + 10 °C with a tendency to increase the soil temperature. Warming of the sowing layer to + 12–14 °C ensures seed germination in the presence of moisture in it. When sowing seeds in an earlier period, it requires more time for germination, which increases the sharp damage to plants by diseases and pests, reduces the germination of seeds[7].

Choosing the time of sowing, one should count on the full use of the vegetation period by plants, soil fertility, features of moisturizing the terrain, because the critical period for water consumption must fall to the flowering-forming phase of beans. The studies conducted in the Forest-Steppe zone of Ukraine indicate that the highest yields were obtained when sowing in the years with early spring in late April, in the years with late spring – in the first decade of May[8, 9].

The rational placement of plants in the area to create optimal conditions for photosynthesis and the functioning of the root system is a subject of constant attention of the researchers. It is noted that soy is characterized by the ability to change its productivity in accordance with the area of nutrition. Thus, no significant fluctuations in soybean

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seed yield with increasing row spacing from 15 to 60 cm[10] were observed in the experiments at Kirovograd Institute of APV of UAAS. When choosing a method of sowing it is important to take into account the high plasticity of soybeans to the area of nutrition, which is manifested in the change of individual productivity of plants. In soybean crops with optimal density and area of plant nutrition, the main number of beans is formed on the main shoot, in the liquefied – on the lateral branches. The negative effect of excessive thickening leads to premature yellowing and falling of leaves, incomplete use of light, moisture, nutrients, reduction of biological nitrogen fixation from the atmosphere[11].

Increasing the rate of seeding from 400 to 1200 t/ha of plants led to a shortening of the growing season, significant plant elongation and reduced seed yields due to the formation of beans only at the top of the plants. In the thickened crops, soybeans were formed in the central and upper part of the stem, such plants quickly dropped leaves, intense lodging was observed and losses were lost during harvesting[12].

Therefore, the row spacing depends on the ripening of the variety, the availability of sowing and harvesting equipment, soil fertility, moisture supply, the ability of plants to branch, the nature of the arrangement of leaves, the shape and height of plants. Late-ripe varieties, prone to lodging and branching, grow better at a smaller plant density, and early ripe varieties are more resistant to lodging and those that do not branch at greater plant density.

The aim of the research was to determine the optimum sowing density of soybeans by properly selecting the sowing rate and sowing method that would ensure optimal plant growth and development and

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high productivity. When determining the sowing period, it was taken into account that the early sowing period corresponds to the minimum soil temperature (8–10 °C) at which germination of soybean seeds is possible. The optimum sowing time was determined when the soil was heated to + 12–14 °C. Late sowing period corresponded to increase in soil temperature to 16–18 °C. In the first two cases, it is also necessary to take into account sufficient moisture supply of the topsoil. Late sowing was more often accompanied by low soil moisture. Meteorological conditions in the years of the experiments were diverse and fully characterized the climate of the area.

When growing soybeans are important not only performance indicators, but also a number of other characteristics of plant height and branching, the height of attachment of the lower beans, the tendency to lay down, the duration of the growing season. During the growth and development of plants, there was a constant change in the distribution of their underground and terrestrial organs in the horizontal and vertical directions, changing the volume of space and soil, depending on the size and configuration of the area of nutrition.

Important indicators that affect the size of the crop are the height of the plants and the height of attachment of the lower beans. The plant height varied under the influence of sowing method. In the continuous row sowing, the lowest plants were at sowing 500 thousand/ha of similar seeds (57.3–63.4 cm). Increase in the seeding rate contributed to the increase in plant height to 61,4–64,3 cm at sowing of 600 thousand/ha, 60,7–64,6 cm – at a seeding rate of 700 thousand/ha, 60,4–66,4 cm – at sowing 800 thousand/ha of similar seeds depending on the sort, term and method of sowing.

Plant density carried out a direct impact not only on plant height, but also on the height of the attachment of the lower beans, which largely determines the loss of harvest in mechanized harvesting. Changing the seeding rate from 500 to 800 thousand/ha of similar seeds in continuous row sowing helped to increase the attachment height of the lower beans from 11.7 cm to 15.7 cm, with widerow sowing with spacing 45 cm – from 12.0 cm to 14, 8 cm when sown in the third decade of April, respectively 12,2–15,7 and 11,4–15,3 – when sown in the first decade of May, 12,1–15,2 cm and 12,6–15,5 cm – when sown in the second decade of May.

As a rule, in the liquefied crops in the lower tier of plants a considerable mass of the crop of seeds is formed, under their weight the branches lean towards the ground, causing losses during harvesting. In thickened crops fewer lateral shoots are smaller, but the stem is very thin, which contributes to the considerable lodging of plants.

The quantity of weeds of the crops depended on the time of sowing and pre-sowing of the soil. The number of weeds per 1 m^2 during the germination was very varied: at early sowing within 287 – 374, the optimum – 197–244, the late – 155–185. Field germination differed with better performance at early (64.8%) and optimal (63.9%) sowing periods. With late sowing, the field germination decreased to 59.7%, which is explained by the conditions of insufficient wetting of the topsoil (Table 3).

Table 3

Soybean seed yield and its structure depending on sowing period

№	Indicators	Sowing period		
		early, 18–24 April	Optimal 3–11 May	late, 16–24 May
1.	Laboratory similarity of seeds,%	97,6	97,6	97,6
2.	Field germination of seeds,%	64,8	63,9	59,7
3.	Height of plants, cm	51,1	47,4	44,0
4.	Attachment height of the lower beans, cm	13,1	14,4	12,4
5.	Number of beans per plant, pcs	27,5	34,0	30,0
6.	Number of seeds per plant, pcs	50,7	55,0	53,8
7.	Weight of seeds from 1 plant, g	6,3	7,3	7,9
8.	Weight of 1000 seeds, g	123,8	134,0	133,8
9.	Yield, t/ha	1,90	2,11	2,01

An analysis of plant height indicates its decrease when sowing soybeans at a later date. In early sowing it was 51.1, in late – 44.4 cm. The intermediate plant height (47.4 cm) was characteristic for the optimal sowing period from 3 to 11 May. The height of attachment of the lower beans was also highest at the optimum time – 14.4 cm then, at early sowing – 13.1, the late – 12.4 cm. The weight of 1000 seeds in the areas of early sowing was 123.8 g, the optimum – 134.0, the late – 133.8 g. of late – by 5%.

In soybean cultivation technologies, the formation of a rational spatial structure of sowing is essential, which ensures a sufficiently uniform placement of the plants in the sowing. These measures significantly increase the competitiveness of soybean crops against weeds. The proposed indicators indicate greater expediency of sowing soybeans with row spacings of 45 cm.

The value of the coefficient of competitiveness confirms that with increasing seeding rate soybean resistance to weeds were increased. The value of this coefficient at the sowing rate of 500–600 thousand/ha of similar seeds was 1.10–1.16 (ordinary row crop, 15 cm). In well-developed crops with a higher rate of sowing of soybeans (700–800 thousand/ha of similar seeds), the coefficient of competitiveness was higher and was respectively 1.34–1.55 and 1.61–2.00.

Analyzing the dependence of soybean yield on the number of weeds in different densities, we found that increasing the seeding rate helped to reduce weediness. When studying the indicators of relative decrease in soybean yield (in % of control) it was found that at the seeding rate of 700–800 thousand/ha of similar seeds, they are significantly higher than at 500–600 thousand/ha.

Investigating the effect of soybean sowing on weediness, we found a slight increase in row sowing. A more significant effect was increased in the rate of seeding of soybeans. There was a significant decrease in the number of weeds with increasing plant density. The indicators of the competitiveness of soybean crops and the harmfulness of weeds in these crops make it possible to properly assess the situation of the stability of cultivated plants in agrophytocenoses and to choose the appropriate methods of effective weed control. The criterion of reasonable application of herbicides should be a competitive relationship between cultural plants and weeds, which are of great importance for the establishment and use of ecological threshold of harmlessness.

