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ADAPTIVE POTENTIAL OF BUCKWHEAT TO ENVIRONMENTAL CONDITIONS AND WAYS OF INCREASING ITS ECOLOGICAL SUSTAINABILITY

Averchev O. V.

INTRODUCTION

The grain farming plays a key role in the economy of the state. In order to ensure the efficient functioning of the grain farming, it is important to fully meet the country's domestic grain requirements and increase its export potential. For Ukraine, increasing grain growing is of strategic importance for raising the national economy, since its successful development creates the conditions for the effective functioning of a number of related industries. Improving the efficiency of grain productivity is one of the most important tasks on which the food security of the country depends. It should be implemented both at the state and regional levels, where food supply issues are addressed[1].

Growing and consumption of cereal crops by the population of Ukraine is traditional. Cereals are an important component of the Ukrainians diet.

The main cereal crops grown in Ukraine are buckwheat, Panicum and rice. All of them are of Asian origin, but the first two can be confidently attributed to traditionally Slavic crops. In Tsarist Russia buckwheat and Panicum were sown no less than wheat, and buckwheat groats and millet occupied a significant place in the population's feeding and were perhaps the largest export items to other countries. Thus, in the beginning of the XIX century, over 4 million hectares were sown with buckwheat, which made 3/4 of its sowings in the world[2], and the share of Panicum in some regions was 40-80% of the total grain area[3].

Buckwheat has long been sown in Russia and Ukraine in both main and post-harvested sowings. It is also was sown as a replacement crop[4,5,6]. Back in

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[5] Аверчев О.В. Адаптивний потенціал проса, гречки та шляхи його підвищення / О.В. Аверчев, З.М. Тимофеєв // Таврійський науковий вісник: збірник наукових праць. – Вип. 24. – Херсон, 2002. – С. 36–41.

1913–1916, some biological features of buckwheat were presented, and the first studies on the intercrop of buckwheat in irrigated lands of southern Ukraine were conducted at the former Kherson Agricultural Research Station in 1924–1925 by Podgorny P.I.

Due to a number of biological features of buckwheat, the different response of this crops to the ecological factors that arise during the growing season are known, and as a result its yield greatly differs over the years.

Buckwheat – Fagopyrum esculentum Moench. (Synonyms: Fagopyrum fagopyrum (L.) Karst., Fagopyrum sagittatum Gilib., Fagopyrum vulgare Hill, Polygonum fagopyrum L.), belongs to the Polygonales, family Polygonacea, genus Fagopyrum P. Mill.

Until recently, two types of arable buckwheat (common buckwheat, Tatar buckwheat) and seven types of wild buckwheat were known. However, the collection is updated annually with new samples, and the updated classification of buckwheat testifies to the existence of 14 types of buckwheat[7].

Among all species, the main place takes common buckwheat. Currently, its geography includes Russia, Ukraine, Belarus, Kazakhstan, Serbia, Croatia, Poland, as well as Japan, China, Mongolia, Korea, USA, Canada, Bhutan and Brazil. In other countries, buckwheat is grown on small areas, mainly as a replacement crop or green manure crop; it is given less attention and often attributed to low-yielding cereals[8,9].

In fact, in terms of grain use in the national economy buckwheat is not inferior to the main cereal crops, and in some biochemical indicators and dietary characteristics buckwheat grain exceeds them. In addition, buckwheat products are environmentally friendly and low investment in production, which is of particular importance in the modern world[10,11].

Buckwheat in a role of intercrop is attributed to the environmentally friendly direction of intensification of agricultural production in Ukraine[12,13]. Thus, the word "green", which labels organic produce and

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[12] Крестьянникова Т.М. Пожнивное выращивание гречихи / Т.М. Крестьянникова / [Под ред. И.Н. Елагина] // Биология и возделывание гречихи. – М.: Сельхозиздат, 1962. – С. 273–302.

indicates its organic origin, is associated with a narrow range of crops, among which buckwheat is prominent[14].

Due to growing demand for eco grain and relatively increasing income, buckwheat displaced spring wheat in the United States[15,16], from year to year, as well as many other crops in crop rotation where buckwheat prevents the development of harmful organisms and contributes to clearing fields of weed. Thus, intercrops of buckwheat in Missouri (USA) provide more additional income than soybeans[17]. In the Czech Republic, the environmental and dietary properties of grain led to an increase in organic buckwheat production in 1997 (more than 200% compared to 1990), and in 1999, from the total harvest of 1,500 tons the share of organic buckwheat grain was 520 tons, and more than 30 types of products are produced from its grain[18]. Recently, buckwheat is in high demand in Japan, where at own production of 20 thousand tons of grain per year, it is consumed up to 110 thousand tons of grain so the rest is imported from China, the US and Canada. Buckwheat sowings are expanding in Australia, where new acreage is being planted in the south of the country. Thus, in 1995, its crops first appeared in the arid state of Victoria .

Considering the fact that the Steppe zone is too plowed (82.8%), including the Kherson region by 89.1%, and the area of arable land per capita in Ukraine is not increasing but decreasing, it becomes clear that production growth of crops can be achieved by growing two crops a year from the same area. It should be noted that even at a yield of 400–500 kg/ha, buckwheat covers all the costs of its growing[19]. Buckwheat is of particular relevance in irrigated areas where it is proven by practice that the agro-climatic resources of southern Ukraine completely satisfy the needs of buckwheat for the main factors of life.

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1. Buckwheat and heat

Although buckwheat is less demanding for heat than, for example, Panicum, it is attributed to thermophilic plants and an important factor in ensuring even sprouts is the absence of low temperatures during the initial growth period. It is known that the sprouts are damaged at a temperature of -2°C, and at -4°C sowings die completely. The cotyledonary leaves and the first real leaves are the most affected by frosts[20]. The crucial role of heat in the first days of life is indicated by the following: the minimum air temperature at 10°C and below during the germination of seeds determines the further growth and development of buckwheat plants.

Obtaining even sprouts also requires a certain soil temperature. The most favorable temperature for seed germination is 27ºC, although the soil temperature range is quite wide – from 7 to 40ºC. Thus Trigub O.V. found that the middle-ripe group is characterized by the highest thermo-resistance in the early stages of plant development, the late-ripening sea group of varieties has the lowest thermos-resistance.

Seed germination intensity and rapid emergence of seedlings are of particular importance to buckwheat, as indicated by the close correlation between germination energy and yield (r = 0.99–0.90)[21]. The future yield is also highly dependent on the success of the II-IV stages of organogenesis. If the optimal conditions are not created at these stages, including at the beginning of the first true leaf unfolding stage, even the most favorable conditions in the future cannot increase the yield[22].

According to the generalized data of some authors, the minimum temperature for germination of buckwheat seeds is 5-6°C, for emergence of seedlings – 8°C, and during the formation of generative organs, fruiting and ripening – 10-12°C.

After the appearance of the second pair of true leaves, buckwheat begins to grow vegetative mass. The growth of leaf surface takes 3-6 weeks. During this period (before the budding phase) buckwheat is less demanding for temperature due to slow growth. Under optimal conditions, flowering occurs on 17-22 days in the early-maturing varieties and 23–28 – in the

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middle-ripening varieties. From this moment, the growth and development of plants become faster[23].

With the onset of flowering, the generative period of plant development begins. During this period, most of the leaves and shoots and 3/4 of the organic matter crop are formed[24]. The process of flowering in buckwheat is extended over time and lasts 4–6 weeks depending on the group of ripeness of varieties and weather conditions. Flowering takes place not at the same time both within the plant and one truss. For example, flowers on one plant bloom for 30-60 days, on the truss – 10–15 days. At the time of bud formation and flowers blooming, when their pollination begins, there is another threat – dry air, which causes the plants to wither, even with sufficient moisture in the soil. Dry hot weather with a temperature of 25°C and higher during this period dries the anthers and causes "fervor" of the fruit-forming elements, as a result of which the grain is shrinked or not formed at all. It is set that under favorable conditions, buckwheat grain is formed 10 days after pollination, after which reserve oils, starch and protein are actively accumulated in the embryo and endosperm. After 20 days dry matter accumulation is completed, the water content in the endosperm decreases at a rate of 850 g/kg on 6th day, up to 220 g/kg on 16th day after pollination. Under unfavorable conditions, the endosperm does not develop and the weevil does not form, although the pericarp reaches normal dimensions of the ripe fruit[25].

The direct link between the high daytime temperatures during the buckwheat flowering-fruit formation period and damage of the fruit elements and ovaries has been extensively enlightened in different works. Scientists estimate that temperatures above 25°C significantly reduce fruit inception and grain yield. At the same time, it was found that the July temperature of 26°C and higher during 18 days causes a fervor and reduces the grain yield by 500–600 kg/ha, and not only the fertilized ovaries dry, but also green fruits. A number of authors also point to the "criticality" of the "flowering – fruit formation" period in relation to the thermal regime. Other scientists provide data on the inverse dependence of buckwheat crop on the temperature of the critical period (r = -0.33) and the close relationship with the temperature in the inter-phase period "flowering – ripening" (r = 0,86).

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[23] Аверчев А.В. Пайова участь досліджуваних факторів у врожайності гречки повторних посівів на зрошуваних землях півдня України / А.В.Аверчев, Ю.В. Аверчев // Збірник наукових праць Уманської державної академії. – Вип. 53. – Умань, 2001. – С. 40–43.

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The most favorable temperature for the formation of vegetative and generative organs ranges from 20–25ºC, during flowering period the need for buckwheat in heat is lower, and in the period of fruit-formation it is higher. The range from 17 to 21°C is considered to be the optimal daily temperatures for flowering.

According to many years of research by the Polish researcher Rushkowski M., at the end of flowering period of buckwheat, temperature should not exceed 17–19°C with precipitation amount 20–30 mm and humidity 50–60%, and in the period of ripening it should be 17–20°C with small precipitation.

Due to the fact that buckwheat actively grows and develops at an average daily temperature of 15–18°C – this is a condition for maximum and effective use of post-harvest heat before frosts.

The uneven flowering of buckwheat leads to the simultaneous ripening of the fruit. Thus, the first ripe fruit can crumble, and the plant continues to grow and forms new shoots, buds and flowers. Researchers have shown a high correlation between the average daily temperature during the period of "sowing – beginning of flowering" and the development of buckwheat plants (r^2 = 0.84) and low correlation between the average daily air temperature and ripening of grain (r^2 = 0.53). It confirms the aforementioned fact that both ripe fruits and flowers can be present on the plant at the same time. Thus, in the middle-ripe varieties the period of "flowering – fruit formation" lasts 30–45 days, "fruit formation – ripening" period lasts from 43–44 to 56 days depending on the air temperature, and seed formation (from the beginning of flowering until ripening the fruit) lasti at an average for 21–24 days. It should be noted that the early September frosts that occur in certain years at the end of the growing season in the southern regions can damage buckwheat tops and lead to brashy stalks, premature leaf fall and fruit crumble, especially in varieties with a long growing season.

Generally, the fruit formation takes 20 days, their harvesting take place on 20–25 days and after 10–12 days they have size typical for the variety. After 7–8 days middle dough stage comes[26,27].

A characteristic reaction of buckwheat plants to adverse thermal conditions is the ability to re-flowering and, accordingly, re-fruiting. This phenomenon is known as "multistory crop". It occurs mainly in the case of high temperatures of air and soil, but after the weakening of the stress factors buckwheat resumes flowering, fruiting and grain filling periods. As

[26] Аверчев О.В. Адаптивний потенціал проса, гречки та шляхи його підвищення / О.В. Аверчев, З.М. Тимофеєв // Таврійський науковий вісник: збірник наукових праць. – Вип. 24. – Херсон, 2002. – С. 36–41.

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Berestovsky G. G noted, buckwheat resumes flowering and fruiting, if it rains after the drought. Moreover, the quantity and quality of buckwheat grains are better than during the first-time harvest[28].

The need for heat for the buckwheat plant of 100 cm high, with 15leaves on the main stem and with 3-5 branches during the growing season is expressed by the sum of effective temperatures (above 5°C) 1200°C. Instead, other scientists say that for the "sprout – flowering" period of buckwheat the sum of effective temperatures above 5°C is 310°C, for the period of "flowering – ripening" – 429°C. And at separate phases of vegetation, the sum of active temperatures for the growth and development of buckwheat is: "sowing – sprouts" – 66–77°C, "sprouts – flowering" – 310–320°C, "flowering – ripening" – 420–489, from sowing to ripening – 796–888°C; for late varieties, this indicator rises to up 1300ºC. However, the required amount of active temperatures, which for buckwheat is 1000–1300°C, depending on the sowing time, varies slightly[29].

Concerning the intercrop, according to Populida K.H., favorable climatic conditions for buckwheat with a vegetation period of 70–90 days are created at the sum of temperatures of 1600°C. Studies have shown a direct relationship between fruit ripening and the sum of effective temperatures (r^2 = 0.93), as well as the relationship between temperature summation and the percentage of ripe grains, which is of some importance for determining the harvesting time.

In the zone of unstable moisture, the main factors affecting buckwheat productivity are the combination of heat and moisture, and the hydrothermal coefficient corresponding to the normal development of plants is 0.8.

2. Buckwheat and moisture

Buckwheat prefers moderate and humid climate, but due to a short growing season and high plasticity, it can be grown in a fairly wide range of climatic conditions. However, in summer sowings, in the conditions of the arid Steppe, the soil cap threatens future plants during seed germination, and soil cracking threatens during the emergence of seedlings. Therefore, air and soil moisture are a second vital factor for buckwheat. Thus, with enough soil moisture, post-harvest buckwheat sprouts appear after 3-5 days, and fast and even sprouts appear at 18% of soil moisture[30].

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[28] Калус Ю.А. Влияние условий выращивания и сортовых особенностей гречихи на ее урожай в южной степи Украины: автореф. дис. на соискание уч. степени канд. с.-х. наук: спец. 06.01.09 – растениеводство / Ю.А. Калус. – Одесса, 1973. – 12 с.

[29] Кадирова Ф.Е. Гречиха и просо – ценные крупяные культуры / Ф.Е. Кадирова // Земледелие. – № 3. – 2006. – С. 11.

[30] Ефименко Д.Я. Установление оптимальных сроков посева гречихи по уровню температурного режима почвы / Д.Я. Ефименко. – М.: ВДНХ СССР, 1988. – 6 с.

Kohut V. indicated on the close connection between soil moisture, heat and the buckwheat crop during separate periods. At the same time, it is set that for rapid emergence of buckwheat seedlings the moisture reserves in the 0–10 cm soil layer should be at least 10 mm at an air temperature not lower than 17 C. As the soil temperature and humidity increase, the period from sowing to germination is reduced, but with lower soil moisture, the temperature does not affect the seed germination rate. It should be noted that heavy and prolonged rainfalls, as well as excessive irrigation, are detrimental to young sprouts. Waterlogging leads to the lodging and shetter losses of grain in the second half of the growing season. Scientists believe that soil moisture within 90% of minimum moisture-holding capacity leads to a slowdown in growth processes. Maintaining soil moisture at 80% of minimum moisture holding capacity throughout the growing season provides the highest productivity of buckwheat. Other scientists say that it is necessary to maintain soil moisture at 70% of minimum moisture holding capacity in summer crops of buckwheat, which corresponds to the three irrigations[31].

A number of researchers point to the influence of soil moisture level on the growth and development of buckwheat plants in different phases of vegetation. The period from the beginning of fruit formation to their browning is called critical for moisture. Scientists believe that the optimum moisture level of the soil during the interphase period of "flowering-fruit formation", which coincides with the beginning of July and lasts until the end of August, guarantees a high yield. At the same time cool evening and night temperatures and high humidity provide the most favorable conditions for plant growth and grain filling.

Buckwheat belongs to water-loving crops: for germination of seeds it requires 45-50% of water by its weight, and for the formation of 100 kg of grain and straw plants need 42 000 kg/ha of water, while wheat requires 23 800 kg, and panicum – 230 kg. On the basis of experimental studies conducted in the Odessa region, water consumption for summer crop of buckwheat was 2250 m^3 and in dry years it increased to 3152 m^3, in wet it decreased to 1478 m^3. Moreover, water consumption is different in the periods of growth and development of plants and significantly depends on fertilizers and methods of buckwheat sowing[32].

The indicator of the water need for plants is usually the transpiration coefficient, which indicates the efficiency of use of moisture and the degree of plasticity to environmental conditions. Transpiration coefficient of buckwheat

[31] Кацов И.И. Роль агроклиматического фактора в реализации потенциала сорта Сумчанка / И.И.Кацов, В.М.Клюс, В.Г. Егоров // Зерновые культуры [Мат. I Межгос. конгр. производ. греч.]. – Спец. вып. № 2. – 1993. – С. 35–37.

[32] Аверчев О.В. Адаптивний потенціал проса, гречки та шляхи його підвищення / О.В. Аверчев, З.М. Тимофеєв // Таврійський науковий вісник: збірник наукових праць. – Вип. 24. – Херсон, 2002. – С. 36–41.

is relatively high – 541, while for panicum it ranges from 140 to 390, for corn – 140–350, for heard wheat – 300–526.[33] Moreover, with the application of complete mineral fertilizers, the transpiration coefficient is reduced to 70% compared to unfertilized crops, and in the morning and evening it rises to 700-1300. Scientists have also determined that the greatest water deficit is found in the late-riparian coastal group of varieties, the lowest – in the middle-ripe mountain group.

In addition, the researchers point out the relatively weak ability of the buckwheat root system to provide significant amount of tops with moisture, since the main mass of buckwheat roots is in a 10–12 cm layer of soil and its share is only 3% of the total weight of the plant. Due to this, buckwheat is not able to withstand drought in high summer temperatures, and this fact should be taken into account during choosing sowing dates. According to other data, buckwheat of summer crops is able to use soil moisture at a depth of 1.5 m.

The lack of moisture in the soil against the backdrop of air drought and temperatures above 30 C is particularly unfavorable for buckwheat. If hot dry wind occurs, in the course of two or three days the ovaries die off, the leaves lose their turgor, and their absorption of carbon dioxide is more than halved.

It should be noted that the steppe winds, especially in the easterly direction, are destructive not only during the flowers pollination, but also during ripening, when the buckwheat stems are tend to lodging and the fruits are tend to shattering. Because of this, the period from the plumpness to the browning of the grain is vulnerable to the adverse wind regime.

3. Buckwheat and light

Researchers refer buckwheat to moderately light-requiring plants. However, buckwheat plants do not tolerate shading, and flowers that have formed in cloudy weather are sterile and underdeveloped, and flowers that have formed in cloudless weather form a full grain[34].

However, opinions regarding the sensitivity of plants to the lasting light are divergent. Some authors tend to consider buckwheat a plant for a short day, at least they are sensitive to such conditions in the first 15 days after emergence. In a short day (8–12 hours), buckwheat plants bloom faster and ripe, branch more, but give way to growth and productivity of plants grown over a long day. Moreover, the decrease in productivity of such plants is often due to a decrease in their height and leafiness. Other researchers claim that buckwheat is a long-day plant and that optimum light conditions are created

[33] Аверчев А.В. Пайова участь досліджуваних факторів у врожайності гречки повторних посівів на зрошуваних землях півдня України / А.В.Аверчев, Ю.В. Аверчев // Збірник наукових праць Уманської державної академії. – Вип. 53. – Умань, 2001. – С. 40–43.

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for the light duration of 17–19 hours a day. However, Aufhammer W. draws attention to the ambiguity of such a statement. He believes that, for certain environmental factors, prolonged light can adversely affect plant development, and gives the data that duration of buckwheat flowering in conditions of a long day at high temperatures extended up to 180 days, and the plants did not bear fruit. Buckwheat study showed that at relatively low temperatures, high clouds and humidity during flowering, buckwheat yields were relatively high – from 600 to 1200 kg/ha[35].

The duration of sunlight has a significant effect on the buckwheat yield in certain periods of development: in the second and third decades of May, the first and second decades of June, the third decade of July and the second decade of August.

Researchers[36,37] believe that buckwheat response to light duration is neutral. The results of studies conducted in the Rostov region showed that the plasticity relative to light in buckwheat plants of summer crops is relatively high. Buckwheat grows well in both short-day and low-light conditions, as well as in long-day and high-light conditions, which allows it to be grown successfully in post-harvest sowings. In addition to this it was set that the short September days at the end of the post-harvest buckwheat vegetation have some effect on fruit ovaries, but contribute to more even ripening, and this offsets the potential yield losses[38,39].

4. Buckwheat and soil and nutrients

Buckwheat grows on different types of soil, but the most favorable of them are of light and medium mechanical composition. Heavy clay and submerged soil, with insufficient aeration, inhibiting the development of the buckwheat root system, are unusable. Although, there are evidences that buckwheat can normally develop in areas with 0.4–0.6 m of groundwater level.

Buckwheat shows better performance on poor soils rather than other crops. Fatyga J. also found that buckwheat grows well on soils with a pH of

[35] Аверчев О.В. Адаптивний потенціал проса, гречки та шляхи його підвищення / О.В. Аверчев, З.М. Тимофеєв // Таврійський науковий вісник: збірник наукових праць. – Вип. 24. – Херсон, 2002. – С. 36–41.

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5 because on such soils it does not respond to liming, and in acid resistance of soil buckwheat is similar to oats and potatoes. In addition, buckwheat does not respond to mineral fertilizers on acid soils. The optimum pH for buckwheat is in the range of 5–7, and soils with a pH of 5 and below should be lime[40].

Obendorf R.L., Slawinska I. express the opinion that the use of high nitrogen soils is inappropriate because buckwheat is relatively undemanding to the level of nutrition, but because of the considerable nutrient application in soil, it affects subsequent crop rotations. Thus, the application of nutrients with buckwheat grain at a yield of 13 kg/ha in the conditions of the state of Minnesota (USA) is: nitrogen – 10, phosphorus – 4 kg, potassium – 14 kg/ha, and at a yield of 22 kg/ha – 44,8, 22, 4 and 14.6 kg/ha, respectively, which corresponds to the application of it with sunflower seeds at an equivalent yield.

Buckwheat root system is characterized by intensive absorption of nutrients. Despite the fact that the buckwheat root system is twice less in length than in oats and 10 times smaller than in potatoes, the solubility of its roots compared to winter rye and spring wheat is 23 and 12 times higher, respectively. Thus, according to Marchuk I.U., in the first one and a half months after sowing, buckwheat absorbs more than half of the required amount of macroelements: 55–65% of nitrogen, 40-45% of phosphorus and 60-70% of potassium accumulate before the flowering phase in plants.

Despite the active absorption of nutrients from the soil, buckwheat plant is sensitive to the additional mineral elements. Perhaps the high buckwheat demand for nutrition is due to its inherent ability to form both vegetative and reproductive organs throughout the growing season. However, a number of researchers have concluded that buckwheat needs nitrogen nutrition first.

Thus, with the content of nitrogen of 8 mg/kg of soil, the yield of buckwheat increases, but with a further increase of nitrogen introduction (from 8 to 60 mg) it decreases. According to Anokhin A.N., high doses of nitrogen dramatically reduce plant resistance to lodging and reduce the nectar productivity of flowers, as well as provoke plant damage by botritis disease in late sowings[41].

Since nitrogen fertilizers are effective only when other elements are present in the soil, there is a need for other fertilizers. This pattern is particularly relevant for phosphorus fertilizers in the southern areas where soils are well supplied with potassium. Thus, Marchuk I.U., Moiseenko A.A., Naumkin V.N. believe that in the second half of the growing season (fruit formation and grain filling) buckwheat requires a large amount of phosphorus.

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Moreover, scientists are convinced of the need of their use in the same doses as for wheat. Pannikov V.D, Podvezko V.V., Ronsal G.A. indicate the positive effect of phosphorus fertilizers in the southern carbonate chernozem, southern chernozem and dark chestnut soils, bogara and other soils.

The presence of nitrogen fertilizers in buckwheat sowings enhances the individual efficiency of phosphorus and potassium. Moreover, the combination of nitrogen and phosphorus fertilizers can reduce the negative effects of extreme environmental factors. However, according to Tkalich I.D. research, nitrogen-phosphorus nutrition of post-harvested buckwheat, even at a low level, does not contribute to increasing its productivity, but only increases the cost and energy consumption of production. Instead, in the experiments of Averchev O.V. application of this rate of fertilizers ensured a maximum yield of buckwheat in the irrigated sowings of the Kherson region – 2050 kg/ha. And the share of nitrogen-phosphorus fertilizers $N_{45}P_{30}$ norm in the formation of buckwheat yield was key and it was 30–43%.

Existing data on the use of potash fertilizers under buckwheat are quite controversial. At the beginning of the last century, the works of Pryanishnikov D.N., Chirikov F.V. and other researchers found that potassium plants can absorb potassium from the mineral part of the soil – silicates and aluminosilicates, and not only its mobile forms, but also potassium in the crystal lattice. Low potassium efficiency on different types of soil or even its negative effect on buckwheat plants is indicated in a lot of works. The low impact of potash fertilizers in the conditions of dark-chestnut residual-saline soils of the Skadovsky region were discovered in the works of Ushkarenko V.O.

The application of complete fertilizer is considered more effective for buckwheat in all types of soils, however, most references refer to the Forest-steppe zone of Ukraine. Moreover, the greatest sensitivity of buckwheat is found on poor sod-podzol and light gray soils in conditions of sufficient moisture. Thus, complete mineral fertilizer provides grain yield increase in Lviv, Chernihiv, Rivne, Podillya, Vinnytsia, Sumy and Poltava regions.

CONCLUSIONS

Buckwheat is not demanding for growing conditions. This short-day crop responds to daylight savings in the second half of summer; it is a warm and light-loving plant, adapted to short-term droughts and moderate fertility soils. The realization of maximum productivity of cereal crops in specific growing conditions is ensured first of all by satisfying the basic agrobiological requirements of the crop. Due to this, increase of indicators, which are closely correlated with the yield, can be achieved by minimizing the effects of those factors that negatively affect the growth and development of plants in the respective phases of the growing season. Formation of these components requires the development of certain agrotechnical measures.

SUMMARY

The article deals with the issues of adaptive potential of buckwheat to environmental conditions. The reaction of buckwheat to the temperature and water regime is established. In the zone of unstable moisture, the main factors affecting buckwheat productivity are the combination of heat and moisture, and the hydrothermal coefficient corresponding to normal plant development is 0.8. The duration of sunlight has a significant effect on the buckwheat yield in certain periods of development: in the second and third decades of May, the first and second decades of June, the third decade of July and the second decade of August. The buckwheat relation to soil and nutrients are discussed. Buckwheat grows on different types of soil, but the most favorable of them are soils of light and medium mechanical composition. Heavy clayey and submerged soils with insufficient aeration that inhibit the development of the buckwheat root system are unsuitable, although there is evidence that buckwheat can develop normally in areas where groundwater levels are 0.4–0.6 m.

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THE DYNAMICS OF PLANTS WATER USE, OPTIMIZATION OF IRRIGATION REGIMES CONSIDERING REGIONAL NATURAL AND CLIMATIC CONDITIONS

Kokovikhin S. V.

INTRODUCTION

An important element in the formation of irrigation regime of crops is the total water use or the amount of water that is needed for plants during the vegetation period to obtain a planned yield in specific natural conditions under the optimization of all technological processes. Water use consists of the water expenses on plants transpiration, evaporation from soil surface and formation of biological mass. In addition, it is necessary to take into account the water use of plants for individual stretches of the vegetation period. The soil moisture expenditures for individual stretches of the vegetation period according to meliorative terminology are called the total evaporation[1,2,3].

Researches directed on the determination of differentiation zones of water-exchange of crops depending on different stages of growth and development, as well as abiotic and anthropogenic factors have a great theoretical and practical value. Firstly, the study of water use dynamics and the need for nutrients will allow to detect the means of influence on the water and nutrition soil regimes, to form the optimal model in the "Soil – atmosphere – plant" system, secondly, these experimental data could be used for the formation of irrigation regimes (regulation of irrigation, adjustment of calculated layer of soil, choice of irrigation method), forecasting the actual level of yield, establishing statistical relations between the intensity of productive process and content and allocation of the productive moisture storages, etc.[4].

In theoretical aspect, such an information is important for the determination of dynamics of the water regime in the system of functioning plant relations with the environment and the possibility of its regulation in

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various current hydro-thermal and agro-technological conditions. The applied nature of such materials is determined by the possibilities of their use for the substantiation of the calculated layer of soil, which is advisable to be humidified by vegetative watering at the minimization of gravitational expenditures of irrigation water and precipitation[5]. Besides, experimental data on the content in of nutrients and their dynamics in the soil depending on a complex of factors are required to be used for the optimization of fertilization system, improvement of economic efficiency and ecological status of agrocenoses.

1. The dynamic of water use by alfalfa and winter wheat depending on the conditions of vegetation, stages of development and conditions of humidification

The water use process in an open natural environment depends on many factors, the main of which is moisturizing of the surface itself and meteorological conditions: the intensity of solar radiation, air humidity and wind speed. The dependence of evaporation on the intensity of solar radiation is very complex. Rays of the sun are the source of those energy evaporation resources, without which it is almost impossible, since the evaporation of water requires near 600 calories of heat per 1 g of water[6].

Observation on the total water use by alfalfa of different years of use shows that the total water use is mainly determined by the level of water supply of the plants (Table 1).

It should be noted that in the non-irrigated variant in all the years it is less than in the irrigated ones and in humid 2004 year it exceeded other more arid years. Due to minor irrigation norms in the years of the research, increasing total water use in the humid year is observed and in the conduct of watering using various ways.

It should be emphasized that alfalfa plants, regardless on weather conditions and application of irrigation, used moisture efficiently from the second meter of the soil. This is testified by the difference between the indicators of the total water use of two-meter and meter soil layers, which in the non-irrigated variant is equal on the average to 402 m^3/ha, at the surface method of irrigation – 346 and at the overhead sprinkler irrigation – 289 m^3/ha, respectively. Total water consumption of alfalfa in the years of the research testifies to approximately the same share of soil moisture and precipitation in the non-irrigated variant.

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Table 1

Total water use of alfalfa of past years from different soil layers, m³/ha

Variant	Soil layer, cm	Year of research			Average
		2003	**2004**	**2005**	
Without irrigation	0 – 100	2893	4622	2525	3347
	0 – 200	2954	5238	3055	3749
Surface watering by strips	0 – 100	2711	6043	3340	4031
	0 – 200	3203	6218	3712	4378
Overhead sprinkler irrigation	0 – 100	3125	6014	3397	4179
	0 – 200	3225	6388	3789	4467
LSD_{05}, m^3/ha	0 – 100	97.9	115.0	87.3	–
	0 – 200	119.4	121.8	91.4	–

An important parameter for planning and operational management of irrigation regimes is the indicators of the daily use of moisture – yield evaporation or by the terminology accepted in the EU, USA, Canada, etc. – evapotranspiration[7,8] by the calendar dates of the vegetation period, as well as setting this indicator according to individual stages of plant development. This figure can be used to schedule the terms and norms of irrigation for crops. The average daily evaporation depends on many factors: the biological characteristics of crops, physical and mechanical properties of the soil, weather conditions, intensity of plant productive processes, agro-technological and meliorative measures, etc.[9].

The results of the research determined that the large influence on the indices of evapotranspiration have a stage of development of individual crops, which can be linked to certain calendar dates, taking into account regional soil and climatic conditions. Additionally, the evaporation indices are significantly affected by the groundwater level. The researches performed found out that

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the average daily evaporation of alfalfa of past years depends on the factors listed above (Table 2).

Table 2

The average daily evaporation of alfalfa of past years (considered) depending on the groundwater level, m^3/ha

Month	Decade	Groundwater level, M		
		More than 3.0	**2.0-2.5**	**1.0-1.5**
March	3	15.0	9.8	6.0
April	1	29.0	18.8	11.6
	2	22.9	14.9	9.2
	3	26.6	17.3	10.6
May	1	40.9	24.5	12.3
	2	40.5	24.3	12.2
	3	41.8	25.1	12.5
June	1	48.2	28.9	12.0
	2	41.3	24.8	10.3
	3	55.7	30.6	13.9
July	1	49.3	27.1	12.3
	2	51.9	28.5	13.0
	3	46.7	25.7	11.7
August	1	48.9	26.9	12.2
	2	43.1	23.7	10.8
	3	46.9	25.8	11.7
September	1	35.6	19.6	10.8
	2	32.1	17.7	9.6
	3	22.9	12.6	6.7
Average ($x_{av.} \pm s_d$)		38.9 ±2.6	22.5 ±1.3	11.0 ±0.5
Coefficient of variation (V),%		29.0	26.0	18.2
Confidence interval (*min-max*)		33.1 ÷ 44.7	19.4 ÷ 25.5	10.0 ÷ 12.1

The highest evaporation rates are fixed for deep (more than 3.0 m) level of groundwater occurrence in the third decade of June (55.7 m^3/ha per day), and also in the first and second decade of July (49.3-51.9 m^3/ha per day). As a result of the moisture requirements compensation due to the soil moisture, the minimum evapotranspiration is fixed under the medium (1.0-1.5 m) groundwater level, which in the same calendar dates averaged to 13.9, 12.3 and 13.0 m^3/ha per day, respectively.

Variable analysis proved the highest amplitude of alfalfa of past years evaporation fluctuations in the areas with deep occurrence of groundwater (confidence interval 33.1 ÷ 44.7 m^3/ha per day). The smallest variation factor (V = 18.2%) was observed in the areas with close groundwater level, testifying about their stabilizing effect.

Many studies have established that there are two large periods in the development of plants and water use in winter wheat: the first one – from the sprouts to the cessation of vegetation (with the termination of vegetation in winter); the second one is from the spring vegetation renewal and to full ripeness.

Scientific literature mainly provides information on the second period, but in some reports there are references and indicators of water use by plants from the sprouts to the winter period[10,11].

However, most researchers do not pay attention to the expenditures of water in winter wheat during the cessation of vegetation in the winter period, which is an important part of the water balance of the field occupied by this crop.

The aim of our research was to establish the dynamics of total water use and value of the evaporation of winter wheat under the optimum irrigation regime from different layers of soil depending on the stages of plant development, calendar dates and depth of groundwater.

During the years of observations, the average amount of precipitation in the periods was: sprouts – cessation of vegetation – 660 m^3/ha, cessation of vegetation – spring regrowth – 1140 m^3/ha, spring regrowth – full ripeness of grain – 1897 m^3/ha, on the whole from sprouts to full ripeness of grain – 3697 m^3/ha (Table 3). Analysis of the obtained experimental data on the use of moisture from different layers of the soil testifies that in the autumn and during the winter period of winter wheat development there is a gradual replenishment of water supplies in deep layers of the soil. The tendency to decrease in the rates of total water use from the soil layer 0-50 cm to the layer 0-200 cm is established. During the spring–summer vegetation, on the contrary, the total water use rates in these layers increased. The obtained data testify that in the spring and summer period the plants use water from the whole two-meter layer of the soil. In general, from sprouting to full ripeness of winter wheat, the active moisture exchange takes place in the range of the upper meter layer.

Comparison of the total water use of winter wheat field to the rainfall during the period from sprouting to full ripeness of grain allows determining water use deficit, which must be compensated through vegetative watering. The data provided in the table allows determining specific water use expenditures in the inter-stage periods. They show that during the winter period wheat crops lost about 700 m^3/ha of water, and the rainfall during the same time was 1140 m^3/ha. Consequently, owing to the winter period, the winter wheat field accumulates about 400-450 m^3/ha of soil moisture.

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Table 3

The dynamics of water expenditures by winter wheat crops for the stages of vegetation under the optimum irrigation, m³/ha

Soil layer, cm	Indicators							
	sprouting-cessation of vegetation		Cessation of vegetation – spring regrowth		Spring regrowth – full ripeness of grain		Total period sprouting – full ripeness of grain	
	Precipitation	Evapo transpiration	Precipitation	Evapo transpiration	Precipitation	Evapo transpiration	Precipitation	Evapo transpiration
0 – 50	660	590	1140	984	1897	3739	3697	5313
0 – 100		555		906		4070		5531
0 – 150		541		798		4174		5513
0 – 200		525		663		4227		5415
LSD_{05}	–	47.1	–	73.9	–	142.5	–	160.7

As for the spring-summer period of vegetation, there was the opposite trend marked – water expenditures for evapotranspiration, and therefore – to ensure the plants productivity processes, are 1.4-1.5 times higher than its income with of atmospheric precipitation. The shortage of available moisture, which was over the years of the research 1842-2330 m³/ha, should be eliminated by the vegetative watering.

In the experiment on optimizing productive processes of winter wheat by choosing the most effective types of irrigation during the regrowth of plants moisture storage in two-meter layer was (in % to the mass of dry soil): in the variant without pre-sowing irrigation – 18.7, with pre-sowing irrigation – 19.4%.

High initial moisture storage in two-meter soil layer, a significant amount of precipitation during the spring-summer vegetation, especially in humid years, positively affected the indices of total water use (Table 4).

On the average for two years, in the variants without irrigation and with one pre-sowing irrigation they were almost similar (3092 and 3175 m³/ha). Carrying out vegetative watering resulted in the increase of the total water use, but it was not equivalent to irrigation norm. It should be emphasized that the rates of total water use were determined by the conditions of the spring-summer vegetation period, especially in the variants without irrigation.

In the variant with pre-sowing and vegetative watering water consumption by the years averaged to 3788 and 3540 m^3/ha, respectively. In the balance of water use in all the studied variants on the average for two years the largest share belongs to the rainfall of the vegetation period (53-63%). Besides, in the variant with vegetative irrigation the percentage of soil water used decreases at the expense of them.

Table 4

Total water use and its balance depending on the conditions of water supply of winter wheat

Variant	Total water use, m^3/ha	Balance of water use from the soil layer 0-200 cm					
		Soil moisture		Precipitation		Irrigation	
		m^3/ha	%	m^3/ha	%	m^3/ha	%
Control (without irrigation)	3092	1132	37	1960	63	–	–
Pre-sowing irrigation	3176	1215	38	1960	62	–	–
Pre-sowing and vegetation irrigation	3664	904	25	1960	53	800	22
LSD_{05}, m^3/ha	164.2	51.8					

Table 5

Average daily evaporation of winter wheat depending on the groundwater level, m^3/ha

Month	Decade	Groundwater level, M		
		Over 3.0	2, 0-2, 5	1.0-1.5
March	2	18.7	18.7	16.8
	3	19.3	19.3	17.4
April	1	22.9	20.6	18.3
	2	28.9	26.0	23.1
	3	35.1	31.6	25.3
May	1	37.7	33.9	30.2
	2	40.0	36.0	32.0
	3	46.2	37.0	27.7
June	1	50.3	40.2	30.2
	2	35.7	28.6	21.4
	3	30.2	21.1	15.1
July	1	27.4	19.2	13.7
	2	28.0	19.8	14.0
Average ($x_{av.} \pm s_d$)		32.3±7.7	27.1±6.0	21.9±4.5
Coefficient of variation (*V*),%		85.6	80.0	73.2
Confidence interval (*min-max*)		15.1÷49.6	13.4÷40.6	11.9÷31.9

Winter wheat during the spring-summer period of vegetation used moisture differently by the stages of development depending on the conditions of water supply of the plants. On average by the years of the research in the variant with regular irrigation the average daily evaporation for inter-stage periods was: regrowth – tillering – 17.9 m^3/ha, tillering – earing – 50.8, earing – milk ripeness of grain – 44.1 m^3/ha and milk – full ripeness of grain – 12.6 m^3/ha. Despite the great amount of precipitation, especially in 2004, in the variant without irrigation the evaporation in the inter-stage periods "tillering – earing" and "earing – milk ripeness of grain were by 21.5 and 11.5 m^3/ha less than the indices in the watering plots.

Summarizing the results of the calculations, it is proved that the average daily evaporation of winter wheat depends on the calendar dates of the spring-summer period and on the groundwater level (Table 5).

The highest evapotranspiration (50.3 m^3/ha per day) was recorded in the first decade of June on the arrays with deep groundwater. The minimum evaporation values of 16.8-18.7 m^3/ha was at the beginning of regrowth in the second decade of March. On average for the spring and summer period daily water use decreased on the plots with the groundwater level of 2.0 m – by 16.1%, and at 1.0 m – by 32.2%, compared to the deep level of groundwater.

Statistical data processing determined very high amplitude of fluctuations in the studied indices – the coefficient of variation was 85.6, 80.0 and 73.2%, respectively. This testifies about the increased variability in the daily evaporation of winter wheat and determines the need for careful control of the availability of easily accessible water to ensure the optimum passing of the productive processes.

2. Study on the dynamics of water use of corn and soybean under their cultivation on the irrigated lands of southern steppe of Ukraine

The studies of the scientists[12,13,14,15,16] indicates the uneven spatial distribution of soil moisture by the surface of the field under the irrigation with large-scale sprinkler machinery and contains recommendations regarding

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the consideration of this inequality in irrigation scheduling to reduce the losses of yield and unproductive water expenditures.

The task of our study was to determine the spatial irregularity of soil moisture, average daily losses depending on natural and anthropogenic factors and to develop the optimized elements of corn cultivation technology.

On average by the years of the research in the non-irrigated variants the total water use was the minimum and averaged to 3293 m^3/ha. In the variants with irrigation, its parameters increased and averaged to (at the irrigation according to the scheme 60-80-60% FC) 4444 m^3/ha, and in the variants of irrigation regime of 80-80-80% FC – 4812 m^3/ha (Table 6).

Table 6

Total water use balance of the soil layer 0-200 cm, m^3/ha

Irrigation regimes,% FC	Indices			
	moisture used from the soil	Precipit ation	Irrigation norm	Total water use
Without irrigation	1003	2290	–	3293
60-80-60 FC	687	2290	1467	4444
80-80-80 FC	589	2290	1933	4812
LSD_{05}, m^3/ha	34.0	–	–	187.3

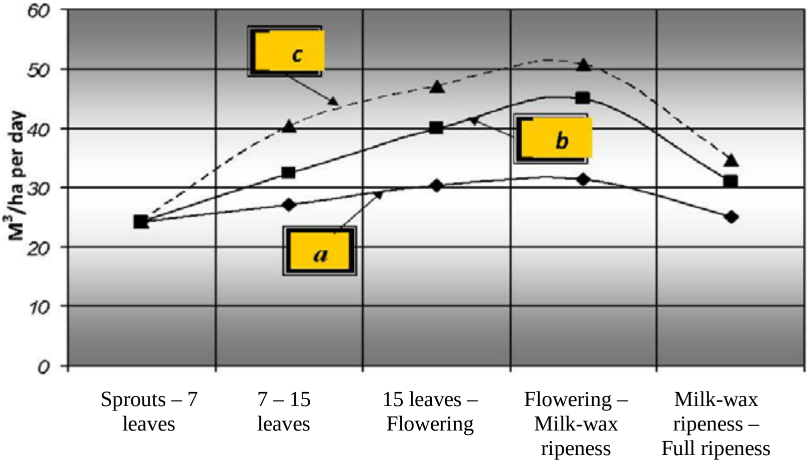

Fig. 1 Average daily evaporation by the inter-stage periods of self-pollinated lines of corn in the variants without irrigation (*a*), with irrigation 60-80-60% FC (*b*) and 80-80-80% FC (*c*)

The proportion of soil moisture in the balance of the total water use of unirrigated variants of the experiment is 30.6%, including the use from the second meter of the soil – 11.9%. In the irrigated variants, the share of soil moisture is much lower (12.2-18.4%) than in the rain-fed conditions, and the main water supply of the plants was formed by the rainfall and vegetation watering.

In our researches we determined the average daily evaporation by corn in different inter-stage periods. It was determined that at the beginning of the vegetation period (sprouts – 7 leaves) daily expenditures of soil moisture were the minimum and averaged to 24.2 m^3/ha (Fig. 1).

