



ANALYSIS OF THE DEPENDENCE OF WINTER WHEAT YIELDING CAPACITY FORMATION ON MINERAL NUTRITION IN IRRIGATION CONDITIONS OF SOUTHERN STEPPE OF UKRAINE

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ABSTRACT

This article is dedicated to the research of analysis of the dependence of growth and development of winter wheat varieties Khersonska Awnless and Odeska 267 on conditions of moisture provision and mineral nutrition status, impact of indicated factors and formation of yielding capacity and grain quality. Years of research significantly varied in rainfall amount during growing season. According to moisture supply, 2016 was dry, 2017 was average humid and 2018 was subhumid, which had an impact on grain yield equation. The lowest winter wheat productivity level was formed in 2016. Under supplemental watering without fertilizers the yield of the Khersonska Awnless variety was at the level 2.07 t/ha, and of Odeska 267 variety - 1.51 t/ha. Under provision of vegetative watering, the yielding capacity increased to 3.14 and 2.94 t/ha.



Fertilizers also had significant impact on production processes of plants, accumulation of over ground biomass, area of assimilating surface that resulted in the yield increase of winter wheat. On average, over the years of research the most significant influence among considered factors had fertilizers - 43%, irrigation - 32% and variety content of winter wheat - 9%.

Keywords: analysis; soft winter wheat; varieties; fertilizer elements; calculated fertilizer dose; yielding capacity; grain quality; water consumption; irrigation; photosynthetic potential.

1. INTRODUCTION

In order to receive high and sustainable crop yields, it is necessary to provide favourable conditions for their growth and development throughout the whole growing season considering biological peculiarities of a crop. Soil nutrient status is one of the factors that influence these indicators. It is regulated by application of various rates of fertilizers and is the main way to interfere circulation of elements in agriculture, to increase yield of agricultural crops and to maintain soil productivity.

The agricultural land of Ukraine is 42.7 million ha (70.8% of the country's land fund), including arable land – 32,5 million ha (78.4% of agricultural land), pasture – 5,5 million ha (13.1%), hayfields – 2,5 million ha (5.8%), perennial plantings - 0.9 million ha (2.1%), deposits – 0,3 million ha (2.6%) (PICHURA et al., 2019).

The Southern steppe of Ukraine is classified as the zone of risky agriculture. According to Pichura (2019), in the Southern Steppe of Ukraine, over the past 200 years, there has been an increase in the average annual air temperature by 1.0-1.2 ° C and with the retention of a retrospective trend-cyclical trend up to 2030, the average annual temperature is forecast to increase by 0.8 ± 0.15 ° C, which will increase the incidence of droughts and reduce the soil and climate potential.

Over the past 75 years (LISETSKII et al., 2016), there has been a manifestation of warming during the first 10 months of the year by 2 ° C (from 10.4 to 12.4 ° C), an increase in precipitation by 90 mm (from 314 to 404 mm). This is accompanied by the negative anomalous phenomena of a single monthly, and in some cases, a semi-annual rainfall rate, which leads to large-scale manifestations of water-erosion destruction of grants (DUDIAK et al., 2019), which leads to a decrease in their fertility, accumulation of erosion products and accumulation of erosion products. degradation of the hydro-ecosystem (PICHURA et al., 2017, 2018).



The lack of regular, uniform supply of mineral fertilizers in the required amount, manifestations of wind and water erosion, including irrigation and soil deflation in the Steppe zone of Ukraine, resulted in an average decrease in content of humus by 0.36%, metabolic potassium by 18%, mobile phosphorus by 34%, 17%; nitrification nitrogen by 17.0% (PICHURA, 2015).

As a result of neuro-prognosis, it was established (LISETSKII et al., 2017) that in the soils of the dry Steppe zone, using existing agricultural technologies, the process of gradual dehumidification is predicted: on rainfed lands - by 0.01, on irrigated lands - by 0.03 percent per year and a reduction in the area of land, characterized by medium and high humus content.

Lisetskii (2012) emphasized that the removal of humus and nutrients with washed away soil leads to a deterioration in its physical properties and a decrease in fertility, a decrease in crop productivity on eroded lands on average by 10-60%, and an increase in the cost of their irrigation and drainage.