In developed crops with a seeding rate of 700–800 thousand/ha of similar seeds, soybeans had a sufficiently high competitiveness for weeds. In areas with a natural weediness of its crops throughout the growing season, the growth and development of soybean plants was significantly sustainable and competed with weeds, ensuring high yields.

The soybeans are sensitive to changes in the size and shape of the area of plant nutrition in crops. In thickened crops soybean plants are extracted, have a thin stem with a small number of leaves, flowers and beans. The beans are formed at the top of the plants, resulting in low seed productivity. In liquefied sowing, soybean plants intensively branch with the formation of a large number of leaves, beans and seeds. In this case the individual productivity of plants is high, but the overall productivity of such sowing is reduced, in addition, with the liquefied placement of plants is characteristic close to the soil surface of the laying of beans, which causes significant losses of harvest during harvesting.

Plant height varied under the influence of sowing method. In continuous row sowing, the plants were the lowest when sowing 500 thousand/ha of similar seeds. With increasing seeding rate, there was an increase in plant height from 66.3 cm when sowing 600 thousand/ha of similar seeds, 69.1 cm – 700 thousand/ha to 73.5 cm when sowing 800 thousand/ha. Changing the seeding rate from 500 to 800 thousand/ha of similar seeds in the ordinary row sowing helped to increase the attachment height of the lower beans from 10.5 to 20.7 cm, row sowing with rows 45 cm – from 12.4 to 20.1 cm, tape sowing – from 12.3 to 19.3 cm.

The seeding rate, more than the sowing method, affected the value of the soybean crop. The best conditions for the formation of crop yields were achieved when sowing 700 thousand/ha of similar seeds. Soybean yield at ordinary row sowing was 2.05 t/ha, at wide-row sowing with spacing 45 cm – 1.91 t/ha, tape – 1.98 t/ha. Increasing the rate of sowing to 800 thousand/ha of similar seeds did not contribute to a significant increase in yields, led to unnecessary costs of seeds and lodging of plants. Very low sowing rate of up to 500 thousand/ha – to decrease field germination of seeds, uneven seedlings, especially in the formation of soil peel and thinning of sowing (Table 4). Taking into account all these features, as well as organizational and economic factors and the impact of sowing on the elements of the structure of the crop, it is most advisable to sow soybean by ordinary row (15 cm) or wide row (45 cm) methods with a seeding rate of 700 thousand/ha of similar seeds.

Table 4

Influence of sowing method and seeding rate on soybean yield

Method of sowing	Seeding rate, thousand/ha of similar seeds	Yield, t/ha			
		2011	2013	2014	Average
Ordinary row, 15 cm	500	1,93	0,97	2,03	1,64
	600	2,07	1,12	2,54	1,91
	700	2,08	1,20	2,88	2,05
	800	1,96	1,43	2,80	2,06
Wide row, with spacing 45 cm	500	1,57	0,96	2,13	1,55
	600	1,60	1,05	2,45	1,70
	700	1,84	1,21	2,68	1,91
	800	1,91	0,90	2,60	1,80
Tape sowing method, 45x15cm	500	1,66	0,89	2,12	1,56
	600	1,78	0,92	2,64	1,78
	700	2,11	1,07	2,75	1,98
	800	1,90	0,93	2,78	1,87

The method and density of plant placement in the area depend, first of all, on the characteristics of the variety and the weather conditions, as well as on the interaction of these factors. Therefore, the question of the right choice of sowing method and seeding rate should be addressed in relation to the selected variety and soil and climatic conditions of the area.

3. Soybean yield depending on the weather factors of the Forest-Steppe of Ukraine

Most of the territory of Ukraine is characterized by favorable conditions for soybean cultivation, but even in relatively favorable areas it is periodically affected by extreme weather conditions. Therefore, the use of different agricultural measures is crucial in increasing the resistance of plants to different types of stressors. In agronomic terms, plant sustainability corresponds to the magnitude of the yield reduction under the influence of the environmental stress and is reflected by the magnitude of the productivity change. According to studies, at different tensions of the same extreme factor, the productivity of plants varies differently, so to compare the stability of species or varieties of plants, their assessment should be carried out in the same stress load[13].

The formation of the commercial soybean crop, as well as other leguminous crops, is a very complicated process in comparison with other crops. This is due to the low property of regulating the number of productive shoots, as well as the slow and very prolonged differentiation of organs and a significant addiction of their development from environment conditions[14,15].

The main components of yield of leguminous crops are: the number of plants per unit area, the number of productive stems, the number of beans per plant, or 1 m^2 of space, the number of seeds in a bean in a plant, or 1 m^2, a mass of seeds from plants, weight 1000 seeds. The dynamics of formation of these components of the yield proceeds in three phases: the main phase; maximum level phase; phase of quantitative reduction[16]. The number of productive shoots per unit area depends on the plant density and the extent of their branching. During vegetation period, under the influence of adverse factors (meteorological conditions, diseases, pests, competition), this indicator decreases significantly.

The main weather factors in the conditions of the Forest-Steppe of Ukraine, which adversely affect the productivity of soybeans in some years, are sharp fluctuations in temperature, uneven and insufficient rainfall during the growing season. According to Japanese researchers, even in the Tokachi area on island Hokkaido (Japan), 1.8–2.0 t/ha of

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soybean grain were obtained in temperature favorable years, and in unfavorable years the yield decreased 3–5 times. This decline in productivity was associated with a decrease in the number of beans and seeds, harvest index, plant height and number of nodes.

Many studies indicate that, depending on the variety and cultivation area, the sum of active temperatures for soybeans is 1700–3200 °C. It is most demanding for heat during the sprouting period, flowering and bean formation. The biological minimum for the flowering of most varieties is 16–18 °C. In the experiments during growing soybeans at a constant temperature of + 15 °C, the beans were practically not formed on the plants. The increase in temperature had a positive effect on the fruit formation[17, 18].

In many cases, the effectiveness of a variety of plants is judged only by the absolute value of its yield under favorable conditions of cultivation. But this is not entirely true, because this estimate does not take into account the degree of change in the potential productivity of the variety under the influence of stress, that is, a measure of plant stability. In order to compare the productivity of different types of crops or varieties, one should focus on their relative resistance to environmental conditions[19].

The technology of growing crops is the result not only of a deep knowledge of the patterns of growth and development of plants, but also the ability to most use them in specific conditions of climatic potential. All these measures should be implemented taking into account the climatic resources of the specific area[20].

The most common leguminous crop for a long period in the forest-steppe zone was peas, which occupied large acreage. For the past ten years, soy has squeezed peas and occupied a large area.

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An example of farms in Poltava region showed that pea crops in the last 20 years have decreased by 5–6 times. For example, the area of sowing of this crop in the period 1985–1994 was in the range of 100.1 to 117.4 ha. Since 1985, its acreage has tended to decline, especially since 2000 to the present time it has decreased by 5 times, the acreage of peas has stabilized at the level of 19.7–25.4 thousand hectares. The sharp fluctuations in weather conditions, especially the rather uneven distribution of rainfall, caused unstable soil moisture during the growing season.

The expediency of soybean cultivation in the farms of the Poltava region has been reflected in the dynamics of acreage over the past 20 years. Significant variations in the area of sowing of soybeans in different years are characteristic. Its largest acreage was in two periods: the first – 1988–1991, it ranged from 9052 to 19090 hectares; the second – 2000–2007, with an area of 121568 hectares in 2006, which is 12 times more than in 2000. For the implementation of the program of further expansion of soybean crops in the following years, it stabilized within 140–180 thousand hectares.

The creative use of modern technology of cultivation, taking into account the soil and climatic conditions, the level of crop culture and biological characteristics of crops allowed to get high yields of soybeans. During the years of the study of fluctuations in the yield of soybean seeds, the average in the Poltava region ranges from 0.56 to 1.65 t/ha. The average statistical yield of soybeans over 20 years is 1.25 t/ha.

An important source of oil is sunflower. However, the area of this crop is over-enlarged and does not meet the agrotechnical requirements of crop rotation. In many agricultural enterprises, the proportion of sunflower is more than 20% of the total acreage, which adversely affects the phytosanitary status of the fields and the economy of the economy. Rapeseed occupies relatively small acreage with a tendency to increase in subsequent years.