The maximum daily evaporation was in the period of "Flowering – Milk-wax ripeness" and averaged in the variants without irrigation to 31.5 m^3/ha, at the irrigation with 60-80-60% FC to 45.2 m^3/ha, at 80-80-80% FC – 50.8 m^3/ha. After the stage of milk-wax ripeness of grain there was a gradual decrease in this index.

Thus, the studies have shown that the greatest water use is in the period of "Flowering – Milk-wax ripeness of grain" that must be taken into account in the formation of the regimes of irrigation of corn hybridization plots. The average daily evaporation in the irrigated conditions increased depending on the irrigation regimes and stages of the plant development in 1.1-1.5 times compared to the non-irrigated plots.

It should be noted that there was no significant effect of growth regulators and plants density on the value of the indices of water use both in general and on the daily levels.

The results of the observations for initial soil moisture testify that in the spring at the beginning of the growing season there is a significant discrepancy in the magnitude of this index on the different fields of the irrigated crop rotation. Despite the leveling effect of precipitation of the autumn-winter period, the difference in productive moisture content on some fields of the crop rotation was from 73.2 to 323.3 m^3/ha, or 6.5-28.6%. We also recorded the variation in soil moisture by individual sections of irrigated array (Fig. 2).

The experimental data on the dynamics of water use the plants of self-pollinated lines of corn allowed setting the intensity of water expenditures from different layers of the soil by stages of growth and development of the plants, and also depending on hydrothermal peculiarities of the years. At the beginning of corn plant development (first 15-30 days of vegetation) water is most intensively used from the soil layer 0-30 cm, where the root system of the young plants is placed.

While on-surface organs growth and penetration of the root system water is mainly used from deeper layers of the soil. In the second month highly intensive use of water begins from the soil layer 0-50 cm, but in the dry years, this zone extends to the depth of 70 cm. In the second half of the vegetation period, non-irrigated corn uptakes water from deeper layers of the soil. It should be mentioned that the basic water-exchange zone does not go beyond 0-70 cm, but weather conditions of the growing season and especially precipitation, correct the areas of intensity of water consumption at different stages of the plant development.

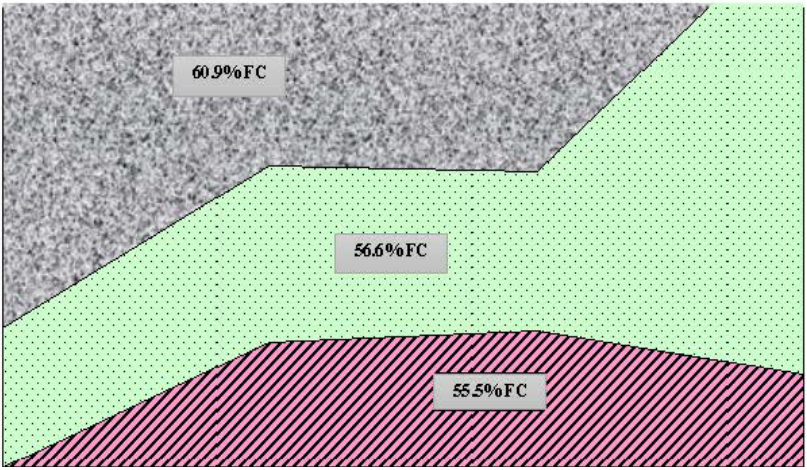

Fig. 2 Difference in soil moisture by individual plots of the field No. 3 of the irrigated areas of corn hybridization after harvesting in the soil layer 0-50 cm

It is noted that in the dry years there is a gradual increase of the soil layer from which the plants use water intensively. This regularity is also observed in the moderate by the deficit of evaporation years, but the zone of intensive water-exchange slightly changes, especially in the second half of vegetation. On the contrary, in humid years the intensive water requirements almost does not change and significant amount of precipitation promotes substantial replenishment of the contents of total and productive moisture.

Ranking the years of the study has shown that at the initial stages of growth and development of corn plants on the plots of hybridization average daily evaporation is insignificant (25.7-29.7 m^3/ha) and slightly depends on meteorological factors (the difference is only 4.1-13.4%). Further analysis of daily water expenditures by individual stages of the vegetation period revealed significant difference in this index, starting with the stage of 7-15 leaves depending on the level of both natural and artificial humidification.

The highest average daily evaporation during the vegetation period of self-pollinated lines is observed in the dry years and it was 40.2 m^3/ha, and the minimum (31.1 m^3/ha) – in humid ones. Regarding individual stages of development the maximum average daily evaporation (63.0 m^3/ha) was observed in the period "flowering – milk ripeness of grain" in the dry years, and the minimum (14.5 m^3/ha) it was in the humid years in the period from milk to full ripeness of grain.

Rapid increase in the indices of evapotranspiration was observed on the irrigated plots, especially in the dry and moderately humid years. Further (after the stage of 15 leaves) the expenditures of water increased and reached the maximum level in the period from flowering to milk ripeness of grain. Average daily evaporation of middle-late hybrids of corn is significantly dependent on the stages of the plants development (vegetation calendar dates) and the depth of groundwater (Table 7).

The maximum evapotranspiration of 59.6 m^3/ha per day was recorded in the second decade of July and coincides with the maximum intensity of plants productivity processes. The least daily water use (11.8-14.8 m^3/ha) was recorded at the beginning of the vegetation – a period of "sprouts – 3-5 leaves".

The variation analysis approved the maximum variability (*V* of 92.5, 84.9 and 75.8%, respectively) of the daily evaporation during the growing season, which predetermined the highest amplitude of confidence interval of this index – from 11.8 ÷ 32.8 (groundwater level of 1.0-1.5 m) to 15.3 ÷ 56.7 m^3/ha per day (at the deep groundwater level).

Table 7

Average daily evaporation of hybrids depending on the groundwater level, m^3/ha

Month	**Decade**	**Groundwater level, m**		
		More than 3.0	**2.0-2.5**	**1.0-1.5**
May	2	14.8	14.1	11.8
	3	17.6	16.7	14.1
June	1	25.4	24.1	20.3
	2	32.8	31.2	25.2
	3	37.9	36.0	30.3
July	1	48.4	36.3	26.6
	2	59.6	44.7	32.8
	3	55.2	41.4	30.4
August	1	49.2	36.9	27.1
	2	38.8	29.1	17.5
	3	32.2	24.2	17.7
September	1	29.0	21.8	16.0
	2	26.7	20.0	20.2
Average ($x_{av.} \pm s_d$)		36.0±9.2	29.0±6.8	22.3±4.7
Coefficient of variation (*V*),%		92.5	84.9	75.8
Confidence interval (*min-max*)		15.3÷56.7	13.6÷44.3	11.8÷32.8

Taking into account the difference in the growing season of corn hybrids of different ripening groups, we conducted ranking of total and daily evaporation rates depending on the FAO groups at the deep groundwater level (Table 8).

Through the accounting it was determined that the maximum expenditures regardless the group of ripening were observed in the second decade of July, but in the middle-late hybrids evapotranspiration was by 10.4% higher, and on average by the vegetation this difference decreased to 3.7%.

Statistical analysis found out almost identical coefficients of variations and confidence intervals, which reflect very high variability in water use of corn plants of different groups of ripening. Statistical analysis of perennial studies of the Institute of irrigated Agriculture of NAAS allowed constructing integral curves of yield evaporation from the soil layer 0-100 cm of different by a group of ripening soybean varieties (Fig. 5).

All the studied varieties demonstrated a rapid increase in daily evaporation, starting from 15 to 40 days of the growing season. It should be mentioned that in ultra-early varieties there was a decrease in this index, starting from the 53 day of the vegetation, and in the early and middle-ripening ones it was recorded only on the 58 and 64 day, respectively. According to the polynomial regression equations, indices of daily evaporation could be predicted in different by the ripening speed soybean varieties and they could be used to carry out operative control of the irrigation regime.

Systematization of total evaporation indices from the soil layer 0-100 cm of different by the ripening speed soybean varieties showed that this parameter increases from the ultra-early ripening varieties to the late ripening ones.

The study of the intensity of water use under the optimum irrigation regime revealed a clear tendency to the increase in the value of total and daily evaporation from dry years to humid ones. Data analysis discovered that water use of crops depends on the conditions of natural humidification and ranges from 3578-4421 m^3/ha in dry and moderate by the evaporation deficiency years, up to 4725-5860 m^3/ha – in moderately humid and humid years.

In dry and moderate years, there is a rapid increase in daily evaporation, starting from the first decade of July. Further, in dry years daily water expenditures are reduced from the first decade of August, and in the moderate years, on the contrary, at this period, the maximum value of this index (68.0 m^3/ha) is recorded. In the humid years there is a slight dynamics to an increase and decrease of daily evaporation by the decades of the growing season. The maximal average daily evaporation (more than 55 m^3/ha) is observed from the first decade of July. It dramatically increases in the moderate and dry years and remains high until the third decade of July – the first decade of August. In addition, the tendency to the increase in daily evaporation from humid years (29.8 m^3/ha) to dry ones (35.4-37.7 m^3/ha) was recorded.

Table 8

The total (E) and average daily $\overline{E}$ evaporation of different by the ripening period corn hybrids, m³/ha

Month	Decade	FAO 250-350 (middle-early and middle-ripening hybrids)		FAO 400-600 (Middle-late)	
		E	$\overline{E}$	***E***	$\overline{E}$
May	2	130	13.0	110	11.0
	3	174	15.8	190	17.2
June	1	224	22.4	255	25.5
	2	345	34.5	362	36.2
	3	462	46.2	368	36.8
July	1	469	46.9	481	48.1
	2	501	50.1	559	55.9
	3	518	47.1	536	48.9
August	1	426	42.6	462	46.2
	2	357	35.7	414	41.4
	3	285	28.5	354	35.4
September	1	231	23.1	300	30.0
	2	–	–	242	24.4
Average ($x_{av.} \pm s_d$)		343.5±109.5	33.8±9.0	356.4±109.0	35.1±9.0
Coefficient of variation (V),%		110.5	91.8	110.3	92.3
Confidence interval (*min-max*)		97.6÷589.4	13.7÷53.9	111.7÷601.1	15.0÷55.3

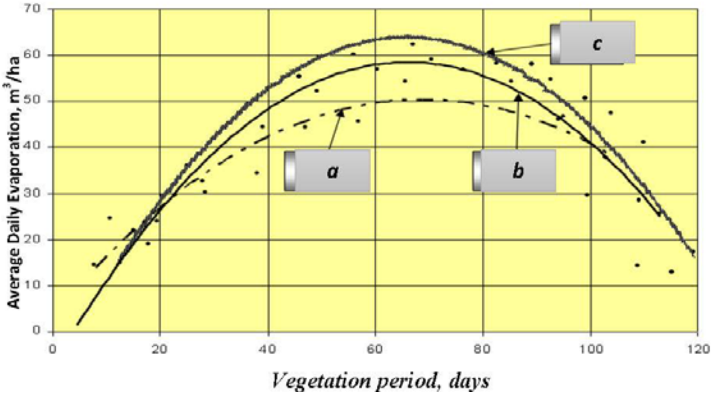

Fig. 3. Indices of daily evaporation of different by the ripening speed soybean varieties:

a – ultra-early ripening (y = – 0, 0091x^2+1, 456x – 10.232; r = 0.863; R^2 = 0.745);
b – early-ripening (y = – 0, 0156x^2+2, 265x – 20.458; r = 994; R^2 = 0.916)
c – middle-ripening (y = – 0, 0169x^2+2, 224x – 9.227; r = 994; R^2 = 0.963)

CONCLUSIONS

1. Alfalfa plants, regardless on weather conditions and application of irrigation, effectively used moisture from the second meter of the soil. The balance of total water use of alfalfa testifies about the same share of soil moisture and precipitation in the non-irrigated variant and significant reduction in their specific share on the irrigated areas. The highest indices of alfalfa evaporation are recorded at the deep groundwater level in the third decade of June. Variable analysis proved the highest amplitude of fluctuations in the daily evaporation of alfalfa of past years in the areas with deep groundwater level.

2. While determining the total water use of winter wheat we should consider the expenses of water for the period from cessation of vegetation in the winter to its regrowth in the spring, as well as the income of atmospheric precipitation during this period. The highest evapotranspiration (50.3 m^3/ha per day) was recorded in the first decade of June in the areas with deep groundwater level. On the average by the spring and summer period daily expenditures decreased in the areas with the groundwater level of 2.0-2.5 m by 16.1%, and at those ones with the groundwater level of 1.0-1.5 m – by 32.2%, compared with the deep level of their allocation.

3. The studies approved a significant difference in soil moisture content depending on the fore-crops, irrigation regimes etc. The differentiation of water content in the soil is also observed in individual areas of the field, and this is due to the differences in the relief of the location, unequal distribution of irrigation water by the irrigation machines, etc., which allows to recommend conducting planning of irrigation schedules for the local areas of individual fields within the crop rotation. Mathematical analysis found the indices of variations and confidence intervals almost identical, which reflect very high variability water use of corn plants.

4. The average daily evaporation varies by the periods of the development of soybean plants, at the beginning and at end of the vegetation it is the minimum – 19.3-33.6 m^3/ha, and the maximum values of the index are reached at the period from flowering to the beginning of ripeness of beans (44.1-63.4 m^3/ha). In dry and moderate years, a rapid increase in daily evaporation, starting from the first decade of July, is recorded.

SUMMARY

The article presents the results of the studies on the dynamics of water use by plants, optimization of irrigation regimes considering regional natural and climatic conditions. It was established that alfalfa, regardless on weather conditions and application of irrigation, effectively used moisture from the second meter of the soil. The balance of total water use of alfalfa testifies about the equal share of soil moisture and precipitation on the non-irrigated

variant and the significant decrease of their specific share on the irrigated plots. The highest indices of alfalfa evaporation are recorded at the deep groundwater level in the third decade of June. Variable analysis proved the highest amplitude of fluctuations of the daily evaporation of alfalfa of past years in the areas with the deep groundwater level. While determining the total water use of winter wheat we should consider the expenses of water for the period from cessation of vegetation in the winter to its regrowth in the spring, as well as the income of atmospheric precipitation during this period. It was proved that there is a differentiation in water content in the soil by individual sub-zones within the field, and this is explained by the variations in the relief of the location, uneven distribution of irrigation water by the sprinkler irrigation machines, etc., which allows to recommend scheduling irrigation regimes by the local areas of individual fields within the crop rotation. Mathematical analysis revealed almost identical indices of variations and confidence intervals, which reflect very high variability of water use of corn plants. The average daily evaporation is changed by the periods of soybean plants development, at the beginning and at the end of the vegetation it reaches the minimum, and the maximum values are recorded in the period from flowering to early ripeness of beans. In dry and moderate years, there is a rapid increase in daily evaporation, starting from the first decade of July.

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EFFICIENCY OF THE SYSTEMS OF BASIC TILLAGE IN THE CROP ROTATIONS ON THE IRRIGATED LANDS OF SOUTHERN STEPPE OF UKRAINE

Maliarchuk M. P.

INTRODUCTION

The Steppe natural and climatic zone occupies southern part of the territory of Ukraine. The area of agricultural land is 17.617 million ha, of which 14.848 million ha of arable land that is 84.28%.

In geomorphological relation the territory almost fully coincides with the Black Sea lowlands.

The surface of the Steppe zone is plain, uneven in genetic and structural relation. Its southern area is situated on the territory of the Black Sea lowlands and is a slightly divided, and to the East of the river Ingul flat, with a great number of closed lowerings, plain. To the South of the Black Sea lowlands it gradually transforms into low (150-300 m) Besarab, Podil, Dnipro and Azov rises.

The surface has general incline from the North (altitude of 150-170 m) to the South (altitude of 1-10 m). Plains are disrupted by river vales with terraces and right banks with a network of gulls.

Dominant rock in the Steppe is loess, the power of which changes from 1 to 30 m. They are heavy-clay by granulometric structure, lightly clay within the Black Sea lowlands, moderately-clay – on the Azov rise, moderately and lightly clay on the terraces of the vale.

Smooth plain relief favored to low erosion tension that provided for preservation of powerful, uniform on the great arrays clay loess cover.

The soil cover of water-dividing plateau of the Steppe on the loess rocks is represented by chernozem and chestnut soils[1].

Southern arid and Dry Steppe soil and ecological subzones of the Steppe zone occupy 5 million 761 thousand agricultural lands in five regions of Ukraine and Crimea, of which arable land occupies 4 million 507 thousand ha or 78.2%. The soil cover is represented by chernozem southern and chestnut soils. The main area of chernozem southern – 62.6% is occupied by model subtypes, 22.2% – micelle-carbonate, 15.1% – alkaline, 25% – eroded. The soils of the chestnut zone are divided into dark-chestnut and chestnut. The latter occupy a narrow strip along the Sivash with a total area of

[1] Класифікація ґрунтів України. К.: Аграрна наука, 2005. 299 с.

219.4 thousand ha. To the north of the chestnut soils are dark-chestnut soils with a total area of 1270 thousand ha.

Experimental field studies of the Institute of Irrigated Agriculture of NAAS were carried out in the Bilozerka natural-agricultural district of Kherson region in the zone of activity of the Ingulets irrigation system. The soil cover of the district is represented by dark-chestnut soils and their complexes with solonetz. They occupy 69.7% of arable land. The soils are characterized by a developed humus profile with a thickness of 52-58 cm, a low content of humus (1.9-2.7%), medium and heavy-loamy granulometric composition, deflation-safe, chemical and physical properties are satisfactory[2,3,4].

On the lands irrigated from the Dnipro estuary and the Ingulets River, secondary alkalination, places of salinization and flooding of the soils are manifested[5,6,7].

The territory of the district is located in northern part of the Black Sea lowland on the right bank of the Dnipro River within the Upper Pliocene terrace.

Geologically, the upper terraces are composed of four horizons of loess-loam thickness of 25-30 m, dissected by 2-3 horizons of buried soils. The forests are covered by red-brown clays that lie on Neogene Pontic lime stones. Sandy and clay deposits occur between lime stones and clays.

The soil of the experimental plot is a dark-chestnut middle-loamy secondary-alkaline silt-stone one. The granulometric composition of the studied soil is mainly represented by the large dust fraction (38.1% in the arable layer), so they are easily susceptible to erosion processes (Table 1).

Due to the fact that irrigation of the experimental plot was carried out by the waters of low mineralization with an unfavorable ratio of one – and divalent cations (irrigation waters of the Ingulets irrigation system according to the DSTU-2730-94 belong to the 2nd class – "limited suitable for irrigation"), there was observed an increased content of exchangeable sodium in the soil absorption complex of the arable layer at different systems of tillage.

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Table 1

Granulometric composition of the dark-chestnut soil of the experimental field of the Institute of Irrigated Agriculture of NAAS

Genetic horizon	Depth of sample taking, cm	Hygroscopic humidity, %	Fractions, mm						Sum of particles, mm	
			1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01	>0.01
H(e) arable	10-20	1.06	0.80	21.44	38.10	13.95	4.89	20.82	39.66	60.34
Hpi	35-45	1.10	0.16	17.74	41.84	11.59	5.85	22.82	40.26	59.74
Phi/к	48-52	1.08	0.25	7.94	40.59	14.26	10.07	26.89	51.22	48.78
Pi/к	55-65	1.08	0.32	8.74	30.72	15.90	11.60	32.72	60.22	39.78
P/к	70-80	1.07	0.40	7.10	31.20	16.20	12.20	32.90	61.30	38.70

Mineralization of irrigation water during vegetation period of 2019 fluctuated within 1.538-1.708 g/dm^3. The content of toxic salts in the equivalents of Chloride that is used to characterize quality of water by secondary salinization of soil, in average for the studied year was 11.47 meq/dm^3 that meets the requirements of the II class (limited suitable for irrigation). By the alkalination hazard and toxic effect on plants the irrigation water also belongs to this class. The pH value of the water is 8.5.

An Important criterion of irrigation water evaluation is a ratio of Calcium to Sodium, which was 0.31 in our study, which testifies about high activity of Sodium cations.

By the results of laboratory studies Chlorides and Sulphates are dominant anions, while Sodium and Magnesium are dominant cations. That means that chemical composition of the water is determined as Chloride-Sulphate Magnesium-Sodium (Table 2).

So, in accordance to the actual standard, the irrigation water belongs to II class, and it is limited suitable for irrigation by the risks of secondary salinization, alkalination and toxic effect on plants.

Analysis of the content of exchangeable cations of absorption complex at the end of vegetation testifies that the amount of exchangeable Sodium in the soil layer 0-40 cm increased at the expense of absorbed Calcium, the content of which relatively decreased (variant 1) under the plowless tillage methods by 1.52-3.03%, and under the plowing in differentiated soil tillage in the crop rotation (variant 5) – by 0.76%. At the tillage in the system of differentiated tillage within the crop rotation (variant 4) the content of $Ca^{2+}$was on the level with plowing (variant 1) and equaled to 13.2 or 67.4% from the sum of cations (Table 3).

Therefore, irrigation with water of high mineralization with unfavorable ratio of mono- and bi- valent cations leads to changes in qualitative composition of soil absorption complex at the end of crops vegetation, where alkaline leaching of Calcium from soil was observed, accompanied by an increase in share of exchangeable Sodium and resulted in development of irrigation salinization of soil.

Soil alkalinity determines unsatisfactory water-physical properties of the arable layer. The low content of water-resistant aggregates in the arable layer of the soil complicates its cultivation in the dry conditions. Under irrigation, the surface layer over-crusts, which impedes the penetration of water into the deeper horizons of the soil. The condition of the physical maturity of the alkaline soil, which determines its suitability for cultivation in the spring, is delayed, and after cultivation – lumpy surface is formed. The clods in the dry state are strong, difficult to cultivate, in addition, in such soils at the depth of 30-35 cm, a compacted illuvial layer is formed, which impedes the penetration into the deeper layers not only for water but also for the root system of plants. Thus, dark-chestnut soils under the irrigation with the waters of the Ingulets Irrigation System require anti-erosion measures and the development and improvement of their tillage with accordance to the certain conditions of the area.

Thus, the dark-chestnut secondary-alkaline and chernozem southern moderately-washed soils by physical, chemical and physic-chemical properties are typical soils of the meliorated agro-landscapes of Southern Steppe of Ukraine.

On the central experimental base of the Institute of Irrigated Agriculture of NAAS, a study devoted to the determination

Table 2

Irrigation evaluation of the irrigation water of the Ingulets irrigation system in 2019

Mineralization, g/dm^3	pH	Concentration of toxic ions in eCl^-, meq/dm^3	$\frac{100\,Na^+}{Ca^{2+}+Mg^{2+}+Na^+}$	$\frac{Mg^{2+}}{Ca^{2+}}$	$\frac{Ca^{2+}}{Na^+}$	Вміст іонів, мекв/дм^3			Клас води за небезпекою (ДСТУ-2730-15)			
						CO_3^-	HCO_3^-	Cl^-	salinization	Sodium hazard	alkalination	toxic effect on plants
1.623	8.5	11,47	46.2	1.6	0.31		2.77	11.79	II	II	II	II

of the impact of basic tillage systems on agro physical, chemical and biological soil properties, phytosanitary conditions of crops, yields and productivity of various types of irrigated and non-irrigated crop rotations have been started since 1966.

Approbation of scientific developments and their improvement for the concrete regional conditions was carried out in research and basic farms of the Institute of Irrigated Agriculture of NAAS.

Introduction in production of prospective tillage systems in crop rotations in regard to ecological and technological classification of lands and their melìorative conditions was conducted on the irrigated lands of Kherson, Zaporizhzhia, Odesa, Mykolaiv, Dnipropetrovsk regions.

Table 3

The content of exchangeable cations in the soil layer 0-40 cm at different systems of basic tillage within the crop rotation on the Ingulets irrigation system (start of vegetation)

Variant No.	System of basic tillage	Content of exchangeable cations, meq/100 g of soil			Sum of exchangeable cations, meq/ 100 g of soil	% from the sum of cations		
		Ca^{2+}	Mg^{2+}	Na^{+}		Ca^{2+}	Mg^{2+}	Na^{+}
No fertilizers								
1	Полицева	13.2	5.6	0.48	19.3	68.5	29.0	2.5
2	Безполицева – 1	13.0	5.7	0.59	19.3	67.4	29.5	3.1
3	Безполицева – 2	12.8	5.9	0.65	19.4	66.1	30.5	3.4
4	Диференційована-1	13.2	5.5	0.46	19.2	68.9	28.7	2.4
5	Диференційована-2	13.1	5.7	0.60	19.4	67.5	29.4	3.1

LSD_{05}, meq/100 g of soil: 0.03 0.02 0.006

Efficiency of ways and systems of tillage in crop rotations on the irrigated lands

Irrigation is the most effective measure to counteract the increasing aridity of climate, especially in southern part of the Steppe zone. Approaches to tillage in crop rotations on the irrigated lands differ significantly from those on the non-irrigated ones, and they are directed to the improvement of the water regime and ensuring ecological safety at the realization of the natural and climatic potential of the region and genetically determined productivity of varieties and hybrids of crops[8,9].

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Fruit-changing and row crop rotations forenterprises with developed dairy and beef cattle

Fruit-changing. Combination for a long time in fruit-changing crop rotation with the coefficient of use of irrigated arable land of 1.25 of the deep plow tillage under the row crops – corn for grain and silage, sugar and forage beetroots, soybean, vegetable crops and alfalfa, with shallow (12-14 cm) disk loosening under the cereals – winter wheat, winter barley, winter rye and surface (6-8 cm) or sowing in the previously untilled soil in the post-harvest and post-mowing terms promoted nitrogen mobilization to a greater extent than the long-termed plowless tillage. At the differentiated system of tillage in crop rotation in comparison to the plowless shallow single-depth one (12-14 cm) the bulk density decreased by 6.3%, the water permeability increased from 1.68 to 2.28 mm/min. (35.7%), the content of waterproof units increased by 9.2%.

Wrapping of plant residues or manure under plowing into the lower part of the cultivated layer in this crop rotation provided a higher level of humification process than introducing fresh organic matter into the top (0-15 cm) soil layer under plowless tillage systems, as evidenced by the results of the long-term experimental researches.

In the 8-field grain-herb-row crop rotation on the background of generally accepted irrigation regimes and organo-mineral fertilization system with the application of $N_{180}P_{120}$ and 15 tons of semi-rotten manure per 1 ha of the crop rotation contributed to the average annual increase of humus at the level of 1.28-1.57 t/ha, whereas at the long-term use (1976–2006) of the system of single-depth shallow tillage in the crop rotation the accumulation was only 0.85 t/ha [10] [11] [12].

The results of the studies, obtained in the first rotation (1966–1976) of fruit-changing crop rotation on the dark-chestnut irrigated middle-loamy soil, indicate that for 10 years of irrigation with the use of five tillage systems with a rotation of the slice to the depth of 20-22 to 38- 40 cm there was an increase in the content of organic matter in the soil layer of 0-40 cm to 111.4-111.8 t/ha with the content of 1.97%, i.e. the average annual increase averaged to 0.71-0.75 t/ha.

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In the next decade (1976-1986) along with systems of plow tillage we studied less energy consuming plowless tillage systems differentiated by the methods and depth. Irrigation regime, fertilization system and cultivation technologies remained unchanged. Humus content determination in the autumn of 1986 revealed that its content in the layer 0-40 cm increased in the variants of long-term differentiated by depth plowing, differentiated plowless tillage, and in the variants, where during the crop rotation plowing was interchanged with flat-cut surface and chisel tillage with one or two slotting per rotation. In the variant with plowless shallow single-depth tillage a decrease in the humus content from 111.7 to 109.8 t/ha was fixed. At the differentiated by depth plowing annual increase was 0.8 t, at surface plowless tillage – 0.67 t, at differentiated tillage with one slotting – 0.82 t, and with slotting two times – 0.84 t/ha. In the variant with plowless shallow single-depth tillage the humus content decreased annually by 0.19 t/ha, mainly in the soil layer 20-40 cm.

Determination of the humus content at the end of the third crop rotation period (1996) revealed a significant difference between the studied tillage systems. At the long-term differentiated by depth plowing the humus content in the layer 0-40 cm increased to 132.0 t/ha, that is the average annual increase was 1.25 t/ha of the area of the crop rotation. Differentiated plowless tillage provided the annual increase of the humus content by 0.2 t/ha lower than on the control, and its total content in the layer 0-40 cm was lower by 3 t because of less accumulation during the years of the second rotation. Single-depth shallow plowless tillage (variant 3) was also favorable for the humus accumulation. Annual average increase in the variant was 0.12 t/ha in the years of the third rotation with the total amounts of 111.0 t/ha in the layer 0-40 cm. At the differentiated by depth systems of tillage (variants 4, 5) the humus content was 131.0 and 126.0 t/ha, respectively, with the annual increase of 1.1 and 0.8 t/ha.

During the fourth crop rotation (1997-2006) the tendency in the accumulation and distribution of organic matter, that was observed during the previous years of the study by the systems of tillage, saved, at the same time, the increase tempo grew lower, in particular, at the single-depth shallow plowless tillage (variant 3) it was 0.8 t/ha. At the differentiated by depth plow and plowless systems of tillage it was, respectively, 1.57 and 1.14 t/ha. Higher tempo of humus accumulation in comparison to plowless tillage (1.28 t/ha) remained in the variant with differentiated tillage including one slotting per the rotation. During the fifth rotation (2007-2016), alfalfa and multicomponent herb mixtures for green manure in the post-harvest period were excluded from the crop rotation, and the entire leaf-stem mass of the crop rotation was used for fertilization. As a result, the tempo of humus accumulation over this 10-year time span decreased in all the variants of the experiment and averaged to 0.1-0.3 t/ha, with the highest rate in the variant of the differentiated basic tillage system, where differentiated by depth plowless methods are inter-changed with one slotting for the crop rotation on the depth of 38-40 cm during the rotation (Fig. 1).

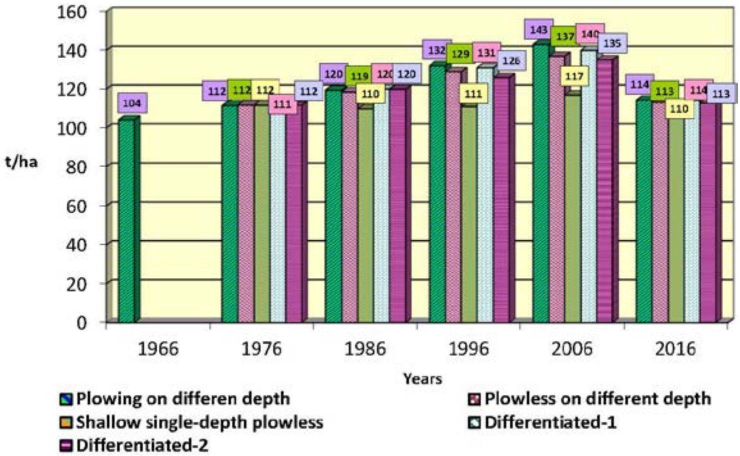

Fig. 1 Dynamics of the humus content in the 0-40 cm layer of dark-chestnut soil under different systems of basic tillage in 8-field fruit-changing irrigated crop rotation for the period of 1966-2016, t/ha

In general, experimental studies of the efficiency of different systems of basic tillage of dark-chestnut soil provided the possibility to find out that the highest productivity of the eight-crop fruit-changing rotation is provided by the differentiated system of basic tillage, in which the plowing to the depth of 20-22 to 30-32 cm under the row crops inter-changes with plowless tillage to the depth of 12-16 cm under winter wheat and spring barley on the background of one slotting (38-40 cm) for the rotation under barley with alfalfa.

The use of the differentiated basic tillage system, at the insignificant decrease in the cultivation technologies expenditures, increased the cost recovery by 9.4% due to the increase in the crop rotation productivity up to 13.0 t/ha of forage units against 11.5 t/ha of forage units at the plowless single-depth shallow (12-14 cm) system of basic tillage (Table 4).

Row forage. The increase of the coefficient of arable land use in the irrigated crop rotations up to 1.75 at the expense of inter-crops in early spring, post-mowing and post-harvest periods makes it possible to increase the efficiency of irrigated hectare and to obtain more products at the same costs for the construction of irrigation network and its exploitation, as well as provides additional accumulation of organic matter, which improves the physical and chemical properties of the soil and activates beneficial microorganisms activity. Owing to inter-crops of leguminous and cabbage crops, nitrogen reserves are increasing, and the weediness of the following crops is reduced.

In the arable soil layer, after sowing of the inter-crops, where the recommended irrigation regime has been maintained, there is sufficient water for its qualitative preparation to sowing. The decisive value for the crops cultivation in the post-mowing and post-harvest periods is not the depth, but the quality of pre-sowing tillage, that is, good seed wrapping and sufficient compaction of the seed bed for better provision with water of the crops with large seeds.

Taking into account that their growth and development is limited in time, it is advisable to observe these conditions. Compliance with the necessary agrotechnical requirements enables the use of combined tillage aggregates for simultaneous tillage, sowing and rolling.

As a result of the introduction of differentiated system of basic tillage in the 4-field row crop rotation with the coefficient of use of irrigated arable land of 1.75, the high efficiency of its saturation with early spring, post-mowing and post-harvest crops has been established.

Table 4

Productivity of 8-field fruit-changing crop rotation at irrigation under the different systems of basic tillage of dark-chestnut soil of the experimental field of the Institute of Irrigated Agriculture of NAAS

Crop of the rotation	**Productivity by the systems, t/ha of forage units**				
	1	**2**	**3**	**4**	**5**
Annual crops for green forage+alfalfa (hay)	13.6	13.1	12.3	13.6	13.2
Alfalfa of the 2nd year (hay)	12.1	12.1	12.2	12.0	12.1
Alfalfa of the 3nd year (hay)	9.8	8.4	8.4	9.7	8.3
Winter wheat+post-harvest (grain+green mass)	$\frac{6,9}{39,2}$	$\frac{71,5}{402}$	$\frac{70,8}{376}$	$\frac{71,2}{400}$	$\frac{70,3}{399}$
Sugar-beet	6.6	5.9	5.5	6.9	6.6
Corn for silage	45.6	42.3	38.3	46.6	47.1
Winter wheat+post-harvest (grain+green mass)	$\frac{65,9}{492}$	$\frac{70,2}{517}$	$\frac{72,9}{505}$	$\frac{68,3}{499}$	$\frac{67,1}{482}$
Grain corn	8.9	7.7	7.5	9.1	8.7
Crop rotation productivity, forage units	12.8	11.8	11.5	13.0	12.6

Note: 1-plowing at different depth, 2-plowless at different depth, 3-shallow single-depth plowless, 4-differentiated-1 with plowing under the row crops and one slotting per rotation, 5-differentiated-2 with plowing under the row crops

The loosening effect of the root system, the protective effect of the vegetative mass of plants in the spring and summer period and the effect of post-harvest residues of inter-crops, directed to the soil improvement, contributed to the reduction of the bulk density of dark-chestnut soil in the layer of 0-30 cm from 1.28 to 1.14-1.19 g/cm^3, or 11.0-8.0% to the optimum values for cereals and row crops.

The highest yield, and correspondingly, the productivity of the crop rotation, was provided by the differentiated tillage, in which the deep plowing under sugar-beet inter-changes with the plowless shallow and surface tillage for intermediate early spring mixtures, winter barley, post-mowing crops of grain corn and sunflower, with sowing of corn for forage in the previously unprepared soil after winter barley (Table 5).

Table 5

Productivity of 4-field row forage crop rotation at irrigation under the different methods of basic tillage of dark-chestnut soil of the experimental field of the Institute of Irrigated Agriculture of NAAS

Field	Crop	Productivity by the systems, t/ha				LSD_{05}, t/ha
		1	2	3	4	
1	Annual herb mixtures	32.4	33.9	33.9	34.5	2.9
	Post-mowing sunflower (seed)	3.0	2.8	3.0	3.2	0.24
2	Annual herb mixtures	31.1	31.4	32.3	32.5	2.6
	Post-mowing corn for forage	38.9	40.6	42.6	40.9	3.0
3	Winter barley (grain)	4.2	4.4	4.4	4.2	0.3
	Post-harvest corn for green forage	37.5	41.1	40.8	39.3	3.0
4	Sugar-beet	52.0	53.3	56.1	55.8	3.6
	Crop rotation productivity, t/ha of forage units	13.8	14.24	14.7	14.6	-

Note: 1-plowing at different depth, 2-plowless at different depth, 3-differentiated with slotting, 4-differentiated with plowing under the row crops.

Row crop rotations for the enterprises working for the industrial processing

Row short crop rotations. During 2007-2019, on the background of continuous application of five basic tillage systems and three organo-mineral fertilizer systems, using as the fertilizer of leaf-stem mass of the crops of the crop rotation, the least experimentally studied and scientifically substantiated row crop rotations were investigated, which were found at the enterprises specializing in the production of cereals and industrial crops for industrial processing. Today, among the total are of the irrigated lands of 510 thousand ha, 265 thousand ha are covered by the row crops, which is 52.0%.

In these newly established large-scale enterprises, where there is no livestock industry, short crop rotations with soybean, corn for grain and sunflower have the priority. Cereal and perennial herbs are not usually cultivated there, they occupy just about 10-15% of the croplands.

Crops, which are the part of row crop rotations, have different requirements for agro-physical properties and nutritional regimes, which are formed mainly under the influence of basic tillage and fertilization systems.

Nowadays, leaf-stem and root post-harvest residues of crops are the main source of fresh organic matter for the soil, which under the activity of microorganisms; oxidation and polymerization processes are transformed into new substances that are contained neither in the input organic residues, nor in microorganisms. According to the results of the research, it is established that on the non-fertilized background every year 4.0 to 4.8 tons of post-harvest residues are incorporated into the soil per 1 ha of the crop rotation area, on the background – $N_{82.5}P_{60}$ from 7.4 to 8.3 tons, and on the background of $N_{120}P_{60}$ application from 7.5 to 9.4 t/ha.

Calculations of humus income into the soil from incorporated post-harvest residues under the different basic tillage systems and nutrition background indicate that a negative humus balance is formed for all tillage systems, while the highest values were at plowless single-depth shallow – 0.33 t/ha and the smallest – 0.16 t/ha for the differentiated-1 tillage with slotting on the depth of 38-40 cm once per rotation.

On the fertilized backgrounds with the application of $N_{82.5}P_{60}$ and $N_{120}P_{60}$ there was an increase in humus content. In the variants of multi-depth plow and differentiated-1 systems of the basic tillage, the increase of humus content was+0.78 t/ha, while under the plowless on different depth it was lower by 14.1% and was+0.68 t/ha.

At the systems of single-depth shallow plowless tillage and the differentiated-2, the humus content increase was also positive, while it was lower in comparison to the control (differentiated plowing) by 51.3 and 38.5%, respectively, at+0.38 and+0.48 t/ha.

To compensate the uptake of mineral nutrients with the crops, there was an input of total nitrogen, phosphorus and potassium into the soil with root and leaf residues. Thus, on a non-fertilized background, with basic plow tillage on the different depth (control), there was an income to the soil of N – 21.8; P_2O_5 – 10.9; K_2O – 26.7 kg, and for the differentiated -1 with one slotting on 38-40 cm for the rotation – N – 22 kg; P_2O_5 – 11.0; K_2O – 26.4 kg per hectare of the crop rotation area. A similar tendency was observed on the fertilized backgrounds, while at the same time the indexes of mineral nutrition income were significantly higher.

At the application of the dose of $N_{82.5}P_{60}$, the income of nitrogen, phosphorus and potassium into the soil with plant residues was 70-80% higher than on the non-fertilized background.

Nitrogen, phosphorus and potassium income into the soil at the doses of $N_{120}P_{60}$ application averaged at the plow tillage on different depth to, respectively: N – 42.6 kg/ha; P_2O_5 – 21.3 and K_2O – 51.1 kg/ha, that is 91.4-95.4% more than in the non-fertilized background (control).

At the multi-depth plowless and differentiated-1 systems of the basic tillage, the reduction of mineral nutrition inputs in comparison to the control was not significant and averaged to 1.8%, 1.5 and 1.7%.

Only under the system of single-depth shallow plowless tillage with its long application in the crop rotation and on all the fertilization backgrounds, there was a significant decrease in the income of all mineral nutrients in comparison to the system of plow tillage on different depth.

In general, the application of mineral fertilizers and the use of post-harvest (leaf and stem) residues as fertilizers contributed to the creation of different levels of content of available forms of mineral nutrients at the beginning of the spring regrowth of winter crops and emergence of spring cereals and industrial crops seedlings.

At the non-fertilized background with the use of post-harvest residues as a fertilizer at the beginning of vegetation of the crops of the crop rotation, the highest content of mobile mineral nutrition compounds was in the variant of the plowing basic tillage system: nitrates 29.8 mg/kg of soil, mobile phosphorus of 31.8 and exchangeable potassium of 289 mg/kg of soil.

The application of mineral fertilizers with the dose of $N_{82.5}P_{60}$ ensured the increase in the content of all the elements of mineral nutrition, while at the same time the advantage remained at the system of differentiated by the depth plowing.

The highest nitrate content of 68.4 mg/kg of soil, mobile phosphorus of 46.4 and exchangeable potassium of 358 mg/kg of soil was formed under the application of mineral fertilizers with the dose of $N_{120}P_{60}$ per hectare of the crop rotation area under the multi-depth plow system of tillage.

Multi-depth plowless and differentiated tillage systems provided close performance with the multi-depth plow tillage system, and only the single-depth shallow plowless loosening system led to a significant decrease in the content of available mineral nutrients in the soil layer of 0-40 cm at the beginning of the spring vegetation of the crops of the rotation.

Before the harvesting, the nitrate content of the soil decreased on all the nutritional backgrounds, while at the same time the smallest indexes were on the non-fertilized background.

It should be mentioned that the basic tillage affected the content of mobile phosphorus and exchangeable potassium. It was the lowest at the plowless shallow single-depth tillage and reached 27.9-38.3 and 259-315 mg/kg at the beginning of the growing season and 18.7-21.9 and 214-254 mg/kg of the soil, respectively, before the harvesting. Before the harvesting, their content reduced and remained within the range of moderate supply.

Analyzing the crop productivity data in the crop rotation on the non-fertilized background it was found that its highest values, expressed in the grain units per 1 ha of the crop rotation area, were obtained at the plowing tillage on the different depth – 4.00, and differentiated-1 – 4.35 t/ha of grain units.

Under the use of the different-depth plowless tillage and the differentiated-2 basic tillage, slightly lower yields of grain units of 3.74 and 3.60 t/ha were obtained. A significant decrease in productivity by 30.7 and 32.5% in comparison to the control was observed in the variant of shallow single-depth plowless tillage.

The productivity of the crops by the variants of the ways and depth of the basic tillage at the application of mineral fertilizers with the dose of $N_{82.5}P_{60}$ increased to 116.2%, and the increase of the dose of fertilizers to $N_{120}P_{60}$ ensured its raise to 140.8%, compared to the non-fertilized backgrounds.

The increase of the dose of mineral fertilizers on the background with the application of $N_{120}P_{60}$ was favorable for the growth of productivity by 16.0% of grain units in comparison to the $N_{82.5}P_{60}$ nutritive background.

Analyzing productivity of the crop rotation by the yield of grain units per hectare of the crop rotation by the backgrounds of mineral nutrition it is necessary to note that the highest out pay of fertilizers was at plow and plowless tillage on different depth and differentiated-1 tillage and was, respectively, 27.7-29.0; 27.3-28.2 and 30.2-30.3 kg/kg of a.s.

At the shallow single-depth and differentiated-2 tillage it fluctuated within 20.6 to 21.3 kg/kg of a.s., respectively. Increasing the dose of fertilizers from $N_{82.5}P_{60}$ to $N_{120}P_{60}$ provided the increase in fertilizers out pay by 1.3 kg/kg of a.s. at plow tillage on different depth.

