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SELECTION OF DROUGHT-RESISTANT CROPS FOR SOUTH STEPPE OF UKRAINE

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The cultivation expediency of more drought-resistant crops, in particular sorghum, millet, false flax, safflower and others, instead of sunflower in the area of the Southern Steppe of Ukraine is substantiated. This is primarily required by climate change both in Ukraine and in the world.

Since 2004, researches of field crops were carried out in the conditions of the Educational and Scientific Practical Center of the Mykolaiv National Agrarian University. Soil phase was the southern chernozem with humus content of 2.96–3.21 % in the 0–30 cm soil layer, with medium and high level of mobile phosphorus and potassium availability, and with low level – mobile nitrogen. Experiments with soriz (Oksamyt hybrid) were conducted during 2004–2006, millet (Tavriiske, Kostiantynivske, Skhidne varieties) in 2008–2010, grain sorghum (Stepovyi 5 hybrid) in 2014–2016, safflower (Lahidnyi variety) in 2017–2019.

The years of research differed significantly in temperature and even more in the amount of precipitation before sowing and during the growing season of crops. However, the weather conditions were typical for the Southern Steppe zone of Ukraine.

It is established that all studied drought-resistant crops positively respond to nutrition optimization - the yield level and grain or seed quality increased. It was found that the soriz productivity depending on the application of fertilizers and sowing dates increased by 37.6–39.2 %, millet – by 33.3–41.6 %, grain sorghum depending on the background of nutrition and growing conditions – by 8.2–33.2 %, safflower – by 11.1–64.6 %.

It was clarified that the nutrition optimization of cultivated crops by application of low doses of the mineral fertilizers before sowing, pre-sowing seed treatment, and plant treatment with growth-regulating chemicals in the main stages of the growing season allows to increase their productivity and resistance to adverse conditions.

Key words: *drought-resistant plants, climatic conditions, nutrition optimization, yield, quality of yield, varieties, sowing dates.*

In recent years, climate change has been observed in Ukraine and around the world, namely, increasing drought and rising temperatures. We have already witnessed that there is no precipitation in the Southern Steppe zone for 100 or more days in summer. In addition, these negative changes in weather conditions were accompanied by a decrease in soil fertility. The content of nutrients and microelements decreased, humus and organic matter lost, the structural condition worsened as a result of which moisture does not accumulate and retained in the soil. Soil moisture in the arid zone of Ukraine largely determines the yield of crops. We have reported on changes of soil fertility in our previous scientific publications [1, 2]. First of all, this problem is connected with lack of scientifically substantiated alternation of field crops in crop rotations, insufficient volumes of fertilizer application, especially organics, and also other negative factors. [3].

Taking into consideration the soil state and weather conditions, it is necessary to make certain adjustments to the usual and accepted management systems, in particular to grow more drought-resistant and less demanding crops to the soil fertility. It is known that such drought- resistant crops include all varieties of sorghum, millet, false flax, safflower and some others.

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The formation of the yield of these crops continues at much lower moisture consumption per unit of production compared to most other field crops growing in the Southern Steppe of Ukraine.

The area of the above crops is still insignificant, and they are not allocated in a separate column in the balance of production in our country. For example, sorghum crops with a wide range of uses are quite valuable: grain, silage, haylage, sugar raw materials, as energy raw materials, for the production of brooms, etc. It is varieties of sorghum under adverse environmental factors temporarily suspend the development, and under optimal conditions it is resumed. In addition, sorghum crops are undemanding to soil fertility, although they respond quite positively by increasing yields to optimize nutrition. Thus, previous researches with a sorghum variety, namely Oksamyt soriz variety, in the Steppe zone of Ukraine revealed the impact on its yield of the predecessor, the background of fertilization and sowing date [5, 6]. In the conditions of the South of Ukraine the positive influence of biologics, microfertilizers and seeding rates on growth processes of plants of sweet sorghum hybrids were defined (Veremeienko & Semenko, 2019) [7]. Scientists have found an increase in the productivity of soriz and the bioethanol yield from sweet sorghum depending on the optimization of mineral nutrition [8, 9].