The Poltava region has a long and rich history of introduction, selection and cultivation of soybeans in Ukraine. It has been one of the largest producers of this valuable culture in the country for the last ten years. This happened due to the introduction into production of new generation of soybean varieties and mastering of the varietal technology of their cultivation.

We have also analyzed the yields of soybean and pea seeds over the past 14 years, and in parallel – soil moisture, rainfall and average daily air temperature during the growing season. The statistical dependence between the yield levels of these crops and the indicators of natural resource efficiency each year had some relationship. The results of statistical studies have shown significant fluctuations in the yields of both crops over the years. The average statistical yield for the years of research was 1.85 t/ha; peas – 2.70 t/ha.

The purpose of our research was to study the influence of external environmental factors on the productivity of soybeans and peas in the conditions of the left-bank part of the forest-steppe. Soybean yields were studied and maximum and minimum crop yields identified in the study. It was respectively 3.51 and 0.65 t/ha and the probability of its recurrence was found. To determine the level of reliability of repetition of different yield levels, depending on the agrometeorological conditions of the zone of non-sustainable wetting of the forest-steppe of Ukraine, over the years, was conventionally divided the resulting yield into five subsequent levels with intervals of 0.5 t. Soybean yield over the years of field research ranged from 0.61 to 3.51 t/ha, peas – from 1.51 to 4.20 t/ha.

In the process of further analysis, the effect of air temperature and rainfall were studied to identify the effects of specific agrometeorological factors on soybean yield. Taking into account that the sum of active temperatures (above +10 °C) in the conditions of the left-bank part of the forest-steppe is 2600–3000 °C, we consider it quite sufficient for the cultivation of early and middle-ripe soybean varieties. A more substantial factor is soil moisturizing, because it has significant fluctuations in rainfall, especially during the growing season of field crops (table. 5). Analyzing the level of soybean yield on the average over the years of research, we point out its significant difference in different years. The most likely yield was in the range of 1.5–2.0 t/ha, which was observed for 4 years out of 10. The soil and climatic conditions of unstable moisture zone are also favorable for obtaining soybean yield within 2.0–2.5 t/ha, observed in 26% of studied years, or 3 years from 10. The probability of obtaining soybean yield in the range of 1.0–1.5 t/ha, as well as the yield above 2.5 t/ha, is 13%.

Droughts that have become characteristic of the climatic conditions of unstable moisturizing especially cause a negative effect in the spring. Pea seedlings do not always have a satisfactory condition or there is a significant lack of moisture during critical water useof pea. Therefore, as the results of the study showed, it is not possible to predict the exact probability of harvesting peas in different years. The statistical correlation between pea yield levels and natural resource efficiency indicators each year was in the range of 10–15% and no statistical regularities could be detected.

Table 5

Statistical analysis of the probable yield of soybeans in the conditions of unstable moistening of the left-bank part of the forest-steppe (average for 2000–2015)

Soybean		Peas	
Yield level, t/ha	The probability of recurring yields by years,%	Yield level, t/ha	The probability of recurring yields by years,%
0,51–1,00	8	Less 2,00	22
1,01–1,50	13	2,01–2,50	26
1,51–2,00	40	2,51–3,00	22
2,01–2,50	26	3,01–3,50	10
2,51 and more	13	3,51 and more	20

Analyzing soil moisture during the growing season of both crops, we can point out the close relationship between the amount of rainfall in the first (May-June) and the second (July-August) half of the growing season and their yield. In order to identify the specific impact of uneven rainfall during the growing season, the rainfall coefficient was determined. Conditionally divided the growing season into 2 parts the first part – May-June, the second – July-August.

The values of the precipitation distribution coefficient were determined by dividing the rainfall of the first part of the growing season by the rainfall of the second part of it. For example, in 2009, the total rainfall in the first half of the growing season was 129.1 mm, in the second half – 42.9 mm. The precipitation distribution coefficient was 129.1 / 42.9 = 3.01. The values of the coefficients for other years of research were similarly determined. The fluctuations in the magnitude of this coefficient ranged from 0.26 to 3.10, i.e. if this indicator was smaller, the less precipitation was observed in the first half of the growing season and the greater rainfall in the second (July-August).

For reliability of the results of the study, the rainfall distribution coefficients were grouped into two groups of 0.2–2.0 and 2.1–3.1 for which the average seed yield was determined. This made it possible to reveal the nature of the influence of precipitation distribution on soybean and pea yields (Table 6).

Table 6

Yield of soybeans and peas depending on the nature of the distribution of rainfall of the first and second part of the growing season (average for 2000–2015)

Culture	Precipitation coefficient	Yield, t/ha
Soybean	0,2 – 2,0 2,1 – 3,1	1,79 1,28
Peas	0,2 – 2,0 2,1 – 3,1	2,66 3,41

It is established that under the conditions of better moisture supply of the soil of the first half of the growing season (May-June) peas provides stable and high yield of grain, i.e. if the value of distribution coefficient of precipitation is 2.1–3.1, yields peas will be high (3.41 t/ha). In the absence of rainfall during this period, the yield of peas sharply decreases. The yield decreased by 2.66 t/ha by a factor of 0.2–2.0.

The nature of the formation of soybean yield is sharply opposite to the distribution of rainfall typical for peas. Higher rainfall in the second half of the growing season (July – August) can provide consistently high soybean yields. With a value of rainfall coefficient in the range of 0.2–2.0, soybean yield will always be high – 1.79 t/ha, and, conversely, if the coefficient index is 2.1–3.1, then the yield will always be low – 1.28 t/ha.

CONCLUSIONS

In order to grow soybeans, it is necessary to pay attention to the meteorological factors of the area and its biological requirements, which will contribute to obtaining high crop yields. For the growth and the development of plants, the formation of the crop requires three main factors, they are: light, heat, moisture. The most variable of them is moisture and heat. The main limiting factor for high productivity of soybeans is the moisture content of the area. In most cases, the sum of effective temperatures for early and mid-early soybean varieties is sufficient to generate high soybean yields.

In the conditions of better moisture supply of soil in May-June, it is more likely to count on the high yield of peas and, conversely, for the uniform distribution of precipitation, and even better their number in July-August, you can count on the high soybean yield. Therefore, these two cultures must be mandatory farms in the left-bank part of the forest for greater probability of stable harvest of grain and protein. Taking into account the weather conditions of the territory of the natural zone will allow in each case to differentiate the development of agrotechnical measures to improve the crop culture and obtain a stable crop yields.

When choosing the period of sowing of soybeans, one should take into account the temperature level and moisture of seed soil layer. Early sowing plants (third decade of April) had a longer growing season than late-sowing plants. With insufficient supply of moist soil and elevated air temperature, the growing season was shortened by 7–12 days. Changing the sowing rate from 500 to 800 thousand/ha of similar seeds helped to increase the attachment height of the lower beans from 10.5 to 16.7 cm. The best conditions for the formation of the crop were formed when sowing 700 thousand/ha of similar seeds. Soybean yield in the row sowing method was – 2.05 t/ha, wide-row spacing 45 cm – 1.91, tape – 1.98 t/ha. Considering the influence of sowing method and sowing rate on the elements of the crop structure, it is most expedient to sow soybeans in the usual row way (15 cm) or wide-row way (45 cm) with a sowing rate of 700 thousand/ha.

SUMMARY

According to the results of the study of soybean varieties, the most productive varieties are selected, which in the conditions of the left-bank forest-steppe combine a short period of vegetation and the main components of productivity. The weather conditions of the growing season significantly influenced the duration of the interphase periods. Seed yields from one plant depended on the height of the main stem, the number of fruiting nodes, beans and seeds on the plant. Late-ripening varieties exhibited a negative influence of the height of attachment of the lower beans on seed productivity.