Main agrotechnical measure, on which crop cultivation technologies are based, is basic tillage, which is conducted on the maximum depth. In the structure of the expenditures for cultivation its share varies from 2 to 10%, while at the same time it largely depends on the productivity of most crops on irrigated lands. Assessing the effectiveness of low-cost, shallow and multi-depth soil tillage systems in the crop rotation, it should be noted that having provided significant cost savings for their implementation, they have little impact on the overall expenditures for crop production on the whole. So, if on a non-fertilized background at the systems of different-depth plowing basic tillage (control), the expenditures for cultivation technology averaged to 9.6 thousand UAH per hectare of the crop rotation area, then for the systems of different-depth plowless tillage and differentiated-1 with one slotting per the rotation and differentiated-2 with one plowing per the rotation (variants 2, 4, 5), they were less by 1.1, 0.9 and 2.4%, respectively.

At the single-depth shallow plowless tillage system (variant 3), expenditures have decreased by 3.3%. The cost of gross production per hectare of the crop rotation area for various plowing systems on the non-fertilized background was 18.3 thousand UAH. In the variant of the differentiated-1 basic tillage system, it was higher and averaged to 19.1 thousand UAH, or increased by 4.2% with a profitability level of 89.5 and 99.3%, respectively.

The lowest payback of crop cultivation technology in the irrigated crop rotation was on the unfavorable background of the single-depth shallow plowless tillage system, with a gross output of 12.1 thousand UAH, which is lower than the control by 33.8% with a profitability level of 29.8%.

CONCLUSIONS

On the dark-chestnut soils in the zone of activity of the Ingulets irrigation system at the irrigation with water of high mineralization we recommend:

1. In the farms with developed animal husbandry it is advisable to introduce fruit-changing crop rotations with the coefficient of irrigated arable land use of 1.25-1.75 and use differentiated systems of tillage, when deep plowing under row crops and perennial grasses (corn, soybean, beet-root, alfalfa) is interchanged with plowless shallow tillage under cereal crops and sowing crops in the unprepared soil in interim terms (early spring, after-mowing, and after-harvesting mixtures of herbs for green forage).

2. In the farms aimed on the production for industrial processing it is advisable to use row crop rotations saturated with liquid high-profitable crops (corn, soybean, sunflower, rape, and winter wheat), leaf-stem mass should be used for a green manure, and apply differentiated tillage with plowing (from 18-20 to 28-30 cm) under rape and sunflower, disk-chisel tillage (12-14+ 38-40 under corn) and shallow (10-12 and 12-14 cm) disk tillage under winter wheat and barley.

Prolonged use of differentiated systems of basic tillage in crop rotation at irrigation has ensured, on the background of application of different doses of mineral fertilizers, the formation of the highest level of productivity. Not significant decrease was observed in the variants of different-depth chisel and single-depth shallow disk loosening, mainly due to the yield of corn grain.

Sowing in untreated soil over 10 years of the research has led to a significant decrease in the crop yields and the crop rotation productivity in general.

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SCIENTIFIC SUBSTANTIATION FOR OPTIMIZATION OF CROP ROTATION STRUCTURE AND IRRIGATION REGIMES OF INGULETS IRRIGATION SYSTEM CONSIDERING THE HYDROMODULE OF WATER SUPPLY

Morozov O. V.

INTRODUCTION

The vast majority of irrigated systems of Ukraine were built for solving problems related to the organization of food security of southern region in all weather conditions. Their task was to create zones of guaranteed production of food and feed grains, vegetables and high-quality forages. The design of irrigation systems envisaged specific structure of acreage: grain crops 40-45%, of which 55-60% of winter crops; forage crops – 35-40%, of which perennial grasses 50-60% and in the remaining areas – vegetable, technical and other crops. Such a structure provided sustainable yield of all crops, irrigation water and technique were used evenly throughout the watering season, soil fertility stabilized and improved[1].

In the conditions of market relations development and the need to produce competitive products, there is a need for agricultural producers in maximum saturation of irrigated crop rotation with technical, vegetable crops, as the most profitable in modern economic conditions in the south of Ukraine. That leads to a decrease in irrigated soil fertility and their productivity[2].

In solving this problem at the present stage of development of irrigated agriculture the important role belongs to crop rotations. The latter, in conjunction with technological measures, increases productivity of arable land by 25-30% with the simultaneous preservation and increase of soil fertility. At high saturation of these intensive crops the role of crop rotation as a biological method of regulation of phytosanitary regime significantly increases[3]. Under such conditions, the problem of reproduction of fertility of irrigated lands and environmental protection acquires a special significance.

The relevance of the subject is justified by the necessity in new approaches to the exploitation of irrigation systems – concentration on

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irrigated lands of the most profitable and cost-effective crops. In the newly created agricultural enterprises with limited irrigation area there is a need in organization of shorter crop rotations, taking into account the hydro module of irrigation system. Selection of crops in such farms should be determined by material and technical capabilities and climatic conditions. According to climatic conditions, selection of the most adapted for the region crops and their ratio should be settled.

The existing chaotic use of irrigated land now led to a substantial decrease in soil fertility, their ecological and agromeliorative conditions, reduced their resistance to self-regulation. Under such conditions it is necessary to substantiate scientifically the ways of stabilization of soil processes, one of which can be optimization of irrigation rates, allocation and ratio of crops.

The purpose of the work is: Scientific substantiation of the calculation of the project hydro module (consumption of water per hectare of irrigated area) in comparison with actual (projected) carrying capacity of inter-economic canals of the Ingulets irrigation system, taking into account land-bound areas of state irrigated lands (on the example of P-1 canal).

To achieve this goal, the following tasks have been solved:

1. Optimizing the structure of acreage in the area of the inter-economic canal P-1, taking into account its carrying capacity;
2. Scientific substantiation of the norms of water requirements of basic crops, taking into account humidification conditions of the year.

1. Research Methodology

Research method: calculative method with a complex of analytical studies.

Hydro module – specific water consumption per 1 ha of a crop rotation area. The hydro module of the canal P-1 of the Ingulets irrigation system is determined by the formula:

$$g_{syst.} = Q / F, \text{ L/sec·ha}, \quad (1)$$

$g_{syst.}$ – ordinate of hydro module of the canal P-1, L/sec ha;

Q – project limit of water supply;

F – project area of the canal P-1, ha.

Water consumption (hydro module), necessary for irrigation of crops on one focal hectare of the canal P-1 of the Ingulets irrigation system, is determined by the formula:

$$g = \alpha m/(3.6\ T\ t), \text{ L/sec ha}, \quad (2)$$

where g – ordinate of hydro module, L/sec ha;

α – share of the sown area of a crop rotation, which is occupied by the crop or the relative area,%;

m – irrigation rate, m^3/ha;

T – duration of irrigation per day, hours;

t – duration of watering the field, days.

The value of the hydro module is determined for each watering of all crops in the irrigated array. The definition is carried out in tabular form.

For irrigated array (where there is a large number of agricultural enterprises, farms, crop rotation plots, crops, etc.) the value of hydro module is determined by summing:

$$g_{\text{irrig. syst.}} = \alpha_1 \cdot \times g_1 + \alpha_2 \cdot \times g_{2+} \ldots + \alpha_i \times q_i. \qquad (3)$$

The structure of sown areas must be in agreement with the water supply of the system. In the presence of irrigation systems with a hydro module of 0.3 L/sec/ha irrigated lands could be saturated with water-resistant crops and crops with close irrigation regime to 40-45%; with a hydro module of 0.4 L/sec/ha – 60-70% and more than 0.5 L/sec/ha – 60-75%. The determination of the ratio of these crops is carried out by the transformed formula of the hydro module

$$a = \frac{q \times 8640 \times T}{m}, \qquad (4)$$

Where *a* is the share of a crop or a group of crops with close irrigation regime,%;

Q – hydro module of the section, L/sec/ha;

T – watering period, days;

m – irrigation rate, m^3/ha.

The ratio of crops in crop rotation should also ensure even distribution of labor during the vegetative period.

2. Calculation of the actual hydro module of the inter-economic canal P-1 of the Ingulets irrigation system considering land areas of state irrigation

The structure of crops on the irrigated lands should contribute to full and uniform use of water during the growing season. At the same time, the largest need in water of all sowing area and individual crops should be fully supplied by the carrying capacity of the inter-economic canal P-1 of the Ingulets irrigation system, and promote rational functioning of irrigation system, prevent idling periods in its work.

Crops included in a crop rotation have different irrigation regime, and hence, an unequal distribution of irrigation water, different irrigation norms and rates. For example, winter wheat uses 40% of irrigation water in May, and the remnants in June and September. For 42 days of the watering season in spring and summer 1800 m^3/ha is used, i.e. 42.8 m^3/ha per day. Spring barley uses all the irrigation water during the month of May. For 31 days 1400 m^3/ha of irrigation water was consumed, i.e. – 45.2 m^3/ha per day.

In corn and soybean, irrigation period started at average in the second decade of June, that is, after its completion in winter wheat, and lasted about[4] 54-64 and 75-81 days[5,6].

During this time, about 54.7 -64.8 and 39.5-42.7 m^3/ha of water per day was used. It should be noted that corn consumes irrigation water during the irrigation period more even than soybean. Thus, corn in June usese about 31% of irrigation water, in July – 43%, and in August – 26%, and soybean – in June – 12%, in July – 33%, and in August – 55%.

Since the crops, which are a part of the acreage in the area of an inter-economic canal P-1, have different irrigation regimes, this affects the formation of the actual hydro module of the Ingulets irrigation system (Table 1, 2, Fig. 1).

Analysis of the obtained values by the hydro module of the Ingulets irrigation system (dated 01.11.2018) under the actual acreage and irrigation regimes in the month of July was 0.42 L/sec/ha. This indicates that July and June are critical months for the use of the inter-economic canal P-1 with 53.2% of saturation with grain corn. The project values of the hydro module of P-1 canal of the Ingulets irrigation system and their parcel stations cannot satisfy it (Fig. 1).

3. Calculation of the project hydro module of the inter-economic canal P-1 of the Ingulets irrigation system considering the land areas of state irrigation.

As a result of the study, the peculiarities of formation of the structure of acreage are scientifically substantiated, and the norms of water requirements (taking into account the moisture supply of the year) of main crops taking into account the carrying capacity of the inter-economic canal P-1 of the Ingulets irrigation system are determined.

On the irrigation systems with a hydro module of 0.36 L/sec/ha the most optimal in terms of total water consumption is a combination of water-resistant (soybean, corn) and more drought-resistant (winter barley and wheat) crops, with specific weight 50 by 50% (Tables 3-8, Fig. 2, 3, 4).

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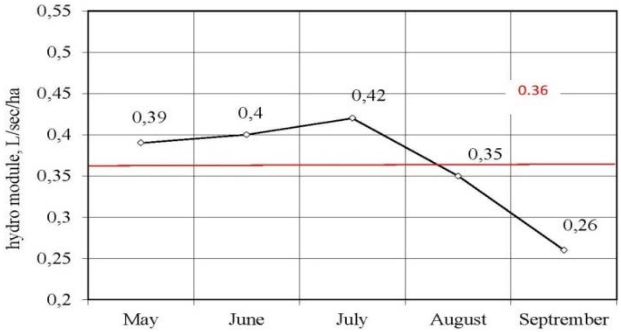

Fig. 1. The average ordinate of a hydro module of the inter-economic canal P-1 of the Ingulets irrigation system in case of actual norms and terms of irrigation, L/sec/ha (dated 01.11.2018)

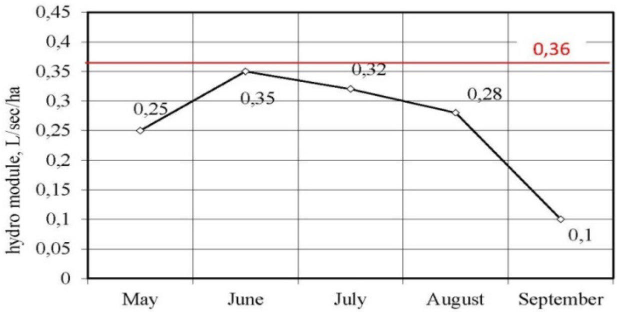

Fig. 2. The average ordinate of the hydro module of the inter-economic canal P-1 of the Ingulets irrigation system at the projected norms and terms of irrigation for dry years (P = 95%), L/sec/ha

Irrigation regime of crops regarding the norms of their water requirements should be calculated depending on:

- distribution of natural humidification coefficient;
- and by the water supply of the years (dry (p = 95%), moderately dry (p = 75%) and moderate (p = 50%).

Such an approach to the use of irrigated lands will allow using the inter-economic canal P-1 of the Ingulets irrigation system in the project mode, stabilizing the melìorative conditions of the irrigated and neighboring lands, and, as a consequence, prevention of soil degradation, and increase in the efficiency of the irrigation system and the irrigated lands.

The increase of the share of corn and soybean over 50.0% leads to an increase in the specific water feed for irrigation, shortage of water resources and, consequently, the violation of scientific and reasonable irrigation regimes and decrease in the productivity of these crops.

Table 1

The actual irrigation rate per 1 ha of the crop rotation area of the inter-economic canal P-1 of the Ingulets irrigation system for the irrigation period of 2018, m^3/ha (dated 01.11.2018)

Month	Crop Sowing areas,% to the acreage				
	Corn middle-ripening 1803.2 ha(53.2%)	Winter wheat 720.7 ha (21.3%)	Vegetables 681.5 ha (20.1%)	Soybean 25.0 ha (0.7%)	Sunflower 158 ha (4.7%)
May 05	500 * / 6 ***	600 / 6	300 + 300 + 300 / 15	500 / 6	500 + 500 / 6 + 6
June 06	600 / 7	500 + 500+ 500 / 5 + 5+ 5	300 + 300 + 300 + 300 / 15	500+ 500 / 6 + 6	500 + 500 / 5 + 5
July 07	600 +600 +600 / 6+6+6	-	400 + 400 + 400 + 400 / 20	500 + 500 / 6 + 6	500 / 6
August 08	500+ 500 / 6 + 6	-	300 + 300 / 15	600 + 600 + 600 / 6 + 6 + +	-
September 09	-	600 **** / 6	-	-	-
Irrigation norm	**3900**	**2100**	**4300**	**1500**	**2500**

**- irrigation rate, m^3/ha;*
***- duration of watering the field, days;*
**** – water-charging irrigation.*

Table 2

The actual average hydro module of the inter-economic canal P-1 of the Ingulets irrigation system in 2018, L/sec/ha (dated 01.11.2018)

Month	Crop Sowing areas,% to the acreage					Average ordinate of the hydro module
	Corn middle-ripening 1803.2 ha (53.2%)	**Winter wheat 720.7 ha (21.3%)**	**Vegetables 681.5 ha (53.2%)**	**Soybean 25.0 ha (0.7%)**	**Sunflower 158 ha (4.7%)**	
May 05	0.55	0.23	0.27	0.009	-	**0.27**
June 06	0.57	0.22	0.27	0.007	0.049	**0.39**
July 07	0.66	-	0.49	0.007	0.059	**0.39**
Serstump 08	0.55	-	0.27	0.009	0.049	**0.31**
September 09	-	0.26	0.27	-	-	**0.21**

Table 3

The average project irrigation norm for dry (P = 95%) by the water supply years per 1 ha of the crop rotation area of the inter-economic canal P-1 of the Ingulets irrigation system for the irrigation period, m^3/ha

Month	Crop Sowing areas,% to the acreage				
	Corn 1694.2 ha (50%)		**Winter wheat 779.3 ha (23%)**	**Barley Winter (Spring) 67.8 ha (2.0%)**	**Vegetables 847.1 ha (25%)**
	Corn middle-ripening 847.1 ha (25%)	**Late-ripening corn 847.1 ha (25%)**			
May 05	500* 6 **	-	600+500 6+6	500+500 5+5	300+300+300 10
June 06	500+500 5+5	500+600 5+6	500+500 5+5	500 5	300+300+300+300 10
July 07	500+400+400 5+5+5	600+600+600 5+5+5	-	-	400+400+400+400 12
August 08	500 5	500+500 5+5	-	-	300+300 6
September 09	-	-	500*** 5	-	-
net water requirements norms for dry (P = 95%) by the water supply years	**3300**	**3900**	**2100**	**1500**	**4300**

** – irrigation rate, m^3/ha;*
*** – duration of watering the field, days;*
**** – water-charging irrigation.*

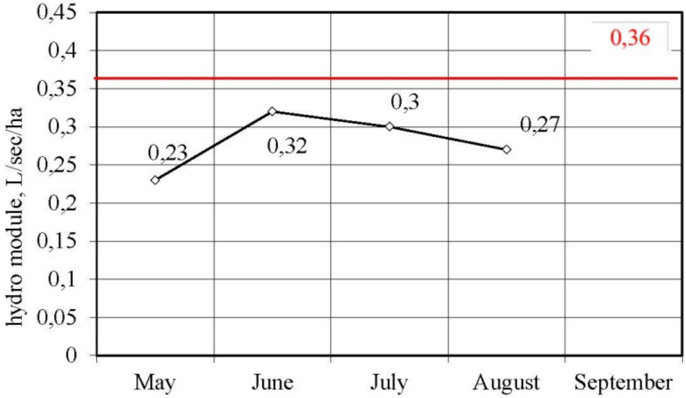

Fig. 3. The average ordinate of the hydro module of the inter-economic canal P-1 of the Ingulets irrigation system at the projected norms and terms of irrigation for moderately dry years (P = 75%), L/sec/ha

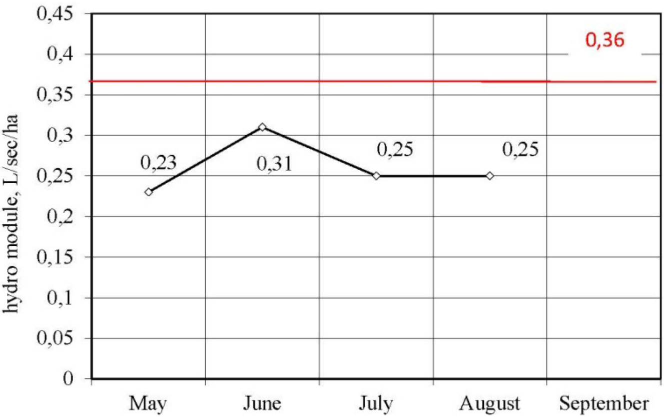

Fig. 4. The average ordinate of the hydro module of the inter-economic canal P-1 of the Ingulets irrigation system at the projected norms and irrigation terms for moderate years (P = 50%), L/sec/ha

Table 4

The average project irrigation norm for the moderately dry (P = 75%) by the water supply years per 1 ha of the crop rotation area of the inter-economic canal P-1 of the Ingulets irrigation system for the irrigation period, m^3/ha

Month	**Crop** **Sowing areas,% to the acreage**				
	Corn **1694.2 ha (50%)**		**Winter wheat** **779.3 ha (23%)**	**Barley Winter (Spring)** **67.8 ha (2.0%)**	**Vegetables** **847.1 ha (25%)**
	Corn medium-ripe **847.1 ha (25%)**	**Late-ripening corn** **847.1 ha (25%)**			
May 05	500* 6 **	-	400+400 5+5	400+400 5+5	300+300+300 9
June 06	400+400 5+5	500+600 5+5	500+400 5+5	400 5	300+300+300+300 12
July 07	400+400+400 5+5+5	500+500+500 5+5+5	-	-	400+400+400+400 12
August 08	500 5	500+500 5+5	-	-	300+300 6
September 09	-	-	500*** 5	-	-
net water requirements norms for dry (P = 95%) by the water supply years	**3000**	**3600**	**1700**	**1200**	**3900**

** – irrigation rate, m^3/ha;*
*** – duration of watering the field, days;*
**** – water-charging irrigation.*

Table 5

The average project irrigation norm for moderate (P = 50%) by the water supply years per 1 ha of the crop rotation area of the inter-economic canal P-1 of the Ingulets irrigation system for the irrigation period, m^3/ha

Month	**Crop** **Sowing areas,% to the acreage**				
	Corn **16942 ha (50%)**		**Winter wheat** **779.3 ha (23%)**	**Barley Winter (Spring)** **67.8 ha (2.0%)**	**Vegetables** **847.1 ha (25%)**
	Corn medium-ripe **847.1 ha (25%)**	**Late-ripening corn** **847.1 ha (25%)**			
May 05	400* 5**	-	500+500 5+5	500+500 5+5	300+300+200 9
June 06	400+400 5+5	500+600 5+5	500 5	-	300+300+300+200 12

Table 5 (continuance)

July 07	400+400+400 5+5+5	500+500+500 5+5+5	-	-	300+300+300+200 12
August 08	400 5	500+400 5+5	-	-	300+300 6
September 09	-	-	-	-	-
net water requirements norms for dry (P = 95%) by the water supply years	**2800**	**3400**	**1500**	**1000**	**3600**

** – irrigation rate, m^3/ha;*
*** – duration of watering the field, days;*
**** – water-charging irrigation.*

Table 6

The average projected ordinate of the hydromodule of the P-1 canal at the optimization of acreage and scientifically based norms of water requirements for dry (P = 95%) by the water supply years, L/sec/ha

Month	**Crop** **Sowing areas,% to the acreage**					**Average ordinate of the hydro module**
	Corn **1694.2 ha (50%)**		**Winter wheat** **779.3 ha (23%)**	**Barley Winter (Spring)** **67.8 ha (2.0%)**	**Vegetables** **847.1 ha (25%)**	
	Corn middle-ripening **847.1 ha (25%)**	**Late-ripening corn** **847.1 ha (25%)**				
May 05	0.26	-	0.27	0.03	0.42	**0.25**
June 06	0.31	0.32	0.29	0.025	0.55	**0.35**
July 07	0.27	0.38	-	-	0.61	**0.32**
August 08	0.32	0.32	-	-	0.46	**0.28**
September 09	-	-	0.34	-	-	**0.10**

CONCLUSIONS

1. The structure of sown areas and crop rotations must be coordinated in accordance with the design and technical conditions of the Ingulets irrigation system and specialization of agricultural enterprises. At the same time, it is necessary to take into account its specialization, size of the land in use and water supply.

Table 7

The average projected ordinate of the hydro module of the P-1 canal at the optimization of acreage and scientifically based norms of water requirements for the moderately dry (P = 75%) by water supply years, L/sec/ha

Month	Crop Sowing areas,% to the acreage					Average ordinate of the hydro module
	Corn 1694.2 ha (50%)		Winter wheat 779.3 ha (23%)	Barley Winter (Spring) 67.8 ha (2.0%)	Vegetables 847.1 ha (25%)	
	Corn middle-ripening 847,1 га25	Late-ripening corn 847,1 га25				
May 05	0.26	-	0.23	0.02	0.46	**0.23**
June 06	0.25	0.34	0.26	0.02	0.46	**0.32**
July 07	0.25	0.32	-	-	0.62	**0.30**
August 08	0.31	0.32	-	-	0.46	**0.27**
September 09	-	-	-	-	-	-

Table 8

The average projected ordinate of the hydro module of the P-1 canal at the optimization of acreage and scientifically based norms of water requirements for moderate (P = 50%) by the water supply years, L/sec/ha

Month	Crop Sowing areas,% to the acreage					Average ordinate of the hydro module
	Corn 1694.2 ha (50%)		Winter wheat 779.3 ha (23%)	Barley Winter (Spring) 67.8 ha (2.0%)	Vegetables 847.1 ha (25%)	
	Corn middle-ripening 847.1 ha (25%)	Late-ripening corn 847.1 ha (25%)				
May 05	0.25	-	0.29	0.025	0.41	0.23
June 06	0.25	0.32	0.29	-	0.42	0.31
July 07	0.26	0.32	-	-	0.42	0.25
August 08	0.26	0.28	-	-	0.46	0.25
September 09	-	-	-	-	-	-

2. On the irrigation systems with a hydro module of 0.36 L/sec/ha the most optimal in terms of total water consumption is a combination of water-resistant (soybean, corn) and more drought-resistant (winter barley and wheat) crops, with a specific weight of 50 by 50%.

3. Increasing the share of corn and soybean over 50.0% leads to an increase in the specific water feed for irrigation, water scarcity and, as a consequence, violation of scientific and reasonable irrigation regimes and decreases productivity of these crops.

SUMMARY

As a result of the study, the peculiarities of formation of the structure of acreage are scientifically substantiated, and the norms of water requirements (taking into account the moisture supply of the year) of main crops taking into account the carrying capacity of the inter-economic canal P-1 of the Ingulets irrigation system are determined.

On the irrigation systems with a hydro module of 0.36 L/sec/ha the most optimal in terms of total water consumption is a combination of water-resistant (soybean, corn) and more drought-resistant (winter barley and wheat) crops, with a specific weight of 50 by 50%.

Increasing the share of corn and soybean over 50.0% leads to an increase in the specific water feed for irrigation, water scarcity and, as a consequence, violation of scientific and reasonable irrigation regimes and decreases productivity of these crops.

This approach to the use of irrigated land will allow using the inter-economic canal P-1 of the Ingulets irrigation system in the projected mode, stabilizing the melìorative conditions of the irrigated and adjacent lands, and, as a consequence, prevention of soil degradation, and an increase in the efficiency of the irrigation system and the irrigated lands.

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PRODUCTIVITY AND ADAPTABILITY INDICES OF CORN HYBRIDS OF DIFFERENT GROUPS OF RIPENING

Naidionov V. H.

INTRODUCTION

Identification of corn genotypes by adaptability parameters should be performed according to the results of tests in an ecological gradient, which is formed by the means of agrotechnical measures and, as far as possible, most fully reflects the range of agroclimatic conditions of possible genotype propagation. The most informative quantification can be obtained on the basis of regression models and variance methods[1].

Modern agro-economic conditions require a wide range of corn genotypes that have specific .adaptability to soil-climatic and technological factors. In recent years, a number of the hybrids have been created at the Institute of Irrigated Agriculture of NAAS, which are characterized by a wide range of vegetation periods duration and adaptability to agro-economic conditions[2]. However, one of the problematic issues in crop production remains a considerable variation in genotype yields under different cultivation conditions[3].

In the conditions of southern region of Ukraine, the main factor of the yield limitation is moisture. However, the use of optimal irrigation regimes has become economically unavailable for many farms due to high energy costs. That is why the development of water-saving technologies for corn cultivation has become the prerogative of research in the scientific institutions in southern region[4].

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1. Productivity of hybrids of different ripening groups and its variation depending on technology and weather conditions

Field experiments with corn hybrids were conducted in the fields of the State Enterprise "Research Farm" Askaniiske "of Askanian State Agricultural Research Station of the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, located in Kakhovka district of Kherson region in the Steppe of Ukraine.

The study of the response of individual genotypes of corn to water supply showed that there is a significant genotype-environment reaction, which can significantly change the ranking of hybrids in terms of yield (Table 1).

Table 1

Reaction of corn genotypes of different ripening groups by FAO on water supply and weather conditions of a year

Genotype No.	Hybrid (Factor A)	FAO	Grain yield (t/ha) depending on the irrigation regime (Factor B))			Average by the Factor A
			Biologically optimal	Water-saving	Without irrigation	
1	Tendra	190	9.23	8.78	4.30	7.44
2	Borysfen 191MV	190	7.87	7.08	3.65	6.20
3	Borysfen 250MV	280	10.66	9.88	4.01	8.18
4	Syvash	280	10.91	9.86	4.56	8.45
5	Borysfen 380MV	320	10.86	9.72	3.43	8.00
6	Azov	360	11.80	9.83	2.92	8.18
7	Borysfen 433MV	430	12.07	9.59	2.78	8.15
8	Borysfen 600MV	550	13.33	7.67	2.11	7.70
Average by Factor B			10.84	9.05	3.47	
LSD_{05}, t/ha: factor A = 0.18; B = 0.12						

It was determined that the highest yielding potential at the optimal irrigation regime resides to hybrids with FAO over 400 (12.0-13.3 t/ha). However, even at the water-saving regime of irrigation, there was a critical decrease in the yield of hybrids with FAO of more than 500, and the first places by the yield is occupied by the middle-early and middle-ripening hybrids.

Significant change in the ranking takes place under the cultivation technologies without irrigation. It should be noted that under favorable weather conditions, there was a significant increase in yield in the irrigated variants on the hybrids of all ripening groups, especially in the middle-late and late hybrids. In general, without irrigation in the sub-zone of southern Steppe, it is advisable to cultivate hybrids with FAO not exceeding 300.

The most versatile are middle-early hybrids, which quite efficiently use the autumn-winter moisture reserves, ripen rapidly in late August and have low grain moisture content. Such hybrids include Borysfen 250MV and Syvash. More early-ripening hybrids should only be used in water-saving technologies and on non-irrigated areas.

Hybrids with FAO exceeding 350 should be used at optimal irrigation and mineral nutrition because their yielding capacity does not have significant advantages over earlier genotypes and grain moisture has worse indices.

In dry weather conditions, the yield level of late hybrids may not be adequate to genotype potential. This leads to the fact that selection of high-yielding FAO hybrids exceeding 400 in dry weather conditions may not be effective, and the most productive is FAO group 280-390, which, owing to their plasticity and less water consumption, provide the highest grain yield in such years.

Hybrids with FAO exceeding 500 have a high yielding potential, however, the strong negative response of these genotypes to environmental fluctuations results in a yield decrease below the level of earlier hybrids and places them outside the group of hybrids suitable for effective use in the irrigated conditions of southern Steppe at the current stage of development of agriculture.

The study of the share of influence of the studied factors on grain yield showed that the irrigation regime is a predominant one (Fig. 1). However, the presented dependence does not reflect the response of individual hybrids to the conditions of the year and agrotechnical background.

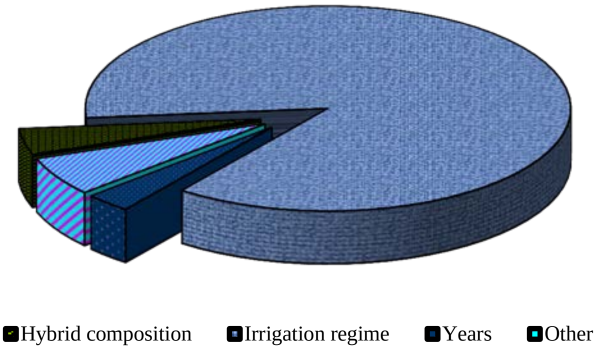

Fig. 1 Distribution of the influence of the studied factors on grain productivity of the hybrids of different FAO groups, %

The study of the genotypic variability of the hybrid composition under different irrigation regimes and in different moisture conditions showed that the optimum irrigation regime showed the greatest variability (R = 4.05 – 6.45 t/ha). The range of genotypic yields at the water-saving regime and without irrigation was significantly inferior (Table 2).

However, the coefficient of genotypic variability (V_g,%) increased significantly with the deterioration of cultivation conditions. This phenomenon is somewhat counterintuitive and contradicts the theory of "environmental permitting capacity", which testifies about opening of genotype potential under optimal technological measures[5,6,7].

However, if we trace back to the analysis of the previous experimental data (see Table 1), we can see the reason for such a critical increase in genotypic variability with deterioration of water supply. This was due to a change in the ranking of the hybrids and a critical decline in the yield of late-ripening hybrids.

The most potentially productive hybrids (Borysfen 600SV, Borysfen 433MV) produced twice less yield without irrigation than the fast-ripening ones. This has led to a misleading increase in the coefficient of genotypic variability.

In favorable by weather conditions years the genotype differences in yields and the coefficient of variation have also slightly decreased. Thus, the statistical indices of the genotypic diversity of corn can be distorted by stressful environmental conditions, so hybrids must be compared by absolute values in the relevant agro-ecological gradients.

The study of the modifying effect of irrigation regime in different weather conditions showed that in favorable weather conditions the coefficients of paratypical variability were significantly less in comparison to the drier (moderate and moderately dry) years (Table 3).

This phenomenon is quite predictable, since the irrigation regime in the conditions of southern arid Steppe is a major factor in the formation of high yields. It is also noteworthy that the coefficients of variation increased in parallel with the increase in the duration of the vegetation period of hybrids (up to 82%), which is a confirmation of the high sensitivity of late-ripening hybrids to drought. Hybrids with FAO 190-300 were the least sensitive to weather conditions and irrigation regime.

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Table 2

Genotype variability in the yields of hybrids depending on different years and at different irrigation regimes

Years	Statistical indices	Irrigation regimes		
		Optimal	Water-saving	Without irrigation
Humid	x, t/ha	11.33	9.70	4.42
	R, t/ha	4.05	2.18	2.23
	V_g,%	10.66	6.31	18.84
Moderate	x, t/ha	10.67	8.80	3.12
	R, t/ha	5.86	4.00	2.73
	V_g,%	15.85	15.13	27.14
Moderately dry	x, t/ha	10.34	8.66	2.83
	R, t/ha	6.45	3.84	2.14
	V_g,%	18.03	15.92	24.09

Table 3

Modification variability (V_m, %) of the hybrids' yields depending on the influence of modification activity of irrigation regime in different years

Hybrids	Years		
	Humid	Moderate	Moderately dry
Tendra	29..42	40..04	42..31
Borysfen 191MV	37..66	34..84	36..87
Borysfen 250MV	38..42	46..64	48..82
Syvash	31..92	43..91	49..97
Borysfen 380MV	45..94	50..91	53..24
Azov	51..31	59..69	57..48
Borysfen 433MV	52..61	61..55	63..21
Borysfen 600SV	59..10	79..48	82..15

The study of the modifying effect of the weather conditions of a year at certain irrigation regimes showed that the optimal regime and water almost offset the effects of extreme weather factors (Table 4).

The absence of irrigation greatly increases the variability of the yield depending on the effects of weather conditions, and in late hybrids (Borysfen 600SV), the weather conditions are almost equal to the effect of the irrigation factor by the impact. Thus, late-ripening corn hybrids are particularly demanding to irrigation regime and can increase yield unpredictability under the extreme weather conditions during the vegetation period. The hybrids of the middle-early and middle-ripening groups are more stable.

Thus, in dry weather conditions, the yield level of late hybrids may not be reduced adequately to genotype potential. This leads to the fact that the selection of high-yielding hybrids with FAO exceeding 400 in dry weather conditions may not be effective, and the most productive group is FAO 280-390, which due to the plasticity and less water consumption in such years provides the highest grain yield.

Table 4

Modification variability (V_m, %) of the hybrids' yields depending on the effect of weather conditions of a year at different irrigation regimes

Hybrids	Irrigation regimes		
	Optimal	Water-saving	Without irrigation
Tendra	6.95	9.94	25.97
Borysfen 191MV	19.49	29.79	19.60
Borysfen 250MB	3.20	4.89	19.41
Syvash	2.14	1.77	27.16
Borysfen 380MB	2.07	2.24	13.53
Азов	9.43	2.21	21.28
Borysfen 433MB	1.14	1.15	22.71
Borysfen 600CB	2.17	7.83	61.33

2. Adaptability of hybrids by grain yield in the conditions of southern Steppe

An important question for crop production is the selection of genotypes with a specific response to technological support and soil-climatic conditions. Under controlled environmental conditions, it is advisable to select for the specific adaptive capacity (SAC). Hybrids of the middle-ripening, middle-late and late-ripening groups showed high SAC, that is, all of them are capable of increasing the yield while improving cultivation conditions (Table 5). The relative stability of the reaction prediction is also inherent in these hybrids.

The coefficient of plasticity (b_i) is the most informative index of genotype's reaction on the changes of environmental conditions. The hybrids are divided into the groups by the coefficient of plasticity:

1. Homeostatic (b_i <1) – hybrids, which are characterized by a weak response to changes in cultivation conditions and providing stable yields under deteriorating conditions. This group includes early maturing hybrids Tendra and Borysfen 191MV.

2. Intensive type (b_i> 1) – high-plastic hybrids with high genetic potential, but with low stability in yields. This group includes middle and late hybrids Azov, Borysfen 433MV, Borysfen 600SV. These hybrids have a very high yielding potential (over 14 t/ha), but require careful and timely execution of technological operations. Disruptions in technology, or weather extremeties, dramatically reduce yields, sometimes to a complete loss.

For the simultaneous selection for the overall adaptive capacity and stability, the index of "genotype breeding value" (GBV) is used. The highest breeding value under these conditions was shown by Syvash hybrid, which showed a rather stable grain yield in different ecological gradients. Hybrids of this type can produce maximum yields even in unfavorable conditions.

Overall adaptive capacity (OAC), an index that combines all previous parameters, also reached the highest values in Syvash hybrid, which emphasizes its prospect for tyhe use in these agro-economic conditions.

To improve the plant breeding theory, determining the environment as the background for plant breeding is of great importance. It is generally accepted to divide the background into a stabilizing one, in which the genotypic polymorphism of the population is narrowed by stabilizing factors; analyzing one, which contributes to the phenotypic manifestation of genotypic inclinations; leveling one, at which the differences between genotypes are minimized [8]. Researchers are usually attracted by the analyzeingbreeding background. To assess the environment as a background for plant breeding, use the indicator DCE (differentiating capacity of the environment). In our experiments, the DCE reached the highest values under the optimal irrigation regime (Table 5).

Table 5

Evaluating environment as a background for plant breeding

Ecological gradient No.	**DCE (differentiating capacity of the environment)**	**Variance of the interaction gene × environment**	**Predictability index**	**Background**
1	166.6	124.1	0.05	Stabilizing
2	326.9	190.4	0.12	Analyzing
3	396.8	243.5	0.14	Analyzing
4	42.8	63.7	0.02	Stabilizing
5	202.7	63.2	0.15	Analyzing
6	217.0	80.7	0.15	Analyzing
7	80.0	128.2	0.001	Leveling
8	81.7	134.1	-0.001	Leveling
9	52.9	103.2	-0.004	Leveling

The genotype × environment interaction variance reahed the highest value in the dry years at the optimal irrigation regime (gradients number 2, 3) Also, significant interaction between genotype and ecological gradient was observed in the non-irrigated variants.

[8] Козубенко Л.В., Гурьева И.А. Селекция кукурузы на раннеспелость. Харьков, 2002. 239 с.

However, the predictability was positive for dry land only in humid years (gradient number 7), and in drought conditions the predictability was negative, indicating a change in the ranking of the hybrids in the rainfed conditions.

The reaction of the hybrids to agrotechnical measures is reflected in the Fig. 2. At the ecological gradient that provides yields at the level of 6-8 t/ha, the potential of most hybrids is at the verge of opening. Optimization of the agricultural background results in higher yields exceeding 12 t/ha in the hybrids with genotypical high-yielding inclinations and their separation from homeostatic ones. When the background is lower than 5 t/ha, the ranking of the hybrids changes, which can lead to mistaken conclusions during the selection of high-yielding hybrids.

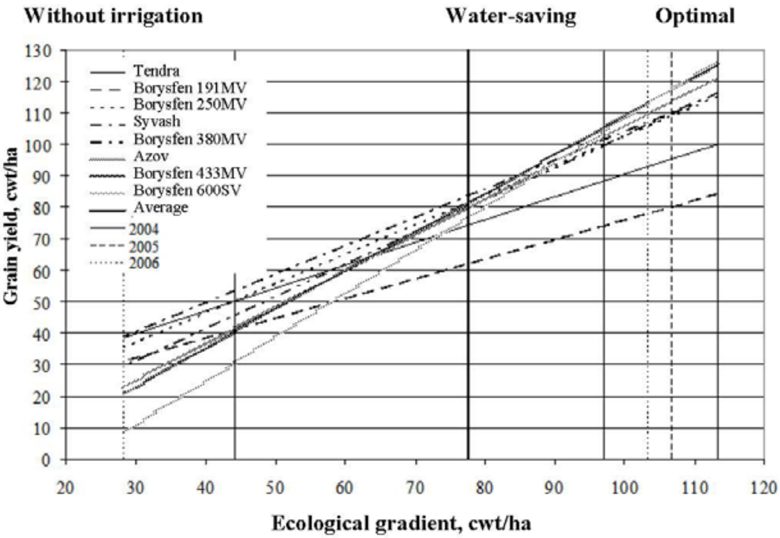

Fig. 2 Regression lines for the index of environmental conditions by the yields of corn hybrids

Thus, the most favorable backgrounds for the selection of corn hybrids of certain ripeness groups and predictable response to technological support are the conditions of the optimal irrigation regime in the years, which are characterized by average (typical) indices of rainfall and air temperature during the vegetation period.

Homeostatic hybrids have been identified, which are characterized by a weak response to the changes in cultivation conditions and provide stable yields under worsening conditions. This group includes early ripening hybrids

Tendra and Borysfen 191MV. Highly plastic hybrids (Azov, Borysfen 433MV, Borysfen 600SV) have been determined as ones owing high genetic potential, but with low stability of yield, that requires careful and timely performance of technological operations. Disruptions of technology or weather extremities critically reduce their productivity.

The most versatile are moderately plastic middle-early hybrids, which use the autumn-winter moisture reserves quite efficiently, have an adequate response to the improvement of cultivation conditions, and are characterized by a restrained response to adverse weather fluctuations and fluctuations in agriculture level. Such hybrids include Syvash hybrid.

3. Manifestation of plants height of corn hybrids depending on irrigation regime

The height of corn plants has received much attention in research because it is closely linked to overall adaptive capacity and potential productivity [9]. Plant height can be a side indicator of total biomass yield, photosynthetic potential, and its less variability in the years of insufficient humidification can be considered as a higher resistance of an individual hybrid to unfavorable conditions, and especially to drought[10,11].

Analysis of plant height of corn hybrids showed that this index increased with the elongation of the vegetation period (Table 6). The highest, on average by years, was the late-ripening Borysfen 600SV hybrid. The fast-ripening hybrids had the lowest height of 226 cm, while others occupied an intermediate position.

Weather conditions of the year had a certain influence on the manifestation of the features, as it is evidenced by the decrease in the plant height in the dry years. The most critical decrease in the indices of this feature was observed in the variants without irrigation.

If the decrease in plant height with water-saving irrigation regime was limited to 13-16 cm in hybrids Borysfen 380MV, Borysfen 433MV, Borysfen 600SV, then without irrigation, the later ripening hybrids critically reduced the height of the plants in unfavorable weather conditions by 30-33 cm. The reaction of the hybrids with FAO 190-300 was more restrained, indicating their increased adaptability to drought.

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Table 6

Effect of irrigation regimes on the plants' height of different ripeness groups of corn by the years of the study, cm

Hybrid (Factor A)	Irrigation regime (Factor B)	Years				Average by Factor A
		Humid	Moderate	Moderately dry	Average	
Tendra	Without irrigation	218.8	217.3	214.8	217.0	226,0
	Water-saving	230.5	227.5	224.5	227.5	
	Optimal	236.8	233.8	230.0	233.5	
Borysfen 191MV	Without irrigation	216.8	216.3	214.8	216.0	226,7
	Water-saving	230.8	229.0	227.8	229.2	
	Optimal	236.3	235.3	233.5	235.0	
Borysfen 250MV	Without irrigation	223.8	222.0	221.0	222.3	234,0
	Water-saving	238.0	236.0	234.8	236.3	
	Optimal	245.8	244.5	240.0	243.4	
Syvash	Without irrigation	233.3	222.8	222.5	226.2	239,1
	Water-saving	242.8	238.5	236.3	239.2	
	Optimal	266.0	246.3	243.0	251.8	
Borysfen 380MV	Without irrigation	249.8	219.0	216.3	228.4	243,0
	Water-saving	253.0	244.3	240.5	245.9	
	Optimal	256.8	255.3	252.0	254.7	
Azov	Without irrigation	238.5	223.0	219.0	226.8	248,8
	Water-saving	251.5	246.0	240.5	246.0	
	Optimal	280.3	272.3	268.0	273.5	
Borysfen 433MV	Without irrigation	234.3	223.5	218.0	225.3	248,3
	Water-saving	259.8	249.0	245.8	251.5	
	Optimal	278.8	265.3	260.3	268.1	
Borysfen 600SV	Without irrigation	226.3	217.5	196.5	213.4	259,9
	Water-saving	279.8	273.3	263.8	272.3	
	Optimal	302.8	294.0	285.0	293.9	
A. Evaluation of the significance of partial differences:						
LSD_{05}	A =	8.8				
	B =	8.1				
B. Evaluation of the significance of means (main effects):						
LSD_{05}	A =	5.1				
	B =	3.1				

The hybrid composition and irrigation regime had a much greater effect on the height of corn plants (Fig. 3). Analyzing the obtained experimental data, we can observe that the share of hybrids in the formation of plant height was the highest in favorable wet by the weather conditions years and was 37%.