About 20% of the irrigated lands of Ukraine are concentrated in the territory of the Kherson region (PICHURA, 2015), their area constitutes about 426,8 (21,65%) thousand hectares, that is one-fifth of all agricultural land in the region, 310.0 thousand hectares (72.6%) of which are used in irrigation, and 116.8 thousand hectares (27.4%) are not used.

In years with various weather conditions, it is possible to obtain high yields of field crops that are grown precisely under irrigation conditions. Highly intensive agricultural crop varieties, fertilizers, and other important factors and components of agrotechnical means do not prove themselves completely under moisture deficit. Evaporation from fields exceeds humidity inflow from rainfall and it breaches water balance. Drought happens every 2-3 years in the steppe area causing large damage.

Winter wheat takes the largest crop sowing area in steppe zone, more than 50% of the area of agricultural land. It is high-yielding and adapted to dry conditions effectively using autumn-winter soil moisture reserves. Soil moisture is the main source of water supply through the root system. Depending on the moisture preservation conditions the moisture content (MMC - 75%) can be full and minimum for obtaining high levels of winter wheat yielding capacity in the southern Ukrainian conditions.

The main feature of moisture regime of the steppe zone soil is its nonpercolative moisturization and lack of rainfalls under high summer temperatures and low humidity. About 20% of the irrigated lands of Ukraine are concentrated in the territory of the Kherson region



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2. MATERIALS AND RESEARCH METHODS

Field research was carried out during 2015-2018 under the conditions of the experimental field of the Institute of Irrigated Agriculture of the Southern Region of the National Academy of Agrarian Sciences of Ukraine, located in the southern part of the steppe zone of Ukraine. The soils of experimental areas are dark-chestnut, medium-loamy, with a height of humus horizon 25 cm and humus content 2.2% at a deep level of groundwater occurrence. Water for irrigation was taken from the basin of Inhulets irrigation system.

The field experiment was based on the four times repeated three-factor scheme, where factor A was the winter wheat varieties: Khersonska Awnless and Odeska 267; factor B was irrigation regimes: supplemental watering and supplemental & vegetative watering; and factor C was various mineral nutrition statuses: unfertilized, unfertilized with feeding with microfertilizers Krystallon (2 kg/ha) and Tenso (0.6 kg/ha); the dose of fertilizers was calculated for the yield level 7.0 t/ha, the same dose of fertilizers for feeding with microfertilizers Krystallon and Tenso;

Under the research program it was planned to study the possibility of reducing the number of winter wheat waterings during growing season and the value of irrigation rate due to use of water-saving watering methods.

Researches on the influence of alternative fertilizers and irrigation regimes on the grain productivity of winter wheat were conducted in the crop rotation link with subsequent succession of crops: 1. spring barley with alfalfa seeding; 2. alfalfa; 3. alfalfa; 4. winter wheat.

That is, the predecessor of winter wheat varieties was alfalfa of three-year growing period. Doses of mineral fertilizers were calculated on the basis of the recommendations for the programmed yielding capacity level, considering subtraction of nutrient elements by crop, the NPK content in soil and coefficients of their use from soil and fertilizers (Table 1).

Table 1: Content of nutrient elements in soil before winter wheat sowing during years of research, mg/100g of soil

Soil layer, cm	NO ³⁻			P ₂ O ₅			K ₂ O		
	2015-2016	2016-2017	2017-2018	2015-2016	2016-2017	2017-2018	2015-2016	2016-2017	2017-2018



0-30	0.80	5.98	9.65	5.65	5.95	3.68	26.5	48.0	33.0
30-50	0.75	4.18	3.09	1.75	1.05	1.47	22.0	35.0	23.0
50-70	0.35	1.13	0.87	0.37	0.70	0.24	15.5	30.0	20.5
70-100	0.35	0.25	0.52	0.41	0.75	0.50	17.0	27.0	19.0

The dose of mineral fertilizers was determined according to the content of nutrients in soil considering subtraction of nutrient elements by preceding crop. During the years of research, nitrogen fertilizers for the basic soil treatment were introduced in an amount from 45 kg of application rate to 138 kg/ha. On average, over the years of research the dose of fertilizers for the planned yielding capacity level 7.0 t/ha was N138P0K0.

Crop tending consisted of chemical weeding with a tank mixture of herbicides Donat – 130 g/ha, Estron - 300 g/ha and fungicide - Impact 0.5 l/ha. Macro and micronutrient application (Krystallon + Tenso) at a rate 2 kg/ha and 0.6 kg/ha was carried out during heading phase and milky ripeness respectively.