Studies of grain sorghum conducted in the Left Bank Forest-Steppe zone of Ukraine during 2015–2017 revealed significant fluctuations in grain yield from 3.98 to 9.14 t/ha depending on the biological characteristics of the hybrid, row spacing, fertilizers and weather conditions [10]. Scientists note that such factor as a hybrid accounted for the largest share in crop formation (43 %), the conditions of the year and the nitrogen fertilizer rates accounted for 21 and 20 %, and the row spacing – only 10 %. P. V. Klymovych also reports on the significant influence of nitrogen nutrition on grain sorghum productivity [11].

With a similar relationship, nutrition optimization and other important elements of cultivation technology affect the yield of millet grain [12, 13], safflower [14, 15] in particular in the Southern regions of Ukraine and the Western Forest-Steppe. Scientists note that if optimal elements are included in growing technologies, the hydrothermal conditions of the growing year and the moisture content during the growing season remain the most influential on the growth processes and productivity of safflower.

In researches on the selection of safflower varietal composition, the determination of sowing methods, and the application rates of plant growth regulators for pre-sowing seed treatment and plant in the main stages of growth and development, it was found that the variety was the most influential factor, and less influential - sowing method and application with Rehoplant in stem elongation stage of safflower [16]. S. V. Solonenko reports that the safflower seed yield of the Soniachnyi variety increased by 0.19 t/ha, or 19.3 %, and the Lahidnyi variety – by 0.18 t/ha, or 23.0 %, respectively, in the case of treatment of plants with Rehoplant. This indicated a higher response of plants in the last variety to foliar fertilization.

Researches conducted in the Steppe zone have found a significant dependence between nutrition optimization and safflower yield by varietal composition [17]. However, researchers noted that the effectiveness of fertilizers decreased with increasing drought in the years of growing crops. Thus, the safflower seed yield of the Zhyvchyk variety ranged from 1.46 to 1.71 t/ha, the Dobrynia variety – 1.55 to 1.85 t/ha, and the increasing grain yield due to the mineral fertilizer application and growth stimulants was 0.11–0.17 and 0.17–0.22 t/ha, respectively. It was found that these varieties formed the maximum productivity in the case of combined application of mineral fertilizers of $N_{60}P_{50}$ rate under the primary tillage and chemicals such as Rost-kontsentrat + Khelatin Oliini and Khelatin Monobor + Khelatin Fosfor Kalii. Seed yield of Zhyvchyk and Dobrynia varieties was 1.71 and 1.85 t/ha, respectively, when they were grown on such a nutrition background [17].

Thus, according to the results of the above researches, crop yield is affected by all the basic elements of cultivation technology, quite significantly the nutrition background and weather conditions. This is confirmed by our research conducted in different years with a lot of drought-resistant crops.

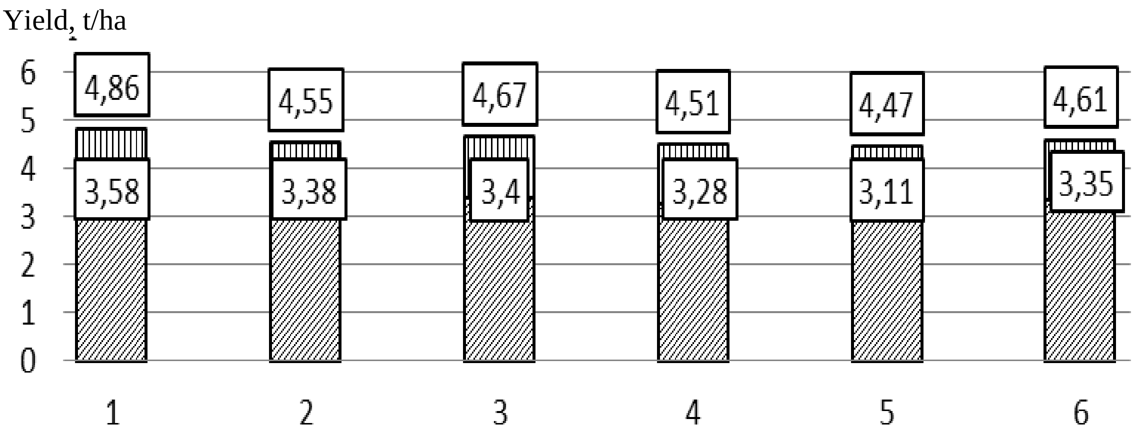
Materials and methods. Experiments with agricultural crops were carried out on the southern chernozem in the Educational Scientific and