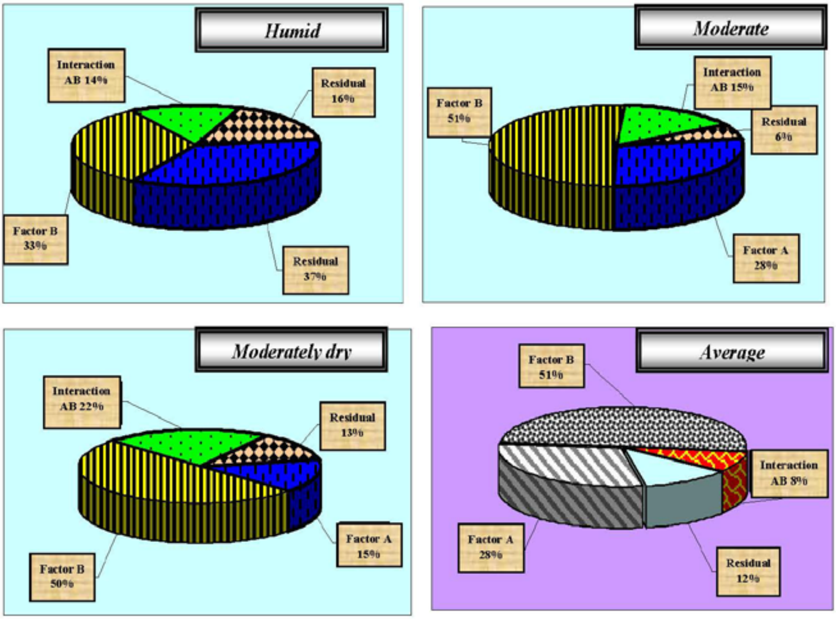

Fig. 3 Share of the hybrid composition (Factor A) and irrigation regime (Factor B) in the formation of the height of corn plants in the years of the study, %

Irrigation regimes this year affected the height of the plants little less – 33%. However, in subsequent, drier years, the irrigation regime (50-51%) was the undisputed major factor in the formation of plant height.

The interaction of irrigation regimes and genotype was most significant in the dry years and reached 22%. This indicates that the features of plant height formation are inherent for individual corn genotypes, and they will be completely determined by the irrigation conditions in severe weather conditions, and the genotype factor may be reduced from 37 to 15%. On average, by the years of the research, the water supply of corn crops determined the formation of plant height by more than a half and the impact of hybrid composition – by 29%.

By the results of the analysis of variances it was found that the least environmental variability was observed in the fast-ripening hybrids (3.4, 4.3%) as well as in the middle-early ones (Table 7).

Table 7

Results of the analysis of variances of variability of the plants height depending on the hybrid composition and irrigation regime, cm

Variants of the experiment	Indices of the analysis of variance				
	$\bar{x}$	s_x	V, %	Lim	
				min	max
Hybrid composition (Factor A)					
Tendra	226.0	4.8	3.4	210.7	241.3
Borysfen 191MV	226.7	5.6	4.3	208.8	244.6
Borysfen 250MV	234.0	6.2	4.6	214.3	253.7
Syvash	239.1	7.4	5.4	215.6	262.6
Borysfen 380MV	243.0	7.7	5.5	218.4	267.6
Azov	248.8	13.6	9.4	205.6	291.9
Borysfen 433MV	248.3	12.5	8.7	208.7	287.9
Borysfen 600SV	259.9	24.1	16.0	183.3	336.4
Irrigation regime (Factor B)					
Without irrigation	221.9	2.0	2.6	217.3	226.6
Water-saving	243.5	5.1	5.9	231.8	255.2
Optimal	256.7	7.3	8.1	239.8	273.6

The steep increase in the coefficient of variation of up to 16% in the late-ripening Borysfen 600SV hybrid testifies about a high instability of manifestation of the feature. The moderate variability of the plant height was demonstrated by hybrids of the middle-late group Azov and Borysfen 433MV. It should be mentioned that the same variability was also fixed in the yield of these hybrids, so it is possible to predict under some circumstances the level of instability of the grain yield of corn hybrids by the variability of plant height.

Thus, the height of plants of corn hybrids in the conditions of southern Steppe is determined mainly by the conditions of moisture supply. The prevailing influence of the hybrid on the plant height is manifested under the conditions of optimal irrigation regime and favorable weather conditions by the years. Variability of the height of the plants of a hybrid depending on weather conditions of a year and conditions of humidification can be used as the express method of determination of stability of manifestation of grain yield.

4. Manifestation of cob setting in corn hybrids depending on irrigation regime and weather conditions

The use of energy-saving corn cultivation technologies has specific requirements to the habitat of hybrids. One among them is the ability to be mechanically harvested through direct threshing in the field. Plants with medium height of 2.0-2.5 meters with a height of the top productive cob setting at least at 50 cm from the soil level are the most suitable for mechanical harvesting[12].

The height of the cob setting is positively correlated with the plant resistance to lodging and the synchrony of flowering in different ripening groups of corn. These are important factors at the use of intensive cultivation technologies. In addition, this feature is one of the main factors affecting the yield of grain, which in its turn determines the potential and actual yield of a particular variety[13].

In the complex of physiological and morphological features that provide adaptation in the conditions of intensive agriculture, an important role belongs to the architectonics of plants. The height of the cob setting is one of the important features that determine the adaptability to modern intensive technologies for cultivation corn hybrids[14].

In our studies, the height of the cob setting was quite variable. Unfavorable dry conditions of the year significantly reduced the height of the cob, even in the conditions of optimal moisture supply (Table 8). Particularly noticeable decrease was observed in the middle-late and late-ripening hybrids (by 20-24 cm). An even more drastic decrease in the height of the cob setting was caused by the water supply restriction. Thus, in the late and middle-late hybrids (Borysfen 600SV, Borysfen 433MV), the height of the cob setting was reduced in the variants without irrigation by more than two times compared to the optimal irrigation regime. Early and late ripening hybrids in the dry years showed the same negative adaptive reaction and had plant architectonics that did not meet the requirements of harvesting (below 50 cm).

It should be mentioned that the height of the cob setting, on average by the factor A, had a positive relationship with the duration of the vegetation period of the hybrids, but this relationship was completely absent in the variants without irrigation. Therefore, the true habitat of plants can only be determined under the conditions of optimal irrigation regime.

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Table 8

The influence of irrigation regimes on the height of the cob setting in different hybrids of corn by the years of the research, cm

Hybrid (Factor A)	Irrigation regime (Factor B)	Years				Average by the Factor A
		Humid	Moderate	Moderately dry	Average	
Tendra	Without irrigation	48.8	48.5	40.8	46.0	55.0
	Water-saving	60.5	58.5	50.5	56.5	
	Optimal	66.8	64.8	56.0	62.5	
Borysfen 191MV	Without irrigation	46.8	44.3	40.8	44.0	55.0
	Water-saving	60.8	58.8	53.8	57.8	
	Optimal	66.3	64.3	59.5	63.4	
Borysfen 250MV	Without irrigation	53.8	51.8	47.0	50.9	62.6
	Water-saving	68.0	66.0	60.8	64.9	
	Optimal	75.8	73.8	66.0	71.9	
Syvash	Without irrigation	63.3	59.8	48.5	57.2	67.4
	Water-saving	72.8	70.8	62.3	68.6	
	Optimal	81.0	79.0	69.0	76.3	
Borysfen 380MV	Without irrigation	79.8	57.3	42.3	59.8	73.3
	Water-saving	83.0	81.0	66.5	76.8	
	Optimal	86.8	84.8	78.0	83.2	
Azov	Without irrigation	68.5	57.5	45.0	57.0	78.7
	Water-saving	81.5	79.5	66.5	75.8	
	Optimal	110.3	105.3	94.0	103.2	
Borysfen 433MV	Without irrigation	64.3	57.3	44.0	55.2	79.3
	Water-saving	89.8	86.3	71.8	82.6	
	Optimal	108.8	104.8	86.3	100.0	
Borysfen 600SV	Without irrigation	56.3	52.8	40.5	49.9	89.9
	Water-saving	109.8	104.3	89.8	101.3	
	Optimal	132.8	113.8	109.0	118.5	
A. Evaluation of the significance of partial effects:						
LSD_{05}	A =	9.2				
	B =	8.1				
B. Evaluation of significance of the means (main effects):						
LSD_{05}	A =	5.3				
	B =	3.1				

The weather conditions of the year had a considerable influence on the proportion of participation of individual factors on the height of the cob setting. If, under favorable weather conditions, the proportion of factor A (hybrids) was dominant (41%), then with the worsening of the weather, the impact rate decreased to 22%. At the same time, the influence of factor B (irrigation regime) increased from 32 to 51%. On average, by the years of the research, the regime of irrigation (46%) had stronger effect on the height of the cob setting.

Under the determination of the indices of variability in the height of the cob setting, it was found that this feature has medium and high coefficients of variation (Table 9).

Table 9

Results of analysis of variance of the variability of the height of the cob setting depending on the hybrid composition and irrigation regime, cm

Variants of the experiment	Indices of the analysis of variance				
	$\bar{x}$	s_x	V, %	Lim	
				min	max
Hybrid composition (Factor A)					
Tendra	55.0	4.82	15.2	39.7	70.3
Borysfen 191MV	55.1	5.8	18.1	36.7	73.4
Borysfen 250MV	62.6	6.2	17.1	42.9	82.2
Syvash	67.4	5.6	14.3	49.7	85.0
Borysfen 380MV	73.3	7.0	16.5	51.0	95.5
Azov	78.7	13.4	29.5	36.0	121.3
Borysfen 433MV	79.3	13.0	28.5	37.8	120.8
Borysfen 600SV	89.9	20.6	39.7	24.3	155.5
Irrigation regime (Factor B)					
Without irrigation	52.5	2.0	10.8	47.9	57.1
Water-saving	73.0	5.2	20.1	61.1	85.0
Optimal	84.9	7.2	24.0	68.3	101.5

The increase in the coefficient of variation from early to late-ripening hybrids was remarkable and reached 39.7% in Borysfen 600SV hybrid. Although the average index for this hybrid was the largest (89.9 cm), the confidence interval overlapped all possible variants of the previous hybrids, which did not give a high predictability of comparing significant differences with other hybrids. However, such high variability and unpredictability were observed at all moisture levels, which do not interfere with provision of more detailed and reliable evaluation of hybrids under the optimal irrigation regime. Confirmation of this is the indices of variability of hybrids under different humidification conditions.

Under the optimal irrigation regime, the coefficient of variation of the hybrid composition exceeded the variant without irrigation by more than 2 times (24%). This provides pre-conditions for an objective assessment of the potential of hybrids only under the conditions of the optimal cultivation technology. The disruption of technology or the effects of extreme weather conditions of the year can significantly mask the potential of corn hybrids, alter the correlation or even change their direction, and in general, create additional barriers to identifying the most promising hybrids by manifestation of phenotypic features.

CONCLUSIONS

1. It is advisable to cultivate hybrids with FAO not exceeding 300 at energy-saving technologies and rain-fed conditions in southern Steppe sub-zone. Such hybrids include Borysfen 250MV and Syvash (grain yields of 8.1-8.4 t/ha). More fast-ripening hybrids should be used at water-saving technologies and on rain-fed lands as previous crops for winter crops (yield 6.2-7.4 t/ha). The hybrids with FAO exceeding 350 should be used at the optimal irrigation and mineral nutrition because their yields have significant advantages over the earlier ripening genotypes only under the mentioned technologies (yield 12.1-13.3 t/ha).

2. In dry weather conditions, the yield level of late hybrids may not be adequate to genotype potential. This leads to the fact that identifying and opening the potency of high-yielding hybrids with FAO exceeding 400 in dry weather may not be effective, but the most productive is the FAO group of 280-390, which, due to its plasticity and less water consumption, provides the highest grain yield in such years. Hybrids with FAO exceeding 500 have a high yield potential, however, the strong negative response of these genotypes to environmental fluctuations results in a decrease in the yield below the level of earlier ripening hybrids and places them outside the group of hybrids, which are suitable for efficient use in southern Steppe in the irrigated conditions at current stage of development of agriculture.

3. The absence of irrigation greatly increases the variability in yield from the influence of weather conditions, and in late-ripening hybrids (Borysfen 600SV), the impact of weather conditions is almost equal to the effect of the irrigation factor. The plasticity factor (b_i) is the most informative index of the genotypes response to the changes in cultivation technology and weather conditions. The most favorable backgrounds for plant breeding of the best corn hybrids of certain ripening groups and predictability of technological support are the conditions of the optimal irrigation regime in the years, which are characterized by average (typical) indices of rainfall and air temperature during the vegetation period.

SUMMARY

The article presents the results of the studies on the effect of hydrothermal conditions on the productivity of corn hybrids of different ripening groups. It has been established that the fast ripening hybrids should be used at the water-saving technologies and on the rain-fed land as previous

crops for winter crops (yield 6.2-7.4 t/ha). The hybrids with FAO exceeding 350 should be used at the optimal irrigation and mineral nutrition because their yields are significantly superior to earlier ripening genotypes only in such technologies (yield 12.1-13.3 t/ha). The interaction of hybrid composition and moisture content was less noticeable compared to plant height and did not exceed 16%. Therefore, by the feature of the "cob setting height" significantly greater differences were observed depending on the studied factors. The height of corn hybrid plants and the height of the cob setting have some specific dependencies on grain yield, which can be used as a marker feature in determination of the productivity of corn hybrids, their level of stability and adaptability to the conditions of mechanized harvesting. The manifestation of correlation can be greatly complicated by the influence of weather and moisture conditions. The height of corn plants, as well as the height of the cob setting, can serve as a marker of grain yield only under the conditions of optimal cultivation technology. Violation of the elements of technology can lead to mistaken conclusions.

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ORGANIZATION OF ECOLOGICAL MONITORING OF CONSTRUCTION

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INTRODUCTION

The volume of construction in Ukraine, as a country with developed industry, is characterized as large-scale, which is why the construction industry occupies an important place among the factors of transformation and environmental pollution. However, existing organizational and technological solutions and measures for environmental protection in the process of construction of industrial and civil objects are insufficiently developed and de-tailored, not integrated into an orderly system, which significantly increases the costs of construction entities for their reconstruction. The issues of operational environmental monitoring and decision-making regarding the localization of identified negative emissions of substances and impacts remain open.

Various aspects of the problematic question raised, concerning the improvement of the basics of environmental protection measures in construction, including the organization of environmental monitoring, are covered in the works of authors and other works of scientists of the world community.

Developed by the author of the classification of factors and major sources of negative impact, as well as a system of typical organizational and technological solutions for the revitalization of construction production processes, ordered by the importance of protected and restored environmental objects, are sufficient only for effective use when designing technology and organizing the construction of facilities. Therefore, the issues of prompt elimination of the effects of environmental pollution during construction remain open.

The scientific substantiation of the organizational and functional structure of environmental monitoring during the construction of structures was chosen for the purpose of this article. The purpose of environmental monitoring is to respond promptly to changes in controlled parameters that describe the current state of the environment where the construction takes place. Therefore, the task of monitoring is, firstly, to receive timely information on the state of the environment and, secondly, to localize the negative impact quickly.

1. Substantiation of the proposed organizational and functional structure of environmental monitoring

The substantiation of the organizational and functional structure of environmental monitoring is carried out by experimental modeling of possible organizational and technological decisions; the subject of modeling were:

A. Organizational structure of the environmental safety point (PEB) with an automated environmental monitoring system (ASEM);

B. Functional structure of environmental monitoring.

Models of organizational and functional structures include: 1. The purpose of creating a structure; 2. The main purpose (function) of the structure; 3. Organizational or functional scheme; 4. Logistical support.

A. Organizational structure of the environmental safety point (PEB) with an automated environmental monitoring system (ASEM).

1. The goal of creating and operating an environmental safety facility is to protect environmental objects from the adverse effects of construction processes.

An environmental safety facility is created at each site and operates throughout the life of the facility.

2. The main purpose of the environmental safety point is the immediate and rapid removal of hazardous contaminants from the construction site and prompt localization of the negative impact revealed by the environmental monitoring means.

3. Organizational scheme of PEB (Fig. 1).

The personnel of the point of environmental safety is appointed by order of the head of the construction organization, whose staff is formed within the existing staffing of the construction organization.

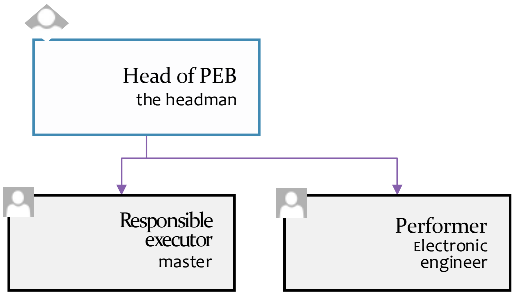


Fig. 1. Organizational chart of the environmental safety point (PEB)

The functions of the PEB chairman are given to the responsible contractor (superintendent, head of the site), the responsible contractor to the master (superintendent), and the executor to the electronic engineer who is involved in permanent work at the construction site.

Additional revitalization works and activities are performed by construction workers engaged in construction and assembly work and are reimbursed at the expense of general construction costs.

2. Logistics of PEB.

Logistical support is provided on the basis of picking up of PEB with a complex of specially selected inventory, devices and equipment and consisting of:

1. A complete set of equipment for immediate and quick removal of dangerous contaminants; containers with sorbents, containers for the transport of radiation substances, containers with sand for the collection of oil, fuel, chemical additives;

2. Complete set of instruments and laboratory equipment: – gas, dust and noise analyzers, electromagnetic radiation and radiation meters, integrated into an automated information collection and analysis system (ACEM) for ongoing monitoring of the state of degraded environmental elements – extent pollution of atmospheric air, waters of reservoirs, soil and groundwater, levels of noise impact, electromagnetic and radiation radiation, nature and levels of damage to vegetation and fauna.

The structure of these kits by their composition and quantity depends on the volume of possible release of hazardous substances, construction conditions, the nature of its distribution into technological zones and the accepted composition of contractors – the number of simultaneously working units of workers.

B. Functional structure of environmental monitoring regulates the interaction of the information and control system with the sensor system and the object of construction (Fig. 2)

The timely receipt of information about the state of the environment is ensured by the functioning of an automated environmental monitoring system (ASEM), as an information and control system within the hardware and software system in the form of a computer system of the required performance and a system of connected sensors, fixing the magnitude of the controlled parameters (Fig. 2): 1) degree of air pollution (gas and dust analyzers); 2) the degree of pollution of the waters of reservoirs, soil and groundwater (analyzers of water, soil, sediments); 3) noise exposure levels (noise analyzers); 4) levels of electromagnetic and radiation radiation (meters of electromagnetic radiation and radiation).

To automate the processes of gathering current information and its statistical processing, a developed application subroutine implemented in MS Excel, PPMDovkilliaOsypovaAnastasia (see Fig. 3) is used.

An example of the statistical processing of current information on the maximum daily sound pressure levels measured directly at a construction site is shown in Fig. 4.

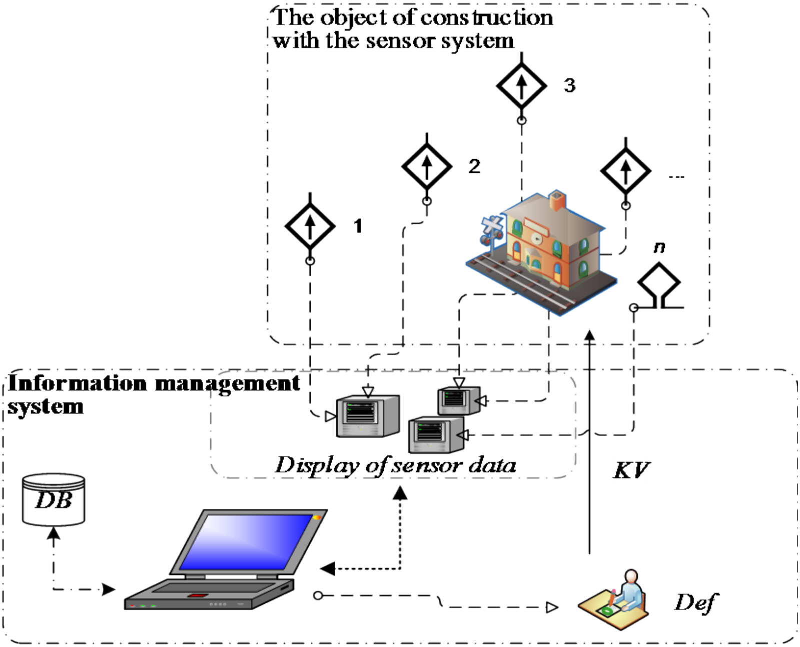


Fig. 2. Interaction of the information-control system with the sensor system and the object of construction: 1, 2, 3,…, n – sensors

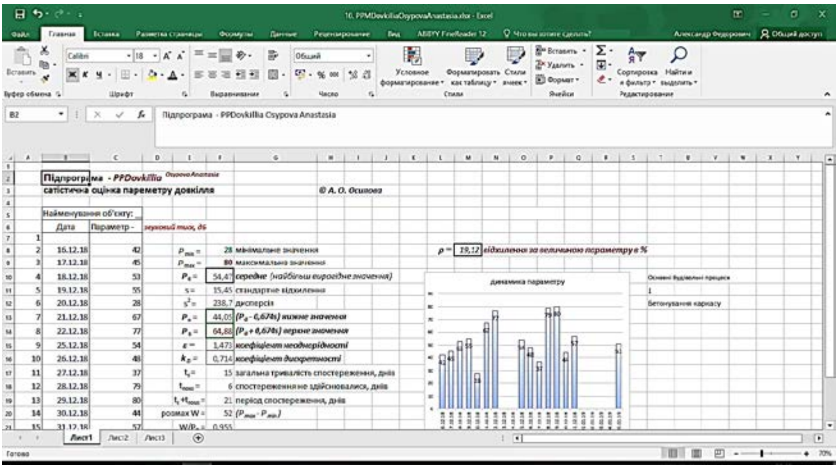


Fig. 3. Graphical shell of PPDovkilliaOsypovaAnastasia subroutine – statistical estimation of environmental parameter

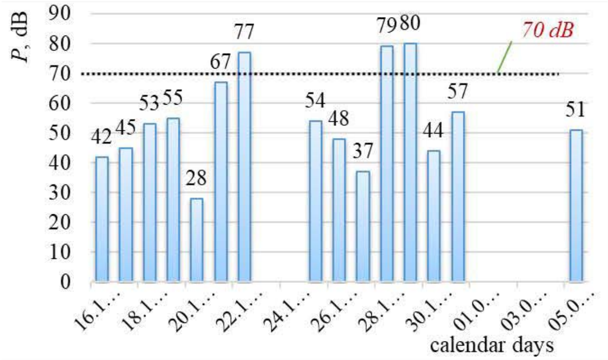


Fig. 4. Dynamics of sound pressure (P, dB) at the construction site (noise source)

The analysis shows that on 21 and 27 and 28 December this year, sound pressures exceeded the maximum permissible for residential development (up to 70 dB).

Operational localization of the negative impact is carried out by performing additional revitalization work and measures, including the use of an existing set of equipment for immediate and rapid removal of dangerous contaminants.

Additional revitalization works and measures, in the form of managerial influence (CV, see Fig. 2), are formed by ODA on the basis of:

- information received on the current state of the environment, the presence and levels of exceedances of MPC by environment (air, water, soil, etc.) and by the levels of negative impacts (noise, light, etc.);

- volumes of revitalization works and measures actually completed in the preparatory period;

- Databases (DBs) about typical OTP-complexes [14] and data on earlier performed revitalization measures at other objects of the construction organization.

For example, an analysis of the dynamics of sound pressures at a construction site (see Figure 4) and the sources of their origin (be it the work of hand-held perforators) need to equip jobs with sound-absorbing screens.

The structure and quantitative composition of the sensor system and their location on a particular construction takes into account:

1) there are negative emissions and impacts generated during the execution of the processes of selective-extreme structure;

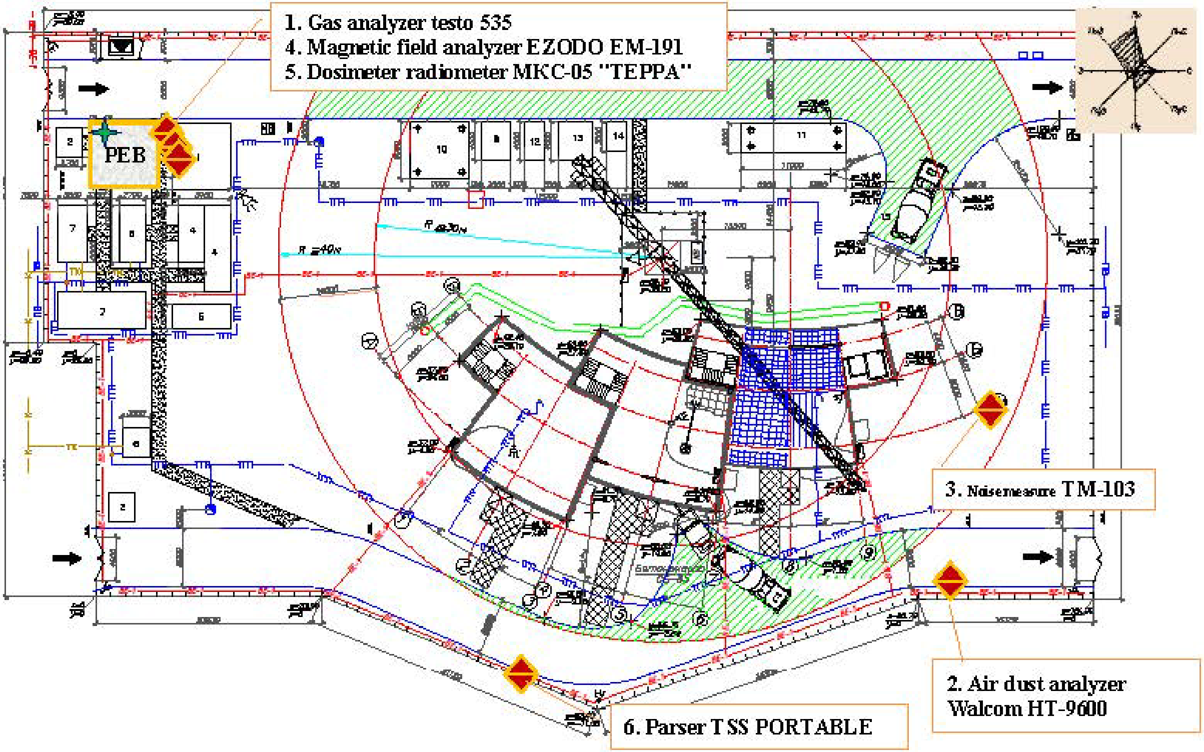
2) physical and geographical location, microclimatic, geological and hydrological characteristics of the construction site; are determined according to the relevant sections of the EIA developed within the work project;

Table 1

Typical structure of sensors-devices is recommended of environmental safety

Appliance name and scope	Notes
Gas analyzer testo 535, industrial gas analyzer testo 350 Price*: 267,60 – 10 278,55 USD. Control of air pollution by the exhaust gases	
1. Walcom HT-9600 dust dust analyzer Price *: 208,04 USD Assessment of air quality by determining the reducing microdispersed dust particles and inhalation dust particles in the air, as well as for measuring temperature and relative humidity	
1. Sound recorder with PC connection Tenmars TM-103 Price *: 7000,00 UAH Control of noise pollution in the general frequency range 30 ... 130 dB	
1. EZODO EM-191 industrial frequency magnetic field intensity analyzer Price *: 2230.00 UAH Measurement of magnetic induction in the low frequency range (EMF) from 30 to 300 Hz.	
1. MKS-05 "TERRA" dosimeter radiometer Price *: 7896,00 UAH Dosimetric and radiometric monitoring at the construction site	
1. TSS PORTABLE analyzer Price *: 7530,00 UAH Surface water, soil and groundwater monitoring in ditches, vegetation and sediment analysis	

** – the price is given at the beginning of April 2019 (the total cost of a set of devices – 36,2… 37,0 thousand UAH)*



1, 2,…, 6 – parameter control sensors - see. tab. 1;

PEB – Environmental Security Point (Office of the Inspectorate, Control Room)

3) urban planning features: the type of anthropogenic landscape that is being transformed (quiet or noisy street, park area, etc.);

4) proximity to nature, residential and industrial areas, architectural and historical monuments and more.

An example of the location of the environmental monitoring system is shown in Fig. 5, and their recommended typical structure – in Table. 1.

The location of the sensors takes into account the wind direction (sensor # 2 – Walcom HT-9600 air dust analyzer) and the available natural terrain – sensor No. 6, which controls surface and groundwater located in the monitoring well at the foot of the slope, and the sound level meter TM 103 .

CONCLUSION

Established and developed organizational and functional structures are applied bases of organization of ecological monitoring of construction aimed at eliminating the causes of negative impact of construction production processes on the environment.

SUMMARY

The scientific substantiation of the organizational and functional structure of environmental monitoring during the construction of industrial and civil structures has been performed. Models of organizational and functional structures include the purpose of creation and the main purpose (function) of the structure, organizational or functional schemes, as well as logistics.

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MORPHO-BIOLOGICAL PARAMETERS OF CORN CROPS AND PHOTOSYNTHETIC PRODUCTIVITY

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INTRODUCTION

In southern part of the steppe zone of Ukraine, the main factors limiting the intensity of productive processes and the level of grain yield of corn seeds are: water regime, content and availability of nutrients, the amount of fertilizer application, the lack of which hinders obtaining of high and stable yields[1,2].

Therefore, development of new and improvement of existing elements of the scientifically based cultivation technology of new hybrids of corn, studying of action and interaction of irrigation regimes, doses of mineral fertilizers and plant density, which most significantly influence on their productivity in the conditions of southern Ukraine, is relevant. By the scale of distribution, versatility of use and energy nutritive value corn is the most important grain and fodder crop[3].

The aim of our study was to improve the elements of cultivation technology of corn hybrids in the conditions of irrigation in the South of Ukraine.

The processes of productivity formation of corn hybrids depending on the conditions of humidification, doses of mineral fertilizers and density of plants were investigated in the conditions of the South of Ukraine on dark-chestnut middle-loamy soil. Growing patterns, patterns of the development and dynamics of plant productivity formation were determined, the indicators of water consumption of corn plants and efficiency of water use by the stages of their growth and development were defined. The elements of the technology of corn seeds growing in the conditions of irrigation in the South of Ukraine, which ensure lower costs of irrigation water and other resources to obtain the seed unit, the reaction of corn plants on changing background of mineral nutrition and a plants density were improved.

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Experiments were conducted with the hybrid of the middle-ripening group (FAO 240), Kros 221M, which is as a maternal form for many modern corn hybrids (Syvash, Ingulsky, Genichesky, etc.).

An important condition for the formation of high crop yields is a sufficient increase in vegetative mass. The absolute value of its increase is the external manifestation of internal processes, which take place in plants. Therefore, the rate of increase in the surface mass could be used to contemplate about the impact of any factor on the plant[4,5].

Scientists note the close link between the crop yield and the mass of its vegetative bodies. After all, plants mobilize from vegetative biomass carbohydrates, nitrogen and other substances for the formation of the reproductive part of their yield[6] .

Field experiments, laboratory and analytical studies for 2009-2018 years were carried out at the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, located on the right bank of the Dnipro River in the zone of the Ingulets irrigation system. According to the schemes the study provided for investigation of such factors as density of plants, various nutritional and watering regimes.

1. Dynamics of crude plant biomass accumulation

According to the scientific sources, the biggest crude biomass per one plant of corn in the conditions of irrigation is reached at the wax ripeness stage of grain[7,8].

It should be noted that in the initial stages of plant growth and development (sprouts – 7 leaves) the intensity of accumulation of surface biomass was not high, the indicator of which fluctuled within 106-112 g per 1 plant (Table 1).

The greater increase in crude biomass per plant of corn in our observations was fixed on all the variants of the experiment starting from an inter-stage period of 11 leaves – flowering. So, if at the stage of 7 leaves the

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difference between the variants was low and averaged to about 1-6 g per plant, then at the stage of 11 leaves, comparing the variants with and without irrigation, the difference was 35-38 g.

Table 1

Dynamics of accumulation of crude biomass by corn plants, g per 1 plant

Conditions of humidification	Mineral nutrition background	Density of plants, thousand pcs/ha		
		40	60	80
Inter-stage period 6 –7 leaves				
Without irrigation	Without fertilizers	107	106	106
	Calculated dose	110	107	108
	Recommended $N_{120}P_{90}$	112	109	109
Inter-stage period 9-11 leaves				
Without irrigation	Without fertilizers	272	265	264
	Calculated dose	278	268	270
	Recommended $N_{120}P_{90}$	282	270	273
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	314	309	296
	Calculated dose	317	310	302
	Recommended $N_{120}P_{90}$	324	312	304
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	311	306	294
	Calculated dose	314	308	299
	Recommended $N_{120}P_{90}$	321	309	301
Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	310	305	293
	Calculated dose	313	307	298
	Recommended $N_{120}P_{90}$	320	308	300
Inter-stage period flowering – grain formation				
Without irrigation	Without fertilizers	620	609	603
	Calculated dose	680	647	632
	Recommended $N_{120}P_{90}$	692	654	646
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	732	679	666
	Calculated dose	792	709	698
	Recommended $N_{120}P_{90}$	804	767	718
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	731	678	664
	Calculated dose	791	708	693
	Recommended $N_{120}P_{90}$	803	765	707

Table 1 (continuance)

Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	728	676	662
	Calculated dose	789	735	681
	Recommended N_{120} P_{90}	800	763	704
Inter-stage period milk and milk-wax ripeness of grain				
Without irrigation	Without fertilizers	754	720	701
	Calculated dose	778	746	726
	Recommended $N_{120}P_{90}$	816	776	753
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	1087	908	839
	Calculated dose	1113	954	871
	Recommended $N_{120}P_{90}$	1118	1015	894
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	1042	935	832
	Calculated dose	1060	955	856
	Recommended $N_{120}P_{90}$	1085	996	869
Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	1032	930	760
	Calculated dose	1069	940	831
	Recommended $N_{120}P_{90}$	1076	975	840
Inter-stage period wax-full ripeness of grain				
Without irrigation	Without fertilizers	716	672	613
	Calculated dose	741	678	648
	Recommended $N_{120}P_{90}$	748	678	665
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	999	820	751
	Calculated dose	1025	866	783
	Recommended $N_{120}P_{90}$	1030	927	806
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	954	847	744
	Calculated dose	972	867	768
	Recommended $N_{120}P_{90}$	997	908	781
Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	944	842	672
	Calculated dose	981	852	743
	Recommended $N_{120}P_{90}$	988	887	752

The maximum amount of crude corn biomass was fixed at the stage of milk-wax ripeness of grain, regardless the influence of factors studied. But the greatest manifestation to the increase of crude biomass of corn accumulation was contributed by the improvement of conditions of humidification of plants through vegetative watering.

A significant amount of crude corn biomass was fixed at the stage of milk grain ripeness, and in the variants with the biologically optimum regime of irrigation 70-80-70% FC in the soil layer 0-50 cm its figure was maximal and averaged by the factors to 978 g. With regard to water-saving and soil-protective regimes, their values were close to the optimum and, accordingly, were 959 and 939 g. Comparing with non-irrigated variants, where the value of the surface crude biomass was 752 g, we found that irrigation provided an increase in biomass by 27.5-30%. Application of mineral fertilizers positively influenced on the indicators of accumulation of green mass by corn plants. The maximum difference between the variants without fertilizers and plots with the application of $N_{120}P_{90}$ and calculated dose was observed at the stage of milk ripeness and averaged to 3.4-5.5%.

The increase in plant density, on the contrary, negatively affected on the raw weight of a plant. Thus, in the period of milk ripeness of grain the increase in the density of crops from 40 to 60 and 80 thousand/ha led to the reduction of raw plant weight by 9.8 and 18.8%, respectively.

Table 2

Dynamics of biomass accumulation at the milk ripeness stage, t/ha

Conditions of humidification	**Mineral nutrition background**	**Density of plants, thousand/ha**			**Average by the factors**	
		40	**60**	**80**	**A**	**B**
Without irrigation	Without fertilizers	30.2	43.2	56.1	12.4	15.2
	Calculated dose	31.1	44.8	58.1		16.6
	Recommended $N_{120}P_{90}$	32.6	46.6	60.2		17.2
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	43.5	54.5	67.1	18.2	
	Calculated dose	44.5	57.2	69.7		
	Recommended $N_{120}P_{90}$	44.7	60.9	71.5		
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	41.7	56.1	66.6	17.5	
	Calculated dose	42.4	57.3	68.5		
	Recommended $N_{120}P_{90}$	43.4	59.8	69.5		
Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	41.3	55.8	60.8	17.2	
	Calculated dose	42.8	56.4	66.5		
	Recommended $N_{120}P_{90}$	43.0	58.5	67.2		
Average by the factor C		11.7	16.6	20.7		
LSD_{05}, t/ha: factor A – 0.8; factor B – 1.4; factor C – 0.9						

At the full ripeness of grain there was a decrease in the productivity of crude biomass of plants in all the variants and in all the years of the study. This is because plastic substances move from the vegetative mass to the grain.

The effectiveness of irrigation, application of mineral fertilizers and increase in the density of corn are also confirmed by the productivity of crude biomass per hectare.

Accumulation of vegetative mass per 1 hectare of crops, on average by the studied factors, during the growing season of corn was rather uneven and depended mainly on the stages of growth and development of the plants. However, the maximum values it reached at the stage of milk ripeness of grain (Table 2).

Analyzing the data of the study, the dynamics of accumulation of raw vegetative mass of the plants concerning irrigation regimes and mineral nutrition effects was like the dynamics of biomass indices per plant. That is, the improvement of water and nutritive regimes of corn plants positively affected the yield of green mass per 1 hectare of the crops, either as per each plant. However, the increase in density of corn plants, in this case, showed positive effect on the weight of surface biomass per hectare of the crops.

Thus, the value of the crude biomass accumulation at the use of irrigation regimes changed in the range from 54.7 to 57.1 t/ha, this is by 22.2-27.5% bigger than at the non-irrigated variant.

Mineral nutrition increased the green mass yield of corn plants by 1.9-3.4 t/ha, or by 3.6-6.7%.

Thickening of the crops resulted in the increase in raw biomass per hectare. Thus, at the density of 40 thousand/ha weight of surface biomass was, on average by the factor, 40.1 t/ha, at 60 thousand/ha – 54.25 t/ha, that is by 35.3% bigger than the previous value. The maximum value of vegetative mass was obtained at the density of plants of 80 thousand/ha, and averaged to 65.15 t/ha, that is by 62.5% bigger than at the density of 40 thousand/ha.

2. Influence of conditions of humidification, background of mineral nutrition and density of plants on the indicators of accumulation of dry matter in the plants of corn

The dynamics of accumulation of dry matter is mostly determined by the conditions of water supply, mineral nutrition and density of plants.

At the beginning of the growing season, the process of accumulation of dry biomass was slow (Table 3). Further, and especially during the intensive formation of leaf apparatus system, the daily gain of dry matter has increased significantly. So, if at the stage of 7 leaves its weight was only 19.0-21.7 g per 1 plant, then in the period of 11 leaves this figure drastically increased and was, on average by the studied factors, 41.7-68.8 g per plant.

Table 3

Dynamics of accumulation of dry biomass by the plants of corn, g per plant

Conditions of humidification	**Mineral nutrition background**	**Density of plants, thousand pcs/ha**		
		40	**60**	**80**
Inter-stage period 6-7 leaves				
Without irrigation	Without fertilizers	20.9	20.4	20.0
	Calculated dose	23.7	22.6	22.0
	Recommended $N_{120}P_{90}$	24.6	23.7	23.1
Inter-stage period 9-11 leaves				
Without irrigation	Without fertilizers	45.1	43.7	41.7
	Calculated dose	51.0	49.9	47.3
	Recommended $N_{120}P_{90}$	52.9	51.0	47.4
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	61.0	59.6	57.6
	Calculated dose	66.9	65.8	63.2
	Recommended $N_{120}P_{90}$	68.8	66.9	63.3
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	57.7	56.3	54.3
	Calculated dose	63.6	62.5	59.9
	Recommended $N_{120}P_{90}$	65.5	63.6	60.0
Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	56.0	54.6	52.6
	Calculated dose	61.9	60.8	58.2
	Recommended $N_{120}P_{90}$	63.8	61.9	58.3
Inter-stage period flowering-grain formation				
Without irrigation	Without fertilizers	103.0	86.7	76.4
	Calculated dose	123.9	107.8	88.8
	Recommended $N_{120}P_{90}$	134.7	125.6	99.9
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	129.0	112.7	102.4
	Calculated dose	149.9	133.8	114.8
	Recommended $N_{120}P_{90}$	160.7	151.6	125.9
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	123.7	107.4	97.1
	Calculated dose	144.6	128.5	109.5
	Recommended $N_{120}P_{90}$	155.4	146.3	120.6
Soil protection 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	122.1	105.8	95.5
	Calculated dose	143.0	126.9	107.9
	Recommended $N_{120}P_{90}$	153.8	144.7	119.0

Table 3 (continuance)

Inter-stage period milk and milk-wax maturity of grain				
Without irrigation	Without fertilizers	130.5	114.2	103.9
	Calculated dose	151.4	135.3	116.3
	Recommended $N_{120}P_{90}$	162.2	153.1	127.4
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	186.5	170.2	159.9
	Calculated dose	207.4	191.3	172.3
	Recommended $N_{120}P_{90}$	218.2	209.1	183.4
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	181.2	164.9	154.6
	Calculated dose	202.1	186.0	167.0
	Recommended $N_{120}P_{90}$	212.9	203.8	178.1
Soil protection 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	179.6	163.3	153.0
	Calculated dose	200.5	184.4	165.4
	Recommended $N_{120}P_{90}$	211.3	202.2	176.5
Inter-stage period wax-full ripeness of grain				
Without irrigation	Without fertilizers	208.5	192.2	181.9
	Calculated dose	229.4	213.3	194.3
	Recommended $N_{120}P_{90}$	240.2	231.1	205.4
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	299.5	278.2	267.9
	Calculated dose	339.4	320.3	290.3
	Recommended $N_{120}P_{90}$	345.2	328.1	300.4
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	289.2	272.9	262.6
	Calculated dose	315.1	300.0	285.0
	Recommended $N_{120}P_{90}$	320.9	311.8	296.1
Soil protection 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	287.6	271.3	261.0
	Calculated dose	308.5	292.4	273.4
	Recommended $N_{120}P_{90}$	319.3	310.2	284.5

The maximum level the dry mass indicators, in contrast to the raw surface biomass, corn plants have reached at the end of the growing season, in the inter-stage period from wax to full ripeness of grain.

The highest value of dry mass of corn was fixed in the variants with the biologically optimal irrigation mode 70-80-70% FC in the soil layer of 0-50 cm, on average by the factors, – 307.7 g per plant. The variants with water-saving and soil-protective regimes are slightly different, their productivity was, respectively, 289.8 and 294.8 g.

Comparing with the variants without irrigation, the amounts of dry mass of which were 181.9-240.2 g, it was determined that irrigation provided the mass increase by 37.5-46.0% depending on the regime of irrigation.

The use of fertilizers positively affected the increase in weight of the dry mass of corn plants. Unlike the plots without fertilizers, the variants with the application of $N_{120}P_{90}$ and calculated doses provided the increase, on average by the factors, by 9.4 and 13.7%, respectively.