The soybean sowing time depends on the germination, the density of the plants, the uniformity of ripening, the size and quality of the crop. The main criterion for the selection of the sowing period is the steady warming of the sowing soil. The minimum temperature for soybean seedlings is about + 10° C, if it has further increase in soil temperature. Warming up the seedbed to + 12–14° C ensures seed germination in the presence of moisture. The optimum sowing period for soybeans is the first half of May. Under these conditions, you can expect maximum yields. Early or late sowing reduces the yield of soybean seeds by 12–14%.

Changing the sowing rate from 500 to 800 thousand/ha of similar seeds helped to increase the attachment height of the lower beans from 10.5 to 16.7 cm. The best conditions for the formation of the crop were formed when sowing 700 thousand/ha of similar seeds. Soybean yield for row sowing was 2.05 t/ha, for wide-row sowing with spacing 45 cm – 1.91, for tape sowing – 1.98 t/ha. Considering the influence of the sowing method and the seeding rate on the elements of the crop structure, it is most expedient to sow soybeans in the usual row way (15 cm) or wide-row sowing (45 cm) with a seeding rate of 700 thousand/ha.

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Information about the author:
Shevnikov M. Ya.,
Doctor of Agricultural Sciences, Professor,
Professor at the Department of Plant Growing,
Poltava Statev Agrarian Academy
1/3, Skovoroda str., Poltava, 36003, Ukraine
ORCID 0000-0003-0810-523X

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IMPROVEMENT OF THE CULTIVATION TECHNOLOGY OF WHITE ANNUAL MELILOT IN THE CONDITIONS OF SOUTHERN STEPPE OF UKRAINE

Vlashchuk A. M.

INTRODUCTION

Today, in Ukraine, the most reliable fixed asset not only for agricultural production, but also for the country's economy is land. Most producers have a standard crop rotation: fallow field – winter wheat – winter rape (sunflower) –sorghum, which lacks the elementary possibility of natural restoration of soils fertility. All these crops require significant doses of nitrogen fertilizers, the prices of which have recently grown too much. Therefore, from the point of basics of soil fertility maintenance, it is necessary to observe the basic laws of agriculture, which foresee a crop rotation with the obligatory cultivation of legumes. At the irrigated lands, it is, first of all, soybean. At the rain-fed lands pea could be used[1, 2].

The cultivation of rare but highly productive legumes, which are multifunctional in use, will increase soil fertility, increase crop production and reduce forage and protein deficiency. Therefore, in Southern Steppe of Ukraine – in the area of risky agriculture, it is advisable to sow the annual white melilot as a drought-tolerant crop. This is especially the case with saline soils. White annual melilot is the crop that can recultivate saline lands – it grows on the grasslands where most plants do not grow. Therewith, this legume is very responsive to irrigation, increasing its productivity by one and a half to two times. This species is one of the best nitrogen fixing green manure crop. Burying melilot plants for green manure, up to 150–200 kg of nitrogen is added to the soil, which is approximately 50–60 tons of

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manure per 1 ha. Therefore, this crop, undoubtfully, fits perfectly to modern short-rotation crop rotations of the steppe land[3, 4].

The annual white melilot is positioned as a highly productive forage protein plant. Yield of green mass – 30 t/ha, hay – 4 t/ha, seeds 600–1200 kg/ha. It has been known for a long time for its high quality as a pharmaceutical raw material for the preparation of various environmentally friendly medicines. It is one of the best honey plants, at long flowering – 45–60 days per one hectare of the crops 350–600 lg of sugar in nectar is secreted. The duration of flowering of the crop during two months promotes the prolongation of feed basis presence for wild leafcutting bees, which allows increasing their number. Leafcutting bees are the main, or only, pollinators of forage legumes – melilot, alfalfa, et al.[5, 6].

At present, there is almost no data in scientific literature in regard to the development of cultivation technology for the crop with taking into account changes in the current conditions of global climate warming. Considering the fact that no breeding of new varieties is being carried out at present and there is no seed production of annual white clover, and in connection with the study of agro-technology of the new variety, there is a need for scientific research to improve the technology of seed production of this crop.

Therefore, researches on the optimization of cultivation technology of the crop in arid conditions of Southern Steppe of Ukraine are of current interest.

During 2016–2018, two experiments were carried out: in the first experiment, we studied seed productivity of annual white melilot depending on the sowing time and sowing rates: factor A – sowing time: the third decade of March, the first decade of April, the second decade of April; factor B – sowing rate: 1.5 million pieces/ha, 2.5 and 3.5 million pieces/ha. The second experiment covered the study of seed

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productivity of the studied crop depending on the application of herbicides and the rate of their application: Factor A – herbicide: control (without herbicides), herbicides Treflan and Pulsar; factor B – application rate: for Treflan preparation – 1.5 L/ha, 2.5 L/ha, 3.0 L/ha, 4.0 L/ha, for Pulsar preparation – 0.5 L/ha, 0.75 L/ha, 1.0 L/ha, 1.5 L/ha.

1. Seed yield of annual white melilot depending on sowing time and sowing rates in Southern Steppe of Ukraine

The aim of the study was to determine the yield and sowing qualities of annual white melilot depending on the sowing time and sowing rates in Southern Steppe of Ukraine.

Field double-factored experiment was conducted by the method of split plots according to the common methods of field experiment conduction and methodological recommendations[7, 8] at the research field of the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine in 2016–2018.

The researches were carried out in four replications, with randomized way of the variants distribution. The area of the sites of the first order – 62 m^2, of the second order – 25 m^2. The soil of the experimental plot is dark chestnut, medium-loamy, slightly saline, the soil-forming rock of which is loess-like loam.

The analysis of literature sources testifies that the maximum seed productivity of melilot can be obtained only under the conditions of differentiated selection of the plants density, taking into account natural and climatic conditions. Under the correct quantitative distribution of plants on the growing area, which is stipulated by the sowing rate, the phytosanitary condition of the crops, water, air and nutritional regime of the soil improves; favorable conditions are created for the increase of the crop productivity[9, 10].

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Formation of optimal plant density of melilot at different time of sowing per unit of the area is an important agrotechnical technique for the increase in crop yields. Thus, we determined the dependence of seed productivity of melilot in dependence on different sowing times and sowing rates (Table 1.1).

By the results presented in the Table we see that at the time of the sprouting higher plants density was determined in the crops of the second time of sowing and it was 67.8–85.6 pc./m^2, but at the moment of harvesting higher index of plants density of melilot was fixed in the crops of the third time of sowing and it was 57.3–73.9 pc./m^2.

Table 1.1

Influence of sowing time and sowing rate on the plants density of annual white melilot, average for 2016–2018

Factor A, time of sowing	Factor B, sowing rate, million	Time of the determination of plants density, pc./m^2		
		sprouting	before flowering	before harvesting
III decade of March	1.5	62.7	54.8	54.0
	2.5	74.8	68.4	64.5
	3.5	81.7	73.2	68.9
I decade of April	1.5	67.8	57.9	54.2
	2.5	80.6	73.8	69.9
	3.5	85.6	76.0	70.7
II decade of April	1.5	65.3	59.4	57.3
	2.5	78.9	71.1	69.2
	3.5	83.2	78.4	73.9

The highest index of the height of melilot plants of 155–160 cm was determined at sowing the crop in the I decade of April with the rate of 2.5 million pc./ha (Table 1.2). The maximum growth of the plants was observed in the inter-stage period flowering – seeds formation.

Table 1.2

Dynamics of growth of annual white melilot plants depending on the times of sowing and sowing rates, average for 2016–2018

Factor A, time of sowing	Factor B, sowing rate, million pc./ha	Phenological stages, cm				
		Ramification	Budding	Flowering	Seed formation	Full ripeness of the seeds
III decade of March	1.5	10	140	144	145	143
	2.5	12	148	151	151	148
	3.5	11	135	139	138	136
I decade of April	1.5	13	150	150	158	156
	2.5	15	155	157	160	158
	3.5	14	146	150	155	153
II decade of April	1.5	11	141	146	150	147
	2.5	13	149	154	155	153
	3.5	10	137	140	151	148

Climate of Southern Steppe of Ukraine is continental, hot, and dry. The annual income of insolation in Kherson region is 115–116 kcal/cm^2, among which 94–95 kcal/cm^2 are coming during the vegetation period. The income of photosynthetically active radiation (PAR) for the vegetation period is 45–50 kcal/cm^2. The annual sum of precipitation fluctuates within 350–470 mm with the changes by years from 140–160 to 600–660 mm. Hydrothermal coefficient (HTC) in the region is 0.4–0.5, whereas in the zone of sufficient humidification – 1.0. The major amount of precipitation

(50–70%) is in the warm period of year. Long rain-free periods lasting 50–60 days are typical.