Predecessor's irrigation regime consisted of the norms and terms of watering that were adapted to climatic conditions of year on the basis of recommended crop irrigation regimes in the southern Ukrainian steppe.

Soil and crop samples were selected from two non-adjointing repetitions. The soil content of nitrate nitrogen (according to the Grandval-Lyazh GOST 26107), labile phosphorus – in 1% carbon-amniotic extract (according to Machihin GOST 26205-91), exchange potassium - from the same extract on a flame photometer (GOST 26205-91) were determined. Soil moisture was determined by the thermostat weight method.

During growing season, biometric measurements were taken in main phases of crop development the following: plant height, growth of crude and dry overground mass of winter wheat, area of leaves; calculations of net productivity of photosynthesis, photosynthetic potential of sowing were performed. The area of leaves was determined by the method of carving (NYCHYPOROVYCH, 1961).

The net productivity of photosynthesis was determined according to methods of A.A. Nychyporovych (NYCHYPOROVYCH, 1982; PYSARENKO; KOKOVIKHIN; HRABOVSKYI, 2011), according to the Kidd-West-Briggs formula:

$$F_{n.pr.} = \frac{B_2 - B_1}{L_1 + L_2} \cdot T \quad \text{where}$$

- $F_{n.pr.}$ – the net productivity of photosynthesis, g/m² per day;

- B_1, B_2 – the dry weight for 1 m² at the beginning and end of the record period, g;
- L_1, L_2 – leaf surface area for 1 m² at the beginning and end of the record period, m²;
- T – number of days between the first and the second determination.

Agricultural technology in the research was commonly accepted for the zone considering the issues being studied. The main treatment after alfalfa harvesting included: disking, 25-27 cm ploughing. The seeds were sown in a depth 4-5 cm. During the years of research, the sowing was carried out in the last decade of September with the sowing rate 5 million similar grains per hectare.

3. RESEARCH RESULTS AND DISCUSSION

It was found in the research that the area of the leaf surface varied depending on the mineral nutrition, vegetative phase of plant and irrigation regimes (Table 2).

It should be noted that from tillering phase to stem elongation, the surface area of leaves of unfertilized plants of both studied winter wheat varieties increased two times on average within the years of study. During growing of winter wheat using fertilizers, this indicator increased 2.5–2.8 times in comparison with the control version without fertilizers.

In further growing season, the area of leaves increased two times the most in comparison with stem elongation phase upon treatment without fertilizers and supplemental and vegetative watering over the years of research. The leaf surface of winter wheat plants varied from 18.6–19.1 to 29.0–31.5 thousand m²/ha in non-fertilized ground under supplemental irrigation.

In the research, the calculated dose of mineral fertilizer N₁₃₈P₀K₀ was used for the planned yield of winter wheat grain 7.0 t/ha.

Table 2: Influence of the researched factors on growth dynamics of area of leaves of winter wheat plants (average for 2016-2018), thous.m²/ha

Nutrient status (factor C)	Irrigation regime (factor B)	Vegetative phase			
		tillering	stem elongation	heading	milky ripeness
Khersonska Awnless (factor A)					
Unfertilized	Supplemental watering	9.8	18.6	31.5	32.7
	Supplemental + vegetative watering	10.1	18.6	39.7	41.3
Calculated dose N ₁₃₈ P ₀ K ₀	Supplemental watering	11.3	29.6	39.7	42.0
	Supplemental + vegetative watering	11.8	31.4	44.8	46.1
Odeska 267 (factor A)					
Without fertilizers	Supplemental watering	10.0	19.1	29.0	30.2

	Supplemental + vegetative watering	9.9	19.1	37.9	39.3
Estimated dose N ₁₃₈ P ₀ K ₀	Supplemental watering	11.5	26.1	38.1	39.6
	Supplemental + vegetative watering	11.7	28.9	43.4	44.7
LSD ₀₅ , thous. m ² /ha		0.21	1.12	1.87	2.03

It allows to significantly reduce the dose of fertilizers upon condition that soil is sufficiently supplied with labile soil nutrients, and due to their high content in soil it allows to avoid application of fertilizers or their varieties. Thus, the phosphoric and potassium fertilizers were not applied in sowing within the years of research, as the content of labile phosphorus and exchange potassium in soil exceeded its average number (MORARU, 1988; HOSPODARENKO, 2010).