Plant density, on the contrary, negatively affected the dry weight per plant. Thus, during the wax ripeness of grain the increase in the density of crops from 40 to 60 thousand/ha led to the reduction of the dry mass per plant by 5.2%, and to 80 thousand/ha – by 11.4%, respectively. However, the recalculation per hectare showed that thickening of corn plants positively affected the weight of the surface dry mass. That is, at the density of 40 thousand/ha at the stage of wax ripeness the weight of surface dry mass was, on average by the factor, 11.7 t/ha, and with the increase in density to 60, 80 thousand/ha – 16.6 and 20.7 t/ha, respectively, or by 42.2 and 77.2% bigger than at the previous values.

3. Dynamics of growth of leaf surface

An important influence on quantitative and qualitative indices of productivity formation are physical and physiological processes that transform solar energy into organic matter in the system atmosphere – leaf – plant – agrocenosis. The intensity of this process depends significantly on the characteristics and spectral composition of solar radiation, the energy balance between the absorbed energy and the expenses on photosynthesis, transpiration, heat and moisture exchange, availability of nutrients and easily accessible moisture, etc[9]. To optimize productive processes and to form the maximum possible corn yield a great value has the size of the plant leaf, which accumulates solar radiation during photosynthesis and provides the creation of organic matter[10].

Researches studied the reaction of corn plants on irrigation regimes, application of mineral fertilizers and density of plants by defining their indices of photosynthetic activity. The area of leaf surface of the crop was rather volatile and depended both on weather conditions during the years of the researches and on the investigated factors (Table 4).

At the beginning of the vegetative period (6-7 leaves), the area of leaf apparatus, on average for the years of the study, in all the plots fluctuated within 4.8-10.3 thousand m^2/ha. Since in this period the leaf apparatus was formed only under natural humidification, there was no significant difference between the variants. At the same time, the area of the assimilation apparatus per plant in this period was the minimum – 1.14-1.38 cm^2.

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Table 4

Leaf area of the plants of corn per 1 ha, thousand m^2
(the average for 2009–2018)

Conditions of humidification	**Mineral nutrition background**	**Density of plants, thousand pcs/ha**		
		40	**60**	**80**
Inter-stage period 6-7 leaves				
Without irrigation	Without fertilizers	4.8	6.9	9.3
	Calculated dose	5.3	7.3	9.6
	Recommended $N_{120}P_{90}$	5.5	7.8	10.3
Inter-stage period 9-11 leaves				
Without irrigation	Without fertilizers	16.7	22.1	24.2
	Calculated dose	18.3	23.0	26.3
	Recommended $N_{120}P_{90}$	19.5	25.2	27.2
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	22.4	28.5	31.7
	Calculated dose	23.3	30.0	32.8
	Recommended $N_{120}P_{90}$	24.7	31.2	33.1
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	18.2	24.7	30.0
	Calculated dose	19.8	25.2	31.7
	Recommended $N_{120}P_{90}$	21.3	28.8	32.4
Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	17.9	23.5	29.2
	Calculated dose	19.1	24.9	30.8
	Recommended $N_{120}P_{90}$	20.9	25.5	31.0
Inter-stage period flowering – grain formation				
Without irrigation	Without fertilizers	20.8	25.9	27.6
	Calculated dose	21.7	26.4	29.2
	Recommended $N_{120}P_{90}$	22.1	27.6	30.4
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	29.7	35.6	41.8
	Calculated dose	31.9	37.8	45.9
	Recommended $N_{120}P_{90}$	33.2	38.1	47.3
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	24.3	29.0	36.2
	Calculated dose	27.3	35.3	41.8
	Recommended $N_{120}P_{90}$	30.9	36.9	43.7
	Without fertilizers	23.0	28.3	32.9
	Calculated dose	25.5	33.5	40.6
	Recommended $N_{120}P_{90}$	28.8	34.8	42.5

Table 4 (continuance)

Inter-stage period milk and milk-wax ripeness of grain				
Without irrigation	Without fertilizers	18.7	20.4	27.3
	Calculated dose	19.1	21.7	28.1
	Recommended $N_{120}P_{90}$	20.1	22.8	28.9
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	22.0	27.9	34.8
	Calculated dose	25.5	31.0	38.2
	Recommended $N_{120}P_{90}$	26.0	31.9	39.3
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	19.1	25.0	30.0
	Calculated dose	23.6	28.9	32.0
	Recommended $N_{120}P_{90}$	24.4	30.9	34.2
Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	18.8	24.2	29.1
	Calculated dose	22.3	27.4	31.7
	Recommended $N_{120}P_{90}$	23.8	29.2	32.7
Inter-stage period wax-full ripeness of grain				
Without irrigation	Without fertilizers	12.4	18.5	21.7
	Calculated dose	13.9	19.6	22.3
	Recommended $N_{120}P_{90}$	14.7	20.1	22.8
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	14.4	20.5	27.4
	Calculated dose	17.0	23.5	30.8
	Recommended $N_{120}P_{90}$	17.8	23.8	31.9
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	14.6	19.6	24.0
	Calculated dose	16.3	22.6	25.9
	Recommended $N_{120}P_{90}$	16.9	23.0	26.6
Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	13.0	19.0	22.6
	Calculated dose	14.3	21.1	23.3
	Recommended $N_{120}P_{90}$	15.1	22.0	24.6

After the first vegetative waterings (10-11 leaves) the indicators of the leaves' area were considerably increased in comparison with the previous stage. The highest values were achieved in the irrigated plants, comparatively to the variants without irrigation, regardless on the plant density and background of mineral nutrition. Thus, on the plots without irrigation the leaf area reached 22.5 m^2/ha, whereas in the variants with the biologically optimal regime of 70-80-70% FC in the soil layer 0-50 cm, it was 28.6 m^2/ha, at the water-saving regime (70-70-70% FC in the soil layer 0-50 cm) – 25.8 m^2/ha, and at the soil-protective one (70-70-70% FC in the soil layer 0-30 cm) – 24.8 m^2/ha. Therefore, irrigation provided an increase in the leaf apparatus area by 10.0-27.3%.

Application of mineral fertilizers, in contrast to the unfertilized plots, provided the increase in the area of the assimilation apparatus only by 1.6-2.3 m^2/ha. A little more increase of this indicator was provided by thickening of the crops from 40 to 60 and 80 thousand/ha, and it was 5.9-9.9 m^2/ha, or 29.1-48.9%, depending on the variant of the experiment.

It was established that the maximum development of the leaf area is reached at the stage of flowering on all the studied variants. However, there is a significant difference between the influence of the studied factors.

The largest area of the leaves of corn plants averaged to 47.3 thousand m^2/ha at the biologically optimal irrigation regime with the application of the recommended norm of fertilizer $N_{120}P_{90}$ and the density of plants 80 thousand/ha, and the smallest one was in the same period on the variant without irrigation, without fertilizers at the density of 40 thousand/ha, and it averaged to 20.8 thousand m^2/ha.

In the inter-stage flowering-grain formation the area of leaf apparatus per plant reached its peak and was 8.3 thousand cm^2 on the above-mentioned variants, but at the density of 40 thousand/ha. The smallest value was fixed on the plots without irrigation, no fertilizers applied at the density of 80 thousand/ha – 3.45 thousand cm^2, which is 58.4% less.

In the inter-stage period of milk-milk-wax ripeness we observed the reduction in the area of leaf index on all the variants of the experiment due to the death of the lower leaves. This process in the variants with vegetative irrigation was slower than on the plots without irrigation.

Observing the growth and development of corn plants we found out that the average daily increase in the area of the assimilation surface reached its maximum in the inter-stage period from 7 leaves to 11 leaves and fluctuated within 0.85-1.48 thousand m^2/day. Further the tendency to gradual reduction in this indicator with a critical decrease in the end of vegetation in all the studied variants was observed.

4. Net productivity of photosynthesis and photosynthetic potential of corn plants

In the field conditions the volume of corn yield under the improved water supply and mineral nutrition and the change in plant density depends mainly on the tempo of formation and the size of the photosynthetic apparatus and the intensity and duration of its work.

Photosynthetic potential accumulates solar energy in the process of photosynthesis and provides the creation of organic matter, which is essential for the accumulation of biomass. This parameter can serve as an indicator of potential of a particular crop and it significantly changes under the influence of soil-ecological, technological conditions and genetic features of a hybrid. The study of morpho-physiological indicators of corn hybrids can provide specific recommendations for the opening of reserved hybrids[11] potential under specific conditions.

According to many scientists, one of the important indicators, which reflects the effectiveness of agro-technical activities of cultivation, is the pure productivity of plant photosynthesis in corn. The value of which ranges from 2 to 25 g/m^2 per day, and this figure reaches the maximum in the inter-stage period from 15 leaves to the beginning of grain [12]formation.

The performed calculations indicate that on the average for 2009–2018 the values of the net performance of photosynthesis in corn crops has significantly changed by the stages of growth and development and strongly depended on the conditions of moisture supply. Thus, under different conditions of humidification at the nutritive background of $N_{120}P_{90}$ and the density of plants 80 thousand/ha this figure had the following values.

It was determined that in the initial stages of the plant growth and development (inter-stage 7-11 leaves), the net the productivity of photosynthesis was not great – 3.3 g/m^2 per day but did not depend on the studied factors. Significant difference between the variants of natural and artificial humidification was observed in the inter-stage of 11 leaves-flowering, when at the variant without irrigation this figure did not exceed 7.5 g/m^2 per day, and in the variant with irrigation regime 70-80-70% FC in the soil layer 0-50 cm it increased almost 1.5 times to 11.4 g/m^2 per day. At the irrigation with pre-watering threshold of 70% FC in the soil layer 0-50 cm throughout the vegetation, and 70-70-70% FC in the soil layer 0-30 cm, it should be noted that the indicator of net photosynthesis productivity slightly decreased in comparison with the biologically optimal irrigation regime, but considerably exceeded the non-irrigated variants, and it averaged to 9.5 g/m^2 per day (Table 5).

The maximum values of net photosynthesis were in the inter-stage period of flowering –grain formation on all the variants of humidification conditions. On the plots without irrigation, this figure did not exceed 10.4 g/m^2 per day, whereas under the use of water-saving and soil-protective regimes of irrigation it was 12.7 and 12.5 g/m^2 per day, respectively. The highest value in this inter-stage period was obtained at the irrigation regime 70-80-70% FC in the soil layer 0-50 cm – 13.2 g/m^2 per day.

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Table 5

Dynamics of net productivity of photosynthesis in corn crops depending on humidification conditions, g/m^2 per day (average for 2009–2018)

Inter-stage periods of growth and development	Conditions of humidification, % FC			
	Without irrigation	70-80-70% FC in the soil layer 0-50 cm	70-70-70% FC in the soil layer 0-50 cm	70-70-70% FC in the soil layer 0-30 cm
7 leaves – 11 leaves	3.3	3.3	3.3	3.3
11 leaves – flowering	7.5	11.4	9.5	9.5
flowering – grain formation	10.4	13.2	12.7	12.5
grain formation – milk ripeness of grain	6.2	9.9	8.1	7.1
milk ripeness of grain – wax ripeness of grain	3.0	5.6	4.8	4.5
Average	6.1	8.7	7.7	7.4

Notes: mineral nutrition background – $N_{120}P_{90}$; density of plants 80 thousand pcs./ha.

Starting from the inter-stage period of formation – milk ripeness of grain, the indicators of net photosynthesis productivity are gradually decreasing and in the stage of wax ripeness it is in the non-irrigated conditions 3.0 g/m^2 per day. In the variant of the biologically optimal irrigation regime – 5.6, and at the water-saving and soil-protective ones – 4.8 and 4.5 g/m^2 per day, respectively.

The volume of grain yield of corn is mainly determined by the development of the leaf apparatus of the plant and photosynthetic potential of the crops, which accumulates solar energy in the process of photosynthesis[13]. Photosynthetic potential is essential for the accumulation of biomass. This indicator can serve as an indicator of potential capacities of the crops of a particular type and significantly changes under the influence of soil, ecological, technological conditions, and hybrid's genotype. Therefore, the study of morpho-physiological parameters of corn plants can provide specific recommendations for opening of the reserved potential of plants under specific conditions[14].

In our study, the photosynthetic potential during the vegetation period differed significantly in various conditions of humidification, application of mineral fertilizers and an increase in the density of plants.

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The largest values were obtained at the variant with the biologically optimal regime of irrigation and was, on the average by the factor, 1743.9 thousand. m^2× days. A little bit lower values were obtained in the variants with water-saving and soil-protective regimes – 1606.8 and 1584.5 thousand m^2× days, respectively.

Consequently, the application of artificial humidification caused the increase of the photosynthetic potential of corn by 12.2-20.1%, compared to the plots without irrigation.

The use of mineral fertilizers increased the photosynthetic potential by 8.7-11.8%. Thus, application of recommended fertilizer dose of $N_{120}P_{90}$ This figure was 1665.7 thousand m^2× days and the calculated dose for the planned yield – 1609.9 thousand m^2× days (Table 6).

Table 6

The photosynthetic potential of corn plants, thousand m^2 × days (average for 2009–2018)

Conditions of humidification	**Mineral nutrition background**	**Density of plants, thousand/ha**			**Average**	
		40	**60**	**80**	**A**	**B**
Without irrigation	Without fertilizers	1068.4	1348.9	1570.1	1391.8	1469.8
	Calculated dose	1117.1	1379.0	1682.6		1609.9
	Recommended $N_{120}P_{90}$	1149.7	1471.0	1739.4		1665.7
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	1269.0	1543.6	2056.0	1743.9	
	Calculated dose	1377.4	1784.9	2214.5		
	Recommended $N_{120}P_{90}$	1408.0	1824.2	2218.1		
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	1128.7	1444.2	1808.5	1606.8	
	Calculated dose	1245.0	1657.9	2000.8		
	Recommended $N_{120}P_{90}$	1332.1	1775.9	2068.5		
Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	1251.5	1414.0	1734.7	1584.5	
	Calculated dose	1296.8	1592.2	1970.3		
	Recommended $N_{120}P_{90}$	1316.8	1679.8	2004.7		
Average by the factor C		1246.7	1576.3	1922.3		
LSD_{05}, t/ha: humidification conditions – 25.6; mineral nutrition background – 45.4; density of plants – 28.6						

The photosynthetic potential increased with the increase in the density of corn plants. At thickening of the crops from 40 to 60-80 thousand/ha, on the average by the studied factors, its indicators increased by 20.9-35.1%, respectively.

The yield of conditioned seeds of corn hybrid Kros 221M at the plots of hybridization fluctuated by the years of the study within 3.89-9.10 t/ha depending on the regimes of irrigation, background of mineral nutrition and plant density (Table 7).

Table 7

The yield of conditioned seeds of corn at the plots of hybridization depending on the studied factors by the years of the study

Conditions of humidification, (Factor A)	**Mineral nutrition background, (Factor B)**	**Density of plants, thousand/ha (Factor C)**			**Average by the factor**	
		40	**60**	**80**	**A**	**B**
Without irrigation	Without fertilizers	3.89	4.11	4.61	4.66	5.77
	Calculated dose	4.58	4.93	5.23		7.07
	Recommended $N_{120}P_{90}$	4.63	4.81	5.11		7.18
Biologically optimal 70-80-70% FC in the soil layer 0-50 cm	Without fertilizers	5.65	6.17	6.98	7.45	
	Calculated dose	7.00	8.13	8.92		
	Recommended $N_{120}P_{90}$	6.96	8.16	9.10		
Water-saving 70-70-70% FC in the soil layer 0-50 cm	Without fertilizers	5.68	6.26	6.99	6.61	
	Calculated dose	6.68	7.66	8.44		
	Recommended $N_{120}P_{90}$	6.79	7.85	8.73		
Soil-protective 70-70-70% FC in the soil layer 0-30 cm	Without fertilizers	5.59	6.50	6.81	7.35	
	Calculated dose	6.76	7.97	8.51		
	Recommended $N_{120}P_{90}$	6.82	8.23	8.93		
Average by the factor C		5.92	6.73	7.36		
LSD_{05}, t/ha: Factor A – 0.37; Factor B – 0.41; Factor C – 0.39						

The results of the study revealed that in the variants without irrigation the yield of conditioned seeds of the hybrid Kros 221M was 3.89-5.11 t/ha, depending on application of mineral fertilizers and density of plants. Application of vegetation watering contributed to the significant increase in grain yield of corn by 1.95-2.79 t/ha or 47.8-59.9%.

Thus, at the biologically optimal regime of irrigation (70-80-70% FC in the soil layer 0-50 cm), the seed yield of 7.45 t/ha was obtained, on the average by the factor. Whereas in the variants with irrigation regime

70-70-70% FC in the soil layer 0-50 cm it was 6.61 t/ha, and on the plots with irrigation regime 70-70-70% FC in the soil layer 0-30 cm – 7.35 t/ha.

The use of fertilizers provided the increase in the yield of conditioned seeds of the hybrid Kros 221M, in comparison to the unfertilized variant, on the average by the factor, by 1.30-1.41 t/ha. Thickening of the crops on the plots of hybridization from 40 to 60 and 80 thousand/ha, on the average by the factor C, contributed to the increase in the yield by 0.81-1.44 t/ha.

CONCLUSIONS

The maximum development of the leaf area was reached during the flowering period on all the studied variants. The largest value it has acquired in the variant with the biologically optimal regime of irrigation at the application of the recommended dose $N_{120}P_{90}$ and the density of plants 80 thousand/ha, where it exceeded 47.0 thousand m^2/ha.

The photosynthetic potential during the vegetation period significantly differed by the studied variants. The largest values it acquired in the variant with the biologically optimal irrigation regime with the application of the recommended fertilizer dose $N_{120}P_{90}$ and the density of plants 80 thousand/ha.

The optimum humidification of corn crops provided obtaining of 7.45 t/ha of conditioned seeds. Irrigation at the pre-watering threshold of moisture 70-70-70% FC in 0-30 and 0-50 cm soil layers reduced the yield, on average by the factor, by 0.10-0.84 t/ha. The use of fertilizers provided the increase in the yield of corn seeds, in comparison with the unfertilized variant, on the average by the factor, by 1.30-1.41 t/ha. Thickening of the crops on the hybridization plots from 40 to 60 and 80 thousand/ha, on the average by the factor, contributed to the increase in the yield by 0.81-1.44 t/ha, respectively.

SUMMARY

The goal of the study was to substantiate and improve the elements of the cultivation technology of the corn hybrid Kros 221M on the plots of hybridization in the irrigated conditions of the South of Ukraine.

The cultivation technology elements for corn seeds growing in the conditions of irrigation in the South of Ukraine were improved, thus reducing the expenditures for irrigation water and other resources on the obtaining of a seed unit, the reaction of corn plants to change in the background of mineral nutrition and density of plants were determined.

The article presents the results of the study on the determination of the effect of irrigation, doses of mineral fertilizers and plant density on the photosynthetic parameters of grain corn. It was determined that the maximum development of the leaf area was reached in the period of flowering on all the studied variants. The highest level of photosynthetic activity of plants and the yield of corn grain was fixed at the biologically optimal regime of irrigation,

application of mineral fertilizers in the dose $N_{120}P_{90}$ and the density of plants 80 thousand/ha. The study determined that the yield of corn seeds on the plots of hybridization reached the maximum level of 9.1 t/ha in the variant with the biologically optimal regime of irrigation (70-80-70% FC in the soil layer 0-50 cm) at the recommended dose of fertilizers $N_{120}P_{90}$ and plant density 80 thousand pcs/ha.

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THE EFFECT OF DRIP IRRIGATION, PHOSPHOGYPSUM AND VARIOUS DOSES AND FORMS OF MINERAL FERTILIZERS ON CHEMICAL, PHYSICAL AND PHYSICO-CHEMICAL PROPERTIES OF DARK CHESTNUT SOIL

Shkoda O. A.

INTRODUCTION

The water reclamation of lands is one of the main factors of intensification of agriculture in the areas with insufficient and unstable humidification. At the same time, irrigation is one of the most active factors of anthropogenic pressure on environment in general and, in particular, on the meliorated land.

The practice of the use of drip irrigation in the conditions of the South of Ukraine has shown that its use without considering regional peculiarities and quality of irrigation water can lead to negative changes in soil processes and regimes and, first of all, to the manifestation of the secondary alkalination and salinization of soils[1,2,3].

In this regard, it is necessary to scientifically substantiate patterns and nature of changes in soil properties, their indices of fertility and ecological state in specific conditions of local humidification, development of measures for prevention of degradation of agro-meliorative state of lands at drip-irrigation with waters of low quality (mineralized water with unfavorable ratio of mono- and divalent cations). Solving these issues is a relevant scientific direction, which promotes preservation of ecological and agro-melìorative soil conditions and obtaining sustainable levels in yields of crops.

The study was carried out at the research field of the Institute of Irrigated Agriculture of NAAS in the short-field experiment, placed in the zone of action of the Ingulets irrigation system. Field study scheme was as follows: 1) without irrigation, fertilizers and ameliorant – control 1; 2) irrigation, without fertilizers and ameliorant – control 2; 3) irrigation+$N_{120}P_{90}$ (recommended fertilizer dose); 4) irrigation+calculated dose of fertilizers (nitrogen fertilizer – ammonium nitrate); 5) irrigation+calculated dose of fertilizers (nitrogen fertilizer – calcium nitrate); 6) irrigation+phosphogypsum

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3.0 t/ha (under pre-sowing cultivation); 7) irrigation+phosphogypsum 1.9 t/ha (in the sowing strip); 8) irrigation+calculated dose of fertilizers (nitrogen fertilizer – calcium nitrate)+phosphogypsum 1.9 t/ha (in the sowing strip); 9) irrigation with improved water (calcination)+calculated dose of fertilizers (nitrogen fertilizer – ammonium nitrate). The crop – annual green onion, variety Khaltsedon. The technology is generally accepted for the Steppe zone of Ukraine, excepting the studied factors. In the experiment we used a strip sowing scheme 7+20+7+20+7+20+7+52.

1. Ion-salt composition of soil solution of dark chestnut at drip irrigation with applications of phosphogypsum and mineral fertilizers

It is known that irrigation engages into production process such important components of biosphere as soil, moisture and plants that are closely interconnected by streams of water, energy, substance and information. The practice of irrigation of dark chestnut soils with mineralized waters in the zone of unstable humidification confirms the ability to obtain high and stable crop yields. At the same time, there is a number of negative effects of irrigation, affecting soil fertility, agro-melìorative conditions and, in particular, the salt regime[4].

Soil solution is the most dynamic and active component of soil. The composition of soil solution is formed at the expense of intra-soil processes – biological, chemical, biochemical, that closely depend on environmental conditions, including adjacent phases of the soil (solid, gaseous), with which the liquid phase is in a dynamic hydrological equilibrium[5].

The studies found that drip irrigation with slightly mineralized water led to accumulation of soluble salts, mainly in the soil layer 0-30 cm (Table 1).

The salt content at the end of the vegetation of the crop increased not only in the area of humidification (sowing strip), but also in the non-irrigated spacing (between the strips). So, in the variant without fertilizer and meliorant, the amount of salts increased on the average for three years of the study in the strip by 0.0382, and between the strips – 0.014 percent points in comparison with the control without irrigation. The increase of salts content in the soil occurred due to the anions of chloride and sulphate and magnesium and sodium cations. In this case, their number in the sowing strip (humidifying) increased by 0.39; 0.25 and 0.14; 0.44 meq/100 g, and between the strips (large inter-row spacing) – by 0.16; 0.08; 0.10 and 0.14 meq/100 g of soil, respectively.

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Table 1

The effect of drip irrigation, application of ameliorant and mineral fertilizers on the ion-salt composition of water extraction of soil at green onions cultivation (soil layer 0-30 cm, average for 2013–2015)

Variant	Place of sampling	Aqueous pH	Ion content, meq/100 g of soil							Amount of salts,%		$\frac{Ca^{2+}}{Na^{+}}$
			CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	total	toxic	
1.	Sowing strip	7.3	0.00	0.43	0.35	0.78	0.52	0.33	0.71	0.1070	0.0660	0.7
	Between strips	7.3	0.00	0.41	0.38	0.77	0.53	0.31	0.72	0.1064	0.0653	0.7
2.	Sowing strip	7.7	0.00	0.42	0.74	1.03	0.57	0.47	1.15	0.1452	0.1017	0.5
	Between strips	7.4	0.00	0.40	0.54	0.86	0.52	0.43	0.85	0.1205	0.0797	0.6
3.	Sowing strip	7.7	0.00	0.46	0.83	0.97	0.65	0.40	1.21	0.1501	0.1000	0.5
	Between strips	7.4	0.00	0.43	0.57	0.88	0.62	0.41	0.85	0.1254	0.0777	0.7
4.	Sowing strip	7.7	0.00	0.41	0.81	0.93	0.58	0.43	1.14	0.1418	0.0970	0.5
	Between strips	7.4	0.00	0.42	0.54	0.87	0.57	0.44	0.82	0.1224	0.0781	0.7
5.	Sowing strip	7.6	0.00	0.46	0.84	1.05	0.72	0.45	1.18	0.1556	0.1007	0.6
	Between strips	7.4	0.00	0.43	0.55	0.87	0.63	0.35	0.87	0.1246	0.0762	0.7
6.	Sowing strip	7.2	0.00	0.46	0.89	2.07	1.41	0.63	1.38	0.2277	0.1258	1.0
	Between strips	7.3	0.00	0.43	0.58	1.87	1.27	0.47	1.14	0.1941	0.1022	1.1
7.	Sowing strip	7.2	0.00	0.44	0.85	2.20	1.57	0.60	1.32	0.2320	0.1195	1.2
	Between strips	7.4	0.00	0.43	0.56	1.01	0.63	0.38	0.99	0.1348	0.0681	0.6
8.	Sowing strip	7.3	0.00	0.43	0.79	2.23	1.61	0.57	1.27	0.2300	0.1149	1.3
	Between strips	7.4	0.00	0.44	0.56	1.03	0.65	0.44	0.94	0.1363	0.0864	0.6
9.	Sowing strip	7.4	0.00	0.43	0.68	1.89	1.20	0.62	1.18	0.2001	0.1124	1.0
	Between strips	7.3	0.00	0.43	0.57	1.02	0.63	0.41	0.98	0.1360	0.0885	0.6
LSD_{05}, meq/100 g of soil				0.03	0.08	0.11	0.06	0.04	0.12	0.0026	0.0019	

Table 2

The effect of drip irrigation, application of ameliorant and mineral fertilizers on ion-salt composition of water extraction of the soil at cultivation of green onions (soil layer 30–50 cm, average for 2013–2015)

Variant	Place of sampling	Aqueous pH	Ion content, meq/100 g of soil							Amount of salts,%		$\frac{Ca^{2+}}{Na^{+}}$
			CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	total	toxic	
1.	Sowing strip	7.5	0.00	0.43	0.16	0.69	0.50	0.29	0.49	0.0899	0.0520	1.0
	Between strips	7.5	0.00	0.43	0.16	0.70	0.50	0.30	0.49	0.0904	0.0527	1.0
2.	Sowing strip	7.9	0.00	0.44	0.19	0.75	0.53	0.30	0.55	0.0965	0.0567	1.0
	Between strips	7.6	0.00	0.43	0.17	0.71	0.50	0.29	0.52	0.0919	0.0540	1.0
3.	Sowing strip	7.9	0.00	0.44	0.20	0.74	0.53	0.30	0.55	0.0964	0.0567	1.0
	Between strips	7.6	0.00	0.44	0.17	0.70	0.51	0.30	0.50	0.0919	0.0533	1.0
4.	Sowing strip	7.9	0.00	0.45	0.21	0.75	0.53	0.32	0.56	0.0983	0.0593	0.9
	Between strips	7.6	0.00	0.44	0.17	0.70	0.51	0.31	0.49	0.0917	0.0533	0.9
5.	Sowing strip	7.9	0.00	0.45	0.20	0.74	0.54	0.32	0.53	0.0970	0.0567	1.0
	Between strips	7.6	0.00	0.45	0.16	0.69	0.50	0.32	0.48	0.0912	0.0533	1.0
6.	Sowing strip	7.8	0.00	0.42	0.22	0.77	0.53	0.33	0.55	0.0977	0.0587	1.0
	Between strips	7.6	0.00	0.42	0.17	0.72	0.50	0.32	0.49	0.0914	0.0540	1.0
7.	Sowing strip	7.8	0.00	0.42	0.22	0.76	0.51	0.33	0.56	0.0971	0.0593	1.0
	Between strips	7.6	0.00	0.43	0.18	0.71	0.50	0.33	0.49	0.0920	0.0547	0.9
8.	Sowing strip	7.8	0.00	0.42	0.21	0.77	0.50	0.33	0.57	0.0972	0.0600	0.9
	Between strips	7.6	0.00	0.42	0.17	0.71	0.50	0.31	0.49	0.0908	0.0533	1.0
9.	Sowing strip	7.8	0.00	0.43	0.20	0.74	0.50	0.30	0.57	0.0957	0.0580	0.9
	Place of sampling	7.5	0.00	0.42	0.17	0.70	0.50	0.31	0.48	0.0901	0.0527	1.0
LSD_{05}, meq/100 g of soil				0.03	0.02	0.04	0.02	0.03	0.05	0.0014	0.0021	

Table 3

The effect of drip irrigation, phosphogypsum and mineral fertilizers on physico-chemical properties of dark chestnut soil (layer 0-30cm, average for 2013-2015)

Variant	Variant	Place of sampling	Content of exchangeable cations, meq/100 g of soil					% of the amount of exchangeable cations		
			Ca^{2+}	Mg^{2+}	Na^+	K^+	Amount	Ca^{2+}	Mg^{2+}	Na^++K^+
1.	Without irrigation, fertilizers and ameliorant – control 1	Sowing strip	15.03	4.27	0.38	0.36	20.04	75.0	21.3	3.7
		Between strips	15.05	4.13	0.40	0.36	19.94	75.5	20.7	3.8
2.	Irrigation, no fertilizers and ameliorant control 2	Sowing strip	13.90	4.90	0.67	0.32	19.79	70.2	24.8	5.0
		Between strips	15.00	4.41	0.44	0.36	20.21	74.2	21.8	4.0
3.	Irrigation+N[illegible]P[illegible] (recommended dose of fertilizers)	Sowing strip	14.32	4.67	0.71	0.33	20.03	71.5	23.3	5.2
		Between strips	15.18	4.33	0.44	0.36	20.31	74.7	21.3	4.0
4.	Irrigation+calculated dose of fertilizers (nitrogen fertilizer – ammonium nitrate)	Sowing strip	13.98	4.80	0.75	0.34	19.87	70.3	24.2	5.5
		Between strips	14.48	4.73	0.44	0.36	20.01	72.1	23.6	4.0
5.	Irrigation+calculated dose of fertilizers (nitrogen fertilizer – calcium nitrate)	Sowing strip	14.59	4.79	0.67	0.33	20.38	71.6	23.5	4.9
		Between strips	15.18	4.51	0.47	0.36	20.52	74.0	22.0	4.0
6.	Irrigation+phosphogypsum 3.0 t/ha (under pre-sowing cultivation)	Sowing strip	15.56	4.55	0.47	0.34	20.92	74.4	21.7	3.9
		Between strips	14.89	4.81	0.45	0.36	20.51	72.6	23.5	3.9
7.	Irrigation+phosphogypsum 1.9 t/ha in sowing strip	Sowing strip	15.19	4.51	0.53	0.34	20.57	73.8	21.9	4.3
		Between strips	14.82	4.09	0.39	0.36	19.66	75.1	20.8	3.8
8	Irrigation+calculated dose of fertilizers (nitrogen fertilizer – calcium nitrate)+phosphogypsum 1.9 t/ha in the sowing strip	Sowing strip	15.87	4.54	0.50	0.34	21.25	74.7	21.3	4.0
		Between strips	15.32	4.47	0.42	0.36	20.57	74.5	21.7	3.9
9.	Irrigation with water of improved quality (calcinated)+calculated dose of fertilizers (nitrogen fertilizer – ammonium nitrate)	Sowing strip	15.09	4.61	0.44	0.34	20.48	73.7	22.5	3.8
		Place of sampling	15.13	4.27	0.48	0.36	20.24	74.8	21.1	4.1

The increase in sodium content in the soil solution was the cause of reduction in the ratio of calcium to sodium by 0.2 units, indicating an increase in the intensity of development of soil salinity. The study of ion-salt composition of the water extraction of the sub-arable layer of the soil (30-50 cm) showed that drip irrigation somewhat increased the content of water-soluble salts only in the humidification zone (Table 2). Thus, their number in the control at irrigation increased by 0.0066%, and in the variants with application of mineral fertilizers and ameliorant – by 0.0053-0.0079% compared with the variant without irrigation. The increase in salt content was due to the toxic salts of chloride and sulphate of sodium.

Application of mineral fertilizers $N_{120}P_{90}$ and calculated dose of fertilizers (nitrogen in the form of ammonium, calcium nitrate) has not significantly changed the qualitative composition of exchangeable cations in the soil absorbtion complex, both in the sowing strip and between strips, compared to the irrigated control. However, it should be noted that application of the calculated dose of fertilizers (nitrogen fertilizer – ammonium nitrate) in the soil of sowing strip there was a tendency to form the highest number of the absorbed sodium – 0.75 meq/100 g, which by 0.5% exceeds the sum of exchangeable cations in the variant with the application of calcium nitrate.

The use of phosphogypsum both in pre-sowing application in the dose 3.0 t/ha and in the sowing strip in 1.9 t/ha had a positive effect on the qualitative composition of the absorbed bases in comparison with the irrigated control. The content of absorbed calcium in the soil in the zone of humidification increased by 1.29-1.66 meq/100 g, and the number of exchangeable magnesium and sodium decreased by 0.35-0.39 and 0.14-0.20 meq/100 g , respectively. The soil after gypsum application belonged to non-saline by the content of exchangeable sodium (2.3-2.6% of the sum of cations).

Combined use of phosphogypsum and calcium nitrate did not contribute to further improvement of qualitative composition of the soil, i.e., reduction of the amount of exchangeable sodium in the soil of sowing strip of green onions. It remained at the level of 2.4% of the sum of cations.

Irrigation with the water of improved quality (after calcination) by the effect on the qualitative composition of the absorbed bases in the soil of the zone of humidification was not inferior to the phosphogypsum fed sowing strip and it was compatible to the use of calcium nitrate. Quantitative indices of exchangeable cations of SAC were approaching the values of the control variant without irrigation.

It should be noted that, according to the total indicator of monovalent cations (Na^{+}+K^{+}), the soil in all the variants of the experiment was classified by the degree of secondary salinity as slightly saline.

3. Agrophysical properties of the soil in the conditions of drip irrigation at the cultivation of green onion

Agrophysical degradation is one of the most common phenomena on irrigated lands. Under the influence of irrigation, agrophysical properties of soils (black, chestnut) undergo significant changes manifested in the destructure of an arable layer, the increase of clodding and the reduction of the agronomically valuable units' content; reduction of porosity, water permeability and compaction of the profile[6] .

The greatest value amonh the agrophysical properties belongs to the bulk density and structural composition. These indicators depend mainly on the granulometric and mineralogical composition of the soil and the content of humus in them. However, the intensity and direction of changes in the soil processes depends on the quality of irrigation water, the regime of irrigation and agricultural machinery used in the cultivation of crops.

One of the important dynamic characteristics of the physical properties of soil is its structure. It is characterized by such values as bulk density and porosity.

The analysis of the data obtained in our researches regarding the bulk density of the soil showed that it was 1.35 g/cm^3 in the control variant without irrigation, and in the variants with the application of mineral fertilizers and phosphogypsum it was 1.35-1.38 g/cm^3.

Therefore, there is no significant difference in the above-mentioned variants. However, a detailed analysis of our research findings showed that the coefficient of variation in the soil bulk density indicators on the variants with irrigation increased in 2.1-4.7 times compared with the control without irrigation, pointing out to a significant imbalance in this indicator in the drip-irrigated conditions.

For the soils of homogeneous granulometric composition the total porosity of the soil is a function of the bulk density. Therefore, the total porosity of the soil layer was also independent on the factors that we have studied. It was almost identical – 46.9-48.1%. The coefficient of variation of the total porosity of the soil in the variants with irrigation was also 2.2-3.7 times higher than in the control without irrigation.

It is known that soil has the ability to form aggregates of different sizes, shapes and durability from mechanical elements. The formation of aggregates is a complex physico-chemical process determined by the action of forces of different nature (capillary, gravity, adhesion, coagulation, etc.).

In the studies, dry sifting of the layer of dark chestnut soil 0-30 cm found out that at the end of vegetation of the plants (technical maturity

[6] Ромащенко М.І. Зрошення земель в Україні. Стан та шляхи поліпшення. К.: «Світанок», 2000. 114 с.

of green onion) drip irrigation in the variant without the use of mineral fertilizers and phosphogypsum led to an increase of soil clodding. The content of aggregates larger than 10 mm in the variant increased by 23.42% compared with a control option without irrigation (Table 4). The increase in this fraction was mainly due to the little fractions of the size of 0.25-1.00 mm and microaggregates (less than 0.25 mm). There was a decrease in the number of agronomically valuable aggregates by 16.61% and the most agronomically valuable aggregates of the size 1-5 mm – by 9.82%.

It was determined that quantitative changes of the aggregate state of the soil under the influence of drip irrigation with slightly mineralized waters of the second class resulted in the decrease of its structural coefficient twice compared with the non-irrigated analogue.

The determination of water resistance aggregates (wet sifting) testified, that the amount of the aggregates with dimensions of more than 0.25 mm in the control variant without irrigation was 36.56%, and under the influence of irrigation on the variant with no fertilizers and phosphogypsum it decreased by 3.99%. Particularly noticeable changes in the water-resistant structure of the irrigated soil were observed in the amount of agronomically valuable aggregates of size 0.25-1.00 mm and the most agronomically valuable (1-3 mm) fractions. Thus, in the conditions of irrigation, the content of agronomic aggregates had a tendency to increase (by 1.84%), which was explained (as noted above), by the formation of dense waterproof (almost without pores) aggregates. At the same time, the most agronomically valuable components of the arable layer of the irrigated soil decreased by 1.9 times. In the determination of the coefficient of water resistance for dry and wet sifting, we found that in the conditions of irrigation, this figure also had a tendency to decrease.

The evaluation of agrophysical state found that at drip irrigation, the degree of degradation of the bulk density of the arable layer (0-30 cm) remains, as in the non-irrigated soil and, at the level of the slight, and by the content of air-dry aggregates with dimensions 0.25-10 mm and waterproof aggregates of more than 0.25 mm – passes from slight to moderate degree of degradation.

So, it was determined that application of mineral fertilizers ($N_{120}P_{90}$, calculated doses of fertilizers (nitrogen fertilizer – ammonium and calcium nitrate) did not substantially affect the aggregate composition of 0-30 cm layer of the irrigated soil (in the area of the sowing strip) comparatively to the control with irrigation. In this case, the parameters of the main indices of the macrostructure of the soil were close: the content of aggregates with dimensions of more than 0.25-1.00 mm – 7.92-8.37% and 0.25-10 mm – 54.39-54.95%, the sum of water-resistant aggregates larger than 0.25 mm – 30.20-32.04%.

Table 4

Parameters of main indices of macrostructure of the layer 0-30 cm of the dark-chestnut soil at drip irrigation, application of phosphogypsum and mineral fertilizers (the numerator is dry sifting,%; denominator-wet sifting, % to air-dry soil), sowing strip, average for 2013–2015

Variant	Dispersion Sum of units < 0.25 mm	Aggregation Sum of units > 0.25 mm	Clodding Sum of units		Little fraction-the sum of aggregates 0.25-1.00 mm	The most agronomically valuable units		Agronomically valuable fraction-the sum of units 0.25-10 mm	The coeeficient of structure (k_c)	The coefficient of water-resistance (K)
			>10 mm	>5 mm		1-5 mm	1-3 mm			
1.	11.59 / 63.44	88.41 / 36.56	17.41	35.16 / 0.57	14.69 / 24.98	38.56 / 11.01	26.76 / 10.23	71.00 / 36.56	2.4	0.41
2.	4.78 / 67.43	95.22 / 32.57	40.83	58.51 / 0.11	7.97 / 26.82	28.74 / 5.64	19.46 / 5.42	54.39 / 32.57	1.2	0.34
3.	4.39 / 67.96	95.61 / 32.04	40.60	58.54 / 0.25	8.37 / 26.95	28.70 / 4.84	19.99 / 4.43	54.95 / 32.04	1.2	0.33
4.	4.20 / 69.80	95.80 / 30.20	40.99	59.28 / 0.12	8.20 / 25.20	28.32 / 4.88	19.40 / 4.56	54.81 / 30.20	1.2	0.32
5.	4.26 / 69.49	95.74 / 30.51	40.59	59.00 / 0.16	7.92 / 25.57	28.82 / 4.78	19.72 / 4.37	55.15 / 30.51	1.2	0.32
6.	8.83 / 64.45	91.17 / 35.55	24.44	42.31 / 0.32	12.39 / 26.09	36.43 / 9.14	26.04 / 9.14	66.77 / 35.55	2.0	0.39
7.	9.05 / 64.14	90.95 / 35.86	24.67	43.60 / 0.69	11.35 / 25.03	36.00 / 10.14	26.27 / 9.45	66.28 / 35.86	2.0	0.39
8.	8.77 / 63.81	91.23 / 36.19	24.83	43.15 / 0.40	12.36 / 25.72	35.72 / 10.07	25.34 / 9.42	66.40 / 36.19	2.0	0.40
9.	8.10 / 64.14	91.90 / 35.86	25.48	45.67 / 0.22	10.16 / 25.57	36.07 / 10.07	25.29 / 9.33	66.42 / 35.86	2.0	0.39

Table 5

Content of mineral nitrogen in the soil under the onion crops at different doses of application of phosphogypsum and fertilizers, mg/kg of soil (average for 2013–2015)

Variant	Layer of soil, cm	Sprouts			Beginning of the bulb formation			Technical ripeness		
		$N\text{-}NO_3$	$N\text{-}NH_4$	$N\text{-}NO_3$+ $N\text{-}NH_4$	$N\text{-}NO_3$	$N\text{-}NH_4$	$N\text{-}NO_3$+ $N\text{-}NH_4$	$N\text{-}NO_3$	$N\text{-}NH_4$	$N\text{-}NO_3$+ $N\text{-}NH_4$
1. without irrigation, fertilizers and ameliorator-control 1	0-30	5.0	3.2	8.2	2.7	2.5	5.2	2.0	2.7	4.7
	0-50	4.0	3.3	7.3	2.3	3.0	5.3	2.0	3.2	5.2
2. irrigation, no fertilizers and ameliorator-control 2	0-30	5.3	3.0	8.3	2.5	2.0	4.5	2.0	2.2	4.2
	0-50	4.2	3.0	7.3	2.3	2.5	4.8	2.0	2.7	4.7
3. irrigation+$N_{120}P_{90}$ (recommended fertilizer dose)	0-30	17.0	3.9	20.9	7.0	1.9	8.9	5.5	2.1	7.6
	0-50	11.1	3.5	14.6	5.0	2.5	7.5	4.4	2.7	7.1
4. irrigation+calculated dose of fertilizers (nitrogen fertilizer – ammonium nitrate)	0-30	19.7	4.2	23.9	7.7	3.2	10.9	5.7	3.5	9.2
	0-50	12.6	3.5	16.1	5.4	3.1	8.5	4.6	3.4	7.1
5. irrigation+calculated dose of fertilizers (nitrogen fertilizer – calcium nitrate)	0-30	19.8	3.7	23.5	8.0	3.3	11.3	6.0	3.5	9.5
	0-50	12.1	3.3	16.1	5.6	3.2	8.8	4.9	3.4	8.3
6. irrigation+phosphogypsum 3.0 t/ha (under pre-sowing cultivation)	0-30	5.5	3.0	8.5	2.5	2.5	5.0	2.0	2.8	4.8
	0-50	4.2	2.8	7.1	2.1	2.6	4.7	2.0	2.9	4.9
7. irrigation+phosphogypsum 1.9 t/ha in the sowing strip	0-30	5.5	3.1	8.6	2.6	2.6	5.2	2.0	2.9	4.9
	0-50	4.1	3.1	7.2	2.2	2.8	5.0	2.1	3.1	5.1
8. irrigation+calculated dose (nitrogen fertilizer – calcium nitrate)+Phosphogypsum 1.9 t/ha in the sowing strip	0-30	19.1	4.0	23.1	7.8	3.0	10.8	6.3	3.2	9.5
	0-50	12.5	3.7	16.2	5.5	3.2	8.7	5.2	3.4	8.6
9. irrigation with water of improved quality (calcination)+calculated dose of fertilizers (nitrogen fertilizer – ammonium nitrate)	0-30	19.0	3.5	22.5	7.7	3.0	10.7	6.2	3.5	9.7
	0-50	12.5	3.3	15.8	5.5	3.1	8.6	4.7	3.5	8.3

The use of phosphogypsum (under the pre-sowing cultivation, in the strip of sowing against the background of mineral fertilizers) and irrigation with the water of improved quality significantly slowed down the level of negative influence of mineralized waters on the soil structure. In this case, the content of the aggregates larger than 10 mm was within 24.44-24.83%, which is by 7.03-7.42% more than on the control variant without irrigation, and by 16.39-16.00% less than in the soil layer of 0-30 cm with drip irrigation.