Practical Center of the Mykolaiv National Agrarian University (NAU). The humus content in the arable layer of the soil in the experimental fields was 2.96–3.21 %, the availability of mobile phosphorus and potassium was medium and high, and mobile nitrogen – low, the pH of the aqueous extract – 6.8–7.2. The lowest moisture content of 0–100 cm soil layer was 21.5 %, wilting moisture is 9.5 % by dry soil weight, and soil density is 1.33–1.41 g/cm^3.

Researches with Oksamyt soriz variety were carried out during 2004–2006, with Tavriiske, Kostiantynivske and Skhidne millet varieties – in 2008–2010, grain sorghum (Stepovyi 5 hybrid) – in 2014–2016, Lahidnyi safflower variety – in 2017–2019. Schemes of experimental variants are covered in the relevant tables and figures. The years of research differed in temperature, and especially in the amount of precipitation during the growing seasons of the studied field crops, but they were typical for the Southern Steppe of Ukraine. Agricultural technology in experiments was generally accepted for the region, except for the studied factors.

Sampling of plants, their measurements, determination were performed in accordance with accepted methodology and DSTU.

Results. Our previous researches initiated with soriz found that it responds significantly to the nutrition background and moisture supply. These factors largely depend on the predecessor of soriz (Fig. 1).



Note: plots of crop rotation
1 – peas–winter barley–soriz; 2 – sunflower–winter barley–soriz;
3 – maize–winter barley–soriz; 4 – winter barley–maize–soriz;
5 – winter wheat–sunflower–soriz; 6 – average for all predecessors
N60P40 without fertilizers

Fig. 1. Influence of crop rotation plots and fertilization on grain yield of soriz (average for 2004–2006), t/ha)

The highest yield of soriz was formed when it was placed in the crop rotation with peas, and the lowest – with sunflower, because it significantly dries the soil and consumes a much larger amount of nutrients. The Figure 1 show a positive influence of mineral fertilizers on the grain yield of soriz, which on average for three years of research after all predecessors ranged from 3.35 t/ha (in control without fertilizers) to 4.61 t/ha (with the $N_{60}P_{40}$ application), or increased by 37.6–39.2 %.

On the basis of the conducted researches, it was established that soriz yield significantly changes depending on sowing dates (Fig. 2). On average for three years of growing soriz the highest yield was observed at the sowing in the first ten-days of May, when the soil is already well warmed, and there is moisture for the emergence of even sprouts.

However, regardless of the sowing dates, significant increases in grain yield were observed when applying mineral fertilizers. Over the years of research for all sowing dates, grain yield increased on average from 3.19 (without fertilizers) to 4.44 t/ha on the background of fertilizer application, or by 39.2 %.