At the same time, the mixed microfertilizer Krystallon and Tenso was used in feeding during heading and kernel milk line period. This was due to the fact that winter wheat was grown in irrigated crop rotation after three years of growing of alfalfa for feeding of animals and organic fertilizers were not applied in crop rotation.

Under such circumstances, the application of micro elements does not always significantly increase the crop yielding capacity, but significantly improves the quality of grown products. The nitrate content during growing of winter wheat varieties was quite high during vegetation (Table 3).

Table 3: Influence of mineral fertilizers and irrigation regime on nitrate content in soil during winter wheat vegetation (average for the years of research according to the factor A), mg / 100 g of soil

Nutrient status (factor C)	Researched soil layer, cm	Irrigation regime (factor B)							
		Supplemental watering				Supplemental + vegetative watering			
		sowing-germination	stem elongation	beginning of heading	complete grain ripeness	sowing-germination	stem elongation	beginning of heading	complete grain ripeness
Unfertilized	0-30	4.92	5.01	5.03	4.21	4.87	5.12	4.62	3.78
	0-50	2.78	2.86	3.14	2.60	2.76	2.81	2.49	2.32
	0-100	1.44	1.49	1.61	1.47	1.46	1.52	1.67	1.54
Calculated dose N ₁₃₈ P ₀ K ₀	0-30	5.28	5.87	6.12	5.42	5.31	5.72	5.46	4.89
	0-50	3.02	3.81	3.88	3.47	2.99	3.74	3.38	3.12
	0-100	1.83	1.74	1.79	1.87	1.94	1.77	1.64	1.85
LSD ₀₅ , mg/100g	0-30	0.14-0.21	0.11-0.17	0.10-0.13	0.08-0.12	0.07-0.12	0.11-0.14	0.07-0.09	0.08-0.11
	0-50	0.09-0.15	0.08-0.12	0.09-0.14	0.06-0.10	0.07-0.09	0.10-0.15	0.10-0.12	0.07-0.09
	0-100	0.05-0.08	0.08-0.14	0.05-0.07	0.06-0.08	0.04-0.07	0.08-0.11	0.05-0.07	0.07-0.08

Such a high NO₃ content in the unfertilized soil is due to the fact that winter wheat was grown on an alfalfa layer, which accumulates a significant amount of root residues with high content of biological nitrogen. This fact explains quite high content of labile nitrogen in soil during the growing season of winter wheat, even without application of nitrogen fertilizer for crop in all studied layers of soil.

Under conditions of using of nitrogen fertilizer, the nitrate content in soil was increasing in accordance with the dose of its introduction (Table 3).

According to the analysis of variance of the grain yielding capacity of winter wheat, it was found that factor C, the nutrient status, had the greatest influence on crop productivity - 43%. The factor B (irrigation) took the second place - 32%, the variety composition of winter wheat (factor A) took only 9%. In addition, the research shows close interaction between irrigation and fertilizers (interaction of factors BC) at the level 7%. The interaction of other factors was less significant and ranged from 1 to 3% (Figure 1).

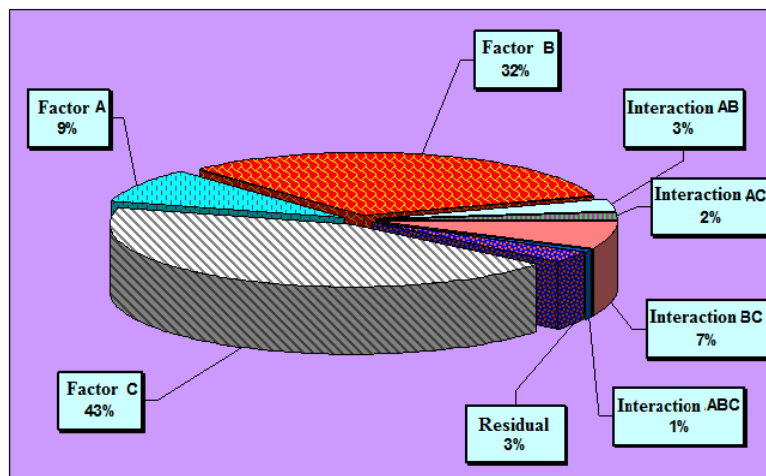


Figure 1: Influence of researched factors on productivity of winter wheat (average for 2016–2018), %

One of the most unfavourable conditions for winter wheat is water disbalance of soil at the beginning of its sowing and during the autumn vegetation. During sowing, the moisture content in soil is often extremely low, and winter wheat cannot germinate timely. The winter wheat seeds accumulate moisture in the autumn-winter period the most. Therefore, the most moisture content in soil is observed in early spring.