On the variants with the use of chemical reclamation of soil and irrigation water, the contents of dry sifted of agronomically valuable and the most agronomically valuable aggregates (the amount of fractions 1-5 mm) was by 4.23-4.72% and by 2.80-2.13%, respectively, lower than on the variant without irrigation. However, compared with the irrigated control, their number increased by 11.89-12.38% and 6.98-7.69%, respectively.

The results of wet sifting of the soil testified that under the application of melioration measures, the main indicators of the water-resistant structure of the surface layer of the soil were preserved close to the control variant without irrigation: the content of water-resistant aggregates (the sum of the aggregates of more than 0.25 mm) – 35.55-36.19%, and the most agronomically valuable aggregates (the amount of the aggregates with the size of 1-3 mm) – 9.14-10.14 at the amount on the control variant without irrigation of 36.56 and 10.23%, respectively. The coefficients of structure and water resistance of 0-30 cm layer of the irrigated soil on the variants with the use of chemical reclamation were the same and close to the indicators on the control version without irrigation.

Assessment of the agro-physical state of 0-30 cm layer by the criteria of the degree of irrigated soil degradation allows us to conclude that the use of phosphogypsum (under pre-sowing cultivation in the dose of 3 t/ha, in the sowing strip of 1.9 t/ha, against the background of mineral fertilizers) and the use for irrigation of the water of improved quality (calcinated one) led to the development of irrigative soil degradation at the level of low degree by the content of air-dry aggregates with the size of 0.25-10 mm, water-resistant aggregates of more than 0.25 mm.

4. Nutrition regime of the dark-chestnut soil under the crops of onion at the application of phosphogypsum and mineral fertilizers

Modern approaches to the development of practical aspects of fertilizers use are associated with the assessment of nutrition conditions of soil. Spatial and timeline dynamics of nutrients, their transformation in the soil is one of the main factors that determine the condition of mineral nutrition, and, as a consequence, the effectiveness of fertilizers, yield and quality of products of crops, including onion[7].

Ammonium nitrogen in the life of plants has much less value as nitrate. This is primarily due to the high nitrification ability of soils. According to the data of scientific literature[8], even under the application of nitrogen fertilizers in the ammonium form after 8-12 days there is no more than 10-15% of ammonium nitrogen from the original quantity available in the soil. Therefore, the analysis of nitrogen soil regime, especially on the irrigated lands, is advisable to be carried out by the mineral nitrogen (the amount of nitrate and ammonium nitrogen).

The results of the study indicate that the amount of mineral nitrogen at the cultivation of onion from seeds in the drip-irrigated conditions in the soil layer 0-30 cm on the control variant without fertilizers was 8.2-8.3, and in the layer 0-50 cm – 7.3 mg/kg of soil (Table 5). Application of mineral fertilizers has increased its content in 0-30 cm layer by 12.6-15.6 and in the layer 0-50 cm – by 7.3-8.9 mg/g of soil, compared with the variant without fertilizers. The highest content of mineral nitrogen was found in the variants with application of the calculated doses of mineral fertilizers regardless on the form of nitrogen in them. We should note that the use of phosphogypsum as an ameliorator did nor significantly affect the amount of nitrogen in the soil.

At the stage of bulb formation the content of mineral nitrogen in the soil layer 0-30 cm decreased in all the variants of the experiment by 3.0-13.0; and in 0-50 cm – by 2.0-7.6 mg/kg of soil. Significant changes in the amount of mineral nitrogen took place mainly in the top 0-30 cm layer of the soil.

The analysis of the obtained results allows to assert that at the beginning of formation of bulbs the reduction of the content of mineral nitrogen in the soil on the control without irrigation (the layer of 0-30 cm) was 36.6% from the content at the beginning of the vegetation (stage of sprouting), whereas in the soil on the control with irrigation it was a little higher – 45.8%.

Phosphogypsum application both under pre-sowing cultivation (3.0 t/ha), and in the sowing strip (1.9 t/ha) without the use of mineral fertilizers did not promote further increase in the intensity of nitrogen reduction compared to control with irrigation.

The highest loss of mineral nitrogen from the soil layer of 0-30 cm for the period sprouting- beginning of the formation of bulbs were observed on the variants with the application of mineral fertilizers ($N_{120}P_{90}$, calculated dose

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[7] Бритвич М.Д., Гончаренко В.Ю. Вплив добрив на врожайність цибулі залежно від сорту і норми висіву насіння. *Овочівництво і баштанництво,* вип. 31. К.: Урожай, 1986. С. 12–13.

[8] Приходько В.Е. Мелиоративное состояние, свойства и продуктивность орошаемых почв. *Тези докладу III съезда почвоведов и агрохимиков Украинской ССР. Мелиорация и охрана по*чв. Х.: УНИИПА, 1990. С. 73–74.

of fertilizers – nitrogen in the form of calcium and ammonium nitrate) – 51.9-57.4%.

As the study testified, at the end of the vegetation of the crop the content of mineral nitrogen decreased in the layer of 0-30 cm on the control variant with irrigation to 4.2 and in 0-50 cm – to 4.7 mg/kg of soil. On the variants with application of mineral fertilizers ($N_{120}P_{90}$, calculated doses of fertilizers – (nitrogen in the form of calcium and ammonium nitrate) its remained content was higher (in the layer 0-30 cm by 3.5-6.4, in the layer 0-50 cm – by 2.4 – 3.9 mg/kg of soil).

During this period, the mineral nitrogen at the application of phosphogypsum (3 t/ha under the pre-sowing cultivation, 1.9 t/ha in the sowing strip) was at the level of the control version with irrigation. It should be noted that the amount of mineral nitrogen in the layer of 30-50 cm almost unchanged during the vegetation of onion due to its intense use by the plants from the topsoil.

Reserves of mobile compounds of phosphorus relate to the basic indices of soil fertility. They depend on the soil granulometric composition, fertilization and agricultural activities[9]. The results of the study testified that the content of the mobile compounds of phosphorus in the soil dynamically changed during the vegetation of onion. The maximum amount of available phosphorus was observed in the stage of the onions sprouting. In the arable layer of the control variant (without irrigation, irrigation without fertilizer) the content of mobile phosphorus was 73.3-73.4 mg/kg of soil. Application of nitrogen fertilizers (calculated dose of fertilizers – nitrogen in the form of calcium and ammonium nitrate) and phosphogypsum significantly affected its quantity in the soil. Application of the recommended dose of mineral fertilizers ($N_{120}P_{90}$) increased the content of mobile phosphorus by 13.6 mg/kg of soil compared with the irrigated control.

In the subsequent stages of the onion development, the reduction in the content of mobile phosphorus in the soil on all the variants of the experiment has been developed. The smallest amount in the soil was observed at the stage of technical ripeness of onion.

On the control variant without irrigation the content of mobile phosphorus in the soil compared to the beginning of vegetation of onion reduced by 28.3%, and in the variants with application of mineral fertilizers and phosphogypsum – by 33.6-42.6%.

It should be noted that in the period "beginning of bulbs formation – technical ripeness" on the variants with the increase of intensity of mobile phosphorus in the soil was almost 2 times higher than in the period of

[9] Киселев В.Д., Кривоносова Г.М. Агрохимическая характеристика черноземов и каштановых почв. *Агрохимическая характеристика почв СССР*. М.: Наука, 1973. С. 227–246.

"sprouts – beginning of bulbs formation". This phenomenon can be explained by the fact that at this time the plants used this nutritive element more intense.

It is known that the chestnut soil has relatively high reserves of potassium, so the dynamics of its exchangeable form under the crops had weak manifestations. In the irrigated conditions changes in the content of exchangeable potassium in the soil are mainly due to the use of it by the plants and transformation of its non-exchangeable form into exchangeable.

The study helped to find that high content of exchangeable potassium 358.0-376.0 mg/kg of soil was observed at the beginning of the crop vegetation in the 0-30 cm soil layer at the start of the onions growing (germination). In the process of the plant development, its number decreased in the soil on all the variants of the experiment. The smallest amount of exchangeable potassium in the soil is fixed in the technical ripeness stage of onions. It should be noted that in this stage its amount reduced in comparison to the stage of sprouting by 13.7-15.1%.

Analyzing the dynamics of potassium content in the soil, it was established that in the period of "sprouts – the beginning of bulbs formation" the reduction of the content of exchangeable potassium due to the uptake by the plants was 3.4-6.4% in comparison to the beginning of the crop growth, and for the period "the beginning of bulbs formation – technical ripeness” it was 1.4-2.9 times higher. Therefore, the maximum amount of potassium was used by onion in the second half of the vegetation period.

CONCLUSIONS

1. Drip irrigation with low mineralized waters of the second class led to the increase in the zone of "humidification" both of total amount of salts and toxic ones. In this case, the transformation of the salts' composition was due to the reduction of calcium salts in the soil layer of 0-30 cm by 8.3% and the increase in sodium salts by 7.6% of the total amount.

2. The application of phosphogypsum and irrigation with the water of improved quality contributed to the increase in the ratio of water-soluble calcium to sodium in the sowing strip (soil layer 0-30 cm) by 0.5-0.8 units that ensured the transition of the active degree of salinity into passive.

3. Irrigation with the water of improved quality and application of the calculated dose of mineral fertilizers with the use of calcium nitrate against the background of phosphogypsum in the sowing strip ensured the stabilization of the content of monovalent cations (Na^{+}+K^{+}) at the level of the control variant without irrigation – 3.8-4.0% against 3.7%, respectively (soil layer 0-30 cm).

4. In the arable layer of soil (0-30 cm) on the chemically ameliorated variants there was a tendency to the improvement of the structure compared to the control with irrigation, which was confirmed by a greater number of agronomic aggregates and higher coefficient of structure.

5. Application of mineral fertilizers provided the increase in the content of nutrients for the plants of onion throughout the vegetation. The highest expenditures of mineral nitrogen ($N\text{-}NO_3$+$N\text{-}NH_4$) in the soil layer 0-30 cm were observed on the variants with application of fertilizers ($N_{120}P_{90}$, calculated doses of fertilizers – nitrogen in the form of calcium and ammonium nitrate) during the period of "sprouts – the formation of bulbs" – 51.9-57.4% of the initial quantity. The intensity of reduction in the content of mobile phosphorus in the soil on the irrigated variants during the "beginning of bulbs formation – technical ripeness" was 2 times higher than in the period of "sprouts-the beginning of bulbs formation". The largest amount of exchangeable potassium used by onion was in the second half of the vegetation period.

SUMMARY

The article presents the results of the study on the impact of drip irrigation with low mineralized waters with adverse ratios of mono- and divalent cations, and methods of phosphogypsum application (scattering of 3 t/ha, 1.9 t/ha in the strip of sowing and calcination of irrigation water) on the agro-meliorative state of soil, taking into account the chemical, physical, physico-chemical properties of dark-chestnut slightly saline soil. The nature and direction of changes in its properties under various ways of the use of ameliorator improved onion's productivity. It was established that phosphogypsum fertilization contributes to the stabilization of secondary salinity at the level of the slight degree.

The method of chemical reclamation with the use of mineral fertilizers (calcium nitrate) and phosphogypsum (in the sowing strip) is offered, which ensures the preservation of agro-meliorative state of the dark-chestnut soil.

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PECULIARITIES OF GROWTH AND DEVELOPMENT OF RICE PLANTS DEPENDING ON BIOLOGICAL PROPERTIES OF VARIETIES AND CULTIVATION CONDITIONS

Vozhehova R. A.

INTRODUCTION

It is typical for rice, as for other higher plants, to form organs during ontogenesis according to the stages of organogenesis. Instead, not all researchers stick to clear boundaries of the division into organogenesis stages. Considering the fact that rice has no clear boundaries between VIII and IX stages, the crop has 11 stages of organogenesis. Such a distribution of stages of organogenesis in rice is inappropriate because of two reasons. Firstly, the characteristics of organs formation peculiarities in all studies related to the species of higher plants at each stage of the organogenesis has been widely introduced in biological literature, and the corresponding number of the stage of organogenesis is perceived not simply as a sequence number, but as a set of organ formation processes. Due to this fact the change in numbering of the last stages brings some confusion. Secondly, VIII and IX stages of organogenesis in rice are not always indistinct. It is established that at lowering of air temperature during the period of panicleing, flowering starts with a delay of 1-3 days and more, that is development of plants at VIII stage of organogenesis is prolonged[1,2,3].

Most of the above mentioned researchers did not succeed in learning phenotypal variability of features depending on genotype, as their experiments were performed on the example of one or three varieties. In addition, the potential opportunities for the development of quantitative features of rice, which could reveal the conditionality of these features by genotype, have not been studied at the time. Without such studies, it is almost impossible to clearly formulate the directions of selection, a model of rice varieties of rice regions of Ukraine and develop backgrounds for effective selection of elite plants[4,5].

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1. Plant height and stem foliaceous dynamics

The research was conducted at the Institute of Rice of the National Academy of Agrarian Sciences of Ukraine in order to define the peculiarities of the formation of quantitative features during the ontogenesis, which determine the productivity of rice in the South of Ukraine. In the study, we used different by the duration of vegetation period varieties: early ripening – Mutant-428, Malysh; middle-ripening Ukraine-96, Myrnyi; late-ripening Krasnodarskyisky-424 and Don-883. To determine the potential opportunities for the development of quantitative characteristics of plants they were cultivated at different density (2×15, 15×15, 30×30) and various doses of nitrogen fertilizers (ammonium sulfate was applied in the doses N_0, N_{90}, N_{180}). Fertilizers were applied in two periods: sowing (70%) and at the stage of 3-4 leaves of the crop (30%).

For biometric processing we selected 20 plants on each variant in the field conditions. We measured their height, the leaves dimensions, the length of the main and lateral panicles, the number of internodes in the main and lateral stems, counted the total number of lateral stems of each order, the number of ears and grains in the main and side panicles, the weight of grain from individual panicles and a plant on the whole.

Vegetative features: the length and foliaceous of the stems, tillering of the plants are not direct elements of productivity, but have a significant impact on its formation, since the plant height depends on the resistance to lodging, and the shape, size and location of leaves determines the level of physiological processes that are associated with yield [6].

Plant height varies significantly depending on the place of cultivation, sowing norms and plant density, doses of nitrogen fertilizers, air temperature and other factors. It is established that the increase in the duration of the day, doses of nitrogen fertilizers, flooding depth predetermine the intense growth of rice plants, and low air temperatures inhibit plant growth[7].

According to Ukrainian researchers[8,9,10,11]modern rice varieties differ significantly in the height of plants, which depends primarily on their genetic

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characteristics, technology of cultivation and weather conditions. Among non-genetic factors, a large influence on the development of features has a plant nutrition area and the level of nitric supply.

Regarding the effect of the area of nutrition on the plant height there are different conclusions in the scientific literature. In particular, D. H. Mamedov[12], N. P. Volkova[13] note that under the thickening of crops the height of plants decreases, but at the same time, I. B. Byzhanov[14] believe that the height of plants, on the contrary, increases with increasing in their number per 1 m^2. Such ambiguous and even opposite conclusions in the researches could be explained by the fact that the works were performed in different geographical points and with different varieties, which react differently on agroecological factors.

Rice plants at the early stages of organogenesis, until V-VI stages, grow very slowly, but at the stage of intensive growth and panicleing (VII-VIII stages of organogenesis) the stem growth is increasing rapidly, as a result, panicle is quickly imposed from the sinuses of the leaf. Further growth is slow. Our research has shown that the decrease in plant density affected differently on the growth intensity of the main stem of rice plants (Table 1): at the early ripening and middle-ripening varieties increase the nutrition area of plants that led to more intensive growth. As you can see, the largest plant height is observed by the nutrition area 30×30 cm, less – in the variant 15×15 cm, and the smallest – in the variant 2×15 cm.

Another reaction on the increase of plant nutrition area was in late-ripening varieties Krasnodarskyi-424 and Don-883. Their largest plant height is defined at the smallest nutrition area – 2×15 cm, and as the nutrition area increases, the height of the plants decreased.

By the nature of the stem growth, the studied rice varieties differed somewhat. After analyzing the experimental data, it could be seen that at the early ripemimg variety Malysh growth of a stem after a massive flowering regardless on plant nutrition area almost stopped, and in other varieties,

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including early-ripening Mutant-428, although it slowed down after massive flowering, it continued to the end of the vegetation.

Table 1

The dynamics of plant height in rice varieties at different nutrition areas, mm

Variety	Nutrition area, cm	Number of days after sprouting						
		15	25	35	55	65	75	95
Mutant-428	2×15	2	2	4	492	562	570	653
	15×15	2	2	4	615	648	690	750
	30×30	2	2	4	530	585	695	785
Malysh	2×15	2	2	4	480	505	635	645
	15×15	2	2	4	585	615	695	705
	30×30	2	2	4	520	570	690	715
Ukraine-96	2×15	2	2	4	615	665	745	903
	15×15	2	2	4	670	710	810	1051
	30×30	2	2	4	685	720	815	1223
Myrnyi	2×15	2	2	4	605	650	740	895
	15×15	2	2	4	680	695	753	915
	30×30	2	2	4	715	725	790	925
Krasnodarskyi-424	2×15	2	2	4	325	612	840	945
	15×15	2	2	5	452	548	815	920
	30×30	2	2	4	330	510	810	900
Don-883	2×15	2	2	4	330	615	842	950
	15×15	2	2	5	448	550	805	942
	30×30	5	5	4	332	512	800	938
LSD_{05}	2×15				13	12	19	20
	15×15				15	14	21	22
	30×30				15	14	23	22

There is a close connection between the height of the plant and the length of the individual internodes changes (Table. 2). In all the studied varieties of rice, starting from the VI stage of organogenesis, the first one, counting from panicle, inter-node, which is characterized with the most intensive growth at VII stage of organogenesis. This internode at the end of the vegetation period has the largest value.

It is established that most varieties of rice develop only 4-6 internodes, with only the first 3-4, counting from the panicles, have a relatively large length, they can be assessed visually or using special equipment.

The next 2-3 internodes are elongated only for a few millimeters, and the remaining internodes in the rice are very close to each other.

Table 2

Length of internodes (mm) in rice varieties at different plant nutrition areas

Variety	Nutrition area, cm	Number of internodes counting from panicle		
		1	2	3
Mutant-428	2×15	351	203	99
	15×15	424	225	101
	30×30	440	230	114
Malysh	2×15	346	208	91
	15×15	380	234	96
	30×30	385	236	93
Ukraine-96	2×15	469	315	96
	15×15	485	334	97
	30×30	494	342	97
Myrnyi	2×15	472	320	103
	15×15	483	326	104
	30×30	498	328	104
Krasnodarskyi-424	2×15	481	350	114
	15×15	478	328	112
	30×30	461	329	110
Don-883	2×15	479	349	122
	15×15	476	345	120
	30×30	474	343	119
LSD_{05}	2×15	11	9	5
	15×15	10	8	5
	30×30	13	10	5

At different nutrition areas, the change in the length of individual internodes is similar to the changes in the overall length of the stem in different varieties. The first, starting from the panicle, internode occupies 51-56% of the total length of the stem. As it is evident from the Table 3, the largest changes were observed in the first and second internodes of early- and middle-ripening varieties: as the plant nutrition area increases, the indicators of these morphostructural elements increased either. The length of the third internodes, starting from the panicle, was stable.

As in other varieties, late-ripe genotypes (Krasnodarskyi-424 and Don-883) had the largest internodes located first starting from the panicle, but their change in different supply areas was slightly different in comparison to more fast-ripening varieties. It turned out that with the increase in the nutrition area the length of internodes in the late varieties decreases. The same regularity was observed in other internodes.

The number of leaves on the plant serves as a varietal feature and fluctuates in the different by vegetation period duration varieties within 10-13. The speed and duration of the formation of leaves depends essentially on theenvironmental conditions.

The foliaceousness is increased by 1-3 leaves under the increasing doses of nitrogen fertilizers, plant nutrition area, and also under the influence of other factors. It is established that in the period of panicleing varietal differences in the number of green leaves disappear or are unclear. There are on average 4, and on a rich agrobackground – 5 green leaves per the stem. The most significant impact on the yield formation has the length and width of the leaves[15].

Dark color of leaves is regarded as an indicator of increased content of chlorophyll. It is assumed that the dark green leaves are more productive in photosynthesis and more intensively accumulate dry matter. Instead, in practice, the forms with wide light-green large leaves appear to be quite productive and not inferior to the yield of dark-coloured[16]. Obviously, in order to use the coloring of the leaf as an indicator (marker) of productivity of plants, it is necessary to possess information about the connection between chlorophyll and yield. But at present there are no works which would reveal the photosynthetic activity of different types of rice plants according to the structure of bush, color of leaves, degree of thickening, etc.

The duration of leaves life and the intensity of utilization of organic matter from vegetative organs to generative have some positive effect on the yield of variety. By the beginning of ripening of rice seeds, in the plants of medium-and late-ripening varieties there remain viable 3-4 upper leaves, and 2-3 ones in early-ripening varieties. The remaining 6-8 leaves die. The dying out is in different forms at different ages both of the leaves themselves and the plants on the whole and depends on the biological characteristics of the samples and the vegetation conditions. Thus, early sowing, elevated doses of nitrogen fertilizers lead to an increase in life-time of leaves[17]. The later leaves die out, the greater is the period they can perform photosynthesis and the more their lives will affect on the productive processes.

Unlike many cereal crops, leaves and straw of rice before the full ripening of grain contains 60-70% of water, they are still viable and contain a significant amount (0.8-1.0 t/ha) of reserved matter that is practically unused. Application of Potassium fertilizers can strengthen the outflow of the

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[17] Дорошенко Т. Н., Петибская В. С. Особенности фотосинтеза и дыхания сортов риса интенсивного типа. *Бюл. НТИ ВНИИ риса*. 1980. Вып. 28. С. 38–42.

substances from the lower leaves to the upper ones[18], but such artificial measures lead only to a partial increase in the attraction of the substance by kernels, resulting in a slightly increased kernel size, but they do not cause a significant increase in the yield.

Thus, the extension of the life of leaves and stems increases the absorption capacity of panicle on the whole and of kernels, in particular, remains an important and relevant question of rice breeding for productivity. The end of functing of the upper leaves should occur simultaneously with grain ripening. This synchronization in the development of rice plants is quite real, because among the collection samples there are forms in which the dying out of all leaves takes place simultaneously with the ripening of grain.

It was established that in the early ripening varieties (Mutant-428, Malysh) at the final stage (II stage of organogenesis) ther is formed, basically, 9-10, only in some years – 11 leaves; in the middle ripening ones (Ukraine-96, Myrnyi) – 11-12, rarely 13 leaves; in the late ripening ones (Krasnodarskyi-424, Don-883) – 12-13 leaves (Table 3). The number of leaves in the same varieties in different years varied insignificantly, it was manifested in different periods of ontogenesis. The slightest differences were manifested on 2-3 day from the beginning of sprouting, then they were slightly increased, but certain patterns in this increase were not found.

Increasing the area of plant nutrition leads to some increase in the number of leaves, but again it was insignificant, by 1-2 leaves (Table 4).

The largest number of leaves was formed in the different area of plants nutrition in the late-ripening varieties; it is somewhat less in middle-ripening and the least – in the early-ripening genotypes.

With more intense mineral nutrition, rice plants' productivity increased. Our research has shown that the dynamics of the formation of leaves depends on the group of ripeness of rice varieties (Table 5). In early and middle-ripening varieties increase in the dose of nitrogen did not lead to changes in the number of leaves in different periods of the plants' ontogenesis. Instead the late varieties (Krasnodarskyi-424 and Don-883) significantly increased the number of leaves at the application of nitrogen fertilizers. This increase was particularly noticeable in the variant of N_{180}.

Thus, late-ripening varieties form not only more leaves per plant, but also have stronge reaction on the increase of nitrogen fertilization by this parameter.

The photosynthetic potential of the plants determines and provides one or another level of productivity, it depends on the size of the leaf surface, other factors and the duration of their life.

[18] Алешин Е. П., Сметанин А. П. Минеральное питание риса. Краснодар: Краснодарское книжное издательство, 1965. 95 с.

Table 3

Dynamics of setting of leaves at different varieties of rice

Varieties	Year	Number of days after sprouting			
		2-3	**14-15**	**23-25**	**37-38**
Mutant-428	2003	5.0	7.8	9.7	10.5
	2004	5.5	8.4	10.3	11.0
	2005	5.6	8.1	10.1	10.6
Malysh	2003	5.1	7.6	8.5	9.3
	2004	5.6	8.2	8.8	9.7
	2005	5.7	7.9	8.7	9.1
Ukraine-96	2003	5.1	7.5	9.4	11.1
	2004	5.4	7.8	9.6	11.7
	2005	5.7	8.0	10.3	12.0
Myrnyi	2003	5.8	8.1	10.9	11.4
	2004	6.0	8.3	10.9	12.0
	2005	5.8	7.9	10.5	12.3
Krasnodarskyi-424	2003	5.3	8.4	10.6	12.9
	2004	5.0	8.8	10.4	12.6
	2005	5.7	8.7	11.1	12.4
Don-883	2003	5.0	7.8	10.9	13.0
	2004	5.6	8.7	10.1	13.1
	2005	6.0	8.4	10.8	12.7
LSD_{05}	2003	0.01	0.15	0.27	0.27
	2004	0.05	0.16	0.31	0.28
	2005	0.04	0.15	0.24	0.25

Table 4

The number of leaves in different varieties of rice, depending on the nutrition area, pcs.

Variety	Plant nutrition area		
	2×15	**15×15**	**30×30**
Mutant-428	10.3±0.22	10.7±0.21	11.0±0.20
Malysh	9.7±0.21	10.2±0.21	10.5±0.21
Ukraine-96	11.8±0.20	12.0±0.20	12.1±0.19
Myrnyi	12.1±0.23	11.8±0.22	12.6±0.19
Krasnodarskyi-424	13.0±0.19	12.7±0.21	13.1±0.21
Don-883	13.1±0.21	12.6±0.19	13.0±0.21

We have established that rice varieties in Ukraine also differ in the area of leaf surface of plants (Table 6). These differences are more clearly manifested between early- and late-ripening varieties; middle-ripening varieties (Ukraine-96, Myrnyi) do not differ from the early-ripening varieties Mutant-428 and Malysh, and the variety Ukraine-96 has a much larger leaf surface than other mentioned varieties of early- and middle-ripening group.

Table 5

Dynamics of setting of leaves on the main stem of rice at different doses of nitrogen fertilizers and nutrition area 30×30 cm, days

Variety	Nitrogen dose, kg/ha	Number of days after the beginning of sprouting				
		2	9	16	23	40
Mutant-428	0	5.1	6.4	7.5	9.6	10.1
	90	5.5	6.1	8.0	10.2	10.6
	180	5.0	6.6	7.6	10.0	10.7
Malysh	0	5.0	6.3	7.4	9.2	10.3
	90	5.2	5.9	8.0	9.5	10.2
	180	5.2	6.4	7.8	9.4	10.1
Ukraine-96	0	5.3	6.1	7.6	9.3	11.5
	90	5.2	6.3	7.8	9.5	11.8
	180	5.4	5.8	8.0	9.4	11.6
Myrnyi	0	5.7	6.3	8.0	10.7	11.8
	90	5.9	6.7	8.5	11.0	12.0
	180	5.8	6.6	8.7	10.9	11.9
Krasnodarskyi-424	0	5.5	7.7	8.1	10.2	11.2
	90	5.8	8.3	8.8	11.0	12.0
	180	6.0	9.0	9.0	11.8	13.1
Don-883	0	5.3	7.8	8.2	10.1	11.0
	90	5.6	8.2	9.0	10.9	12.2
	180	5.8	9.1	9.4	12.0	13.5
LSD_{05}	0	0.06	0.11	0.18	0.22	0.18
	90	0.10	0.11	0.17	0.21	0.21
	180	0.09	0.12	0.19	0.19	0.26

It should be noted, according to the average group characteristics of the ealy- and middle-ripening rice varieties may be distinguished by the area of leaf surface, but within each group there is a differentiation of genotypes by the investigated characteristic. It is obvious that late-ripening varieties form a much larger leaf surface than the genotypes of other groups of ripeness.

Given in the Table 6 data indicate that the increase in the nutrition area, as a rule, leads to an increase in the total area of the leaf surface of plants in the varieties with a different type of growth and development. This process of growth of the total leaf area is pre-conditioned by the corresponding increase in the leaves of different layers, Table 6 presents presents the dynamics of the leaf area of the 1st and 2nd leaves from panicle areas.

Table 6

Leaf area of rice varieties depending on the plant nutrition area

Variety	Nutrition area, cm	The total area of the leaf surface of plants, cm²	The area of leaves, cm²	
			1st from panicle	2nd from panicle
Mutant-428	2×15	70.8±1.2	26.1±0.6	18.9±0.4
	15×15	75.6±1.8	28.3±0.7	20.0±0.4
	30×30	80.4±1.9	29.4±0.7	22.4±0.5
Malysh	2×15	65.7±1.1	22.1±0.5	24.4±0.5
	15×15	68.3±1.2	23.5±0.4	25.5±0.5
	30×30	70.7±1.4	24.0±0.6	27.2±0.5
Ukraine-96	2×15	86.3±1.0	28.3±0.9	32.0±0.7
	15×15	91.6±1.2	30.1±0.7	34.0±0.7
	30×30	99.3±1.2	32.4±0.9	35.3±0.8
Myrnyi	2×15	67.2±0.7	20.4±0.3	21.2±0.3
	15×15	71.3±0.7	21.2±0.3	22.6±0.3
	30×30	73.5±0.7	23.2±0.3	24.0±0.3
Krasnodarskyi-424	2×15	85.6±0.9	30.5±0.6	28.4±0.5
	15×15	92.2±1.0	33.3±0.6	30.3±0.6
	30×30	97.6±1.2	35.6±0.7	32.3±0.6
Don-883	2×15	98.5±1.2	32.2±0.7	33.1±0.4
	15×15	111.4±1.3	34.0±0.8	35.1±0.7
	30×30	118.6±1.2	35.4±0.9	36.6±0.7

It is necessary to point out one important detail of the varietal, i.e. genotypical specificity in the formation of leaves. It was found out that in some varieties (Mutant-428 and Ukraine-96) a larger area is in the upper leaves, while in others (Malysh, Krasnodarskyiskyi-424), on the contrary, higher values of the leaf area are in the second layer. The varieties Myrnyi and Don-883 are characterized by their original feature: they have almost the same area of the first and the second layer leaves, but the reaction to the change of the area of nutrition is the same as in other varieties: in the thickened crops the area of leaves is the least and with an increase in the area of nutrition it increases respectively by the layers of leaves.

Analyses have shown that in early-ripening and middle-ripening varieties, the length of the 1^{st} from a panicle leaves is less than the length of the 2^{nd} leaves. The width of the same leaves, on the other hand, is greater than in the 1^{st} layer. In addition, the data of the Table 7 indicate that the difference between the varieties in the indices of dimensions of the top leaves (length, width, area) is small; we can only draw conclusions, that there is a tendency to higher values of width and area of the upper leaves in the middle-ripening varieties. The same tendency to some increase in the parameters in the middle-ripening genotypes exists in the 2nd from the panicle leaves.

2. Indices of plants tillering

The term of "tillering of plants" has combined such signs as the total number of stems per plant, the number of productive and unproductive stems, as well as the number of buds per plant, which to a certain extent serve as an indicator of the potential of plants to tillering[19].

Studies have shown that each variety at cultivation in equal conditions has permanent number of stems that is the named feature clearly defines the varietal specificity. Under normal conditions, buds of side shoots are set in the leaf sinuses regardless on varietal features, but grow and form side shoots only by those buds that are in the most favorable conditions[20].

It is known that the number of side shoots increases under the increasing dose of nitrogen fertilizers, reducing plant density, lowering water temperature at the stage of tillering, changing water regime, etc. It is established that by changing the conditions of the environment at different stages of ontogenesis, it is possible to control the process of shoots formation, causing them to appear in different parts of the bush[21].

There is a positive correlation between the productive tillering and yield. Instead, the maximum productivity varieties form not at the expense of a certain number of productive stems per plant, but as a result of the formation of the optimum number of stems per the unit of area. The highest yield, especially for highly thinned sprouts, will have the varieties with a greater potential ability to create side shoots[22]. In this regard, the study of potential ability to create side shoots in the promising varieties and rice samples is of a practical importance, especially for the northern areas of rice cultivation.

The main stem has the largest number of leaves and nodes. Under normal conditions, it is the most productive [23]. All shoots of the first, second and other orders are less productive. In this case, the performance decreases with increasing order and place of attaching the shoots on the mother plant.

In our experiments, increasing the nutrition area from 2×15 to 30×30 cm led to an increase in the total number of shoots in 1.8-2.2 times

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[23] Тур Н. С. Причины изреживания посевов от засоления и роль кущения в формировании стебля риса: автореф. дис. … канд. биол. наук. Ростов-на-Дону, 1968. 20 с.

(Table 7). It is discovered that the number of shoots of the 2nd order has slightly changed in most varieties, and the biggest changes took place with the shoots of the 3rd and 4th orders. The studied varieties significantly differed by the total number of shoots and shoots of different order. The largest number of stems was formed by the varieties Antey and Ukraine-96. The first variety refers to the middle-late ripening group, and the second one – to the middle-ripening group.

Table 7

The number of shoots of different orders in the varieties at different areas of plants nutrition, pcs.

Variety	Nutrition area, cm	Order of the shoot				
		2	3	4	5	6
Mutant-428	2×15	6.5	13.6	9.4	0.0	0.0
	15×15	7.0	18.1	22.3	0.0	0.0
	30×30	7.2	25.3	31.4	2.3	0.0
Malysh	2×15	6.1	11.3	13.4	0.0	0.0
	15×15	7.0	16.4	18.2	0.0	0.0
	30×30	7.5	25.8	29.3	0.0	0.0
Ukraine-96	2×15	6.3	11.7	12.0	0.0	0.0
	15×15	7.6	15.3	19.5	3.3	0.0
	30×30	8.5	24.0	41.6	12.5	0.0
Krasnodarskyi-424	2×15	6.0	9.7	12.4	0.0	0.0
	15×15	6.6	13.7	18.7	7.8	0.0
	30×30	7.2	19.5	26.0	6.3	2.2
Dnipro	2×15	5.3	8.9	13.0	0.0	0.0
	15×15	7.0	12.3	16.4	1.6	0.0
	30×30	7.8	19.0	28.4	8.5	0.0
Antey	2×15	6.4	13.1	14.0	1.3	0.0
	15×15	7.2	26.0	28.4	8.0	0.0
	30×30	8.1	29.1	32.6	9.2	2.2

It was found out that even at the absence of fertilizers in thinned crops (30×30 cm) there was formed a much larger total number and number of productive stems, than in the conditions of fertilization.

The varieties differ in nature of tillering under the influence of various doses of nitrogen fertilizers, but the differences between them were insignificant.

According to the Table 8 it is possible to conclude that in the reaction of the varieties there is only a tendency to increase the indicated number of stems: productive stems in the variety Ukraine-96 compared with Mutant-428.

Obviously, the differentiation of genotypes by the sensitivity to mineral nutrition, especially nitrogen, is manifested against the background of contrasting by the vegetative period varieties: the longer the vegetation period of the sample is, the greater the need for elements of root nutrition is, which is met by additional doses, and elevated doses of fertilizers contribute to the setting and development of additional shoots.

Table 8

Number of productive and unproductive stems of different orders in rice varieties under different cultivation conditions, pcs.

Variety	**Power area, SM**	**Nitrogen dose, kg/ha**	**The order of the stems**							
			2		**3**		**4**		**5**	
			I	**II**	**I**	**II**	**I**	**II**	**I**	**II**
Mutant-428	2 × 15	0	5.4	2.5	13.1	2.3	8.8	1.5	0.0	0.0
		90	6.0	4.1	16.4	3.6	9.5	1.7	0.6	0.0
		180	6.3	4.5	17.2	3.7	10.2	1.6	1.2	0.0
	15 × 15	0	6.8	3.7	18.3	3.5	22.5	0.6	0.0	0.0
		90	7.3	4.9	19.5	4.1	23.0	1.0	2.2	0.0
		180	7.6	5.0	20.1	5.3	25.2	0.9	2.6	0.5
	30 × 30	0	7.2	3.6	24.9	4.0	30.6	0.7	2.5	0.3
		90	7.8	4.6	25.1	4.5	31.3	1.1	3.1	1.0
		180	8.2	5.0	26.3	5.2	33.5	0.6	3.6	1.3
Ukraine-96	2 × 15	0	5.8	3.6	12.4	1.8	12.0	0.0	0.0	0.0
		90	6.1	4.0	14.3	2.4	12.8	0.0	0.3	0.0
		180	6.5	4.7	17.8	3.7	14.0	0.4	0.8	0.0
	15 × 15	0	7.2	3.6	16.1	2.2	20.6	1.0	3.5	0.9
		90	7.8	4.1	21.4	2.8	21.3	0.8	4.6	1.1
		180	8.3	4.5	23.5	3.0	23.4	0.7	5.0	0.5
	30 × 30	0	7.6	3.6	25.6	2.5	39.7	0.8	11.6	0.5
		90	8.1	3.9	26.3	2.8	40.5	0.9	12.4	0.6
		180	8.5	4.5	27.8	3.1	41.8	0.9	13.0	0.7
LSD_{05}	by area of nutrition	0.04	0.05	0.08	2.12	0.03	0.92	-	0.01	-
	by dose of fertilizers	0.03	0.05	0.07	1.96	0.03	0.87	-	0.01	-

Note: I – The total number of shoots; II – The number of productive shoots of each order

The total number of shoots included all shoots that were formed. As a rule, at the ninth stage of organogenesis of the rice plant there can be observed shoots, which are at all stages of organogenesis, this is a biological specificity of rice. In the transition of the main panicle to the XI-XII stages of organogenesis, the correlation in the development of shoots changes significantly. Shoots, which are on V-VI stages, continue to develop and in favorable conditions reach the XII stage, that is mature; shoots that do not achieve until this time to the V stage, slow down their development and do not form after this stage, i.e. remain unproductive.

Moreover, a part of the fully formed stems under different unfavorable conditions (diseases, pests) does not realize its potential possibilities, that is, does not form kernels.

On the basis of the performed studies, we can conclude that side shoots of rice plants in the South of Ukraine are formed throughout the vegetation period, but the potential and real productivity is determined only by the shoots that begin to develop intensively at the early stages of organogenesis, reach to the onset of ripeness of the main panicle the V-VII stages of organogenesis, and the rest shoots stop their development until the maturation of the main one. Rice varieties differ in the proportion of the shoots of different orders, especially in the number of shoots of the 3-4 orders. The formation of lateral shoots is greatly affected by the nutrition area of plants than by the amount of nitrogen nutrition.

3. Duration and intensity of flowering

Flowering, pollination and fertilization occur at the IX stage of organogenesis. This is a very important period in ontogenesis of rice, because all the processes that occur at this stage have a direct relation to grain formation, and productivity of plants.

The duration, intensity, and character of rice flowering in various environmental conditions have been studied by many researchers. According to A. I. Siedlovsky and collaborators, in the Krasnodarskyi territory flowering of rice usually starts at 9-10 a.m. and ends at 14-16 o'clock. In the Primorsky Krai at the air temperature of 19-20°C rice begins to flower from 10-11 hours in sunny weather and from 13-15 hours in cloudy. At the temperature of 23°C and higher flowering lasts from 8-10 hours to 16-17 hours [24].

According to our observations in the conditions of Skadovsky and Kalanchaksky districts of Kherson region flowering of rice in most cases starts from 10 o'clock in the morning and lasts up to 15-16 hours; in some days with high temperatures (above 20°C in the morning) flowering can be finished by 17 o'clock. The duration of flowering of different varieties of rice varies within 10-30 days, and the period of flowering of individual plants is 5-10 days. It depends on weather conditions and genetic features of a variety. The most intense rice flowering is on the 3rd, 4th and 5th day. It is possible to conclude that the nature of rice flowring depends on the biology of variety and meteorological conditions of the environment[25].

[24] Shibata M. progress in breeding cold – tolerant rice in Japan. Per. Rice Cold Tolerance Work Shop. Manila: IRRI, 1979. P. 21–124.

[25] Сметанин А. П. Создание сортов риса для северных районов отечественного рисосеяния: дис. … д-ра биол. наук. Краснодар, 1975. 393 с.

We have studied the peculiarities of flowering of different varieties of rice in the field researches at the Institute of Rice of NAAS (Skadovsk, Kherson region) and Kiliyska Research Station of Rice (Odesa region).

It is established that in the studied varieties that belong to different groups of ripeness, the duration of flowering is different (Table 9).

In the early-ripening varieties Mutant-428 and Malysh flowering lasts within 6-9 days, in the early variety Ukraine 96 and Mutant-428 – 7-10 days and in the late ripening ones Krasnodarskyi-424 and Don-883 – within 9-12 days. Data show that in the studied genotypes under different environmental conditions flowering of the plants lasts within the period of 6-12 days, with the influence of environmental conditions (conditions of the years/ geographical point of research) the duration of the flowering period may vary by 2-3 days.

The shortest period of flowering was in the early-ripening samples among the existing genetic collection (27 samples were investigated). It was found out that in this group of samples the genotypical differences on the flowering of panicles in different weather conditions is limited to 2-3 days (Table 10).

In the middle-ripening samples genotypical diversity by the duration of flowering is more essential and it is within 6-7 days. The biggest differences by the studied biological feature of rice were established between the late-ripening samples, 9-10 days. Krasnodarskyi-424, Don-7115 belongs to the varieties with the shortest period of flowering; the genotypes of the longest flowering – Aromatica 834, MGR, AzROS / Corbetta. Rice varieties that are on the list of the State Register of Plant Varieties of Ukraine, the period of massive flowering lasts: Dniprovskyi – 6-8, Yantarnyi – 6-8, Agat – 6-8, Prestyzh – 7-9; Ukraine-96 – 9-11, Pamiati Hychkina – 9-12, Slavutych – 9-11 days, respectively.