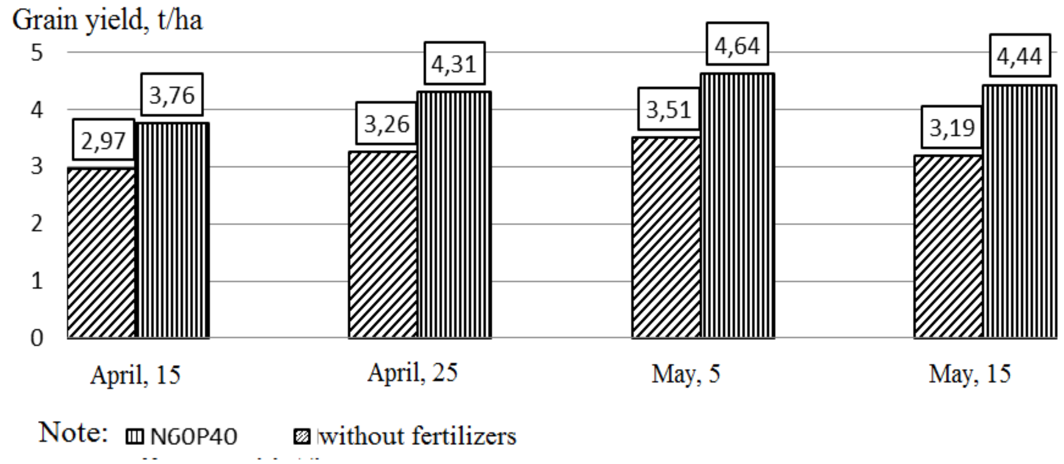


Fig. 2. Influence of nutrition background and sowing dates on grain yield of soriz (average for 2004–2006), t/ha)

Similar data according to the influence of sowing dates and nutrition optimization on grain yield were obtained when growing three varieties of millet (Fig. 3).

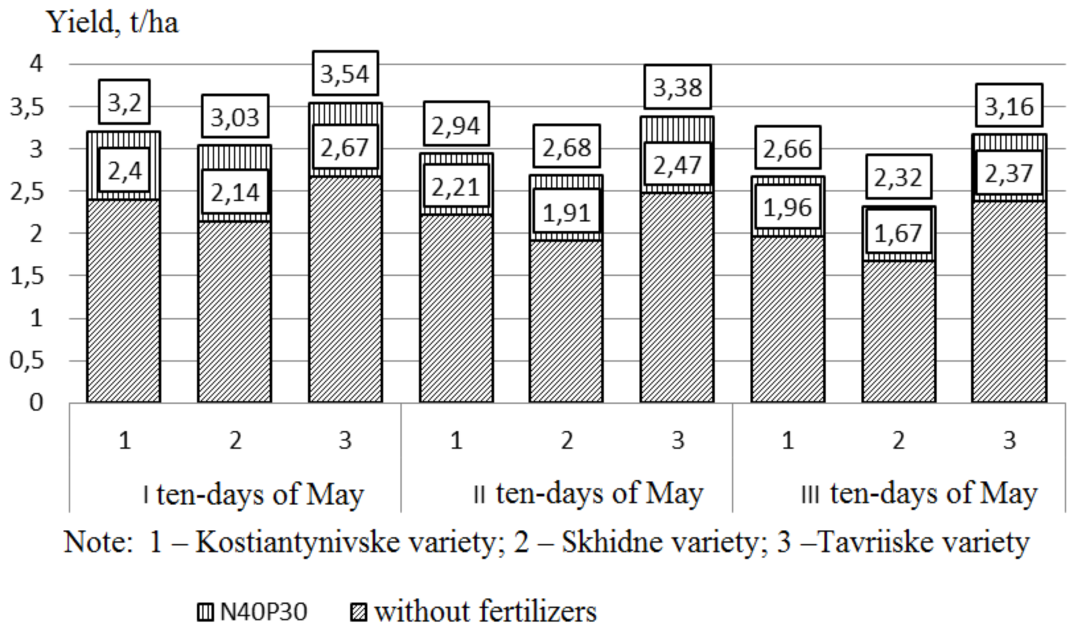


Fig. 3. Grain yield of millet varieties depending on sowing dates and nutrition background (average for 2004–2006), t/ha.)

According to the data presented in Figure 3, the highest yield of millet grain was formed during sowing in the first ten-days of May and increased significantly in the case of mineral fertilization. The lowest productivity of millet was at late sowing, at this time the moisture content in the soil decreases. In dry years the seedling emergence was much later. The yield of millet increased at applying mineral fertilizers regardless of the sowing dates and varietal characteristics. Attention should be given to grain productivity of three studied millet varieties. The Tavriiske variety was characterized by highest grain productivity, followed by the Konstiantynivske variety and the lowest indicators had the Skhidne variety. Pattern regarding the response of millet plants to mineral nutrition and sowing dates were similar.