Weather conditions in the years of the trials conduction were typical for Southern Steppe zone of the country. The maximum precipitation amount – 218 mm was observed in 2016, there were much less precipitation in 2017 and 2018, 172 and 150 mm, respectively. It was defined that the total water consumption of the crop changes in dependence on the time of sowing and sowing rates. The lowest coefficient of water use – 57.3 m^3/t was determined at sowing in the I decade of April at the rate of 2.5 million pc./ha (Table 1.3).

Table 1.3

Water consumption of annual white melilot depending on the time of sowing and sowing rate, average for 2016–2018

Factor A, time of sowing	Factor B, sowing rate, million pc./ha	Start moisture content in the soil, m^3/ha	Moisture content in the soil at harvesting, m^3	Precipitation during the vegetaion, m^3/ha	Total water consumption, m^3/ha	Coefficient of water use, m^3/t
III decade of March	1.5	1174	503	161.0	832	105.3
	2.5	1169	491	161.0	839	101.1
	3.5	1171	484	161.0	848	146.2
I decade of April	1.5	973	489	151.2	635	73.8
	2.5	962	475	151.2	638	63.2
	3.5	970	468	151.2	653	90.7
II decade of April	1.5	1175	476	152.5	852	127.2
	2.5	1168	464	152.5	857	105.7
	3.5	1172	459	152.5	866	151.9

The maximum seed yield of melilot is formed in the conditions of the optimum ratio of all the constituent elements. At the insufficient development of one constituent element yield could be compensated at the expense of other components. As separate components are formed at different stages of organogenesis they require optimal environmental conditions for its successful development. Realization of the laid reproductive elements of the melilot plants begins with the start of flowering stage when water consumption of the plants increases. At the favorable environmental conditions flowering stage lasts for 1.5–2 and more months.

The researches conducted in 2016–2018 showed that sowing rate had significant effect on the formation of seed yield of annual white melilot. Depending on the factors of the trial, the plants are falling in different agrometeorological conditions, grow and develop differently, i.e., they form different productivity. Seed yield of melilot at different times of sowing and sowing rates varied from 0.57 t/ha to 1.01 t/ha (Table 1.4).

Table 1.4

Seed yield of annual white melilot depending on times of sowing and sowing rates, average for 2016–2018

Factor A, time of sowing	Factor B, sowing rate, million pc./ha	Yield, t/ha		
		Average for three years	By factor A	Be factor B
III decade of March	1.5	0.79	0.73	0.77
	2.5	0.83		0.88
	3.5	0.58		0.62
I decade of April	1.5	0.86	0.86	
	2.5	1.01		
	3.5	0.72		
II decade of April	1.5	0.67	0.68	
	2.5	0.81		
	3.5	0.57		
Evaluation of significance of partial differences				
LSD_{05}	A	0.043		
	B	0.035		
Evaluation of significance of main effects				
LSD_{05}	A	0.025		
	B	0.020		

It is evident from the Table that all the studied factors affected the formation of seed productivity of annual white melilot. The maximum average yield for 2016–2018 – 1.01 t/ha the crop formed at sowing in the I decade of April under the rate of 2.5 million pc./ha (LSD_{05} A – 0.025 t/ha, B – 0.020 t/ha).

The maximum yield by the factor A (sowing time) – 0.86 t/ha – the plants of annual white melilot formed at sowing in the I decade of April (LSD_{05} A – 0.43 t/ha). By the factor B (sowing rate) this index reached the maximum at the use of sowing rate 2.5 million pc./ha – 0.88 t/ha (LSD_{05} B – 0.35 t/ha).

The results of the study determined that the yield was affected by all the studied factors. But the strongest effect on the seed yield was caused by the time of sowing. On average for 2016–2018, its share was 63.4%, the share of the factor B – 43.8% (Fig. 1.1).

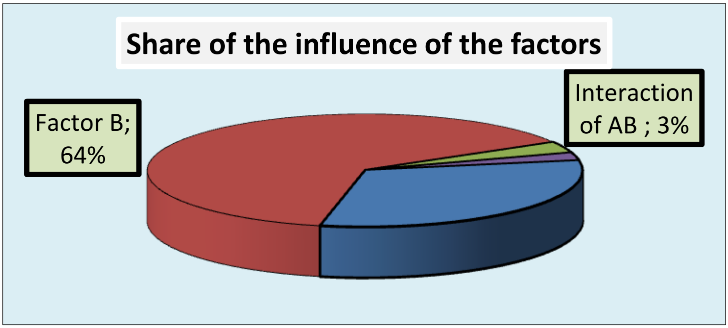

Fig. 1.1. The share of the effect of the studied factors on the seed yield of annual white melilot, average for 2016–2018

Economic efficiency of new variety of annual white melilot depends mainly on the seed yield, its quality and price, and also on the money saving for the cultivation. The results of economic analysis for the years of the study testify that all the studied factors affect the economic efficiency indexes of the crop cultivation.

The prices for the seeds of white melilot were used in accordance with the data of the Institute of Irrigated Agriculture of NAAS and were 100 UAH/kg (100,000 UAH/t of the seeds) of elite seed material. These data were used in the calculations of the main indexes of economic efficiency.

It was determined that among the studied times of sowing the maximum profitability of 355% was achieved at sowing in the I decade of April, the minimum index of 256% was defined at sowing in the

II decade of April. Among the studied sowing rates the maximum profitability of 342% was obtained at 2.5 million pc.ha, the minimum – 238% at sowing rate of 3.5 million pc.ha (Fig. 1.2, 1.3).

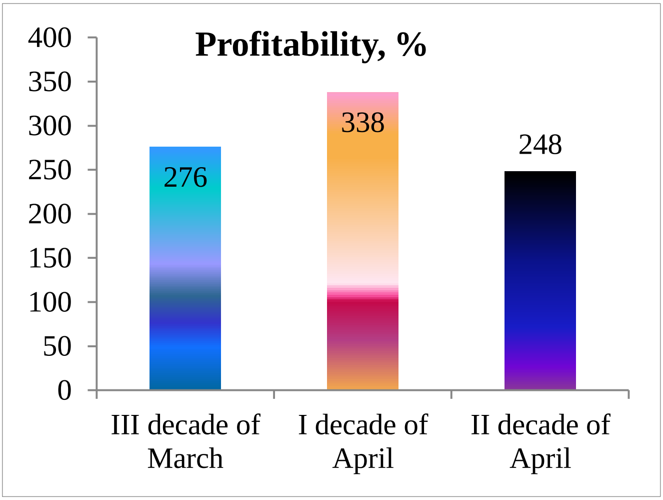

Fig. 1.2. Profitability of annual white melilot variety Pivdennyi depending on time of sowing, average for 2016–2018

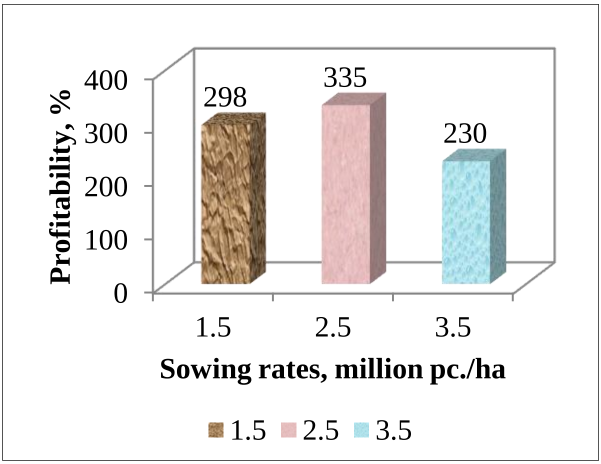

Fig. 1.3. Profitability of annual white melilot variety Pivdennyi depending on sowing rate, average for 2016–2018

This is explained by the fact that seed productivity of annual white melilot is in direct dependence on soil and climatic conditions of the zone of cultivation. Therefore, to obtain the maximum seed yield of annual white melilot in Southern Steppe of Ukraine it is recommended to sow the crop in the I decade of April with the rate of 2.5 million pc./ha.