Table 9

The duration of flowering of rice varieties in different environmental conditions, days

Variety	Skadovsk, Kherson region			Kiliya, Odesa region		
	Years			Years		
	2002	2003	2004	2002	2003	2004
Mutant-428	7	6	8	8	7	9
Malysh	7	6	7	8	7	8
Ukraine 96	8	7	9	9	8	10
Myrnyi	8	7	10	9	8	10
Krasnodarskyi-424	9	10	11	10	10	11
Don-883	9	11	12	10	10	12

Table 10

The duration of flowering of rice samples of different ripening groups, days

Group of ripening	Number of samples studied	Years			
		2001	2002	2003	2004
Early-ripening	27	7-9	6-9	6-7	8-11
Middle-ripening	56	8-15	8-15	7-13	10-16
Late ripening	25	10-20	9-18	10-19	11-21

CONCLUSIONS

1. The growth of rice stems depends on the biological characteristics of the varieties and plant nutrition area. In the South of Ukraine in some early-ripening varieties (Malysh) stem growth is stopped after flowering, but in most varieties (including early-ripening variety Mutant-428 and others) the growth of the stem continues until the end of the vegetation. An increase in the plant nutrition area leads to increased length and more significant accumulation of biomass in the plants until the end of vegetation.

2. The number of the formed leaves varies by the duration of the vegetation period: in the early-ripening varieties of rice – 9-10 leaves, middle-ripening ones – 11-12, late-ripening ones – 12-13 leaves. Late-ripening varieties form a much larger leaf surface than the genotypes of other groups of ripening. Under the increase in the plant nutrition area the total leaf surface area of the plants, including the area of the upper leaves, increases.

3. Side shoots of rice plants are formed throughout the vegetation period, but the potential and real productivity of plants is determined only by those shoots, which develop intensively at the early stages of organogenesis and reach to the beginning of the full ripeness of the main panicle to the V-VII stages of organogenesis. Flowering of rice plants in the early-ripening varieties takes place for 6-9 days, in the middle-ripening ones – 7-10 days and in the late-ripening ones – 9-12 days. The most intense flowering is attributed to the early-ripening varieties; the middle-ripening varieties have prolonged flowering period; and the least intensity and most prolonged flowering is in the late-ripening genotypes.

SUMMARY

The article contains the results of the researches on the dynamics of processes of growth and development of the plants depending on biological properties of varieties and cultivation conditions. The growth of rice stems depends on biological characteristics of varieties and plant nutrition area. In the South of Ukraine in some early-ripening varieties (Malysh) the stem growth is stopped after flowering, instead, most varieties (including early-ripening varieties Mutant-428 and others) are characterized with the continuous growth of stem to the end of the vegetation. Increase in the plant

nutrition area leads to the increased length and more significant accumulation of biomass in the plants before the end of vegetation. The early-ripening varieties of rice form, mainly, 9-10 leaves, middle-ripening ones – 11-12, late-ripening – 12-13 leaves. Late-ripening varieties form a much larger leaf surface than the genotypes of other ripening groups. With the increase in the plant's nutrition area, the total area of the leaf surface of the plants, including the area of the upper leaves, increases. Lateral shoots in the rice plants are formed during the entire vegetation period, but the potential and real productivity of the plants is determined only by those shoots that develop intensively at the early stages of organogenesis and reach by the ripening of the main panicle to the V-VII stages of organogenesis. Flowering of rice plants in the early-ripening varieties lasts for 6-9 days, in the middle-ripening – 7-10 days and in the late ripening – 9-12 days, respectively. The most intense flowering is attributed to the early-ripening varieties; the middle-ripening varieties are characterized with prolonged flowering period and the least intensity and the longest time span of flowering is a feature of the late-ripening genotypes.

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SCIENTIFIC AND PRACTICAL PRINCIPLES OF THE NATIONAL VARIETAL RESOURCES FORMATION: CURRENT STATE AND PROSPECTS

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INTRODUCTION

The main task of the agricultural policy of Ukraine today is to raise productivity and improve the quality of crop production by increasing and maintaining varietal plant resources which determine the food security of the state and can be used in the further selection process[1].

With the biological science development and the increase demands of agrarian market in providing agriculture with high-quality resources of plant varieties, the state ensures the quality of registration of cultivated in Ukraine varieties, the protection of plant breeders' rights and the introduction of seed certification in Ukraine in accordance with the international requirements.

Variety plant resources play a special role in the economic and social development of Ukraine, first of all, in stabilizing and increasing the volume of crop production as a basis for the country's food security.

The State Register of varieties, valuable for cultivation in Ukraine, includes more than 11 thousand varieties of about 450 botanical taxa of agricultural, cereal, vegetable, fruit, ornamental and other groups of plants which varieties are cultivated now[2].

Formation of the national plant variety resources is based on the results of state scientific and technical examination of plant varieties. Every year, the State Register of varieties, valuable for cultivation in Ukraine, is replenished by the new varieties that meet the criteria of distinctness, uniformity and stability and meet the needs of consumers, do not endanger the human health and do no harm to the environment by commercially valuable characteristics [3]. It is exactly this testing that ensures the quality of national varietal resources

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formation and use. Finally, varietal research is the scientific study of plant varieties in the field and laboratory conditions in order to obtain complete knowledge of valuable characteristics (morphological, physiological, economical, etc) and worthiness of using them to meet the needs of consumers and in the further selection process[4].

The lack of information related to the response to extreme environmental factors, resistance to pathogens and pests of the new cultivated in Ukraine varieties remains as an urgent problem. Comparative analysis between the degree of these characteristics manifestation and the results of scientific and technical expertise can be conducted by post-registration study (hereinafter PRS), which will allow to determine not only the economic feasibility of further cultivation, but also influence on the volume and structure of the sown areas in the certain regions of the country.

The quality characteristics of the varieties obtained during PRS will allow identifying the most environmentally friendly zones for processing, food and pharmacological industries[5].

The optimal solution to the problem of the national plant variety resources formation is based on the results of the monitoring in countries of the Commonwealth of Independent States (CIS), the European Union (EU) and the International Union for the Protection of New Varieties of Plants (UPOV)[6].

This makes it possible to say that the development of breeding in plant-growing plays a crucial role in the varietal plant resources formation, and the state scientific and technical examination of plant varieties through the regulatory, controlling and advisory mechanisms is the single-source to ensure the formation and legal protection of varietal plant resources.

Analysis of the variety quality characteristics in dynamics along the process of economic, biological, consumer and intellectual value transformation will create the conditions for fund and effort targeting in the genetic bank formation and certification of the plant varieties as the basis for state food security[7].

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1. Historical aspects of the plant variety resources formation in Ukraine

The year 1923 is considered to be the beginning of the system of domestic variety examination, when the All-Ukrainian Society of Seed Production created a special research network, the tasks of which included only varietal testing of maize,

spring and winter wheat and potatoes[8]. Later (1927–1930) the program of variety examination was significantly expanded – all major field and garden crops were involved to it. Then, a universal methodology to study the plant varieties was developed for the first time and the list of plant varieties with the main variety features was formed in accordance with the local soil-climatic conditions of different regions. The autonomous network of variety examination of the Ukrainian People's Commissariat of Agriculture and the All-Ukrainian Society of Seed Production, as on 1928 with the main State Variety Network numbered 26 units. Economic and organizational work in the units of plant examination is shown in the Figure 1.

In 1932, the Ukrainian variety network for plant examination of the Ukrainian People's Commissariat of Agriculture was merged with the variety testing department of the All-Union Institute of Plant Growing (Moscow) and the All-Union State Variety Testing Network (State Grid Network) was created (later the State Commission on Variety Testing).

Fig. 1. Plant care at the maize experimental plot

[8] Vasyliuk P. M. (2013) *Stanovlennia ta rozvytok naukovykh zasad sortovyprobuvannia v Ukraini* [Formation and development of scientific foundations of variety testing in Ukraine]. Kyiv: Niland-LTD.

The decree of the Soviet People's Commissar of the USSR of 29.07.1937 "On Measures to Improve Cereal Seeds" laid out the principles of testing the varieties of cereals, including the establishment of a network of state variety experimental plots.

During the period 1937-1938, 193 plots were organized in the Ukrainian Republic: Vinnytsia region – 25, Dnipropetrovsk – 30, Donetsk – 26, Odessa – 30, Kharkiv – 35, Chernihiv – 16.

In Ukraine, even before the World War II, 150 plots were organized to test cereals, oilseeds and herbs. The network of variety centers was formed according to the district principle (each district or group of districts with similar soil and climatic conditions).

Almost all cultivated plants were under examination and field testing was designed in accordance with 2, 3 or 6-fold replications. Due to seed control laboratory tests, the varieties were examined not only for yield, pest resistance, climatic conditions resistance, but also determined flour and baking quality of grain, protein and gluten content, diastatic activity of flour, etc.

The results obtained together with the results of the soil survey made it possible to develop varietal zoning.

In 1940, the variety experimental plots of extended set and of main network were formed in order to improve the quality of work, to ensure a comprehensive study of the economically valuable features of the variety and to ease strains on the main “State Variety Network”. The general view of field experiments on experimental plots is shown in Fig. 2.

Fig. 2. Plant care during the field examination

In the early 50es of the last century, through the organization of variety examination plots at the collective and state farms the variety examination activity was raised up to the pre-war level.

The number of variety experimental plots in the Soviet Ukrainian Republic increased to 225.

As of the beginning of 1970, the main functions of the state variety examination network were and remain to give an objective and accurate comparative evaluation of varieties and hybrids of crops, identification of more yielding and valuable varieties for zoning and their introduction into agricultural production.

The general provisions of the variety examination methodology are uniform for all experimental plots, regardless of their specialization, production base and geographical location.

As of November 1, 1985, the network of variety examination stations and plots of the Ukrainian SSR included 258 units, of which, on the basis of collective farms – 154, state farms and other enterprises – 86, on an independent balance – 17, 1 – specialized variety examination station.

In accordance with the Decree of the Council of Ministers of the UkrSSR of 27.12.1989 №292 "On the organizational structure of state examination and zoning of crop varieties" the Inspectorate of the State Commission for Crops Variety Examination in the UkrSSR was reorganized into the State Commission for Agricultural Crops Examination of the Main State Agricultural Industry (hereinafter Commission), which included the network of institutions: 25 regional inspectorates, 8 regional state stations for plant variety examination, 17 state experimental plot centers and Ukrainian central laboratory for testing the quality of variety examination in Kyiv. Field experiment is shown in Fig. 3.

Fig. 3. Feald examinatin of maize varieties

In accordance with the Decree of the Council of Ministers of the UkrSSR of 27.12.1989 № 292 "On the organizational structure of state examination and zoning of crop varieties" the Inspectorate of the State Commission for Crops Variety Examination in the UkrSSR was reorganized into the State Commission for Agricultural Crops Examination of the Main State Agricultural Industry (hereinafter Commission), which included the network of institutions: 25 regional inspectorates, 8 regional state stations for plant variety examination, 17 state experimental plot centers and Ukrainian central laboratory for testing the quality of variety examination in Kyiv.

The main task of the Commission was to implement state examination of all new varieties, hybrids and lines of domestic and foreign breeding[9].

In 1992 the State Commission for Agricultural Crops Examination of the Main State Agricultural Industry of the UkrSSR was renamed to the State Commission of Ukraine for Examination and Protection of Plant Varieties of the Ministry of Agrarian Policy and Food of Ukraine (State Commission), which carried out state administration of field plant variety examination.

The purpose of its creation was to ensure public administration of the plant varietal resources formation of Ukraine and the protection of breeders' rights.

The State Commission numbered 25 regional inspectorates, 66 regional state stations for plant variety examination, 122 stations for plant variety examination, 8 laboratories and 4 enterprises.

Decree of the Cabinet of Ministers of Ukraine 3116-XII of 21.04.1993 adopted the Law of Ukraine "On Protection of Plant Variety Breeders' Rights", which provides regulation of property and personal non-property relations arising in connection with the acquisition, exercise and protection of intellectual property rights on plant varieties.

Pursuant to the Law, the Decree of the Cabinet of Ministers of Ukraine № 935 of 22.11.1993 "On the Register of Plant Varieties of Ukraine" approved the Regulation on the Register of Plant Varieties of Ukraine, and adopted a number of by-laws regulating acts for the Register introduction[10].

Formation of the State Register of Plant Varieties of Ukraine allowed to create internal market for varieties and hybrids and accelerate their introduction into production, eliminates artificial restrictions of their use and gives producers more rights to choose the best varieties according to seed potential.

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[9] Diialnist ta istoriia Ukrainskoho instytutu ekspertyzy sortiv roslyn (2019) [Activity and History of Ukrainian Institute for Plant Variety Examination] https://sops.gov.ua/istoria-uiesr-2.

[10] Pro okhoronu prav na sorty roslyn: Zakon Ukrainy vid 21.04.1993 roku № 3116- XII [The Law On Protection of Rights to Plant Varieties of 21.04.1993 № 3116-XII]. http://zakon4.rada.gov.ua/laws/show/3116-12.

In 1995, Ukraine became a member of the International Union for the Protection of New Varieties of Plants (UPOV). The Verkhovna Rada of Ukraine adopted the Law of Ukraine of June 2, 1995 № 209/95-VR "On Accession of Ukraine to the International Convention for the Protection of New Varieties of Plants".

And in 1997, cooperation between Ukraine and the Organization for Economic Co-operation and Development (OECD) was initiated through the signing Agreement on Privileges, Immunities and Benefits Granted to the OECD in Ukraine.

The agreement was ratified by the Verkhovna Rada of Ukraine in July 1999 (Law of Ukraine dated 07.07.99 № 850-XIV).

In 2000, the variety examination network of the State Commission of Ukraine for Plant Varieties Examination and Protection of the Ministry of Agriculture and Food of Ukraine numbered 92 regional state stations for plant variety examination, and 47 experimental plot centers.

Fig. 4. Ukrainian Institute for Plant Variety Examination

New approaches to the concept of the variety and the world experience in right protection have prompted the government to take appropriate steps to develop legal, scientific, methodological and international components of the system of variety examination and rights protection. The decree of the Cabinet of Ministers of Ukraine in 2001 approved a number of top priority measures for solving the most important tasks of seed production and crop breeding, and provided the establishment of the Ukrainian Institute for Plant Variety Examination[11].

[11] Analitychna zapyska pro riven rozvytku naukovoho (naukovo-tekhnichnoho) potentsialu i rezultatyvnosti diialnosti Ukrainskoho instytutu ekspertyzy sortiv roslyn ta obgruntuvannia napriamiv i zakhodiv z optymizatsii diialnosti Ustanovy za 2015–2017 roky. [Analytical note on the level of development of scientific (scientific and technical) potential and performance of the Ukrainian Institute for Plant Variety Examination and substantiation of directions and measures for optimization of the Institute's activities for 2015–2017]. https://sops.gov.ua/uploads/page/images.

In 2002, the Ukrainian Institute for Plant Variety Examination (UIPVE) was created through the reorganization of the State Center for Certification, Identification and Quality of Plant Varieties of the State Commission for Plant Varieties Examination and Protection of the Ministry of Agrarian Policy (Cabinet of Ministers of Ukraine of 01.06.2002, №714 "On Establishment of the State Service for plant varieties protection and UIPV")[12].

Within the Ministry of Agrarian Policy and Food, the State Commission for Plant Variety Rights Protection was established on the basis of the State Commission of Ukraine for Plant Varieties Examination and Protection, and UIPVE and experimental plot centers were subordinated to this governmental body.

In 2003, the UIPVE launched the publication of the official Bulletin "Protection of Plant Variety Rights", aimed officially publishing the results of research on the basis of which state registration of the variety and/or its rights is conducted. In 2003, the Verkhovna Rada of Ukraine adopted the Law of Ukraine № 411-IV of 26.12.2003 "On seeds and planting material", which defined the basic principles of production and circulation of seeds and planting materials, as well as the procedure for state control over them[13].

Cooperation between Ukraine and the Community Plant Variety Office (CPVO) was initiated in 2005. On April 25, 2005, a Memorandum of Understanding between the CPVO and the State Commission for Plant Variety Rights Protection was signed in Kyiv, that include exchange of information, experience, training and technical cooperation (training of technical staff, participation of Ukrainian representatives as observers in CPVO expert meetings)[14].

The Verkhovna Rada of Ukraine adopted the Law of Ukraine of 02.08.2006 № 60-V "On Accession of Ukraine to the International Convention for the Protection of New Varieties of Plants".

Ratification of the 1991 Act of the International Convention for the Protection of New Varieties of Plants allowed protecting plant varieties of all botanical taxa.

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[12] Leshchuk N. V., Rudnyk O. I. (2002) Isnuiucha systema sortovyprobuvannia ta identyfikatsiia sortiv silskohospodarskykh kultur [Existing system of variety testing and identification of crops varieties] *Naukovyi visnyk Natsionalnoho ahrarnoho universytetu* [Scientific Bulletin of the National Agrarian University], № 57, pp. 143-146.

[13] Volkodav V. V. (2012) Zakonodavche udoskonalennia haluzi nasinnytstva – zaporuka vysokykh i stalykh vrozhaiv [Legislative improvement of the seed industry is the key to high and sustainable crops]. *Naukovyi visnyk Natsionalnoho universytetu bioresursiv i pryrodokorystuvannia Ukrainy*. [Scientific Bulletin of the National University of Life and Environmental Sciences of Ukraine] Ser.: Ahronomiia, № 176. Pp. 301-306.

[14] Pushkar M. V. (2005) Do pytannja systematyzaciji zakonodavstva Ukrajiny u sferi intelektualjnoji vlasnosti na sorty roslyn [On the systematization of the legislation of Ukraine in the field of intellectual property for plant varieties] *Visnyk ghospodarsjkogho sudochynstva* [Bulletin of economic justice]. № 5. Pp. 167-173.

Year by year the material and technical base of the state system for plant varieties protection was strengthened and a team of professional specialists was formed. Today, there are 24 regional state centers for plant varieties examination (branches) in the structure of the Ukrainian Institute for Plant Variety Examination with 96 scientists, including 4 professors and 24 – doctors. Scientific and methodological support provides high quality of field and laboratory researches for plant examination, Fig. 5.

In 2013, Ukraine ensured the holding of the 42nd session of the UPOV Technical Working Group on Field Crops in Ukraine (Kyiv), which was attended by 58 foreign participants from 30 countries (UPOV member countries)[15].

Fig. 5. Field examination 2013

Ukraine also closely works with the intergovernmental Organization for Economic Cooperation and Development (OECD) as an associate member: it has joined the OECD Seed Schemes for the certification of cereal, maize, sorghum, oilseed, cruciferous and sugar beet seeds. The OECD conducts regular peer reviews in the member countries.

Conducting such a review in Ukraine contributes to the deepening of cooperation with the OECD, is of great practical importance as it contains specific recommendations for improving public policy in the field of variety identification and variety certification of seeds and planting materials[16].

[15] Dehtiarenko Yu. (2018) Aktualni ta problemni pytannia zakonodavstva Ukrainy u sferi okhorony sortiv roslyn u spivvidnoshenni z uhodoiu pro asotsiatsiiu z YeS [Current and problem issues of Ukrainian legislation in the field of protection of plant varieties in the context of the European Union Association Agreement] *Teoriia i praktyka intelektualnoi vlasnosti*. [Theory and Practice of Intellectual Property], № 5, pp.75-82.

[16] Tkachyk S.O., Leshchuk N.V., Hryniv S.M., Kostenko N.P. (2018) *Metodyka provedennja diljankovogho (gruntovogho) ta laboratornogho sortovogho kontrolju (POST-control).* [Methods of conducting the site (soil) and laboratory varietal control (POST-control)], Vinnytsia: Niland-LTD.

2. Concept of national varietal resources formation

The market of seeds and planting materials of plant varieties puts forward urgent requests, namely: assortment, pure-seed, its authenticity; maximum of criteria, minimum of conditions; State Register of Plant Varieties (National Catalog): support examination on distinctness, uniformity, stability and suitability for cultivation in Ukraine; quality certification system: compliance with international requirements, coordination and transparency of actions; pre-registration and post-registration study of varieties, with further formation of regional lists[17].

Modern methods and directions of plant variety selection provide quality product for market needs.

Current priorities in the selection practices of plant varieties are the criteria that should ensure: yield (positive dynamics), resistance against pathogens and pests, resistance to abiotic stress, productivity potential, product quality, yield efficiency, nutritional quality and product safety, qualitative storage, optimal cost, more efficient land use, economic viability, new markets and variety competitiveness[18].

An important factor is the annual filling of the Register of Ukraine by the new competitive plant varieties. The analysis of variety replacement along the last 5 years for strategic crops of grain group in Ukraine is 55–71% (Table 1).

Further formation of the national varietal plant resources requires improving the mechanism of its legislative, regulatory, methodological, organizational, staff, scientific, technical, technological and financial regulation in accordance with international and European requirements[19]. The concept of the national varietal plant resources formation for 2006–2011 revealed the causes of unbalanced system of its formation:

- mismatch of actual crop production volumes to the needs of the internal and external markets due to inefficient use of varietal plant resources induced by the post-registration research absence;
- unregulated market relations in the civil circulation of plant varieties, which leads to imbalance in supply and demand on the market of plant varieties;

[17] Andriushchenko A. V., Tkachenko V. M. (2011) Pro neobkhidnist perehliadu Metodyky derzhavnoho vyprobuvannia sortiv roslyn na prydatnist do poshyrennia v Ukraini. [On the need to review the methodology of state VCU testing of plant varieties Ukraine] Sortovyvchennia ta okhorona prav na sorty roslyn. [Plant Varieties Studying and Protection] № 1, pp. 55–57. DOI: https://doi.org/10.21498/2518-1017.1(13).2011.60076.

[18] Haievets M. V. (2012) *Superechlyvist norm zakonodavstva Ukrainy u zdiisnenni derzhavnoi reiestratsii prav intelektualnoi vlasnosti na sorty roslyn*. [The controversy of the norms of Ukrainian legislation in the registration of intellectual property rights to plant varieties]. *Teoriia i praktyka intelektualnoi vlasnosti* [Theory and Practice of Intellectual Property], № 3, pp. 6–10.

[19] Zakharchuk O. V. (2009) Sort yak innovatsiina osnova rozvytku roslynnytstva [Variety as an innovative basis of crop development] *Ahroinkom*, № 5/8, pp. 17-22.

Table 1

Rates of variety replacement in the State Register of Plant Varieties Valuable for Cultivation in Ukraine

Botanical taxa	Variety amount in the Register			% of replacement during 2015–2019
	2005	2015	2019	
soft winter wheat	111	313	218	70
sowing rye	29	34	19	56
spring barley	79	129	71	55
soft spring wheat	35	45	32	71
maize	291	880	568	65
sunflower	138	583	363	62
sugar beet	96	169	87	52
potatoes	107	180	43	24
soybean	72	166	115	69

- low rates of scientific and technical potential realization in plant selection;

- insufficient state motivation and support in plant variety domestic breeding and seed development;

- the lack of a modern genetic bank of varietal plant resources;

- insufficient financial, material, technical, scientific, staff, information and consulting support in the state scientific and technical examination of plant varieties[20].

With that in mind, appeared the need to create a new concept of national varietal plant resources formation and their effective use[21]. The main tasks of the concept of national varietal plant resources formation are:

- state regulation of plant varieties civil circulation and creation of competitive varieties of domestic breeding, variety certification introduction and international market entry;

[20] Kontseptsiia formuvannia natsionalnykh sortovykh roslynnykh resursiv na 2006–2011 roky. Rozporiadzhennia Kabinetu Ministriv Ukrainy vid 2 serpnia 2005 r. № 302-r [The concept of national varietal plant resources formation for 2006-2011. Ordinance of the Cabinet of Ministers of Ukraine of August 2, 2005 № 302-p]. https://zakon.rada.gov.ua/laws/show/302-2005-%D1%80.

[21] Lypchuk V. V., Malakhovskyi D. V. (2015) Sortovi resursy zernovykh kultur v Ukraini: stan ta problemy rozvytku [The sorts resources of grain crops in Ukraine: status and problems of development] Innovatsiina ekonomika [Innovative economy], № 1, pp.12-17.

- harmonization of the domestic policy related to intellectual property rights on plant varieties with the state policies of the countries – members of the European Union and other world leading countries;

- increasing the competitiveness of domestic crop production and products of its processing on the domestic and foreign markets.

The state funds allocated for the state scientific and technical examination of plant varieties are not enough, and the issue of attracting non-state investments has not been resolved.

The issues of scientific and technical, personnel and information – consulting support remain also unresolved. There is no mechanism for interaction between state and non-governmental scientific institutions and organizations in the process of national varietal plant resources formation[22].

Such researches will form the organizational principles for scientifically sound monitoring of varieties and hybrids involved into commercial circulation based on the analysis of studies and modern European practice to decide independently the state registration of plant varieties for cultivation in Ukraine and the state registration of their rights.

This solution creates the conditions for involving community and the institute of intellectual property representatives for plant varieties as an expert bodies for consideration this issue[23].

The problem of varietal plant resources formation is supposed to be solved through:

- ensuring the priority of the development of state system of plant variety rights protection in the implementation of domestic and foreign state policies in the budget, credit, price, insurance, tax and regulatory spheres;

- improving the legal framework related to the plant variety rights protection;

- development of mechanisms of interaction between state and non-governmental institutions and organizations in ensuring the varietal plant resources formation;

- development of scientific and technical, innovative activity and standardization in the field of intellectual property for plant varieties, including varietal study;

- formation of information, communication and consulting system of economic usability and protectability of plant varieties.

The varietal plant resources formation will be carried out at the expense of:

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[22] Sabluk P.T., Khadzhymatov V. A., Kisilj M. I., Zakharchuk O. V. (2009) Normatyvni vytraty na provedennia ekspertyzy sortiv roslyn. [Standard costs for the examination of plant varieties]. Kyiv.

[23] Leshchuk N. V., Zribniak M. M. (2005) Derzhavna reiestratsiia sortiv ovochevykh kultur – osnova formuvannia natsionalnykh sortovykh resursiv [State registration of vegetable varieties is the basis for the national varietal resources formation] *Sortovyvchennia ta okhorona prav na sorty roslyn* [Plant Varieties Studying and Protection], № 2, pp. 86–96.

- state budget funds, including revenues from payment of fees for actions related to the acquisition, exercise and protection of plant variety rights, as well as the provision of paid services for conducting a field and laboratory VCU research and other types of expertise and by-products realization, carrying out scientific-production activity of the state examination institutions of the system of plant varieties rights protection;

- funds of the International Charitable Foundation for the Protection of Intellectual Property and grants of international technical assistance;

- state fund for varietal plant resources formation.

The implementation of the concept will provide: solution of the state food security, creation of new domestic highly productive adapted plant varieties and introduction of varietal certification of seeds according to OECD requirements, production volume increase, quality and competitiveness of domestic production on the domestic and foreign markets, that will help to increase the annual gross income in the field of crop production.

CONCLUSIONS

The implementation of scientific research on the development of the Concept of national varietal plant resources formation for 2020–2025 will provide:

1. Solving the national food security question, creation of new domestic high-performance, adapted, competitive plant varieties.
2. Substantiation of post-registration variety study to form regional lists of plant varieties on request of economic entities of different forms of ownership.
3. Implementation of varietal certification of seeds and planting materials according to the international requirements of the Organization for Economic Cooperation and Development.
4. Increasing production and improving the quality of marketable products and seeds on the domestic and foreign markets.
5. Increase in the annual gross income in the field of crop production by the category "Sort" by 25–50%.

SUMMARY

Varietal plant resources play a special role in the economic and social development of Ukraine, first of all, in stabilizing and increasing the volume of crop production as a basis for the country's food security.

Varietal quality is a reliable and cost-effective factor in increasing crop yields under any growing technology. Modern varieties and hybrids must be distinctive, uniform and stable, meet the needs of consumers, without endangering the environment and human health.

Research methods. Methods were used for research: field, laboratory, statistical, historical with elements of extrapolation, analysis and synthesis.

Research results. The historical aspects of the national varietal resources formation, the current state and prospects of development of the plant varieties rights protection are revealed. The reasons for the development of the Concept of National Varietal Resources Formation are substantiated, the tasks and ways of their realization are determined.

Conclusions. The implementation of the concept will provide: addressing the food security of the state, creation of new domestic highly productive adapted plant varieties and introduction of varietal certification of seeds according to OECD international requirements, increase production volumes, quality and competitiveness of domestic production on the domestic and foreign markets, which will help to increase the annual gross income in the field of crop production.

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of varieties of agricultural plant species (OB L 193, 20.07.2002, p. 1). (in Ukrainian) https://www.kmu.gov.ua/storage/app/media/uploaded-files/es-2015412.pdf.

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LIQUID COMPLEX FERTILIZERS ON THE CULTURES OF AGRICULTURAL CULTURES OF THE BLACK SEA STEP OF UKRAINE

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INTRODUCTION

In Ukraine, the production of liquid complex fertilizers (LCF) of the brands 11:37 and 10:34 (nitrogen: phosphorus), in which phosphorus is presented in the form of ammonium ortho- and polyphosphates, is set up again, with the share of the latter being 65-75%. Polyphosphates become available to plant roots after their transformation under the action of the soil enzyme pyrophosphatase, while phosphor phosphate is available to plants directly. Managers of agricultural enterprises are attracted by their numerous advantages[1]:

- can be brought to the soil surface without the need for immediate tillage; compared to solid fertilizers more evenly distributed over the surface of the field; uniformity of composition: each drop of liquid fertilizer has the same composition;
- other components (microelements, growth regulators, pesticides) can be introduced into their composition, with the added components being distributed throughout the fertilizer and this allows them to be introduced as evenly as possible;
- in comparison with liquid nitrogen fertilizers LCF do not contain free ammonia, so they can be transported and stored in leaky containers;
- works with the LCF are fully mechanized, losses during overloading and storage do not exceed 1%, whereas for solid fertilizers this figure is 10-15% and more;
- the cost of LCF is lower than solid fertilizers due to the exclusion of energy-intensive technological stages (granulation, drying, dust collection, etc.).

In the period up to 1990, agricultural research institutions have shown in numerous experiments the high efficiency of the use of LCFand CAS(Ammoniac mixture) for basic crops[2]. But over time, there have been and

[1] Loginova I. (2016) Liquid complex fertilizers. Agronomist. No. 2 (52). URL: https: //agronom.com.ua/zhydkye-kompleksnye-udobrenyya/.

[2] Getmanets A.Ya., Kramarev S.M., Bondar V.P., Usenko Yu.I. (1990) Efficiency of co-application of liquid complex fertilizers and herbicides in crops of corn cultivated using intensive technologies. Collection of scientific papers of the All-Russian Research Institute of Corn. S. 55-62; Kramarev S.M. (1990) The effect of co-administration of LCF, KAS-28 and herbicides on some

are changing climatic conditions, soil fertility, and some elements of cultivation technologies are being improved, which necessitates an assessment of the efficiency of the LCF for the present.

Active and scientifically based use of LCF in some measure will help to solve the problem of phosphorus state of the black soil of Ukraine. According to statistics, between 1966 and 1990, the use of phosphorus fertilizers increased steadily and reached 40 kg of active substance per hectare . In this case, the weighted average content of mobile phosphorus in the steppe zone increased from 67 mg per 1 kg of soil to 93 mg/kg.

A sharp decrease in the level of application of phosphorus fertilizers begins in 1991 and already in 1997 it amounted to 4.1 kg bw/ha; the annual deficit of mineral phosphorus reached 15-20 kg/ha (4-5 mg/kg)[3]. The minimum amount of phosphorus fertilizers (2-3 kg/ha) was introduced in 2000–2003, since 2004 the gradual increase in the volumes of introduction of phosphorus fertilizers began, although it remained unacceptably low (7-10 kg/ha).

Under the harvest 2017–2019. in the Odessa region, phosphorus fertilizers of 5-6 kg dw/ha were introduced and in the total amount of mineral fertilizers introduced the share of phosphorus was 18%, potassium – 14% and nitrogen – 68%.Prolonged application of low rates of phosphorus fertilizers has led to a significant deterioration of the phosphate regime of soils of Ukraine as a whole and of the Steppe zone as well.

1. Material and Methods

To determine the effectiveness of liquid complex fertilizers (LCF) 10: 34: 0 in the conditions of the Black Sea agricultural zone of the Odessa region were done trial with the main crops in the field of field crop rotation: corn for grain, peas, winter wheat, sunflower.

In addition, LCF was applied into black fallow and explored the possibility of its use for pre-sowing seed treatment as an adhesive.

Soil of the trial field of the Odessa State Agricultural Experimental Station – chernozem southern low humus heavy loam.

The arable layer of the experimental plot was characterized by the following indicators: humus content – 3.11%, mobile phosphorus and

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physiological and photosynthetic indicators of corn plants. Alma-ata. Thes. doc. (Republican scientific and practical conference of young scientists and specialists). S. 117-118; Nevskaya V.N. (1988) CAS solutions with trace elements, nitrification inhibitors, and pesticides. Chemicalization. Number 3. S. 30-32; Radchenko V.V., Berezina N.L. (1988) Specialization issues in the use of solid and liquid mineral fertilizers. Improving the economic mechanism in the agricultural sector. Thes. reports of the 2nd Belarusian scientific and practical. conf. young scientists and specialists. Minsk. S. 477-478.

[3] Kramaryov S. Phosphor, the problem of Ukrainian black soil and the possibility of hatches of the Russian Federation. Farmer. URL: https://imptorgservis.uaprom.net/a170873-fosforna-problema-ukrayinskih.html.

potassium – 100.0 mg/kg soil and 105.0 mg/kg, respectively. The size of the plot is 140 square meters, the accounting area is 84.0 m^2, the repetition rate is four times. In the trials was used recognized variety.

Fertilizers were used as ammonium nitrate, simple granulated superphosphate, potassium salt and LCF 10: 34: 0. Schemes of experiments on individual cultures are given in the presentation of the results. Time of experiments 2018–2019 agricultural year.

1.1. Weather conditions of time of experiments

Summarizing long-term meteorological data it is proved that in the Odessa region 444 mm of precipitation falls during the year. It should be noted that rainfall is very unevenly distributed, leading to an acute shortage of moisture and a sharp decrease in yield. During the summer, 34-40% of the total annual rainfall occurs, and in other seasons fall by 20%, which emphasizes a distinct continental character.

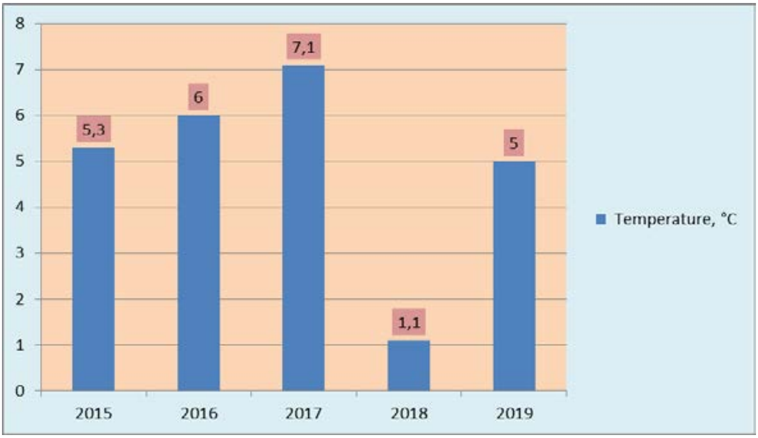
The hydrothermal coefficient of the Black Sea Steppe is 0.5-0.8. According to long-term observations of the Odessa Hydrometeorological Station, the frost-free period lasts 175-180 days, the sum of effective air temperatures (above + 10^{o}C) is 3200-3400o.

The average annual air temperature is 9-10^{o}C. The rainfall here is 330-380 mm. Precipitation is a very variable element of the climate of the area. Their distribution during the growing season, both in time and in intensity is very uneven, which prevents their effective use.

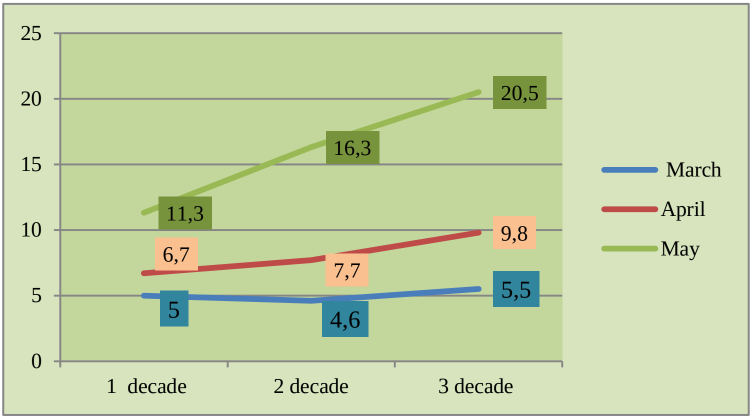
The productivity of the crop industry, as well as of agriculture in general, depends to a large extent on the influence of climatic factors, especially on the amount and uniformity of the rainfall, as well as on the temperature and relative humidity. March 2019 was at the level of 2015 (Picture 1). The average monthly temperature in the south of Ukraine for this month was 5.0°C, which is higher than the long-term norm by 2.3°C. For comparison, we show the average monthly outdoor air temperature in March for the last 5 years.

This year, the transition of the average daily air temperature through the mark of plus five degrees, which is considered to be during the steady spring resumption of the vegetation of winter crops in the conditions of the Odessa Agricultural Experimental Station, was noted on March 17, which was noticeably earlier than last year – March 31 and later in Compared with 2017 – March 5. In general, in April there was a rapid increase in heat in the third decade. If in the first ten days of April it was 6.7°C, in the second 7.7°C, and in the third – 14.5°C (Picture. 2). The average temperature for the month was 9.8°C, which corresponds to a long-term norm.

In May, a high air temperature was observed with an excess of the average annual norm of 4.8°C. The ten-day increase in temperature was gradual: in the 1st decade, the temperature was 11.3°C, in the 2nd decade – 16.3°C and in the 3rd – 20.5°C.

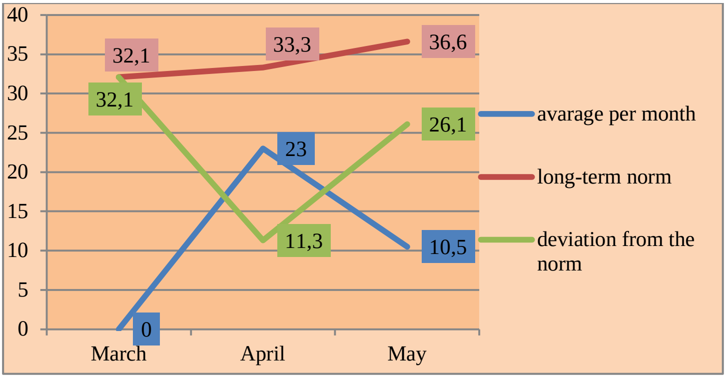


Pic. 1. The average monthly air temperature in March for the last 5 years, °C



Pic. 2. Ten-day average air temperature in the spring of 2019 according to the weather station of Odessa State Agricultural Experimental Station

The spring period of 2019 turned out to be largely arid: in March there was no precipitation (Picture. 3), in April it fell in the second decade (23 mm), which is 10.3 mm lower than the average long-term norm; in May there was very little rainfall of -10.5 mm (28.7% of the average annual norm). The lack of precipitation in sufficient quantities and the high temperatures of the spring period negatively influenced the growth and development of all crops.



Pic. 3. Long-term average rate and monthly precipitation in the spring of 2019

2. Results

2.1. Corn for grain

The equivalence of LCF and solid mineral fertilizers for corn is shown in Table 1. There was a tendency to an increase in yield (+2.8 c/ha) during the spring application of liquid complex fertilizers before sowing corn in combination with the main nitrogen-potassium fertilizer in comparison with the similar option, where liquid complex fertilizers served as the main fertilizer (options 3.4).The use of liquid complex fertilizers in its pure form led to a certain decrease in yield relative to its integrated application, but there was also a tendency to higher yields during spring to sowing. The use of liquid complex fertilizers for top dressing in phase 12-17 (according to the European classification of BBCH) increased the yield in comparison with the pure control by 7,1%.

An analysis of the available nutrients in the soil by the phases of corn organogenesis showed a higher content of mobile phosphorus in the variants of spring application of LCF and in top dressing: on average, the excess was from 43.5% (5 days after application) and 10.9% after 20 days, both in relation to pure control, and to solid mineral fertilizers. In the content of available forms of nitrogen, no significant differences were observed.

The nitrogen content in the corn grain of all variants was slightly (1.3 ... 10.3%) higher than the control variant, but the maximum protein yield per unit area was observed in the variants where phosphorus in the composition of solid mineral fertilizer was replaced by 10:34 equivalent grade liquid-fat formative agents and applid LCF in the spring before sowing or in top dressing in phase 12-17 BBCH. The excess was 26.8% and 31.6% compared with the pure control and 8.1%, 12.2% – in relation to the main application of solid mineral fertilizers.

Table 1

Harvest of corn grain, depending on the form of fertilizers, kg/ha

№ plot	Option Content	repetition				Average	± control	
		I	II	III	IV		t/ha	%
1.	Control (without fertilizer)	42,4	43,0	41,2	41,4	42,0	-	-
2.	N90P60P60 *	47,6	49,2	48,3	49,5	48,6	6,6	15,7
3.	LCF ** + NP	46,1	49,1	50,6	47,4	48,3	6,3	15,0
4.	LCF in the spring before crops + NP the main application	49,8	52,6	52,4	49,7	51,1	9,1	21,9
5.	LCF in top dressing + NP the main application	51,1	51,1	49,5	49,8	50,4	8,4	20,0
6.	Liquid Complex Fertilizers in the fall – the main	47,3	46,9	45,5	46,9	46,6	4,6	11,0
7.	Liquid Complex Fertilizers in the spring before crops sowing	45,6	47,8	47,4	48,0	47,2	5,2	12,4
8.	LCF in top dressing	44,7	44,3	45,2	45,9	45,0	3,0	7,1
experimental error,%								1,5
Least significant difference 95% ($LSD_{0,95}$)								2,0

** – solid mineral fertilizers (SMF) – the main application in the fall;*

*** – LCF is normally equivalent to P60 (in all cases) and NP is equivalent to option 2 (in all cases) – main application.*

2.2. Peas

In preliminary studies in a long stationary experiment, we found[4] that to obtain a high yield of peas in a crop rotation with organic fertilizers directly under the peas, it is sufficient to apply phosphorus-potassium fertilizers. But, since according to the last round of agrochemical examination, the soils of most agricultural enterprises in Odessa region have sufficient reserves of exchange potassium and an insufficient potential for producing available nitrogen, as well as a low content of mobile phosphorus, then under such conditions liquid complex fertilizers grade 10:34 should be ideal for this culture.

The excess of the pea grain harvest relative to the pure control in the variants with liquid complex fertilizers(LCF) application was 22,9% and 28,2%, relative to solid mineral fertilizers (SMF) – 5,55 and 10,1%, moreover, higher growths were observed when using LCF in the spring before sowing

[4] Burikina S.I. (2009) Norms of payback – the basis for formulating the regulatory framework for planning and forecasting the development of crops. Newsletter of agrarian science of the south region. Odessa: SMIL, 2009. Issue 10, pp. 9-13.

the crop. Due to the higher yield, the protein yield per unit area also increased – by 19,7% and 26,7% relative to the variant without fertilizers and small (2,5% and 8,5%), but still an excess compared to SMF. The absolute nitrogen content in the pea grain varied according to the experimental variants in a narrow range of values – 3,39 ... 3,49%.