Grain sorghum plants also respond positively to fertilizer application and nutrition optimization (Table 1).

As established by our research, the grain yield of sorghum varies significantly and depends on the weather conditions of cultivation year as well as the applied rates and the mineral fertilizer ratio. It should be noted here that the

1. Yield of sorghum grain depending on mineral nutrition, t/ha

Fertilizer rate	2014	2015	2016	Average for 2014–2016	Gain to control	
					t/ha	%
Without fertilizer (control)	3,85	2,80	5,25	3,96	0,00	0
$N_{45}P_{45}$	4,03	2,86	5,42	4,10	0,14	3,5
$N_{45}P_{45}K_{30}$	4,07	2,99	5,58	4,21	0,25	6,3
$N_{90}P_{90}$	4,34	3,65	5,53	4,51	0,55	13,9
$N_{90}P_{90}K_{60}$	4,38	3,73	5,68	4,60	0,64	16,2
LSD_{05}	0,11	0,31	0,29			

productivity of sorghum plants, especially during wet years, is more affected by weather conditions. For example, in 2016, the greatest amount of precipitation fell during the growing season of sorghum plants, the grain yield when applying $N_{90}P_{90}K_{60}$ was 5.68 t/ha and was higher than the control by only 8.2%. In a drier 2015, the application of the same fertilizer rate provided an increase in grain yield at 33.2%, which is much higher than in a favorable year.

Our research shows that the sorghum grain yield increases when optimizing nutrition, primarily due to increasing the rate of nitrogen fertilizer, while phosphorus-potassium fertilizers have little effect on productivity plants due to the average and increased availability of soil with these elements.

Yield gains from higher rates of PK fluctuate within the LSD, i.e. they are not significant. No significant effect of studied rates and ratios of mineral fertilizers on the density of grain sorghum plants at ripening harvest was established. (Fig. 4). It should be noted a positive trend towards some increase in this indicator due to the optimization of plant nutrition.

We have already pointed to a gradual decrease in soil fertility. The volume of mineral fertilizers application in recent years is insufficient due to its high cost. Low starter rates of mineral fertilizers are used in combination with growth-regulating substances or modern biologicals for the seed treatment before sowing or plants in the main stage of growing seasons.

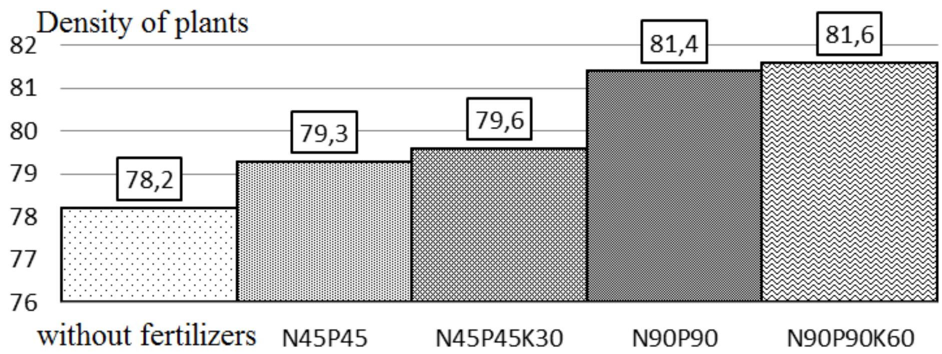


Fig. 4. Influence of mineral fertilizers to density of grain sorghum plants (average for 2014–2016), ths. pcs/ha)

In the course of our research, a positive effect was revealed on crops productivity of modern growth-regulating chemicals and biostimulators when used together against the background of low starting rates of mineral fertilizers [18–20]. The effectiveness of combination of these chemicals is to improve the overall metabolism in the plant, better resistance to stress factors, in particular increasing the plant resistance to high temperatures, prolonged droughts during the growing season, etc.