In the research, the irrigation rate varied depending on the amount of rainfall in the years of growing of winter wheat varieties (Table 4).

Table 4: Irrigation rate in winter wheat growing, m³/ha

Years of vegetation	Supplemental irrigation	Vegetative irrigation			Total irrigation rate, m ³ /ha
		Number of waterings, times	Watering depth	Irrigation rate	
2015-2016	700	3	500	1500	2200
2016-2017	700	1	500	500	1200
2017-2018	700	3	500	1500	2200
Average in years	700	2,3	500	1167	1867

Supplemental watering rate for all years of research was 700 m³/ha, and vegetative irrigation rate was 500 m³/ha.

The winter wheat grain yield is influenced by many factors of cultivation. First of all, these are agrotechnical measures, biological features of variety, terms of sowing, seed quality during sowing, moisture conditions, peculiarities of weather and climate during year, use of protective means, etc. The introduction of mineral fertilizers in the calculated doses for productivity of winter wheat 7.0 t/ha increased the grain yielding capacity of the studied winter wheat varieties. It reached its maximum value under supplemental watering upon introduction of calculated dose of fertilizer N138P0K0 for the yield level 7.0 t/ha and made 4.02 t/ha of the Khersonska Awnless variety and 3.63 t/ha of the Odeska 267 variety.

Top dressing with microelements in fertilized grounds also did not result in a significant increase of grain yielding capacity (Table 5).

It should be noted that top dressing with a complex microfertilizer Krystallon in the dose 2 kg/ha mixed with Tenso (0.6 kg/ha during interphase heading period and the beginning of kernel milk line period increased winter wheat yield of both studied varieties from 0.6 to 3.0 t/ha.

Table 5: Yielding capacity of winter wheat varieties depending on fertilizers and irrigation regime in research years, t/ha

Nutrient status (factor C)	Variety (factor A)	Irrigation regime (factor B) and years of research					
		2016		2017		2018	
		1*	2*	1	2	1	2
Unfertilized	Khersonska Awnless	2.07	3.14	4.35	5.15	3.42	4.07
	Odeska 267	1.51	2.94	4.28	4.95	3.4	3.91
Unfertilized + Krystallon + Tenso	Khersonska Awnless	2.13	3.19	4.43	5.30	3.68	4.13
	Odeska 267	1.68	3.02	4.44	5.18	3.74	3.99
Calculated dose N ₁₃₈ P ₀ K ₀	Khersonska Awnless	4.02	5.25	6.56	7.34	4.42	6.61
	Odeska 267	3.63	4.78	6.12	6.93	4.32	6.39
Calculated dose N ₁₃₈ P ₀ K ₀ + Krystallon + Tenso	Khersonska Awnless	3.87	5.23	6.52	7.53	4.73	6.72

	Odeska 267	3.79	5.12	6.18	7.09	4.68	6.45
LSD _{05, t/ha}	as per factor A	0.155		0.113		0.19	
	as per factor B	0.095		0.197		0.17	
	as per factor C	0.146		0.113		0.22	

Notes: * 1 – supplemental watering; 2 – supplemental + vegetative waterings

4. CONCLUSIONS

In order to receive grain yielding capacity at the level 7.0 t/ha and higher under low content of nitrogen and increased content of labile phosphorus potassium in soil, it is reasonable to add mineral fertilizers as the main soil treatment at the calculated rate N138P0K0 along with top dressing with a mixture of complex fertilizers Krystallon and Tenso as calculated 2.0 and 0.6 kg/ha in the interphase period between the beginning of heading and kernel milk line period.

Spatial environmentally sound differentiation of crop rotation, regular and uniform supply of mineral fertilizers to the soil will provide an improvement in its agrochemical and physical properties. This will reduce the negative impact of acrogenic load on soil fertility, contribute to increasing crop yields, income from plant residues of organic material and increasing the biological potential of the soil, and improve the processes of conversion of organic matter and humus formation in the steppe soils of Ukraine.

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