2. Seed yield of annual white melilot depending on the application of herbicides in the conditions of Southern Steppe of Ukraine

The aim of the study was to determine the yield and sowing qualities of annual white melilot depending on the application of herbicides and their application rates in the conditions of Southern Steppe of Ukraine.

The tasks of the study include:

– the determination of weed species and the level of weed contamination of the crop;

– the determination of technical efficiency of different herbicides application rates against weeds in the melilot crop;

– the determination of seed productivity of annual white melilot depending on the application of different rates of herbicides;

– the determination of the optimal application rate for the most efficient herbicide against weeds in the crop of annual white melilot in the conditions of theSouth of Ukraine at different application rates;

– the determination of economic and energy efficiency of annual white melilot cultivation depending on the application of different rates of herbicides in Southern Steppe of Ukraine.

The experiment is double-factored, in four replications, the variants are placed by using the randomized split plots with accordance to generally accepted methods of field trials conduction at the experimental field of the Institute of Irrigated Agriculture of NAAS in 2016–2018[11]. The experimental area was 900 m^2, the area of a single plot – 24 m^2. The soil of the experimental field was dark-shestnut, middle-loamy, slightly saline, with the loess-like loam soil-forming rock material.

[11] Бабич А.О. Методика проведення дослідів по кормовиробництву. Вінниця: Іскра, 1994. 87 с.

Quantitative and balance registration of weeds was performed on five areas, each of which was 0.5 m^2. At the first registration – 10 days after the application of herbicides – quantitative registration, before harvesting – quantitative and balance one. Annual white melilot variety Pivdennyi was sown in the experiment.

To obtain planned and qualitative yield of the crop it is obligatory to conduct recommended and various measures for control of quantity and development of weeds. Among the recommended and such that provide reliable protection of crop sprouts there is a measure of weed control through the application of soil herbicides. One of the valuable advantages of soil herbicides is the possibility of their use through the soil spraying before sowing, a the moment of sowing and even after sowing before the sprouts appear[12].

With the aim of provision of planned and qualitative yield of crops and efficient weed control it is necessary to take into account such an index as their selectivity. Selective herbicides are divided into soil and post-sprouting. Soil (basic) herbicides are mostly used before sprouts of crops appear. Their features include the formation of protective shield and oppression of weeds germination. Therefore, soil herbicides are applied mainly for the limitation of annual weeds. The advantage of soil herbicides is a possibility to control several waves of germinating weeds that provides powerful start for crop sprouts. Technical efficiency of soil herbicides depends on moisture and quality of soil tillage[13].

The main advantage of these herbicides is the duration of protective activity, which is often spread for the whole vegetation period. Their advantages also include the fact that their toxic activity almost is not dependent on weather conditions. In contrary, precipitation only amplify the effect of the preparations through more equal distribution in soil; the influence of wind is manifested less because big-drip sprinkling through the sprayers with big outlets, which are not clogged with side dashes, are used. To the advantages of

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[12] Макрушин М.М. Насіннєзнавство польових культур. Київ: Урожай, 1994. 208 с.

[13] Голобородько С.П., Снеговой В.С., Сахно Г.В. Люцерна. Херсон: Айлант, 2007. 328 с.

soil preparations should be attributed the possibility of their application with other agricultural operations, e.g., sowing, cultivation, dragging, etc. The disadvantage of this kind of herbicides is, in particular cases, dependence of their efficiency from soil moisture. As a rule, technical efficiency of soil preparations, which are located in dry soil layer, is low[14, 15].

In this connection, we tested in our trials herbicides that have different mechanisms of activity. Soil herbicide Treflan 480. Peculiarities of the application: to achieve the best efficiency of the preparation it should be incorporated into the soil at the depth of 6–8 cm as soon as possible (during 4 hours after the application). The optimal temperature of environment for the application of the preparation is +5 °C to +25 °C. If the herbicide is used with accordance to the recommendations, there are no limitations in the crop rotation. System herbicide Pulsar 40, which is absorbed both by herbage and root system of weeds. Peculiarities of the application: the crops could be treated with the herbicide Pulsar 40 just once a season; it mustn't be used in the mixtures with anticereal herbicides; after the herbicide was used it is not allowed to apply the preparations belonging to the groups of sulfonylurea and imidazolinones; the herbicide Pulsar 40 mustn't be applied in windy (wind speed > 5 m/sec) to avoid its unequal distribution and drift on the neighboring fields; the application of the preparations with the active substance from the group of imidazolinones is allowed just once a three years on the same field; it requires equal distribution through the whole area (overlapping of a syringe passes should be minimum); do not allow drift of the active fluid on the neighboring fields; requires qualitative pre-sowing soil tillage (clods not more than 2 cm).

The results of the influence of the preparations are presented in the Table 2.1.

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[14] Іващенко О.О. Бур'яни в агрофітоценозах: монографія. Київ: Світ, 2002. 236 с.

[15] Швартау В.В. Гербіциди. Київ: Логос, 2009., Т. 2. 1046 с.

Table 2.1

Influence of the applied herbicides on weed contamination of annual white melilot crop, average for 2016–2018

Factor A, herbicide	Factor B, application rate, L/ha	After the application of herbicide			Before the crop harvesting		
		Number of species, pc./m^2	Number of plants, pc./m^2	Mass of weeds, g	Number of species, pc./m^2	Number of plants, pc./m^2	Mass of weeds, g
Treflan 480	Control 1	4	17	206.2	5	92	930.1
	1.5	3	12	193.3	3	33	598.4
	2.5	3	10	171.4	4	20	285.5
	3.0	2	7	151.2	4	10	164.9
	4.0	1	6	141.8	3	9	138.6
Pulsar 40	Control 2	4	16	193.7	5	90	908.9
	0.5	4	5	164.4	5	11	141.7
	0.75	2	5	154.7	4	7	138.9
	1.0	2	3	143.6	3	6	127.6
	1.25	1	3	105.9	2	4	105.1

The main point of the herbicides action is that they oppress the processes of photosynthesis, respiration, nutrients uptake that causes the disturbance of free amino acids synthesis. In connection with this it should be remembered that such actions are possible in the direction of the crop (annual white melilot) in favorable environmental conditions. The degree of the herbicides effect on the crop depends on the application rate and type of herbicide, and on the environmental conditions. The results of such an influence told upon the plants of melilot by the time of the period of full sprouts. So, plant density of the plants of melilot at the treatment with the preparation Treflan 480 was within 53.9–77.2 pc./m^2, at the application of the herbicide Pulsar 40 – 80.8–81.9 pc./m^2, that points out on more oppression of the crop at the application of Treflan 480, and plant density decreased on the background of higher application rate of the preparation (Table 2.2).

Yield of crops mostly depends on climatic conditions and structural indexes, where perennial and annual herbs as fore-crops in the crop rotation acquire special value. Owing to their strong root system that percolates deep in the soil, the plant of white melilot feels less negative effect of atmospheric drought and lack of moisture in the upper layer of the soil[16].

Table 2.2

Influence of the application of the herbicides on the plant density of annual white melilot, average for 2016–2018

Factor A, herbicide	Factor B, application rate, L/ha	Plants density, pc./m^2		
		At the time of sprouts	Before flowering	Before harvesting
Treflan 480	Control 1	79.9	62.4	61.1
	1.5	77.2	60.2	59.7
	2.5	75.1	64.4	63.1
	3.0	64.5	60.8	60.0
	4.0	53.9	50.1	48.5
Pulsar 40	Control 2	79.7	61.6	60.2
	0.5	81.1	63.9	63.1
	0.75	80.8	66.1	65.6
	1.0	81.9	68.9	68.0
	1.25	81.6	65.5	64.6

The yield component of annual white melilot are plants density per the unit of area, total number of branches and bunches per plant, average number of seeds per bunch, 1000 seeds weight. At the optimal ratio of these indexes the maximum seed yield is formed, but at the insufficient development of one or more components the yield could be compensated at the expense of other constituents. Separate components are formed at different stages of ontogenesis, therefore they require different agrotechnological conditions for their successful development.