Our researches conducted in 2015–2017 with a not widespread crop – spring false flax of Stepovyi 1 variety, it was found that seed yield increased by an average of 0.2 t/ha due to the seed treatment before sowing with K6, and

Eskort-bio – by 0.25 t/ha, respectively. The false flax yield increased to 1.6 t/ha under application of these chemicals in the main stages of their growth and development. It was also found that the fat content in false flax seeds increased from 39.6 % (in control) to 41.2 % (in the best variants) while reducing the erucic acid from 1.95 % in the control variant to 1.29–1.71 % under nutrition optimization. In addition, the nutrition optimization with using biologicals provides high economic efficiency of growing this crop [21].

At the growing safflower, similar results on the application of mineral fertilizers and the use of biologicals for pre-sowing treatment of seeds were obtained (Table 2).

2. Grain yield of safflower depending on nutrition optimization, t/ha

Variants of nutrition	2017	2018	2019	Average for three years	Increase in yield to control	
					t/ha	%
Control	1,20	0,84	0,93	0,99	0,00	0,00
Seed and plant treatment with Orhanik D-2M	1,25	0,97	1,08	1,10	0,11	11,1
$N_{30}P_{30}$	1,54	1,14	1,26	1,31	0,32	32,3
$N_{30}P_{30}$ + Orhanik D-2M	1,69	1,25	1,37	1,44	0,45	45,5
$N_{60}P_{60}$	1,73	1,37	1,50	1,53	0,54	54,5
$N_{60}P_{60}$ + Orhanik D-2M	1,79	1,47	1,63	1,63	0,64	64,6
$LSD_{0,5}$ t/ha	0,12	0,11	0,12			

According to the research data for 2017–2019, the increase in safflower grain yield only due to the treatment with the Orhanik D-2M fertilizer averaged 11.1 %, when $N_{30}P_{30}$ applied before sowing – 32.3 % and $N_{60}P_{60}$ – 54.5 %. When sowing safflower on these mineral nutrition backgrounds and treated seeds, the increase in grain yield can be close to 45.5 and 64.6 %. It should be noted that the improvement of safflower plant nutrition had a positive effect on both yield and seed quality (Table 3).

Thus, protein and fat content in the seeds, and also relative harvest of these components per unit area increased, which is extremely important.

3. Influence of nutrition optimization on safflower seed quality (average for 2017–2019)

Nutrition variants	Protein content, %	Fat content, %	Relative harvest, t/ha	
			protein	oil
Control	19,1	38,1	0,19	0,38
Seed and plant treatment with Orhanik D-2M	20,2	38,5	0,22	0,42
$N_{30}P_{30}$	20,4	39,6	0,27	0,52
$N_{30}P_{30}$ + Orhanik D-2M	20,5	40,2	0,30	0,58
$N_{60}P_{60}$	20,6	39,4	0,32	0,60
$N_{60}P_{60}$ + Orhanik D-2M	20,6	39,9	0,34	0,65
$LSD_{0,5}$ over years of research	0,2–0,3	0,3–0,6		

It should be noted that safflower oil is especially valuable. Safflower is a well-known and important medicinal plant. Profitability of safflower cultivation significantly exceeds the most widespread oil crop – sunflower. The sorghum, spring false flax, safflower and other drought-resistant plants in level of grain or seed yield are almost close to sunflower, and in some indicators even exceed it.

Conclusions. The climate of the Southern Steppe is changing to more arid (increasing temperature and prolonging period without precipitations). For this reason, it is expedient a part of the sown areas under sunflower was occupied for growing not widespread drought-resistant crops. These can be all kinds of sorghum, millet, false flax, safflower, etc.

Our research confirmed the high economy

ic efficiency of growing the above field crops in the southern arid region.

As established by the research of our and other scientists, they all respond positively to the nutrition optimization, especially when applying low doses of mineral fertilizers before sowing and the using of growth-regulating chemicals for pre-sowing seed treatment and plants in the main stages of growth and development.

The importance of modern growth-regulating chemicals in increasing the crop resistance to adverse environmental conditions was substantiated.

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