Table 2

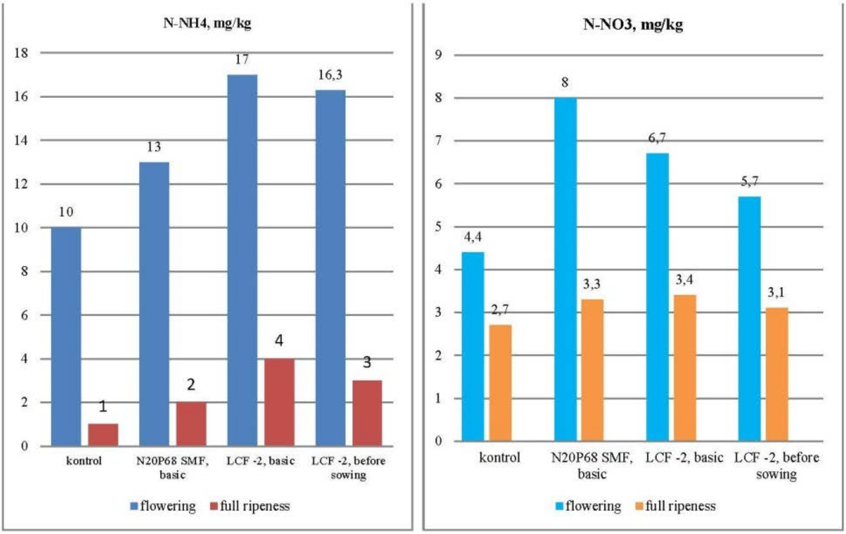
The Impact of the terms of liquid complex fertilizers on the crop and the main indicators of the quality of pea grain, variety Light

№ plot	Option Content	Harvest, c/ha					Weight 1000 seeds, grams	The yield of protein, kg/ha
		Repetition				Average		
		I	II	III	IV			
1.	Control (without fertilizer)	18,8	19,3	18,3	19,0	18,8	224,1	408,9
2.	N20P68 – main application	21,2	21,5	22,8	22,0	21,9	231,8	477,7
3.	LCF, 200 kg/ha physical. weights – the main application	22,5	22,3	24,2	23,4	23,1	231,3	489,4
4.	LCF, 200 kg/ha physical. weights – in the spring before sowing	24,4	24,2	23,6	24,1	24,1	231,8	518,2
experimental error,%						1,7	3,8	-
Least significant difference 0,95						1,1	5,6	-

The content of mobile forms of nitrogen in the soil of the control variant is lower than in the experimental plots. The concentration of ammonia nitrogen in the flowering phase was higher when applying LCF, both in the main application and when sowing in comparison with the variant of fertilizers by 70% and 63%, and in comparison with the main application of solid mineral fertilizers by 30,8 and 28,5 percent. To full ripeness, the content of ammonium nitrogen decreases to very small values (1 ... 4 mg/kg), but the patterns remain.

A relatively higher content of nitrate nitrogen in the soil layer of 0-30 cm is observed in Flowering during the main application of SMF; to full ripeness, the difference in its concentration by fertilizer options is almost leveled. At the same time, the nitrification ability, which characterizes the level of accumulation of nitrate nitrogen in the soil when it is composted for 14 days under optimal temperature conditions and moisture, is in the option of pre-sowing application of LCF by the end pea vegetation, almost twice exceeded the net control (1.8 times) and the options for the main application of both SMF and LCF (by 61.5% and 53.7%, respectively). By the flowering phase, the differences in soil nitrification ability in the control variant and with the main addition of SMF were insignificant (4.8% higher in the second case); the basic application of LCF exceeded SMF with the same method of application by 23,0% and by 16,3% – LCF when applied before sowing peas. Obviously, the application of LCF brand 10:34 activates the nitrifying microflora of the southern chernozem, regardless of the period of application.

The utilization rate of fertilizer phosphorus by pea plants during the main application of SMF was 2.5 times lower than with the LCF 10:34 with the same application period.



Pic. 4. The content of ammonium and nitrate nitrogen under sowing peas (layer 0-20 cm)

2.3. Winter wheat pre-crop peas

Options for experience:

1. Control of fertilizers;
2. $N_{60}P_{30}K_{60}$ – the main application of solid mineral fertilizers – background;
3. Background + $N_{15}P_{51}$ – solid mineral fertilizer was applied locally at the beginning of spring tillering;
4. Background + LCF is equivalent to $N_{15}P_{51}$ – foliar application to plants at the beginning of spring tillering;
5. Background + LCF is equivalent to $N_{15}P_{51}$ foliar application to plants in the phase of the beginning of exit into the tube.

The grain yield of winter wheat Cantata variety when grown on peas amounted to 45,7 c/ha without fertilizing, against the background of SMF – 53,6 c/ha. When the top dressing was introduced in the form of SMF, the grain yield increased to 55,6 c/ha, the same was the crop when using LCF for spring top dressing (55,6 c/ha). Using the background of the main application of LCFin the phase of the beginning of the exit to the tube, 54,4 c/ha of winter wheat was obtained. The yield growth due to top dressing amounted to (t/ha) 2,9; 2,9 and 0,8, and due to the whole norm – 9,9; 9,9 and 7,3 with a LSD of 0,95 = 1,7 c/ha.

The physical quality parameters of winter wheat grains such as the mass of 1000 kernels and bulk density did not differ significantly in the options for the use of LCF, and in the case of the background fertilizer, the mass of 1000 kernels significantly less control without fertilizers (table 3).

The vitreousness of the grain from the plots of fertilizer application did not differ, but in relation to the non-fertilized version – they are significantly higher.

Table 3

Quality of winter wheat grains with various technologies for making housing and communal services

№ plot	Weight 1 liter, grams	Weight 1000 grains, grams	vitreousness, %	Gluten, %	protein, %	Protein harvest, kg/ha	P_2O_5, %
1.	795,2	45,8	82,5	19,9	11,32	517,3	0,71
2.	793,5	42,6	96,0	26,4	13,31	713,4	0,79
3.	799,0	44,3	97,5	29,6	13,82	768,4	0,79
4.	800,0	44,6	98,0	33,2	15,12	840,7	0,86
5.	797,8	43,0	98,5	31,1	14,87	808,9	0,91
$LSD_{0,95}$	12,6	2,9	4,0	3,0	1,02	-	0,14

In terms of gluten content, applying fertilizers had a significant advantage, both in relation to the control and the background variant, and a significant increase in protein concentration in winter wheat grain in relation to the main use of SMF was observed during the feeding of LCF in both of the studied vegetation phases . The phosphorus content in the grain significantly exceeded the control also in the case of using LCF for spring feeding (table 3).

2.4. Sunflower

The experiment with sunflower was carried out according to a scheme similar to peas, the difference consisted in the dose of fertilizers. $N_{30}P_{102}$ was added under the sunflower, which amounted to 300 kg/ha of physical weight in the form of LCF. The crop increased from 24,0 c/ha in the control to

26,6 c/ha with the introduction of solid mineral and up to 27,0-27,8 c/ha with the application of LCF. Crop growth with the use of LCF amounted to 4,3-5,3 c/ha, SMF – 3,1 c/ha with a LSD of 0,95 = 1,1 c/ha.In the arid conditions of 2019, sunflower seeds were small: the mass of 1000 seeds from the fertilized varieties did not go beyond 69,2-701 grams against 65,8 grams on unfertilized ones. Seed huskiness was 21,6-21,8% versus 22,5%.

The fat content in the core (56,32-57,17%) did not differ much in fertilizer options, but its collection from 1 ha significantly (by 11,3-12,9%) increased in the plots of the main fertilizer application, including when apply LCF for sowing – by 15,8%.The utilization rates of phosphorus from liquid fertilizers were 1,8–2,0 times higher than from solid mineral fertilizers at equal application doses.

2.5. Using liquid complex fertilizers in the black fallow

In 2018, in a specially designated area for the trial with black fallow, fertilizers were applied according to the scheme shown in table 4.

Table 4

The presence of mobile nutrients in the soil under fallow

№ plot	Option Content	Sample Depth, cm	Sample in fallow 18.05 2019			Sample in germinate winter wheat – 11.10.2019		
			$N\text{-}NO_3$	P_2O_5	K_2O	$N\text{-}NO_3$	P_2O_5	K_2O
			mg per kg of soil					
1.	No fertilizer	0-10	13,2	100,0	125,0	7,0	112,5	150,0
		10-20	9,7	87,5	95,5	5,8	120,0	150,0
		20-40	8,9	87,5	77,5	4,3	120,0	77,5
2.	$N_{30}P_{102}$ – SMF when fallow was plowing	0-10	20,8	147,5	135,2	8,9	112,5	120,0
		10-20	20,4	85,0	101,2	8,0	107,5	95,0
		20-40	8,5	87,5	72,5	6,0	95,0	105,0
3.	$N_{30}P_{102}$ – LCF with equalization of black fallow in the fall	0-10	19,0	147,5	135,5	8,9	162,5	192,5
		10-20	7,5	92,5	91,5	6,0	140,0	185,0
		20-40	6,6	87,5	65,0	9,5	147,0	170,0
4.	$N_{30}P_{102}$ LCF in the spring with black fallow cultivation	0-10	21,7	132,5	135,5	10,8	125,0	185,0
		10-20	8,3	105,0	135,5	10,8	125,0	157,5
		20-40	5,1	112,5	72,5	5,6	100,0	170,0
5.	$N_{30}P_{102}$ – LCF before sowing of winter wheat	0-10	12,2	127,5	132,5	10,8	154,0	150,0
		10-20	9,1	101,5	115,5	10,9	145,0	150,0
		20-40	8,5	87,5	72,5	9,6	129,0	135,0

When LCF was applied to black fallow in a soil layer of 0-20 cm, slightly less nitrate nitrogen was contained in comparison with simple mixtures of solid mineral fertilizers in the spring of 2019. When LCF was applied before fallow cultivation and before winter wheat sowing, winter seedlings showed a higher content of nitrate nitrogen (by 21.3%) in layers of 0-10 cm and 10-20 cm, and the availability of mobile phosphorus to these soil layers was higher in all cases use of LCF.

2.6. The use of LCF as an adhesive

When dressing seeds of winter cereal crops even when diluted with water in a ratio of 1: 2 reduced laboratory and field germination by 4.0% to 12%.

3. Discussion

In our studies on the southern chernozem, there was a significant difference in the agronomic efficiency of 10:34 LCF and solid mineral fertilizers when they are used on crops of corn and winter wheat, and only LCF on peas.

Nosov V.V. also notes that there is no difference in the effectiveness of liquid and solid phosphorus fertilizers in most soil types, therefore, the decision to use a particular product depends on its cost and ease of use in each specific condition. Nevertheless, according to the results of several studies, in some soil and climatic conditions (on carbonate soils), liquid phosphorus fertilizers, including ammonium polyphosphate, can have certain advantages over solid fertilizers[5].

So, in his experiments on winter wheat with the addition of ammonium nitrate in the spring (N69), a yield of 7.32 t/ha was obtained, with the use of diammonium phosphate in the fall and ammonium nitrate in the spring with a total dose of N105P92 – 8.14 t / ha and with the application of LCF in autumn + in the spring, ammonium nitrate (N100-101P104-109) – 8.90 t/ha.

Studies by the University of Minnesota (USA) showed that starting application of P-fertilizers for sugar beets is more effective than spreading. Starting application of P contributes to a better development of plants in the initial period of vegetation. A decrease in the dose of phosphorus at the initial application can reach 50% compared with the introduction of scatter[6].

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[5] Nosov V. V. (2016) Efficiency of using diddy complex fertilizers containing ammonium polyphosphates. Plant nutrition. No. 1. S. 11-16.

[6] The effect of starting application of LCF 10-34-0 on sugar beet yield in the USA Adapted from: American Crystal Sugar Company URL: https: //www.crystalsugar.com/ media/18371/ag_starter_fertilizer_lr.pdf.

At the day of the field in the Republic of Moldova[7], many speakers noted such advantages of liquid phosphorus fertilizers as the convenience of storage on farms, as well as more accurate and more uniform application of phosphorus to the soil.According to the Lithuanian NIIZ, when applying LCF 10: 34: 0 under winter rye, the norm is 45 kg per 1 ha NP, the operating costs for the use of fertilizers were 17% lower than the application of the dry mix. Labor costs, in accordance with the accepted average costs for the use of LCF 10: 34: 0, are 1.5 times less than for a mixture of double superphosphate[8]. In the experiments Marchenko L.A. and Mochkova T.V., the technologies of differential application of LCF and pesticides were developed and tested[9].As an effective way of introducing micronutrients, many researchers used the addition of micronutrient fertilizers in LCF solutions[10]. At the same time, they noted that each drop of the solution contains the same amount of components.Liquid ammonium polyphosphate, as in our experiments, was also successfully used for foliar application of plants[11].

CONCLUSIONS

In the conditions of 2019:

- on corn crops, equivalent effect of LCF 10:34 and a mixture of simple solid fertilizers with main application were obtained; there was a tendency to an increase in grain yield, when LCF was introduced in the spring before sowing corn in addition to the main one (increase due to LCF was 2.8 centner/ha with LSD 0.95 = 2.0 centner/ha);

- on peas of the Light variety, before sowing the application of LCF in the norm of N20P68, it had higher agronomic efficiency compared to the main application of the same dose of solid mineral fertilizers – the payback of 1 kg of active ingredient of LCF was 6.0 kg/kg, and SMF – 3.5 kg/kg;

- for sunflower, applying LCF 10:34 in the norm of 300 kg of physical weight per 1 ha (N30P102) was equivalent to solid mineral fertilizers during main application and insignificant advantage (+0.8 c/ha) of applying LCF before sowing before its main application was noted;

[7] Day of the sugar beet field (2017), Balti, Republic of Moldova, 06/14/2017. URL: http://eeca-ru.ipni.net/ipniweb/region/eecaru.nsf/$FILE/Moldova_Sugar%20beet_RUS.pdf.

[8] Application of liquid complex fertilizers URL: http: //agrohimija24.ru/compleksnye-udobreniya/2130-zhidkie-kompleksnye-udobreniya-i-ih-primenenie.html.

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- the use of LCF in spring for foliar top dressing of winter wheat crops at a dose of N15P51 against the background of the main application of a mixture of solid mineral fertilizers at a dose of N60P30K60 was equivalent to solid mineral fertilizers in agronomic efficiency; the protein and gluten content in the grain, when used for top dressing of LCF, although it was significantly higher than when used for early spring top dressing of SMF, was within the requirements of one quality class (first).

SUMMARY

The article discusses the effectiveness of the use of liquid complex fertilizers based on ammonium polyphosphates in comparison with solid phosphorus fertilizers in the crop rotation link for corn – peas – winter wheat – sunflower – black fallow in the Black Sea Steppe of Ukraine on the southern chernozem. According to research results, when applied to the crops of the main field crops, liquid ammonium polyphosphates have the same agronomic efficiency as solid phosphorus fertilizers.

Nevertheless, on peas, before sowing, application of LCF in the norm of N20P68 was more effective in comparison with the main application of the same dose of solid mineral fertilizers – the payback of 1 kg of active ingredient of LCF was 6.0 kg/kg, and SMF – 3.5 kg/kg.

The concentration of protein and gluten in winter wheat when grown with peas was significantly higher with early spring feeding of LCF 10:34 at a dose of N15P51 than when using a mixture of solid mineral fertilizers at the same dose and at the same time: protein 15.12% versus 13.82% (LSD 0.95 = 1.02%), gluten – 33.2% versus 29.6% with LSD 0.95 = 3.0%, although in both cases the indicators remained within the requirements of the first quality class.

To apply of LCF before cultivation of fallow and before sowing winter wheat in pairs at a dose of N30P102 increased nitrate nitrogen content by seedlings of winter at 21.3% in layers of 0-10 cm and 10-20 cm, and the supply of these soil layers with mobile phosphorus is higher in all cases use of LCF.

The utilization factors of phosphorus from LCF are 1.6-2.0 times higher than from solid mineral fertilizers with their equal application doses.

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SCIENTIFIC ASPECTS OF WATER MANAGEMENT IMPROVEMENT IN UKRAINE

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INTRODUCTION

The water-economy and melìorative complex is one of the most powerful segments of the economy in Ukraine and on the whole, and in Kherson region in particular. It is represented by a significant number of water economy and melioration facilities that are designed to meet the needs of the population and sectors of the economy in qualitative water and, creation of the optimal conditions for crops cultivation and rational use of reclaimed lands in the context of food security of Ukraine.

Attraction of large volumes of water resources of southern region into economic exchange to ensure the development of branches of economy: industry, recreation, agriculture, including irrigation melioration, has led to a change in the hydrological regime in the water-catching areas, violation of natural balance, a sharp decrease in the quality of water-resource potential, the superiority of degradation processes over self-healing and self-purifying capacities of water ecosystems. At present, there is a great need to solve the problems of integrated development of water economy as a holistic ecological and economic system of the region taking into account the needs for insurance of protection and rational use of all natural resources, modern changes in environmental management and social development strategy of the region.

Today, there is almost no area on the globe, wherever there was no manifestation of direct or indirect effect of anthropogenic change on the natural landscape, including hydrosphere. Hydrosphere contains about 1.6 billion km^3 of free resources, including 1.37 billion km^3 of the oceans share. On the continents – 90 million km^3, 60 million km^3 of them – groundwater (almost all are saline), 27 million km^3 – the glaciers of Antarctica, Arctic and mountains. A useful volume of available fresh water concentrated in the rivers, lakes, ponds, reservoirs, subsurface waters to the depth of 1 km is 3 million km^3 [1]. This is a relatively small supply of fresh water, but due to recycling, it is constantly replenished and solves the problem of water supply of the planet. However, unfortunately, the condition of full preservation of the quality of water resources is not provided at all. Even the most advanced

[1] Сербіна Р.А. Екологічне страхування меліорованих земель – метод компенсації імовірності виникнення еколого-економічних ризиків. Економіка. Рівне, 2011. С. 40-46.

purification technologies, including biological one, do not provide complete and qualitative purification of wastewater. All dissolved inorganic substances and about 10% of organic pollutants remain in the purified wastewater. The World watershed balance states that about 2200 km^3 of water per year is used for all directions of water use. Dissolving wastewater consumed 20% of freshwater resources, and 1 km^3 of treated sewage contaminates 10 km^3 of the river water, untreated ones – 3-5 times more[2].

According to the state Water Resources Agency of Ukraine, the volume of water resources of Ukraine, which consists of surface and groundwater, is 73.1 km^3 per year, and the volume of an annual use is 19-24 km^3. Almost one third of the total reserve of water resources is annually used by the industrial complex of Ukraine and in the form of waste waters, purified, insufficiently purified and non-purified, it is dropped into water sources. Thus, the amount of fresh water in a voluminous expression does not decrease, but its quality worsens dramatically, and the consequence of this is an increase in the deficit of qualitative fresh water resources. The provided examples of the development of anthropogenic processes indicate the presence of real ecological risk, which is formed both at the regional and at the global level under the poorly balanced further development of the economic and industrial complex of the region.

The process of management of the water and meliorative complex of southern region as a complex ecological-economic system provides the complex systematic approach to solving all the problems of development of each subsystem and the ecological and economic system, ensuring the water use and preservation of the environment. The development of each of the subsystems and individual industries have different, and sometimes quite opposite requirements for water resources, which leads to conflicts of interest in the field of water use of the region. While solving these conflicts, water users' attention focuses on the use of water resources and conditions, and the issue of protection and reconstruction of resources relies on state power structures, or even is inherited by further generations[3].

Complexity of management of the catchment area of the region provides for the solution of questions concerning the use, protection and restoration of water resources of the country. In this connection, there is an indisputable need to intensify the process of ecologization of water activities in the system of the watershed and meliorative complex, as well as public relations on ensuring the sustainability and balance of the development of a complex water ecological and economic system of the region.

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[2] Ромащенко М.І. Концептуальні засади відновлення зрошення у Південному регіоні України. Меліорація і водне господарство. Київ, 2013. Вип. 100. С. 7-17.

[3] Галушкіна Т.П., Грановська Л.М. Еколого-збалансовані пріоритети розвитку територій: концептуальні засади та організаційний механізм. Одеса: ІРРЕЕП, 2009. 372 с.

To restore and expand the irrigation areas according to the approved by the Cabinet of Ministers of Ukraine in 2019, Irrigation and drainage strategy in Ukraine for the period until 2030[4], and ensuring the ecological and sustainable development of water systems it is necessary to solve a number of environmental and meliorative problems, first of all, it is necessary to introduce the systems of environmental management in the water economy of Ukraine, conduct ecological audit and define modern technological facilities of irrigation systems and hydrotechnical constructions, improve the system of ecological monitoring in order to assess ecological and melìorative conditions of agricultural land, provide integrated water management, adapt the work of irrigation systems and regimes of irrigation of crops to change in climate, improve the quality and fertility of irrigated soils, introduce innovative methods of irrigation, improve the system of land ownership and land use, as well as the system of institutional support for effective management of water resources. All these will create conditions for the sustainable socio-economic development of the agricultural sector in the zone of irrigation and rural areas. The issues of renewal and expansion of irrigation areas in southern region of Ukraine remain relevant, and the issues of combination of the current ecological conditions of the irrigated land by the directions of legislation improvement and the introduction of environmental management both in the water management system at the national level and at the regional and local levels remain unresolved.

1. Theoretical justification of principles and trends in introduction of environmental management and audit in the water economy sector of Ukraine

The first definition of "environmental management" was proclaimed in "Agenda for the XXI century", adopted in Rio de Janeiro in 1992, which emphasized that "environmental management is attributed to key dominant sustainable development and at the same time to higher priorities of economic activity and entrepreneurship".

For the realities of Ukraine it is necessary to specify this concept, taking into account that without transformation of the general system of management of sectors of the economic and industrial complex, it is impossible to speak about the reformation of the management system at the local level, i.e. at the level of the organizations. Such a quotation is defined by the motivation and incentives to implement the system of environmental management. We are talking about the preparation of the appropriate basic

[4] Про схвалення Стратегії розвитку аграрного сектору економіки на період до 2020 року. Кабінет Міністрів України; Розпорядження. Стратегія від 17.10.2013 № 806-р. Верховна рада.

basis (legislative, regulatory, economic), which would ensure the development of environmental management in Ukraine. At present, it can be argued that the systems of motivation incentives for the introduction of environmental management and auditing in Ukraine and elsewhere are somewhat different. For the West – it is a conscious desire to improve the image and enter the market leaders, which gives additional chances to obtain a guarantee of the bank for credit, and for Ukraine – the desire of the enterprise to get the system of privileges in the legislative order (in taxation, crediting, social programs). This is explained by the fact that for Ukrainian environmental management there is not yet formed that benevolent macro-environment that would have prompted them to independently seek an effective management decisions on ecologiztion of the system of existing management.

Thus, it can be claimed that the most important factor of reforming the existing water management system at the current stage is the creation of organizational bases and corresponding motivation incentives to introduce in the water industry of innovative management with the elements of environmental management. Today, however, this direction is still insufficient, whereas the strategic goal of Ukraine's development is transformation of its natural resource potential into the main resistance of economic growth for sustainable development from the point of view of the global community[5]. Environmental management should be regarded as a qualitatively new ideology of management of water economy activities in the market conditions, which is based on the following principles:

• *Importance of the role of water industry branch for the development of the country's economy.* Water industry provides sectors of the economy, including agriculture and the population with water for drinking needs, irrigation and communal needs. All these create jobs, allows the development of the economy of regions and the country on the whole. The strategy of irrigation and drainage in Ukraine for the period until 2030, which is implemented in the water industry, will solve the priority tasks of the Strategy of agriculture and rural areas development for the period until 2020[6];

• *Complexity of the development of the economy, settlements and rural areas.* Complex principle will allow to send investment resources in the innovative development of the water industry, agriculture and rural areas; will ensure the creation of a legislative institutional environment for the formation and development of decentralized and environmentally balanced enterprises and associations in the agricultural sector of the economy in the zone

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[5] Програма економічних реформ Президента «Заможне суспільство, конкурентоспроможна економіка, ефективна держава». http://www.president.gov.ua/docs/Programa_reform_FINAL_1.pdf.

[6] Стратегія зрошення та дренажу в Україні на період до 2030 року. https//zakon.rada.gov.ua/laws/688-2019-p/print.

of irrigation through the introduction of state-private partnerships in the water economy[7];

• *Complex management of water resources.* Agriculture in southern region of Ukraine is a powerful user of water resources, but the complex management of water resources should provide for conflict-free supply with water resources of all the water users: agriculture, industry, municipal economy, population and recreation;

• *Separation of the water management functions and water economy infrastructure.* Today, these two functions of water management are carried out by the state Water Resources Agency of Ukraine that sometimes leads to contradictory actions and decisions. Hydrotechnical constructions and water facilities are built for the needs of industries and have the most regional significance (anti-flood protection, drinking water supply, land reclamation, groundwater level control), so the management of these objects should be decentralized and not combined with the function of water resources control. Water users have to be involved into water management at the level of the amelioration system;

• *Introduction of state-private partnerships in water management.* This principle involves the transfer of management of irrigation and drainage systems to a lower level, that is, the unification of water users (associations, etc.). On the basis of researches of the Sumy school scientists it was proved that state-private partnership in the field of natural resources can be defined as legally designed for a certain period mutually beneficial cooperation of bodies and organizations of State power and business-entrepreneurial structures (environmental) infrastructure. Such a partnership provides for the allocation of responsibility, risk and results between partners with the purpose of the most effective implementation of environmental projects that have important state, regional and social values. Therefore, the system of state-private partnerships in the water sector can be stated as a mutually beneficial cooperation between the bodies of the state control system with private ownership of engineering infrastructure. The management of main canals and pipelines and water economy objects of interregional significance is carried out by regional state operators and the management of amelioration system objects must be carried out by water users, which are united in an organization or association of water users.

The law of Ukraine "on state-private partnership" (2010) defined the organizational and legal principles of interaction of State partners with private partners and the basic principle of a state-private partnership on a contractual basis, defined the spheres and applications of state-private partnerships

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[7] Закон України «Про державно-приватне партнерство». Відомості Верховної Ради України (ВВР), 2010. № 40. Ст. 524.

including the water industry, and defined the forms of a state-private partnership and the types of contracts , which could be concluded between the State and private partners (concession, cooperation and others);

- *Reconstruction and modernization of water facilities with the aim of their ecological safety and ecological reliability.* To perform this principle, it is necessary to introduce a system of ecological audit of the entire infrastructure of the water industry and irrigated agricultural lands, because the base for the development of the stages of reconstruction and expansion of irrigation areas and the construction of melioration systems are to be the results of ecological audit.
- *Environmental audit as a basis for the reconstruction and development of the water industry.* Environmental audit is one of the most important tools of the environmental management in the field of environmental activity. The audit, as an individual control, has been developing in the United States since the early 70's and at the end of the 80's years of the XX century, some companies have reached a high, compared with the provided by the legislation, environmental indices. The active environmental audit, as well as environmental management, has begun to be implemented not only in the U.S. companies, but also was honored with a great trust in European companies. At present, environmental audit is actively introduced in the enterprises of Canada, Great Britain, Sweden and other countries. The leader in the development of environmental audit is the United Kingdom, where in 1992 the British Institute of Standardization has developed the standard of management of surrounding natural environment BS 7750 (Specification for Environmental Management System). Since the 80's of the last century, Europe adopted a system of ISO 14000 standards for environmental management and ISO 9000 for quality management, which in 1997 were approved to be the State standards of Ukraine and are the legal basis for the activities in the sphere of environmental audit. The need in the organization of environmental audit of the meliorated lands and water-melioration objects is substantiated by deterioration of the ecological conditions of irrigated, drained and adjacent lands, reduction in the volume of repair and reconstruction works on water economy facilities and hydrotechnical constructions, decompiling the lands of the meliorative fund, changing the ownership forms on agricultural land and water-melioration objects, transformation of the economic conditions in the country and in the system of the water economy. Environmental audit of water economy objects is a tool of management of anthropogenic economic activity with the aim of protection of the environment, increasing environmental safety and reduction of the risks probability as a result of economic activity and in the interests of sustainable development. The results of environmental audit are the basis for the development of directions and measures for the reconstruction and

modernization of the infrastructure of the water industry and the restoration and expansion of irrigated areas with different technologies and ways of crops irrigation;

- *Principle of financial and ecological balance.* Reconstruction and modernization of the infrastructure of water industry can be carried out only if there is an investment, since this process is long-term, gradual and costly. Modernization is not just the replacement of the "old" infrastructure, it is a complex system of activities, for which it is necessary to define the specific directions and priorities. To ensure ecologically balanced and environmentally safe use of water it is necessary to carry out the reconstruction of irrigation canals, pumping stations, hydrotechnical constructions, sprinkler machinery and equipment. The methodology of estimation of the expenses for water supply for the needs of irrigation and drinking needs remains topical. Water tariffs should be calculated clearly with accordance to the expenses for water transportation and cost of water as a natural resource.
- *Environmental management as a condition of providing environmentally-safe functioning of water economy in Ukraine.* To implement an effective environmental management system in the water sector of the economy it is necessary to:
- Create the effective institutional infrastructure of environmental management taking into account the clear division of functions, rights and responsibilities of central, regional and local bodies of state and executive power in respect of water activities;
- Develop a stimulating tax system and benefits mechanism to ensure environmentally-safe and complex use of water resources;
- Form a flexible system of ecological insurance for water management objects with the aim of accumulation of financial funds for the elimination of losses that may be inflicted to the natural environment;
- Implement special regimes of an investment activity to stimulate investors, which comprehensively promote ecologization of water economy infrastructure and contribute to the introduction of environmentally-safe projects in the water economy;
- Improve the organizational and economic mechanism of introduction of the environmental management system in Ukraine, which is based on the development of methodology for the formation of environmental management; implementation of monitoring of current legislation in the system of water activities so that it could be improved.

Thus, ensuring the improvement of environmental quality should be the task of national value, and the main way of its solution is the state support, development and implementation of environmental quality management systems in accordance with the standards of DSTU ISO Series 9000 and 14000, the principles of environmental initiatives recognized in Europe and in the world. In this respect, the aim of introduction of environmental management is to determine the strategic directions and priorities, environmental and economic foundations for the implementation of the State policy in water management, protection and reproduction. However, the mechanism for the introduction of environmental management is impossible without evaluation of the ecological and meliorative conditions of the irrigated and adjacent lands. This evaluation is provided by environmental monitoring, which is not currently perfect and requires development of directions and mechanisms for its improvement.

2. Theoretical aspects of the development of environmental monitoring of agricultural lands in the zone of irrigation

Agricultural land use is one of the main forms of negative impact on the environment. Ignoring the environmental principles of agricultural environmental use will inevitably accelerate the degradation and depletion of unique natural resources in southern region of Ukraine, reduce ecological and economic efficiency of agricultural production and, all in all, deepen the economic and socio-ecological problems of food security.

Ecologization of land use and limiting the negative impact of economic activity on the conditions of land and water resources in the zone of irrigation requires the formation of an effective system of ecological control, directed to checking the implementation of plans and measures for the rational nature and land conservation, compliance with the requirements of environmental legislation and environmental norms, especially in the zone of active development of irrigated agriculture. The decisive consideration in solving these tasks belongs to the introduction of an effective mechanism of environmental monitoring of agricultural land, which requires special attention in the context of transformation of the environmental legislation of Ukraine to the requirements of the European Union.

At the same time, there is a need to improve theoretical, methodical and scientific-practical foundations for the improvement of the environmental monitoring system of irrigated lands considering the existing legal and regulatory base, environmental limitations and incentives for rational nature.

Analysis of the existing situation in the agricultural land use in the zone of irrigation shows that irrigated land have been playing an important role in the food security of the country. This is due to the fact that a significant part of the country is allocated in the zone of insufficient and unstable humidification, and therefore, sustainable agriculture in these regions is possible only under the conditions of irrigation. Irrigated lands are an insurance foundation for sustainable agricultural production, especially in dry and extremely dry years. One of the key barriers to the reconstruction and further development of crops irrigation in Kherson region is the lack of an effective system of ecological monitoring of both irrigated and other agricultural lands, the result of which forms the base for the formation of systems of economic activity. The study of a change in the conditions of the irrigated soils after cessation of their irrigation is of a particular value because these lands are marked by the complex of negative processes, namely: secondary salinization and secondary alkalination of the soils. In addition, the irrigated lands have problems that are connected with the imperfect system of organization of agricultural production and land regulation, violation of the technological unity of the irrigated arrays, which is caused on the one hand, by distribution of the land between shareholders, and, as a consequence, by crushing and increasing the number of land users, and on the other hand – by transfer of intra-economic systems in communal ownership and the balance of farmer and collective enterprises under the state ownership on the inter-economic network.

The structure of the monitoring system of the lands, soils and of the environmental monitoring of agricultural land in the zone of irrigation,its implementation is ineffective because the system uses parameters and indices that are not harmonized with the requirements of the European standards. Therefore, the issue of scientific substantiation of the directions for the improvement of environmental monitoring system as one of the functions of natural and environmental protection is closely linked to the features such as environmental expertise, environmental control and environmental audit.

As a result of scientific researches, a methodological approach to ecological and economic evaluation of agricultural land was developed on the basis of environmental monitoring as the basis for rehabilitation of agricultural lands by quantitative and qualitative parameters. Land use methodology is proposed to characterize the coefficient of ecological stability of the territory ($K_{ec.st.}$), which further determines the land use structure [8].

The scale of gradation of the ecological stability coefficient of a territory was developed on the basis of expert estimates: unstable territory ($K_{ec.st.t}$) < 0.33; seesaw stable ($K_{ec.st.}$) varies within 0.34 – 0.50; moderately stable ($K_{ec.st.}$) – 0.51 – 0.66; stable ($K_{ec.st.}$) > 0.67. The basis of the methodical approach is a theoretical approach to evaluating the level of environmental and economic efficiency of the use of agricultural landscapes of the south of Ukraine as a whole territorial system, which is described in the inter-regional aspect.

On the basis of the methodological approach integral evaluation of the irrigated agricultural lands was carried out, which includes criteria and indices according to the following groups: sanitary-hygienic state of soil, ecological

[8] Консервація деградованих, малопродуктивних і техногенно забруднених земель. Закон України «Про охорону земель». Стаття 172. Діє від 27.06.2015 р. URL: http://zakon3.rada.gov.ua/laws/show/962-15.

resistance of soil, agrochemical parameters of soil fertility and hydrogeological-meliorative indices of land resources. The totality of these indices diagnoses the degree of environmental stability of different types of degradation processes in soils in the irrigated conditions. In this case, the integral evaluation is performed by the complex of indices that characterize the composition, properties, structure and condition of the main components of the ecosystem, the orientation and intensity of its transformation in the conditions of irrigation, the condition of water and soil pollution and other environmental changes. The integrated evaluation should be the basis for the conduction of natural-agricultural, eco-economic, anti-erosion and other types of zoning of the irrigated lands, the introduction of tools and levers of economic stimulation, rational use of soil protection technologies and increase in soil fertility (Fig. 1). The results of the study proved that the improvement of the existing monitoring system is possible only through the formation and introduction of the Unified State Ecological Monitoring System (USEMS) of a regional nature and defining the territorial subsystems in the formation of the regional environmental monitoring system.

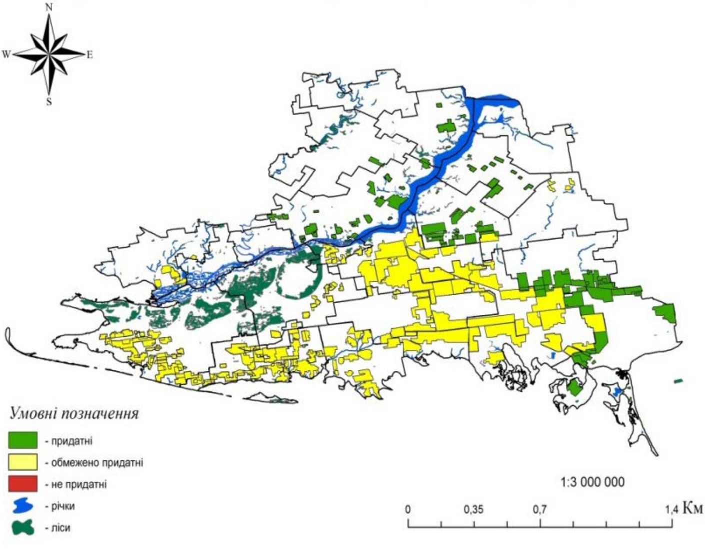

Fig. 1. Integral evaluation of suitability of the irrigated lands of Kherson region for cultivation ecologically safe agricultural products

In order to increase the level of ecological safety of epy irrigated agricultural land use a scientifically based scenario of ecologically-oriented systems of land use in the zone of irrigation were developed, namely: the use of the irrigated lands for cultivation ecologically safe products; the use of the irrigated lands in generally accepted zonal systems of irrigated agriculture; removing land from irrigation by conservation and separation of the arrays of the irrigated lands, which are in a degraded conditions.

The direction of processes, frequency and speed of transformation of soils under the influence of irrigation determine the quality of irrigation water, initial condition of soils, and degree of natural drainage of the territory, irrigation technology and usage intensity of the irrigated lands. Environmental monitoring of the irrigated lands provides a systematic evaluation of environmental situation, shows the area of the territory, which is under harmful phenomena, and the ability to develop proposals for the elimination of degradation processes (Fig. 2).

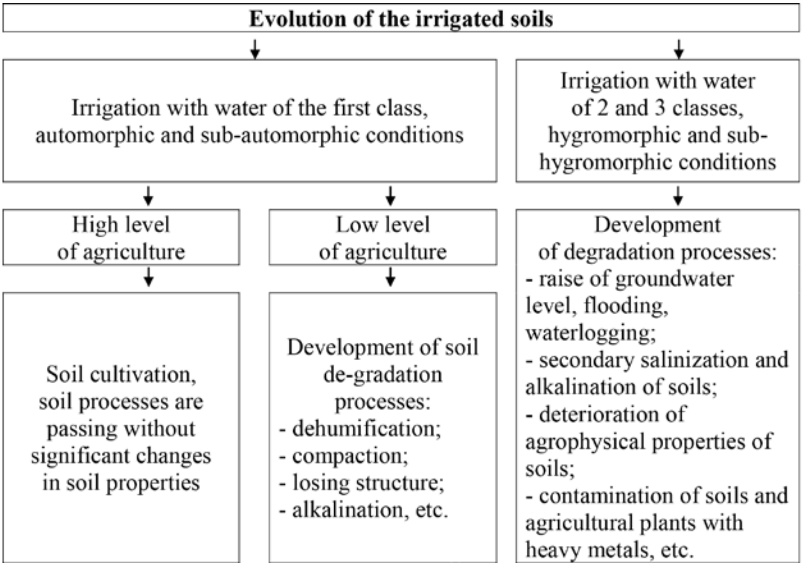

Fig. 2. Scheme of evolution of the irrigated soils

Choosing models of optimal development of environmental situations for further use of the irrigated lands is carried out by multifactor analysis of distributed in space and time information that describes the variability of sanitary and hygienic conditions of the soils (contamination by Cesium, Strontium, heavy metals, pesticides), indices of ecological stability of the soil (the content of humus in the arable layer, chemical reaction of the soil solution, bulk density, etc.), agro-chemical indices (the content of macro- and micro-elements) and hydrogeological-melìorative indices (quality of irrigation water, depth of occurrence and mineralization of groundwater, etc.).

For each condition of the irrigated land there was developed a system of environmental measures directed on the prevention of the development of degradation processes in the conditions of irrigation, protection and reproduction of soil fertility and improved systematical complex of environmental standards of land use on the irrigated lands. Normative base of soil protection and rational use of land resources in the conditions of irrigation should be created on the hierarchical principle and include the following blocks: eco-technical and eco-technological norms; eco-economic and socio-ecological norms; safety standards[9].

Organizational and economic mechanism of introduction of the environmental monitoring of agricultural land in the irrigation zone is carried out by the means of land policy: norms, standards, orders, recommendations and instructions. The normative base of soil protection and rational use of land resources in the conditions of irrigation in the system of environmental monitoring should be built on the hierarchical principle and include the following blocks: eco-technical and eco-technological norms; eco-economic and socio-ecological norms; protection standards; coordination of the development and execution of the programs of environmental monitoring; regulation and control of collection and processing of reliable and comparative data; storage of information, special data banks creation and maintenance and their harmonization (coordination, telecommunication) with international ecological and information systems; activity on the evaluation and prediction of environmental objects, natural resources, ecosystem reviews and public health under anthropogenic impact; availability of integrated environmental information for a wide range of consumers.

One of the measures that should be particularly pointed out due to its capacity to ensure the introduction of ecologically oriented systems of the land use on the basis of environmental monitoring in the conditions of irrigation is a withdrawal of land from irrigation[10]. Now this process takes place spontaneously, without complying with any rules and requirements. It often happens that irrigation is going on while it had to being stopped and, in contrary, irrigation is not carried out only because there is no technical means for this. One of the ways of rehabilitation of agricultural lands is their conservation – a withdrawal from the agricultural use for a certain period to carry out measures to restore their fertility. The priority of removal from agricultural use is subjected to low-productive and erosion-hazardous lands. Conservation of land is carried out by the means of turning them into grasslands or afforestation.

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[9] Земельний кодекс України від 25.10.2001 р. № 2768. Із змінами. Діє з 05.12.2013 р. http: // search.ligazakon.ua/l_doc2.nsf/link1/T012768.html.

[10] Закон України «Про охорону земель». Діє від 27.06.2015 р. URL: http://zakon3.rada.gov.ua/laws/show/962-15.

It is possible to preserve both specific land plots and large land arrays. National and regional conservation programs for land can be developed to order interested executive authorities or local governments. After the coordination and approval of these programs by the relevant bodies of executive power or local self-government development of land conservation projects and their implementation are carried out within the respective administrative units (order of the State Committee of Ukraine on land resources from 17.10.2002 No. 175 "About the procedure of land conservation").

According to Art. 172 of the Law of Ukraine the conservation is subjected to degraded, low-productive and contaminated lands. The above-mentioned points are almost literally reproduced in Art. 51 of the Law of Ukraine "About the protection of lands", they are detailed in the Order of the State Committee of Ukraine on land resources from 17.10.2002 No. 175 "About the procedure of land conservation". Legal concepts of technogenously contaminated lands are given in Art. 169, and of degraded and underproductive lands – in Article 171[11].

The choice of conservation forms depends on the specific characteristics of the land plot. In particular, it is advisable to implement the afforestation in case of ravines, steep slopes, land plots along the roads, along the banks of reservoirs. It is advisable to turn the land plot into grassland before involvement of it in agricultural cultivation, etc.

According to the results of scientific researches it is possible to draw the conclusion that in order to improve the system of environmental monitoring of agricultural land, it is necessary to transform the existing legislation with accordance the requirements of the EU by introducing a unified state environmental monitoring system that should take into account the impact of irrigation and quality of irrigation water on soil conditions. It is necessary to add to the Land Code of Ukraine and the Law of Ukraine "About land reclamation"[12] the point about giving the irrigated lands a special status, taking into account the personal responsibility of owners and tenants of such land for their intended use not only as agricultural, but also as irrigated lands and in order to stimulate their unification into holistic technological arrays.

SUMMARY

The article provides the principles of introduction of the system of environmental management, audit and monitoring in the water economy of Ukraine in order to ensure its ecologically safe functioning. Environmental audit and its results both for water economy and hydrotechnical objects and

[11] Концепція національної екологічної політики України на період до 2020 року. Діє від 17.10.2007 р. URL: http://zakon2.rada.gov.ua/laws/show/880-2007-%D1%80.

[12] Закон України «Про меліорацію земель». Відомості Верховної Ради України (ВВР). 2000. № 11. Ст. 90. URL: https://zakon.rada.gov.ua/laws/show/1389-14.

agricultural land are the basis for the introduction of engineering, melioration and environmental measures in the system of environmental management and audit. It is proved that the existing system of monitoring and environmental monitoring is the basis for the introduction of environmental management in the water economy of Ukraine and needs improvement. The proposals to extend the Land Code of Ukraine and the Law of Ukraine "About land reclamation" with new points in order to give the irrigated lands a special status taking into account the personal responsibility of owners and tenants of such land for their intended use are proved. Methodological approach to ecological and economic evaluation of agricultural land on the basis of environmental monitoring as a basis for the rehabilitation of agricultural lands for quantitative and qualitative indices was improved. In order to increase the level of environmental safety of the irrigated agricultural land use on the basis of the unified State system of ecological monitoring of irrigated land was developed and scientifically substantiated scenarios of ecological-oriented land use systems in the irrigation zone were proposed.

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