[16] Мордерер Є.Ю., Мережинський Ю.Г. Гербіциди. Механізм дії та практика застосування. Київ: Логос, 2009, Т. 1. 380 с.

High correlation between the seed yield and the number of branches per plant, the number of bunches per plant, the number of seeds per bunch, 1000 seeds weight was determined. The connection between these indexes allowed creation of correlation polynomial models of the dependence of seed yield and different structural indexes (Fig. 2.1, 2.2, 2.3. 2.4).

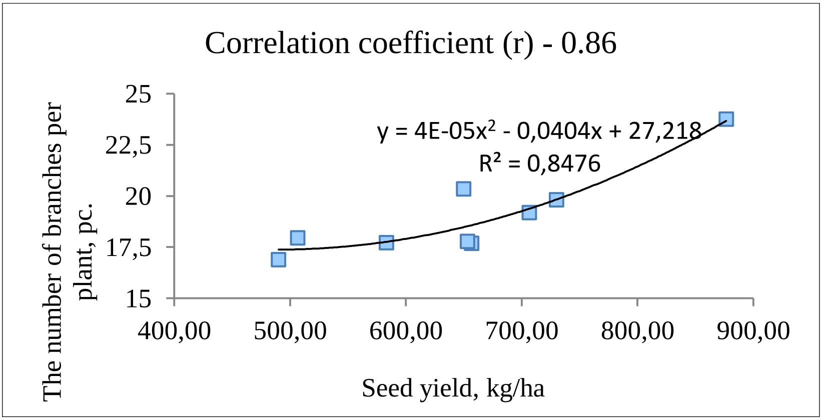

Fig. 2.1. Correlation (r) between the number of branches per plant of white melilot and seed yield (average for 2016–2018)

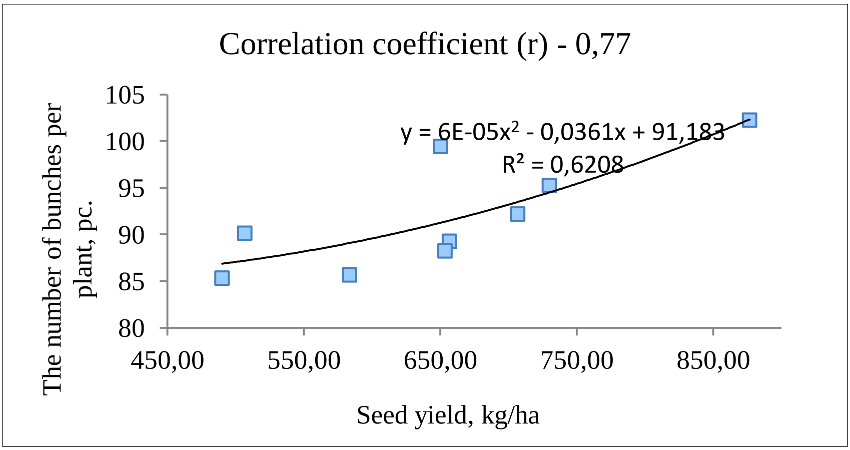

Fig. 2.2. Correlation (r) between the number of bunches per plant of white melilot and seed yield (average for 2016–2018)

This correlation model allowed determination of close connection between the seed yield of white melilot variety Pivdennyi and the number of bunches per plant – the correlation coefficient is 0.77.

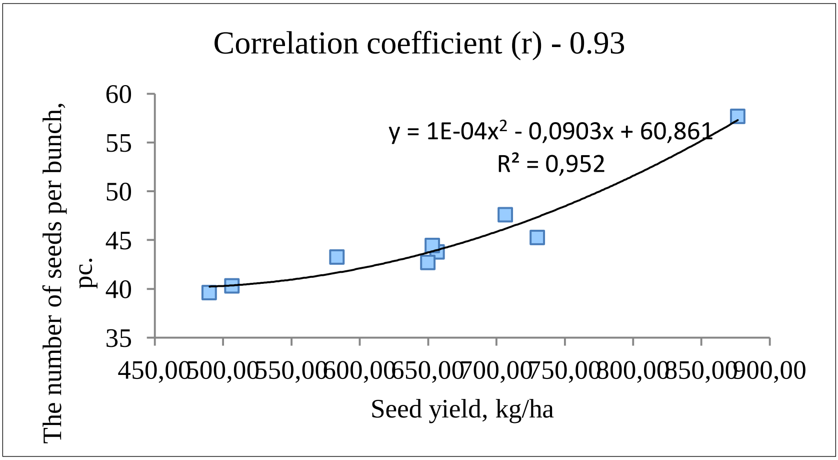

Fig. 2.3. Correlation (r) between the number of seeds per bunch and the seed yield of white melilot (average for 2016–2018)

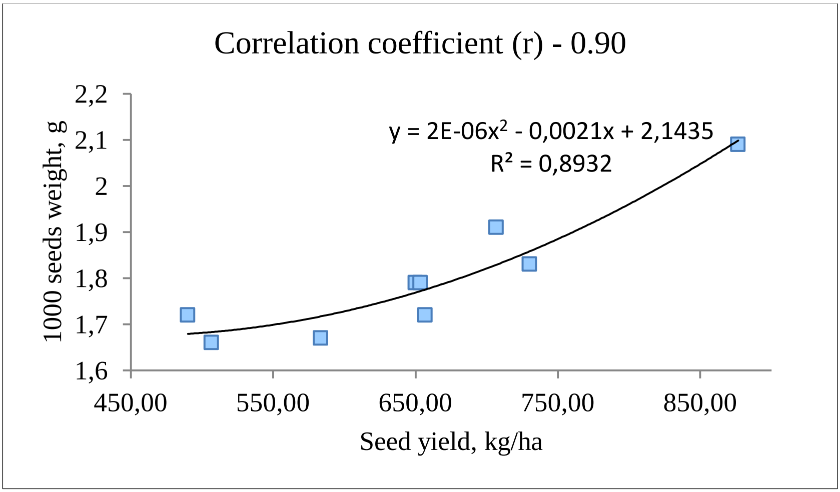

Fig. 2.4. Correlation (r) between 1000 seeds weight and the seed yield of white melilot (average for 2016–2018)

The modeled indexes prove that the determined number of branches per plant of white melilot differed at different times of sowing and sowing rates. The conducted study showed that at the application of the herbicides with different rates they have significant effect on the development of plants, seed yield formation of annual white melilot. Depending on the factors of the experiment, the plants are coming into different agrometeorological conditions, grow and develop differently, form different yield. The seed yield of annual white melilot at the herbicides application with different rates varied within 0.72 t/ha to 0.92 t/ha (Table 2.3).

Table 2.3

The yield of annual white melilot in dependence on the herbicides application, average for 2016–2018

Factor A, herbicide	Factor B, application rate, L/ha	Yield		By factor	
		t/ha	Additional yield t/ha	A	B
Treflan 480	Control 1	0.58	-	0.77	0.59
	1.5	0.74	0.16		0.76
	2.5	0.78	0.20		0.82
	3.0	0.82	0.24		0.87
	4.0	0.72	0.14		0.80
Pulsar 40	Control 2	0.60	-	0.86	
	0.5	0.78	0.20		
	0.75	0.86	0.28		
	1.0	0.92	0.34		
	1.25	0.89	0.31		
Evaluation of significance of partial differences					
LSD_{05}	A	0.042			
	B	0.034			
Evaluation of significance of main effects					
LSD_{05}	A	0.017			
	B	0.024			

It is evident from the Table that all the studied factors affected the seed productivity of annual white melilot. The maximum average yield for 2016–2018 – 0.92 t/ha plants of the crop formed at the application of herbicide Pulsar 40 in the rate of 1.0 L/ha (LSD_{05} A – 0.042 t/ha, B – 0.034 t/ha).

The maximum average yield by the factor A (herbicide) – 0.86 t/ha, the plants of annual melilot formed at the application of the preparation Pulsar 40 (LSD_{05} A – 0.24 t/ha). By the factor B (application rate), the maximum index was at the third variant – 0.87 t/ha (LSD_{05} B – 0.20 t/ha). On the control plots the yield was lower because of considerable quantity of weeds.

The results of ANOVA determined that the strongest effect on the seed productivity formation of the crop was caused by the factor A (application of a herbicide). In 2016–2018, its share of influence was 43.8%, the share of influence of factor B – 35.8% (Fig. 2.5).

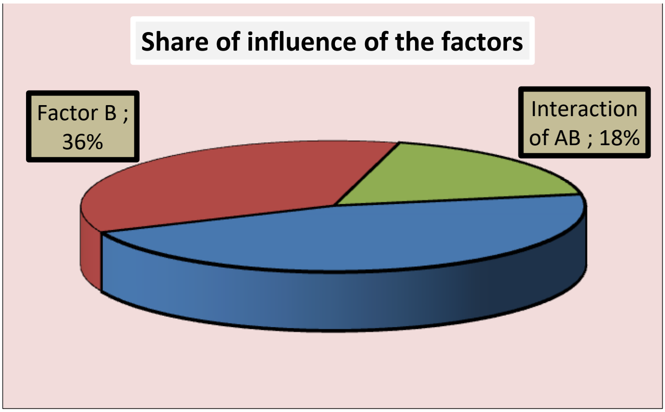

Fig. 2.5. Share of influence of the studied factors on the seed yield of annual white melilot, average for 2016–2018

Taking in consideration significant fluctuation of seed productivity of annual white melilot variety Pivdennyi, and the indexes of production expenditures, seed production cost and obtained pure profit, the profitability was determined in percents (Fig. 2.6, 2.7). Having conducted the analysis of economic efficiency of the application of preparations Treflan 480 and Pulsar 40 at different application rates we determined that the highest production profitability of 374% was obtained at the application of Treflan 480 with the rate of 3.0 L/ha, and Pulsar 40 with the rate of 1.0 L/ha when profitability reached 415%. The lowest index of profitability was determined on the control plots without chemical protection of the crop.

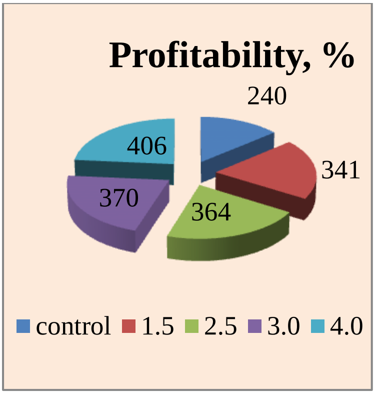

Fig. 2.6. Indexes of profitability in dependence on the application of Pulsar 40, L/ha, average for 2016–2018

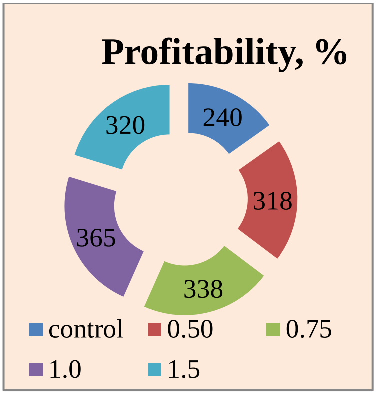

Fig. 2.7. Indexes of profitability in dependence on the application of Treflan 480, L/ha, average for 2016–2018

Thus, the study conducted in 2016–2018 allow concluding that cultivation of annual white melilot variety Pivdennyi in combination with the improved elements of cultivation – application of the herbicides Treflan 480 and Pulsar 40 in the seminal crop is one of the major factors of the crop productivity formation and is closely dependent on the soil and weather conditions of the zone, agrotechnics and morpho-biological features of the plants. By the results of the analysis of three years of the study, the highest gross product value per 1 ha – 55,200 UAH was obtained at the crop of annual white melilot variwty Pivdennyi at the application of herbicide Pulsar 40 in the rate of 1.0 L/ha. The lowest production cost of 1 t of seed material was also established on this variant – 13,800 UAH, the summarizing index of economic efficiency – profitability – was the highest and reached the value of 415%.

CONCLUSIONS

1. The analysis of the conducted during 2016–2018 experimental investigations allowed concluding that application of different time of sowing and sowing rate in the agrotechnology is one of the major factors of the formation of the crop productivity and are dependent on

soil and climatic conditions of the zone, cultivation technology and morpho-biological features of the plants of annual white melilot variety Pivdennyi.

2. The optimal conditions for growth and development of the annual white melilot plants formed at sowing in the I decade of April, when average seed yield was 0.86 t/ha, at the same time, at sowing in the III decade of March it was 0.73 t/ha, in the II decade of April – 0.68 t/ha (LSD_{05} = 0.025 t/ha).

3. The level of yield in the crop at the first sowing time was 0.58–0.83 t/ha, at the second – 0.72–1.01, at the third – 0.57–0.81 t/ha, that allows recommending these elements for the improvement of seed production technology of melilot in the conditions of Southern Steppe of Ukraine.

4. The highest average seed yield of the crop – 1.01 t/ha in 2016–2018 was obtained at sowing in the I decade of April at the rate of 2.5 million pc./ha.

5. The maximum index of profitability – 355% – was obtained at sowing in the I decade of April; the minimum index – 256% – was at sowing in the II decade of April. Among the studied sowing rates the maximum profitability of 342% was at the sowing rate of 2.5 million pc./ha, the minimum one – 238% – at the sowing rate of 3.5 million pc./ha.

6. At the application of the herbicides, the maximum seed yield of annual white melilot was 0.92 t/ha at the application of Pulsar 40 herbicide with the rate of 1.0 L/ha (LSD_{05} A – 0.042 t/ha, B – 0.034 t/ha).

7. The maximum gross product value per 1 ha of 55,200 UAH at the lowest production cost of 1 t of the seed material (13,800 UAH) and the highest profitability of 415% was obtained in the crop of annual white melilot variety Pivdennyi at the application of Pulsar 40 herbicide with the rate of 1.0 L/ha.

SUMMARY

The article presents the results of three-year study dedicated to the investigation of the effect of sowing time, sowing rate and herbicides on the seed productivity of annual white melilot variety Pivdennyi in the conditions of Southern Steppe of Ukraine. The soil of the experimental field – dark-chestnut middle-loamy slightly saline,

typical for Southern Steppe zone of Ukraine. The maximum average yield in 2016–2018 – 1.01 t/ha the crop formed at sowing in the I decade of April at sowing rate of 2.5 million pc./ha (LSD_{05} A – 0.025 t/ha, B – 0.020 t/ha). The maximum yield by the factor A (sowing time) – 0.86 t/ha – the plants of annual white melilot formed at sowing in the I decade of April (LSD_{05} A – 0.43 t/ha). By the factor B (sowing rate) this index was the maximum at the rate of 25 million pc./ha – 0.88 t/ha (LSD_{05} B – 0.35 t/ha). The maximum average yield in 2016–2018 at the application of the herbicides – 0.92 t/ha – the crop formed at the application of Pulsar 40 with the rate of 1.0 L/ha (LSD_{05} A – 0.042 t/ha, B – 0.034 t/ha). The highest profitability – 415% – was obtained in the crop of annual white melilot variety Pivdennyi where Pulsar 40 herbicide was applied in the rate of 1.0 L/ha.

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Information about the author:
Vlashchuk A. M.,
Candidate (Ph.D.) of Agricultural Sciences, Senior Researcher,
Head of the Department of Primary and Elite Seed Growing,
Institute of Irrigated Agriculture
of the National Academy of Agrarian Sciences of Ukraine
Kherson, Naddnipryanske, 73483, Ukraine

NOTES

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